



PRODUCT MANUAL



Rabbit[®] 6000 Microprocessor

User's Manual

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Rabbit 6000 Microprocessor User's Manual

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1. THE RABBIT 6000 PROCESSOR

1.1 Introduction

Rabbit Semiconductor was formed expressly to design a better microprocessor for use in small- and medium-scale, single-board computers. The first microprocessors were the *Rabbit 2000*, *Rabbit 3000*, *Rabbit 4000*, and the *Rabbit 5000*. The latest microprocessor is the *Rabbit 6000*. Rabbit microprocessor designers have had years of experience using Z80, Z180, and HD64180 microprocessors in small single-board computers. The Rabbit microprocessors share a similar architecture and a high degree of compatibility with these microprocessors, but represent a vast improvement.

The Rabbit 6000 is a high-performance microprocessor with low electromagnetic interference (EMI), and is designed specifically for embedded control, communications, and network connectivity. Extensive integrated features and glueless architecture facilitate rapid hardware design, while a C-friendly instruction set promotes efficient development of even the most complex applications.

The Rabbit 6000 is the second Rabbit microprocessor to have a full 16-bit internal bus architecture, providing significant performance improvements when used with external 16-bit memory devices. It also has the ability to support both 8-bit and 16-bit external memory devices.

The Rabbit 6000 is also the fastest microprocessor from Rabbit, now a Digi International brand, running at up to 200 MHz, with compact code and support for up to 16 MB of memory. Operating with a 1.2 V core and 3.3 V I/O, the Rabbit 6000 boasts 16 channels of DMA, six serial ports with IrDA, 64+ digital I/O, quadrature decoder, PWM outputs, I²C port, and pulse capture and measurement capabilities. It also features a battery-backable real-time clock, glueless memory and I/O interfacing, and ultra-low power modes. Four levels of interrupt priority allow fast response to real-time events. Its compact instruction set and high clock speeds give the Rabbit 6000 exceptionally fast math, logic, and I/O performance.

The Rabbit 6000 contains 1MB of internal high-speed 16-bit RAM, which can be used for both code and data. It also contains 32 KB of battery-backable 16-bit SRAM (also high speed) for applications where data retention is critical. It is capable of booting off of a standard serial flash, so a microcontroller application with no external parallel memory is possible.

The Rabbit 6000 provides two options for network connectivity — a full 10/100Base-T Ethernet MAC and PHY built into the device, and a wireless 802.11 a/b/g MAC compatible with several standard Wi-Fi transceivers. Both network interfaces can be active at the same time. The Rabbit 6000 also contains a USB 2.0-compatible full-speed USB host MAC and PHY.

The Rabbit 6000 also features two “flexible interface modules,” or FIMs. These two modules can be loaded with customized designs to support a variety of interfaces, including serial ports and CAN-bus interfaces.

1.2 Features

The Rabbit 6000 contains an internal phase-locked loop (PLL) that is fully controlled by software and provides up to a 200 MHz clock from a 25 MHz input. Other clock options are available as well, including the clock doubler and divider features present in earlier Rabbit devices.

The Rabbit 6000 has several powerful design features that practically eliminate EMI problems, which is essential for OEMs who need to pass CE and regulatory radio-frequency emissions tests. The amplitude of any electromagnetic radiation is reduced by the internal spectrum spreader, by gated clocks (which prevent unnecessary clocking of unused registers), and by separate power planes for the processor core and I/O pins (which reduce noise crosstalk). An external I/O bus can be used by designers to enable separate buses for I/O and memory, or to limit loading the memory bus to reduce EMI and ground bounce problems when interfacing external peripherals to the processor. The external I/O bus accomplishes this by duplicating the Rabbit's data bus on Parallel Port A, and uses Parallel Port B to provide the processor's six or eight least significant address lines for interfacing with external peripherals.

The high-performance instruction set offers both greater efficiency and execution speed of compiler-generated C code. Instructions include numerous single-byte opcodes that execute in two clock cycles, 16-bit and 32-bit loads and stores, 16-bit and 32-bit logical and arithmetic operations, 16×16 multiply (executes in 12 clocks), long jumps and returns for accessing a full 16 MB of memory, and one-byte prefixes to turn memory-access instructions into internal and external I/O instructions. Hardware-supported breakpoints ease debugging by trapping on code execution or data reads and writes.

The Rabbit 6000 requires no external memory driver or interface logic. Its 24-bit address bus, 8-bit or 16-bit data bus, three chip-select lines, two output-enable lines, and two write-enable lines can be interfaced directly with up to six memory devices. Up to 1 MB of code memory and 15 MB of data memory can be accessed directly via the Dynamic C development software. The Rabbit 6000 also contains 1 MB of internal high-speed 16-bit RAM and 32 KB of battery-backed SRAM, which can be used instead of or in addition to any external memory devices.

A built-in slave port allows the Rabbit 6000 to be used as master or slave in multi-processor systems, permitting separate tasks to be assigned to dedicated processors. An 8-line data port and five control signals simplify the exchange of data between devices. A remote cold boot enables startup and programming via a serial port, a slave port, or from a standard external serial flash device.

The Rabbit 6000 features eight 8-bit parallel ports, yielding a total of 64 digital I/O. Six CMOS-compatible serial ports are available. All six are configurable as asynchronous (including output pulses in IrDA format), while four are configurable as clocked serial (SPI) and two are configurable as SDLC/HDLC. The various internal peripherals share the parallel port's I/O pins. Drive strength, slew rate, and pullup/pull-down resistors can be controlled on all of the parallel ports.

The Rabbit 6000 also offers many specialized peripherals. Two input-capture channels each have a 16-bit counter, clocked by the output of an internal timer, that can be used to capture and measure pulses. These measurements can be extended to a variety of functions such as measuring pulse widths or for baud-rate auto detection. Two Quadrature Decoder channels each have two inputs, as well as an 8-bit or 10-bit up/down counter. Each Quadrature Decoder channel provides a direct interface to quadrature encoder units. Four independent pulse-width modulator (PWM) outputs, each based on a 1024-pulse frame, are driven by the output of a programmable internal timer. The PWM outputs can be filtered to create a 10-bit D/A converter or they can be used directly to drive devices such as motors or solenoids. The Rabbit 6000 has eight

external interrupt vectors, two of which can each multiplex inputs from up to three external pins. A new addition to the Rabbit 6000 is a fully featured I²C port capable of up to 400 kbits/s and 10-bit addressing.

The Rabbit 6000 has three timer systems. Timer A consists of twelve 8-bit counters, each of which has a programmed time constant. Six of them can be cascaded from the primary Timer A counter. Timer B contains a 10-bit counter, two match registers, and two step registers. An interrupt can be generated or an output pin can be updated when the counter reaches a match value, and the match value can then be incremented automatically by the step value. Timer C is a 16-bit counter that counts up to a programmable limit. It contains eight match registers so that up to four PWM (both synchronous and variable-phase) or quadrature signals for motor-control applications can be created.

The Rabbit 6000 also provides support for protected operating systems. Support for two levels of operation, known as *system* and *user* modes, allow application-critical code to operate in safety while user code is prevented from inadvertently disturbing the setup of the processor. Memory blocks as small as 4 KB can be write-protected against accidental writes by user code, and stack over/underflows can be trapped by high-priority interrupts.

Security features are also available in the Rabbit 6000. New instructions were added to the existing encryption support to increase encryption algorithm speeds dramatically, and 32 bytes of battery-backed RAM can store an encryption key away from prying eyes.

The Rabbit 6000 supports sixteen channels of DMA access to internal or external memory, internal I/O addresses, and the external I/O bus. Directing a DMA channel to or from an internal peripheral such as a serial port or the Ethernet port automatically connects DMA enable signals. Burst size, priority, and guaranteed cycles for the processor are all under program control. DMA operations to/from the internal memory and peripherals can operate simultaneously with code fetches, so no performance hit occurs. When accessing external memory, DMA operations will alternate between DMA and code fetches as in previous Rabbit designs.

The Rabbit 6000 contains an 802.11a/b/g wireless MAC peripheral, also designed to operate with the DMA peripheral. It includes support for all standard Wi-Fi features, including infrastructure and ad-hoc modes. The high-speed internal A/D converter and D/A converter and clocked-serial control port provide a generic interface to several common Wi-Fi transceivers. A low-speed A/D converter is also available to monitor the transmit signal strength if desired. The two A/D converters and single D/A converter are available for customer use when the Wi-Fi peripheral is disabled.

The Rabbit 6000 also contains a full-featured 10/100Base-T Ethernet MAC peripheral and PHY. Designed to operate with the DMA peripheral, the Ethernet peripheral is fully compliant with the 802.3 Ethernet standard, including support for auto-negotiation, link detection, multicast filtering, and broadcast addresses.

The Rabbit 6000 provides an Open Host Controller Interface (OHCI) USB device MAC and PHY. Fully supported by the DMA peripheral, the MAC and PHY are USB 2.0 compliant, full-speed (12 Mbit/s) devices.

Another new feature of the Rabbit 6000 is a 12-bit, 8-channel A/D converter. This A/D converter can run at up to 1 megasample per second, based on either the internal clock or an external clock input. The A/D converter is muxed across eight channels which can be sampled individually or continuously across all channels.

1.3 Block Diagram

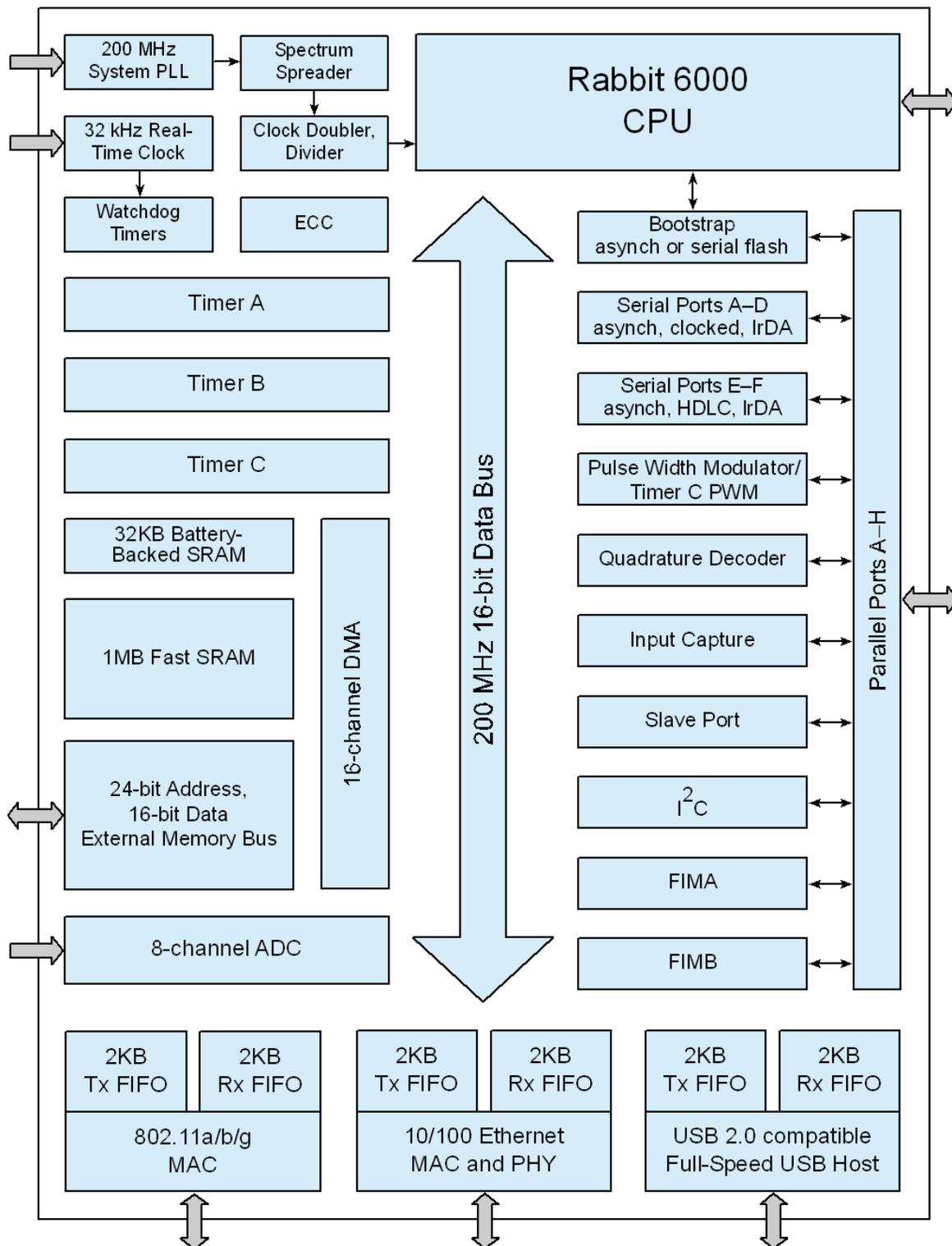


Figure 1.1 Rabbit 6000 Block Diagram

1.4 Basic Specifications

Two versions of the Rabbit 6000 are available—the standard 292-ball BGA and a smaller 233-ball BGA for specialty Wi-Fi applications. The larger package is intended for most Rabbit applications; the smaller package has no address or data bus, and is intended for particular applications. If you need further information, please contact your Rabbit sales representative.

Table 1-1. Rabbit 6000 Specifications and Features

Package	292-ball BGA	233-ball BGA
Package Size	17 mm × 17 mm × 1.3 mm	15 mm × 15 mm × 1.3 mm
Operating Voltage	1.2 V DC core, 3.3 V DC I/O ring	
Operating Current (typ)	372 μ A/MHz @ 1.2 V/3.3 V, 25-200 MHz (Wi-Fi and Ethernet disabled)	
Operating Temp.	-40°C to +85°C	
Maximum Clock Speed	200 MHz	
Digital I/O	64+ (arranged in eight 8-bit ports)	
Network Interfaces	10/100Base-T 802.11b/g Wi-Fi	
Serial Ports	6 CMOS-compatible	2 CMOS-compatible
Baud Rate	Clock speed/8 max. asynchronous	
I ² C Ports	1	1
Address Bus	24-bit	None
Data Bus	8/16-bit	None
Timers	Twelve 8-bit, one 10-bit with 2 match registers, and one 16-bit with 8 match registers	
Real-Time Clock	Yes, battery-backable	
RTC Oscillator Circuitry	External	
Watchdog Timer/Supervisor	Yes	
Clock Modes	1×, 2×, /2, /3, /4, /6, /8*	
Power-Down Modes	Sleepy (32 kHz) Ultra-Sleepy (16, 8, 4, 2 kHz)*	
External I/O Bus	8 data, 8 address lines	No
A/D Converters	10-bit, 2 synchronous channels, up to 40 megasamples/s 10-bit, single channel, up to 1 megasamples/s 12-bit, eight multiplexed channels, up to 1 megasamples/s	
D/A Converters	10-bit, 2 synchronous channels, up to 80 megasamples/s	

* Limitations on the use of the 1MB internal RAM are present when running in lower CPU frequency or sleepy modes. See Section 5.3.1, “Internal RAM”.

1.5 Comparing Rabbit Microprocessors

The Rabbit 2000, Rabbit 3000, Rabbit 4000, Rabbit 5000, and Rabbit 6000 features are compared below.

Feature	Rabbit 6000	Rabbit 5000	Rabbit 4000	Rabbit 3000	Rabbit 2000
Maximum Clock Speed, industrial	200 MHz	100 MHz	60 MHz	55.5 MHz	30 MHz
Maximum Clock Speed, commercial	200 MHz	100 MHz	60 MHz	58.8 MHz	30 MHz
Maximum Crystal Frequency Main Oscillator (may be increased internally up to maximum clock speed)	24–42 MHz (crystal) 20–200 MHz (ext. clock)	100 MHz	60 MHz	30 MHz	30 MHz
32.768 kHz Crystal Oscillator	External	External	External	External	Internal
Operating Voltage, core	1.2 V ± 10%	1.8 V ± 10%	1.8 V ± 10%	3.3 V ± 10%	5.0 V ± 10%
Operation Voltage, I/O	1.2 V ± 10% 3.3 V ± 10%	1.8 V ± 10% 3.3 V ± 10%	1.8 V ± 10% 3.3 V ± 10%		
Maximum I/O Input Voltage	3.6 V	3.6 V	3.6 V	5.5 V	5.5 V
Current Consumption (32kHz – 200MHz)	0.37 mA/MHz @ 1.2 V/3.3 V (Wi-Fi and Ethernet disabled)	0.57 mA/MHz @ 1.8 V/3.3 V (Wi-Fi and Ethernet disabled)	0.35 mA/MHz @ 3.3 V	2 mA/MHz @ 3.3 V	4 mA/MHz @ 5 V
Number of Package Pins	292/233	289/196	128	128	100
Size of Package, LQFP/PQFP	N/A		16 × 16 × 1.5 mm	16 × 16 × 1.5 mm	24 × 18 × 3 mm
Spacing Between Package Pins	N/A		0.4 mm (16 mils)	0.4 mm (16 mils)	0.65 mm (26 mils)
Size of Package, BGA (mm)	17 × 17 × 1.3	15 × 15 × 1.4	10 × 10 × 1.2	10 × 10 × 1.2	N/A
Spacing Between Package Pins	0.8 mm	0.8 mm	0.8 mm	0.8 mm	
Separate Power and Ground for I/O Buffers (EMI reduction)	Yes	Yes	Yes	Yes	No
Clock Spectrum Spreader	Yes	Yes	Yes	Yes	Rabbit 2000B/C
Phase-Locked Loop	Yes, up to 200MHz	No	No	No	No
Clock Modes	1×, 2×, /2, /3, /4, /6, /8*	1×, 2×, /2, /3, /4, /6, /8	1×, 2×, /2, /3, /4, /6, /8	1x, 2x, /2, /3 /4, /6, /8	1x, 2x, /4, /8

Feature	Rabbit 6000	Rabbit 5000	Rabbit 4000	Rabbit 3000	Rabbit 2000
Powerdown Modes, sleepy	32 kHz	32 kHz	32 kHz	32 kHz	32 kHz
Powerdown Modes, ultra sleepy	16, 8, 4, 2 kHz*	16, 8, 4, 2 kHz	16, 8, 4, 2 kHz	16, 8, 4, 2 kHz	
Low-Power Memory Control	Short and Self-Timed Chip Selects	None			
Extended Memory Timing for High-Frequency Operation	Yes	Yes	Yes	Yes	No
Address Bus Size	24 bits	20–24 bits	20–24 bits	20 bits	20 bits
External Data Bus Size	8/16 bits	8/16 bits	8/16 bits	8 bits	8 bits
Internal Data Bus Size	16 bits	16 bits	8 bits	8 bits	8 bits
Internal RAM	1 MB + 32KB battery-backed	128KB	None	None	None
Number of 8-bit I/O Ports	8	6	5	7	5
External I/O Data/Address Bus	Yes	Yes	Yes	Yes	None
Number of Serial Ports	6	6	6	6	4
DMA Channels	16	8	8	None	None
Serial Ports Capable of SPI/Clocked Serial	4 (A, B, C, D)	2 (A, B)			
Serial Ports Capable of SDLC/HDLC	2 (E, F)	2 (E, F)	2 (E, F)	2 (E, F)	None
Asynch Serial Ports With Support for IrDA Communication	6	6	6	6	None
Serial Ports with Support for SDLC/HDLC IrDA Communication	2 (E,F)	2 (E,F)	2 (E,F)	2 (E,F)	None
Serial Ports with 4-Byte FIFO	6	2 (E,F)	2 (E,F)	2 (E,F)	None
Maximum Asynchronous Baud Rate	Clock speed/8	Clock Speed/8	Clock Speed/8	Clock Speed/8	Clock Speed/32
Hardware I ² C Ports	1	None	None	None	None
Ethernet Port	10/100Base-T with PHY	10/100Base-T (MAC only)	10Base-T (partial PHY)	None	None
Wi-Fi (802.11a/b/g)	Yes	Yes	No	No	No
USB (2.0 compatible)	Full-speed host	No	No	No	No
PWM Outputs	4	4	4	4	None

Feature	Rabbit 6000	Rabbit 5000	Rabbit 4000	Rabbit 3000	Rabbit 2000
Variable-Phase PWM Outputs (PPM)	4	4	4	None	None
Input Capture Units	2	2	2	2	None
External Interrupts/Vectors	22/8	6/2	6/2	4/2	4/2
Quadrature Decoders	2 channels	2 channels	2 channels	2 channels	None
Flexible Interface Modules	2	None	None	None	None
Hardware Breakpoints	7	7	7	None	None
User A/D Converter Channels	8	None	None	None	None
A/D Converter Channels (Wi-Fi disabled)	3	3	None	None	None
D/A Converter Channels (Wi-Fi disabled)	2	2	None	None	None

* Limitations on the use of the 1MB internal RAM are present when running in lower CPU frequency or sleepy modes. See Section 5.3.1, “Internal RAM”.

2. CLOCKS

2.1 Overview

The Rabbit 6000 supports up to five separate clocks at once—the main clock, the 32 kHz clock, the 20 MHz Wi-Fi clock, the 25 MHz Ethernet clock, and the 48 MHz USB clock. The main clock is used to drive the processor clock and the peripheral clock inside the processor. The 32 kHz clock is used to drive the asynchronous serial bootstrap, the real-time clock, the periodic interrupt, and the watchdog timers.

The 32 kHz clock input requires an external clock signal; the remaining clock inputs have internal oscillators that can be driven with just an external crystal. If desired, each of the remaining clock inputs can also be used with an external clock as well, bypassing the internal oscillator.

The Ethernet peripheral can be driven from the main clock instead of the PHY clock input, removing the need for separate main and Ethernet clocks. When this feature is enabled, the main clock must be 25 MHz for proper Ethernet operation.

The main clock can be fed into a phase-locked loop (PLL), generating CPU and peripheral clocks in the range of 150–200 MHz, depending on the input clock and PLL settings. This clock can be further adjusted by the clock divider if desired. Dividers exist for most peripherals to scale their clocks over a wide range of frequencies.

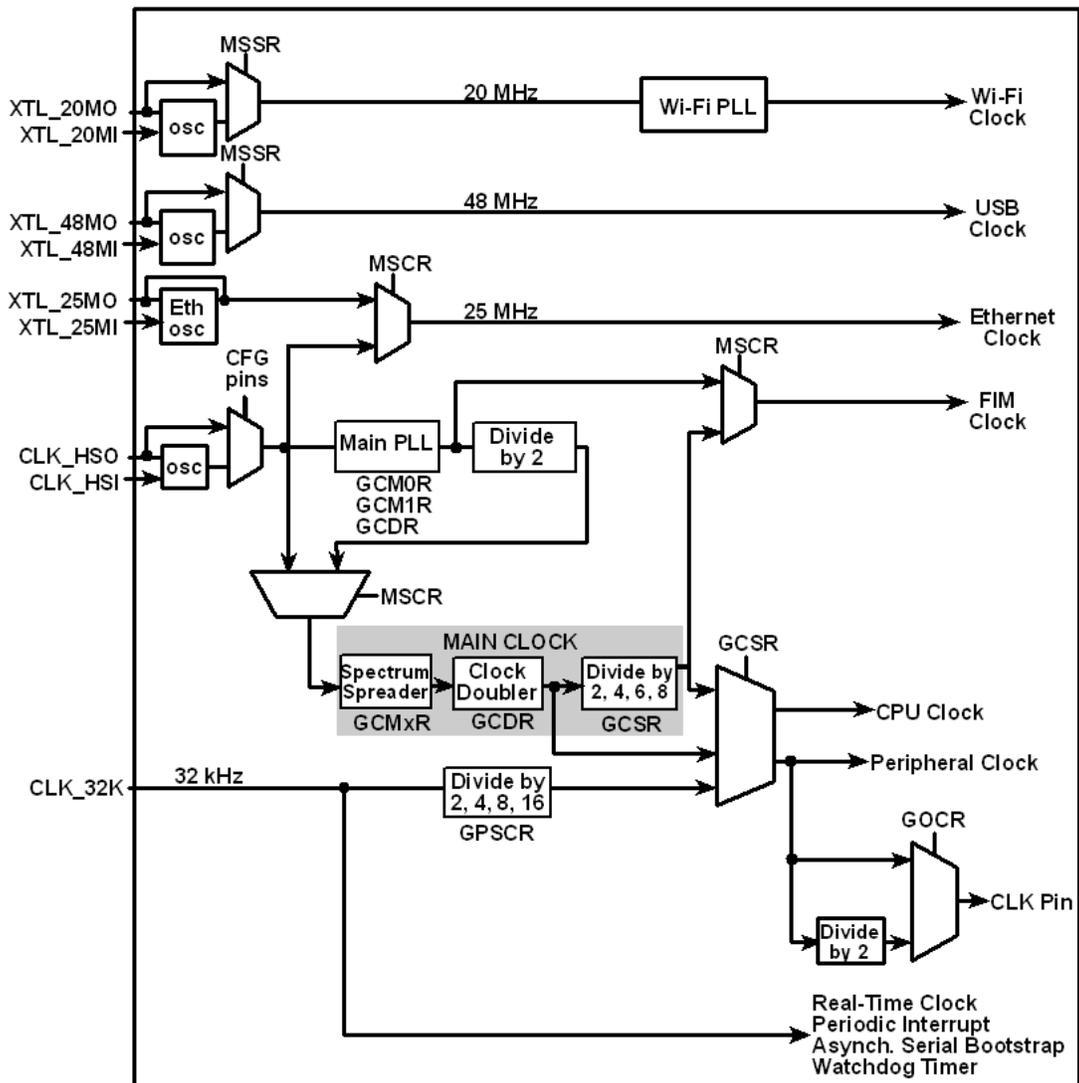
The Rabbit 6000 has a spectrum spreader on the main clock that shortens and lengthens clock cycles. This has the net effect of reducing the peak energy of clock harmonics by spreading the spectral energy into nearby frequencies, which reduces EMI and facilitates government-mandated EMI testing. Gated clocks are used whenever possible to avoid clocking unused portions of the processor, and separate power-supply pins for the core and I/O ring further reduce EMI from the Rabbit 6000. Note that the spectrum spreader is not usable at main clock frequencies above 115 MHz because of the short period.

The main clock can be doubled or divided by 2, 4, 6, or 8 to reduce EMI and power consumption. The 32 kHz clock (which can be divided by 2, 4, 8, or 16) can be used instead of the main clock to generate processor and peripheral clocks as low as 2 kHz for significant power savings. Note that dividing the 32 kHz clock only affects the processor and peripheral clocks; the full 32 kHz signal is still provided to the real-time clock and watchdog timer peripherals that use it directly. The periodic interrupt is disabled automatically since there is not enough time to process it when it is running off the 32 kHz clock. Also, note that the internal RAM content will not be maintained at CPU frequencies below 12MHz.

There is also a 25 MHz Ethernet oscillator that connects directly to the Ethernet PHY if you are using the Ethernet option, but want a different main clock frequency. See Chapter 25 for more details on the Ethernet clock.

The Wi-Fi peripheral requires a 20 MHz clock input, which goes to a dedicated PLL to produce the required clocks for the 802.11a/b/g peripheral. The USB peripheral requires a 48 MHz clock for proper operation.

2.1.1 Block Diagram



2.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Global Control/Status Register	GCSR	0x0000	R/W	11000000
Global Clock Modulator 0 Register	GCM0R	0x000A	W	00000000
Global Clock Modulation 1 Register	GCM1R	0x000B	W	00000000
Global Clock Double Register	GCDR	0x000F	R/W	00000000
Master System Configuration Register	MSCR	0x0434	R/W	00000000
Master System Status Register	MSSR	0x0435	R/W	00000x00

2.2 Dependencies

2.2.1 I/O Pins

The main, Wi-Fi, Ethernet, and USB clocks contain a bypassable internal oscillator, so either a crystal or an external clock input can be used. The selection of a crystal or an external signal for the main oscillator is determined by the state of the CFG pins on startup, and by the Master System Status Register (MSSR). The Ethernet clock source (main clock or PHY oscillator) is selected in the Master System Configuration Register (MSCR). Table 2-1 lists the pins assigned to each clock and how they are controlled.

Table 2-1. Clock Pin Assignments

Clock	Frequency	Crystal Pins	External Clock Signal Pins	Crystal/External Clock Selection by
Main Clock	24 –42 MHz (crystal) 20–200 MHz (external clock)	CLK_HSI CLK_HSO	CLK_HSO	CFG pins (see chapter 3)
W-Fi Clock	20 MHz	XTL_20MI XTL_20MO	XTL_20MO	MSSR
Ethernet Clock	25 MHz	XTL_25MI XTL_25MO	XTL_25MO	—
USB Clock	48 MHz	XTL_48MI XTL_48MO	XTL_48MO	MSSR
32 kHz Clock	32 kHz	—	CLK_32K	—

The 32 kHz clock input is on the CLK_32K pin. There is an internal Schmitt trigger on this pin to reduce sensitivity to noise.

The peripheral clock or peripheral clock divided by 2 may be optionally output on the CLK pin by enabling it via bits 7–6 in GOCR.

2.2.2 Other Registers

Register	Function
GOCR	Used to set up the CLK output pin.
MSCR	Used to: <ul style="list-style-type: none">- select clock input or PLL output for CPU clock- select main clock or external 25 MHz clock for Ethernet- select CPU clock or PLL output for Flexible Interface Modules
MSSR	Used to select crystal or external oscillator for Wi-Fi and USB clocks, and read main and Wi-Fi PLL status.
GCM0R, GCM1R	Used to select the main PLL loop and pre-divider values.
GCDR	Used to enable the main PLL.
ENPR	Used to enable the Wi-Fi PLL (automatic when Wi-Fi is enabled).

2.3 Operation

2.3.1 Main Clock

The main clock is based on the main oscillator output, which in turn is driven by the CLK_HSI and CLK_HSO pins. This output serves as the input for the main PLL, which can be programmed for various frequencies or bypassed completely. There is an option for the resulting output to then be sent through the spectrum spreader and then the clock doubler, which are described later. This resulting clock is the main clock.

Different main clock modes may be selected via the GCSR, as shown in Table 2-2. Note that one GCSR setting slows the processor clock while the peripheral clock operates at full speed; this allows some power reduction while keeping settings like serial baud rates and the PWM at their desired values.

Table 2-2. Clock Modes

GCSR Setting	Processor Clock	Peripheral Clock
xxx010xx	Main clock	Main clock
xxx011xx	Main clock / 2	Main clock / 2
xxx110xx	Main clock / 4	Main clock / 4
xxx111xx	Main clock / 6	Main clock / 6
xxx000xx	Main clock / 8	Main clock / 8 (default on startup)
xxx001xx	Main clock / 8	Main clock
xxx100xx	32 kHz clock (possibly divided)	32 kHz clock (possibly divided via GPSCR)
xxx101xx	32 kHz clock (possibly divided); main clock disabled via CLKIEN output signal	32 kHz clock (possibly divided via GPSCR)

When the 32 kHz clock is enabled in GCSR, it can be further divided by 2, 4, 8, or 16 to generate even lower frequencies by enabling those modes in bits 0–2 of GPSCR. See Table 2-6 for more details.

2.3.2 Main PLL

The main PLL is optimally tuned for a 25 MHz clock input and to produce a 400 MHz output, which can be fed directly to the Flexible Interface Modules (FIMs), and is divided by two to 200 MHz for processor and peripheral operation. Note that the main PLL can be bypassed if lower frequencies are desired.

The main PLL is enabled in GCDR, but is not selected as the main clock until enabled in MSCR. If the 32 kHz clock is present, then the switchover to the PLL output for the main clock will not occur until 200 μ s after the bit is enabled in MSCR to allow the PLL output to stabilize. The status of the main PLL (stable output or not) can be read in bit 0 of MSSR.

The main PLL input clock is restricted to 20–200 MHz, and the output frequency range is limited to 300–400 MHz. There are further restrictions on the internal frequency

The main PLL divider values are located in GCM0R and GCM1R. These should be set to a nonzero value before enabling the PLL. Some suggested PLL settings are described in Table 2-3, chosen to match other clock requirements in the design to allow clock sharing. If other PLL settings are desired, please contact your sales representative at Digi International.

Table 2-3. Suggested PLL Modes

Input Clock	Main Clock (max)	FIM Clock (max)	GCM0R Setting	GCM1R Setting
20 MHz	150 MHz	300 MHz	xxx10000	xxxx0001
20 MHz	200 MHz	400 MHz	xxx10100	xxxx0001
25 MHz	150 MHz	300 MHz	xxx01100	xxxx0001
25 MHz	200 MHz	400 MHz	xxx10000	xxxx0001
48 MHz	156 MHz	312 MHz	xxx01101	xxxx0010
48 MHz	192 MHz	384 MHz	xxx10000	xxxx0010

Note that if the PLL is enabled, restrictions may exist for the use of the spectrum spreader and clock doubler. The following sections provide more details.

2.3.3 Spectrum Spreader

When enabled, the spectrum spreader stretches and compresses the main clock in a complex pattern that spreads the energy of the clock harmonics over a wider range of frequencies. Note that the spectrum spreader cannot operate at frequencies above 115 MHz as it uses up too much of the available clock period, so care must be exercised when using the main PLL.

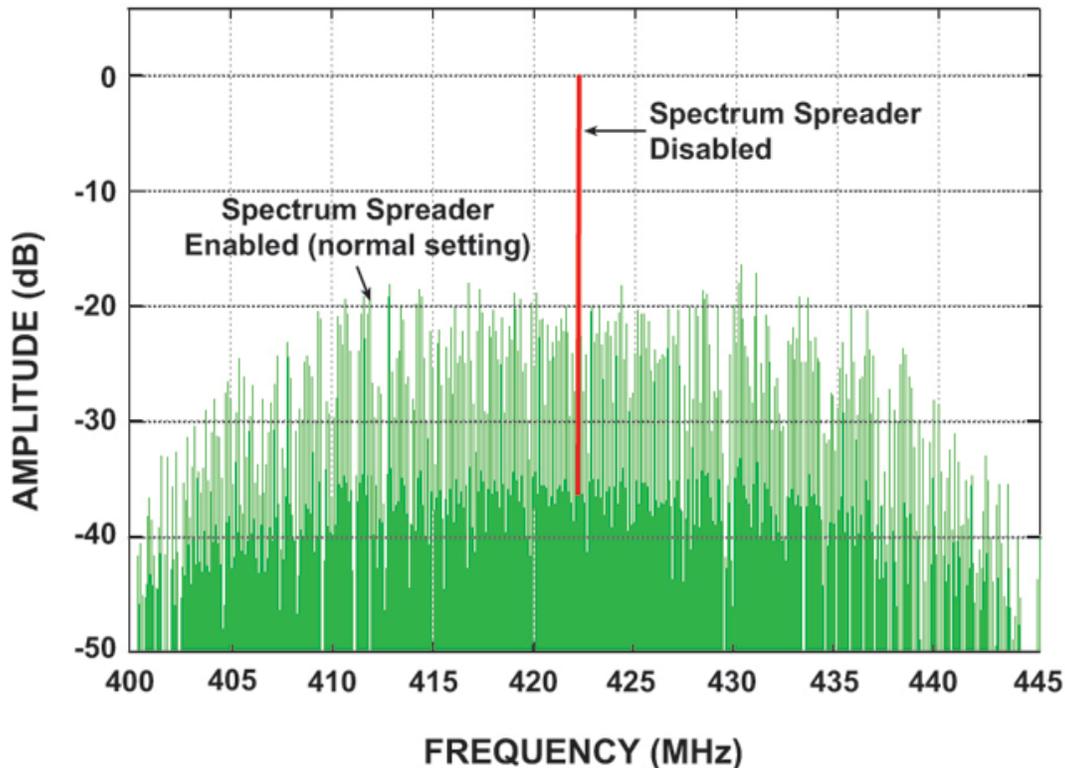


Figure 2.1 Effects of Spectrum Spreader

There are three settings that correspond to normal and strong spreading in the 0–50 MHz and >50 MHz main clock range. Each setting will affect the clock cycle differently; the maximum cycle shortening (at 1.8 V and 25°C) is shown in Table 2-4 below.

Table 2-4. Spectrum Spreader Settings

0–50 MHz	50 - 150 MHz	GCM0R Value	Description	Max. Cycle Shortening
—	Normal	01xxxxxx	Normal spreading of frequencies over 50 MHz	2.3 ns
Normal	Strong	00xxxxxx	Normal spreading of frequencies up to 50 MHz; strong spreading of frequencies over 50 MHz	3 ns
Strong	—	10xxxxxx	Strong spreading of frequencies up to 50 MHz; normal spreading of frequencies over 50 MHz	4.5 ns

The spectrum spreader either stretches or shrinks the low plateau of the clock by a maximum of 3 ns for the normal spreading and up to 4.5 ns for the strong spreading. If the clock doubler is used, this will cause an additional asymmetry between alternate clock cycles.

Both normal and strong modes reduce clock harmonics by approximately 15 dB for frequencies above 100 MHz; for lower frequencies the strong setting has a greater effect in reducing the peak spectral strength as shown in Figure 2.2.

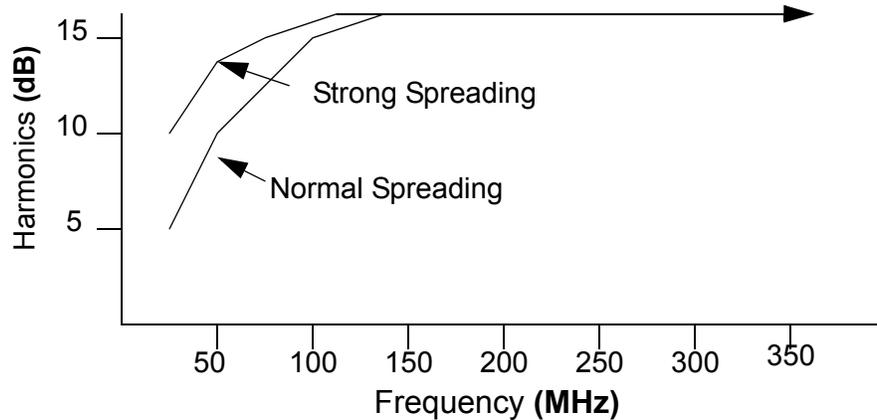


Figure 2.2 Peak Spectral Amplitude Reduction by Spectrum Spreader

Two registers control the clock spectrum spreader. These registers must be loaded in a specific manner with proper time delays. GCM0R is only read by the spectrum spreader at the moment when the spectrum spreader is enabled by setting bit 7 of GCM1R. If bit 7 of GCM1R is cleared (when disabling the spectrum spreader), there is up to a 500-clock delay before the spectrum spreader is actually disabled. The proper procedure is to clear GCM1R, wait for 500 clocks, set GCM0R, and then enable the spreader by writing a 1 to bit 7 of GCM1R.

The spectrum spreader is applied to the main clock before the clock doubler, so if both are enabled there will be additional asymmetry between alternate clock cycles. If the clock doubler is used, the spectrum spreader affects every other cycle and reduces the clock high time. If the doubler is not used, then the spreader affects every clock cycle, and the clock low time is reduced.

2.3.4 Clock Doubler

The clock doubler allows a lower frequency crystal to be used for the main oscillator and to provide an added range over which the clock frequency can be adjusted. The clock doubler is controlled via the Global Clock Double Register (GCDR).

The clock doubler uses an on-chip delay circuit that must be programmed by the user at startup if there is a need to double the clock. Table 2-5 lists the recommended delays in GCDR for various oscillator or crystal frequencies.

Table 2-5. Recommended Delays Set In GCDR for Clock Doubler

Recommended GCDR Value	Frequency Range
0x0F	≤ 7.3728 MHz
0x0B	7.3728–11.0592 MHz
0x09	11.0592–16.5888 MHz
0x06	16.5888–20.2752 MHz
0x03	20.2752–52.8384 MHz
0x01	52.8384–77.4144 MHz
0x00	> 77.4144 MHz

When the clock doubler is used and there is no subsequent division of the clock, the output clock will be asymmetric, as shown in Figure 2.3.

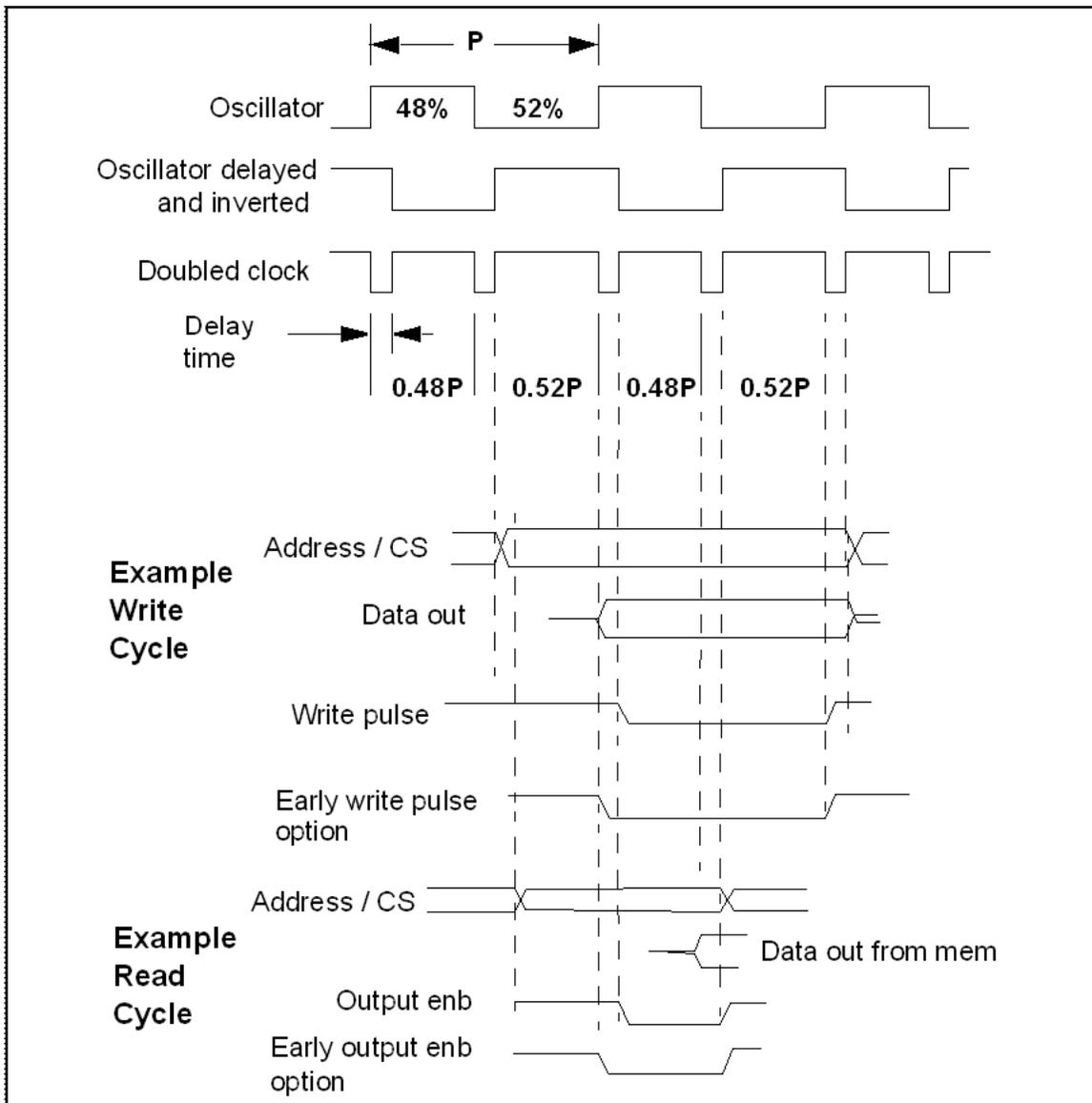


Figure 2.3 Effect of Clock Doubler

The doubled-clock low time is subject to wide (50%) variation since it depends on process parameters, temperature, and voltage. The times given above are for a core supply voltage of 1.8 V and a temperature of 25°C. The values increase or decrease by 1% for each 5°C increase or decrease in temperature. The doubled clock is created by xor'ing the delayed and inverted clock with itself. If the original clock does not have a 50-50 duty cycle, then alternate clocks will have a slightly different length. Since the duty cycle of the built-in oscillator can be as asymmetric as 52%/48%, the clock generated by the clock doubler will exhibit up to a 4% variation in period on alternate clocks. The memory access time is not affected because the memory bus cycle is 2 clocks long and includes both a long and a short clock, resulting in no net change due to asymmetry. However, if an odd number of wait states is used, then the memory access time will be affected slightly.

The maximum allowed clock speed must be reduced slightly if the clock is supplied via the clock doubler. The only signals clocked on the falling edge of the clock are the memory and I/O write pulses, and the early option memory output enable. See Chapter 5 for more information on the early output enable and write enable options.

The power consumption is proportional to the clock frequency, and for this reason power can be reduced by slowing the clock when less computing activity is taking place. The clock doubler provides a convenient method of temporarily speeding up or slowing down the clock as part of a power management scheme.

2.3.5 32 kHz Clock

The 32.768 kHz clock is used to drive the asynchronous serial bootstrap, the real-time clock, the periodic interrupt, and the watchdog timers; see Section 4.3 for detailed descriptions of these features. If these features are not used in a design, the use of the 32 kHz clock is optional.

A self-contained external oscillator is the recommended oscillator circuit for the Rabbit 6000, but a tunable oscillator circuit such as the one shown below may be used. The values of resistors and capacitors may need to be adjusted for various frequencies and crystal load capacitances. Rabbit's Technical Note TN235, *External 32.768 kHz Oscillator Circuits*, is available on the Rabbit Web site and goes into this circuit in detail.

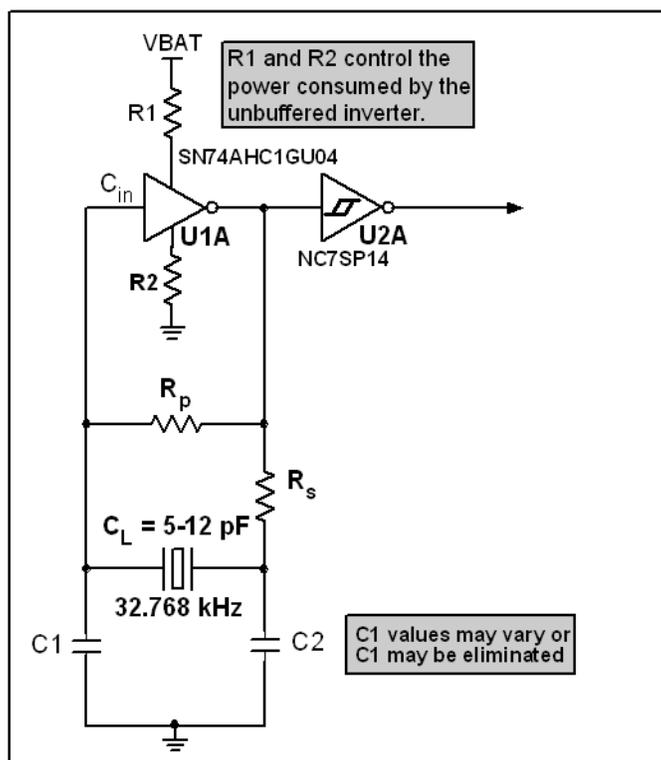


Figure 2.4 Basic 32.768 kHz Oscillator Circuit

The 32.768 kHz circuit consumes microampere-level currents and has a very high impedance, making it susceptible to noise, moisture, and environmental contaminants. It is strongly recommended to conformally coat this circuit to limit the effects of humidity and dust on the oscillation frequency. Details about this requirement are available in Technical Note TN303, “Conformal Coating”, from the Rabbit Web site. The need for a conformal coating can be avoided by using a single external clock chip.

The 32.768 kHz oscillator is slow to start oscillating after power-on. The startup delay may be as much as 5 seconds. For this reason, a wait loop in the BIOS waits until this oscillator is oscillating regularly before continuing the startup procedure. If the clock is battery-backed, there will be no startup delay since the oscillator is already oscillating. Crystals with low series resistance ($R < 35 \text{ k}\Omega$) will start faster.

The 32 kHz oscillator can be used to drive the processor and the peripheral clock to provide significant power savings in “ultra-sleepy” modes. The 32 kHz oscillator can be divided by 2, 4, 8, or 16 to provide clock speeds as low as 2.048 kHz, although there are limitations on use of the 1MB internal RAM at those low clock speeds (See Section 5.3.1, “Internal RAM”). Special self-timed chip selects are available to keep the memory devices enabled for as short a time as possible when an ultra-sleepy mode is enabled; see Chapter 36 for more details on reducing power consumption.

Table 2-6. Ultra-Sleepy Clock Modes

GPSCR Setting	Processor and Peripheral Clock
xxxxx000	32.768 kHz
xxxxx100	16.384 kHz
xxxxx101	8.192 kHz
xxxxx110	4.096 kHz
xxxxx111	2.048 kHz

When the 32 kHz clock is enabled as the CPU clock, the periodic interrupt is disabled automatically. The real-time clock and watchdog timers keep running, and use the full 32 kHz clock speed even when the processor and peripheral clocks use a divider on the 32 kHz clock.

2.4 Register Descriptions

Global Control/Status Register (GCSR) (Address = 0x0000)		
Bit(s)	Value	Description
7:5 (rd-only)	000	No reset or watchdog timer timeout since the last read.
	010	The watchdog timer timed out. These bits will be cleared by reading the register.
	110	Hardware reset occurred. These bits will be cleared by reading the register.
	111	Power-on reset occurred. These bits will be cleared by reading the register.
5 (write)	0	No effect on the Periodic interrupt.
	1	Force a Periodic interrupt to be pending.
4:2	000	Processor clock from the main clock, divided by 8. Peripheral clock from the main clock, divided by 8.
	001	Processor clock from the main clock, divided by 8. Peripheral clock from the main clock.
	010	Processor clock from the main clock. Peripheral clock from the main clock.
	011	Processor clock from the main clock, divided by 2. Peripheral clock from the main clock, divided by 2.
	100	Processor clock from the 32 kHz clock, optionally divided via GPSCR. Peripheral clock from the 32 kHz clock, optionally divided via GPSCR.
	101	Processor clock from the 32 kHz clock, optionally divided via GPSCR. Peripheral clock from the 32 kHz clock, optionally divided via GPSCR. The main clock is disabled.
	110	Processor clock from the main clock, divided by 4. Peripheral clock from the main clock, divided by 4.
	111	Processor clock from the main clock, divided by 6. Peripheral clock from the main clock, divided by 6.
1:0	00	Periodic interrupts are disabled.
	01	Periodic interrupts use Interrupt Priority 1.
	10	Periodic interrupts use Interrupt Priority 2.
	11	Periodic interrupts use Interrupt Priority 3.

Global Clock Modulator 0 Register (GCM0R) (Address = 0x000A)		
Bit(s)	Value	Description
7:6	00	Clock dither in 1 ns steps, from 0 ns to 26 ns. Do not modify while the dither function is enabled.
	01	Clock dither in 0.5 ns steps, from 0 ns to 13 ns.
	10	Clock dither in 2 ns steps, from 0 ns to 52 ns.
	11	This bit combination is reserved and must not be used.
5:4		These bits are reserved and should be written with zeros.
4:0		System PLL loop divider value. All zeros is not a valid value for the PLL loop divider. The PLL output frequency is the input frequency divided by the value of the PLL pre-divider, and multiplied by the value of the PLL loop divider. Neither divider value should not be modified while the PLL is supplying the clock to the system.

Global Clock Modulator 1 Register (GCM1R) (Address = 0x000B)		
Bit(s)	Value	Description
7	0	Disable the clock dither function. The disable does not take effect until the dither pattern has returned to the 0 ns base delay value.
	1	Enable the clock dither function.
6:5		These bits are reserved and should be written with zeros.
3:0		System PLL pre-divider value. All zeros is not a valid value for the PLL pre-divider. Neither divider value should not be modified while the PLL is supplying the clock to the system.

Global Clock Double Register (GCDR) (Address = 0x000F)		
Bit(s)	Value	Description
7	0	Disable system PLL.
	1	Enable system PLL. Setting this bit does not select the system PLL as the clock source.
6:5		These bits are reserved and should always be written with zeros.
4:0	00000	The clock doubler circuit is disabled.
	00001	9 nS nominal Low time.
	00010	10.5 nS nominal Low time.
	00011	12 nS nominal Low time.
	00100	13.5 nS nominal Low time.
	00101	15 nS nominal Low time.
	00110	16.5 nS nominal Low time.
	00111	18 nS nominal Low time.
	01000	19.5 nS nominal Low time.
	01001	21 ns nominal Low time.
	01010	22.5 ns nominal Low time.
	01011	24 ns nominal Low time.
	01100	25.5 ns nominal Low time.
	01101	27 ns nominal Low time.
	01110	28.5 ns nominal Low time.
	01111	30 ns nominal Low time.
	10001	4.5 nS nominal Low time.
10010	6 nS nominal Low time.	

Global Output Control Register (GOCR) (Address = 0x000E)		
Bit(s)	Value	Description
7:6	00	CLK pin is driven with peripheral clock.
	01	CLK pin is driven with peripheral clock divided by 2.
	10	CLK pin is low.
	11	CLK pin is high.
5:4	00	STATUS pin is active (low) during a first opcode byte fetch.
	01	STATUS pin is active (low) during an interrupt acknowledge.
	10	STATUS pin is low.
	11	STATUS pin is high.
3:2	00	/WDTOUT pin functions normally.
	01	Enable /WDTOUT for test mode. Reserved for internal use only.
	10	/WDTOUT pin is low (1 cycle min, 2 cycles max, of 32 kHz).
	11	This bit combination is reserved and should not be used.
1:0	00	/BUFEN pin is active (low) during external I/O cycles.
	01	/BUFEN pin is active (low) during data memory accesses.
	10	/BUFEN pin is low.
	11	/BUFEN pin is high.

Master System Configuration Register (MSCR) (Address = 0x0434)		
Bit(s)	Value	Description
7	0	CPU clock direct from oscillator.
	1	CPU clock from system PLL output (divided by two). Response to this setting may be delayed until the PLL output is stable (roughly 200 μ s after enabling the system PLL, uses 32 kHz clock to generate delay).
6		This bit is reserved and should be written as zero.
5	0	Clock on-chip 10/100 PHY from system oscillator.
	1	Enable embedded oscillator in the internal 10-100 PHY. If using this option, the oscillator must be enabled at least 500 ns before the PHY is enabled in ENPR. This delay must be created in software.
4 (Write-only)	0	No reset of the internal 10/100 PHY. Reads always return zero.
	1	Reset the internal 10/100 PHY hardware. This command must not be issued until at least 600 ms after the internal PHY has been enabled in ENPR. This delay must be created in software.
3:2	00	FIMB clock is disabled.
	01	FIMB clock is identical to the CPU clock.
	10	This bit combination is reserved and should not be used.
	11	FIMB clock from system PLL output. Response to this setting may be delayed until the PLL output is stable (roughly 200 μ s after enabling the system PLL, uses 32 kHz clock to generate delay).
1:0	00	FIMA clock is disabled.
	01	FIMA clock is identical to the CPU clock.
	10	This bit combination is reserved and should not be used.
	11	FIMA clock from system PLL output. Response to this setting may be delayed until the PLL output is stable (roughly 200 μ s after enabling the system PLL, uses 32 kHz clock to generate delay).

Master System Status Register		(MSSR)	(Address = 0x0435)
Bit(s)	Value	Description	
7:6		These bits are reserved and should be written with zeros.	
5	0	Direct Wi-Fi clock input.	
	1	Enable Wi-Fi crystal oscillator.	
4	0	Direct USB clock input.	
	1	Enable USB crystal oscillator.	
3 (Read-only)	0	Normal operation.	
	1	Small package address and data bus option enabled (TEST = 0xF or 0xC).	
2 (Read-only)	0	Large package.	
	1	Small package.	
1 (Read-only)	0	Wi-Fi PLL not enabled or output not stable.	
	1	Wi-Fi PLL is enabled, with stable output.	
0 (Read-only)	0	System PLL not enabled or output not stable.	
	1	System PLL is enabled, with stable output.	

Enable Network Port Register (ENPR) (Address = 0x0430)		
Bit(s)	Value	Description
7	0	Disable Network Port C (the Wi-Fi port).
	1	Enable Network Port C (the Wi-Fi port).
6	0	Disable Network Port B (the 10/100Base-T Ethernet port).
	1	Enable Network Port B (the 10/100Base-T Ethernet port).
5	0	Disable Network Port D (the USB port).
	1	Enable Network Port D (the USB port).
4	0	Internal 10/100 PHY. This bit is ignored unless bit 6 of this register is also set, at which point the internal PHY is powered up.
	1	External 10/100 PHY.
3:2	00	Network Port D interrupts are disabled.
	01	Network Port D interrupts use Interrupt Priority 1.
	10	Network Port D interrupts use Interrupt Priority 2.
	11	Network Port D interrupts use Interrupt Priority 3.
1:0	00	Network Port C interrupts are disabled.
	01	Network Port C interrupts use Interrupt Priority 1.
	10	Network Port C interrupts use Interrupt Priority 2.
	11	Network Port C interrupts use Interrupt Priority 3.



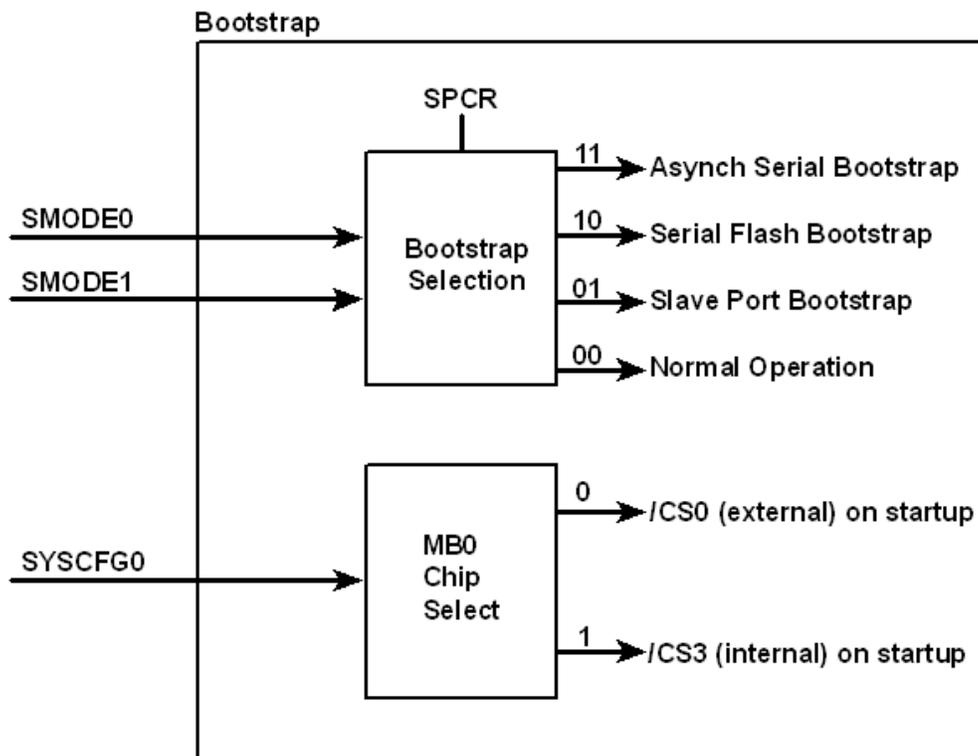
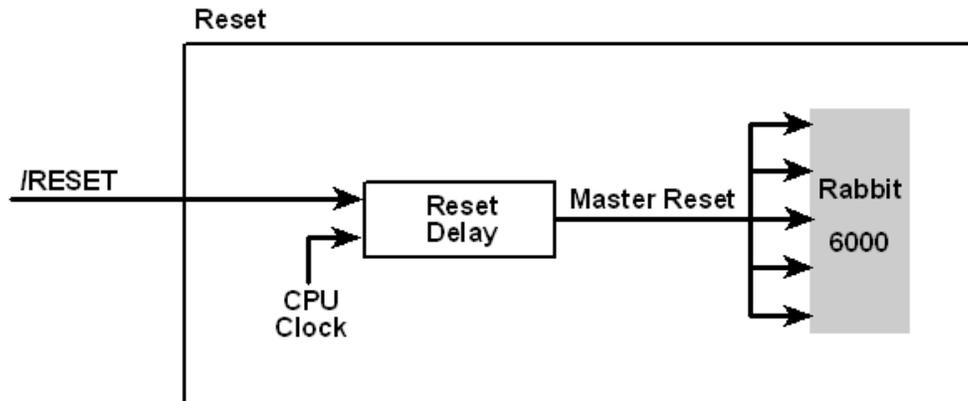
3. RESET AND BOOTSTRAP

3.1 Overview

The Rabbit 6000's /RESET pin initializes everything in the processor except for the real-time clock registers, the contents of the battery-backed onchip-encryption RAM and the 32K battery-backed SRAM. If a write cycle is in progress, it waits until the write cycle is completed to avoid potential memory corruption.

After reset, the Rabbit 6000 checks the state of the SMODE and SYSCFG pins. Depending on the state of the SMODE pins, it either begins normal operation by fetching instruction bytes from memory bank zero, which is mapped to either /CS0 or /CS3 depending on the state of the SYSCFG pin, or it enters a special bootstrap mode where it fetches bytes from either Serial Port A or the slave port. In this mode, bytes can be written to internal registers to set up the Rabbit 6000 for a particular configuration, or to memory to load a program. The processor can begin normal operation once the bootstrap operation is completed.

3.1.1 Block Diagram



3.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Slave Port Control Register	SPCR	0x0024	R/W	0xx0000

3.2 Dependencies

3.2.1 I/O Pins

SMODE0, SMODE1 — When the Rabbit 6000 is first powered up or when it is reset, the state of the SMODE0 and SMODE1 pins controls its operation.

SYSCFG — When the Rabbit 6000 is first powered up or when it is reset, the state of this pin controls whether memory bank zero is mapped to /CS0 or the internal SRAM (/CS3).

/RESET — Pulling the /RESET pin low will initialize everything in the Rabbit 6000 except for the real-time clock registers, the 32K battery-backed RAM and the onchip-encryption RAM.

/CS1 — During reset the impedance of the /CS1 pin is high, and all other memory and I/O control signals are held high. The special behavior of /CS1 allows an external RAM to be powered by the same source as the VBATIO pin (which powers /CS1). In this case, a pullup resistor is required on /CS1 to keep the RAM deselected during powerdown.

RESOUT — The RESOUT pin, which is powered by the backup battery, is high during reset and powerdown as long as VBAT and VBATIO are present, but low at all other times, and can be used to control an external power switch to disconnect VDDIO from VBATIO when the main power source is removed.

3.2.2 Clocks

The processor requires a 32 kHz clock input to generate the 2400 bps internal clock required for asynchronous serial bootstrap, which is used when booting via Dynamic C and the Rabbit Field Utility. No 32 kHz clock is required for either clocked serial or slave port bootstrap.

When the processor comes out of reset, the CPU clock and peripheral clocks are both in divide-by-8 mode.

3.2.3 Other Registers

Register	Function
SPCR	Enable/disable processor monitoring of SMODE pins; read current state of SMODE pins.

3.2.4 Interrupts

There are no interrupts associated with reset or bootstrap.

3.3 Operation

Pulling the /RESET pin low will initialize everything in the Rabbit 6000 except for the real-time clock registers, the 32K battery-backed RAM and the onchip-encryption RAM. The reset of the Rabbit 6000 is delayed until any write cycles in progress are completed; the reset takes effect as soon as no write cycles are occurring. The reset sequence requires a minimum of 128 cycles of the main clock to complete in either case.

During reset, the impedance of the /CS1 pin is high and all other memory and I/O control signals are held high. The special behavior of /CS1 allows an external RAM to be powered by the same source as the VBATIO pin (which powers /CS1). In this case, a pullup resistor is required on /CS1 to keep the RAM deselected during powerdown. The RESOUT pin, which is powered by the backup battery, is high during reset and powerdown as long as VBAT and VBATIO are present, but low at all other times, and can be used to control an external power switch to disconnect VDDIO from VBATIO when the main power source is removed.

Table 3-1 lists the condition of the processor after reset takes place. The state of all registers after reset is provided in the chapter describing the specific peripheral.

Table 3-1. Rabbit 6000 Condition After Reset

Function	Operation After Reset
CPU Clock, Peripheral Clock	Divide-by-8 mode
Clock Doubler, Clock Dither	Disabled
Memory Bank 0 Control Register	/CS0, /OE0, write-protected, 4 wait states
Memory Advanced Control Register	8-bit interface
CPU Registers: PC, SP, IIR, EIR, HTR	0x0000
Interrupt Priority (IP Register)	0xFF (Priority 3)
Watchdog Timer	Enabled (2 seconds)
Secondary Watchdog Timer	Disabled

The processor checks the SMODE and SYSCFG pins after the /RESET signal is inactive. Table 3-2 summarizes what happens.

Table 3-2. SMODE Pin Settings

SMODE Pins [1,0]	SYSCFG	Operation
00	0	No bootstrap; code is fetched from address 0x0000 on /CS0, /OE0. The internal SRAM is enabled as a 16-bit memory device.
00	1	No bootstrap; code is fetched from address 0x0000 on /CS3, /OE0. The internal SRAM is enabled as a 16-bit memory device.
01	x	Bootstrap from the slave port.
10	x	Bootstrap from Serial Port A, serial flash mode.
11	x	Bootstrap from Serial Port A, asynchronous mode.

If both SMODE pins are zero, the Rabbit 6000 begins fetching instructions from the memory device mapped into memory bank 0. When SYSCFG is low, memory bank 0 is set to /CS0 and /OE0. If SYSCFG is high, memory bank 0 is set to /CS3 and /OE0. In both cases, the internal SRAM is selected in 16-bit mode. If a 16-bit memory is used in memory bank 0, the first section of code must immediately select the 16-bit bus mode. Chapter 5 provides a short sample program to do this.

If either of the SMODE pins is high, the processor will enter the bootstrap mode and accept triplets from Serial Port A, the serial flash bootstrap port, or the slave port, depending on the SMODE pin selection. It is good practice to place pulldown resistors on the SMODE pins to ensure the proper operation of your design.

In the bootstrap mode, the processor inhibits the normal memory fetch, and instead fetches instructions from a small internal boot ROM. This program reads triplets of three bytes from the selected peripheral. The first byte is the most-significant byte of a 16-bit address, the second byte is the least-significant byte of the address, and the third byte is the data to be written. If the uppermost bit of the address is 1, then the address is assumed to be an internal register address instead of a memory address, and the data are written to the appropriate register instead. For example, a triplet of (0x04, 0x34, 0x5A) will write 0x5A to logical memory address 0x0434, while a triplet of (0x80, 0x34, 0x5A) will write 0x5A to processor register 0x34. Processor registers with addresses above 0xFF are not accessible in the bootstrap mode.

The boot ROM program waits for data to be available; each byte received automatically resets the watchdog timer with a 2-second timeout. Bytes must be received quickly enough to prevent timeout (or the watchdog must be disabled).

The device checks the state of the SMODE pins each time it jumps back to the start of the ROM program and responds according to the current state. In addition, by setting bit 7 of the Slave Port Control Register (SPCR) high, the processor can be told to ignore the state of the SMODE pins and continue normal operation.

Note that the processor can be told to re-enter bootstrap mode at any time by setting bit 7 of SPCR low; once this occurs and the least significant four bits of the current PC address are zero, the processor will sample the state of the SMODE pins and respond accordingly. This feature allows in-line downloading from the selected bootstrap port; once the download is complete, bit 7 of SPCR can be set high and the processor will continue operating from where it left off.

As a security feature, any attempt to enter the bootstrap mode from either the SMODE pins or by writing to bit 7 of the SPCR will erase the data stored in the onchip-encryption RAM. This prevents loading a small program in memory to read out the data.

3.3.1 Asynchronous Serial Bootstrap

When the *asynchronous serial bootstrap mode* is selected by the SMODE pins, the Rabbit 6000 will begin accepting triplets at 2400 bps on Serial Port A. The baud rate is generated from the 32 kHz clock input, so a 32 kHz clock is required for this mode.

3.3.2 Serial Flash Bootstrap

When the *serial flash bootstrap mode* is selected by the SMODE pins, the Rabbit 6000 will enable the SPI serial flash bootstrap port on pins PD4, PD5, PD6, and PB0; the pins' functionality is listed in Table 3-3 below. Note that these pins can be used for Serial Port B in normal operation, so the serial flash may be accessed with that serial port during normal operation.

Table 3-3. Serial Flash Bootstrap Pin Functions

Pin	SPI Signal	Operation
PD4	MOSI	Rabbit data transmit (to serial flash)
PD5	MISO	Rabbit data receive (from serial flash)
PD6	CS	Chip select (to serial flash)
PB0	SCK	Serial clock (output to serial flash)

The Rabbit 6000 divides the main clock by 64 to provide the SPI clock for the serial flash bootstrap. Once this mode is entered, the Rabbit 6000 will send the byte sequence “0x03 0x00 0x00 0x00”, which is an industry-standard command that enables continuous read mode starting at serial flash address 0x0. Figure 3.1 provides a sample timing diagram. The Rabbit 6000 will then read triplets out of the serial flash until the bootstrap mode is exited.

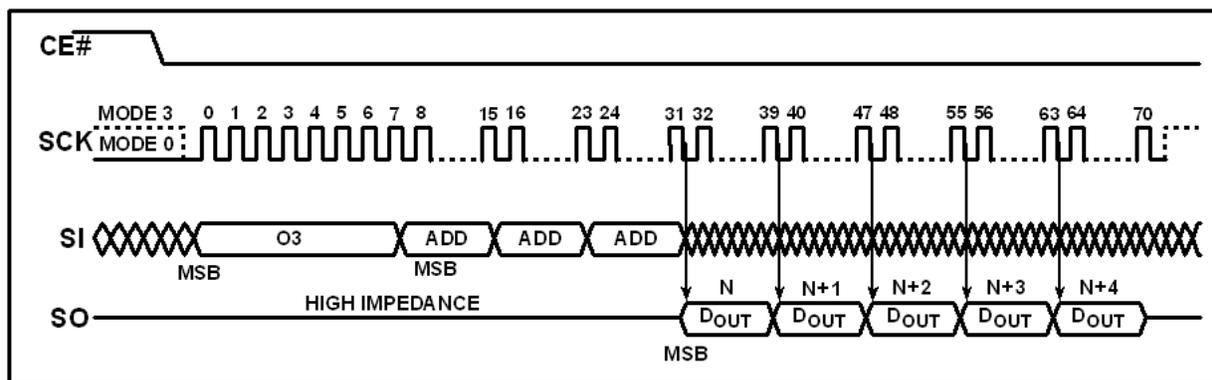


Figure 3.1 SPI Timing Diagram for Serial Flash Bootstrap Mode

3.3.3 Parallel Bootstrap

When the *parallel bootstrap mode* is selected by the SMODE pins, the Rabbit 6000 will enable the parallel slave port interface on Parallel Ports A and B, and will wait for triplets to be sent to that interface. See Chapter 21 for more details on the operation of the slave port.

3.4 Register Descriptions

Slave Port Control Register (SPCR) (Address = 0x0024)		
Bit(s)	Value	Description
7	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
	Write	These bits are ignored and should be written with zero.
4:2	000	Disable the slave port. Parallel Port A is a byte-wide input port.
	001	Disable the slave port. Parallel Port A is a byte-wide output port.
	010	Enable the slave port, with /SCS from Parallel Port E bit 7.
	011	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:2] is used for the address bus.
	100	This bit combination is reserved and should not be used.
	101	This bit combination is reserved and should not be used.
	110	Enable the slave port, with /SCS from Parallel Port B bit 6.
	111	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:0] is used for the address bus.
1:0	00	Slave port interrupts are disabled.
	01	Slave port interrupts use Interrupt Priority 1.
	10	Slave port interrupts use Interrupt Priority 2.
	11	Slave port interrupts use Interrupt Priority 3.

4. SYSTEM MANAGEMENT

4.1 Overview

There are a number of basic system peripherals in the Rabbit 6000 processor, some of which are covered in later chapters. The peripherals covered in this chapter are the periodic interrupt, the real-time clock, the watchdog timers, the battery-backed onchip-encryption RAM, and some of the miscellaneous output pins and their control and processor registers that provide the processor ID and revision numbers.

The periodic interrupt, when enabled, is generated every 16 clocks of the 32 kHz clock (every 488 μ s, or 2.048 kHz). This interrupt can be used to perform periodic tasks.

The real-time clock (RTC) consists of a 48-bit counter that is clocked by the 32 kHz clock. It is powered by the VBAT pin, and so can be battery-backed. The value in the counter is not affected by reset, and can only be set to zero by writing to the RTC control register. The 48-bit width provides a 272-year span before rollover occurs.

There are two watchdog timers in the Rabbit 6000, both clocked by the 32 kHz clock. The main watchdog timer can be set to time out from 250 ms to 2 seconds, and resets the processor if not reloaded within that time. Its purpose is to restart the processor when it detects that a program gets stuck or disabled.

The secondary watchdog timer can time out from 30.5 μ s up to 7.8 ms, and generates a Priority 3 secondary watchdog interrupt when it is not reset within that time. The primary use for the secondary watchdog is to act as a safety net for the periodic interrupt — if the secondary watchdog is reloaded in the periodic interrupt, it will count down to zero if the periodic interrupt stops occurring. In addition, it can be used as a periodic interrupt on its own.

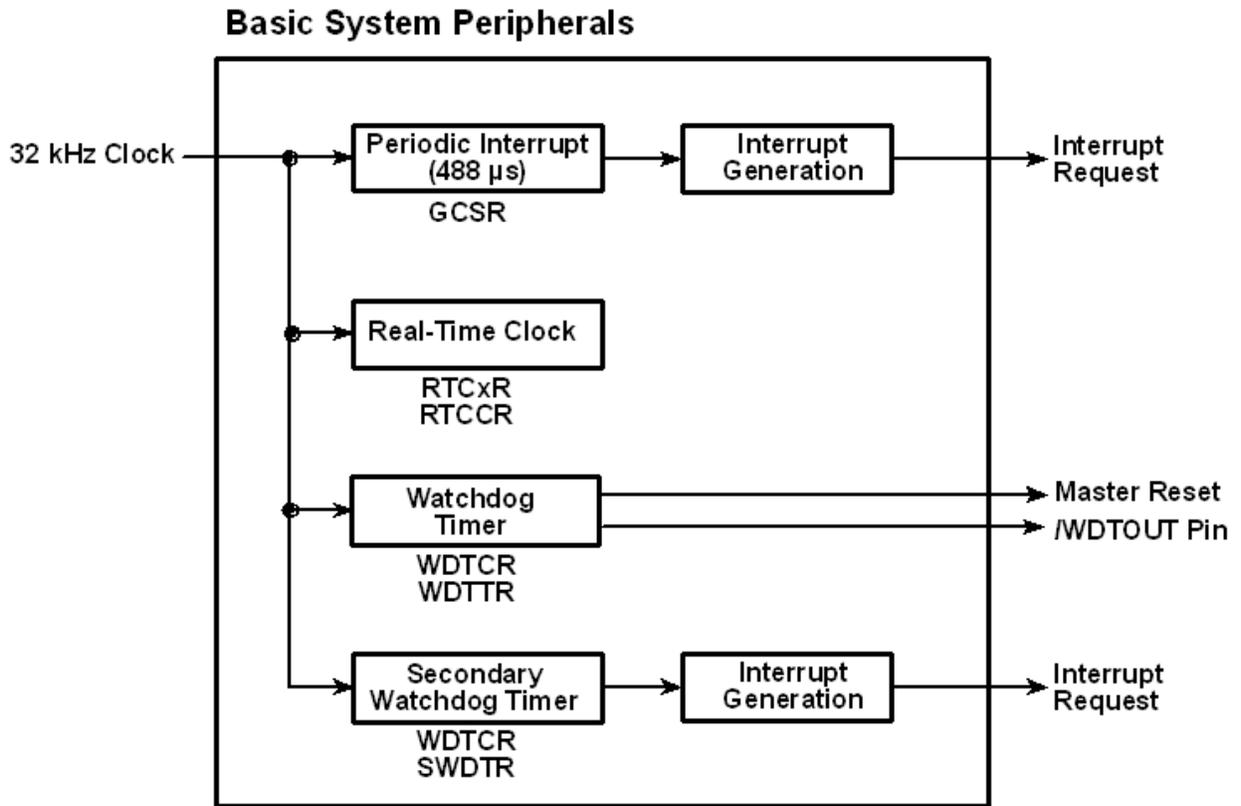
The battery-backed onchip-encryption RAM consists of 32 bytes of memory that are powered by the VBAT pin (note that this RAM is separate from the battery-backed 32 KB SRAM). Their values are not affected by a reset, but are erased if the state of the SMODE pins changes. These 32 bytes are intended for storing sensitive data (such as an encryption key) somewhere other than an external memory device. The “tamper-protection” erase feature erases these bytes if an attempt is made to load a program into the onchip RAM to read out the bytes.

A feature new to the Rabbit 6000 is a 14-bit CPU clock cycle counter. This counter counts the number of CPU cycles that occur during one 32 kHz clock period. This is useful for determining the frequency of the main CPU oscillator which can be used in baud rate calculations as well as other CPU clock dependant features.

The following other registers are also described in this chapter.

- Global Output Control Register (GOCR), which controls the behavior of the CLK, STATUS, /WDT, and /BUFEN pins
- Global CPU Register (GCPU), which holds the identification number of the processor.
- Global Revision Register (GREV), which hold the revision number of the processor.

4.1.1 Block Diagram



4.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Global Control/Status Register	GCSR	0x0000	R/W	11000000
Real-Time Clock Control Register	RTCCR	0x0001	W	00000000
Real-Time Clock Byte 0 Register	RTC0R	0x0002	R/W	xxxxxxxx
Real-Time Clock Byte 1 Register	RTC1R	0x0003	R	xxxxxxxx
Real-Time Clock Byte 2 Register	RTC2R	0x0004	R	xxxxxxxx
Real-Time Clock Byte 3 Register	RTC3R	0x0005	R	xxxxxxxx
Real-Time Clock Byte 4 Register	RTC4R	0x0006	R	xxxxxxxx
Real-Time Clock Byte 5 Register	RTC5R	0x0007	R	xxxxxxxx
Watchdog Timer Control Register	WDTCR	0x0008	W	00000000
Watchdog Timer Test Register	WDTTR	0x0009	W	00000000
Secondary Watchdog Timer Register	SWDTR	0x000C	W	11111111
Global Output Control Register	GOCR	0x000E	R/W	00000000
Global ROM Configuration Register	GROM	0x002C	R	0xx00000
Global RAM Configuration Register	GRAM	0x002D	R	0xx00000
Global CPU Configuration Register	GCPU	0x002E	R	0xx00010
Global Revision Register	GREV	0x002F	R	0xx00000
Battery-Backed Onchip-Encryption RAM Bytes 00–1F	VRAM00– VRAM1F	0x0600– 0x061F	R/W	xxxxxxxx
Master System Configuration Register	MSCR	0x0434	R/W	00000000
Master System Status Register	MSSR	0x0435	R/W	00000x00

4.2 Dependencies

4.2.1 I/O Pins

The CLK, STATUS, /WDTOUT, and /BUFEN pins are controlled by GOCR. Each of these pins can be used as general-purpose outputs by driving them high or low.

- The CLK pin can output the peripheral clock, the peripheral clock divided by two, or be driven high or low.
- The STATUS pin can be active low during the first byte of each opcode fetch, active low during an interrupt acknowledge, or driven high or low.
- The /WDTOUT pin can be active low whenever the watchdog timer resets the device or driven low.
- The /BUFEN pin can be active low during external I/O cycles, active low during data memory cycles, or driven high or low.

The values in the battery-backed onchip-encryption RAM bytes are cleared if the signal on the SMODE pins changes state.

4.2.2 Clocks

The periodic interrupt, real-time clock, watchdog timer, and secondary watchdog timer require the 32 kHz clock.

4.2.3 Interrupts

The periodic interrupt is enabled in GCSR, and will occur every 488 μ s. It is cleared by reading GCSR. It can operate at Priority 1, 2, or 3.

The secondary watchdog interrupt will occur whenever the secondary watchdog is enabled and allowed to count down to zero. It is cleared by restarting the secondary watchdog by writing 0x5F to WDTCR or writing a new timeout value to SWDTR. The secondary watchdog interrupt always occurs at Priority 3.

4.3 Operation

4.3.1 Periodic Interrupt

The following steps explain how a periodic interrupt is used.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Enable the periodic interrupt by writing to GCSR.
3. The interrupt request is cleared by reading from GCSR.

A sample interrupt handler is shown below.

```
periodic_isr::
    push af
    ioi ld a, (GCSR)      ; clear the interrupt request and get status

    ; handle any periodic tasks here

    pop af
    ipres
    ret
```

4.3.2 Real-Time Clock

The real-time clock consists of six 8-bit registers that together comprise a 48-bit value. The real-time clock is not synchronized to the read operation, so the least-significant byte should be read twice and checked for matching values; if the two reads do not match, then the real-time clock may have been updating during the read and should be read again.

Writing to RTC0R latches the current real-time clock value into the RTCxR holding registers, so the following sequence should be used to read the real-time clock.

1. Write any value to RTC0R and then read back a value from RTC0R.
2. Write a value to RTC0R again, and again read back a value from RTC0R.
3. If the two values do not match, repeat Step 2 until the last two readings are identical.
4. At this point, registers RTC1R through RTC6R can also be read and used.

Note that the periodic interrupt and the real-time clock are clocked by the same edge of the 32 kHz clock; if read from the periodic interrupt, the count is guaranteed to be stable and only needs to be read once (assuming it occurs within one clock of the 32 kHz clock).

The real-time clock can be reset by writing the sequence 0x40 – 0x80 to RTCCR. It can be reset and left in the byte increment mode by writing 0x40 – 0xC0 to RTCCR and then writing bytes repeatedly to RTCCR to increment the appropriate bytes of the real-time clock. The byte increment mode is disabled by writing 0x00 to RTCCR.

4.3.3 Watchdog Timer

The watchdog timer is enabled on reset with a 2-second timeout. Unless specific data are written to WDTCR before that time expires, the processor will be reset. The watchdog timer can be disabled by writing a sequence of two bytes to WDTTR as described in the register description.

Table 4-1. Watchdog Timer Settings

WDTCR Value	Effect
0x5A	Restart watchdog timer with 2-second timeout.
0x57	Restart watchdog timer with 1-second timeout.
0x59	Restart watchdog timer with 500-millisecond timeout.
0x53	Restart watchdog timer with 250-millisecond timeout.
0x5F	Restart the secondary watchdog timer.

The watchdog timer also contains a special test mode that speeds up the timeout period by clocking it with the peripheral clock instead of the 32 kHz clock. This mode can be enabled by writing to WDTTR.

4.3.4 Secondary Watchdog Timer

The secondary watchdog timer is disabled on reset. The following steps explain how to use the secondary watchdog timer.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Write the desired timeout period to SWDTR. This also enables the secondary watchdog timer.
3. Restart the secondary watchdog timer by either writing the timeout period to SWDTR or writing 0x5F to WDTCR.

If the secondary watchdog timer counts down to zero, a Priority 3 secondary watchdog interrupt will occur. This interrupt request is cleared by writing a new timeout value to SWDTR. A sample interrupt handler is shown below.

```
secwd_isr::
    push af

    ; determine why the interrupt occurred and take appropriate
    action

    ld a, 0x40          ; timeout period of 0x40/32kHz = 1.95ms
    ioi ld (SWDTR), a  ; clear the interrupt request

    pop af
    ipres
    ret
```

4.3.5 CPU Clock Cycle Counter

This counter counts the number of CPU cycles that occur during one 32 kHz clock period. The least significant 8 bits of this 14-bit counter are accessed by reading WDTCR, and the upper 6 bits are accessed by reading WDTTR. This value is updated continually, so be careful to not change the main clock frequency between reading the two registers.

4.4 Register Descriptions

Global Control/Status Register (GCSR) (Address = 0x0000)		
Bit(s)	Value	Description
7:5 (rd-only)	000	No reset or watchdog timer timeout since the last read.
	010	The watchdog timer timed out. These bits will be cleared by reading the register.
	110	Hardware reset occurred. These bits will be cleared by reading the register.
	111	Power-on reset occurred. These bits will be cleared by reading the register.
5 (write)	0	No effect on the Periodic interrupt.
	1	Force a Periodic interrupt to be pending.
4:2	000	Processor clock from the main clock, divided by 8. Peripheral clock from the main clock, divided by 8.
	001	Processor clock from the main clock, divided by 8. Peripheral clock from the main clock.
	010	Processor clock from the main clock. Peripheral clock from the main clock.
	011	Processor clock from the main clock, divided by 2. Peripheral clock from the main clock, divided by 2.
	100	Processor clock from the 32 kHz clock, optionally divided via GPSCR. Peripheral clock from the 32 kHz clock, optionally divided via GPSCR.
	101	Processor clock from the 32 kHz clock, optionally divided via GPSCR. Peripheral clock from the 32 kHz clock, optionally divided via GPSCR. The main clock is disabled.
	110	Processor clock from the main clock, divided by 4. Peripheral clock from the main clock, divided by 4.
	111	Processor clock from the main clock, divided by 6. Peripheral clock from the main clock, divided by 6.
1:0	00	Periodic interrupts are disabled.
	01	Periodic interrupts use Interrupt Priority 1.
	10	Periodic interrupts use Interrupt Priority 2.
	11	Periodic interrupts use Interrupt Priority 3.

Real-Time Clock Control Register (RTCCR) (Address = 0x0001)		
Bit(s)	Value	Description
7:0	0x00	No effect on the real-time clock counter, or disable the byte increment function, or cancel the real-time clock reset command.
	0x40	Arm the real-time clock for reset or byte increment. This command must be written prior to either the real-time clock reset command or the first byte increment write.
	0x80	Reset all six bytes of the real-time clock counter to 0x00. The reset must be preceded by writing 0x40 to arm the reset function.
	0xC0	Reset all six bytes of the real-time clock counter to 0x00, and remain in byte-increment mode in preparation for setting the time.
7:6	01	This bit combination must be used with every byte-increment write.
5:0	0	No effect on the real-time clock counter.
	1	Increment the corresponding byte of the real-time clock counter.

Real-Time Clock x Register		
(RTC0R) (Address = 0x0002)		
(RTC1R) (Address = 0x0003)		
(RTC2R) (Address = 0x0004)		
(RTC3R) (Address = 0x0005)		
(RTC4R) (Address = 0x0006)		
(RTC5R) (Address = 0x0007)		
Bit(s)	Value	Description
7:0	Read	The current value of the 48-bit real-time clock counter is returned.
	Write	Writing to RTC0R transfers the current count of the real-time clock to a holding register while the real-time clock continues counting.

Watchdog Timer Control Register (WDTCR) (Address = 0x0008)		
Bit(s)	Value	Description
7:0	0x5A	Restart the watchdog timer with a 2-second timeout period.
	0x57	Restart the watchdog timer with a 1-second timeout period.
	0x59	Restart the watchdog timer with a 500 ms timeout period.
	0x53	Restart the watchdog timer with a 250 ms timeout period.
	0x5F	Restart the secondary watchdog timer.
	other	No effect on watchdog timer or secondary watchdog timer.
	read	Return the least-significant 8bits of the CPU clock cycle counter.

Watchdog Timer Test Register (WDTTR) (Address = 0x0009)		
Bit(s)	Value	Description
7:0	0x51	Clock the least significant byte of the watchdog timer from the peripheral clock.
	0x52	Clock the most significant byte of the watchdog timer from the peripheral clock.
	0x53	Clock both bytes of the watchdog timer, in parallel, from the peripheral clock.
	0x54	Disable the watchdog timer. This value, by itself, does not disable the watchdog timer. Only a sequence of two writes, where the first write is 0x51, 0x52, or 0x53, followed by a write of 0x54, actually disables the watchdog timer. The watchdog timer will be re-enabled by any other write to this register.
	other	Normal clocking (32 kHz clock) for the watchdog timer.
5:0	read	Return the most-significant 6 bits of the CPU clock cycle counter.

Secondary Watchdog Timer Register (SWDTR) (Address = 0x000C)		
Bit(s)	Value	Description
7:0		The time constant for the secondary watchdog timer is stored. This time constant will take effect the next time that the secondary watchdog counter counts down to zero. The timer counts modulo $n + 1$, where n is the programmed time constant. The secondary watchdog timer can be disabled by writing the sequence 0x5A – 0x52 – 0x44 to this register.

Global ROM Configuration Register (GROM) (Address = 0x002C)		
Bit(s)	Value	Description
7 (Read-only)	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
4:0	00000	ROM identifier for this version of the chip.

Global RAM Configuration Register (GRAM) (Address = 0x002D)		
Bit(s)	Value	Description
7 (Read-only)	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
4:0	00010	RAM identifier for this version of the chip.

Global Output Control Register (GOCR) (Address = 0x000E)		
Bit(s)	Value	Description
7:6	00	CLK pin is driven with peripheral clock.
	01	CLK pin is driven with peripheral clock divided by 2.
	10	CLK pin is low.
	11	CLK pin is high.
5:4	00	STATUS pin is active (low) during a first opcode byte fetch.
	01	STATUS pin is active (low) during an interrupt acknowledge.
	10	STATUS pin is low.
	11	STATUS pin is high.
3:2	00	/WDTOUT pin functions normally.
	01	Enable /WDTOUT for test mode. Reserved for internal use only.
	10	/WDTOUT pin is low (1 cycle min, 2 cycles max, of 32 kHz).
	11	This bit combination is reserved and should not be used.
1:0	00	/BUFEN pin is active (low) during external I/O cycles.
	01	/BUFEN pin is active (low) during data memory accesses.
	10	/BUFEN pin is low.
	11	/BUFEN pin is high.

Global CPU Register (GCPU) (Address = 0x002E)		
Bit(s)	Value	Description
7 (Read-only)	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
4:0	00100	CPU identifier for this version of the chip.

Global Revision Register (GREV) (Address = 0x002F)		
Bit(s)	Value	Description
7 (Read-only)	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
4:0	00000	CPU identifier for this version of the chip.

Battery-Backed Onchip-Encryption RAM (VRAM00) (Address = 0x0600) through (VRAM31) (Address = 0x061F)		
Bit(s)	Value	Description
7:0		General-purpose RAM locations. Cleared by Intrusion Detect conditions.

5. MEMORY MANAGEMENT

5.1 Overview

The Rabbit 6000 supports both 8-bit and 16-bit external flash and SRAM devices; three chip selects, and two read/write-enable strobes allow up to six external devices to be attached at once. The 8-bit mode allows 0, 1, 2, or 4 wait states to be specified for each device, and the 16-bit mode allows 0 to 7 wait states depending on the settings. Both 8-bit and 16-bit page-mode devices are also supported.

In addition, the Rabbit 6000 contains 1 MB of internal high-speed RAM and 32 KB of battery-backed SRAM (also high speed) that reside on their own chip select signal. They can both be enabled in either the 8-bit or the 16-bit mode.

The Rabbit 6000's physical memory space contains four consecutive banks, each of which can be set for equal sizes ranging from 128 KB up to 4 MB, providing a total physical memory range from 512 KB up to 16 MB. Each bank can be mapped to an individual chip-select/enable strobe pair for a memory device. In addition, each bank can be divided into two equal-sized low and high sub banks with separate chip-select/enable strobe mapping. Figure 5.1 shows a sample configuration.

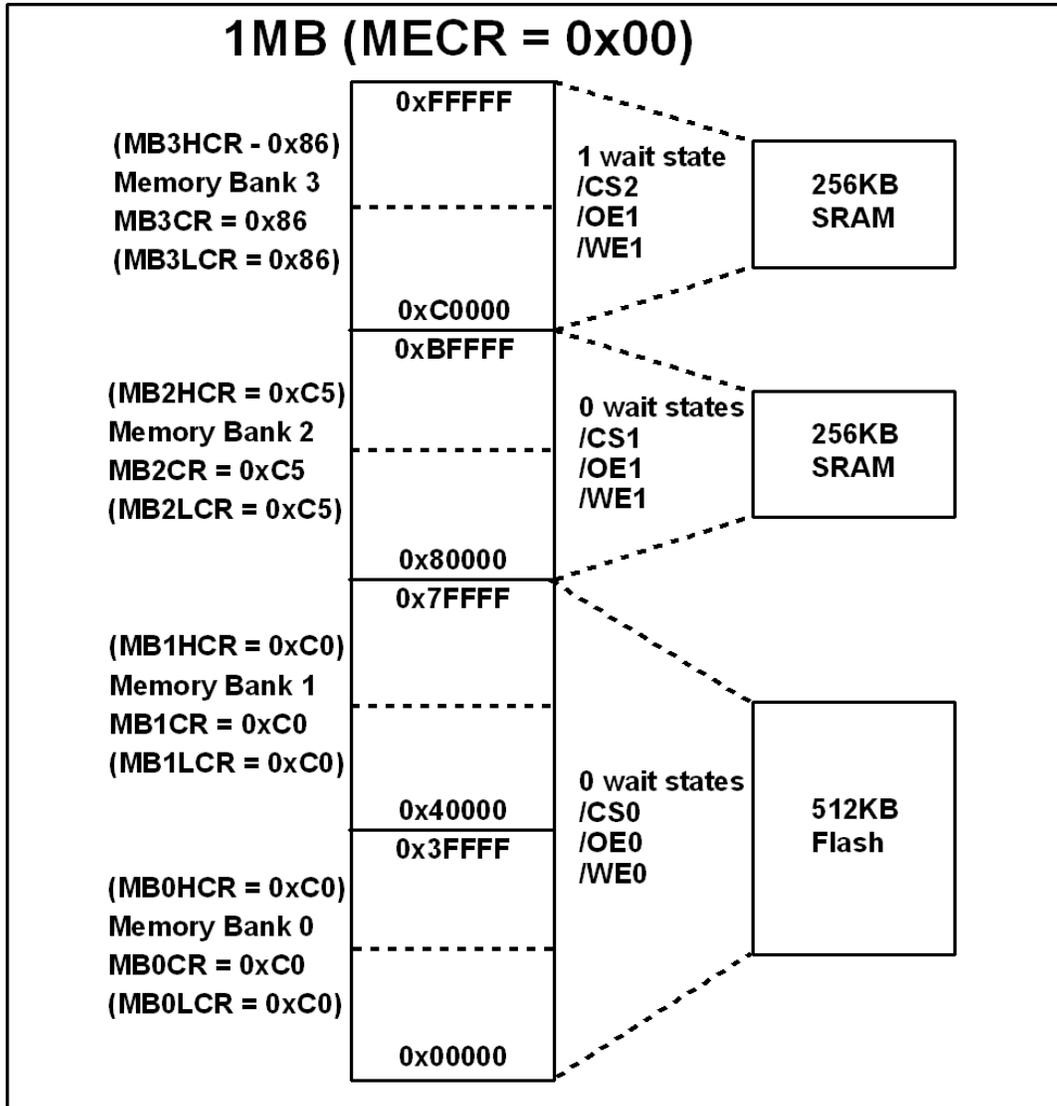


Figure 5.1 Mapping Rabbit 6000 Physical Memory Space

Either one or both of the two most significant address bits (which are used to select the quadrant) can be inverted, providing the ability to bank-switch other pages from a larger memory device into the same memory bank.

Code is executed in the 64 KB logical memory space, which is divided into four segments: root, data, stack, and XMEM. The root segment is mapped directly to physical address 0x000000, while the data and stack segments can be mapped to 4 KB boundaries anywhere in the physical space. The boundaries between the root and data segments and the data and stack segments can be adjusted in 4 KB blocks as well.

The XMEM segment is a fixed 8 KB, and points to a physical memory address block specified in the LXPC register. It is possible to run code in the XMEM window, providing an easy means of storing and executing code beyond the 64 KB logical memory space. Special call and return instructions to physical addresses are provided that automatically update the LXPC register as necessary.

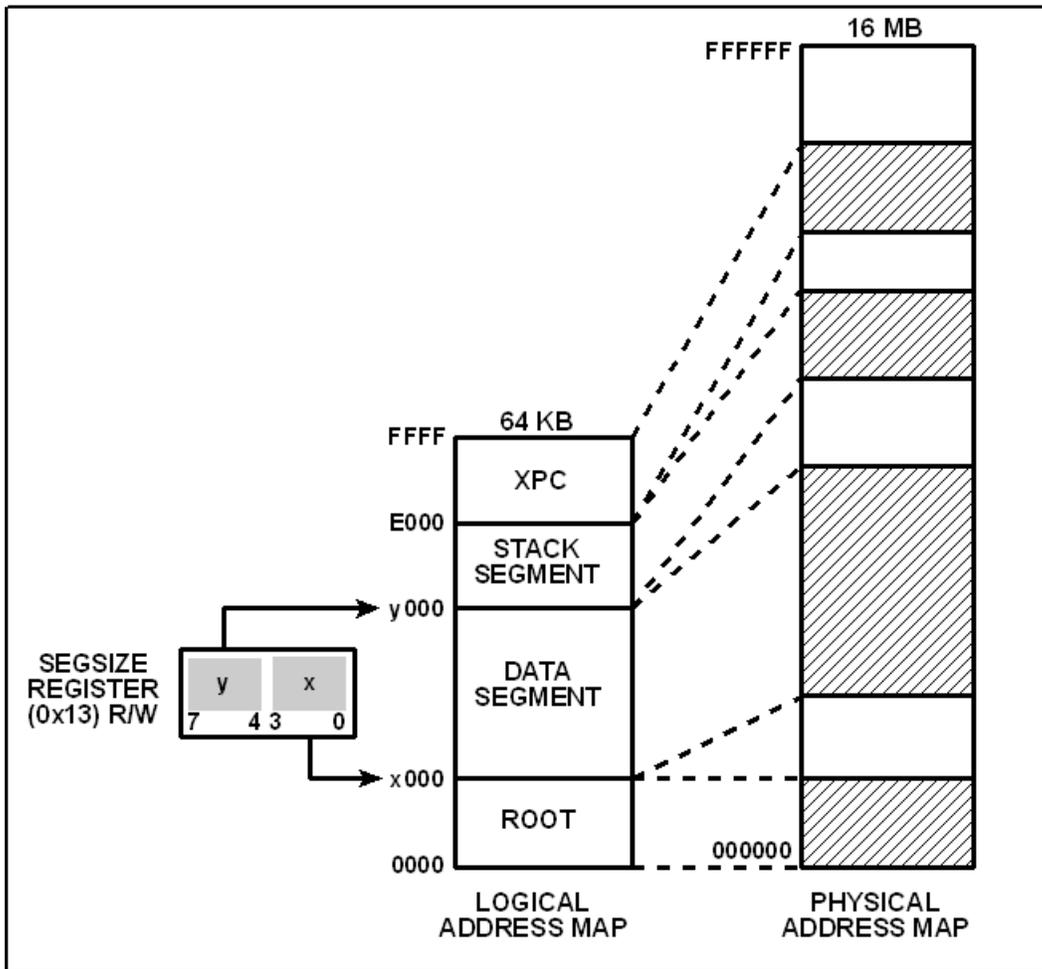


Figure 5.2 Logical and Physical Memory Mapping

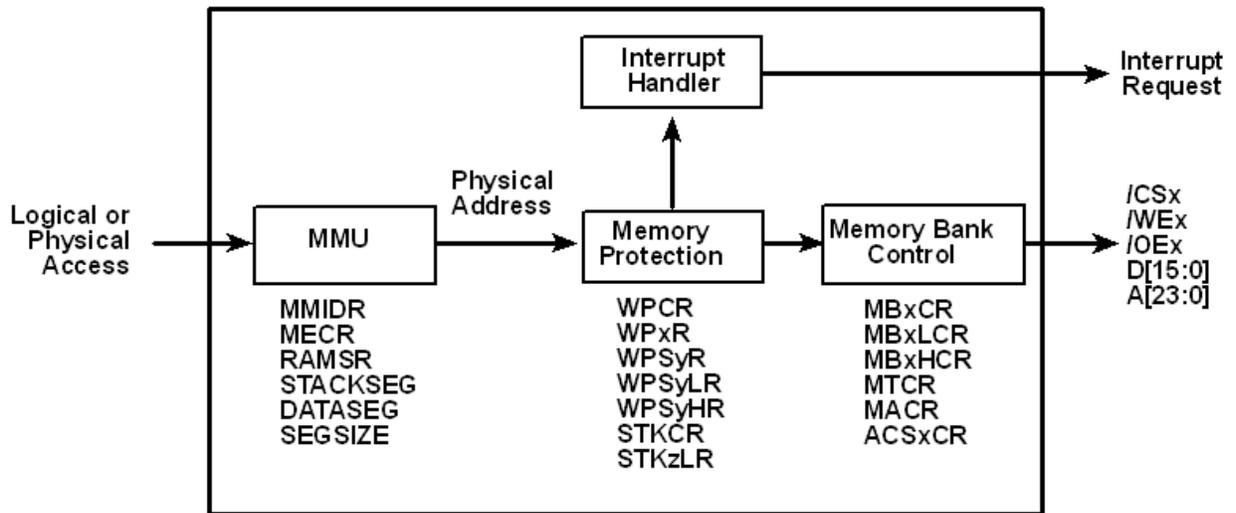
The Rabbit 2000 and 3000 had numerous instructions for reading and writing data to logical addresses, but only had limited support for reading and writing data to a physical memory address. In the Rabbit 4000, a wide range of instructions was provided to read and write to physical addresses. The same instructions can be used to write to logical addresses. All of these instructions are available in the Rabbit 6000, as well as new instructions for more operations using physical addresses.

The 64 KB logical memory space limitation can also be expanded by using the separate instruction and data space mode. When this mode is enabled, address bit A16 is inverted for all data accesses in the root and/or data segments, and the most-significant bit of the bank select bits is inverted for all data accesses in the root and/or data segments before bank selection (physical device) occurs. These two features allow both code and data to access separate 64 KB logical spaces instead of sharing a single space.

It is possible to protect memory in the Rabbit 6000 at three different levels—each of the memory banks can be made read-only, physical memory can be write-protected in 64 KB blocks, and two of those 64 KB blocks can be protected with a granularity of 4 KB. A Priority 3 interrupt will occur if a write is attempted in one of the protected 64 KB or 4 KB blocks. In addition, it is possible to place limits around the code execution stack and generate an interrupt if a stack-related write occurs within 16 bytes of those limits.

The drive strength and slew rate can be controlled for the address bus, data bus, and memory strobes (other than /CS1, which has fixed functionality). In addition, a 75 kΩ pullup or pulldown resistor can be enabled on the data bus.

5.1.1 Block Diagram



5.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
MMU Instruction/Data Register	MMIDR	0x0010	R/W	00000000
Stack Segment Register	STACKSEG	0x0011	R/W	00000000
Stack Segment LSB Register	STACKSEGL	0x001A	R/W	00000000
Stack Segment MSB Register	STACKSEGH	0x001B	R/W	00000000
Data Segment Register	DATSEG	0x0012	R/W	00000000
Data Segment LSB Register	DATSEGL	0x001E	R/W	00000000
Data Segment MSB Register	DATSEGH	0x001F	R/W	00000000
Segment Size Register	SEGSIZE	0x0013	R/W	11111111
Memory Bank 0 Control Register	MB0CR	0x0014	R/W	00001000
Memory Bank 1 Control Register	MB1CR	0x0015	R/W	xxxxxxxx
Memory Bank 2 Control Register	MB2CR	0x0016	R/W	xxxxxxxx
Memory Bank 3 Control Register	MB3CR	0x0017	R/W	xxxxxxxx
MMU Expanded Code Register	MECR	0x0018	R/W	00000000
Memory Timing Control Register	MTCR	0x0019	R/W	00000000
Memory Alternate Control Register	MACR	0x001D	R/W	00000000
Memory Bank 0 Low Control Register	MB0LCR	0x0400	R/W	00001000
Memory Bank 0 High Control Register	MB0HCR	0x0401	R/W	00001000
Memory Bank 1 Low Control Register	MB1LCR	0x0402	R/W	00001000
Memory Bank 1 High Control Register	MB1HCR	0x0403	R/W	00001000
Memory Bank 2 Low Control Register	MB2LCR	0x0404	R/W	00001000
Memory Bank 2 High Control Register	MB2HCR	0x0405	R/W	00001000
Memory Bank 3 Low Control Register	MB3LCR	0x0406	R/W	00001000
Memory Bank 3 High Control Register	MB3HCR	0x0407	R/W	00001000
Advanced /CS0 Control Register	ACS0CR	0x0410	R/W	00000000
Advanced /CS1 Control Register	ACS1CR	0x0411	R/W	00000000
Advanced /CS2 Control Register	ACS2CR	0x0412	R/W	00000000
RAM Segment Register	RAMSR	0x0448	R/W	00000000
Write-Protect n Register (n = 0–31)	WPnR	0x460 + n	W	00000000

Register Name	Mnemonic	I/O Address	R/W	Reset
Write-Protect Segment A Register	WPSAR	0x0480	W	00000000
Write-Protect Segment A Low Register	WPSALR	0x0481	W	00000000
Write-Protect Segment A High Register	WPSAHR	0x0482	W	00000000
Write-Protect Segment B Register	WPSBR	0x0484	W	00000000
Write-Protect Segment B Low Register	WPSBLR	0x0485	W	00000000
Write-Protect Segment B High Register	WPSBHR	0x0486	W	00000000
Stack Limit Control Register	STKCR	0x0444	R/W	00000000
Stack Low Limit Register	STKLLR	0x0445	W	xxxxxxxx
Stack High Limit Register	STKHLR	0x0446	W	xxxxxxxx
Address Bus Pin Control Register	ADPCR	0x04A0	W	xxx00000
Data Bus Pin Control Register	DBPCR	0x04A1	W	xxx00000
Control Pin Control Register	CPCR	0x04A2	W	xxx00000

5.2 Dependencies

5.2.1 I/O Pins

There are three chip select pins, /CS0, /CS1, and /CS2; two read strobes, /OE0 and /OE1; and two write strobes, /WE0 and /WE1. /CS3 is available to the internal SRAMs only and does not come out to a pin.

There are 16 dedicated data bus pins, D0 through D15, and 25 dedicated address pins, A0 through A23, and /A0 to allow byte access to 16 bit devices.

If the SYSCFG pin is held high on startup, the Memory Bank 0 Control Register and Memory Bank 0 Low Control Register are set to a particular value that maps to the internal SRAM. See Section 5.3.1 for more details.

The drive strength and slew rate are selectable for the address and data bus pins and for the memory strobe pins (except /CS1) via ADPCR, DBPCR, and CPCR. /CS1 has a fixed setting of 8 mA drive and fast slew. Internal pullup and/or pulldown resistors are also selectable on the data bus.

5.2.2 Clocks

All memory operations are clocked by the processor clock.

5.2.3 Interrupts

When a write is attempted to a write-protected 64 KB or 4 KB block, a write-protection violation interrupt is generated. The interrupt request is cleared when it is handled. The write-protection violation interrupt vector is in the IIR at offset 0x090. It is always set to Priority 3.

When a stack-related write is attempted to a region outside that set by the stack limit registers, a stack limit violation occurs. The interrupt request is cleared when it is handled. The stack limit violation interrupt vector is in the IIR at offset 0x1B0. It is always set to Priority 3.

5.3 Operation

5.3.1 Internal RAM

There are two internal RAM devices in the Rabbit 6000. A 1 MB RAM is located on /CS3, /OE0, /WE0, and a 32 KB battery-backed SRAM is located on /CS3, /OE1, /WE1. Both of them can be run at speeds up to 200 MHz with no additional wait states.

The 1 MB RAM is a pipelined device, meaning that the DMA peripheral can access it between code fetches and data read/writes, providing a significant performance improvement for applications that use DMA such as networking. However, there are some restrictions in the use of the 1 MB RAM:

1. If the 32 kHz clock is not present, its performance will be halved. This will not be noticeable unless DMA is also operational.
2. The data contents will only be preserved if the main clock is greater than 12 MHz.

The internal 32 KB SRAM is powered by the VBAT pin. Its contents will be preserved as long as 1.2 V is kept on VBAT.

5.3.2 Memory Management Unit (MMU)

Code execution takes place in the 64 KB logical memory space, which is divided into four segments: root, data, stack, and extended (XMEM). The root segment is always mapped starting at physical address 0x000000, but the other segments can be remapped to start at any physical 4 KB block boundary.

The data and stack segment mappings are set by writing to the appropriate register, as shown in Table 5-1. The DATASEG and STACKSEG registers provide backwards compatibility to the Rabbit 2000 and 3000 processors; these registers map directly to DATASEGL and STACKSEGL, but the contents of DATASEGH and STACKSEGH are set to zero.

Table 5-1. Memory Management Registers

Register	Segment	Size	Comments
DATASEG	Data	8 bits	Maps to DATASEGL; DATASEGH set to 0x00
DATASEGL	Data	8 bits	—
DATASEGH	Data	4 bits	—
STACKSEG	Stack	8 bits	Maps to STACKSEGL; STACKSEGH set to 0x00
STACKSEGL	Stack	8 bits	—
STACKSEGH	Stack	4 bits	—
XPC	XMEM	8 bits	Loaded via instructions LD XPC, A and LD A, XPC
LXPC	XMEM	12 bits	Loaded via instructions: LD LXPC, HL and LD HL, LXPC

Each of these registers provides a multiple-of-4 KB offset that is added to the logical address to provide a physical address as shown in Figure 5.3.

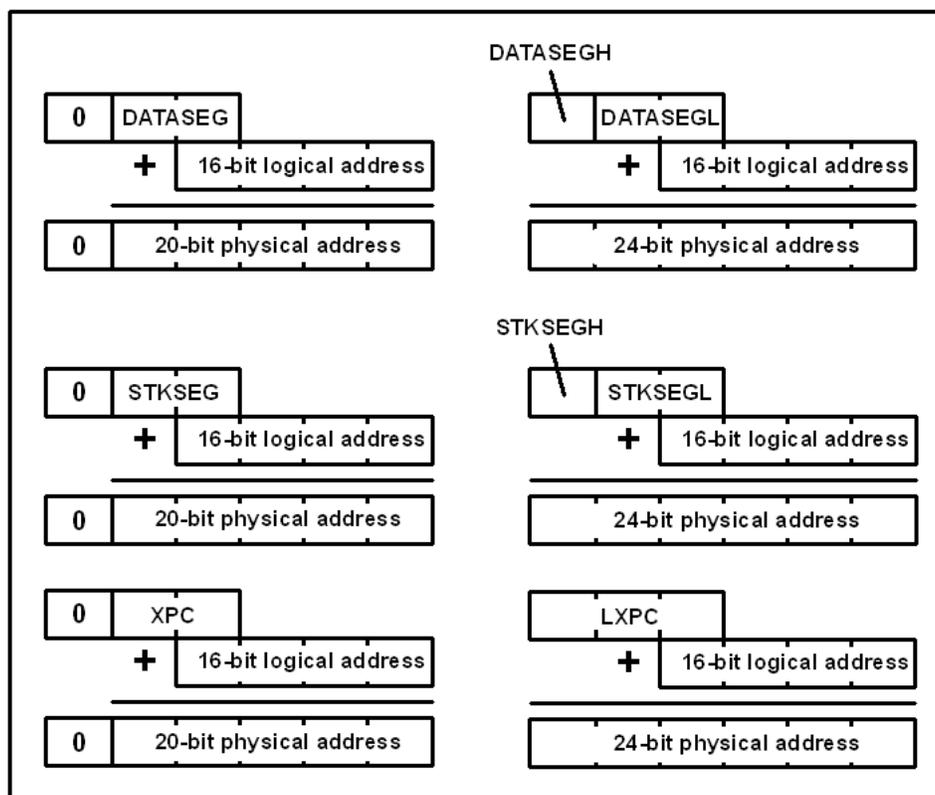


Figure 5.3 MMU Operation

5.3.3 Memory Bank Operation

On startup the Rabbit 6000 checks the status of the SYSCFG pin. To provide support for external memory, the SYSCFG pin should be set low and Memory Bank 0 enabled to use /CS0, /OE0, and /WE0 in 8-bit mode with four wait states and write protection enabled. It is expected that an external flash device containing startup code is attached to those strobes. The other memory banks come up undefined and their controls should be set via the appropriate MBxCR register to a valid setting before use.

If SYSCFG is high, Memory Bank 0 is enabled to use /CS3, /OE0, and /WE0 in 16-bit mode. This allows the processor to start operation directly out of the internal 1 MB RAM.

The size of the memory banks is defined in the MECR register. The default size is 256 KB (the bank selection looks at the two most significant address bits), but this value can be adjusted down to 128 KB or up to 4 MB per bank.

Each bank can be further subdivided into two equal-sized sub banks by configuring them in MBxLCR and MBxHCR. Each sub bank can be mapped to a separate chip-select/enable combination, allowing up to eight separate devices to be mapped in simultaneously.

The two address bits used to select the bank can be inverted in MBxCR/MBxLCR/MBxHCR, which enables mapping different sections of a memory device larger than the current memory bank into memory. Figure 5.4 shows an example of this feature.

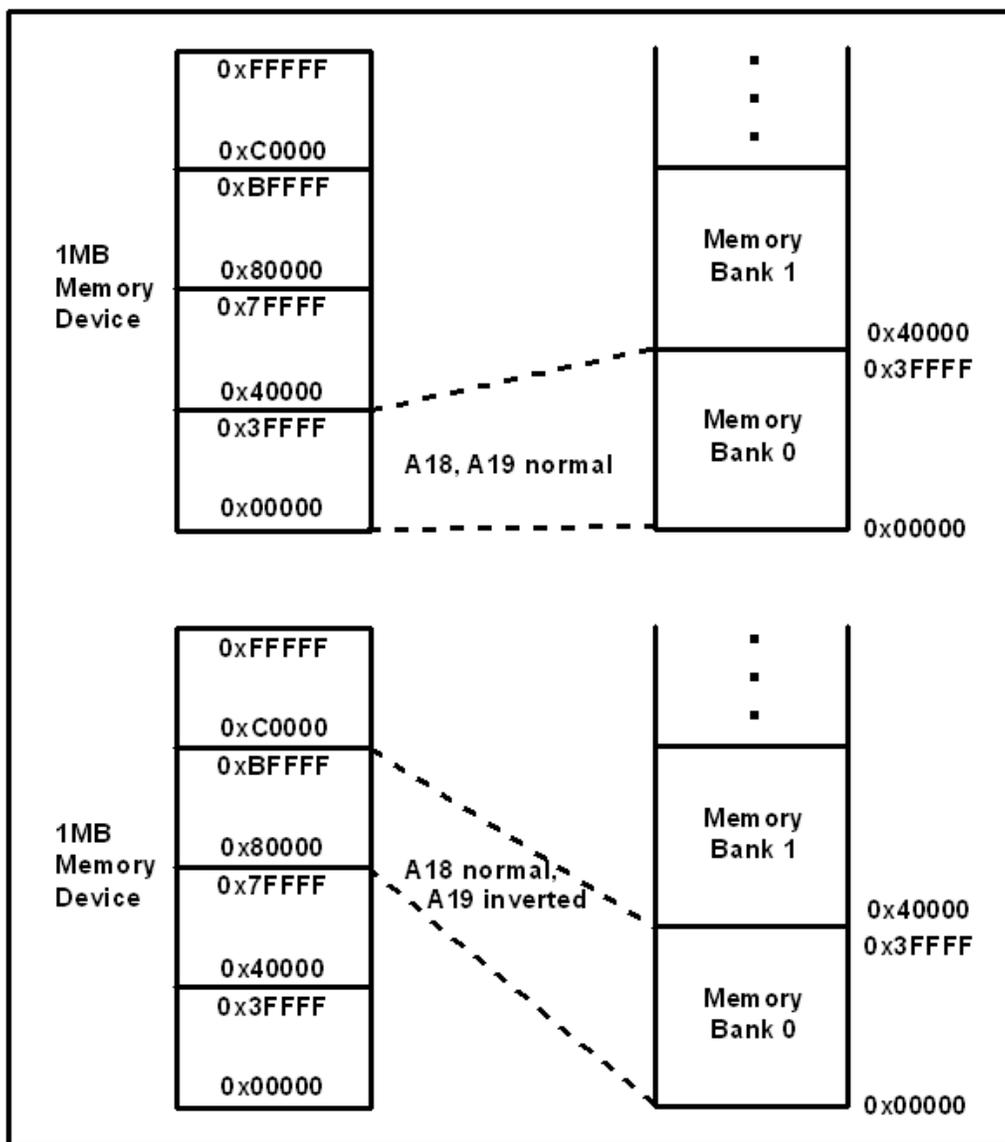


Figure 5.4 Mapping Different Sections of a Memory Device Larger Than the Current Memory Bank

It is possible to extend the timing of the /OE and/or /WE strobes by one half of a clock. This provides slightly longer strobes for slower memories; see the timing diagrams in Chapter 37. These options are available in MTCR.

It is possible to force /CS1 to be always active in MMIDR; enabling this will cause conflicts only if a device shares a /OE or /WE strobe with another device. This option allows faster access to particular memory devices.

5.3.4 Memory Modes

The Rabbit 6000 supports both 8-bit and 16-bit memories on all chip selects, including both internal RAMs. It also provides support for page-mode devices. The mode for each chip select is set in MACR; 8-bit mode is the default for all chip selects.

When in basic 8-bit mode, the wait states are selected in the memory bank registers, MBxCR; the options are 0, 1, 2, or 4 wait states. Note that this may put an upper bound on the processor clock speed, depending on the access time of your 8-bit memory device. When in 16-bit or page-mode (either 8- or 16-bit), the wait states are selected by both the MBxCR and the advanced chip select registers, ACSxCR.

Table 5-2. Memory Modes

Mode	Byte Writes?	Word Reads?	Word Writes?	Wait State Register	Wait State Options
8-bit	Yes	No	No	MBxCR	0, 1, 2, 4
16-bit	Selectable	Yes	Yes	MBxCR ACSxCR	0–19
8-bit Page Mode	Yes	No	No	MBxCR ACSxCR	0–19 first access, 0–11 page accesses
16-bit Page Mode	Selectable	Yes	Yes	MBxCR ACSxCR	0–19 first access, 0–11 page accesses

A 16-bit memory device may or may not support byte writes, so there is an option to select between these two cases in ACSxCR. With the default option any byte writes or unaligned word writes to a 16-bit memory will be suppressed (i.e., the /WE will not be asserted). Any aligned word reads or writes are recognized internally and are combined into just one write transaction on the external bus. The other option for the 16-bit bus does not inhibit byte writes or unaligned word writes, and replicates the byte data on both halves of the data bus in these cases. In this mode the A0 and /A0 signals must be used by the memory to enable the individual bytes.

Table 5-3. A0 and /A0 Signals for Various Transaction Types

Transaction Type	A0	/A0
Word Read (prefetch only)	Low	Low
Word Write	Low	Low
Byte Read or Write — Even Address	Low	High
Byte Read or Write — Odd Address	High	Low

All of the power-saving modes in Chapter 36 can be used with the 16-bit mode.

The second advanced bus mode is the Page Mode. This mode also can be enabled for any external chip select, and can be used with either 8-bit or 16-bit memories connected to these chip selects. Page-Mode memories provide for a faster access time if the requested data are in the same page as the previous data. In the Rabbit 6000 (and most memory devices) a page can be selected as either 8 or 16 bytes. Thus, if an address is identical to the previous address except in the lower four bits, the access time is assumed to be faster. These wait-state options are also controlled in the ACSxCR.

In Page Mode the chip select and /OE remain active from one page access to the next, and only the three or four least-significant bits of the address change to request the new data. This obviously interferes with a number of the power-saving modes and will take precedence over them for chip select accesses, as appropriate. The power-saving modes will still apply to the other chip select and output-enable signals. The logic recognizes which /OE is being used with each chip select in the Page Mode.

As mentioned previously, the ACSxCR registers each contain three fields to control the generation of wait states in the advanced bus modes. These settings are in addition to the wait-state setting in MBxCR when an advanced bus mode is enabled. When the 16-bit bus is enabled, one to fifteen automatic wait states for memory read bus cycles can be enabled in addition to the zero to four wait states in MBxCR. This setting is also used for the first access when the Page Mode is enabled; a second setting selects the number of wait states for all subsequent reads in the Page Mode, allowing from zero to three automatic wait states for the same-page accesses in the Page Mode. The choices available for the advanced bus wait states are sufficient to allow interfacing to a variety of standard memories for any Rabbit 6000 speed grade.

When a 16-bit memory is connected to /CS0, the first few instructions must program the device to operate in 16-bit mode. This code is shown below. This code should be the first thing executed by your device. Because the processor is fetching bytes from a 16-bit memory device that is not connected to A0, only one-byte instructions can be used, and they must occur in pairs.

```

ORG          0000h
XOR          A          ; a <= 00000000
XOR          A
LD           H, A       ; h <= 00000000
LD           H, A
SCF
SCF
RLA          ; a <= 00000001
RLA          ; a <= 00000010
LD           B, A       ; b <= 00000010
LD           B, A
SCF
SCF
ADC          A, B       ; a <= 00000101
ADC          A, B       ; a <= 00000111
ADD          A, A       ; a <= 00001110
ADD          A, A       ; a <= 00011100
SCF
SCF
ADC          A, H       ; a <= 00011101
ADC          A, H
LD           L, A       ; l <= 00011101
LD           L, A
IOI          ; two IOIs same as one
IOI
LD           (HL), B    ; MACR <= 00000010
LD           (HL), B    ; dummy memory write (no /WE
NOP          ; required delay to start
NOP          ; up the 16-bit bus

```

5.3.5 Separate Instruction and Data Space

To make better use of the 64 KB of logical space, an option is provided to map code and data accesses in the same address space to separate devices. This is accomplished by enabling the inversion of A16 and the most-significant bit of the bank select bits for accesses in the root and data segments. Careful use of these features allows both code and data to separately use up to 64 KB of logical memory.

The RAM segment register (RAMSR) provides a shortcut for updating code by accessing it as data. It provides a “window” that uses the instruction address decoding when read or written as data. This mapping will only occur when the RAMSR is within the root or data segments; the RAMSR will be ignored if it is mapped to the stack segment or XPC window.

5.3.6 Memory Protection

Memory blocks may be protected at three separate granularities, as shown in Table 5-4. Writes can be prevented to any memory bank by writing to MBxCR. Writes can be prevented and trapped at a resolution of 64 KB by enabling protection for that block in the appropriate WPxR register. For further control, two of those 64 KB blocks can be further subdivided into 4 KB blocks by selecting them as the write protect segments A or B.

When a write is attempted to a block protected in WPxR, WPSxLR, or WPSxHR, a Priority 3 write-protect interrupt occurs. This feature is automatically enabled by writing to the block protection registers; to disable it, set all the write-protect block registers to zero.

Table 5-4. Memory Protection Options

Method	Block Size	Registers Used
Memory Bank	128 KB – 4 MB	MBxCR, MECR
Write-Protect Blocks	64 KB	WPxR
Write Protect Segment A/B	4 KB	WPSxR, WPSxLR, WPSxHR

5.3.7 Stack Protection

The Rabbit 6000 provides stack overflow and underflow protection. Low and high logical address limits can be set in STKLLR and STKHLR; a Priority 3 stack-violation interrupt occurs when a stack-based write occurs within the 16 bytes below the upper limit or within the 16 bytes above the lower limit. Note that the writes will still occur even if they are within the 16 bytes surrounding the limits, but the interrupt can serve as a warning to the application that the stack is in danger of being over or underrun.

The stack checking can be enabled or disabled by writing to STKCR.

5.4 Register Descriptions

MMU Instruction/Data Register		(MMIDR)	(Address = 0x0010)
Bit(s)	Value	Description	
7	0	Internal I/O addresses are decoded using only the lower eight bits of the internal I/O address bus. This restricts internal I/O addresses to the range 0x0000–0x00FF.	
	1	Internal I/O addresses are decoded using all 15 bits of the address internal I/O address bus. This option must be selected to access internal I/O addresses of 0x0100 and higher.	
6		This bit is reserved and must be written with zero.	
5	0	Enable A16 and bank select address MSB inversion independent of instruction/data.	
	1	Enable A16 and bank select address MSB inversion for data accesses only. This enables the instruction/data split.	
4	0	Normal /CS1 operation.	
	1	Force /CS1 always active. This will not cause any conflicts as long as the memory using /CS1 does not also share an output enable or write enable with another memory.	
3	0	Normal operation.	
	1	For a data segment access, invert bank select address MSB before MBxCR decision.	
2	0	Normal operation.	
	1	For a data segment access, invert A16	
1	0	Normal operation.	
	1	For a root segment access, invert bank select address MSB before MBxCR decision.	
0	0	Normal operation.	
	1	For a root segment access, invert A16	

Stack Segment Register (STACKSEG) (Address = 0x0011)		
Bit(s)	Value	Description
7:0	Read	The current contents of this register are reported.
	Write	Eight LSBs (MSBs are set to zero by write) of physical address offset to use if $SEGSIZ[7:4] \leq Addr[15:12] < 0xE$

Stack Segment Low Register (STACKSEGL) (Address = 0x001A)		
Bit(s)	Value	Description
7:0	Read	The current contents of this register are reported.
	Write	Eight LSBs of physical address offset to use if $SEGSIZ[7:4] \leq Addr[15:12] < 0xE$

Stack Segment High Register (STACKSEGH) (Address = 0x001B)		
Bit(s)	Value	Description
7:4		These bits are reserved and should always be written as zero. These bits always return zeros when read.
3:0	Read	The current contents of this register are reported.
	Write	Four MSBs of physical address offset to use if $SEGSIZ[7:4] \leq Addr[15:12] < 0xE$

Data Segment Register (DATSEG) (Address = 0x0012)		
Bit(s)	Value	Description
7:0	Read	The current contents of this register are reported.
	Write	Eight LSBs (MSBs are set to zero by write) of physical address offset to use if: $SEGSIZ[3:0] \leq Addr[15:12] < SEGSIZ[7:4]$

Data Segment Low Register (DATSEGL) (Address = 0x001E)		
Bit(s)	Value	Description
7:0		Eight LSBs of physical address offset to use if SEGSIZ[3:0] ≤ Addr[15:12] < SEGSIZ[7:4]

Data Segment High Register (DATSEGH) (Address = 0x001F)		
Bit(s)	Value	Description
7:4		These bits are reserved and should always be written as zero. These bits always return zeros when read.
3:0		Four MSBs of physical address offset to use if SEGSIZ[3:0] ≤ Addr[15:12] < SEGSIZ[7:4]

Segment Size Register (SEGSIZ) (Address = 0x0013)		
Bit(s)	Value	Description
7:0	Read	The current contents of this register are reported.
7:4	Write	Boundary value for switching from DATSEG to STACKSEG for translation.
3:0	Write	Boundary value for switching from none to DATSEG for translation.

Memory Bank x Control Register (MB0CR) (Address = 0x0014) (MB1CR) (Address = 0x0015) (MB2CR) (Address = 0x0016) (MB3CR) (Address = 0x0017)		
Bit(s)	Value	Description
7:6	00	Four (five for writes) wait states for accesses in this bank.
	01	Two (three for writes) wait states for accesses in this bank.
	10	One (two for writes) wait states for accesses in this bank.
	11	Zero (one for writes) wait states for accesses in this bank.
5	0	Pass bank select address MSB for accesses in this bank.
	1	Invert bank select address MSB for accesses in this bank.
4	0	Pass bank select address LSB for accesses in this bank.
	1	Invert bank select address LSB for accesses in this bank.
3:2	00	/OE0 and /WE0 are active for accesses in this bank.
	01	/OE1 and /WE1 are active for accesses in this bank.
	10	/OE0 only is active for accesses in this bank (i.e., read-only). Transactions are normal in every other way.
	11	/OE1 only is active for accesses in this bank (i.e., read-only). Transactions are normal in every other way.
1:0	00	/CS0 is active for accesses in this bank.
	01	/CS1 is active for accesses in this bank.
	10	/CS2 is active for accesses in this bank.
	11	/CS3 (internal memory) is active for accesses in this bank. When standalone operation is selected (by strapping the SCFG pin high), this bit combination is forced for MB0CR only.

Memory Bank x Low/High Control Register		
(MB0LCR) (Address = 0x0400)		
(MB0HCR) (Address = 0x0401)		
(MB1LCR) (Address = 0x0402)		
(MB1HCR) (Address = 0x0403)		
(MB2LCR) (Address = 0x0404)		
(MB2HCR) (Address = 0x0405)		
(MB3LCR) (Address = 0x0406)		
(MB3HCR) (Address = 0x0407)		
Bit(s)	Value	Description
7:6	00	Four (five for writes) wait states for accesses in this bank.
	01	Two (three for writes) wait states for accesses in this bank.
	10	One (two for writes) wait states for accesses in this bank.
	11	Zero (one for writes) wait states for accesses in this bank.
5	0	Pass bank select address MSB for accesses in this bank.
	1	Invert bank select address MSB for accesses in this bank.
4	0	Pass bank select address LSB for accesses in this bank.
	1	Invert bank select address LSB for accesses in this bank.
3:2	00	/OE0 and /WE0 are active for accesses in this bank.
	01	/OE1 and /WE1 are active for accesses in this bank.
	10	/OE0 only is active for accesses in this bank (i.e., read-only). Transactions are normal in every other way.
	11	/OE1 only is active for accesses in this bank (i.e., read-only). Transactions are normal in every other way.
1:0	00	/CS0 is active for accesses in this bank.
	01	/CS1 is active for accesses in this bank.
	10	/CS2 is active for accesses in this bank.
	11	/CS3 (internal memory) is active for accesses in this bank. When standalone operation is selected (by strapping the SCFG pin high), this bit combination is forced for MB0CR only.

MMU Expanded Code Register (MECR) (Address = 0x0018)		
Bit(s)	Value	Description
7:5	000	Bank Select Address is A19-A18.
	001	Bank Select Address is A20-A19.
	010	Bank Select Address is A21-A20.
	011	Bank Select Address is A22-A21.
	100	Bank Select Address is A23-A22.
	101	This bit combination is reserved and should not be used.
	110	This bit combination is reserved and should not be used.
	111	Bank Select Address is A18-A17.
4		This bit is reserved and should be written with zero. Read returns zeros.
3:0	0000	Normal operation.
	0001	This bit combination is reserved and should not be used.
	0010	This bit combination is reserved and should not be used.
	0011	This bit combination is reserved and should not be used.
	0100	For an XPC access, use MB0LCR independent of Bank Select Address.
	0101	For an XPC access, use MB1LCR independent of Bank Select Address.
	0110	For an XPC access, use MB2LCR independent of Bank Select Address.
	0111	For an XPC access, use MB3LCR independent of Bank Select Address.

Memory Timing Control Register (MTCR) (Address = 0x0019)		
Bit(s)	Value	Description
7:4		These bits are reserved and should be written with zeros.
3	0	Normal timing for /OE1 (rising edge to rising edge, one clock minimum).
	1	Extended timing for /OE1 (one-half clock earlier than normal).
2	0	Normal timing for /OE0 (rising edge to rising edge, one clock minimum).
	1	Extended timing for /OE0 (one-half clock earlier than normal).
1	0	Normal timing for /WE1 (rising edge to falling edge, one and one-half clocks minimum).
	1	Extended timing for /WE1 (falling edge to falling edge, two clocks minimum).
0	0	Normal timing for /WE0 (rising edge to falling edge, one and one-half clocks minimum).
	1	Extended timing for /WE0 (falling edge to falling edge, two clocks minimum).

Memory Alternate Control Register (MACR) (Address = 0x001D)		
Bit(s)	Value	Description
7	0	Normal 8-bit operation for /CS3. Use MBxCR for wait states. This bit is used only when external memory is present.
	1	Normal 16-bit operation for /CS3. Use MBxCR for wait states. When stand-alone operation is selected (by strapping a pin), this bit is forced high.
6		This bit is reserved and must not be used.
5:4	00	Normal 8-bit operation for /CS2.
	01	Page-Mode 8-bit operation for /CS2.
	10	Normal 16-bit operation for /CS2.
	11	Page-Mode 16-bit operation for /CS2.
3:2	00	Normal 8-bit operation for /CS1.
	01	Page-Mode 8-bit operation for /CS1.
	10	Normal 16-bit operation for /CS1.
	11	Page-Mode 16-bit operation for /CS1.
1:0	00	Normal 8-bit operation for /CS0.
	01	Page-Mode 8-bit operation for /CS0.
	10	Normal 16-bit operation for /CS0.
	11	Page-Mode 16-bit operation for /CS0.

Advanced Chip Select x Control Register (ACS0CR) (Address = 0x0410) (ACS1CR) (Address = 0x0411) (ACS2CR) (Address = 0x0412)		
Bit(s)	Value	Description
7:5	000	Zero extra wait states for reads, writes, or first Page-Mode access.
	001	One extra wait state for reads, writes, or first Page-Mode read access.
	010	Two extra wait states for reads, writes, or first Page-Mode access.
	011	Three extra wait states for reads, writes, or first Page-Mode read access.
	100	Four extra wait states for reads, writes, or first Page-Mode read access.
	101	Five extra wait states for reads, writes, or first Page-Mode read access.
	110	Six extra wait state for reads, writes, or first Page-Mode read access.
	111	Seven extra wait state for reads, writes, or first Page-Mode read access.
4:3	00	Zero extra wait states for subsequent Page-Mode accesses.
	01	One extra wait state for subsequent Page-Mode accesses.
	10	Two extra wait states for subsequent Page-Mode accesses.
	11	Three extra wait states for subsequent Page-Mode accesses.
2		This bit is reserved and should not be used.
1	0	Page size 16 bytes.
	1	Page size 8 bytes.
0	0	Disable byte writes on 16-bit bus.
	1	Enable byte writes on 16-bit bus.

RAM Segment Register (RAMSR) (Address = 0x0448)		
Bit(s)	Value	Description
7:2		Compare value for RAM segment limit checking.
1:0	00	Disable RAM segment limit checking.
	01	Select data-type MMU translation if PC[15:10] is equal to RAMSR[7:2].
	10	Select data-type MMU translation if PC[15:11] is equal to RAMSR[7:3].
	11	Select data-type MMU translation if PC[15:12] is equal to RAMSR[7:4].

Write-Protect Segment x Register (WPSAR) (Address = 0x0480) (WPSBR) (Address = 0x0484)		
Bit(s)	Value	Description
7:0		When these eight bits [23:16] match bits of the physical address, write-protect that 64 KB range in 4 KB increments using WPSxLR and WPSxHR.

Write-Protect Segment x Low Register (WPSALR) (Address = 0x0481) (WPSBLR) (Address = 0x0485)		
Bit(s)	Value	Description
7	0	Disable 4 KB write protect for relative address 0x7000–0x7FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x7000–0x7FFF in WP Segment x.
6	0	Disable 4 KB write protect for relative address 0x6000–0x6FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x6000–0x6FFF in WP Segment x.
5	0	Disable 4 KB write protect for relative address 0x5000–0x5FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x5000–0x5FFF in WP Segment x.
4	0	Disable 4 KB write protect for relative address 0x4000–0x4FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x4000–0x4FFF in WP Segment x.
3	0	Disable 4 KB write protect for relative address 0x3000–0x3FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x3000–0x3FFF in WP Segment x.
2	0	Disable 4 KB write protect for relative address 0x2000–0x2FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x2000–0x2FFF in WP Segment x.
1	0	Disable 4 KB write protect for relative address 0x1000–0x1FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x1000–0x1FFF in WP Segment x.
0	0	Disable 4 KB write protect for relative address 0x0000–0x0FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x0000–0x0FFF in WP Segment x.

Write-Protect Segment x High Register (WPSAHR) (Address = 0x0482) (WPSBHR) (Address = 0x0486)		
Bit(s)	Value	Description
7	0	Disable 4 KB write protect for relative address 0xF000–0xFFFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0xF000–0xFFFF in WP Segment x.
6	0	Disable 4 KB write protect for relative address 0xE000–0xEFFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0xE000–0xEFFF in WP Segment x.
5	0	Disable 4 KB write protect for relative address 0xD000–0xDFFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0xD000–0xDFFF in WP Segment x.
4	0	Disable 4 KB write protect for relative address 0xC000–0xCFFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0xC000–0xCFFF in WP Segment x.
3	0	Disable 4 KB write protect for relative address 0xB000–0xBFFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0xB000–0xBFFF in WP Segment x.
2	0	Disable 4 KB write protect for relative address 0xA000–0xAFFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0xA000–0xAFFF in WP Segment x.
1	0	Disable 4 KB write protect for relative address 0x9000–0x9FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x9000–0x9FFF in WP Segment x.
0	0	Disable 4 KB write protect for relative address 0x8000–0x8FFF in WP Segment x.
	1	Enable 4 KB write protect for relative address 0x8000–0x8FFF in WP Segment x.

Stack Limit Control Register (STKCR) (Address = 0x0444)		
Bit(s)	Value	Description
7:1		These bits are reserved and should be written with zeros.
0	0	Disable stack-limit checking.
	1	Enable stack-limit checking.

Stack Low Limit Register (STKLLR) (Address = 0x0445)		
Bit(s)	Value	Description
7:0		Lower limit for stack-limit checking. If a stack operation or stack-relative memory access is attempted at an address less than {STKLLR, 0x10}, a stack-limit violation interrupt is generated.

Stack High Limit Register (STKHLR) (Address = 0x0446)		
Bit(s)	Value	Description
7:0		Upper limit for stack-limit checking. If a stack operation or stack-relative memory access is attempted at an address greater than {STKHLR, 0xEF}, a stack-limit violation interrupt is generated.

Address Bus Pin Control Register (ADPCR) (Address = 0x04A0)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0		These bits are reserved and should be written with zeros.

Data Bus Pin Control Register (DBPCR) (Address = 0x04A1)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistors.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

Control Pin Control Register (CPCR) (Address = 0x04A2)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0		These bits are reserved and should be written with zeros.

6. INTERRUPTS

6.1 Overview

The Rabbit 6000 can operate at one of four priority levels, 0–3, with Priority 0 being the expected standard operating level. The current priority and up to three previous priority levels are kept in the processor’s 8-bit IP register, where bits 0–1 contain the current priority. Every time an interrupt is handled or an IPSET instruction occurs, the value in the register is shifted left by two bits, and the new priority placed in bits 0–1. When an IPRES or IRET instruction occurs, the value in IP is shifted right by two bits (bits 0–1 are shifted into bits 6–7). On reset, the processor starts at Priority 3.

Most interrupts can be set to be Priority 1–3. A pending interrupt will be handled only if its interrupt priority is greater than the current processor priority. This means that even a Priority 3 interrupt can be blocked if the processor is currently at Priority 3. The System Mode Violation, Stack Limit Violation, Write Protection Violation, secondary watchdog, and breakpoint interrupts are always enabled at Priority 3. In addition, when the System/User Mode is enabled and the processor is in the User Mode, the processor will not actually enter Priority 3; any attempt to enter Priority 3 will actually be requested as Priority 2.

When an interrupt is handled, a call is executed to a fixed location in the interrupt vector tables. This operation requires 11 clocks, the minimum interrupt latency for the Rabbit 6000. There are two vector tables, the internal and the external interrupt vector tables, that can be located anywhere in logical memory by setting the processor’s IIR and EIR registers. The IIR and EIR registers hold the upper byte of each table’s address. For example, if IIR is loaded with 0xC4, then the internal interrupt vector table will start at the logical memory address 0xC400.

Both the internal and external interrupt vector table occupy 512 bytes. Since the RST and SYSCALL vectors use all eight bits of the IIR for addressing, the lowermost bit of IIR should always be set to zero so to keep some vectors from inadvertently overlapping.

Each interrupt’s vector begins on a 16-byte boundary inside the vector tables. It may be possible to fit a small routine into that space, but it is typical to place a call to a separate routine in that location.

Some Rabbit 6000 instructions are “chained atomic,” which means that an interrupt cannot occur between that instruction and the following instruction. These instructions are useful for doing things like exiting interrupt handlers properly or updating semaphores.

6.2 Operation

To ensure proper operation, all interrupt handler routines should be written according to the following guidelines.

- Push all registers to be used by the routine onto the stack before use, and pop them off the stack before returning from the ISR.
- Keep the ISR as short and fast as possible. The use of assembly code is strongly recommended.
- If the ISR will run for some time, lower the interrupt priority as soon as possible within the ISR to allow other interrupts to occur.
- A number of special rules apply to interrupts when operating in the system/user mode; please see the appropriate chapter for more details.

6.3 Interrupt Tables

Table 6-1 shows the structure of the internal interrupt vector table. The first column is the vector address offset within the table. The second column shows the vectors in the first 256 bytes of the table, and the third column shows the vectors in the second 256 bytes. Interrupts that are new to the Rabbit 6000 are highlighted as such.

Table 6-1. Internal Interrupt Vector Table Structure

Offset	0x0000 + Offset	0x0100 + Offset
0x00	Periodic Interrupt	Network Port C (Wi-Fi) 
0x10	Secondary Watchdog	Network Port D (USB) 
0x20	RST 10	—
0x30	RST 18	FIMA 
0x40	RST20	FIMB 
0x50	RST 28	I ² C 
0x60	Syscall Instruction	8-Channel A/D Converter 
0x70	RST 38	PWM
0x80	Slave Port	Sys/User Mode Violation
0x90	Write Protect Violation	Quadrature Decoder
0xA0	Timer A	Input Capture
0xB0	Timer B	Stack Limit Violation
0xC0	Serial Port A	Serial Port E
0xD0	Serial Port B	Serial Port F
0xE0	Serial Port C	Network Port B (Ethernet)
0xF0	Serial Port D	Timer C

Table 6-2 shows the structure of the external interrupt vector table. Each interrupt vector falls on a 16-byte boundary inside the table. Interrupts that are new to the Rabbit 6000 are highlighted as such.

Table 6-2. External Interrupt Vector Table Structure

Offset	0x0000 + Offset	0x0100 + Offset
0x00	External Interrupt 0	—
0x10	External Interrupt 1	—
0x20	External Interrupt 2 NEW	—
0x30	External Interrupt 3 NEW	—
0x40	External Interrupt 4 NEW	Breakpoints NEW
0x50	External Interrupt 5 NEW	—
0x60	External Interrupt 6 NEW	—
0x70	External Interrupt 7 NEW	—
0x80	DMA Channel 0	DMA Channel 8 NEW
0x90	DMA Channel 1	DMA Channel 9 NEW
0xA0	DMA Channel 2	DMA Channel 10 NEW
0xB0	DMA Channel 3	DMA Channel 11 NEW
0xC0	DMA Channel 4	DMA Channel 12 NEW
0xD0	DMA Channel 5	DMA Channel 13 NEW
0xE0	DMA Channel 6	DMA Channel 14 NEW
0xF0	DMA Channel 7	DMA Channel 15 NEW

Note that the breakpoint interrupt moved from its location in previous Rabbit processors to make room for the new external interrupt vectors.

There is a priority among interrupts if multiple requests are pending, as shown in Table 6-3. Interrupts marked as “cleared automatically” have their requests cleared when the interrupt is first handled.

Table 6-3. Interrupt Priorities

Priority	Interrupt Source	Action Required to Clear the Interrupt	
Highest	Breakpoint	Read the status from BDCR.	
	System Mode Violation	Cleared automatically by interrupt acknowledge cycle.	
	Stack Limit Violation	Cleared automatically by interrupt acknowledge cycle.	
	Write Protection Violation	Cleared automatically by interrupt acknowledge cycle.	
	Secondary Watchdog	Restart secondary watchdog by writing to WDTCR.	
	External Interrupt 7–0	Cleared automatically by interrupt acknowledge cycle.	
	Periodic Interrupt (2 kHz)	Read the status from GCSR.	
	Quadrature Decoder	Read the status from QDCSR.	
	Timer B	Read the status from TBCSR.	
	Timer A	Read the status from TACSR.	
	Input Capture	Read the status from ICCSR.	
	PWM	Write any PWM register.	
	Timer C	Read the status from TCCSR.	
	Slave Port	Rd: Read from SPD0R, SPD1R or SPD2R. Wr: Write to SPD0R, SPD1R, SPD2R or dummy write to SPSR.	
	DMA 15–0	Cleared automatically by interrupt acknowledge cycle.	
	Network Port B	Read interrupt status from NBCSR.	
	Network Port C	Read interrupt status from NCCSR.	
	Network Port D	Remove the interrupting condition.	
	Flexible Interface Module A	Write a 1 to bit 7 of FAIRR, wait for FIMA to clear the interrupt code in FAOIR, and then clear bit 7 of FAIRR.	
	Flexible Interface Module B	Write a 1 to bit 7 of FBIIR, wait for FIMB to clear the interrupt code in FBOIR, and then clear bit 7 of FBIIR.	
	A/D Converter	Read from ADCLR.	
	Serial Port E	Rx: Read from SEDR or SEAR. Tx: Write to SEDR, SEAR, SELR or dummy write to SESR.	
	Serial Port F	Rx: Read from SFDR or SFAR. Tx: Write to SFDR, SFAR, SFLR or dummy write to SFSR.	
	Serial Port G (I ² C)	Remove the interrupting condition.	
	Serial Port A	Rx: Read from SADR or SAAR. Tx: Write to SADR, SAAR, SALR or dummy write to SASR.	
	Serial Port B	Rx: Read from SBDR or SBAR. Tx: Write to SBDR, SBAR, SBLR or dummy write to SBSR.	
	Serial Port C	Rx: Read from SCDR or SCAR. Tx: Write to SCDR, SCAR, SCLR or dummy write to SCSR.	
	Lowest	Serial Port D	Rx: Read from SDDR or SDAR. Tx: Write to SDDR, SDAR, SDLR or dummy write to SDSR.



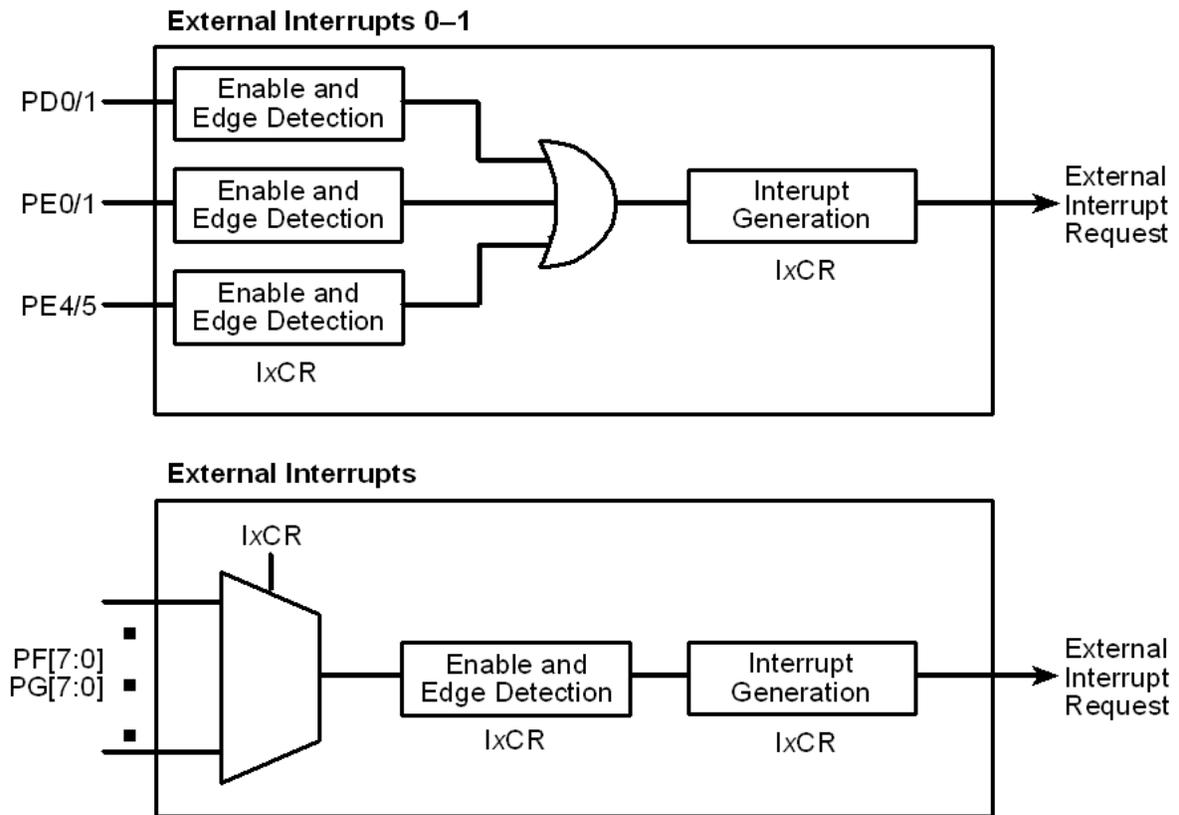
7. EXTERNAL INTERRUPTS

7.1 Overview

The Rabbit 6000 has eight external interrupt vectors. Interrupts 0 and 1 can share up to three pins each, and interrupts 2–7 each only have one pin, providing a total of up to 12 external interrupt inputs out of 22 possible pins. In the case of multiple interrupts sharing an interrupt vector for interrupts 0 or 1, the data register corresponding to the parallel port(s) being used can be read. Each interrupt vector can be set to trigger on a rising edge, a falling edge, or both edges.

The signal on the external interrupt pin must be present for at least three peripheral clock cycles to be detected. In addition, the Rabbit 6000 has a minimum latency of 11 clocks to respond to an interrupt, so the minimum external interrupt response time is three peripheral clock cycles plus 11 processor clock cycles. Note that this just gets the program to the ISR jump table. An additional 5 or 7 clocks is required for the `jp` (jump) instruction plus whatever remaining clocks need to be executed in the “current” instruction.

7.2 Block Diagram



7.2.1 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Interrupt 0 Control Register	I0CR	0x0098	R/W	00000000
Interrupt 1 Control Register	I1CR	0x0099	R/W	00000000
Interrupt 2 Control Register	I2CR	0x009A	R/W	xx000000
Interrupt 3 Control Register	I3CR	0x009B	R/W	xx000000
Interrupt 4 Control Register	I4CR	0x009C	R/W	xx000000
Interrupt 5 Control Register	I5CR	0x009D	R/W	xx000000
Interrupt 6 Control Register	I6CR	0x009E	R/W	xx000000
Interrupt 7 Control Register	I7CR	0x009F	R/W	xx000000

7.3 Dependencies

7.3.1 I/O Pins

External interrupts 0 and 1 can be enabled on pins PD0, PD1, PE0, PE1, PE4, and PE5. The remaining interrupts can be enabled on any pin of Parallel Ports F or G. Each pin is associated with a particular interrupt vector as shown in Table 7-1 below.

Table 7-1. Rabbit 6000 Interrupt Vectors

Vector	Register	Pins
Interrupt 0	I0CR	PD0, PE0, PE4
Interrupt 1	I1CR	PD1, PE1, PE5
Interrupt 2	I2CR	PF0–PF7, PG0–PG7
Interrupt 3	I3CR	PF0–PF7, PG0–PG7
Interrupt 4	I4CR	PF0–PF7, PG0–PG7
Interrupt 5	I5CR	PF0–PF7, PG0–PG7
Interrupt 6	I6CR	PF0–PF7, PG0–PG7
Interrupt 6	I7CR	PF0–PF7, PG0–PG7

7.3.2 Clocks

The external interrupts are controlled by the peripheral clock. A pulse must be present for at least three peripheral clock cycles to trigger an interrupt.

7.3.3 Interrupts

An external interrupt is generated whenever the selected edge occurs on an enabled pin. The interrupt request is automatically cleared when the interrupt is handled.

The external interrupt vectors are in the EIR at offsets 0x000–0x070. They can be set as Priority 1, 2, or 3 in the appropriate IxCR.

7.4 Operation

The following steps must be taken to enable the external interrupts.

1. Write the vector(s) to the interrupt service routine to the external interrupt table.
2. Configure IxCR to select which pins are enabled for external interrupts, what edges are detected on each pin, and the interrupt priority.
3. When an interrupt occurs for interrupt 0 or 1, read PDDR and/or PEDR to determine which pin has a signal if more than one pin is enabled for a given external interrupt. Interrupts 2-7 allow only a single input at any one time.

7.4.1 Example ISR

A sample interrupt handler is shown below.

```
extInt_isr::  
; respond to external interrupt here  
; interrupt is automatically cleared by interrupt acknowledge  
ipres  
ret
```

7.5 Register Descriptions

Interrupt x Control Register (I0CR) (Address = 0x0098) (I1CR) (Address = 0x0099)		
Bit(s)	Value	Description
7:6	00	Parallel Port D low nibble interrupt disabled.
	01	Parallel Port D low nibble interrupt on falling edge.
	10	Parallel Port D low nibble interrupt on rising edge.
	11	Parallel Port D low nibble interrupt on both edges.
5:4	00	Parallel Port E high nibble interrupt disabled.
	01	Parallel Port E high nibble interrupt on falling edge.
	10	Parallel Port E high nibble interrupt on rising edge.
	11	Parallel Port E high nibble interrupt on both edges.
3:2	00	Parallel Port E low nibble interrupt disabled.
	01	Parallel Port E low nibble interrupt on falling edge.
	10	Parallel Port E low nibble interrupt on rising edge.
	11	Parallel Port E low nibble interrupt on both edges.
1:0	00	This external interrupt is disabled.
	01	This external interrupt uses Interrupt Priority 1.
	10	This external interrupt uses Interrupt Priority 2.
	11	This external interrupt uses Interrupt Priority 3.

Interrupt x Control Register		
(I2CR) (Address = 0x009A)		
(I3CR) (Address = 0x009B)		
(I4CR) (Address = 0x009C)		
(I5CR) (Address = 0x009D)		
(I6CR) (Address = 0x009E)		
(I7CR) (Address = 0x009F)		
Bit(s)	Value	Description
7	0	Interrupt from Parallel Port F.
	1	Interrupt from Parallel Port G.
6:4	000	Interrupt from parallel port bit 0.
	001	Interrupt from parallel port bit 1.
	010	Interrupt from parallel port bit 2.
	011	Interrupt from parallel port bit 3.
	100	Interrupt from parallel port bit 4.
	101	Interrupt from parallel port bit 5.
	110	Interrupt from parallel port bit 6.
	111	Interrupt from parallel port bit 7.
3:2	00	Interrupt disabled.
	01	Interrupt on falling edge.
	10	Interrupt on rising edge.
	11	Interrupt on both edges.
1:0	00	This external interrupt is disabled.
	01	This external interrupt uses Interrupt Priority 1.
	10	This external interrupt uses Interrupt Priority 2.
	11	This external interrupt uses Interrupt Priority 3.

8. PARALLEL PORT A

8.1 Overview

Parallel Port A is a byte-wide port that can be used as an input or an output port. Parallel Port A is also used as the data bus for the slave port and external I/O bus. The Slave Port Control Register (SPCR) is used to configure how Parallel Port A is used. Parallel Port A is an input after reset. If the SMODE pins have selected the slave port bootstrap mode, Parallel Port A will be the slave port data bus until disabled by the processor. Parallel Port A can also be used as an external I/O data bus to isolate external I/O from the main data bus.

The drive strength and slew rate can be individually controlled for each Parallel Port A pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

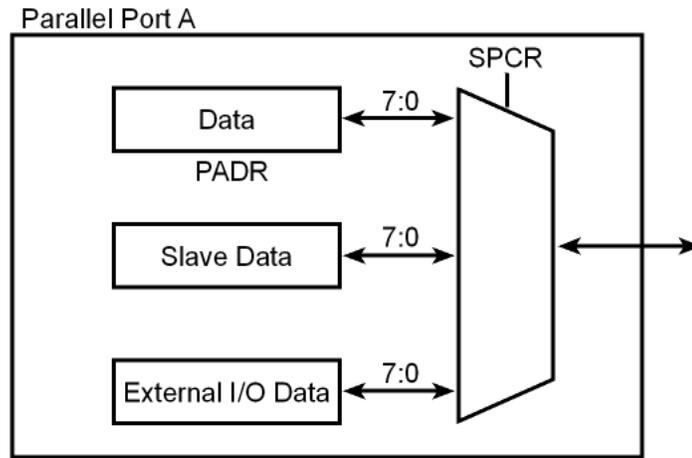
Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

Table 8-1. Parallel Port A Pin Alternate Output Functions

Pin Name	Slave Port Data Bus	External I/O Bus
PA[7:0]	SD[7:0]	ID[7:0]

After reset, the default condition for Parallel Port A is all inputs. When PADR is read, the actual voltage on the pins is returned, whether the port is set as an input or an output.

8.1.1 Block Diagram



8.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port A Data Register	PADR	0x0030	R/W	xxxxxxxx
Port Ax Control Register (x = 0-7)	PAxCR	0x04B0 + x	W	xxx00000

8.2 Dependencies

8.2.1 I/O Pins

Parallel Port A uses pins PA0 through PA7. These pins can be used as follows.

- General-purpose 8-bit data input (write 0x080 to SPCR)
- General-purpose 8-bit data output (write 0x084 to SPCR)
- Slave port data bus (write 0x088 to SPCR)
- External I/O data bus (write 0x08C to SPCR)

All Parallel Port A bits are inputs at startup or reset.

Drive strength, slew rate, and the pullup/down resistor status are selectable via PAxCR.

See the associated peripheral chapters for details on how they use Parallel Port A.

8.2.2 Clocks

Any outputs on Parallel Port A are clocked by the peripheral clock.

8.2.3 Other Registers

Register	Function
SPCR	Used to set up Parallel Port A.

8.2.4 Interrupts

There are no interrupts associated with Parallel Port A, except when the slave port is being used.

8.3 Operation

The following steps explain how to set up Parallel Port A.

1. Select the desired mode using SPCR.
2. If a particular drive strength, slew rate, or pullup/down resistor status is desired for a Parallel Port A pin, set that in the appropriate PAXCR.
3. If the slave port or external I/O bus is selected, refer to the chapters for those peripherals for further setup.

Once Parallel Port A is set up, data can be read or written by accessing PADR. Note that Parallel Port A is not available for general-purpose I/O while the slave port or the external I/O bus is selected, or when it is being used by one of the Flexible Interface Modules. Selecting the slave port or external I/O bus options for Parallel Port A affects Parallel Port B as well because Parallel Port B is then used for address and control signals.

If one of the Flexible Interface Modules has been enabled to use Parallel Port A, writing to PADR will no longer change the state of the pins. The other Parallel Port A registers are still valid. Refer to Chapter 33 for more details.

8.4 Register Descriptions

Parallel Port A Data Register (PADR) (Address = 0x0030)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port A pins PA7–PA0 is reported.
	Write	The Parallel Port A buffer is written with this value for transfer to the Parallel Port A output register on the next rising edge of the peripheral clock.

Parallel Port Ax Control Register		
(PA0CR) (Address = 0x04B0)		
(PA1CR) (Address = 0x04B1)		
(PA2CR) (Address = 0x04B2)		
(PA3CR) (Address = 0x04B3)		
(PA4CR) (Address = 0x04B4)		
(PA5CR) (Address = 0x04B5)		
(PA6CR) (Address = 0x04B6)		
(PA7CR) (Address = 0x04B7)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

Slave Port Control Register (SPCR) (Address = 0x0024)		
Bit(s)	Value	Description
7	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	read	These bits report the state of the SMODE pins.
	write	These bits are ignored and should be written with zero.
4:2	000	Disable the slave port. Parallel Port A is a byte-wide input port.
	001	Disable the slave port. Parallel Port A is a byte-wide output port.
	010	Enable the slave port, with /SCS from Parallel Port E bit 7.
	011	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:2] is used for the address bus.
	100	This bit combination is reserved and should not be used.
	101	This bit combination is reserved and should not be used.
	110	Enable the slave port, with /SCS from Parallel Port B bit 6.
	111	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:0] is used for the address bus.
1:0	00	Slave port interrupts are disabled.
	01	Slave port interrupts use Interrupt Priority 1.
	10	Slave port interrupts use Interrupt Priority 2.
	11	Slave port interrupts use Interrupt Priority 3.

9. PARALLEL PORT B

9.1 Overview

Parallel Port B is a byte-wide port with each bit programmable for direction. The Parallel Port B pins are also used to access other peripherals on the chip—the slave port, the auxiliary I/O address bus, and clock I/O for clocked serial mode option for Serial Ports A and B. The Slave Port Control Register (SPCR) is used to configure how Parallel Port B is used when selecting the slave port or the external I/O bus modes.

When the slave port is enabled, either under program control or during parallel bootstrap, Parallel Port B pins carry the Slave Attention output signal, and the Slave Read strobe, Slave Write strobe, and Slave Address inputs. The Slave Chip Select can also be programmed to come from a Parallel Port B pin.

When the external I/O bus option is enabled, either six or eight pins carry the external I/O address signals selected in SPCR.

Two pins are used for the clocks for Serial Ports A and B when they are configured for the clocked serial mode. These two inputs can be used as clock outputs for these ports if selected in the respective serial port control registers. Note that when enabled, the clocked serial output overrides all other programming for the two relevant Parallel Port B pins.

The drive strength and slew rate can be individually controlled for each Parallel Port B pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

Table 9-1. Parallel Port B Pin Alternate Output Functions

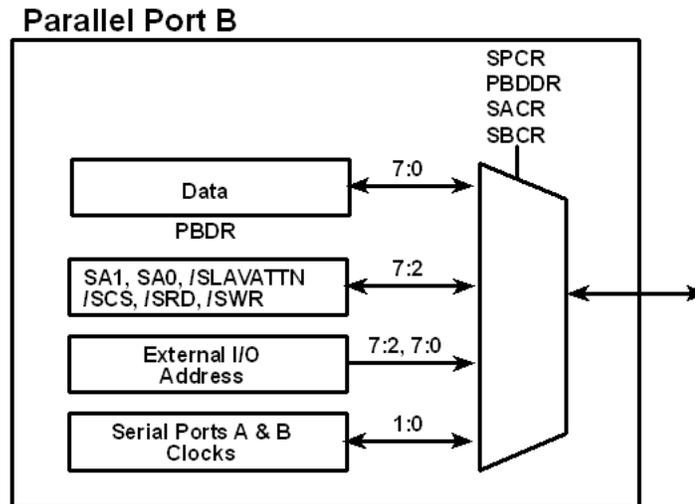
Pin Name	Serial Ports A–D	External I/O Bus
PB7	—	IA5
PB6	—	IA4
PB5	—	IA3
PB4	—	IA2
PB3	—	IA1
PB2	—	IA0
PB1	SCLKA	IA7
PB0	SCLKB	IA6

Table 9-2. Parallel Port B Pin Alternate Input Functions

Pin Name	Slave Port	Serial Ports A–D
PB7	—	—
PB6	/SCS	—
PB5	SA1	—
PB4	SA0	—
PB3	/SRD	—
PB2	/SWR	—
PB1	—	SCLKA
PB0	—	SCLKB

After reset, the default condition for Parallel Port B is six inputs (bits 2-7) and two outputs (bits 0-1). When PBDR is read, the actual voltage on the pins is returned, whether the pins are set as inputs or outputs.

9.1.1 Block Diagram



9.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port B Data Register	PBDR	0x0040	R/W	00xxxxxx
Port B Data Direction Register	PBDDR	0x0047	R/W	11000000
Port Bx Control Register	PBxCR	0x04C0 + x	W	xxx00000

9.2 Dependencies

9.2.1 I/O Pins

Parallel Port B uses pins PB0 through PB7. These pins can be used individually as data inputs or outputs; as the address bits for the external I/O bus; as control signals for the slave port; or as clocks for Serial Ports A and B.

On startup, bits 6 and 7 are outputs set low for backwards compatibility with the Rabbit 2000. All other pins are inputs.

Drive strength, slew rate, and the pullup/down resistor status are selectable via PBxCR.

Note that when the external I/O bus or slave port is enabled in SPCR, the Parallel Port B pins associated with those peripherals perform those actions, no matter what the settings are in PBDR or PBDDR. See the associated peripheral chapters for details on how they use Parallel Port B.

9.2.2 Clocks

All outputs on Parallel Port B are clocked by the peripheral clock (perclk).

9.2.3 Other Registers

Register	Function
SPCR	Sets the Parallel Port B function for some pins if the slave port or external I/O bus is enabled.

9.2.4 Interrupts

There are no interrupts associated with Parallel Port B, except when the slave port is being used.

9.3 Operation

The following steps must be taken before using Parallel Port B.

1. Select the desired input/output direction for each pin via PBDDR. Note that this setting is superseded for some pins if the slave port or external I/O bus is enabled in SPCR or if the clocked serial mode is enabled for Serial Ports A or B.
2. If a particular drive strength, slew rate, or pullup/down resistor status is desired for a Parallel Port B pin, set that in the appropriate PBxCR.
3. If the slave port or the external I/O bus is selected, refer to the chapters for those peripherals for further setup information.

Once the port is set up, data can be read or written by accessing PBDR. The value in PBDR of an output pin will reflect its current output value, but any value written to an input pin will not appear on that pin until that pin becomes an output.

If one of the Flexible Interface Module has been enabled to use Parallel Port B, writing to PBDR will no longer change the state of the pins. The other Parallel Port B registers are still valid. Refer to Chapter 33 for more details.

9.4 Register Descriptions

Parallel Port B Data Register (PBDR) (Address = 0x0040)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port B pins PB7–PB0 is reported.
	Write	The Parallel Port B buffer is written with this value for transfer to the Parallel Port B output register on the next rising edge of the peripheral clock.

Parallel Port B Data Direction Register (PBDDR) (Address = 0x0047)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port Bx Control Register		
(PB0CR) (Address = 0x04C0)		
(PB1CR) (Address = 0x04C1)		
(PB2CR) (Address = 0x04C2)		
(PB3CR) (Address = 0x04C3)		
(PB4CR) (Address = 0x04C4)		
(PB5CR) (Address = 0x04C5)		
(PB6CR) (Address = 0x04C6)		
(PB7CR) (Address = 0x04C7)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

Slave Port Control Register (SPCR) (Address = 0x0024)		
Bit(s)	Value	Description
7	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
	Write	These bits are ignored and should be written with zero.
4:2	000	Disable the slave port. Parallel Port A is a byte-wide input port.
	001	Disable the slave port. Parallel Port A is a byte-wide output port.
	010	Enable the slave port, with /SCS from Parallel Port E bit 7.
	011	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:2] is used for the address bus.
	100	This bit combination is reserved and should not be used.
	101	This bit combination is reserved and should not be used.
	110	Enable the slave port, with /SCS from Parallel Port B bit 6.
	111	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:0] is used for the address bus.
1:0	00	Slave port interrupts are disabled.
	01	Slave port interrupts use Interrupt Priority 1.
	10	Slave port interrupts use Interrupt Priority 2.
	11	Slave port interrupts use Interrupt Priority 3.

10. PARALLEL PORT C

10.1 Overview

Parallel Port C is a byte-wide port with each bit programmable for data direction and drive level. These are simple inputs and outputs controlled and reported in the Port C Data Register (PCDR).

All the Parallel Port C pins have alternate output functions, and most of them can be used as inputs to various on-chip peripherals.

The drive strength and slew rate can be individually controlled for each Parallel Port C pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

Table 10-1. Parallel Port C Pin Alternate Output Functions

Pin Name	Alt Out 0	Alt Out 1	Alt Out 2	Alt Out 3
PC7	TXA	I7	PWM3	SCLKC
PC6	TXA	I6	PWM2	TXE
PC5	TXB	I5	PWM1	RCLKE
PC4	TXB	I4	PWM0	TCLKE
PC3	TXC	I3	TIMER C3	SCLKD
PC2	TXC	I2	TIMER C2	TXF
PC1	TXD	I1	TIMER C1	RCLKF
PC0	TXD	I0	TIMER C0	TCLKF

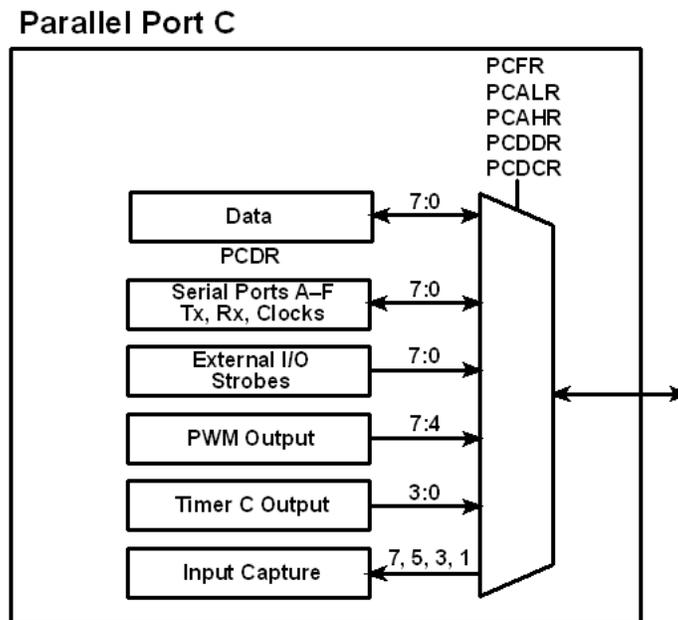
NOTE: I0-I7 are strobes for External I/O

Table 10-2. Parallel Port C Pin Alternate Input Functions

Pin Name	Input Capture	Serial Ports A–D	Serial Ports E–F
PC7	yes	RXA	RXE
PC6	—	—	—
PC5	yes	RXB	RCLKE
PC4	—	—	TCLKE
PC3	yes	RXC	RXF
PC2	—	—	—
PC1	yes	RXD	RCLKF
PC0	—	—	TCLKF

After reset, the default condition for Parallel Port C is four outputs (the even-numbered bits) and four inputs (the odd-numbered bits). For compatibility with the Rabbit 2000 and the Rabbit 3000 microprocessors, these outputs are driven with a logic zero (low) on PC6 and a logic one (high) on PC4, PC2, and PC0. When PCDR is read, the actual voltage on the pins is returned, whether the pins are set as inputs or outputs.

10.1.1 Block Diagram



10.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port C Data Register	PCDR	0x0050	R/W	00010101
Port C Data Direction Register	PCDDR	0x0051	R/W	01010101
Port C Alternate Low Register	PCALR	0x0052	R/W	00000000
Port C Alternate High Register	PCAHR	0x0053	R/W	00000000
Port C Drive Control Register	PCDCR	0x0054	R/W	00000000
Port C Function Register	PCFR	0x0055	R/W	00000000
Port Cx Control Register	PCxCR	0x04D0 + x	W	xxx00000

10.2 Dependencies

10.2.1 I/O Pins

Parallel Port C uses pins PC0 through PC7. These pins can be used individually as data inputs or outputs, as serial port transmit and receive for Serial ports A–F, as clocks for Serial Ports C–F, as external I/O strobes, or as outputs for the PWM and Timer C peripherals. The input capture peripheral can also watch pins PC7, PC5, PC3, and PC1.

On startup, PC4, PC2, and PC0 are outputs set high, PC6 is set low, and the other pins are inputs for compatibility with the Rabbit 3000.

The individual pins can be set to be open-drain via PCDCR. Drive strength, slew rate, and the pullup/down resistor status are selectable via PCxCR.

See the associated peripheral chapters for details on how they use Parallel Port C.

10.2.2 Clocks

All outputs on Parallel Port C are clocked by the peripheral clock.

10.2.3 Other Registers

Register	Function
SACR, SBCR, SCCR, SDCR, SECR, SFCR	Select a Parallel Port C pin as serial data (and optional clock) input.
ICS1R, ICS2R	Select a Parallel Port C pin as a start/stop condition for Input Capture input.

10.2.4 Interrupts

There are no interrupts associated with Parallel Port C.

10.3 Operation

The following steps must be taken before using Parallel Port C.

1. Select the desired input/output direction for each pin via PCDDR.
2. Select driven or open-drain functionality for outputs via PCDCR.
3. If a particular drive strength, slew rate, or pullup/down resistor status is desired for a Parallel Port C pin, set that in the appropriate PCxCR.
4. If an alternate peripheral output function is desired for a pin, select it via PCALR or PCAHR and then enable it via PCFR. Refer to the appropriate peripheral chapter for further use of that pin.

Once the port is set up, data can be read or written by accessing PCDR. The value in PCDR of an output pin will reflect its current output value, but any value written to an input pin will not appear on that pin until that pin becomes an output.

If one of the Flexible Interface Modules has been enabled to use Parallel Port C, writing to PCDR will no longer change the state of the pins, and the settings of PCFR, PCALR, and PCAHR will be ignored. The other Parallel Port C registers are still valid. Refer to Chapter 33 for more details.

10.4 Register Descriptions

Parallel Port C Data Register (PCDR) (Address = 0x0050)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port C pins PC7–PC0 is reported.
	Write	The Parallel Port C buffer is written with this value for transfer to the Parallel Port C output register on the next rising edge of the peripheral clock.

Parallel Port C Data Direction Register (PCDDR) (Address = 0x0051)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port C Alternate Low Register (PCALR) (Address = 0x0052)		
Bit(s)	Value	Description
7:6	00	Parallel Port C bit 3 alternate output 0 (TXC).
	01	Parallel Port C bit 3 alternate output 1 (I3).
	10	Parallel Port C bit 3 alternate output 2 (TIMER C3).
	11	Parallel Port C bit 3 alternate output 3 (SCLKD).
5:4	00	Parallel Port C bit 2 alternate output 0 (TXC).
	01	Parallel Port C bit 2 alternate output 1 (I2).
	10	Parallel Port C bit 2 alternate output 2 (TIMER C2).
	11	Parallel Port C bit 2 alternate output 3 (TXF).
3:2	00	Parallel Port C bit 1 alternate output 0 (TXD).
	01	Parallel Port C bit 1 alternate output 1 (I1).
	10	Parallel Port C bit 1 alternate output 2 (TIMER C1).
	11	Parallel Port C bit 1 alternate output 3 (RCLKF).
1:0	00	Parallel Port C bit 0 alternate output 0 (TXD).
	01	Parallel Port C bit 0 alternate output 1 (I0).
	10	Parallel Port C bit 0 alternate output 2 (TIMER C0).
	11	Parallel Port C bit 0 alternate output 3 (TCLKF).

Parallel Port C Alternate High Register (PCAHR) (Address = 0x0053)		
Bit(s)	Value	Description
7:6	00	Parallel Port C bit 7 alternate output 0 (TXA).
	01	Parallel Port C bit 7 alternate output 1 (I7).
	10	Parallel Port C bit 7 alternate output 2 (PWM3).
	11	Parallel Port C bit 7 alternate output 3 (SCLKC).
5:4	00	Parallel Port C bit 6 alternate output 0 (TXA).
	01	Parallel Port C bit 6 alternate output 1 (I6).
	10	Parallel Port C bit 6 alternate output 2 (PWM2).
	11	Parallel Port C bit 6 alternate output 3 (TXE).
3:2	00	Parallel Port C bit 5 alternate output 0 (TXB).
	01	Parallel Port C bit 5 alternate output 1 (I5).
	10	Parallel Port C bit 5 alternate output 2 (PWM1).
	11	Parallel Port C bit 5 alternate output 3 (RCLKC).
1:0	00	Parallel Port C bit 4 alternate output 0 (TXB).
	01	Parallel Port C bit 4 alternate output 1 (I4).
	10	Parallel Port C bit 4 alternate output 2 (PWM0).
	11	Parallel Port C bit 4 alternate output 3 (TCLKC).

Parallel Port C Drive Control Register (PCDCR) (Address = 0x0054)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit, as an output, is driven high and low.
	1	The corresponding port bit, as an output, is open-drain.

Parallel Port C Function Register (PCFR) (Address = 0x0055)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit functions normally.
	1	The corresponding port bit carries its alternate signal as an output. See Table 10-1.

Parallel Port Cx Control Register		
(PC0CR) (Address = 0x04D0)		
(PC1CR) (Address = 0x04D1)		
(PC2CR) (Address = 0x04D2)		
(PC3CR) (Address = 0x04D3)		
(PC4CR) (Address = 0x04D4)		
(PC5CR) (Address = 0x04D5)		
(PC6CR) (Address = 0x04D6)		
(PC7CR) (Address = 0x04D7)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

11. PARALLEL PORT D

11.1 Overview

Parallel Port D is a byte-wide port with each bit programmable for data direction and drive level. These are simple inputs and outputs controlled and reported in the Port D Data Register (PDDR).

All of the Parallel Port D pins have alternate output functions, and all of them can be used as inputs to various on-chip peripherals.

When used as simple digital outputs, the Parallel Port D bits are buffered, with the data written to PDDR transferred to the output pins on a selected timing edge. Either the peripheral clock or the outputs of Timer A1, Timer B1, or Timer B2 can be used for this function, with each nibble of the port having a separate select field to control this timing. Each bit can either be programmed as open-drain or driven high and low.

Because of the buffered nature of Parallel Port D, a read-modify-write type of operation can lead to old data being written to PDDR. To alleviate this potential problem, each bit of the port can be written individually using a separate address for each bit.

The drive strength and slew rate can be individually controlled for each Parallel Port D pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

Table 11-1. Parallel Port D Pin Alternate Output Functions

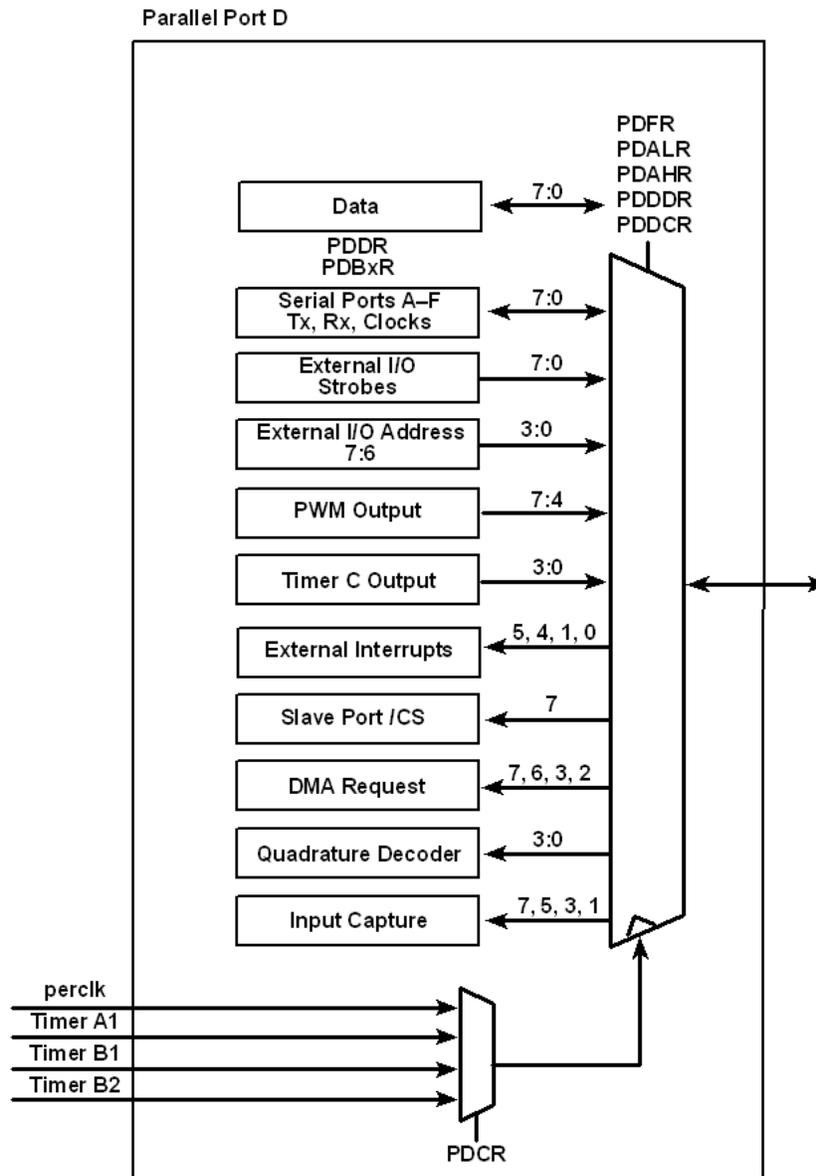
Pin Name	Alt Out 0	Alt Out 1	Alt Out 2	Alt Out 3
PD7	IA7	I7	PWM3	SCLKC
PD6	TXA	I6	PWM2	TXE
PD5	IA6	I5	PWM1	RCLKE
PD4	TXB	I4	PWM0	TCLKE
PD3	IA7	I3	TIMER C3	SCLKD
PD2	SCLKC	I2	TIMER C2	TXF
PD1	IA6	I1	TIMER C1	RCLKF
PD0	SCLKD	I0	TIMER C0	TCLKF

NOTE: IA6 and IA7 are address bits for External I/O.

Table 11-2. Parallel Port D Pin Alternate Input Functions

Pin Name	Input Capture	Serial Ports A–D	Serial Ports E–F	DMA	External Interrupts	Quad Decode
PD7	yes	RXA	RXE	—	—	—
PD6	—	—	—	—	—	—
PD5	yes	RXB	RCLKE	—	—	—
PD4	—	—	TCLKE	—	—	—
PD3	yes	RXC	RXF	DREQ1	—	QD2A
PD2	—	SCLKC	—	DREQ0	—	QD2B
PD1	yes	RXD	RCLKF	—	INT1	QD1A
PD0	—	SCLKD	TCLKF	—	INT0	QD1B

11.1.1 Block Diagram



11.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port D Data Register	PDDR	0x0060	R/W	xxxxxxxx
Port D Alternate Low Register	PDALR	0x0062	R/W	00000000
Port D Alternate High Register	PDAHR	0x0063	R/W	00000000
Port D Control Register	PDCR	0x0064	R/W	xx00xx00
Port D Function Register	PDFR	0x0065	R/W	xxxxxxxx
Port D Drive Control Register	PDDCR	0x0066	R/W	xxxxxxxx
Port D Data Direction Register	PDDDR	0x0067	R/W	00000000
Port D Bit x Register	PDBxR	0x0068+x	W	xxxxxxxx
Port Dx Control Register	PDxCR	0x04E0 + x	W	xxx00000

11.2 Dependencies

11.2.1 I/O Pins

Parallel Port D uses pins PD0 through PD7. These pins can be used individually as data inputs or outputs; as serial port transmit and receive for Serial Ports A, B, E, and F; as clocks for Serial Ports C–F; as external I/O strobes; or as outputs for the PWM and Timer C peripherals. The input capture peripheral can also watch pins PD7, PD5, PD3, and PD1.

All pins are set as inputs on startup.

The individual bits can be set to be open-drain via PDDCR. Drive strength, slew rate, and the pullup/down resistor status are selectable via PDxCR.

See the associated peripheral chapters for details on how they use Parallel Port D.

11.2.2 Clocks

All outputs on Parallel Port D are clocked by the peripheral clock unless changed in PDCR, where the option of updating the Parallel Port D pins can be synchronized to the output of Timer A1, Timer B1, or Timer B2.

11.2.3 Other Registers

Register	Function
SACR, SBCR, SCCR, SDCR, SECR, SFCR	Select a Parallel Port D pin as serial data (and optional clock) input.
ICS1R, ICS2R	Select a Parallel Port D pin as a start/stop condition for Input Capture input.
QDCR	Select a Parallel Port D pin as a Quadrature Decoder input.
I0CR, I1CR	Select a Parallel Port D pin as an external interrupt input.
DMR0CR, DMR1CR	Select a Parallel Port D pin as an external DMA request input.

11.2.4 Interrupts

External interrupts can be accepted from pins PD1 or PD0; see Chapter 7 for more details.

11.3 Operation

The following steps must be taken before using Parallel Port D.

1. Select the desired input/output direction for each pin via PDDDR.
2. Select driven or open-drain functionality for outputs via PDDCR.
3. If a particular drive strength, slew rate, or pullup/down resistor status is desired for a Parallel Port D pin, set that in the appropriate PDxCR.
4. If an alternative peripheral output function is desired for a pin, select it via PDALR or PDAHR and then enable it via PDFR. Refer to the appropriate peripheral chapter for further use of that pin.

Once Parallel Port D is set up, data can be read or written by accessing PDDR. Read PDDR to learn the current state of a Parallel Port D pin; any value written to an input pin will not appear on that pin until that pin becomes an output.

If one of the Flexible Interface Module has been enabled to use Parallel Port D, writing to PDDR will no longer change the state of the pins, and the settings of PDFR, PDALR, and PDAHR will be ignored. The other Parallel Port D registers are still valid. Refer to Chapter 33 for more details.

11.4 Register Descriptions

Parallel Port D Data Register (PDDR) (Address = 0x0060)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port D pins PD7–PD0 is reported.
	Write	The Parallel Port D buffer is written with this value for transfer to the Parallel Port D output register on the next rising edge of the port transfer clock. The port transfer clock is established by PDCR.

Parallel Port D Alternate Low Register (PDALR) (Address = 0x0062)		
Bit(s)	Value	Description
7:6	00	Parallel Port D bit 3 alternate output 0 (IA7).
	01	Parallel Port D bit 3 alternate output 1 (I3).
	10	Parallel Port D bit 3 alternate output 2 (TIMER C3).
	11	Parallel Port D bit 3 alternate output 3 (SCLKD).
5:4	00	Parallel Port D bit 2 alternate output 0 (SCLKC).
	01	Parallel Port D bit 2 alternate output 1 (I2).
	10	Parallel Port D bit 2 alternate output 2 (TIMER C2).
	11	Parallel Port D bit 2 alternate output 3 (TXF).
3:2	00	Parallel Port D bit 1 alternate output 0 (IA6).
	01	Parallel Port D bit 1 alternate output 1 (I1).
	10	Parallel Port D bit 1 alternate output 2 (TIMER C1).
	11	Parallel Port D bit 1 alternate output 3 (RCLKF).
1:0	00	Parallel Port D bit 0 alternate output 0 (SCLKD).
	01	Parallel Port D bit 0 alternate output 1 (I0).
	10	Parallel Port D bit 0 alternate output 2 (TIMER C0).
	11	Parallel Port D bit 0 alternate output 3 (TCLKF).

Parallel Port D Alternate High Register (PDAHR) (Address = 0x0063)		
Bit(s)	Value	Description
7:6	00	Parallel Port D bit 7 alternate output 0 (IA7).
	01	Parallel Port D bit 7 alternate output 1 (I7).
	10	Parallel Port D bit 7 alternate output 2 (PWM3).
	11	Parallel Port D bit 7 alternate output 3 (SCLKC).
5:4	00	Parallel Port D bit 6 alternate output 0 (TXA).
	01	Parallel Port D bit 6 alternate output 1 (I6).
	10	Parallel Port D bit 6 alternate output 2 (PWM2).
	11	Parallel Port D bit 6 alternate output 3 (TXE).
3:2	00	Parallel Port D bit 5 alternate output 0 (IA6).
	01	Parallel Port D bit 5 alternate output 1 (I5).
	10	Parallel Port D bit 5 alternate output 2 (PWM1).
	11	Parallel Port D bit 5 alternate output 3 (RCLKC).
1:0	00	Parallel Port D bit 4 alternate output 0 (TXB).
	01	Parallel Port D bit 4 alternate output 1 (I4).
	10	Parallel Port D bit 4 alternate output 2 (PWM0).
	11	Parallel Port D bit 4 alternate output 3 (TCLKC).

Parallel Port D Control Register (PDCR) (Address = 0x0064)		
Bit(s)	Value	Description
7:6		These bits are ignored and should be written with zero.
5:4	00	The upper nibble of the port transfer clock is perclk/2.
	01	The upper nibble of the port transfer clock is the output of Timer A1.
	10	The upper nibble of the port transfer clock is the output of Timer B1.
	11	The upper nibble of the port transfer clock is the output of Timer B2.
3:2		These bits are ignored and should be written with zero.
1:0	00	The lower nibble of the port transfer clock is perclk/2.
	01	The lower nibble of the port transfer clock is the output of Timer A1.
	10	The lower nibble of the port transfer clock is the output of Timer B1.
	11	The lower nibble of the port transfer clock is the output of Timer B2.

Parallel Port D Function Register (PDFR) (Address = 0x0065)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit functions normally.
	1	The corresponding port bit carries its alternate signal as an output. See Table 11-1.

Parallel Port D Drive Control Register (PDDCR) (Address = 0x0066)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit, as an output, is driven high and low.
	1	The corresponding port bit, as an output, is open-drain.

Parallel Port D Data Direction Register (PDDDR) (Address = 0x0067)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port D Bit 0 Register (PDB0R) (Address = 0x0068)		
Bit(s)	Value	Description
7:1		These bits are ignored.
0	Write	The port buffer (bit 0) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 1 Register (PDB1R) (Address = 0x0069)		
Bit(s)	Value	Description
7:2,0		These bits are ignored.
1	Write	The port buffer (bit 1) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 2 Register (PDB2R) (Address = 0x006A)		
Bit(s)	Value	Description
7:3,1:0		These bits are ignored.
2	Write	The port buffer (bit 2) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 3 Register (PDB3R) (Address = 0x006B)		
Bit(s)	Value	Description
7:4,2:0		These bits are ignored.
3	Write	The port buffer (bit 3) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 4 Register (PDB4R) (Address = 0x006C)		
Bit(s)	Value	Description
7:5,3:0		These bits are ignored.
4	Write	The port buffer (bit 4) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 5 Register (PDB5R) (Address = 0x006D)		
Bit(s)	Value	Description
7:6,4:0		These bits are ignored.
5	Write	The port buffer (bit 5) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 6 Register (PDB6R) (Address = 0x006E)		
Bit(s)	Value	Description
7,5:0		These bits are ignored.
6	Write	The port buffer (bit 6) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port D Bit 7 Register (PDB7R) (Address = 0x006F)		
Bit(s)	Value	Description
6:0		These bits are ignored.
7	Write	The port buffer (bit 7) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the port transfer clock

Parallel Port Dx Control Register		
(PD0CR) (Address = 0x04E0)		
(PD1CR) (Address = 0x04E1)		
(PD2CR) (Address = 0x04E2)		
(PD3CR) (Address = 0x04E3)		
(PD4CR) (Address = 0x04E4)		
(PD5CR) (Address = 0x04E5)		
(PD6CR) (Address = 0x04E6)		
(PD7CR) (Address = 0x04E7)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

12. PARALLEL PORT E

12.1 Overview

Parallel Port E is a byte-wide port with each bit programmable for data direction and drive level. These are simple inputs and outputs controlled and reported in the Port E Data Register (PEDR).

All of the Parallel Port E pins have alternate output functions, and all of them can be used as inputs to various on-chip peripherals.

When used as simple digital outputs, the Parallel Port E bits are buffered, with the data written to PEDR transferred to the output pins on a selected timing edge. Either the peripheral clock or the outputs of Timer A1, Timer B1, or Timer B2 can be used for this function, with each nibble of the port having a separate select field to control this timing. Each bit can either be programmed as open-drain or driven high and low.

Because of the buffered nature of Parallel Port E, using a read-modify-write type of operation can lead to old data being written to PEDR. To alleviate this potential problem, each bit of the port can be written individually using a separate address for each bit.

Bit 7 of Parallel Port E is used as the default chip select input for the slave port when the slave port is enabled, either for parallel bootstrap or under program control.

The drive strength and slew rate can be individually controlled for each Parallel Port E pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

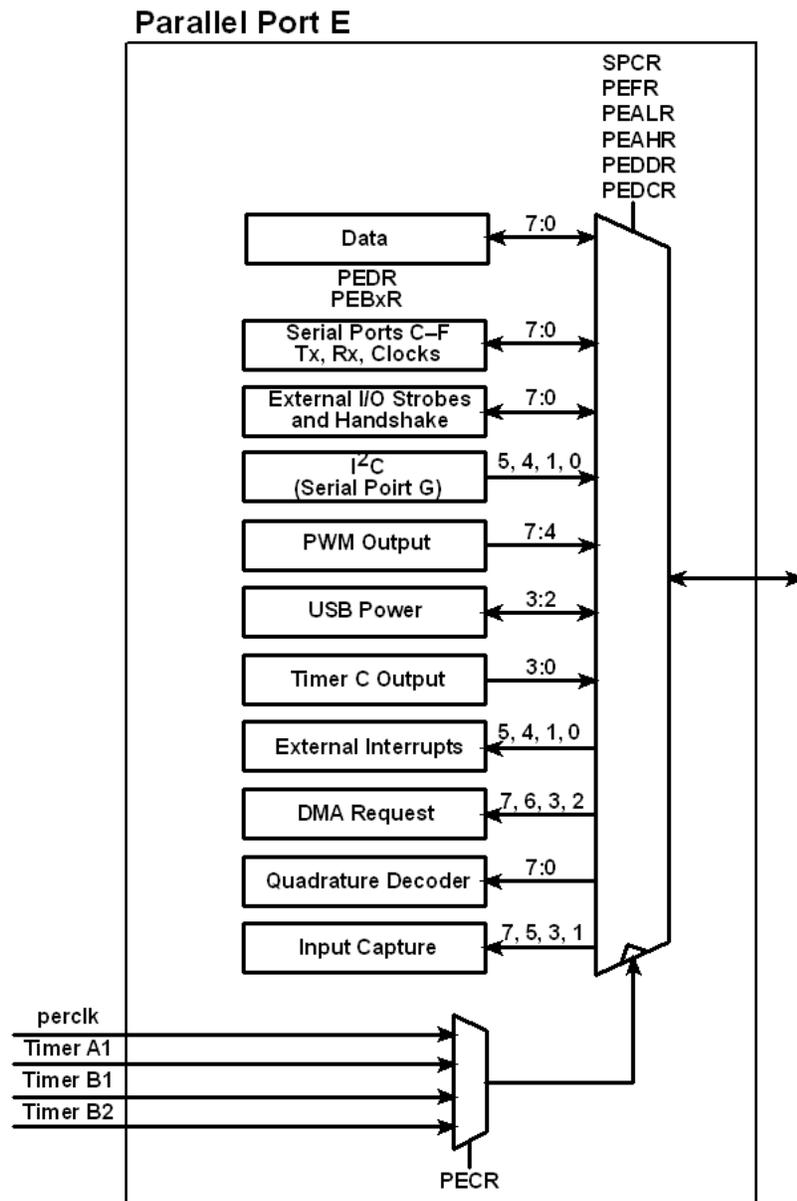
Table 12-1. Parallel Port E Pin Alternate Output Functions

Pin Name	Alt Out 0	Alt Out 1	Alt Out 2	Alt Out 3
PE7	I7	—	PWM3	SCLKC
PE6	I6	—	PWM2	TXE
PE5	I5	SCLKG	PWM1	RCLKE
PE4	I4	SDATG	PWM0	TCLKE
PE3	I3	—	TIMER C3	SCLKD
PE2	I2	USB_PWR	TIMER C2	TXF
PE1	I1	SCLKG	TIMER C1	RCLKF
PE0	I0	SDATG	TIMER C0	TCLKF

Table 12-2. Parallel Port E Pin Alternate Input Functions

Pin Name	Input Capture	I/O Handshake	Serial Ports A–D	Serial Ports E–F	DMA	External Interrupts	Quad Decode	USB
PE7	yes	yes	RXA	RXE	DREQ1	—	QD2A	
PE6	—	yes	—	—	DREQ0	—	QD2B	
PE5	yes	yes	RXB	RCLKE	—	INT1	QD1A	
PE4	—	yes	—	TCLKE	—	INT0	QD1B	
PE3	yes	yes	RXC	RXF	DREQ1	—	QD2A	OVCR
PE2	—	yes	SCLKC	—	DREQ0	—	QD2B	
PE1	yes	yes	RXD	RCLKF	—	INT1	QD1A	
PE0	—	yes	SCLKD	TCLKF	—	INT0	QD1B	

12.1.1 Block Diagram



12.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port E Data Register	PEDR	0x0070	R/W	xxxxxxxx
Port E Alternate Low Register	PEALR	0x0072	R/W	00000000
Port E Alternate High Register	PEAHR	0x0073	R/W	00000000
Port E Control Register	PECR	0x0074	R/W	xx00xx00
Port E Function Register	PEFR	0x0075	R/W	00000000
Port E Drive Control Register	PEDCR	0x0076	R/W	00000000
Port E Data Direction Register	PEDDR	0x0077	R/W	00000000
Port E Bit x Register	PEBxR	0x0078+x	W	xxxxxxxx
Port Ex Control Register	PE _x CR	0x04F0 + x	W	xxx00000

12.2 Dependencies

12.2.1 I/O Pins

Parallel Port E uses the pins PE0 through PE7. These pins can be used individually as data inputs or outputs; as serial port transmit and receive for Serial Ports E and F; as clocks for Serial Ports C–F; as data and clocks for I²C (Serial Port G); as external I/O strobes; as outputs for the PWM and Timer C peripherals; or as power control signals for the USB peripheral. The input capture peripheral can also watch pins PE7, PE5, PE3, and PE1. There is also an option to provide the slave port chip select on PE7.

All pins are set as inputs on startup.

The individual bits can be set to be open-drain via PEDCR. Drive strength, slew rate, and the pullup/down resistor status are selectable via PEXCR.

See the associated peripheral chapters for details on how they use Parallel Port E.

12.2.2 Clocks

All outputs on Parallel Port E are clocked by the peripheral clock unless changed in PECR, where the option of updating the Parallel Port E pins can be synchronized to the output of Timer A1, Timer B1, or Timer B2.

12.2.3 Other Registers

Register	Function
SACR, SBCR, SCCR, SDCR, SECR, SFCR	Select a Parallel Port E pin as serial data (and optional clock) input.
ICS1R, ICS2R	Select a Parallel Port E pin as a start/stop condition for Input Capture input.
QDCR	Select a Parallel Port E pin as a Quadrature Decoder input.
I0CR, I1CR	Select a Parallel Port E pin as an external interrupt input.
DMR0CR, DMR1CR	Select a Parallel Port E pin as an external DMA request input.
SPCR	Select slave chip select on PE7.
IHCR, IHSR, IHTR	Select a Parallel Port E pin for I/O handshake.
USBWR	Enable USB overcurrent detection on PE3.

12.2.4 Interrupts

External interrupts can be accepted from pins PE5, PE4, PE1 or PE0; see Chapter 7 for more details.

12.3 Operation

The following steps must be taken before using Parallel Port E.

1. Select the desired input/output direction for each pin via PEDDR.
2. Select high/low or open-drain functionality for outputs via PEDCR.
3. If a particular drive strength, slew rate, or pullup/down resistor status is desired for a Parallel Port E pin, set that in the appropriate PExCR.
4. If an alternative peripheral output function is desired for a pin, select it via PEALR or PEAHR and then enable it via PEFR. Refer to the appropriate peripheral chapter for further use of that pin.

Once the port is set up, data can be read or written by accessing PEDR. Read PEDR to learn the current state of a Parallel Port E pin; any value written to an input pin will not appear on that pin until that pin becomes an output.

If one of the Flexible Interface Modules has been enabled to use Parallel Port E, writing to PEDR will no longer change the state of the pins, and the settings of PEFR, PEALR, and PEAHR will be ignored. The other Parallel Port E registers are still valid. Refer to Chapter 33 for more details.

12.4 Register Descriptions

Parallel Port E Data Register (PEDR) (Address = 0x0070)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port E pins PE7–PE0 is reported.
	Write	The Parallel Port E buffer is written with this value for transfer to the Parallel Port E output register on the next rising edge of the port transfer clock. The port transfer clock is established by PECR.

Parallel Port E Alternate Low Register (PEALR) (Address = 0x0072)		
Bit(s)	Value	Description
7:6	00	Parallel Port E bit 3 alternate output 0 (I3).
	01	Parallel Port E bit 3 alternate output 1 (no functionality).
	10	Parallel Port E bit 3 alternate output 2 (TIMER C3).
	11	Parallel Port E bit 3 alternate output 3 (SCLKD).
5:4	00	Parallel Port E bit 2 alternate output 0 (I2).
	01	Parallel Port E bit 2 alternate output 1 (USB_PWR).
	10	Parallel Port E bit 2 alternate output 2 (TIMER C2).
	11	Parallel Port E bit 2 alternate output 3 (TXF).
3:2	00	Parallel Port E bit 1 alternate output 0 (I1).
	01	Parallel Port E bit 1 alternate output 1 (SCLKG).
	10	Parallel Port E bit 1 alternate output 2 (TIMER C1).
	11	Parallel Port E bit 1 alternate output 3 (RCLKF).
1:0	00	Parallel Port E bit 0 alternate output 0 (I0).
	01	Parallel Port E bit 0 alternate output 1 (SDATG).
	10	Parallel Port E bit 0 alternate output 2 (TIMER C0).
	11	Parallel Port E bit 0 alternate output 3 (TCLKF).

Parallel Port E Alternate High Register (PEAHR) (Address = 0x0073)		
Bit(s)	Value	Description
7:6	00	Parallel Port E bit 7 alternate output 0 (I7).
	01	Parallel Port E bit 7 alternate output 1 (no functionality).
	10	Parallel Port E bit 7 alternate output 2 (PWM3).
	11	Parallel Port E bit 7 alternate output 3 (SCLKC).
5:4	00	Parallel Port E bit 6 alternate output 0 (I6).
	01	Parallel Port E bit 6 alternate output 1 (no functionality).
	10	Parallel Port E bit 6 alternate output 2 (PWM2).
	11	Parallel Port E bit 6 alternate output 3 (TXE).
3:2	00	Parallel Port E bit 5 alternate output 0 (I5).
	01	Parallel Port E bit 5 alternate output 1 (SCLKG).
	10	Parallel Port E bit 5 alternate output 2 (PWM1).
	11	Parallel Port E bit 5 alternate output 3 RCLKE).
1:0	00	Parallel Port E bit 4 alternate output 0 (I4).
	01	Parallel Port E bit 4 alternate output 1 (SDATG).
	10	Parallel Port E bit 4 alternate output 2 (PWM0).
	11	Parallel Port E bit 4 alternate output 3 (TCLKE).

Parallel Port E Control Register (PECR) (Address = 0x0074)		
Bit(s)	Value	Description
7:6		These bits are ignored and should be written with zero.
5:4	00	The upper nibble peripheral clock is perclk/2.
	01	The upper nibble peripheral clock is the output of Timer A1.
	10	The upper nibble peripheral clock is the output of Timer B1.
	11	The upper nibble peripheral clock is the output of Timer B2.
3:2		These bits are ignored and should be written with zero.
1:0	00	The lower nibble peripheral clock is perclk/2.
	01	The lower nibble peripheral clock is the output of Timer A1.
	10	The lower nibble peripheral clock is the output of Timer B1.
	11	The lower nibble peripheral clock is the output of Timer B2.

Parallel Port E Function Register (PEFR) (Address = 0x0075)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit functions normally.
	1	The corresponding port bit carries its alternate signal as an output. See Table 12-1.

Parallel Port E Drive Control Register (PEDCR) (Address = 0x0076)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit, as an output, is driven high and low.
	1	The corresponding port bit, as an output, is open-drain.

Parallel Port E Data Direction Register (PEDDR) (Address = 0x0077)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port E Bit 0 Register (PEB0R) (Address = 0x0078)		
Bit(s)	Value	Description
7:1		These bits are ignored.
0	Write	The port buffer (bit 0) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 1 Register (PEB1R) (Address = 0x0079)		
Bit(s)	Value	Description
7:2,0		These bits are ignored.
1	Write	The port buffer (bit 1) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 2 Register (PEB2R) (Address = 0x007A)		
Bit(s)	Value	Description
7:3,1:0		These bits are ignored.
2	Write	The port buffer (bit 2) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 3 Register (PEB3R) (Address = 0x007B)		
Bit(s)	Value	Description
7:4,2:0		These bits are ignored.
3	Write	The port buffer (bit 3) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 4 Register (PEB4R) (Address = 0x007C)		
Bit(s)	Value	Description
7:5,3:0		These bits are ignored.
4	Write	The port buffer (bit 4) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 5 Register (PEB5R) (Address = 0x007D)		
Bit(s)	Value	Description
7:6,4:0		These bits are ignored.
5	Write	The port buffer (bit 5) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 6 Register (PEB6R) (Address = 0x007E)		
Bit(s)	Value	Description
7,5:0		These bits are ignored.
6	Write	The port buffer (bit 6) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port E Bit 7 Register (PEB7R) (Address = 0x007F)		
Bit(s)	Value	Description
6:0		These bits are ignored.
7	Write	The port buffer (bit 7) is written with the value of this bit. The port buffer will be transferred to the port output register on the next rising edge of the peripheral clock.

Parallel Port Ex Control Register		
(PE0CR) (Address = 0x04F0)		
(PE1CR) (Address = 0x04F1)		
(PE2CR) (Address = 0x04F2)		
(PE3CR) (Address = 0x04F3)		
(PE4CR) (Address = 0x04F4)		
(PE5CR) (Address = 0x04F5)		
(PE6CR) (Address = 0x04F6)		
(PE7CR) (Address = 0x04F7)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 kΩ pullup resistor.
	10	75 kΩ pulldown resistor.
	11	75 kΩ keeper.

13. PARALLEL PORT F

13.1 Overview

Parallel Port F is a byte-wide port with each bit programmable for data direction and drive level. These are simple inputs and outputs controlled and reported in the Port F Data Register (PFDR).

All of the Parallel Port F pins have alternate output functions, and all of them can be used as inputs to various on-chip peripherals.

When used as simple digital outputs, the Parallel Port F bits are buffered, with the data written to PFDR transferred to the output pins on a selected timing edge. Either the peripheral clock or the outputs of Timer A1, Timer B1, or Timer B2 can be used for this function, with each nibble of the port having a separate select field to control this timing. Each bit can either be programmed as open-drain or driven high and low.

The drive strength and slew rate can be individually controlled for each Parallel Port F pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

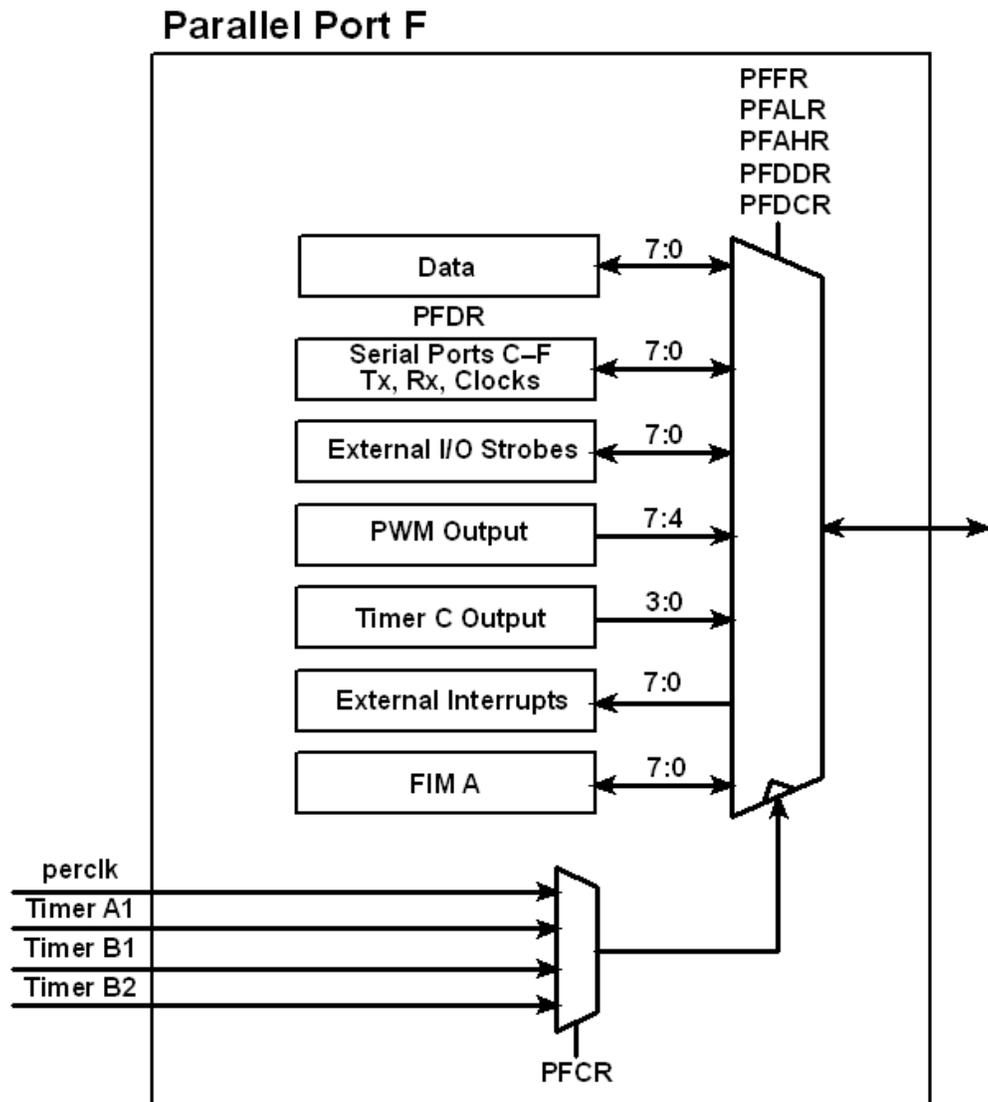
Table 13-1. Parallel Port F Pin Alternate Output Functions

Pin Name	Alt Out 0	Alt Out 1	Alt Out 2	Alt Out 3
PF7	FIMA7	I7	PWM3	SCLKC
PF6	FIMA6	I6	PWM2	TXE
PF5	FIMA5	I5	PWM1	RCLKE
PF4	FIMA4	I4	PWM0	TCLKE
PF3	FIMA3	I3	TIMER C3	SCLKD
PF2	FIMA2	I2	TIMER C2	TXF
PF1	FIMA1	I1	TIMER C1	RCLKF
PF0	FIMA0	I0	TIMER C0	TCLKF

Table 13-2. Parallel Port F Pin Alternate Input Functions

Pin Name	External Interrupts	FIM
PF7	INT2-7	FIMA7
PF6	INT2-7	FIMA6
PF5	INT2-7	FIMA5
PF4	INT2-7	FIMA4
PF3	INT2-7	FIMA3
PF2	INT2-7	FIMA2
PF1	INT2-7	FIMA1
PF0	INT2-7	FIMA0

13.1.1 Block Diagram



13.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port F Data Register	PFDR	0x0038	R/W	xxxxxxxx
Port F Alternate Low Register	PFALR	0x003A	R/W	00000000
Port F Alternate High Register	PFAHR	0x003B	R/W	00000000
Port F Control Register	PFCR	0x003C	R/W	xx00xx00
Port F Function Register	PFFR	0x003D	R/W	00000000
Port F Drive Control Register	PFDCR	0x003E	R/W	00000000
Port F Data Direction Register	PFDDR	0x003F	R/W	00000000
Port Fx Control Register	PFxCR	0x04B8 + x	W	xxx00000

13.2 Dependencies

13.2.1 I/O Pins

Parallel Port F uses the pins PF0 through PF7. These pins can be used individually as data inputs or outputs; serial port signals, PWM or Timer C outputs, external interrupt, external I/O strobes, or inputs and outputs for Flexible Interface Module A.

All pins are set as inputs on startup.

The individual bits can be set to be open-drain via PFDCR. Drive strength, slew rate, and the pullup/down resistor status are selectable via PFxCR.

See the associated peripheral chapters for details on how they use Parallel Port F.

13.2.2 Clocks

All outputs on Parallel Port F are clocked by the peripheral clock unless changed in PFCR, where the option of updating the Parallel Port F pins can be synchronized to the output of Timer A1, Timer B1, or Timer B2.

13.2.3 Other Registers

Register	Function
I2CR, I3CR, I4CR, I5CR, I6CR, I7CR	Select a Parallel Port F pin as an external interrupt input.

13.2.4 Interrupts

External interrupts can be accepted from any pin on Parallel Port F; see Chapter 7 for more details.

13.3 Operation

The following steps must be taken before using Parallel Port F.

1. Select the desired input/output direction for each pin via PFDDR.
2. Select high/low or open-drain functionality for outputs via PFDCR.
3. If a particular drive strength, slew rate, or pullup/down status is desired for a Parallel Port F pin, set that in the appropriate PFxCR.
4. If an alternative peripheral output function is desired for a pin, select it via PFALR or PFAHR and then enable it via PFFR. Refer to the appropriate peripheral chapter for further use of that pin.

Once the port is set up, data can be read or written by accessing PFDR. Read PFDR to learn the current state of a Parallel Port F pin; any value written to an input pin will not appear on that pin until that pin becomes an output.

It is possible to enable a Flexible Interface Module to override Parallel Port F, which is a different option than the alternate output selection of the FIMA interface. If one of the Flexible Interface Modules has been enabled to override Parallel Port F, writing to PFDR will no longer change the state of the pins, and the settings of PFFR, PFALR, and PFAHR will be ignored. The other Parallel Port F registers are still valid. Refer to Chapter 33 for more details.

13.4 Register Descriptions

Parallel Port F Data Register (PFDR) (Address = 0x0038)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port F pins PF7–PF0 is reported.
	Write	The Parallel Port F buffer is written with this value for transfer to the Parallel Port F output register on the next rising edge of the port transfer clock. The port transfer clock is established by PFCR.

Parallel Port F Alternate Low Register (PFALR) (Address = 0x003A)		
Bit(s)	Value	Description
7:6	00	Parallel Port F bit 3 alternate output 0 (FIMA3).
	01	Parallel Port F bit 3 alternate output 1 (I3).
	10	Parallel Port F bit 3 alternate output 2 (TIMER C3).
	11	Parallel Port F bit 3 alternate output 3 (SCLKD).
5:4	00	Parallel Port F bit 2 alternate output 0 (FIMA2).
	01	Parallel Port F bit 2 alternate output 1 (I2).
	10	Parallel Port F bit 2 alternate output 2 (TIMER C2).
	11	Parallel Port F bit 2 alternate output 3 (TXF).
3:2	00	Parallel Port F bit 1 alternate output 0 (FIMA1).
	01	Parallel Port F bit 1 alternate output 1 (I1).
	10	Parallel Port F bit 1 alternate output 2 (TIMER C1).
	11	Parallel Port F bit 1 alternate output 3 (RCLKF).
1:0	00	Parallel Port F bit 0 alternate output 0 (FIMA0).
	01	Parallel Port F bit 0 alternate output 1 (I0).
	10	Parallel Port F bit 0 alternate output 2 (TIMER C0).
	11	Parallel Port F bit 0 alternate output 3 (TCLKF).

Parallel Port F Alternate High Register (PFAHR) (Address = 0x003B)		
Bit(s)	Value	Description
7:6	00	Parallel Port F bit 7 alternate output 0 (FIMA7).
	01	Parallel Port F bit 7 alternate output 1 (I7).
	10	Parallel Port F bit 7 alternate output 2 (PWM3).
	11	Parallel Port F bit 7 alternate output 3 (SCLKC).
5:4	00	Parallel Port F bit 6 alternate output 0 (FIMA6).
	01	Parallel Port F bit 6 alternate output 1 (I6).
	10	Parallel Port F bit 6 alternate output 2 (PWM2).
	11	Parallel Port F bit 6 alternate output 3 (TXE).
3:2	00	Parallel Port F bit 5 alternate output 0 (FIMA5).
	01	Parallel Port F bit 5 alternate output 1 (I5).
	10	Parallel Port F bit 5 alternate output 2 (PWM1).
	11	Parallel Port F bit 5 alternate output 3 (RCLKC).
1:0	00	Parallel Port F bit 4 alternate output 0 (FIMA4).
	01	Parallel Port F bit 4 alternate output 1 (I4).
	10	Parallel Port F bit 4 alternate output 2 (PWM0).
	11	Parallel Port F bit 4 alternate output 3 (TCLKC).

Parallel Port F Control Register (PFCR) (Address = 0x003C)		
Bit(s)	Value	Description
7:6		These bits are ignored and should be written with zero.
5:4	00	The upper nibble peripheral clock is perclk/2.
	01	The upper nibble peripheral clock is the output of Timer A1.
	10	The upper nibble peripheral clock is the output of Timer B1.
	11	The upper nibble peripheral clock is the output of Timer B2.
3:2		These bits are ignored and should be written with zero.
1:0	00	The lower nibble peripheral clock is perclk/2.
	01	The lower nibble peripheral clock is the output of Timer A1.
	10	The lower nibble peripheral clock is the output of Timer B1.
	11	The lower nibble peripheral clock is the output of Timer B2.

Parallel Port F Function Register (PFFR) (Address = 0x003D)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit functions normally.
	1	The corresponding port bit carries its alternate signal as an output. See Table 13-1.

Parallel Port F Drive Control Register (PFDCR) (Address = 0x003E)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit, as an output, is driven high and low.
	1	The corresponding port bit, as an output, is open-drain.

Parallel Port F Data Direction Register (PFDDR) (Address = 0x003F)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port Fx Control Register		
(PF0CR)	(Address = 0x04B8)	
(PF1CR)	(Address = 0x04B9)	
(PF2CR)	(Address = 0x04BA)	
(PF3CR)	(Address = 0x04BB)	
(PF4CR)	(Address = 0x04BC)	
(PF5CR)	(Address = 0x04BD)	
(PF6CR)	(Address = 0x04BE)	
(PF7CR)	(Address = 0x04BF)	
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

14. PARALLEL PORT G

14.1 Overview

Parallel Port G is a byte-wide port with each bit programmable for data direction and drive level. These are simple inputs and outputs controlled and reported in the Port G Data Register (PGDR).

All of the Parallel Port G pins have alternate output functions, and all of them can be used as inputs to various on-chip peripherals.

When used as outputs, the Parallel Port G bits are buffered, with the data written to PGDR transferred to the output pins on a selected timing edge. Either the peripheral clock or the outputs of Timer A1, Timer B1, or Timer B2 can be used for this function, with each nibble of the port having a separate select field to control this timing. Each bit can either be programmed as open-drain or driven high and low.

The drive strength and slew rate can be individually controlled for each Parallel Port G pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

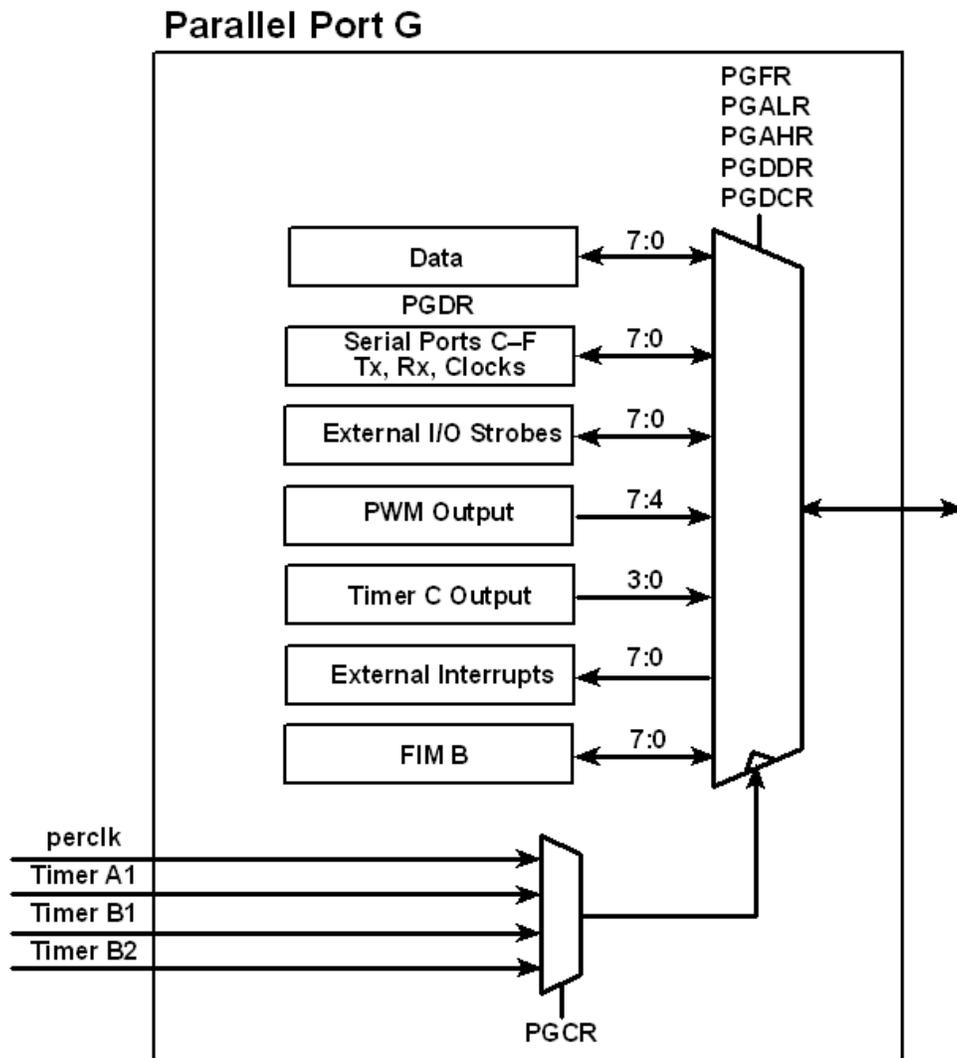
Table 14-1. Parallel Port G Pin Alternate Output Functions

Pin Name	Alt Out 0	Alt Out 1	Alt Out 2	Alt Out 3
PG7	FIMB7	I7	PWM3	SCLKC
PG6	FIMB6	I6	PWM2	TXE
PG5	FIMB5	I5	PWM1	RCLKE
PG4	FIMB4	I4	PWM0	TCLKE
PG3	FIMB3	I3	TIMER C3	SCLKD
PG2	FIMB2	I2	TIMER C2	TXF
PG1	FIMB1	I1	TIMER C1	RCLKF
PG0	FIMB0	I0	TIMER C0	TCLKF

Table 14-2. Parallel Port G Pin Alternate Input Functions

Pin Name	External Interrupts	FIM
PG7	INT2-7	FIMB7
PG6	INT2-7	FIMB6
PG5	INT2-7	FIMB5
PG4	INT2-7	FIMB4
PG3	INT2-7	FIMB3
PG2	INT2-7	FIMB2
PG1	INT2-7	FIMB1
PG0	INT2-7	FIMB0

14.1.1 Block Diagram



14.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port G Data Register	PGDR	0x0048	R/W	xxxxxxxx
Port G Alternate Low Register	PGALR	0x004A	R/W	00000000
Port G Alternate High Register	PGAHR	0x004B	R/W	00000000
Port G Control Register	PGCR	0x004C	R/W	xx00xx00
Port G Function Register	PGFR	0x004D	R/W	00000000
Port G Drive Control Register	PGDCR	0x004E	R/W	00000000
Port G Data Direction Register	PGDDR	0x004F	R/W	00000000
Port Gx Control Register	PGxCR	0x04C8 + x	W	xxx00000

14.2 Dependencies

14.2.1 I/O Pins

Parallel Port G uses the pins PG0 through PG7. These pins can be used individually as data inputs or outputs, serial port signals, PWM or Timer C outputs, external interrupt or input capture inputs, external I/O strobes, or inputs and outputs for Flexible Interface Module B.

All pins are set as inputs on startup.

The individual bits can be set to be open-drain via PGDCR. Drive strength, slew rate, and the pullup/down resistor status are selectable via PGxCR.

See the associated peripheral chapters for details on how they use Parallel Port G.

14.2.2 Clocks

All outputs on Parallel Port G are clocked by the peripheral clock unless changed in PGCR, where the option of updating the Parallel Port G pins can be synchronized to the output of Timer A1, Timer B1, or Timer B2.

14.2.3 Other Registers

Register	Function
I2CR, I3CR, I4CR, I5CR, I6CR, I7CR	Select a Parallel Port G pin as an external interrupt input.

14.2.4 Interrupts

External interrupts can be accepted from any pin on Parallel Port G; see Chapter 7 for more details.

14.3 Operation

The following steps must be taken before using Parallel Port G.

1. Select the desired input/output direction for each pin via PGDDR.
2. Select high/low or open-drain functionality for outputs via PGDCR.
3. If a particular drive strength, slew rate, or pullup/down status is desired for a Parallel Port G pin, set that in the appropriate PGxCR.
4. If an alternative peripheral output function is desired for a pin, select it via PGALR or PGAHR and then enable it via PGFR. Refer to the appropriate peripheral chapter for further use of that pin.

Once the port is set up, data can be read or written by accessing PGDR. Read PGDR to learn the current state of a Parallel Port G pin; any value written to an input pin will not appear on that pin until that pin becomes an output.

It is possible to enable a Flexible Interface Module to override Parallel Port G, which is a different option than the alternate output selection of the FIMB interface. If one of the Flexible Interface Modules has been enabled to override Parallel Port G, writing to PGDR will no longer change the state of the pins, and the settings of PGFR, PGALR, and PGAHR will be ignored. The other Parallel Port G registers are still valid. Refer to Chapter 33 for more details.

14.4 Register Descriptions

Parallel Port G Data Register (PGDR) (Address = 0x0048)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port G pins PG7–PG0 is reported.
	Write	The Parallel Port G buffer is written with this value for transfer to the Parallel Port G output register on the next rising edge of the port transfer clock. The port transfer clock is established by PGCR.

Parallel Port G Alternate Low Register (PGALR) (Address = 0x004A)		
Bit(s)	Value	Description
7:6	00	Parallel Port G bit 3 alternate output 0 (FIMB3).
	01	Parallel Port G bit 3 alternate output 1 (I3).
	10	Parallel Port G bit 3 alternate output 2 (TIMER C3).
	11	Parallel Port G bit 3 alternate output 3 (SCLKD).
5:4	00	Parallel Port G bit 2 alternate output 0 (FIMB2).
	01	Parallel Port G bit 2 alternate output 1 (I2).
	10	Parallel Port G bit 2 alternate output 2 (TIMER C2).
	11	Parallel Port G bit 2 alternate output 3 (TXF).
3:2	00	Parallel Port G bit 1 alternate output 0 (FIMB1).
	01	Parallel Port G bit 1 alternate output 1 (I1).
	10	Parallel Port G bit 1 alternate output 2 (TIMER C1).
	11	Parallel Port G bit 1 alternate output 3 (RCLKF).
1:0	00	Parallel Port G bit 0 alternate output 0 (FIMB0).
	01	Parallel Port G bit 0 alternate output 1 (I0).
	10	Parallel Port G bit 0 alternate output 2 (TIMER C0).
	11	Parallel Port G bit 0 alternate output 3 (TCLKF).

Parallel Port G Alternate High Register (PGAHR) (Address = 0x004B)		
Bit(s)	Value	Description
7:6	00	Parallel Port G bit 7 alternate output 0 (FIMB7).
	01	Parallel Port G bit 7 alternate output 1 (I7).
	10	Parallel Port G bit 7 alternate output 2 (PWM3).
	11	Parallel Port G bit 7 alternate output 3 (SCLKC).
5:4	00	Parallel Port G bit 6 alternate output 0 (FIMB6).
	01	Parallel Port G bit 6 alternate output 1 (I6).
	10	Parallel Port G bit 6 alternate output 2 (PWM2).
	11	Parallel Port G bit 6 alternate output 3 (TXE).
3:2	00	Parallel Port G bit 5 alternate output 0 (FIMB5).
	01	Parallel Port G bit 5 alternate output 1 (I5).
	10	Parallel Port G bit 5 alternate output 2 (PWM1).
	11	Parallel Port G bit 5 alternate output 3 (RCLKE).
1:0	00	Parallel Port G bit 4 alternate output 0 (FIMB4).
	01	Parallel Port G bit 4 alternate output 1 (I4).
	10	Parallel Port G bit 4 alternate output 2 (PWM0).
	11	Parallel Port G bit 4 alternate output 3 (TCLKE).

Parallel Port G Control Register (PGCR) (Address = 0x004C)		
Bit(s)	Value	Description
7:6		These bits are ignored and should be written with zero.
5:4	00	The upper nibble peripheral clock is perclk/2.
	01	The upper nibble peripheral clock is the output of Timer A1.
	10	The upper nibble peripheral clock is the output of Timer B1.
	11	The upper nibble peripheral clock is the output of Timer B2.
3:2		These bits are ignored and should be written with zero.
1:0	00	The lower nibble peripheral clock is perclk/2.
	01	The lower nibble peripheral clock is the output of Timer A1.
	10	The lower nibble peripheral clock is the output of Timer B1.
	11	The lower nibble peripheral clock is the output of Timer B2.

Parallel Port G Function Register (PGFR) (Address = 0x004D)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit functions normally.
	1	The corresponding port bit carries its alternate signal as an output. See Table 14-1.

Parallel Port G Drive Control Register (PGDCR) (Address = 0x004E)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit, as an output, is driven high and low.
	1	The corresponding port bit, as an output, is open-drain.

Parallel Port G Data Direction Register (PGDDR) (Address = 0x004F)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port Gx Control Register		
(PG0CR)	(Address = 0x04C8)	
(PG1CR)	(Address = 0x04C9)	
(PG2CR)	(Address = 0x04CA)	
(PG3CR)	(Address = 0x04CB)	
(PG4CR)	(Address = 0x04CC)	
(PG5CR)	(Address = 0x04CD)	
(PG6CR)	(Address = 0x04CE)	
(PG7CR)	(Address = 0x04CF)	
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

15. PARALLEL PORT H

15.1 Overview

Parallel Port H is a byte-wide port with each bit programmable for data direction and drive level. These are simple inputs and outputs controlled and reported in the Port H Data Register (PHDR).

All of the Parallel Port H pins have alternate output functions. Parallel Port H has no alternate input functionality.

When used as outputs, the Parallel Port H bits are buffered, with the data written to PHDR transferred to the output pins. Each bit can either be programmed as open-drain or driven high and low.

Parallel Port H acts as the upper byte of the external I/O bus when the 16-bit mode is enabled; all other Parallel Port H functionality will be disabled automatically when that mode is in effect.

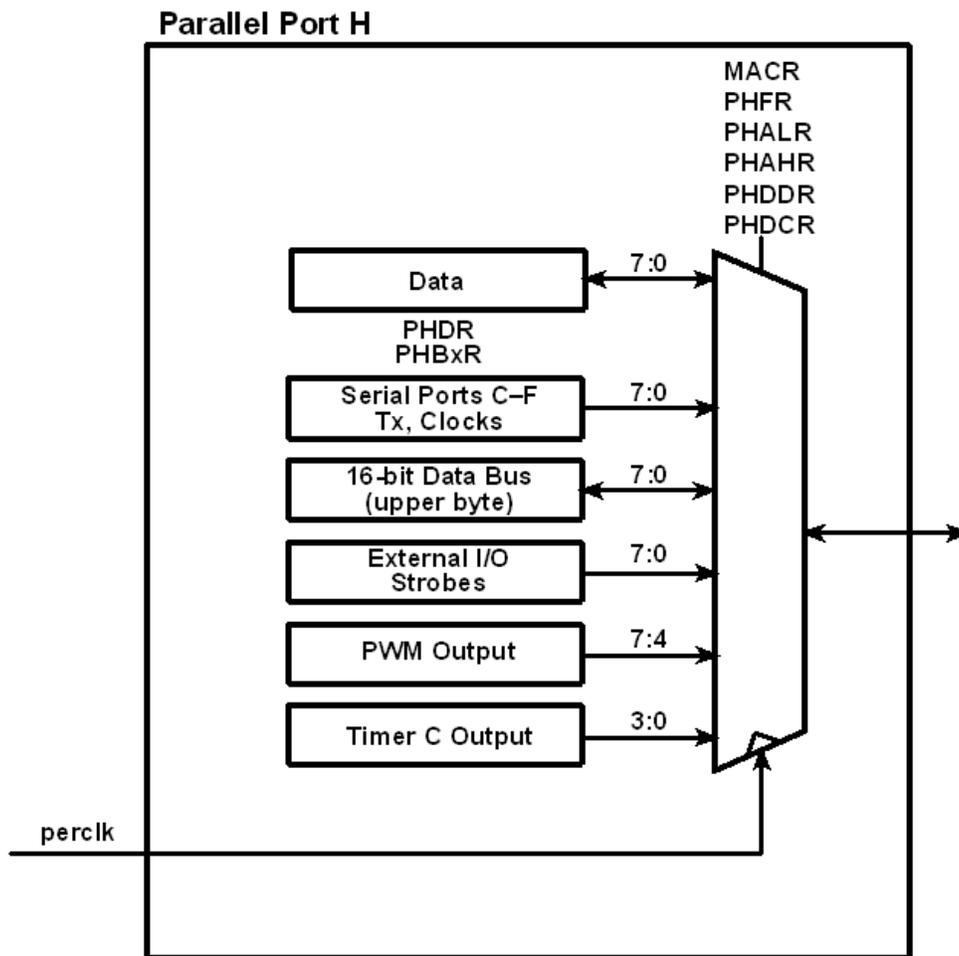
The drive strength and slew rate can be individually controlled for each Parallel Port H pin. In addition, a 75 k Ω pullup or pulldown resistor can be enabled on each pin.

Note that it is possible for either Flexible Interface Module to use any of the parallel ports. See Chapter 33 for more information.

Table 15-1. Parallel Port H Pin Alternate Output Functions

Pin Name	Alt Out 1	Alt Out 2	Alt Out 3	16-bit I/O Bus
PH7	I7	PWM3	SCLKC	D15
PH6	I6	PWM2	TXE	D14
PH5	I5	PWM1	RCLKE	D13
PH4	I4	PWM0	TCLKE	D12
PH3	I3	TIMER C3	SCLKD	D11
PH2	I2	TIMER C2	TXF	D10
PH1	I1	TIMER C1	RCLKF	D9
PH0	I0	TIMER C0	TCLKF	D8

15.1.1 Block Diagram



15.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Port H Data Register	PHDR	0x0034	R/W	00000000
Port H Alternate Low Register	PHALR	0x0032	R/W	00000000
Port H Alternate High Register	PHAHR	0x0033	R/W	00000000
Port H Function Register	PHFR	0x0035	R/W	00000000
Port H Drive Control Register	PHDCR	0x0036	R/W	00000000
Port H Data Direction Register	PHDDR	0x0037	R/W	00000000
Port Hx Control Register	PE _x CR	0x04D8 + x	W	xxx00000

15.2 Dependencies

15.2.1 I/O Pins

Parallel Port H uses pins PH0 through PH7. These pins can be used individually as:

- Data inputs or outputs
- The serial port transmit for Serial Ports E and F
- The clock transmit (internal clock mode) for Serial Ports C–F
- External I/O strobes
- Outputs for the PWM and Timer C peripherals.

In addition, Parallel Port H acts as the upper byte of the data bus (D[15:8]) for external I/O when 16-bit data is enabled.

All pins are set as inputs on startup.

The individual bits can be set to be open-drain via PHDCR. Drive strength, slew rate, and the pullup/down resistor status are selectable via PHxCR.

See the associated peripheral chapters for details on how they use Parallel Port H.

15.2.2 Clocks

All outputs on Parallel Port H are clocked by the peripheral clock.

15.2.3 Other Registers

Register	Function
IBxER	Enable 16-bit data bus.

15.2.4 Interrupts

There are no interrupts associated with Parallel Port H.

15.3 Operation

The following steps must be taken before using Parallel Port H.

1. Select the desired input/output direction for each pin via PHDDR.
2. Select high/low or open-drain functionality for outputs via PHDCR.
3. If a particular drive strength, slew rate, or pullup/down status is desired for a Parallel Port H pin, set that in the appropriate PHxCR.
4. If an alternative peripheral output function is desired for a pin, select it via PHALR or PHAHR and then enable it via PHFR. Refer to the appropriate peripheral chapter for further use of that pin.
5. All these settings will be superseded if a 16-bit memory interface is selected since Parallel Port H is used for the upper half of the data bus in that mode.

Once Parallel Port H is set up, data can be read or written by accessing PHDR. The value of an output pin read in from PHDR will reflect its current output value, but any value written to an input pin will not appear on that pin until that pin becomes an output.

If one of the Flexible Interface Modules has been enabled to use Parallel Port H, writing to PHDR will no longer change the state of the pins, and the settings of PHFR, PHALR, and PHAHR will be ignored. The other Parallel Port H registers are still valid. Refer to Chapter 33 for more details.

15.4 Register Descriptions

Parallel Port H Data Register (PHDR) (Address = 0x0034)		
Bit(s)	Value	Description
7:0	Read	The current state of Parallel Port H pins PH7–PH0 is reported.
	Write	The Parallel Port H buffer is written with this value for transfer to the Parallel Port H output register on the next rising edge of the peripheral clock.

Parallel Port H Alternate Low Register (PHALR) (Address = 0x0032)		
Bit(s)	Value	Description
7:6	00	This value is reserved and must not be used.
	01	Parallel Port H bit 3 alternate output 1 (I3).
	10	Parallel Port H bit 3 alternate output 2 (TIMER C3).
	11	Parallel Port H bit 3 alternate output 3 (SCLKD).
5:4	00	This value is reserved and must not be used.
	01	Parallel Port H bit 2 alternate output 1 (I2).
	10	Parallel Port H bit 2 alternate output 2 (TIMER C2).
	11	Parallel Port H bit 2 alternate output 3 (TXF).
3:2	00	This value is reserved and must not be used.
	01	Parallel Port H bit 1 alternate output 1 (I1).
	10	Parallel Port H bit 1 alternate output 2 (TIMER C1).
	11	Parallel Port H bit 1 alternate output 3 (RCLKF).
1:0	00	This value is reserved and must not be used.
	01	Parallel Port H bit 0 alternate output 1 (I0).
	10	Parallel Port H bit 0 alternate output 2 (TIMER C0).
	11	Parallel Port H bit 0 alternate output 3 (TCLKF).

Parallel Port H Alternate High Register (PHAHR) (Address = 0x0033)		
Bit(s)	Value	Description
7:6	00	This value is reserved and must not be used.
	01	Parallel Port H bit 7 alternate output 1 (I7).
	10	Parallel Port H bit 7 alternate output 2 (PWM3).
	11	Parallel Port H bit 7 alternate output 3 (SCLKC).
5:4	00	This value is reserved and must not be used.
	01	Parallel Port H bit 6 alternate output 1 (I6).
	10	Parallel Port H bit 6 alternate output 2 (PWM2).
	11	Parallel Port H bit 6 alternate output 3 (TXE).
3:2	00	This value is reserved and must not be used.
	01	Parallel Port H bit 5 alternate output 1 (I5).
	10	Parallel Port H bit 5 alternate output 2 (PWM1).
	11	Parallel Port H bit 5 alternate output 3 (RCLKC).
1:0	00	This value is reserved and must not be used.
	01	Parallel Port H bit 4 alternate output 1 (I4).
	10	Parallel Port H bit 4 alternate output 2 (PWM0).
	11	Parallel Port H bit 4 alternate output 3 (TCLKC).

Parallel Port H Function Register (PHFR) (Address = 0x0035)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit functions normally.
	1	The corresponding port bit carries its alternate signal as an output. See Table 15-1.

Parallel Port H Drive Control Register (PHDCR) (Address = 0x0036)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit, as an output, is driven high and low.
	1	The corresponding port bit, as an output, is open-drain.

Parallel Port H Data Direction Register (PHDDR) (Address = 0x0037)		
Bit(s)	Value	Description
7:0	0	The corresponding port bit is an input.
	1	The corresponding port bit is an output.

Parallel Port Hx Control Register		
(PH0CR) (Address = 0x04D8)		
(PH1CR) (Address = 0x04D9)		
(PH2CR) (Address = 0x04DA)		
(PH3CR) (Address = 0x04DB)		
(PH4CR) (Address = 0x04DC)		
(PH5CR) (Address = 0x04DD)		
(PH6CR) (Address = 0x04DE)		
(PH7CR) (Address = 0x04DF)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0	00	No pullup or pulldown resistor.
	01	75 k Ω pullup resistor.
	10	75 k Ω pulldown resistor.
	11	75 k Ω keeper.

16. TIMER A

16.1 Overview

The Timer A peripheral consists of 12 separate eight-bit countdown timers, A1–A12. Each counter counts down from a programmed time constant, which is automatically reloaded into the respective counter when the count reaches zero. For example, if the reload register contains 127, then 128 pulses enter on the left before a pulse exits on the right (see Figure 16.1). If the reload register contains zero, then each pulse on the left results in a pulse on the right, that is, there is division by one. The reload register can contain any number in the range from 0 to 255. The counter divides by $(n + 1)$.

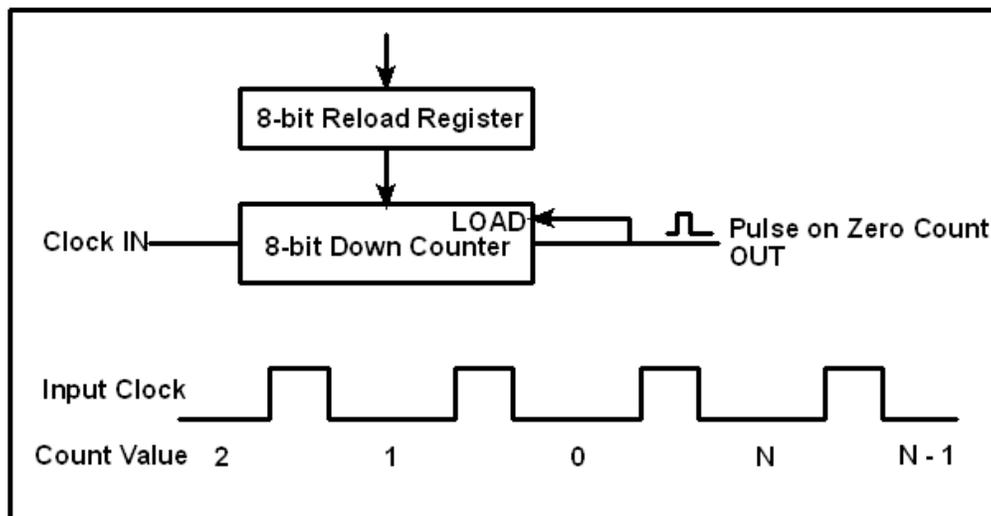


Figure 16.1 Reload Register Operation

The output pulses are always one clock wide. Clocking of the timers takes place on the negative edge of these pulses. When the counter reaches zero, the reload register is loaded into the counter on the next input pulse instead of a count being performed. The terminal count condition for Timers A1–A7 is reported in a status register and can be programmed to generate an interrupt. Six of these seven timers (A2–A7) have the option of being cascaded from Timer A1, but the primary clock for all of the timers is the peripheral clock either directly or divided by TAPR (the default = 2).

Timers A2–A7 can be used to generate baud rates for Serial Ports A–F, or they can be used as general-purpose timers if the dedicated baud rate timers on the Rabbit 6000 serial ports are used. Timers A8, A9, A10, and A11 serve as prescalers which determine the resolution of the input capture, PWM, quadrature decoder, and Timers B/C peripherals respectively. The peripherals clocked by these timers can generate

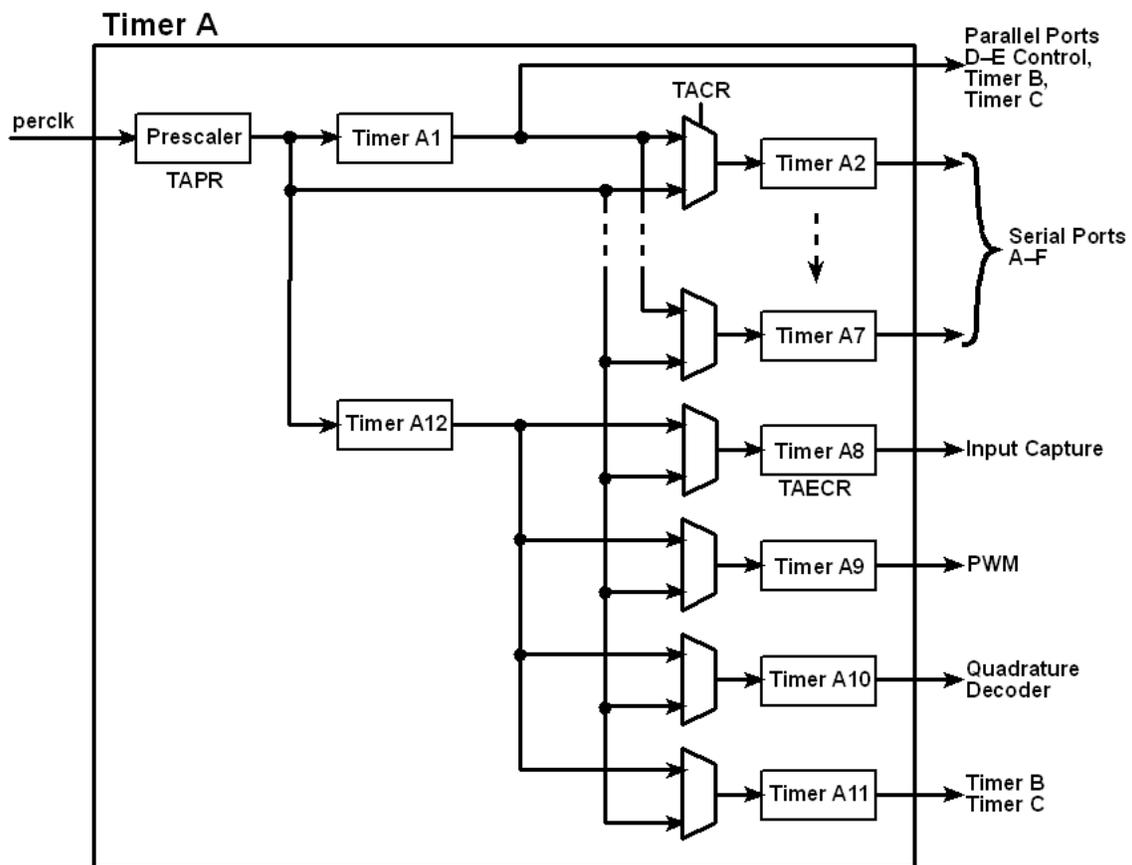
interrupts but the timers themselves cannot. They have the option of being cascaded from Timer A12 to provide a larger range of frequencies.

The individual Timer A capabilities are summarized in the table below. There is a bit in the control/status register to disable all 12 timers globally.

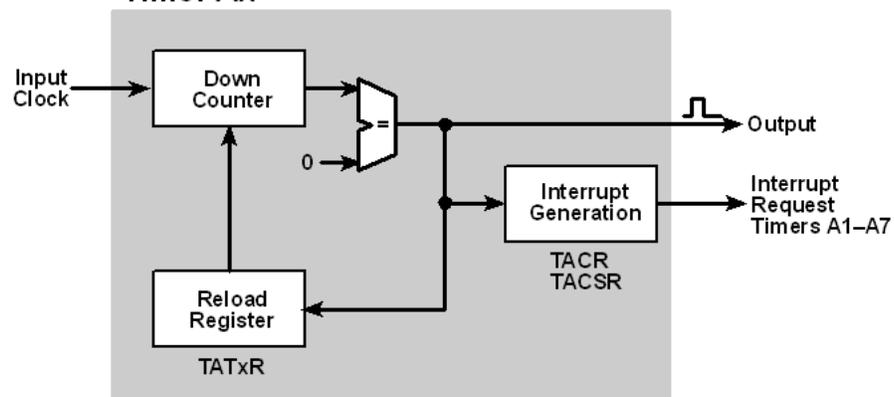
Timer	Cascadable from	Interrupt	Associated Peripheral
A1	None	Yes	Parallel Ports D–E, Timers B–C
A2	A1	Yes	Serial Port E
A3	A1	Yes	Serial Port F
A4	A1	Yes	Serial Port A
A5	A1	Yes	Serial Port B
A6	A1	Yes	Serial Port C
A7	A1	Yes	Serial Port D
A8	A12	No	Input Capture
A9	A12	No	Pulse-Width Modulator
A10	A12	No	Quadrature Decoder
A11	A12	No	Timer B, Timer C
A12	None	No	Timers A8–A11

There is one interrupt vector for Timer A and a common interrupt priority. A common status register (TACSR) has bits for Timers A1–A7 that indicate if the output pulse for that timer has taken place since the last read of the status register. These bits are cleared when the status register is read. No bit will be lost. Either it will be read by the status register read or it will be set after the status register read is complete. If a bit is on and the corresponding interrupt is enabled, an interrupt will occur when priorities allow. However, a separate interrupt is not guaranteed for each bit with an enabled interrupt. If the bit is read in the status register, it is cleared and no further interrupt corresponding to that bit will be requested. It is possible that one bit will cause an interrupt, and then one or more additional bits will be set before the status register is read. After these bits are cleared, they cannot cause an interrupt. The proper rule to follow is for the interrupt routine to handle all bits that it sees set.

16.1.1 Block Diagram



Timer Ax



16.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Timer A Control/Status Register	TACSR	0x00A0	R/W	00000000
Timer A Prescale Register	TAPR	0x00A1	R/W	00000001
Timer A Extended Control Register	TAECR	0x00A2	R/W	00000000
Timer A Time Constant 1 Register	TAT1R	0x00A3	R/W	xxxxxxxx
Timer A Control Register	TACR	0x00A4	R/W	00000000
Timer A Time Constant 2 Register	TAT2R	0x00A5	R/W	xxxxxxxx
Timer A Time Constant 8 Register	TAT8R	0x00A6	R/W	xxxxxxxx
Timer A Time Constant 3 Register	TAT3R	0x00A7	R/W	xxxxxxxx
Timer A Time Constant 9 Register	TAT9R	0x00A8	R/W	xxxxxxxx
Timer A Time Constant 4 Register	TAT4R	0x00A9	R/W	xxxxxxxx
Timer A Time Constant 10 Register	TAT10R	0x00AA	R/W	xxxxxxxx
Timer A Time Constant 5 Register	TAT5R	0x00AB	R/W	xxxxxxxx
Timer A Time Constant 11 Register	TAT11R	0x00AC	R/W	00000000
Timer A Time Constant 6 Register	TAT6R	0x00AD	R/W	xxxxxxxx
Timer A Time Constant 12 Register	TAT12R	0x00AE	R/W	00000000
Timer A Time Constant 7 Register	TAT7R	0x00AF	R/W	xxxxxxxx

16.2 Dependencies

16.2.1 I/O Pins

The Timer A outputs do not come out directly on any of the I/O pins. They can be used to control when the output occurs on Parallel Ports D–G, generate the baud rates of Serial Ports A–F, and used to clock the PWM, input capture, and quadrature decoder. They can also be used as input clocks for Timers B and C.

16.2.2 Clocks

The timers in Timer A are clocked by the Timer A Prescaler, TAPR. In addition, Timers A2–A7 can be clocked by the output of Timer A1 by selecting that option in TACSR, and Timers A8–A11 can be clocked by the output of timer A12 by selecting that option in TAECR.

16.2.3 Other Registers

Register	Function
GCSR	Select peripheral clock mode.

16.2.4 Interrupts

A Timer A interrupt can be generated whenever Timers A1–A7 decrement to zero by enabling the appropriate bit in TACSR. The interrupt request is cleared when TACSR is read.

The Timer A interrupt vector is in the IIR at offset 0x0A0. It can be set as priority 1, 2, or 3 in TACR.

16.3 Operation

The following steps explain how to set up a Timer A timer.

1. Use the default `perclk/2` in `TAPR` as the Timer A input clock. You may instead select to divide `perclk` by 1–256 in `TAPR`.
2. Select the source clocks for Timers A2–A7 in `TACR`. Select the source clocks for Timers A8–A11 in `TAECR`.
3. Write the desired divider value to `TATxR` for all timers that will be used.
4. Enable Timer A by writing a 1 to bit 0 of `TACSR`.

16.3.1 Handling Interrupts

The following steps explain how an interrupt is set up and used.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure `TACSR` to select which timers will generate an interrupt.
3. Configure `TACR` to select the interrupt priority (note that interrupts will be enabled once this value is set). This should be done last.

The interrupt request is cleared by reading from `TACSR`.

16.3.2 Example ISR

A sample interrupt handler is shown below.

```
timerA_isr::
    push af                ; save used registers
    ioi ld a, (TACSR)     ; clear the interrupt request and get status

    ; handle all interrupts flagged in TACSR here

    pop af                ; restore registers
    ipres
    ret
```

16.4 Register Descriptions

Timer A Control/Status Register (TACSR) (Address = 0x00A0)		
Bit(s)	Value	Description
7:1 (Read-only)	0	The corresponding Timer A counter has not reached its terminal count.
	1	The corresponding Timer A counter has reached its terminal count. These status bits (not the interrupt enable bits) are cleared by the read of this register, as is the Timer A interrupt.
7:1 (Write-only)	0	The corresponding Timer A interrupt is disabled.
	1	The corresponding Timer A interrupt is enabled.
0	0	The clock input for Timer A is disabled.
	1	The clock input for Timer A is enabled.

Timer A Prescale Register (TAPR) (Address = 0x00A1)		
Bit(s)	Value	Description
7:0		Time constant for the Timer A prescaler. This time constant will take effect the next time that the Timer A prescaler counts down to zero.

Timer A Extended Control Register (TAECR) (Address = 0x00A2)		
Bit(s)	Value	Description
7:4		These bits are reserved and should be written with zero.
3	0	Timer A11 clocked by the main Timer A clock.
	1	Timer A11 clocked by the output of Timer A12.
2	0	Timer A10 clocked by the main Timer A clock.
	1	Timer A10 clocked by the output of Timer A12.
1	0	Timer A9 clocked by the main Timer A clock.
	1	Timer A9 clocked by the output of Timer A12.
0	0	Timer A8 clocked by the main Timer A clock.
	1	Timer A8 clocked by the output of Timer A12.

Timer A Control Register (TACR) (Address = 0x00A4)		
Bit(s)	Value	Description
7	0	Timer A7 clocked by the output of TAPR.
	1	Timer A7 clocked by the output of Timer A1.
6	0	Timer A6 clocked by the output of TAPR.
	1	Timer A6 clocked by the output of Timer A1.
5	0	Timer A5 clocked by the output of TAPR.
	1	Timer A5 clocked by the output of Timer A1.
4	0	Timer A4 clocked by the output of TAPR.
	1	Timer A4 clocked by the output of Timer A1.
3	0	Timer A3 clocked by the output of TAPR.
	1	Timer A3 clocked by the output of Timer A1.
2	0	Timer A2 clocked by the output of TAPR.
	1	Timer A2 clocked by the output of Timer A1.
1:0	00	Timer A interrupts are disabled.
	01	Timer A interrupt use Interrupt Priority 1.
	10	Timer A interrupt use Interrupt Priority 2.
	11	Timer A interrupt use Interrupt Priority 3.

Timer A Time Constant x Register		
(TAT1R) (Address = 0x00A3)		
(TAT2R) (Address = 0x00A5)		
(TAT3R) (Address = 0x00A7)		
(TAT4R) (Address = 0x00A9)		
(TAT5R) (Address = 0x00AB)		
(TAT6R) (Address = 0x00AD)		
(TAT7R) (Address = 0x00AF)		
(TAT8R) (Address = 0x00A6)		
(TAT9R) (Address = 0x00A8)		
(TAT10R) (Address = 0x00AA)		
(TAT11R) (Address = 0x00AC)		
(TAT12R) (Address = 0x00AE)		
Bit(s)	Value	Description
7:0		Time constant for the Timer A counter. This time constant will take effect the next time that the Timer A counter counts down to zero. The timer counts modulo $n + 1$, where n is the programmed time constant.

17. TIMER B

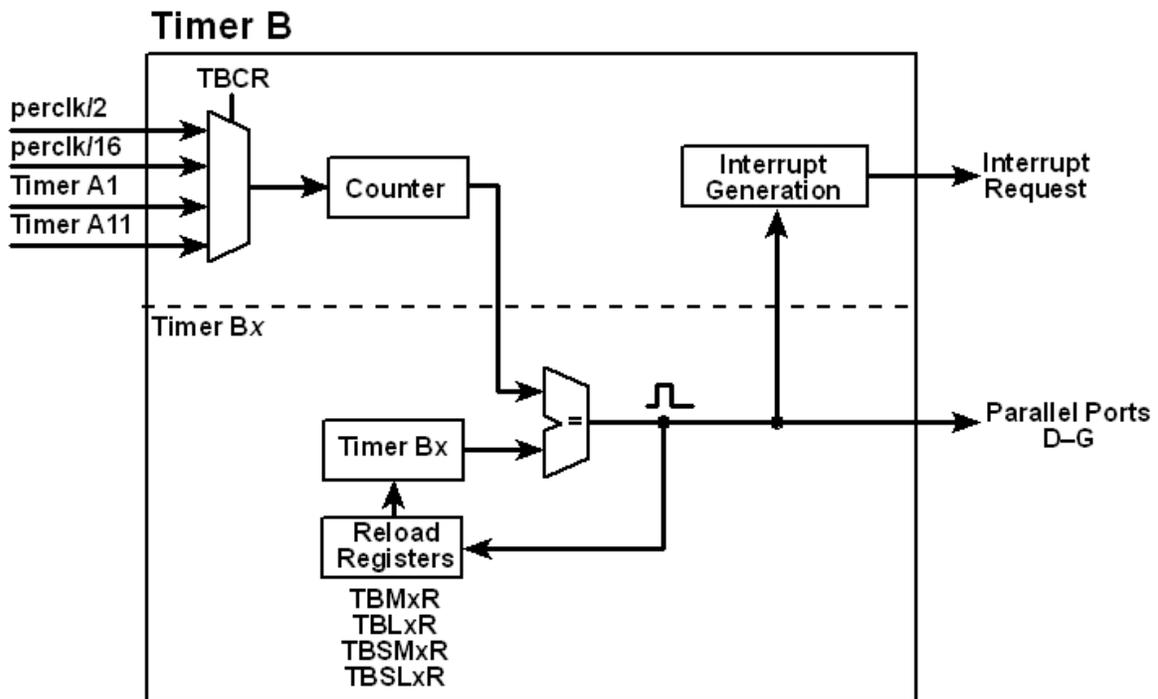
17.1 Overview

The Timer B peripheral consists of a ten-bit free running up-counter, two match registers, and two step registers. Timer B is driven by $\text{perclk}/2$, by $\text{perclk}/16$, or by the output of Timers A1 or A11. Timer B generates an output pulse whenever the counter reaches the match value. This output pulse can generate an interrupt and will set a status bit in the status register. The processor may then write a new value to the match register. This allows Timer B to be used for pulse-width or pulse-position modulation because the outputs of Timer B can clock the outputs on Parallel Ports D–G.

The compare value comes from either the match register or the value internally generated via the step register. When using the match register, a new match value must be written to the match register after each match condition, LSB last. When using the step register, the hardware automatically calculates the next match value by adding the contents of the step register to the current match value. This allows Timer B matches to be generated at regular periods without calculating the new match value during the interrupt service routine.

The match registers are buffered; if a match value is loaded and then another one is loaded before the match has occurred, the new value will be buffered until the first match occurs, and then loaded into the actual match register. If there is no pending match value, the new value is loaded immediately.

17.1.1 Block Diagram



17.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Timer B Control/Status Register	TBCSR	0x00B0	R/W	xxxx0000
Timer B Control Register	TBCR	0x00B1	R/W	xx000000
Timer B MSB 1 Register	TBM1R	0x00B2	R/W	xxxxxxxx
Timer B LSB 1 Register	TBL1R	0x00B3	R/W	xxxxxxxx
Timer B MSB 2 Register	TBM2R	0x00B4	R/W	xxxxxxxx
Timer B LSB 2 Register	TBL2R	0x00B5	R/W	xxxxxxxx
Timer B Step LSB 1 Register	TBSL1R	0x00BA	R/W	xxxxxxxx
Timer B Step MSB 1 Register	TBSM1R	0x00BB	R/W	xxxxxxxx
Timer B Step LSB 2 Register	TBSL2R	0x00BC	R/W	xxxxxxxx
Timer B Step MSB 2 Register	TBSM2R	0x00BD	R/W	xxxxxxxx
Timer B Count MSB Register	TBCMR	0x00BE	R	xxxxxxxx
Timer B Count LSB Register	TBCLR	0x00BF	R	xxxxxxxx

17.2 Dependencies

17.2.1 I/O Pins

The output of Timer B does not come out directly on any of the I/O pins. It can be used to control when the output occurs on Parallel Ports D–G.

17.2.2 Clocks

The timer in Timer B can be clocked by $\text{perclk}/2$, $\text{perclk}/16$, or by countdown Timers A1 or A11 as selected in TBCR. TA12 may be used as a prescaler for TA11.

17.2.3 Other Registers

Register	Function
GCSR	Select peripheral clock mode.
TAECR	Enables selection of TA12 as prescaler for TA8-TA11.
TAPR	The output of TAPR drives Timers A1 and A12.

17.2.4 Interrupts

A Timer B interrupt can be generated whenever the counter equals one of the match registers by enabling the appropriate bit in TBCSR. The interrupt request is cleared when TBCSR is read.

17.3 Operation

The following steps explain how to set up a Timer B countdown timer.

1. Select perclk/2, perclk/16, Timer A1, or Timer A11 in TBCR.
2. Use TBCR to select whether countdown Timers B1–B2 operate normally with the match registers or whether they use the step registers to calculate match values.
3. Enable Timer B by writing a 1 to bit 0 of TBCSR.

17.3.1 Handling Interrupts

The following steps explain how an interrupt is set up and used.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure TBCSR to select which match register will generate an interrupt.
3. Configure TBCR to select the interrupt priority (note that interrupts will be enabled once this value is set; this step should be done last).

The interrupt request is cleared by reading from TBCSR.

17.3.2 Example ISR

A sample interrupt handler is shown below.

```
timerB_isr::
    push af                ; save used registers
    ioi ld a, (TBCSR)     ; clear the interrupt request and get status

    ; handle all interrupts flagged in TBCSR here
    ; reload match register(s) if necessary

    pop af                ; restore used registers
    ipres
    ret
```

17.4 Register Descriptions

Timer B Control/Status Register		(TBCSR)	(Address = 0x00B0)
Bit(s)	Value	Description	
7:3		These bits always read as zero.	
2:1 (Read-only)	0	The corresponding Timer B comparator has not encountered a match condition.	
	1	The corresponding Timer B comparator has encountered a match condition. These status bits (but not the interrupt enable bits) are cleared by the read of this register, as is the Timer B interrupt.	
2:1 (Write-only)	0	The corresponding Timer B interrupt is disabled.	
	1	The corresponding Timer B interrupt is enabled.	
0	0	The clock input for Timer B is disabled.	
	1	The clock input for Timer B is enabled.	

Timer B Control Register		(TBCR)	(Address = 0x00B1)
Bit(s)	Value	Description	
7:6		These bits are reserved and should be written with zero.	
5	0	Normal Timer B2 operation using the match registers.	
	1	Enable Timer B2 to use the step registers to calculate match values.	
4	0	Normal Timer B1 operation, using the match registers.	
	1	Enable Timer B1 to use the step registers to calculate match values.	
3:2	00	Timer B clocked by perclk/2.	
	01	Timer B clocked by the output of Timer A1.	
	10	Timer B clocked by the peripheral clock divided by 16.	
	11	Timer B clocked by the output of Timer A11.	
1:0	00	Timer B interrupts are disabled.	
	01	Timer B interrupt use Interrupt Priority 1.	
	10	Timer B interrupt use Interrupt Priority 2.	
	11	Timer B interrupt use Interrupt Priority 3.	

Timer B Count MSB x Register (TBM1R) (Address = 0x00B2) (TBM2R) (Address = 0x00B4)		
Bit(s)	Value	Description
7:6		Two MSBs of the compare value for the Timer B comparator. This compare value will be loaded into the actual comparator when the current compare detects a match.
5:0		These bits are reserved and should be written with zero.

Timer B Count LSB x Register (TBL1R) (Address = 0x00B3) (TBL2R) (Address = 0x00B5)		
Bit(s)	Value	Description
7:0		Eight LSBs of the compare value for the Timer B comparator. This compare value will be loaded into the actual comparator when the current compare detects a match.

Timer B Step LSB x Register (TBSL1R) (Address = 0x00BA) (TBSL2R) (Address = 0x00BC)		
Bit(s)	Value	Description
7:0		Eight LSBs of the step size for the Timer B comparator. The new compare value will be loaded into the actual comparator when the current compare detects a match.

Timer B Step MSB x Register (TBSM1R) (Address = 0x00BB) (TBSM2R) (Address = 0x00BD)		
Bit(s)	Value	Description
7:2		These bits are ignored but should be written with zeros.
1:0		Two MSBs of the step size for the Timer B comparator. The new compare value will be loaded into the actual comparator when the current compare detects a match.

Timer B Count MSB Register (TBCMR) (Address = 0x00BE)		
Bit(s)	Value	Description
7:6	Read	The current value of the two MSBs of the Timer B counter is reported.
5:0		These bits are always read as zeros.

Timer B Count LSB Register (TBCLR) (Address = 0x00BF)		
Bit(s)	Value	Description
7:0	Read	The current value of the eight LSBs of the Timer B counter is reported.

18. TIMER C

18.1 Overview

The Timer C peripheral is a 16-bit up-counter clocked by the peripheral clock divided by 2, by the peripheral clock divided by 16, or by the output of countdown Timers A1 or A11. The counter counts from zero to the limit programmed into the Timer C divider registers and then restarts at zero, so the overall cycle count is the value in the divider registers plus one. There are four Timer C outputs that are called Timers C0–C3. Each output is controlled by a 16-bit set value and a 16-bit reset value. Each output is set to one when the count matches the value in the corresponding set register and is cleared when the count matches the value programmed in the corresponding reset register. This allows the creation of quadrature signals or three-phase signals with a variable frequency for motor-control applications. The values in all of the Timer C registers are transferred to holding registers for use during the count cycle when the counter rolls over, allowing the control registers to be reloaded at any time during the count cycle.

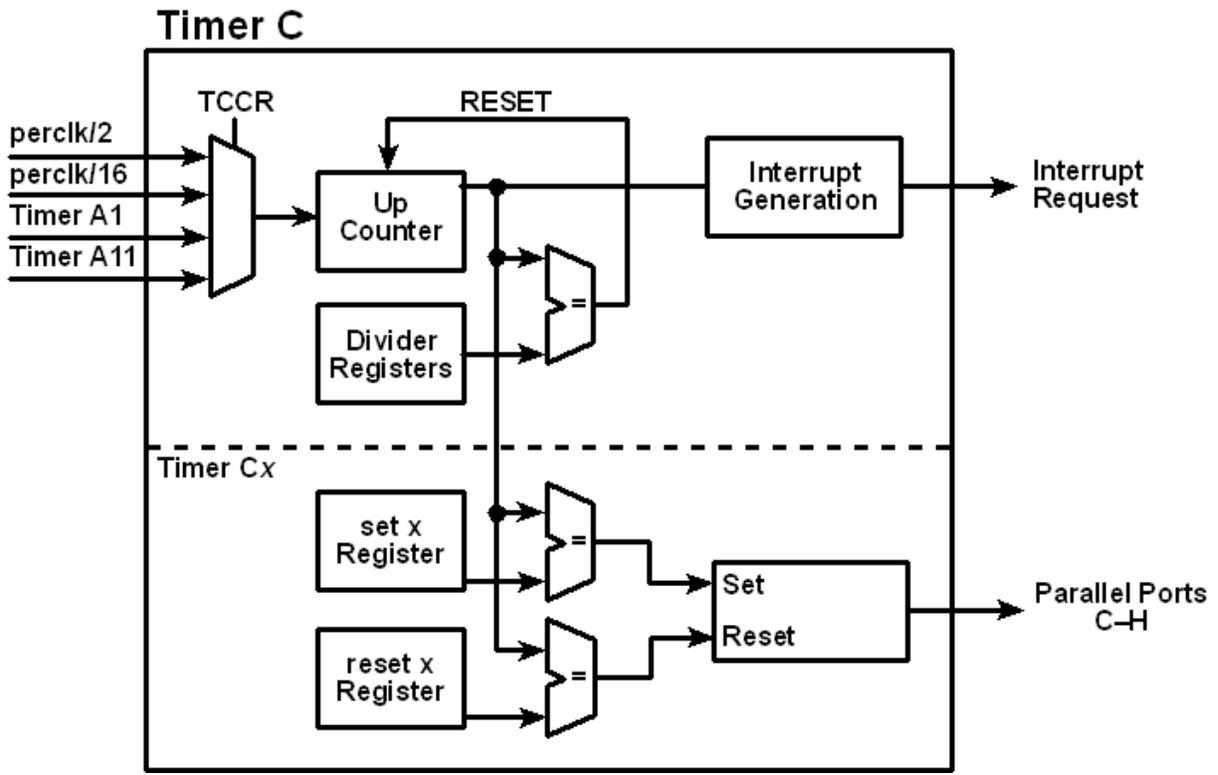
Timer C can generate an interrupt when the count limit value is reached.

A separate Timer C Block Access Register (TCBAR) and Timer C Block Pointer Register (TCBPR) are available to allow DMA control of Timer C. The pointer register contains the address of the Timer C register to be accessed via the access register. Each read or write of the access register automatically increments the pointer register through the sequence shown below. Note that only the lower five bits of the pointer register actually change. This allows the DMA to write to a fixed internal I/O location but still program all of the relevant timer registers. The pointer register can be written and read if necessary. Normally the pointer register TCBPR is initialized to 0x02 (the offset of the Timer C Divider Low Register), and the DMA then transfers blocks of 18 bytes to completely reprogram Timer C.

```
0x502 -> 0x503 -> 0x508 -> 0x509 -> 0x50A -> 0x50B ->
0x50C -> 0x50D -> 0x50E -> 0x50F -> 0x518 -> 0x519 ->
0x51A -> 0x51B -> 0x51C -> 0x51D -> 0x51E -> 0x51F ->
```

When the DMA destination address is the TCBAR, the DMA request from Timer C is connected automatically to the DMA.

18.1.1 Block Diagram



18.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Timer C Control/Status Register	TCCSR	0x0500	R/W	xxxx0000
Timer C Control Register	TCCR	0x0501	R/W	xx000000
Timer C Divider Low Register	TCDLR	0x0502	R/W	00000000
Timer C Divider High Register	TCDHR	0x0503	R/W	00000000
Timer C Set 0 Low Register	TCS0LR	0x0508	R/W	xxxxxxxx
Timer C Set 0 High Register	TCS0HR	0x0509	R/W	xxxxxxxx
Timer C Reset 0 Low Register	TCR0LR	0x050A	R/W	xxxxxxxx
Timer C Reset 0 High Register	TCR0HR	0x050B	R/W	xxxxxxxx
Timer C Set 1 Low Register	TCS1LR	0x050C	R/W	xxxxxxxx
Timer C Set 1 High Register	TCS1HR	0x050D	R/W	xxxxxxxx
Timer C Reset 1 Low Register	TCR1LR	0x050E	R/W	xxxxxxxx
Timer C Reset 1 High Register	TCR1HR	0x050F	R/W	xxxxxxxx
Timer C Set 2 Low Register	TCS2LR	0x0518	R/W	xxxxxxxx
Timer C Set 2 High Register	TCS2HR	0x0519	R/W	xxxxxxxx
Timer C Reset 2 Low Register	TCR2LR	0x051A	R/W	xxxxxxxx
Timer C Reset 2 High Register	TCR2HR	0x051B	R/W	xxxxxxxx
Timer C Set 3 Low Register	TCS3LR	0x051C	R/W	xxxxxxxx
Timer C Set 3 High Register	TCS3HR	0x051D	R/W	xxxxxxxx
Timer C Reset 3 Low Register	TCR3LR	0x051E	R/W	xxxxxxxx
Timer C Reset 3 High Register	TCR3HR	0x051F	R/W	xxxxxxxx
Timer C Block Access Register	TCBAR	0x00F8	W	xxxxxxxx
Timer C Block Pointer Register	TCBPR	0x00F9	W	00000010

18.2 Dependencies

18.2.1 I/O Pins

The four Timer C outputs can be directed to bits 0-3 of parallel ports C–H.

18.2.2 Clocks

The timer in Timer C is a 16-bit up-counter clocked by the peripheral clock divided by 2, by the peripheral clock divided by 16, the output of Timer A1, or the output of Timer A11 as selected in TCCR. TA12 may be used as a prescaler for TA11.

18.2.3 Other Registers

Register	Function
GCSR	Select peripheral clock mode.
PCFR, PCALR PDFR, PDALR PEFR, PEALR PFFR, PFALR PGFR, PGALR PHFR, PHALR	Alternate port output selection
TAECR	Enables selection of TA12 as prescaler for TA8-TA11.
TAPR	The output of TAPR drives Timers A1 and A12.

18.2.4 Interrupts

A Timer C interrupt is enabled in TCCR, and will occur whenever the count limit value is reached. The interrupt request is cleared when TCCSR is read.

18.3 Operation

The following steps explain how to set up a Timer C timer.

1. Select perclk/2, perclk/16, Timer A1, or Timer A11 in TCCR.
2. Load the desired upper limit for the counter into TCDLR and TCDHR. The overall clock count per Timer C cycle will be the value loaded into the divider registers plus one.
3. Load the desired set and reset values for the Timer C outputs into the set and reset registers (TCSxLR, TCSxHR, TCRxLR, and TCRxHR).
4. If you intend to use DMA control of Timer C, use TCBAR to access the Timer C register pointed to by TCBPR.
5. Enable the desired output pins for Timer C by writing to the appropriate parallel port function and alternate output registers.
6. Enable Timer C by writing a 1 to bit 0 of TCCSR.

18.3.1 Handling Interrupts

The following steps explain how an interrupt is used.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure TCCR to select the interrupt priority (note that interrupts will be enabled once this value is set).

The interrupt request is cleared by reading from TCCSR.

18.3.2 Example ISR

A sample interrupt handler is shown below.

```
timerC_isr::
    push af                ; save used registers
    ioi ld a, (TCCSR)     ; clear the interrupt request and get status

    ; handle all interrupts flagged in TCCSR here

    pop af                ; restore used registers
    ipres
    ret
```

18.4 Register Descriptions

Timer C Control/Status Register		(TCCSR)	(Address = 0x0500)
Bit(s)	Value	Description	
7:2		These bits are always read as zero.	
1 (Read-only)	0	Timer C divider has not reached its maximum value.	
	1	Timer C divider has reached its maximum value. This status bit is cleared by the read of this register, as is the Timer C interrupt.	
0	0	The clock input for Timer C is disabled.	
	1	The clock input for Timer C is enabled.	

Timer C Control Register		(TCCR)	(Address = 0x0501)
Bit(s)	Value	Description	
7:4		These bits are reserved and should be written with zero.	
3:2	00	Timer C clocked by main Timer C clock (i.e. CLK/2).	
	01	Timer C clocked by the output of Timer A1.	
	10	Timer C clocked by main Timer C clock divided by 8 (i.e. CLK/16).	
	11	Timer C clocked by the output of Timer A11.	
1:0	00	Timer C interrupts are disabled.	
	01	Timer C interrupt use Interrupt Priority 1.	
	10	Timer C interrupt use Interrupt Priority 2.	
	11	Timer C interrupt use Interrupt Priority 3.	

Timer C Divider Low Register		(TCDLR)	(Address = 0x0502)
Bit(s)	Value	Description	
7:0		The eight LSBs of the divider limit value for Timer C are stored.	

Timer C Divider High Register		(TCDHR)	(Address = 0x0503)
Bit(s)	Value	Description	
7:0		The eight MSBs of the divider limit value for Timer C are stored.	

Timer C Set x Low Register		
(TCS0LR)	(Address = 0x0508)	
(TCS1LR)	(Address = 0x050C)	
(TCS2LR)	(Address = 0x0518)	
(TCS3LR)	(Address = 0x051C)	
Bit(s)	Value	Description
7:0		Eight LSBs of the match value to set Timer C Output x.

Timer C Set x High Register		
(TCS0HR)	(Address = 0x0509)	
(TCS1HR)	(Address = 0x050D)	
(TCS2HR)	(Address = 0x0519)	
(TCS3HR)	(Address = 0x051D)	
Bit(s)	Value	Description
7:0		Eight MSBs of the match value to set Timer C Output x.

Timer C Reset x Low Register		
(TCR0LR)	(Address = 0x050A)	
(TCR1LR)	(Address = 0x050E)	
(TCR2LR)	(Address = 0x051A)	
(TCR3LR)	(Address = 0x051E)	
Bit(s)	Value	Description
7:0		Eight LSBs of the match value to reset Timer C Output x.

Timer C Reset x High Register		
(TCR0HR)	(Address = 0x050B)	
(TCR1HR)	(Address = 0x050F)	
(TCR2HR)	(Address = 0x051B)	
(TCR3HR)	(Address = 0x051F)	
Bit(s)	Value	Description
7:0		Eight MSBs of the match value to reset Timer C Output x.

Timer C Block Access Register (TCBAR) (Address = 0x00F8)		
Bit(s)	Value	Description
7:0		Access the Timer C register pointed to by TCBPR. TCBPR is automatically updated to the next Timer C register address in the sequence.

Timer C Block Pointer Register (TCBPR) (Address = 0x00F9)		
Bit(s)	Value	Description
7:5		These bits always read as 0x0.
4:0		Five least significant bits of the Timer C register address for indirect access.

19. SERIAL PORTS A – D

19.1 Overview

Serial Ports A, B, C, and D are identical, except for the source of the data clock and the transmit, receive, and clock pins. In addition to being used as a regular serial port, Serial Port A can be used to bootstrap the processor. Each serial port can be used in the asynchronous or the clocked serial mode with an internal or external clock.

In the asynchronous mode, either 7 or 8 data bits can be transferred, and a parity bit and/or a ninth data bit can be appended as well. Parity and the ninth data bits are also detected when they are received. The asynchronous mode is full-duplex, while the clocked mode can be half or full-duplex.

The transmit and receive buffers have 4 bytes each. A serial port interrupt is generated whenever at least one byte is available in the receive buffer, whenever a byte is shifted out of the transmit buffer, and whenever the transmit buffer is empty. Each serial port has a separate interrupt vector.

The status of each serial port is available in its Serial Port Status Register (SxSR), and contains information on whether a received byte is available, the receive buffer was overrun, a parity error was received, the transmit buffer is empty or busy sending a byte, and the state of the ninth data bit (whether it is an address bit or a stop bit).

All four common SPI clock modes are supported, and the bit order of the data may be either MSB or LSB first. The transmit and receive operations are under program control as well.

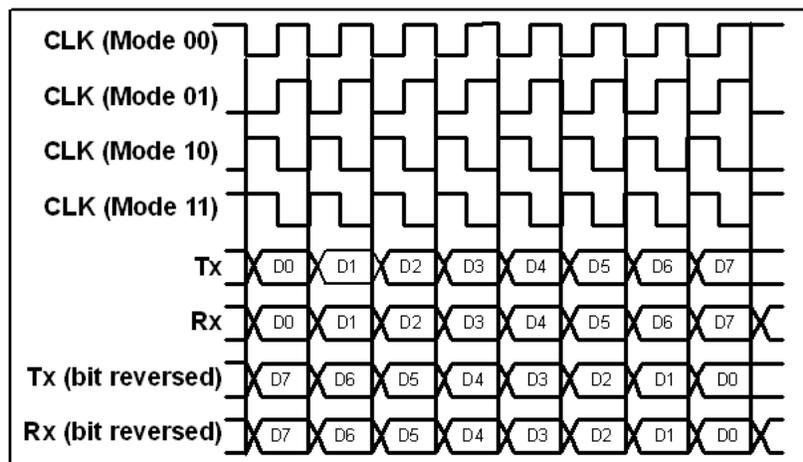


Figure 19.1 Serial Ports A – D Operation in Clocked Serial Mode

In the asynchronous mode, IrDA-compliant RZI encoding can be enabled to reduce the bit widths to 3/16 the normal width (1/8 the normal width if the serial data clock is 8× instead of 16×), which allows the serial port signal to be connected directly to an IrDA transceiver.

It is possible to select the same pin on Parallel Port C for both transmit and receive operation. This allows glueless support for single-wire serial protocols.

It is possible to synchronize a clocked serial transfer to the match registers of Timer B to generate precisely timed transmissions.

The serial port data clocks can be generated from the appropriate 8-bit timer from Timer A shown in Table 19-1 or from a dedicated 15-bit divider. In either case, the resulting bit data rate in the asynchronous mode is 1/8 or 1/16 the data clock rate (selectable). However, the bit data rate in the clocked serial mode is equal to the data clock rate as generated from the appropriate Timer A timer or from the dedicated 15-bit divider.

When Serial Port A is used in the asynchronous bootstrap mode, the 32 kHz clock is used to generate the expected 2400 bps data rate.

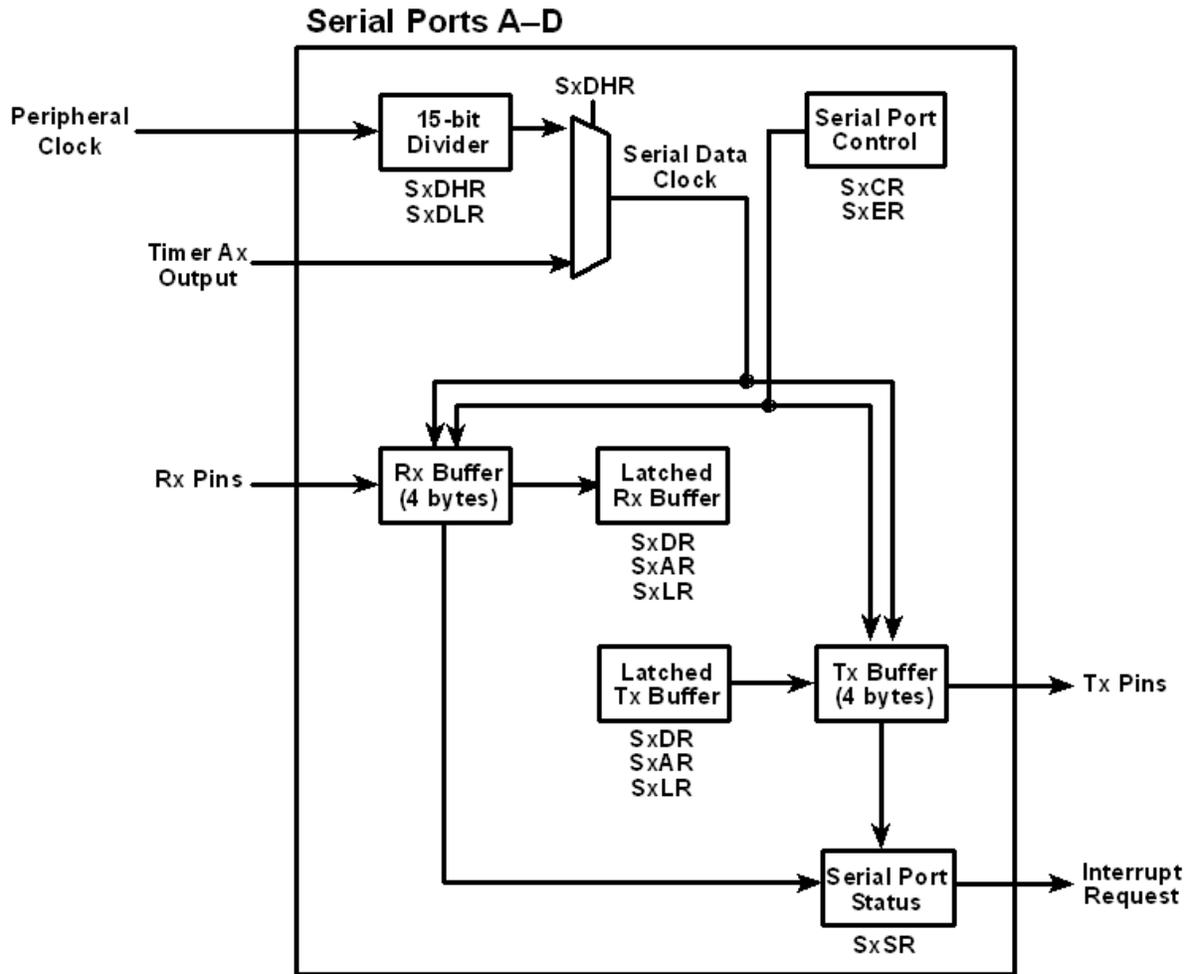
The behavior of the serial port during a break (line held low) is configurable; character assembly can continue during the break condition to allow for timing the break, or character assembly can be inhibited to reduce the interrupt overhead.

NOTE: The maximum external serial clock rate for the SPI port is 1/6 of the peripheral clock rate.

Table 19-1. Timer A Data Clocks

Serial Port	Data Clock
A	Timer A4
B	Timer A5
C	Timer A6
D	Timer A7

19.1.1 Block Diagram



19.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Serial Port A Data Register	SADR	0x00C0	R/W	xxxxxxxx
Serial Port A Address Register	SAAR	0x00C1	W	xxxxxxxx
Serial Port A Long Stop Register	SALR	0x00C2	W	xxxxxxxx
Serial Port A Status Register	SASR	0x00C3	R	0xx00000
Serial Port A Control Register	SACR	0x00C4	R/W	xx000000
Serial Port A Extended Register	SAER	0x00C5	R/W	00000000
Serial Port A Divider Low Register	SADLR	0x00C6	R/W	xxxxxxxx
Serial Port A Divider High Register	SADHR	0x00C7	R/W	0xxxxxxxx
Serial Port B Data Register	SBDR	0x00D0	R/W	xxxxxxxx
Serial Port B Address Register	SBAR	0x00D1	W	xxxxxxxx
Serial Port B Long Stop Register	SBLR	0x00D2	W	xxxxxxxx
Serial Port B Status Register	SBSR	0x00D3	R	0xx00000
Serial Port B Control Register	SBCR	0x00D4	R/W	xx000000
Serial Port B Extended Register	SBER	0x00D5	R/W	00000000
Serial Port B Divider Low Register	SBDLR	0x00D6	R/W	xxxxxxxx
Serial Port B Divider High Register	SBDHR	0x00D7	R/W	0xxxxxxxx
Serial Port C Data Register	SCDR	0x00E0	R/W	xxxxxxxx
Serial Port C Address Register	SCAR	0x00E1	W	xxxxxxxx
Serial Port C Long Stop Register	SCLR	0x00E2	W	xxxxxxxx
Serial Port C Status Register	SCSR	0x00E3	R	0xx00000
Serial Port C Control Register	SCCR	0x00E4	R/W	xx000000
Serial Port C Extended Register	SCER	0x00E5	R/W	00000000
Serial Port C Divider Low Register	SCDLR	0x00E6	R/W	xxxxxxxx
Serial Port C Divider High Register	SCDHR	0x00E7	R/W	0xxxxxxxx
Serial Port D Data Register	SDDR	0x00F0	R/W	xxxxxxxx
Serial Port D Address Register	SDAR	0x00F1	W	xxxxxxxx
Serial Port D Long Stop Register	SDLR	0x00F2	W	xxxxxxxx
Serial Port D Status Register	SDSR	0x00F3	R	0xx00000
Serial Port D Control Register	SDCR	0x00F4	R/W	xx000000
Serial Port D Extended Register	SDER	0x00F5	R/W	00000000
Serial Port D Divider Low Register	SDDLRL	0x00F6	R/W	xxxxxxxx
Serial Port D Divider High Register	SDDHR	0x00F7	R/W	0xxxxxxxx

19.2 Dependencies

19.2.1 I/O Pins

Serial Port A can transmit on parallel port pins PC7, PC6, or PD6, and can receive on pins PC7, PD7, or PE7. If the clocked serial mode is enabled, the serial clock is either transmitted or received on PB1. When an internal clock is selected in the clocked serial mode, PB1 is automatically enabled as a clock output.

Serial Port B can transmit on parallel port pins PC5, PC4, or PD4, and can receive on pins PC5, PD5, or PE5. If the clocked serial mode is enabled, the serial clock is either transmitted or received on PB0. When an internal clock is selected in the clocked serial mode, PB0 is automatically enabled as a clock output.

Serial Port C can transmit on parallel port pins PC3 or PC2, and can receive on pins PC3, PD3, or PE3. If the clocked serial mode is enabled, the serial clock can be transmitted on PC7, PD7, PD2, or PE7, and can be received on PD2 or PE2.

Serial Port D can transmit on parallel port pins PC1 or PC0, and can receive on pins PC1, PD1, or PE1. If the clocked serial mode is enabled, the serial clock can be transmitted on PC3, PD3, PD0, or PE3, and can be received on PD0 or PE0.

Table 19-2. Pin Usage Serial Ports A – D

Function	Serial Port A	Serial Port B	Serial Port C	Serial Port D
Transmit	PC7, PC6, PD6	PC5, PC4, PD4	PC3, PC2	PC1, PC0
Receive	PC7, PD7, PE7	PC5, PD5, PE5	PC3, PD3, PE3	PC1, PD1, PE1
Transmit Clock	PB1	PB0	PC7, PD7, PD2, PE7, PF7, PG7, PH7	PC3, PD3, PD0, PE3, PF3, PG3, PH3
Receive Clock	PB1	PB0	PD2, PE2	PD0, PE0

19.2.2 Clocks

The data clocks for Serial Ports A – D are based on the peripheral clock and are divided by either a Timer A divider or a dedicated 15-bit divider. In either case, the overall clock divider will be the value in the selected register plus one.

19.2.3 Other Registers

Register	Function
TAT4R	Serial Port A baud rate generation
TAT5R	Serial Port B baud rate generation
TAT6R	Serial Port C baud rate generation
TAT7R	Serial Port D baud rate generation
PCFR, PCAHR, PCALR PDFR, PDAHR, PDALR PEFR, PEAHR, PEALR	Alternate port output selection
TAT1R	Prescaler for TAT4R-TAT7R
TAPR	Prescaler for TAT1R
TACR	Input selection for TAT4R-TAT7R

19.2.4 Interrupts

A serial port interrupt will be generated whenever any of the following occurs.

- A byte is available in the receive buffer.
- A byte is moved from the transmit buffer to the transmitter.
- The transmitter is idle.

These occurrences correspond to bits 7, 3, and 2 of the Serial Port Status Registers.

The serial port interrupt vectors are located in the IIR as follows.

- Serial Port A at offset 0x0C0
- Serial Port B at offset 0x0D0
- Serial Port C at offset 0x0E0
- Serial Port D at offset 0x0F0

Each of them can be set as Priority 1, 2, or 3 in SxCR, where x is A – D for the four serial ports.

19.3 Operation

TIP: Remember to set up the serial port registers before commanding the serial port to send or receive any data.

19.3.1 Asynchronous Mode

The following steps explain how to set up Serial Ports A – D for asynchronous operation. These instructions also apply to the asynchronous operation of Serial Ports E – F.

1. Write the interrupt vector for the interrupt service routine to the internal interrupt table.
2. Set up the desired transmit pin by writing to the appropriate parallel port function register (PxFR) and alternate output register (PxALR or PxAHR).
3. Select the appropriate mode by writing to SxCR (receive input port and 7 or 8 bits). Also select the interrupt priority.
4. Select additional options by writing to SxER (parity, RZI encoding, clock polarity, and behavior during break).
5. Write the desired divider value to TATxR for the appropriate serial port, or else write a divider value to the dedicated 15-bit divider in SxDLR and SxDHR. If the dedicated divider is to be used, write a 1 to the most-significant bit of SxDHR to enable it.

A sample asynchronous serial interrupt handler is shown below for Serial Port A.

```
async_sera_isr::
    push af                ; save used registers
    ioi ld a, (SASR)      ; get status
    bit a,7               ; check if byte ready in RX buffer
    push af               ; save status for next check
    jr z, check_for_tx
rx_ready:
    ioi ld a, (SADR)      ; read byte and clear interrupt

    ; do something with byte here

check_for_tx:
    pop af
    bit a,3               ; check if TX buffer was emptied
    jr nz, done

    ; get next byte to be transmitted into A here

    ioi ld (SADR), a      ; load next byte into TX buffer and clear
                        ; interrupt

done:
    pop af                ; restore used registers
    ipres
    ret
```

To transmit with a “1” address bit appended, write the data to SxAR instead of SxDR; to append a “0” address bit write to SxLR instead.

19.3.2 Clocked Serial Mode

The following steps explain how to set up Serial Ports A – D for the clocked serial mode. When the internal clock is selected, the Rabbit 6000 is in control of all transmit and receive operations. When an external clock is selected the other device controls all transmit and receive operation. For both situations the decision between polling and interrupt-driven methods is application dependent.

1. Write the interrupt vector for the interrupt service routine to the internal interrupt table.
2. Set up the desired data transmit and clock pins by writing to the appropriate parallel port function register (PxFR) and alternate output register (PxALR or PxAHR).
3. Select the appropriate mode by writing to SxCR (receive input port and clock source). Also select the interrupt priority.
4. Select additional options by writing to SxER (clock polarity, bit order, and clock source if external).
5. If your serial port will be the master, write the desired divider value to TATxR for the appropriate serial port, or else write a divider to the dedicated 15-bit divider in SxDLR and SxDHR. If the dedicated divider is to be used, write a 1 to the most-significant bit of SxDHR to enable it.
6. There are two methods to transfer a byte; write the byte to SxDR and then write 10 (or 11) to bits 6-7 of SxCR to enable the transfer; or write the byte to SxAR which will automatically start the transfer.

NOTE: If the internal clock is selected, the transmission will begin immediately; if an external clock is selected, the transmission will begin when the clock is detected.

7. There are two methods to receive a byte; write 01 to bits 6–7 of SxCR to start the receive operation, or read the byte from SxAR, which will automatically start the transfer based on whether an internal or an external clock was selected.

NOTE: If the internal clock is selected, the clock will begin immediately and the data will be read; if an external clock is selected, the receive will occur when the clock is detected.

A sample clocked serial interrupt handler for a master shown below for Serial Port B.

```
clocked_serb_isr::
    push af                ; save used registers
    ioi ld a, (SBSR)      ; get status
    bit a,7                ; check if byte ready in RX buffer
    push af                ; save status for next check
    jr z, check_for_tx

rx_ready:
    ioi ld a, (SBDR)      ; read byte and clear interrupt

    ; do something with received byte here

    ld a, 0x4D            ; set bits 6-7 to 01, the other bits should
                        ; represent the desired SBCR setup
                        ; (Parallel Port C, internal clock,
                        ; Interrupt Priority 1 in this example)

    ioi ld (SBCR), a      ; start a new receive operation

check_for_tx:
    pop af
    bit a,3                ; check if TX buffer was emptied
    jr nz, done

    ; get next byte to be transmitted into Register A here

    ; load TX buffer with next byte, clear interrupt, and start
    ;transmission
    ioi ld (SBAR), a

done:
    pop af                ; restore used registers
    ipres
    ret
```

19.4 Register Descriptions

Serial Port x Data Register		
(SADR)	(Address = 0x00C0)	
(SBD R)	(Address = 0x00D0)	
(SCDR)	(Address = 0x00E0)	
(SDDR)	(Address = 0x00F0)	
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer.
	Write	Loads the transmit buffer with a data byte for transmission.

Serial Port x Address Register		
(SAAR)	(Address = 0x00C1)	
(SBAR)	(Address = 0x00D1)	
(SCAR)	(Address = 0x00E1)	
(SDAR)	(Address = 0x00F1)	
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer. Reading the data from this register in the clocked serial mode automatically causes the receiver to start a byte-receive operation, eliminating the need for software to issue the start-receive command.
	Write	Loads the transmit buffer with an address byte, marked with a “zero” address bit, for transmission. Writing the data to this register in the clocked serial mode causes the transmitter to start a byte-transmit operation, eliminating the need for the software to issue the start-transmit command.

Serial Port x Long Stop Register		
(SALR)	(Address = 0x00C2)	
(SBLR)	(Address = 0x00D2)	
(SCLR)	(Address = 0x00E2)	
(SDLR)	(Address = 0x00F2)	
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer.
	Write	Loads the transmit buffer with an address byte, marked with a “one” address bit, for transmission.

Serial Port x Status Register (SASR) (Address = 0x00C3) (SBSR) (Address = 0x00D3) (Asynchronous Mode Only) (SCSR) (Address = 0x00E3) (SDSR) (Address = 0x00F3)		
Bit(s)	Value	Description
7	0	The receive data register is empty
	1	There is a byte in the receive buffer. The serial port will request an interrupt while this bit is set. The interrupt is cleared when the receive buffer is empty.
6	0	The byte in the receive buffer is data, received with a valid stop bit.
	1	The byte in the receive buffer is an address, or a byte with a framing error. If an address bit is not expected, and the data in the buffer is all zeros, this is a break.
5	0	The receive buffer was not overrun.
	1	The receive buffer was overrun. This bit is cleared by reading the receive buffer.
4	0	The byte in the receive buffer has no parity error (or was not checked for parity).
	1	The byte in the receive buffer had a parity error.
3	0	The transmit buffer is empty.
	1	The transmit buffer is not empty. The serial port may request an interrupt when the transmitter takes a byte from the transmit buffer. Transmit interrupts are cleared when the transmit buffer is written, or any value (which will be ignored) is written to this register.
2	0	The transmitter is idle.
	1	The transmitter is sending a byte. An interrupt may be generated when the transmitter clears this bit, which occurs only if the transmitter is ready to start sending another byte and the transmit buffer is empty.
1:0	00	These bits are always zero in the asynchronous mode.

Serial Port x Status Register (SASR) (Address = 0x00C3) (SBSR) (Address = 0x00D3) (Clocked Serial Mode Only) (SCSR) (Address = 0x00E3) (SDSR) (Address = 0x00F3)		
Bit(s)	Value	Description
7	0	The receive data register is empty
	1	There is a byte in the receive buffer. The Serial Port will request an interrupt while this bit is set. The interrupt is cleared when the receive buffer is empty.
6	0	This bit is always zero in clocked serial mode.
5	0	The receive buffer was not overrun.
	1	The receive buffer was overrun. This bit is cleared by reading the receive buffer.
4	0	This bit is always zero in clocked serial mode.
3	0	The transmit buffer is empty.
	1	The transmit buffer is not empty. The Serial Port will request an interrupt when the transmitter takes a byte from the transmit buffer. Transmit interrupts are cleared when the transmit buffer is written, or any value is written to this register.
2	0	The transmitter is idle.
	1	The transmitter is sending a byte. An interrupt is generated when the transmitter clears this bit, which occurs only if the transmitter is ready to start sending another byte but the transmit buffer is empty.
1	0	Normal clocked serial transmit (command per byte).

Serial Port x Control Register (SACR) (Address = 0x00C4) (SBCR) (Address = 0x00D4) (SCCR) (Address = 0x00E4) (SDCR) (Address = 0x00F4)		
Bit(s)	Value	Description
7:6	00	No operation. These bits are ignored in the asynchronous mode.
	01	In the clocked serial mode, start a byte-receive operation.
	10	In the clocked serial mode, start a byte-transmit operation.
	11	In the clocked serial mode, start a byte-transmit operation and a byte-receive operation simultaneously.
5:4	00	Parallel Port C is used for input.
	01	Parallel Port D is used for input.
	10	Parallel Port E is used for input.
	11	Disable the receiver input.
3:2	00	Asynchronous mode with 8 bits per character.
	01	Asynchronous mode with 7 bits per character. In this mode the most significant bit of a byte is ignored for transmit, and is always zero in receive data.
	10	Clocked serial mode with external clock.
	11	Clocked serial mode with internal clock.
1:0	00	The serial port interrupt is disabled.
	01	The serial port uses Interrupt Priority 1.
	10	The serial port uses Interrupt Priority 2.
	11	The serial port uses Interrupt Priority 3.

Serial Port x Extended Register (SAER) (Address = 0x00C5) (SBER) (Address = 0x00D5) (Asynchronous Mode Only) (SCER) (Address = 0x00E5) (SDER) (Address = 0x00F5)		
Bit(s)	Value	Description
7:5	000	Disable parity generation and checking.
	001	This bit combination is reserved and should not be used.
	010	This bit combination is reserved and should not be used.
	011	This bit combination is reserved and should not be used.
	100	Enable parity generation and checking with even parity.
	101	Enable parity generation and checking with odd parity.
	110	Enable parity generation and checking with space (always zero) parity.
	111	Enable parity generation and checking with mark (always one) parity.
4	0	Normal asynchronous data encoding.
	1	Enable RZI coding (3/16 bit cell IrDA-compliant).
3	0	Normal break operation. This option should be selected when address bits are expected.
	1	Fast break termination. At the end of break, a dummy character is written to the buffer, and the receiver can start character assembly after one bit time.
2	0	Asynchronous clock is 16× data rate.
	1	Asynchronous clock is 8× data rate.
1	0	Continue character assembly during break to allow timing the break condition.
	1	Inhibit character assembly during break. One character (all zeros, with framing error) at start and one character (garbage) at completion.
0		This bit is ignored in the asynchronous mode.

Serial Port x Extended Register (SAER) (Address = 0x00C5) (SBER) (Address = 0x00D5) (Clocked Serial Mode Only) (SCER) (Address = 0x00E5) (SDER) (Address = 0x00F5)		
Bit(s)	Value	Description
7	0	Normal clocked serial operation.
	1	Timer-synchronized clocked serial operation.
6	0	Timer-synchronized clocked serial uses Timer B1.
	1	Timer-synchronized clocked serial uses Timer B2.
5:4	00	Normal clocked serial clock polarity, inactive high. Internal or external clock.
	01	Normal clocked serial clock polarity, inactive low. Internal clock only.
	10	Inverted clocked serial clock polarity, inactive low. Internal or external clock.
	11	Inverted clocked serial clock polarity, inactive high. Internal clock only.
3	0	Normal bit order (LSB first) for transmit and receive.
	1	Reverse bit order (MSB first) for transmit and receive.
2	0	Serial clock (input mode only) from Parallel Port D (SCER and SDER only).
	1	Serial clock (input mode only) from Parallel Port E (SCER and SDER only).
1	0	No effect on transmitter.
	1	Terminate current clocked serial transmission. No effect on buffer.
0	0	No effect on receiver.
	1	Terminate current clocked serial reception.

Serial Port x Divider Low Register (SADLR) (Address = 0x00C6) (SBDLR) (Address = 0x00D6) (SCDLR) (Address = 0x00E6) (SDDLRL) (Address = 0x00F6)		
Bit(s)	Value	Description
7:0		Eight LSBs of the divider that generates the serial clock for this channel. This divider is not used unless the MSB of the corresponding SxDHR is set to one.

Serial Port x Divider High Register		
(SADHR) (Address = 0x00C7)		
(SBDHR) (Address = 0x00D7)		
(SCDHR) (Address = 0x00E7)		
(SDDHR) (Address = 0x00F7)		
Bit(s)	Value	Description
7	0	Disable the serial port divider and use the output of Timer A to clock the serial port.
	1	Enable the serial port divider, and use its output to clock the serial port. The serial port divider counts modulo $n + 1$ and is clocked by the peripheral clock.
6:0		Seven MSBs of the divider that generates the serial clock for this channel.

20. SERIAL PORTS E – F

20.1 Overview

Serial Ports E and F are identical to each other, and their asynchronous operation is identical to that of Serial Ports A – D except for the source of the data clock, and the transmit, receive, and clock pins. Each serial port can be used in the asynchronous or the HDLC mode with an internal or external (HDLC mode) clock.

In the asynchronous mode, either 7 or 8 data bits can be transferred, and both a parity bit and/or ninth data bit can be appended as well. Parity and the ninth data bits are also detected when they are received. The asynchronous mode is full-duplex.

The transmit and receive buffers of Serial Ports E and F have 4 bytes each; this reduces the interrupt overhead requirements because an interrupt does not have to be generated as often. A serial port interrupt may be generated whenever at least one byte is available in the receive buffer or whenever a byte is shifted out of the transmit buffer.

The status of each serial port is available in its Serial Port Status Register (SxSR), and contains information on whether a received byte is available, the receive buffer was overrun, a parity error was received, the transmit buffer is empty or busy sending a byte, and the state of the ninth data bit (whether it is an address bit or a stop bit).

Serial Ports E and F support the HDLC mode with either an internal or an external clock; separate pins are used for the transmit and receive clocks. The HDLC packet flag encapsulation, flag escapes, and CRC calculation and check are handled automatically by the processor. The serial port can detect end-of-frame, short-frame, and CRC errors. Interrupts are generated by the reception of an end-of-frame, at the end of a transmission of a CRC, by an abort sequence, or by a closing flag. Transmit and receive operations are essentially automatic.

The standard CRC-CCITT polynomial ($x^{16} + x^{12} + x^5 + 1$) is implemented for the CRC, with the generator and checker preset to all ones.

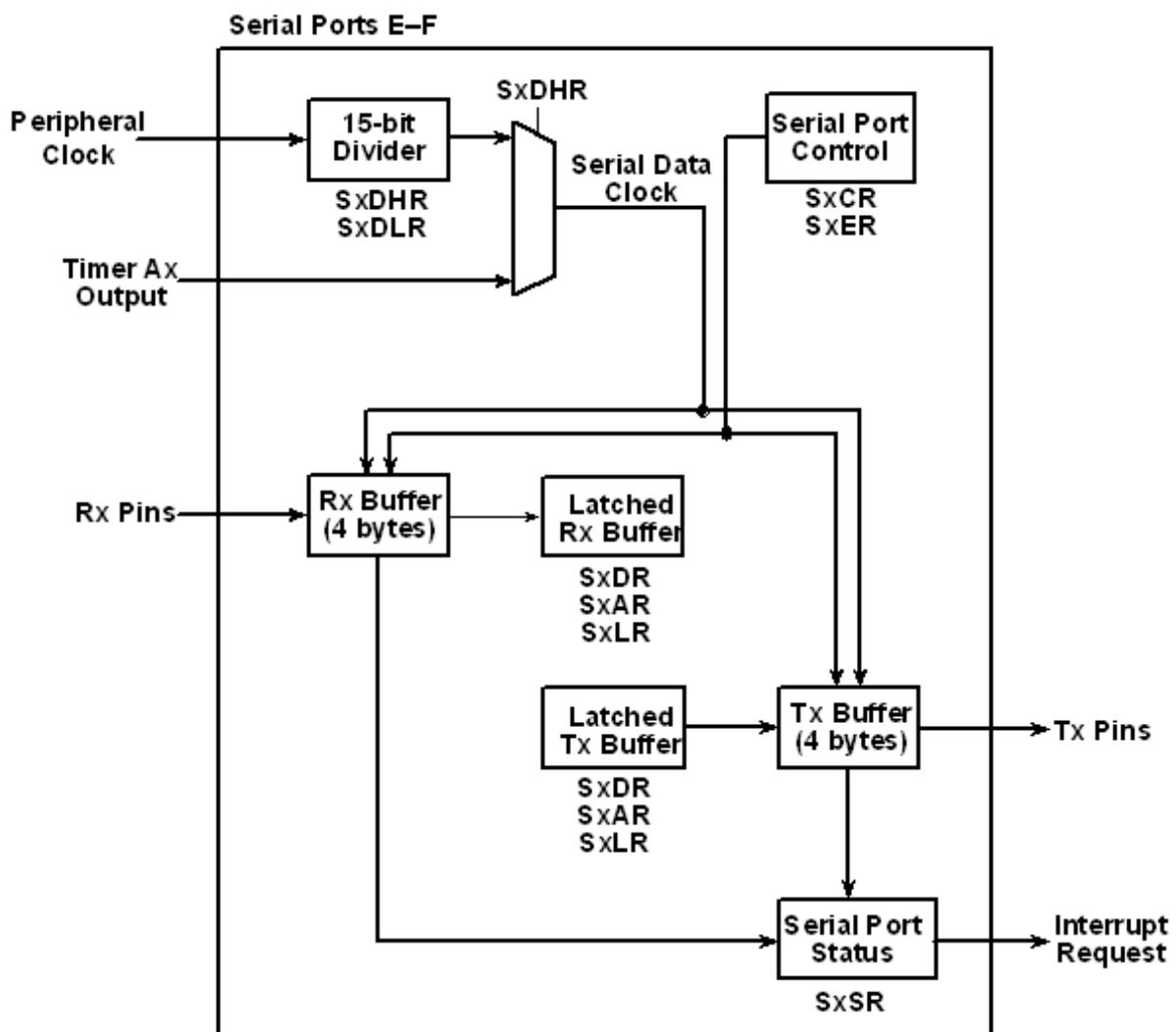
It is possible to send packets with or without a CRC appended. It is also possible to select whether an abort or flag will be transmitted if the transmitter underflows. A packet under transition can be aborted and the abort pattern sent. The idle condition of the line can be flags or all ones.

Several types of data encoding are available in HDLC mode: NRZ, NRZI, biphase-level (Manchester), biphase-space (FM0), and biphase-mark (FM1). IrDA-compliant RZI encoding is also available in HDLC mode; it reduces the bit widths to $\frac{1}{4}$ the normal width, which allows the serial-port signal to be connected directly to an IrDA transceiver.

If an internal clock is selected, the serial port data clocks can be generated from the appropriate 8-bit timer (Timer A2 for Serial Port E and Timer A3 for Serial Port F) or from a dedicated 15-bit divider. In HDLC mode, the bit data rate is equal to the data clock rate divided by 16.

When using an external clock, a 1× (same speed as the data rate) clock is supported. In this case, the maximum data rate is 1/6 of the peripheral clock rate. The receive clock is generated from the transitions in the data stream via a digital phase-locked loop (DPLL). The timing of this synchronization is adjusted with each incoming transition, allowing for tracking if the two external clocks differ slightly in frequency. For more on the clock synchronization and data encoding, see Section 20.3.3.

20.1.1 Block Diagram



20.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Serial Port E Data Register	SEDR	0x00C8	R/W	xxxxxxxx
Serial Port E Address Register	SEAR	0x00C9	W	xxxxxxxx
Serial Port E Long Stop Register	SELR	0x00CA	W	xxxxxxxx
Serial Port E Status Register	SESR	0x00CB	R	0xx00000
Serial Port E Control Register	SECR	0x00CC	R/W	xx000000
Serial Port E Extended Register	SEER	0x00CD	R/W	00000000
Serial Port E Divider Low Register	SEDLR	0x00CE	R/W	xxxxxxxx
Serial Port E Divider High Register	SEDHR	0x00CF	R/W	0xxxxxxxx
Serial Port F Data Register	SFDR	0x00D8	R/W	xxxxxxxx
Serial Port F Address Register	SFAR	0x00D9	W	xxxxxxxx
Serial Port F Long Stop Register	SFLR	0x00DA	W	xxxxxxxx
Serial Port F Status Register	SFSR	0x00DB	R	0xx00000
Serial Port F Control Register	SFCR	0x00DC	R/W	xx000000
Serial Port F Extended Register	SFER	0x00DD	R/W	00000000
Serial Port F Divider Low Register	SFDLR	0x00DE	R/W	xxxxxxxx
Serial Port F Divider High Register	SFDHR	0x00DF	R/W	0xxxxxxxx

20.2 Dependencies

20.2.1 I/O Pins

Serial Port E can transmit on parallel port pins PC6, PD6, PE6, or PH6, and can receive on pins PC7, PD7, or PE7. If the HDLC mode is enabled, the transmit serial clock is either transmitted or received on PC4, PD4, or PE4, while the receive serial clock is either transmitted or received on PC5, PD5, or PE5. The transmit and receive clocks can also be transmitted on PH4 or PH0 if internal clock generation is enabled.

Serial Port F can transmit on parallel port pins PC2, PD2, PE2, or PH2, and can receive on pins PC3, PD3, or PE3. If the HDLC mode is enabled, the transmit serial clock is either transmitted or received on PC0, PD0, or PE0, while the receive serial clock is either transmitted or received on PC1, PD1, or PE1. The transmit and receive clocks can also be transmitted on PH5 or PH1 if internal clock generation is enabled.

Table 20-1. Serial Ports E and F Pin Usage

Function	Serial Port E	Serial Port F
Transmit	PC6, PD6, PE6, PH6	PC2, PD2, PE2, PH2
Receive	PC7, PD7, PE7	PC3, PD3, PE3
Transmit Clock	PC4, PD4, PE4, PH4	PC0, PD0, PE0, PH0
Receive Clock	PC5, PD5, PE5, PH5	PC1, PD1, PE1, PH1

20.2.2 Clocks

The data clocks for Serial Ports E – F are based on the peripheral clock and divided by either a Timer A divider or a dedicated 15-bit divider in SxDLR and SxDHR. In either case, the overall clock divider will be the value in the appropriate register plus one.

20.2.3 Other Registers

Register	Function
TAT2R	Serial Port E baud rate generation
TAT3R	Serial Port F baud rate generation
PCFR, PCAHR, PCALR PDFR, PDAHR, PDALR PEFR, PEHR, PEALR PHFR, PHHR, PHALR	Alternate port output selection
TAT1R	Prescaler for TAT2R-TAT3R
TAPR	Prescaler for TAT1R
TACR	Input selection for TAT2R-TAT3R

20.2.4 Interrupts

In the asynchronous mode, a serial port interrupt will be generated whenever any of the following occurs:

- A byte is available in the receive buffer.
- A byte is moved from the transmit buffer to the transmitter.
- The transmitter becomes idle.

These occurrences correspond to bits 7, 3, and 2 of the Serial Port Status Registers.

In the HDLC mode, interrupts are also generated by the reception of an end-of-frame (with abort, valid CRC, or CRC error), at the end of a transmission of a CRC, by an abort sequence, or by a closing flag.

The serial port interrupt vectors are located in the IIR as follows:

- Serial Port E at offset 0x1C0
- Serial Port F at offset 0x1D0

Each of them can be set as Priority 1, 2, or 3 in SxCR, where x is E – F for the two serial ports.

20.3 Operation

TIP: Remember to set up the serial port bits before commanding the serial port to send or receive any data.

20.3.1 Asynchronous Mode

The steps to set up Serial Ports E – F for asynchronous operation are identical to those described in Section 19.3.1 to set up Serial Ports A – D.

20.3.2 HDLC Mode

The following steps explain how to set up Serial Ports E – F for the HDLC mode.

1. Write the interrupt vector for the interrupt service routine to the internal interrupt table.
2. Set up the desired data transmit and clock pins by writing to the appropriate parallel port function register (PxFR) and alternate output register (PxALR or PxAHR).
3. Select the appropriate mode by writing to SxCR (receive input port and clock source). Also select the interrupt priority.
4. Select additional options by writing to SxER (data encoding, idle line condition, underrun behavior, and combined or separate clocks).
5. Write the desired divider value to TATxR for the appropriate serial port, or else write a divider to the dedicated 15-bit divider in SxDLR and SxDHR. If the dedicated divider is to be used, write a 1 to the most-significant bit of SxDHR to enable it. In either case, the overall clock divider will be the value in the appropriate register plus one.
6. To start transmission of a packet, write the first byte to SxDR. If internal clock is selected, the transmission will begin immediately; if an external clock is selected the transmission will begin when the clock is detected.
7. Continue writing bytes when space is available in the transmit buffer until the final byte of the packet. If a CRC is to be appended to the packet, write the final byte to SxAR. If no CRC is required, write the final byte to SxLR and just a closing flag will be appended. If it is desirable to abort the current packet, write 11 to bits 6–7 of SxCR, and an abort pattern will be transmitted.
8. The receiver will be synchronized on flag bytes and will reset the CRC. By monitoring the received bytes, decisions can be made about the incoming packet; if it is not desired (i.e., it is not addressed to this device), writing a 01 to bits 6–7 of SxCR will force the receiver back into the flag search mode.

A sample HDLC interrupt handler is shown below for Serial Port E.

```

hdlc_sere_isr::
    push af
    ioi ld a, (SESR)    ; get status
    bit a,7            ; check if byte ready in RX buffer
    push af            ; save status for next check
    jr z, check_for_tx
rx_ready:

    ; check status byte in A for abort or invalid CRC flags

    ioi ld a, (SEDR)    ; read byte and clear interrupt

    ; store byte in A here

check_for_tx:
    pop af
    bit a,3            ; check if TX buffer was emptied
    jr nz, done

    ; check status byte in A for transmit finish reason (CRC, abort, etc.)

    ; get next byte to be transmitted into A here; if it is the last
    ; byte of the packet, load it into SEAR or SELR instead

    ioi ld (SEDR), a    ; load next byte into buffer and clear interrupt
done:
    pop af
    ipres
    ret

```

20.3.3 More on Clock Synchronization and Data Encoding

The transmitter is not capable of sending an arbitrary number of bits, but only a multiple of bytes. However, the receiver can receive frames of any bit length. If the last “byte” in the frame is not eight bits, the receiver sets a status flag that is buffered along with this last byte. Software can then use the table below to determine the number of valid data bits in this last “byte.” Note that the receiver transfers all bits between the opening and closing flags, except for the inserted zeros, to the receiver data buffer.

Last Byte Bit Pattern	Valid Data Bits
bbbbbbb0	7
bbbbbb01	6
bbbbbb011	5
bbbb0111	4
bbb01111	3
bb011111	2
b0111111	1

Several types of data encoding are available in the HDLC mode. In addition to the normal NRZ, they are NRZI, biphas-level (Manchester), biphas-space (FM0), and biphas-mark (FM1). Examples of these encodings are shown below. Note that the signal level does not convey information in NRZI, biphas-space, and biphas-mark. Instead it is the placement of the transitions that determine the data. In biphas-level it is the polarity of the transition that determines the data.

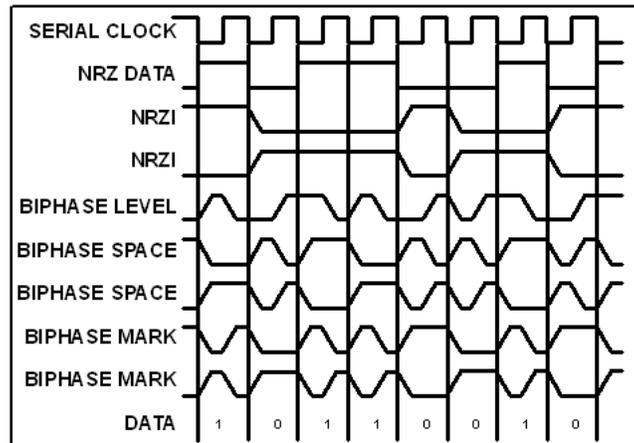


Figure 20-1. Examples of Data Encoding In the HDLC Mode

In the HDLC mode the internal clock comes from the output of Timer A2/Timer A3 or the dedicated divider. The timer/divider output is divided by 16 to form the transmit clock, and is fed to the digital phase-locked loop (DPLL) to form the receive clock. The DPLL is basically just a divide-by-16 counter that uses the timing of the transitions on the receive data stream to adjust its count. The DPLL adjusts the count so that the DPLL output will be properly placed in the bit cells to sample the receive data. To work properly, then, transitions are required in the receive data stream. NRZ data encoding does not guarantee transitions in all cases (a long string of zeros, for example), but the other data encodings do. NRZI guarantees transitions because of the inserted zeros, and the biphas encodings all have at least one transition per bit cell.

The DPLL counter normally counts by 16, but if a transition occurs earlier or later than expected, the count will be modified during the next count cycle. If the transition occurs earlier than expected, it means that the bit cell boundaries are early with respect to the DPLL-tracked bit-cell boundaries, so the count is shortened by either one or two counts. If the transition occurs later than expected, it means that the bit-cell boundaries are late with respect to the DPLL-tracked bit-cell boundaries, so the count is lengthened by either one or two counts. The decision to adjust by one or by two depends on how far off the DPLL-tracked bit cell boundaries are. This tracking allows for minor differences in the transmit and receive clock frequencies.

With NRZ and NRZI data encoding, the DPLL counter runs continuously, and adjusts after every receive data transition. Since NRZ encoding does not guarantee a minimum density of transitions, the difference between the sending data rate and the DPLL output clock rate must be very small, and depends on the longest possible run of zeros in the received frame. NRZI encoding guarantees at least one transition every six bits (with the inserted zeros). Since the DPLL can adjust by two

counts every bit cell, the maximum difference between the sending data rate and the DPLL output clock rate is $1/48$ (~2%).

With biphasic data encoding (either biphasic-level, biphasic-mark, or biphasic-space), the DPLL runs only as long as transitions are present in the receive data stream. Two consecutive missed transitions causes the DPLL to halt operation and wait for the next available transition. This mode of operation is necessary because it is possible for the DPLL to lock onto the optional transitions in the receive data stream. Since they are optional, they will eventually not be present, and the DPLL can attempt to lock onto the required transitions. Since the DPLL can adjust by one count every bit cell, the maximum difference between the sending data rate and the DPLL output clock rate is $1/16$ (~6%).

With biphasic data encoding, the DPLL is designed to work in multiple-access conditions where there might not be flags on an idle line. The DPLL will generate an output clock correctly based on the first transition in the leading zero of an opening flag. Similarly, only the completion of the closing flag is necessary for the DPLL to provide the extra two clocks to the receiver to assemble the data correctly. The transition is specified as follows.

- In the biphasic-level mode this means the transition that defines the last zero of the closing flag.
- In the biphasic-mark and the biphasic-space modes this means the transition that defines the end of the last zero of the closing flag.

Figure 20-2 shows the adjustment ranges and output clock for the different modes of operation of the DPLL. Each mode of operation will be described in turn.

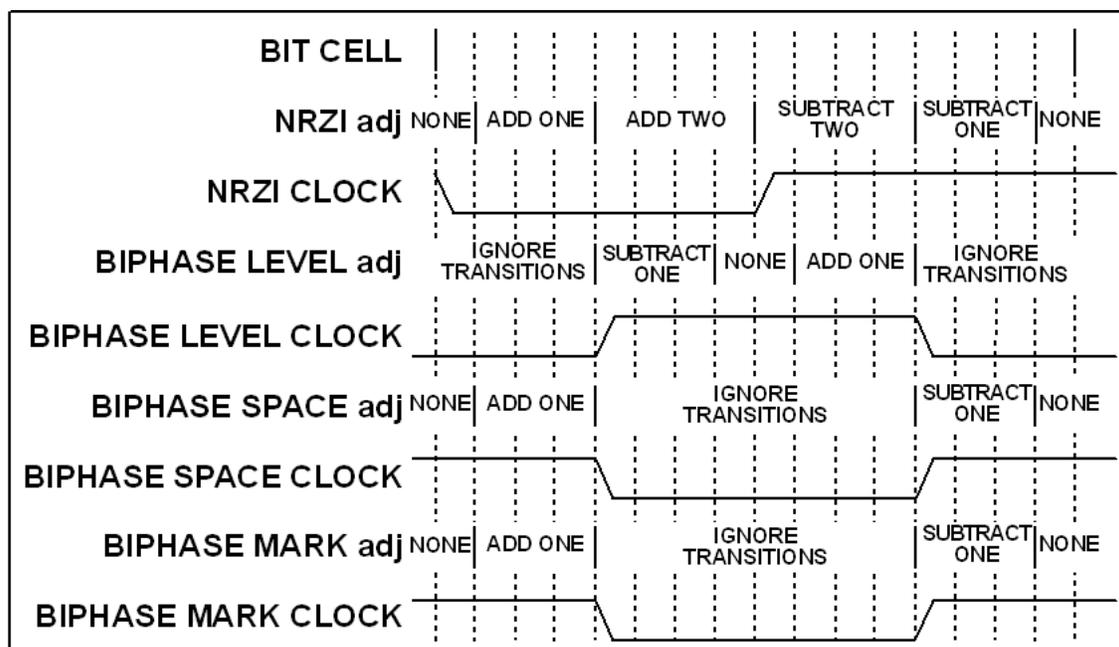


Figure 20-2. Adjustment Ranges and Output Clock for Different DPLL Modes

With NRZ and NRZI encoding, all transitions occur on bit-cell boundaries and the data should be sampled in the middle of the bit cell. If a transition occurs after the expected bit-cell boundary (but before the midpoint), the DPLL needs to lengthen the count to line up the bit-cell boundaries. This corresponds to the “add one” and “add two” regions shown. If a transition occurs before the bit-cell boundary (but after the midpoint), the DPLL needs to shorten the count to line up the bit-cell boundaries. This corresponds to the “subtract one” and “subtract two” regions shown. The DPLL makes no adjustment if the bit-cell boundaries are lined up within one count of the divide-by-16 counter. The regions that adjust the count by two allow the DPLL to synchronize faster to the data stream when starting up.

With biphas-level encoding, there is a guaranteed “clock” transition at the center of every bit cell and optional “data” transitions occur at the bit cell boundaries. The DPLL only uses the clock transitions to track the bit-cell boundaries by ignoring all transitions occurring outside a window around the center of the bit cell. This window is half a bit cell wide. Additionally, because the clock transitions are guaranteed, the DPLL requires that they always be present. If no transition is found in the window around the center of the bit cell for two successive bit cells, the DPLL is not in lock and immediately enters the search mode. The search mode assumes that the next transition seen is a clock transition and immediately synchronizes to this transition. No clock output is provided to the receiver during the search operation. Decoding biphas-level data requires that the data be sampled at either the quarter or three-quarter point in the bit cell. The DPLL here uses the quarter point to sample the data.

Biphase-mark encoding and biphase-space encoding are identical as far as the DPLL is concerned, and are similar to biphase-level encoding. The primary difference is the placement of the clock and data transitions. With these encodings the clock transitions are at the bit-cell boundary, the data transitions are at the center of the bit cell, and the DPLL operation is adjusted accordingly. Decoding biphase-mark or biphase-space encoding requires that the data be sampled by both edges of the recovered receive clock.

20.4 Register Descriptions

Serial Port x Data Register (SEDR) (Address = 0x00C8) (SFDR) (Address = 0x00D8)		
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer.
	Write	Loads the transmit buffer with a data byte for transmission.

Serial Port x Address Register (SEAR) (Address = 0x00C9) (SFAR) (Address = 0x00D9)		
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer.
	Write	Loads the transmit buffer with an address byte, marked with a “zero” address bit, for transmission. In the HDLC mode, the last byte of a frame must be written to this register to enable subsequent CRC and closing flag transmission.

Serial Port x Long Stop Register (SELR) (Address = 0x00CA) (SFLR) (Address = 0x00DA)		
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer.
	Write	Loads the transmit buffer with an address byte, marked with a “one” address bit, for transmission.

Serial Port x Status Register (SESR) (Address = 0x00CB) (SFSR) (Address = 0x00DB) (Asynchronous Mode Only)		
Bit(s)	Value	Description
7	0	The receive data register is empty
	1	There is a byte in the receive buffer. The serial port will request an interrupt while this bit is set. The interrupt is cleared when the receive buffer is empty.
6	0	The byte in the receive buffer is data, received with a valid stop bit.
	1	The byte in the receive buffer is an address, or a byte with a framing error. If an address bit is not expected, and the data in the buffer is all zeros, this is a break.
5	0	The receive buffer was not overrun.
	1	The receive buffer was overrun. This bit is cleared by reading the receive buffer.
4	0	The byte in the receive buffer has no parity error (or was not checked for parity).
	1	The byte in the receive buffer had a parity error.
3	0	The transmit buffer is empty.
	1	The transmit buffer is not empty. The serial port will request an interrupt when the transmitter takes a byte from the transmit buffer. Transmit interrupts are cleared when the transmit buffer is written, or any value (which will be ignored) is written to this register.
2	0	The transmitter is idle.
	1	The transmitter is sending a byte. An interrupt is generated when the transmitter clears this bit, which occurs only if the transmitter is ready to start sending another byte and the transmit buffer is empty.
1:0	00	These bits are always zero in the asynchronous mode.

Serial Port x Status Register (SESR) (Address = 0x00CB) (SFSR) (Address = 0x00DB) (HDLC Mode Only)		
Bit(s)	Value	Description
7	0	The receive data register is empty
	1	There is a byte in the receive buffer. The serial port will request an interrupt while this bit is set. The interrupt is cleared when the receive buffer is empty.
6,4	00	The byte in the receive buffer is data.
	01	The byte in the receive buffer was followed by an abort.
	10	The byte in the receive buffer is the last in the frame, with valid CRC.
	11	The byte in the receive buffer is the last in the frame, with a CRC error.
5	0	The receive buffer was not overrun.
	1	The receive buffer was overrun. This bit is cleared by reading the receive buffer.
3	0	The transmit buffer is empty.
	1	The transmit buffer is not empty. The serial port will request an interrupt when the transmitter takes a byte from the transmit buffer, unless the byte is marked as the last in the frame. Transmit interrupts are cleared when the transmit buffer is written, or when any value (which will be ignored) is written to this register.
2:1	00	Transmit interrupt due to buffer empty condition.
	01	Transmitter finished sending CRC. An interrupt is generated at the end of the CRC transmission. Data written in response to this interrupt will cause only one flag to be transmitted between frames, and no interrupt will be generated by this flag.
	10	Transmitter finished sending an abort. An interrupt is generated at the end of an abort transmission.
	11	The transmitter finished sending a closing flag. Data written in response to this interrupt will cause at least two flags to be transmitted between frames.
0	0	The byte in the receiver buffer is 8 bits.
	1	The byte in the receiver buffer is less than 8 bits.

Serial Port x Control Register (SECR) (Address = 0x00CC) (SFCR) (Address = 0x00DC)		
Bit(s)	Value	Description
7:6	00	No operation. These bits are ignored in the asynchronous mode.
	01	In HDLC mode, force receiver in flag search mode.
	10	No operation.
	11	In HDLC mode, transmit an abort pattern.
5:4	00	Parallel Port C is used for data (and optional clock) input.
	01	Parallel Port D is used for data (and optional clock) input.
	10	Parallel Port E is used for data (and optional clock) input.
	11	Disable the receiver data input. Clocks from Parallel Port E.
3:2	00	Asynchronous mode with 8 bits per character.
	01	Asynchronous mode with 7 bits per character. In this mode the most significant bit of a byte is ignored for transmit, and is always zero in receive data.
	10	HDLC mode with external clock. The external clocks are supplied via parallel port pins.
	11	HDLC mode with internal clock. The clock is 16× the data rate, and the DPLL is used to recover the receive clock. If necessary, the receiver and transmitter clocks can be output via parallel port pins.
1:0	00	The serial port interrupt is disabled.
	01	The serial port uses Interrupt Priority 1.
	10	The serial port uses Interrupt Priority 2.
	11	The serial port uses Interrupt Priority 3.

Serial Port x Extended Register (SEER) (Address = 0x00CD) (SFER) (Address = 0x00DD) (Asynchronous Mode Only)		
Bit(s)	Value	Description
7:5	000	Disable parity generation and checking.
	001	This bit combination is reserved and should not be used.
	010	This bit combination is reserved and should not be used.
	011	This bit combination is reserved and should not be used.
	100	Enable parity generation and checking with even parity.
	101	Enable parity generation and checking with odd parity.
	110	Enable parity generation and checking with space (always zero) parity.
	111	Enable parity generation and checking with mark (always one) parity.
4	0	Normal asynchronous data encoding.
	1	Enable RZI coding (3/16 bit cell IrDA-compliant).
3	0	Normal break operation. This option should be selected when address bits are expected.
	1	Fast break termination. At the end of break, a dummy character is written to the buffer, and the receiver can start character assembly after one bit time.
2	0	Asynchronous clock is 16× data rate.
	1	Asynchronous clock is 8× data rate.
1	0	Continue character assembly during break to allow timing the break condition.
	1	Inhibit character assembly during break. One character (all zeros, with framing error) at start and one character (garbage) at completion.
0		This bit is ignored in the asynchronous mode.

Serial Port x Extended Register (SEER) (Address = 0x00CD) (SFER) (Address = 0x00DD) (HDLC Mode Only)		
Bit(s)	Value	Description
7:5	000	NRZ data encoding for HDLC receiver and transmitter.
	010	NRZI data encoding for HDLC receiver and transmitter.
	100	Biphase-level (Manchester) data encoding for HDLC receiver and transmitter.
	110	Biphase-space data encoding for HDLC receiver and transmitter.
	111	Biphase-mark data encoding for HDLC receiver and transmitter.
4	0	Normal HDLC data encoding.
	1	Enable RZI coding ($\frac{1}{4}$ bit cell IrDA-compliant). This mode can only be used with an internal clock and NRZ data encoding.
3	0	Idle line condition is flags.
	1	Idle line condition is all ones.
2	0	Transmit flag on underrun.
	1	Transmit abort on underrun.
1	0	Separate HDLC external receive and transmit clocks.
	1	Combined HDLC external and transmit clock, from transmit clock pin.
0		This bit is ignored in HDLC mode.

Serial Port x Divider Low Register (SEDLR) (Address = 0x00CE) (SFDLR) (Address = 0x00DE)		
Bit(s)	Value	Description
7:0		Eight LSBs of the divider that generates the serial clock for this channel. This divider is not used unless the MSB of the corresponding SxDHR is set to one.

Serial Port x Divider High Register (SEDHR) (Address = 0x00CF) (SFDHR) (Address = 0x00DF)		
Bit(s)	Value	Description
7	0	Disable the serial port divider and use the output of Timer A to clock the serial port.
	1	Enable the serial port divider, and use its output to clock the serial port. The serial port divider counts modulo $n + 1$ and is clocked by the peripheral clock.
6:0		Seven MSBs of the divider that generates the serial clock for this channel.

21. SLAVE PORT

21.1 Overview

The slave port is a parallel communication port that can be used to communicate with an external master device. The slave port consists of three data input and data output registers, and a status register.

The data input registers are written by the master (the external device) and are read by the slave. The data output registers are written by the slave and are read by the master. Note that the data registers are named from the point of view of the slave. The slave device can only read the data input registers and write to the data output registers. Similarly, the master device can only read the data input registers and write the data output registers. Both devices can read and write to the status register.

The status register contains the interrupt status bits and a status flag corresponding to each data input or data output register to indicate the empty or full status of the data register. Data registers are marked full when written by the source side of the interface, and are marked empty when read by the destination side of the interface.

The hardware interface to the external master consists of an 8-bit bidirectional data bus with a read strobe, write strobe, and chip select. There are two address lines that select one of the three data registers or the status register.

Table 21-1. Slave Port Addresses

Slave Port Address	Slave Port Register
00	Data Register 0
01	Data Register 1
10	Data Register 2
11	Status Register

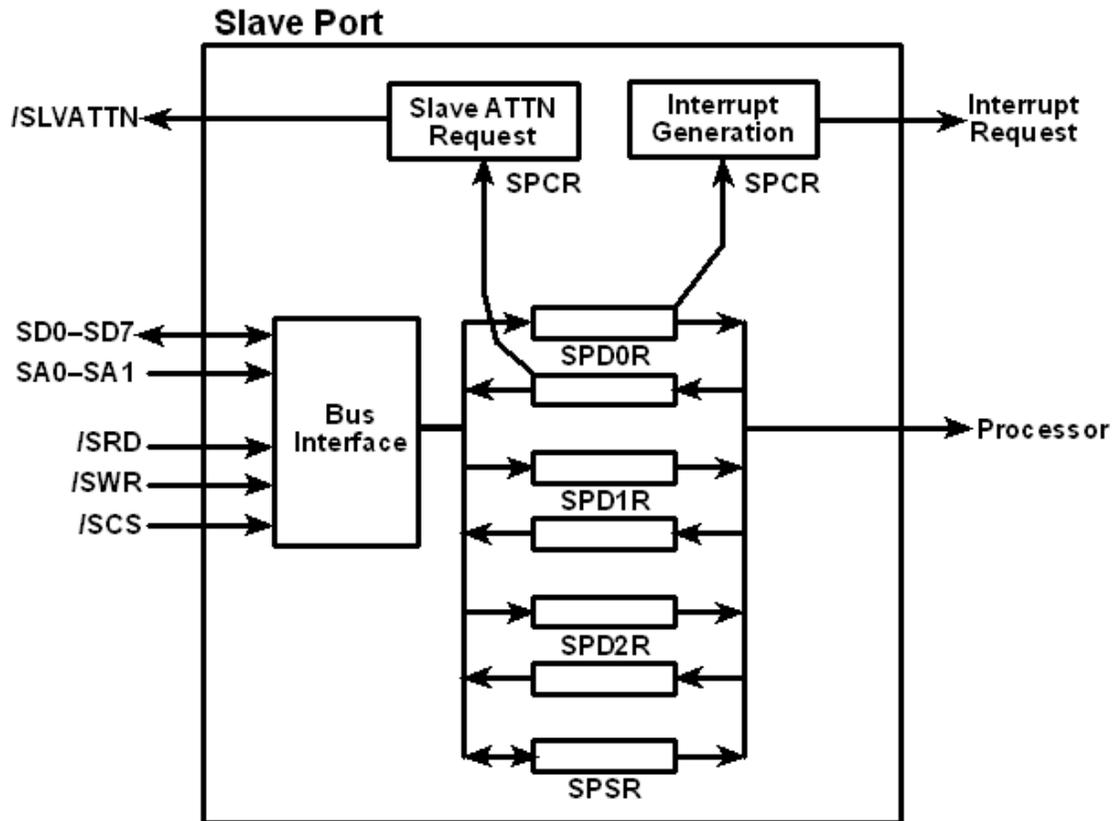
A slave attention signal is asserted when the slave writes to its SPD0R and can be deasserted by the master by performing a dummy write to the status register. This signal can be used to interrupt the master to indicate that the master needs to read data from the slave.

The slave port interrupt is asserted when the master writes to SPD0R. The slave clears this interrupt condition by writing to the status register.

The slave port can be used to bootstrap the processor by setting the SMODE pins appropriately. See Chapter 3 for more information on this mode.

If a Rabbit is used as the master device as well as the slave, the recommended bus interface for the master to use is the External I/O bus.

21.1.1 Block Diagram



21.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Slave Port Data 0 Register	SPD0R	0x0020	R/W	xxxxxxxx
Slave Port Data 1 Register	SPD1R	0x0021	R/W	xxxxxxxx
Slave Port Data 2 Register	SPD2R	0x0022	R/W	xxxxxxxx
Slave Port Status Register	SPSR	0x0023	R	00000000
Slave Port Control Register	SPCR	0x0024	R/W	0xx00000

21.2 Dependencies

21.2.1 I/O Pins

When the slave port is enabled by writing to SPCR, the following pins are enabled for slave port mode. Note that enabling the slave port mode will override any general-purpose I/O or external I/O bus settings for these pins; when the slave port is enabled they will perform slave port functionality.

Table 21-2. Slave Port Pin Functionality

Pin(s)	Slave Port Signal	Direction	Functionality
PA0–PA7	SD0–SD7	Bidirectional	Slave data bus
PB7	/SLVATTN	Output	Slave interrupt request (output)
PB6	/SCS	Input	Slave chip select
PB4–PB5	SA0–SA1	Input	Slave address bus
PB3	/SRD	Input	Slave port read strobe
PB2	/SWR	Input	Slave port write strobe
PE7	/SCS	Input	Alternate slave chip select

21.2.2 Clocks

All slave port operations are based on the processor clock.

21.2.3 Interrupts

If slave port interrupts are enabled, a slave port interrupt will occur on the slave device whenever the master writes to SPD0R. The /SLVATTN pin is asserted whenever the slave device writes to SPD0R. Either of these conditions is cleared when either the master or slave reads or writes any of the slave port registers.

The slave port interrupt vector is in the IIR at offset 0x080. It can be set as Priority 1, 2, or 3 by writing to SPCR.

21.3 Operation

Figure 21.1 shows a typical slave port connection between a Rabbit processor as the master and two slaves.

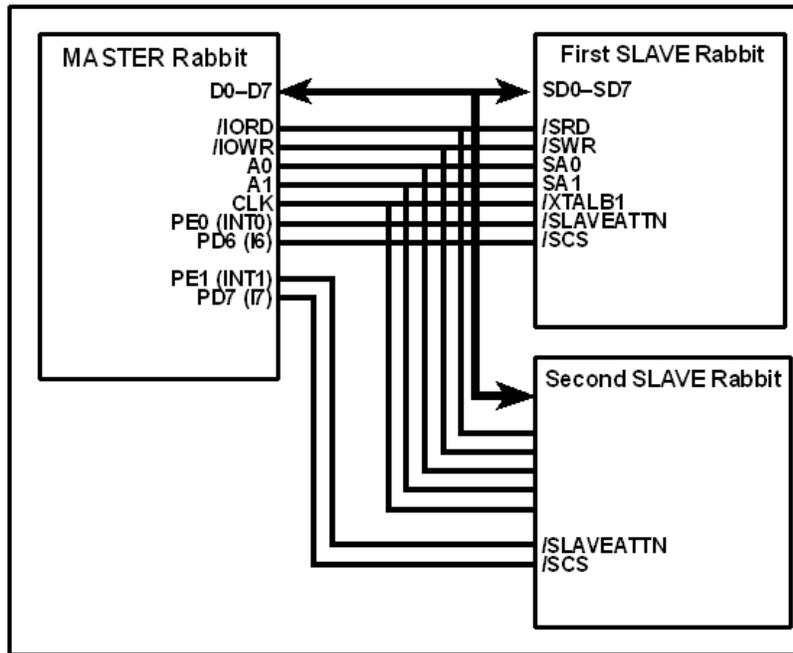


Figure 21.1 Master/Slave Port Connections

These connections are summarized in Table 21-3.

Table 21-3. Typical Slave Port Connections

Master		Slave #1		Slave #2	
Data Bus	D0–D7	SD0–SD7	PA0–PA7	SD0–SD7	PA0–PA7
Address Bus	A0–A1	SA0–SA1	PB4–PB5	SA0–SA1	PB4–PB5
I/O Read Strobe	/IORD	/SRD	PB3	/SRD	PB3
I/O Write Strobe	/IOWR	/SWR	PB2	/SWR	PB2
Slave #1 Chip Select (I/O strobe I6)	PD6	/SCS	PB6	—	—
Slave #2 Chip Select (I/O strobe I7)	PD7	—	—	/SCS	PB6
External Interrupt 0 (from Slave #1)	PE0	/SLVATTN	PB7	—	—
External Interrupt 1 (from Slave #2)	PE1	—	—	/SLVATTN	PB7

Note that the slave port on the master Rabbit processor is *not* used; the master uses the data bus to send and receive data to the slave port data registers on the slave devices.

In this setup, pins PD6 and PD7 are set up as chip selects for the two slave devices, and PE0 and PE1 are used as external interrupt inputs to monitor the /SLVATTN signals from the slaves.

In this setup, the slave port is used as follows:

- The slave responds to the interrupt and reads the slave port data registers.
- When the slave wishes to send data to the master, it writes the slave port data registers, writing SPD0R last, which enables the /SLVATTN signal.
- When the master detects the change on /SLVATTN, it reads the slave port data registers.

21.3.1 Master Setup

1. Enable the I/O strobes on PD6 and PD7 (as chip selects) by writing to the appropriate Parallel Port D pin and External I/O registers.
2. Enable the external interrupts on PE0 and PE1 by writing to the appropriate external interrupt registers.

21.3.2 Slave Setup

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure SPCR to select the interrupt priority (note that interrupts will be enabled once this value is set).

21.3.3 Master/Slave Communication

1. The master writes data to the appropriate external I/O address on the data bus for the slave device and register desired. For example, in the setup described here, the master would write to register SPD2R on the first slave by writing to the address 0xC002 (0xC000 for the I6 strobe, and 0x0002 for SPD2R on that slave).
2. If the master is writing multiple bytes, it should write to SPD0R last since that will trigger an interrupt on the slave device. If only one byte is being sent, it should be written to SPD0R.
3. The slave responds to the interrupt, reading the data from the slave port data registers.

21.3.4 Slave/Master Communication

1. The slave writes data to the appropriate slave port data register. If it is writing multiple bytes, SPD0R should be written last, which enables the /SLVATTN line.
2. The master receives an external interrupt from the /SLVATTN line, and reads the data out of the slave port data registers via external I/O reads on the data bus.

21.3.5 Handling Interrupts

The interrupt request on the slave is cleared by either the master or the slave accessing one of the slave port registers. To clear the interrupt without affecting the register values, a dummy write can be made to SPSR.

21.3.6 Example ISR

A sample interrupt handler is shown below.

```
slave_isr::
    push af                ; save used registers

    ; read the data sent by the master
    ioi ld a, (SPD2R)
    ld (to_slv_d2), a
    ioi ld a, (SPD1R)
    ld (to_slv_d1), a
    ioi ld a, (SPD0R)
    ld (to_slv_d0), a

    ; if a response is required, perform it here
    ld a, (to_mas_d2)
    ioi ld (SPD2R), a
    ld a, (to_mas_d1)
    ioi ld (SPD1R), a

    ld a, (to_mas_d0)
    ioi ld (SPD0R), a    ; this write asserts /SLVATTN

    ; the interrupt request is cleared by any read/write of the
    ; registers

    pop af                ; restore used registers
    ipres
    ret
```

21.3.7 Other Configurations

There are other slave port configurations possible:

- The master could use the external I/O bus instead of the memory bus.
- All devices could poll the slave port status register to determine when data is present instead of relying on interrupts.
- The master could write to SPD0R, triggering an interrupt on the slave. The slave could then simply write a response into SPD0R, which the master detects by polling SPSR. This configuration is useful when fewer signals are desired, or the master device has no external interrupts available.

If polling is to be used, it is important to note that not all bits in the status register may be updated at once; it is possible to read a transitional value as the register updates. To guarantee a proper polling read, the status register should be read twice; when the same value is read both times the value is correct.

Similarly, it is possible to receive a scrambled value from a data register if it is read while being written. The protocol used should take account of this and prevent it from occurring (the protocol described above guarantees this will not occur).

21.3.8 Timing Diagrams

The following table explains the parameters used in Figure 21.2.

Symbol	Parameter	Minimum (ns)	Maximum (ns)
Tsu(SCS)	/SCS Setup Time	5	—
Th(SCS)	/SCS Hold Time	0	—
Tsu(SA)	SA Setup Time	5	—
Th(SA)	SA Hold Time	0	—
Tw(SRD)	/SRD Low Pulse Width	40	—
Ten(SRD)	/SRD to SD Enable Time	0	—
Ta(SRD)	/SRD to SD Access Time	—	30
Tdis(SRD)	/SRD to SD Disable Time	—	15
Tsu(SRW – SRD)	/SWR High to /SRD Low Setup Time	40	—
Tw(SWR)	/SWR Low Pulse Width	40	—
Tsu(SD)	SD Setup Time	10	—
Th(SD)	SD Hold Time	5	—
Tsu(SRD – SWR)	/SRD High to /SWR Low Setup Time	40	—

Figure 21.2 shows the sequence of events when the master reads/writes the slave port registers.

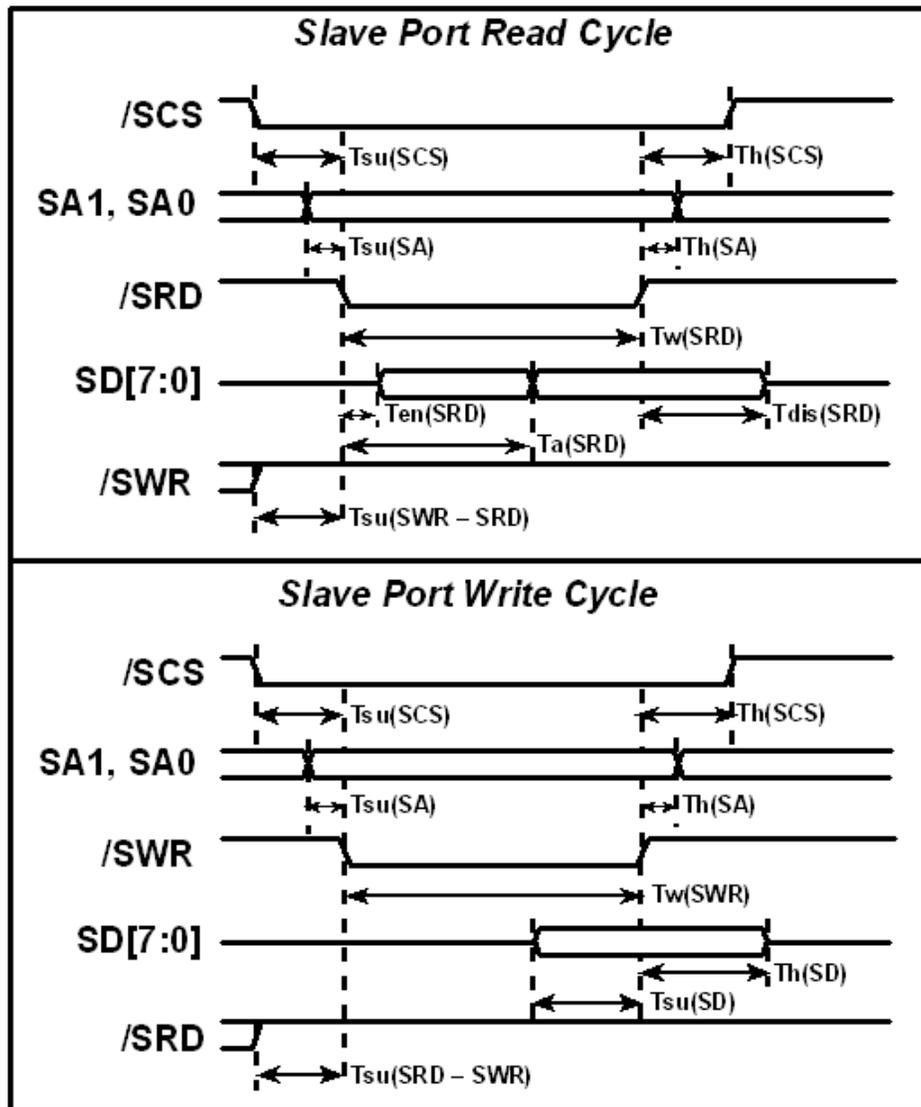


Figure 21.2 Slave Port R/W Timing Diagram

21.4 Register Descriptions

Slave Port Data x Registers (SPD0R) (Address = 0x0020) (SPD1R) (Address = 0x0021) (SPD2R) (Address = 0x0022)		
Bit(s)	Value	Description
7:0	Read	The corresponding byte of the slave port is read.
	Write	The corresponding byte of the slave port is written.

Slave Port Status Register (SPSR) (Address = 0x0023)		
Bit(s)	Value	Description
7	0	Slave wrote to SPSR.
	1	Master wrote to Data Register 0.
6	0	Slave port read byte 2 is empty.
	1	Slave port read byte 2 is full.
5	0	Slave port read byte 1 is empty.
	1	Slave port read byte 1 is full.
4	0	Slave port read byte 0 is empty.
	1	Slave port read byte 0 is full.
3	0	Master wrote to SPSR.
	1	Slave wrote to SPD0R.
2	0	Slave port write byte 2 is empty.
	1	Slave port write byte 2 is full.
1	0	Slave port write byte 1 is empty.
	1	Slave port write byte 1 is full.
0	0	Slave port write byte 0 is empty.
	1	Slave port write byte 0 is full.

Slave Port Control Register (SPCR) (Address = 0x0024)		
Bit(s)	Value	Description
7	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
	Write	These bits are ignored and should be written with zero.
4:2	000	Disable the slave port. Parallel Port A is a byte-wide input port.
	001	Disable the slave port. Parallel Port A is a byte-wide output port.
	010	Enable the slave port, with /SCS from Parallel Port E bit 7.
	011	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:2] is used for the address bus.
	100	This bit combination is reserved and should not be used.
	101	This bit combination is reserved and should not be used.
	110	Enable the slave port, with /SCS from Parallel Port B bit 6.
	111	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:0] is used for the address bus.
1:0	00	Slave port interrupts are disabled.
	01	Slave port interrupts use Interrupt Priority 1.
	10	Slave port interrupts use Interrupt Priority 2.
	11	Slave port interrupts use Interrupt Priority 3.

22. WI-FI ANALOG COMPONENTS

22.1 Overview

The Rabbit 6000 has a 11-bit single-channel A/D converter, a 10-bit two-channel differential-input A/D converter, and a 10-bit two-channel differential current output D/A converter for 802.11 Wi-Fi operation. The Wi-Fi analog features are available for customer use when Wi-Fi is not being used. Table 22-1 summarizes the analog features.

Table 22-1. Analog Components

Component Number	Function	Sampling Rate	Description	Operation	Pin(s)
0	A/D Converter	Up to 40 megasamples/s	Voltage-sensing, 2 channels, 10-bit, differential	Continuous	VRXI+, VRXI-, VRXQ+, VRXQ-
1	D/A Converter	Up to 80 megasamples/s	Current-sourcing, 2 channels, 10-bit, differential	Continuous	ITXI+, ITXI-, ITXQ+, ITXQ-
2	A/D Converter	Up to 1 megasamples/s	Voltage-sensing, 1 channel, 11-bit, single-ended, convert on signal	Convert on signal	S_VIN

The actual conversion rates depend on the clock sources used — each analog component can accept a clock from an external I/O pin or divide the peripheral clock by a value between 2 and 256.

The Rabbit 6000 also has a dedicated 1 megasamples/s, 12-bit A/D converter with an 8-way multiplexer, and is described in Chapter 23.

Table 22-1 lists the detailed features for each analog component.

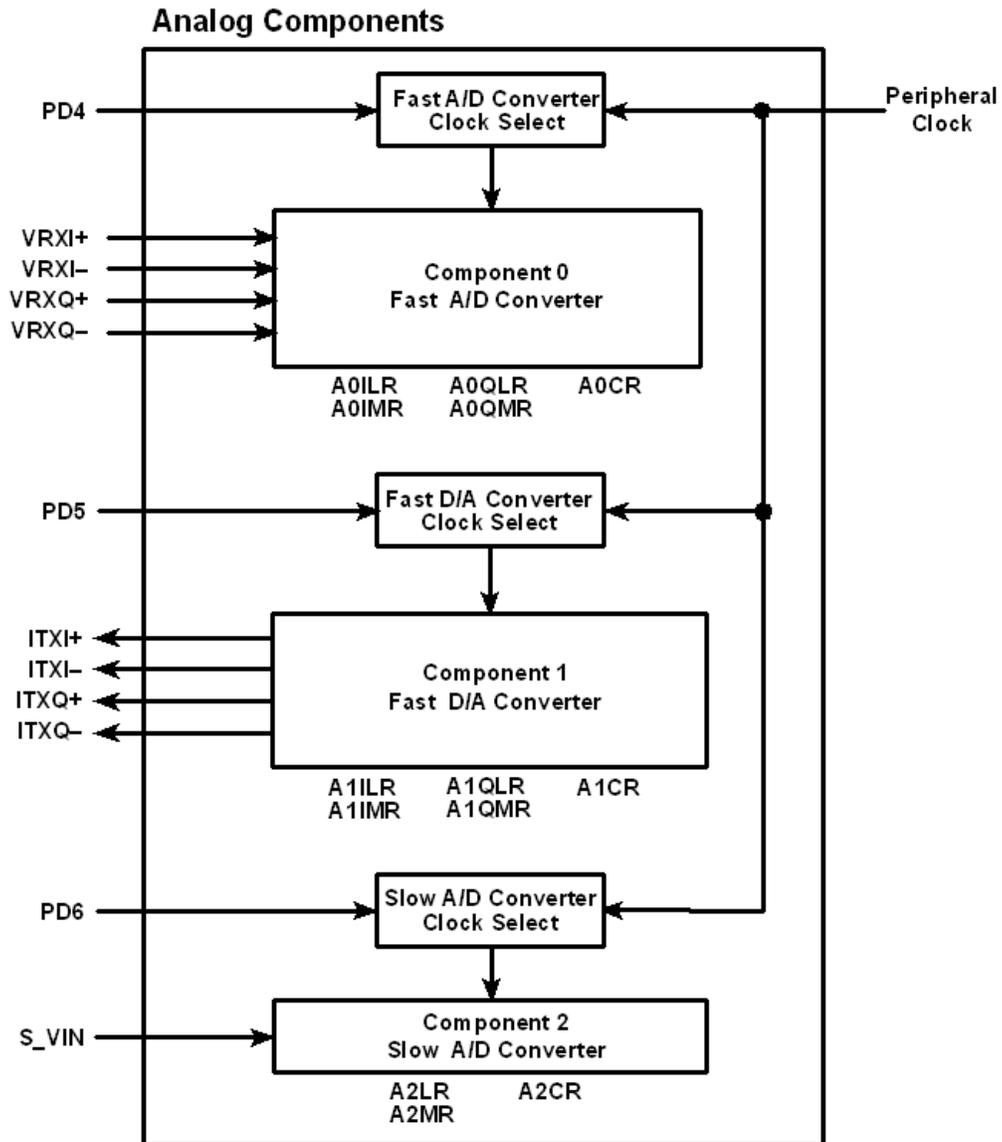
Table 22-2. Wi-Fi Analog Component Specifications

Analog Component	Feature	Specification
0 Wi-Fi fast A/D converter	Resolution	10 bits
	Max sample rate Clock	40 megasamples/sec 40MHz
	Input Range Common mode Differential	0.6 V ± 0.5 V from common mode
	Operating Current Active Standby Power down	40 mA @ 1.2 V 3.5 mA @ 1.2 V 10 μ A @ 1.2 V
	Nonlinearity Differential (DNL) Integral (INL)	± 0.7 LSB typ. ± 1.2 LSB typ.
	1 Wi-Fi fast D/A converter	Resolution
Max sample rate Clock		80 megasamples/sec 80 MHz
Output Range		0 – 4 mA
Output Loading Capacitive Resistance		5 pF max 225 Ω max
Output Voltage Compliance Range		-0.2V to 1.45V
Operating Current Active Standby Power down		13 mA @ 2.5 V 0.7 mA @ 2.5V < 1 μ A @ 2.5 V
Nonlinearity Differential (DNL) Integral (INL)		± 0.5 LSB typ. ± 1 LSB typ.

Table 22-2. Wi-Fi Analog Component Specifications

Analog Component	Feature	Specification
2 Wi-Fi slow A/D converter	Resolution	11 bits
	Max sample rate Clock	1 megasample/sec 13MHz
	Input Range Single-ended	0.1 x VCC33A to 0.9 x VCC33A
	Operating Current Active Standby	5 mA @ 3.3 V < 10 μ A @ 3.3 V
	Nonlinearity Differential (DNL) Integral (INL)	\pm 0.8 LSB typ. \pm 2 LSB typ.

22.2 Block Diagram



22.2.1 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Analog Component 0 I LSB Register	A0ILR	0x0800	R/W	xxxxxxxx
Analog Component 0 I MSB Register	A0IMR	0x0801	R/W	xxxxxxxx
Analog Component 0 Q LSB Register	A0QLR	0x0802	R/W	xxxxxxxx
Analog Component 0 Q MSB Register	A0QMR	0x0803	R/W	xxxxxxxx
Analog Component 0 Control Register	A0CR	0x0804	R/W	00000000
Analog Component 1 I LSB Register	A1ILR	0x0810	R/W	xxxxxxxx
Analog Component 1 I MSB Register	A1IMR	0x0811	R/W	xxxxxxxx
Analog Component 1 Q LSB Register	A1QLR	0x0812	R/W	xxxxxxxx
Analog Component 1 Q MSB Register	A1QMR	0x0813	R/W	xxxxxxxx
Analog Component 1 Control Register	A1CR	0x0814	R/W	00000000
Analog Component 2 LSB Register	A2LR	0x0820	R/W	xxxxxxxx
Analog Component 2 MSB Register	A2MR	0x0821	R/W	xxxxxxxx
Analog Component 2 Control Register	A2CR	0x0824	R/W	00000000

22.3 Dependencies

22.3.1 I/O Pins

The fast A/D converter accepts differential input on the pin pairs VRXI+/VRXI- and VRXQ+/VRXQ-. The AD_RSET pin should be connected as shown in the sample circuit in Figure 22.1. The VBG pin is for testing use only and should remain unconnected.

The fast D/A converter provides differential current output from 0–4mA on the pin pairs ITXI+/ITXI- and ITXQ+./ITXQ-. DA_RSET and COMP should be connected as shown in the sample circuit in Figure 22.2. Note that the fast D/A converter uses the 2.5 V power from an internal regulator; the proper connection for this is also in the sample circuit diagram.

The slow A/D converter accepts a single input on the S_VIN pin. The S_AD_REF+ and S_AD_REF- pins are for testing use only and should remain unconnected. The sample circuit is shown in Figure 22.3.

The PD4, PD5, and PD6 pins can be used instead of the peripheral clock as clock inputs for analog component 0, 1, or 2 respectively.

22.3.2 Clocks

Each of the analog components can be clocked by the peripheral clock divided by 2, 4, 8, 16, 32, 64, 128, or 256, or by a clock input on PD4, PD5, or PD6, depending on the component. Exercise care when selecting the clock to keep the data rate below the maximum sample rate of the component you are configuring.

22.4 Operation

22.4.1 Fast A/D Converter

The following steps must be taken to operate the fast A/D converter.

1. Select the clock source and enable the fast A/D converter by writing to A0CR.
2. Read the channel data in the A0IxR and A0QxR registers. Reading the least-significant bit registers first will lock the value in the most-significant bit register until it is read.
3. For faster update, an 8-bit value can be obtained by only reading the most-significant bit registers (A0IMR or A0QMR).
4. To reduce power consumption, the fast A/D converter can be put into sleep mode by writing to A0CR.

22.4.2 Fast D/A Converter

The following steps must be taken to operate the fast D/A converter.

1. Select the clock source and enable the fast D/A converter by writing to A1CR.
2. Write the channel data to the A1IxR and A1QxR registers. Writing the least-significant bit registers first will hold the conversion output until the most-significant bit register is written.
3. For faster update, an 8-bit value can be output by only writing the most-significant bit registers (A1IMR or A1QMR).
4. To reduce power consumption, the fast D/A converter can be put into sleep mode by writing to A1CR.

22.4.3 Slow A/D Converter

The following steps must be taken to operate the slow A/D converter.

1. Select the clock source and enable the slow A/D converter by writing to A2CR.
2. Start a conversion by writing to bit 2 of A2CR.
3. Monitor bit 3 of A2CR to determine when the conversion is complete, then read the data in the A2LR and A2MR registers. Reading the least-significant bit registers first will lock the value in the most-significant bit register until it is read.
4. For faster update, an 8-bit value can be obtained by only reading A2MR.
5. To reduce power consumption, the slow A/D converter can be put into a sleep mode by writing to A2CR.

22.5 Sample Circuits

Sample circuits are shown below for the analog components. Since each analog component has dedicated power and ground, be sure to allow enough filtering for each block as shown — a range of ferrite beads may be used — we obtained good results with ferrite beads rated at $120\ \Omega$ at $100\ \text{MHz}$. Also note that a common ground plane is used; better results may be expected if a separate analog ground plane is laid out.

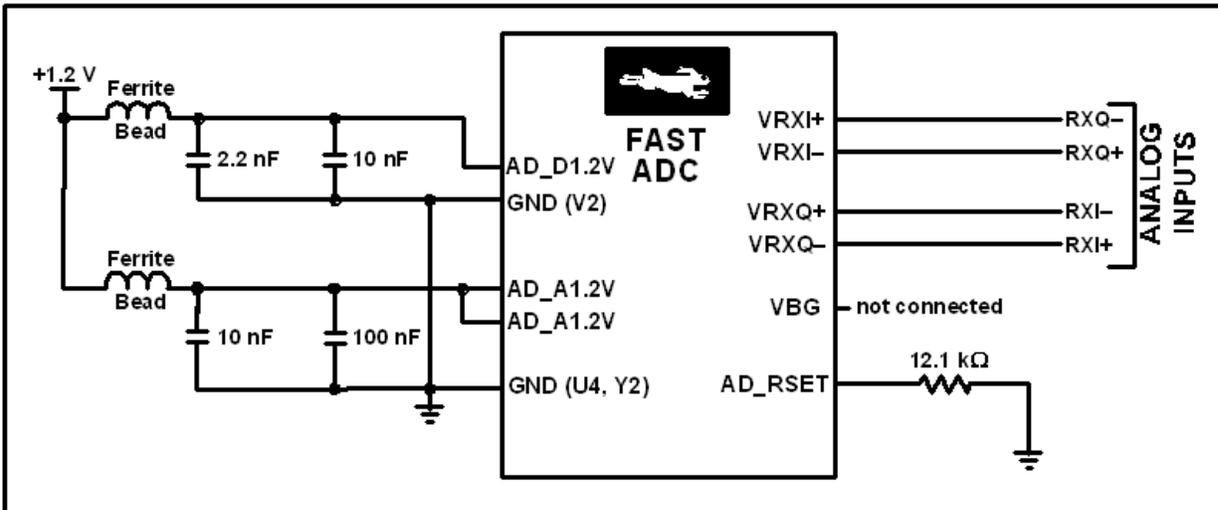


Figure 22.1 Sample Fast A/D Converter Circuit

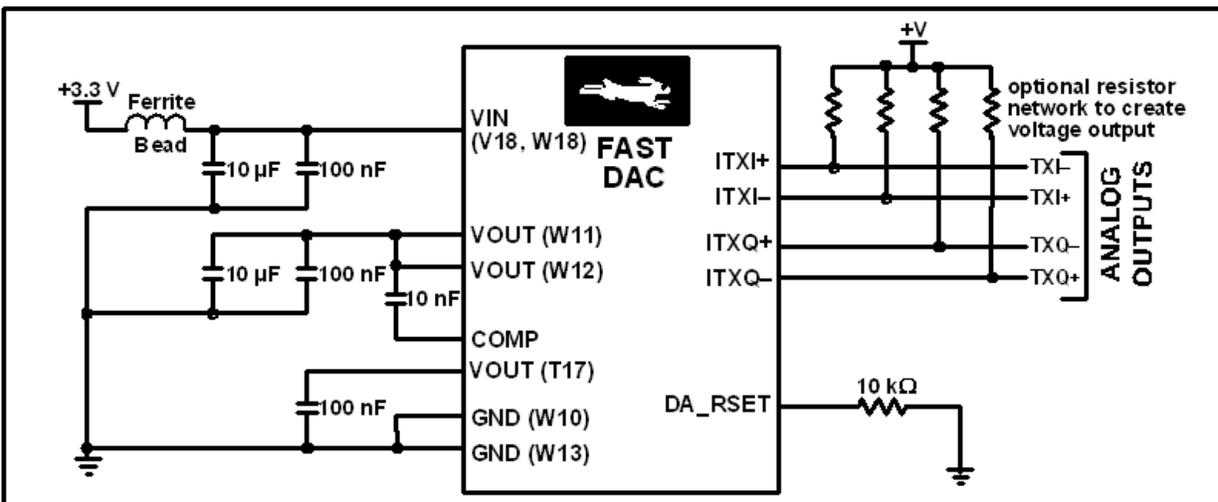


Figure 22.2 Sample Fast D/A Converter Circuit

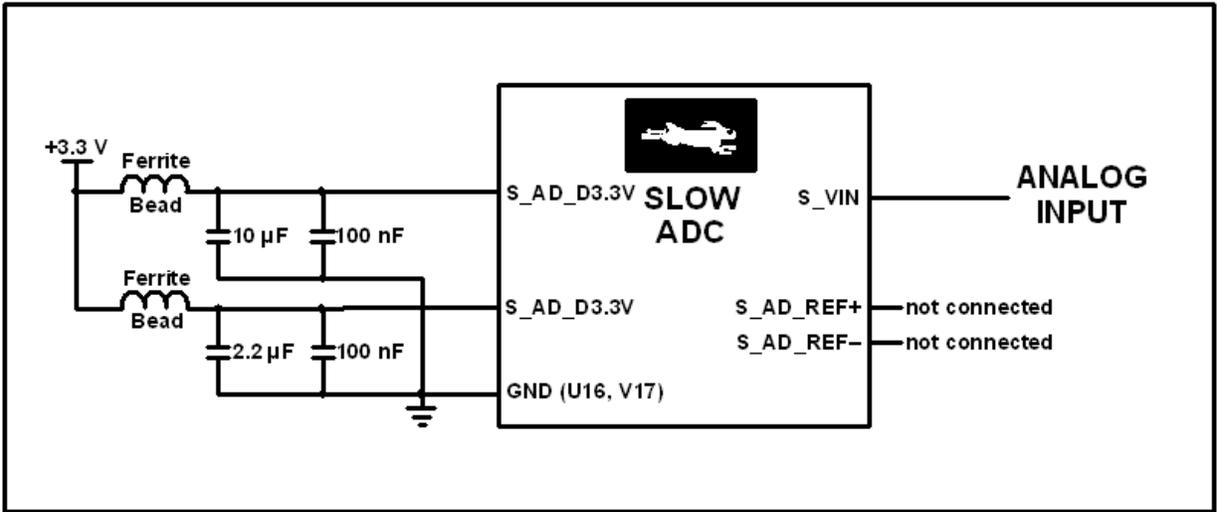


Figure 22.3 Sample Slow A/D Converter Circuit

22.6 Register Descriptions

Analog Component 0 I LSB Register Analog Component 0 Q LSB Register		(A0ILR) (A0QLR)	(Address = 0x0800) (Address = 0x0802)
Bit(s)	Value	Description	
7:6	Read	The current value of the two least-significant bits of the fast A/D converter are returned. Reading this register locks the value in the corresponding MSB register to guarantee that the full 10 bits are valid.	
	Write	Writes to these bits are ignored.	
5:0		These bits are ignored and will always return zeros when read.	

Analog Component 0 I MSB Register Analog Component 0 Q MSB Register		(A0IMR) (A0QMR)	(Address = 0x0801) (Address = 0x0803)
Bit(s)	Value	Description	
7:0	Read	The current value of the eight most-significant bits of the fast A/D converter are returned.	
	Write	Writes to this register are ignored.	

Analog Component 0 Control Register (A0CR) (Address = 0x0804)		
Bit(s)	Value	Description
7	0	Use peripheral clock as fast A/D converter clock source.
	1	Use Parallel Port PD4 as fast A/D converter clock source.
6:4	000	Clock divided by 2.
	001	Clock divided by 4.
	010	Clock divided by 8.
	011	Clock divided by 16.
	100	Clock divided by 32.
	101	Clock divided by 64.
	110	Clock divided by 128.
	111	Clock divided by 256.
3:2		These bits are reserved and should be written with zeros.
1:0	00	Fast A/D converter powered down.
	01	Fast A/D converter in sleep mode.
	10	This bit combination is reserved and should not be used.
	11	Fast A/D converter active.

Analog Component 1 I LSB Register (A1ILR) (Address = 0x0810) Analog Component 1 Q LSB Register (A1QLR) (Address = 0x0812)		
Bit(s)	Value	Description
7:6	Write	The two least-significant bits for the fast D/A converter are stored. These bits will not be transferred to the fast D/A converter until the corresponding MSB register is written to guarantee that the full 10 bits are valid.
	Read	These bits always return zeros when read.
5:0		These bits are ignored and will always return zeros when read.

Analog Component 1 I MSB Register		(A1IMR)	(Address = 0x0811)
Analog Component 1 Q MSB Register		(A1QMR)	(Address = 0x0813)
Bit(s)	Value	Description	
7:0	Write	The eight most-significant bits for the fast D/A converter are stored. Writing these bits transfers the entire 10 bits to the fast D/A converter.	
	Read	These bits always return zeros when read.	

Analog Component 1 Control Register		(A1CR)	(Address = 0x0814)
Bit(s)	Value	Description	
7	0	Use peripheral clock as fast D/A converter clock source.	
	1	Use Parallel Port PD5 as fast D/A converter clock source.	
6:4	000	Clock divided by 2.	
	001	Clock divided by 4.	
	010	Clock divided by 8.	
	011	Clock divided by 16.	
	100	Clock divided by 32.	
	101	Clock divided by 64.	
	110	Clock divided by 128.	
	111	Clock divided by 256.	
3		This bit is reserved and should be written as zero.	
2	0	Fast D/A converter uses 2's compliment coding.	
	1	Fast D/A converter uses binary encoding.	
1:0	00	Fast D/A converter powered down.	
	01	Fast D/A converter in sleep mode.	
	10	This bit combination is reserved and should not be used.	
	11	Fast D/A converter active.	

Analog Component 2 LSB Register (A2LR) (Address = 0x0820)		
Bit(s)	Value	Description
7:5	Read	The current value of the three least-significant bits of the slow A/D converter are returned. Reading this register locks the value in the corresponding MSB register to guarantee that the full 11 bits are valid.
	Write	Writes to this register are ignored.
4:0		These bits are ignored and will always return zeros when read.

Analog Component 2 MSB Register (A2MR) (Address = 0x0821)		
Bit(s)	Value	Description
7:0	Read	The current value of the eight most-significant bits of the slow A/D converter are returned.
	Write	Writes to this register are ignored.

Analog Component 2 Control Register (A2CR) (Address = 0x0824)		
Bit(s)	Value	Description
7	0	Use peripheral clock as slow A/D converter clock source.
	1	Use Parallel Port PD6 as slow A/D converter clock source.
6:4	000	Clock divided by 2.
	001	Clock divided by 4.
	010	Clock divided by 8.
	011	Clock divided by 16.
	100	Clock divided by 32.
	101	Clock divided by 64.
	110	Clock divided by 128.
	111	Clock divided by 256.
3 (Read-only)	0	Conversion not complete.
	1	Conversion complete.
2 (Write-only)	0	No effect on slow A/D converter.
	1	Start conversion.
1		This bit is reserved and should be written as zero.
0	0	Slow A/D converter in sleep mode.
	1	Slow A/D converter active.

23. ANALOG/DIGITAL CONVERTER

23.1 Overview

The Rabbit 6000 has a 1 megasamples/s, 12-bit A/D converter with a separate 8-channel multiplexer available at all times. Each individual multiplexer channel can be read separately. Note that use of the multiplexer reduces the effective accuracy to 11 bits.

The actual conversion rates depend on the clock sources used — each analog component can accept a clock from an external I/O pin or divide the peripheral clock by a value between 2 and 256.

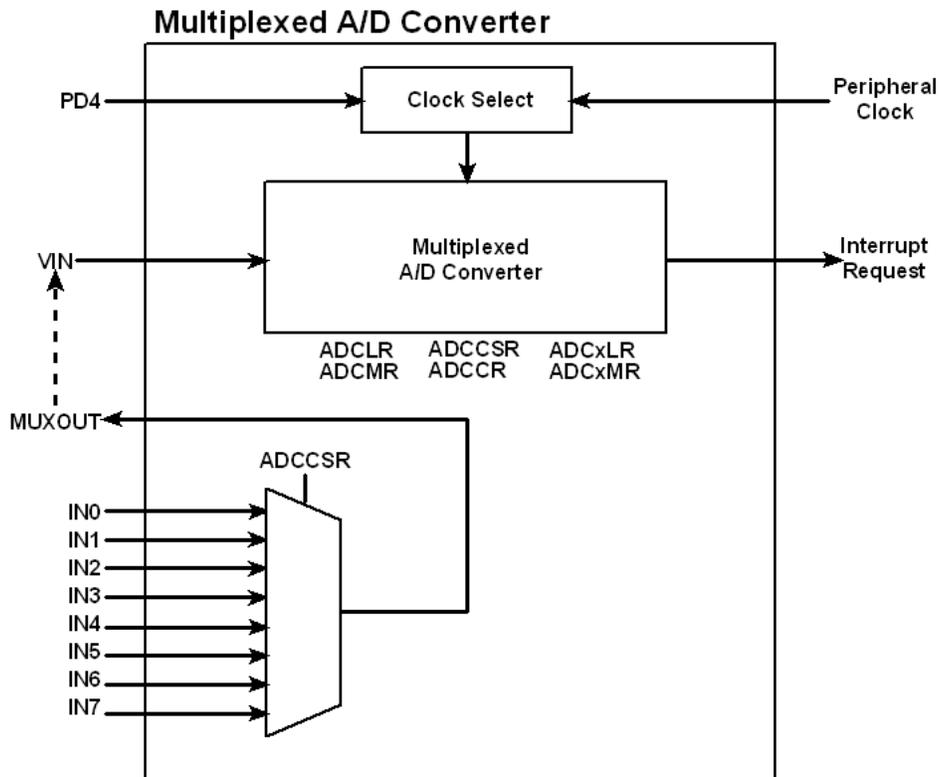
The Rabbit 6000 also has a 11-bit single-channel A/D converter, a 10-bit two-channel differential-input A/D converter, and a 10-bit two-channel differential-output D/A converter for 802.11 Wi-Fi operation. The Wi-Fi analog features are available for customer use when Wi-Fi is not being used; see Chapter 22 for more information.

Table 23-1 lists the detailed features for the multiplexed A/D converter.

Table 23-1. Multiplexed A/D Converter Specifications

Analog Component	Feature	Specification
Dedicated A/D converter with MUX	Resolution	12 bits (accuracy is 11 if mux is used)
	Max sample rate Clock	1 megasample/sec 13MHz
	A/D Input Range	0.07 V - 3.23 V
	Mux Input Range	0V - 3.3V
	Operating Current Active Power down	5 mA @ 3.3 V 5 μ A @ 3.3 V
	Nonlinearity Differential (DNL) Integral (INL)	± 0.8 LSB typ. ± 2 LSB typ.

23.2 Block Diagram



23.2.1 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
ADC LSB Register	ADCLR	0x0540	R	00000000
ADC MSB Register	ADCMR	0x0541	R	00000000
ADC Command/Status Register	ADCCSR	0x0543	R/W	00000000
ADC Control Register	ADCCR	0x0544	R/W	00000000
ADC x LSB Register	ADCxLR	$0x0550 + 2*x$	R	00000000
ADC x MSB Register	ADCxMR	$0x0551 + 2*x$	R	00000000

NOTE: x = Mux channel number (0-7).

23.3 Dependencies

23.3.1 I/O Pins

The A/D converter is physically separated from the multiplexer on the chip. The multiplexer accepts inputs on pins IN7–IN0, and outputs the selected channel on MUXOUT. The A/D converter accepts input on VIN. If desired, conditioning circuitry can be placed between MUXOUT and VIN, or they can simply be connected directly.

External voltage references can be used with the multiplexed A/D converter; if enabled they should be supplied on REF+ and REF-.

The PD4 pin can be used as a clock input instead of the peripheral clock.

23.3.2 Clocks

The A/D converter can be clocked by the peripheral clock divided by 2, 4, 8, 16, 32, 64, 128, or 256, or by a clock input on PD4, depending on the value set in ADCCR. Exercise care when selecting the clock to keep the data rate below the maximum sample rate of the component you are configuring.

23.4 Operation

23.4.1 Single Reading

The following steps must be taken to operate the multiplexed A/D converter in the single-read mode:

1. Select the clock source and enable the multiplexed A/D converter by writing to ADCCR.
2. Select the multiplexer channel and desired reference in ADCCSR, but do not start the conversion yet. This provides greater settle time for the multiplexer switchover.
3. Enable a conversion by setting bit 0 of ADCCSR.
4. Wait for the conversion to complete by monitoring bits 0-1 of ADCLR. When complete, read the rest of the A/D converter result in ADCMR.

23.4.2 Continuous Read

The following steps must be taken to operate the multiplexed A/D converter in the continuous-read mode:

1. Select the clock source and enable the multiplexed A/D converter by writing to ADCCR.
2. Enable the continuous read mode by setting bit 7 of ADCCSR.
3. To get a particular channel reading, check bits 0–1 of the ADCxLR that corresponds to that channel. If the conversion is complete, read ADCxMR as well to get the full reading.

23.4.3 Handling Interrupts

The following steps explain how an interrupt is used.

1. Write the vector to the interrupt service routine to the internal interrupt table
2. Configure ADCR to select the interrupt priority (note that interrupts will be enabled once this value is set; this step should be done last).

The following actions occur within the interrupt service routine.

- Read ADCLR to get the 4 least-significant bits of the result and clear the interrupt flag.
- Read ADCMR to get the 8 most-significant bits of the result.

23.5 Sample Circuit

A sample circuit is shown below for the analog components. For more information about possible post-multiplexer/pre-A/D converter filtering circuits, please contact your sales representative at Digi International.

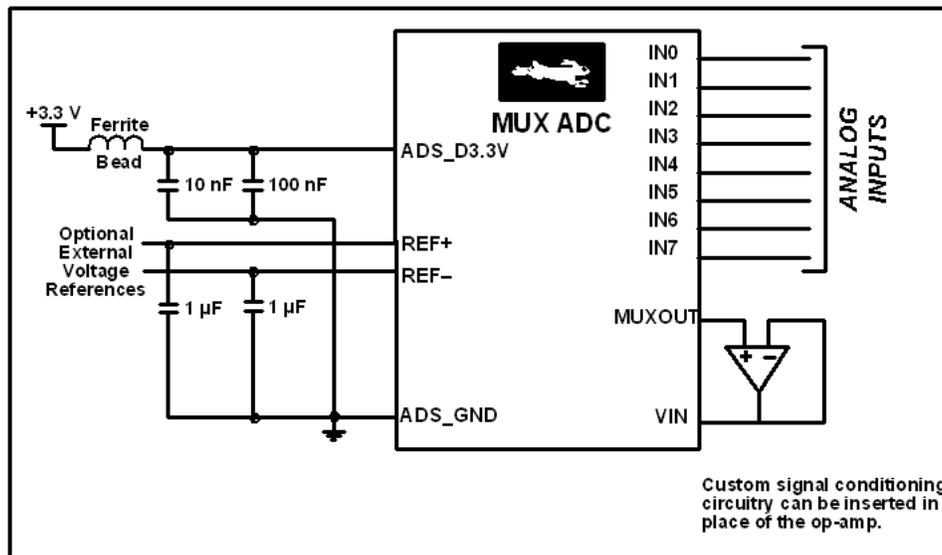


Figure 23.1 Sample Multiplexed A/D Converter Circuit

23.6 Register Descriptions

ADC LSB Register (ADCLR) (Address = 0x0540)		
Bit(s)	Value	Description
7:0	Write	Writes to this register are ignored.
7:4	Read	The current values of the 4 least-significant bits of the multiplexed A/D converter channel are returned. Reading this register locks the value in the corresponding MSB register to guarantee that the full 12 bits are valid. The channel is selected in ADCCSR.
3:2	Read	These bits always return zeros when read.
1	0	No conversion is running.
	1	A conversion is in progress.
0	0	Conversion is not complete or data have been read.
	1	Conversion is complete. This bit is cleared by a read of this register.

ADC MSB Register (ADCMR) (Address = 0x0541)		
Bit(s)	Value	Description
7:0	Read	The current values of the 8 most-significant bits of the multiplexed A/D converter channel are returned. The channel is selected in ADCCSR.
	Write	Writes to this register are ignored.

ADC Command/Status Register (ADCCSR) (Address = 0x0543)		
Bit(s)	Value	Description
7	0	Normal processor-controlled conversions.
	1	Continuous conversions for each channel sequentially.
6:4	000	Select A/D Converter Channel 0 for conversion.
	001	Select A/D Converter Channel 1 for conversion.
	010	Select A/D Converter Channel 2 for conversion.
	011	Select A/D Converter Channel 3 for conversion.
	100	Select A/D Converter Channel 4 for conversion.
	101	Select A/D Converter Channel 5 for conversion.
	110	Select A/D Converter Channel 6 for conversion.
	111	Select A/D Converter Channel 7 for conversion.
3:2	00	Floating reference.
	01	Internal reference (0.1VDDA – 0.9VDDA).
	10	External reference (REF+ and REF- pins).
	11	Internal reference (rail-to-rail).
1		This bit is reserved and should be written as zero. Reads always return zero.
0	0	No conversion start. This bit always returns zero during read.
	1	Start conversion command, using the accompanying channel selection. This command is ignored while in the continuous conversion mode. This command can be issued while another conversion is running for maximum throughput.

ADC Control Register (ADCCR) (Address = 0x0544)		
Bit(s)	Value	Description
7	0	Use peripheral clock as multiplexed A/D converter clock source.
	1	Use PD4 as multiplexed A/D converter clock source.
6:4	000	Clock divided by 2.
	001	Clock divided by 4.
	010	Clock divided by 8.
	011	Clock divided by 16.
	100	Clock divided by 32.
	101	Clock divided by 64.
	110	Clock divided by 128.
	111	Clock divided by 256.
3		This bit is reserved and should be written with zero.
2	0	Multiplexed A/D converter powered down.
	1	Multiplexed A/D converter active.
1:0	00	Multiplexed A/D converter interrupt is disabled.
	01	Multiplexed A/D converter uses Interrupt Priority 1.
	10	Multiplexed A/D converter uses Interrupt Priority 2.
	11	Multiplexed A/D converter uses Interrupt Priority 3.

ADC x LSB Register		
(ADC0LR)	(Address = 0x0550)	
(ADC1LR)	(Address = 0x0552)	
(ADC2LR)	(Address = 0x0554)	
(ADC3LR)	(Address = 0x0556)	
(ADC4LR)	(Address = 0x0558)	
(ADC5LR)	(Address = 0x055A)	
(ADC6LR)	(Address = 0x055C)	
(ADC7LR)	(Address = 0x055E)	
Bit(s)	Value	Description
7:0	Write	Writes to this register are ignored.
7:4	Read	The current values of the 4 least-significant bits of the multiplexed A/D converter channel are returned. Reading this register locks the value in the corresponding MSB register to guarantee that the full 12 bits are valid.
3:2	Read	These bits always return zeros when read.
1	0	No conversion is running.
	1	A conversion for this channel is in progress.
0	0	Conversion is not complete or data have been read.
	1	Conversion for this channel is complete. This bit is cleared by a read of this register.

ADC x MSB Register		
(ADC0MR)	(Address = 0x0551)	
(ADC1MR)	(Address = 0x0553)	
(ADC2MR)	(Address = 0x0555)	
(ADC3MR)	(Address = 0x0557)	
(ADC4MR)	(Address = 0x0559)	
(ADC5MR)	(Address = 0x055B)	
(ADC6MR)	(Address = 0x055D)	
(ADC7MR)	(Address = 0x055F)	
Bit(s)	Value	Description
7:0	Read	The current values of the 8 most-significant bits of the multiplexed A/D converter channel are returned.
	Write	Writes to this register are ignored.

24. DMA CHANNELS

24.1 Overview

There are 16 independent DMA channels on the Rabbit 6000. All 16 channels are identical, and are capable of transferring data between memory, external I/O, or internal I/O. The priority among the channels can be either fixed or rotating, and the DMA use of the external bus can be limited to guarantee interrupt latency or CPU throughput. The DMA channels are capable of special handling for the last byte of data when sending data to selected internal I/O addresses (such as the HDLC serial ports or to the Ethernet peripheral), and can also transfer end-of-frame status after transferring data from selected internal I/O addresses.

The DMA channels can watch the data being transferred, and can terminate a transfer when a particular byte is matched. A mask is available for the byte match to allow termination only on particular bit settings in the data instead of an exact byte match.

There are two DMA transfer methods available in the Rabbit 6000 — the bus-interleaving mode and the bus-sharing mode. If all sources and destinations are internal to the device, the bus-interleaving mode should be used. In this mode, the pipelined functionality of the internal SRAM allows both DMA and code execution to occur simultaneously, as shown in Figure 24.1. This mode is different from the DMA functionality in previous processors, and is enabled by default whenever possible.

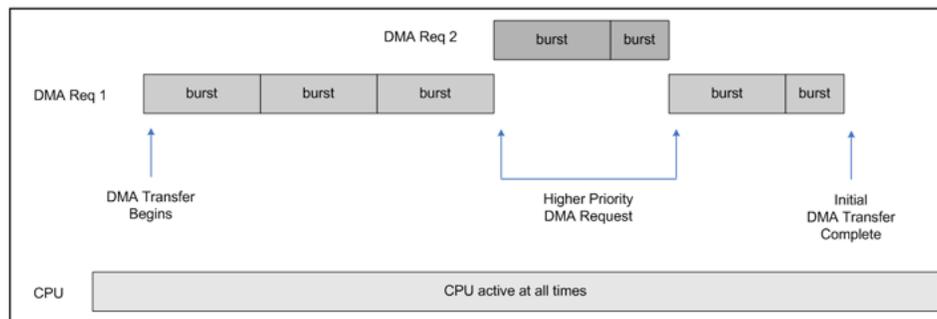


Figure 24.1 Bus-Interleaving Mode

The other mode is used whenever an external device is used for the source or destination, and matches the DMA behavior of the Rabbit 4000 and 5000 processors. In this bus-sharing mode, the memory bus alternates between DMA and processor use, as shown in Figure 24.2. When DMA is active, the CPU is not processing instructions, and vice-versa.

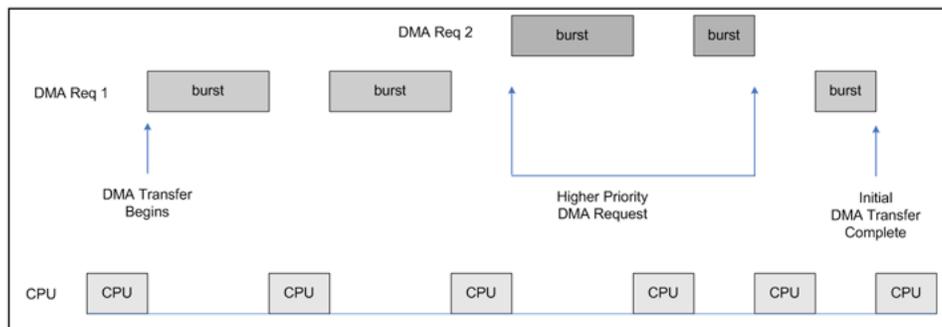


Figure 24.2 Bus-Sharing Mode

Memory-to-memory transfers proceed at the maximum transfer rate unless they are gated by an external request signal or the internal timed request. Transfers to or from a number of internal I/O addresses are controlled by transfer request signals. These transfer request signals are connected automatically as a function of the internal I/O address loaded into the DMA channel. Note that if both the source and the destination are internal I/O, the source register’s transfer request is used by the DMA channel and not the destination register’s request.

The DMA channels support both byte and word transfers, although most I/O transfers are byte only (the Ethernet, Wi-Fi, and USB ports are special cases). When the 16-bit bus is enabled and the DMA source or destination address is a network port data register, the DMA will attempt to transfer words if the memory address is aligned. The same is true for memory-to-memory transfers if both the source and the destination addresses are aligned.

There are two inputs available for requests linked to external I/O devices, DREQ0 and DREQ1. These two external requests may be assigned to any DMA channel. These requests may also be used by a channel that has an internal I/O as a destination. In this case, the external request acts as a “flow control” signal for the DMA transfers because the external request is “ANDed” with the automatically connected internal request.

To facilitate periodic DMA transfers, there is also an internal *timed request*. This request is generated from a programmable 16-bit counter and may be assigned to any DMA channel. As in the case of the external requests, this request is “ANDed” with any internal or external request that is also assigned to that DMA channel. This periodic request can be programmed to transfer one byte or an entire buffer. The single-byte option is useful for driving an output port to create a sampled waveform, while the entire-buffer option can be used, for example, to send precisely timed serial messages over a serial port.

The DMA Timed Request is generated by a 16-bit down-counter clocked by the peripheral clock divided by two. The counter counts down from the limit programmed into the DMA Timed Request Divider registers to zero and then reloads. The timed request is generated by the reload condition.

The DMA operation is controlled by memory structures called buffer descriptors. The current buffer descriptor resides in the registers of the DMA channel, but may have been either placed there by the processor or loaded directly by the DMA channel itself. Buffer descriptors may be used singly to transfer one block of data, or they may be linked together for “scatter-gather” operation. Each DMA channel also contains an “initial address” that points to the first buffer descriptor in memory and allows the DMA channel to rewind itself automatically in the case of a transmit retry by the network port. Each buffer descriptor contains a

pair of control bytes, a byte count for the data, a source address, a destination address, and an optional link address. In addition, each DMA channel retains a count of the number of bytes remaining in the buffer to allow software to determine the amount of valid data in a buffer that are terminated early by the source of the data.

A buffer descriptor in memory consists of either 12 or 16 consecutive bytes organized as shown in Table 24-2. The DMA channel uses the information in the control byte to determine the length of the buffer descriptor as well as which information to fetch from the buffer descriptor. If no link address field is present, the buffer descriptor is only 12 bytes long. A memory address for either source or destination causes the DMA channel to fetch three bytes from the corresponding field in the buffer descriptor. An internal I/O or external I/O address for either source or destination causes the DMA channel to fetch two bytes from the corresponding field in the buffer descriptor.

DMA memory addresses are always physical addresses, and are never translated by the MMU. All DMA memory addresses use the memory control signals, wait states, and flipped bits as selected in the Master Memory Bank Control registers. All DMA external I/O addresses use the I/O control signals and wait states as selected in the external I/O registers.

The first byte in the first buffer descriptor (the byte pointed to by the initial address) is reserved for status information when transferring data from an internal serial or network device. This automatic status transfer means that the processor does not need to service any interrupts from a serial or network receiver except in the case of an error condition.

When transferring data to an internal HDLC serial or Ethernet transmitter, the last byte of the last buffer will be written automatically to a special destination address to tag the data as the last in the frame, without processor intervention. However, this function is not available in the case where the buffer contains only one byte of data. If this case should occur, the buffer descriptor must contain the special destination address.

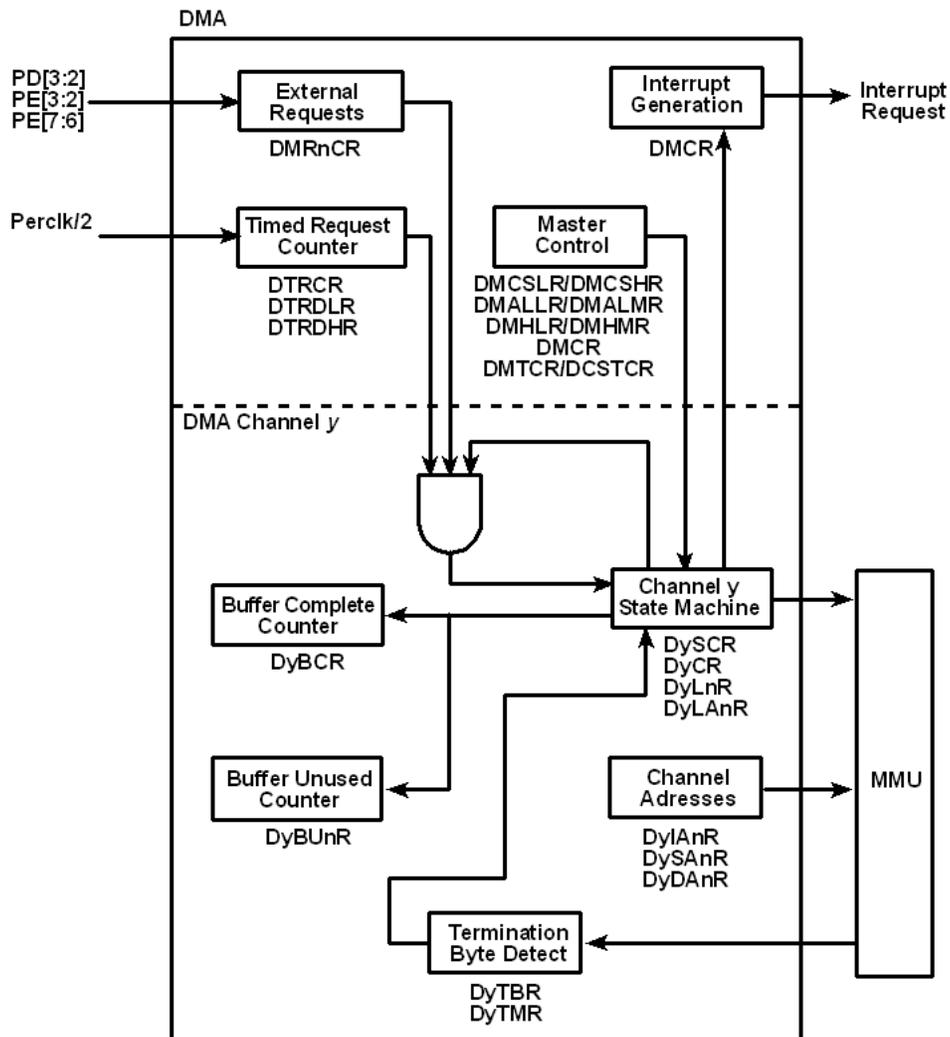
All the DMA channels request interrupts at the same priority level, which is set by a field in the DMA Master Control Register, but each DMA channel has its own interrupt vector location. This speeds up interrupt processing for the DMA interrupts by eliminating the need to resolve which DMA channel is actually requesting an interrupt.

DMA transfers may be programmed to occur at any priority level. If the programmed level is greater than or equal to the current CPU operating level, DMA transfers will occur on demand. When the CPU operating level is greater than the programmed DMA operating level, no DMA transfers can occur. This allows interrupt services routines, or other critical code, to run with a guarantee that there will be no DMA activity during execution. Note that a simultaneous interrupt request and DMA transfer request will be resolved in favor of the DMA transfer request.

Normally all DMA transfers are flow-through, meaning that the DMA does separate read and write transactions to transfer the data. However, the Rabbit 6000 DMA also contains dedicated buses to support fly-by transactions to and from certain internal I/O addresses on the Ethernet, Wi-Fi, and USB peripherals. A fly-by transfer looks like a single transaction on the internal and external bus, where data are transferred directly to/from the peripheral from/to a memory device. The DMA automatically recognizes internal I/O addresses that support fly-by transfers.

Operating the DMA with the USB peripheral is complicated by the fact that the USB controller needs access to a number of different data streams to and from memory. There is a special control field in DxSCR to identify the two DMA channels dedicated to the USB controller, one for reading from memory and one for writing to memory. Only one channel can be enabled for each direction at a time. No other DMA programming is required for the two DMA channels dedicated to the USB controller as the controller handles all the other setup.

24.1.1 Block Diagram



24.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
DMA Master Control/Status LSB Register	DMCSLR	0x0100	R/W	00000000
DMA Master Control/Status MSB Register	DMCSMR	0x0101	R/W	00000000
DMA Master Auto-load LSB Register	DMALLR	0x0110	W	00000000
DMA Master Auto-load MSB Register	DMALMR	0x0111	W	00000000
DMA Master Halt LSB Register	DMHLR	0x0120	W	00000000
DMA Master Halt MSB Register	DMHMR	0x0121	W	00000000
DMA y Buffer Complete Register	DyBCR	0x0103 *	R	00000000
DMA Master Control Register	DMCR	0x0104	R/W	00000000
DMA Master Timing Control Register	DMTCR	0x0105	R/W	00000000
DMA Master Request 0 Control Register	DMR0CR	0x0106	R/W	00000000
DMA Master Request 1 Control Register	DMR1CR	0x0107	R/W	00000000
DMA Timed Request Control Register	DTRCR	0x0115	R/W	00000000
DMA Timed Request Divider Low Register	DTRDLR	0x0116	R/W	xxxxxxxx
DMA Timed Request Divider High Register	DTRDHR	0x0117	R/W	xxxxxxxx
DMA Cycle-Steal Timing Control Register	DCSTCR	0x0125	R/W	xx000000
DMA y Termination Byte Register	DyTBR	0x0108 *	R/W	xxxxxxxx
DMA y Termination Mask Register	DyTMR	0x0109 *	R/W	00000000
DMA y Buffer Unused [7:0] Register	DyBU0R	0x010A *	R	00000000
DMA y Buffer Unused [15:8] Register	DyBU1R	0x010B *	R	00000000
DMA y Initial Address [7:0] Register	DyIA0R	0x010C *	R/W	xxxxxxxx
DMA y Initial Address [15:8] Register	DyIA1R	0x010D *	R/W	xxxxxxxx
DMA y Initial Address [23:16] Register	DyIA2R	0x010E *	R/W	xxxxxxxx
DMA y Special Control Register	DySCR	0x0180 *	R/W	00000000
DMA y Control Register	DyCR	0x0181 *	R/W	00000000
DMA y Buffer Length [7:0] Register	DyL0R	0x0182 *	R/W	xxxxxxxx
DMA y Buffer Length [15:8] Register	DyL1R	0x0183 *	R/W	xxxxxxxx
DMA y Source Address [7:0] Register	DySA0R	0x0184 *	R/W	xxxxxxxx
DMA y Source Address [15:8] Register	DySA1R	0x0185 *	R/W	xxxxxxxx

Register Name	Mnemonic	I/O Address	R/W	Reset
DMA y Source Address [23:16] Register	DySA2R	0x0186 *	R/W	xxxxxxxx
DMA y Destination Addr [7:0] Register	DyDA0R	0x0188 *	R/W	xxxxxxxx
DMA y Destination Addr [15:8] Register	DyDA1R	0x0189 *	R/W	xxxxxxxx
DMA y Destination Addr [23:16] Register	DyDA2R	0x018A *	R/W	xxxxxxxx
DMA y Link Address [7:0] Register	DyLA0R	0x018C *	R/W	xxxxxxxx
DMA y Link Address [15:8] Register	DyLA1R	0x018D *	R/W	xxxxxxxx
DMA y Link Address [23:16] Register	DyLA2R	0x018E *	R/W	xxxxxxxx

NOTE: The y in “DMA y ...” expresses the DMA channel number (0–15).

The I/O address shown with an asterisk is the address of the DMA Channel 0 register. To find the address of the corresponding register a different DMA channel, refer to Table 24-1.

Table 24-1. DMA Channel-Specific Register Mapping

Register Name	DMA Channels 0-7	DMA Channels 8-15
$y = 0-15$	$v = y+8$	$z = y-8$
DMA y Buffer Complete Register	0x01y3	0x09z3
DMA y Termination Byte Register	0x01y8	0x09z8
DMA y Termination Mask Register	0x01y9	0x09z9
DMA y Buffer Unused [7:0] Register	0x01yA	0x09zA
DMA y Buffer Unused [15:8] Register	0x01yB	0x09zB
DMA y Initial Address [7:0] Register	0x01yC	0x09zC
DMA y Initial Address [15:8] Register	0x01yD	0x09zD
DMA y Initial Address [23:16] Register	0x01yE	0x09zE
DMA y Special Control Register	0x01v0	0x09y0
DMA y Control Register	0x01v1	0x09y1
DMA y Buffer Length [7:0] Register	0x01v2	0x09y2
DMA y Buffer Length [15:8] Register	0x01v3	0x09y3
DMA y Source Address [7:0] Register	0x01v4	0x09y4
DMA y Source Address [15:8] Register	0x01v5	0x09y5
DMA y Source Address [23:16] Register	0x01v6	0x09y6
DMA y Destination Addr [7:0] Register	0x01v8	0x09y8
DMA y Destination Addr [15:8] Register	0x01v9	0x09y9
DMA y Destination Addr [23:16] Register	0x01vA	0x09yA
DMA y Link Address [7:0] Register	0x01vC	0x09yC

Register Name	DMA Channels 0-7	DMA Channels 8-15
DMA y Link Address [15:8] Register	0x01vD	0x09yD
DMA y Link Address [23:16] Register	0x01vE	0x09yE

24.2 Dependencies

24.2.1 I/O Pins

External DMA Request 0 can be enabled from pins PD2, PE2, or PE6. External DMA Request 1 can be enabled from pins PD3, PE3, or PE7.

The DMA can be directed to use either the memory bus or the External I/O bus to perform its transfers, and will use either the memory bus or External I/O bus strobes as appropriate.

24.2.2 Clocks

The DMA peripheral uses the peripheral clock for all operations. If the timed request option is enabled, then the 16-bit timed request counter will be clocked by the peripheral clock and will provide a DMA request each time it counts down to zero.

24.2.3 Other Registers

Register	Function
NCDWR	Sets number of wait states for DMA accesses to the Wi-Fi peripheral.

24.2.4 Interrupts

Each DMA channel has its own dedicated interrupt that can occur at the end of any DMA transfer, as specified in DyCR (normally loaded from the buffer descriptor). The interrupt request is automatically cleared when the interrupt is handled.

The DMA interrupt vectors are in the EIR starting at offsets 0x080–0x0F0 for DMA Channels 0 to 7, and 0x180–0x1F0 for DMA Channels 8 to 15. They can be set as Priority 1, 2, or 3.

24.3 Operation

It is possible to set up and start a DMA operation by writing directly to all the relevant address, length, and control registers, but it is expected that the typical operation would be to create a buffer descriptor in memory, write the address of that descriptor to the initial address registers (DyIAnR), and use a write to DMALR to auto-load the values from memory into the registers and start the transfer. The DMA transfer will then continue reading buffer descriptors until a buffer-marked halt is completed.

The descriptor can be either 12 or 16 bytes in length; a bit in the channel control byte (which corresponds to DyCR) selects whether the link address is present or not. The processor skips the read of those bytes if a 12-byte descriptor is selected, and always skips the reads of the bytes marked “not used.”

Table 24-2. DMA Buffer Descriptor

	Byte 0	Byte 1	Byte 2	Byte 3
Bytes 0–3	Special Channel Control / Frame Status	Channel Control	Buffer Length [15:0]	
Bytes 4–7	Source Address [23:0]			Not Used
Bytes 8–11	Destination Address [23:0]			Not Used
Bytes 12–15	Link Address [23:0]			Not Used

Note that a length value of 0x0000 will result in a 65536-byte transfer.

The C structure to hold a descriptor is shown below.

```
typedef struct {
    char    frameStatus; // DxSCR
    char    chanControl; // DxCR
    unsigned int  bufLength; // DxL0R, DxL1R
    dma_addr_t  srcAddress; // DxSA0R, DxSA1R, DxSA2R
    dma_addr_t  destAddress; // DxDA0R, DxDA1R, DxDA2R
    dma_addr_t  linkAddress; // DxLA0R, DxLA1R, DxLA2R
} DMABufDesc;
```

It is possible to abort a DMA transfer by writing the appropriate bit to the halt register, DMHLR/DMHMR. It is also possible to restart a DMA transfer using the already-loaded register values by writing to DMCSLR/DMCSHR.

The following steps explain how to set up a DMA channel.

1. Select the DMA transfer and interrupt priorities by writing to DMCR.
2. Select the DMA channel priority and maximum burst size by writing to DCSTCR. If not using the bus-interleaving mode, use DMTCR instead and include the minimum clocks between bursts as well.
3. If using an interrupt, write the interrupt vector for the interrupt service routine to the external interrupt table.
4. If using an external DMA request, enable an external request line by writing to DMR0CR or DMR1CR. Make sure that the pin selected is set up as an input. Note that this enable will be logical-ANDed to any internal DMA enables if the DMA transfer is to/from an internal peripheral.

5. If using an internal-timed DMA transfer, enable the internal-timed transfer request by writing to DTRCCR. Select the divider value by writing to DTRDLR and DTRDHR. Note that this enable will be logical-ANDed to any internal DMA enables if the DMA transfer is to/from an internal peripheral.
6. Select a byte to terminate the transfer on by writing to the appropriate DyTBR and DyTMR registers.
7. The desired control, length, and address registers should be written to a buffer descriptor (or descriptors) in memory if not done already. Several automatic options (auto-increment, auto-decrement, special peripheral enables) can be overridden by settings in DySCR.
8. The initial address registers (DyIAnR) should be loaded with the physical address of the first buffer descriptor.
9. The buffer descriptor can be loaded and the DMA transfer started by writing to the appropriate bit of DMALLR or DMALMR.

24.3.1 Handling Interrupts

The DMA interrupt request is cleared automatically when the interrupt is handled. A DMA interrupt will occur at the end of a transfer for any buffer descriptor that has bit 4 of DyCR set.

24.3.2 Example ISR

A sample interrupt handler is shown below.

```
dma_isr::
    push af

    ; do something with the data in the current buffer
    ; the interrupt request is automatically cleared

    pop af
    ipres
    ret
```

24.3.3 DMA Priority with the Processor

When the bus-interleaving mode is in use, DMA transfers will not interrupt the CPU code execution, so the priority is of less importance than when the bus-sharing mode is in use. In that situation, normal code execution cannot occur while the DMA is active. This includes handling interrupts, so it is important to limit the amount of time that the DMA can operate if the bus-sharing mode is used.

This is handled in several ways. First of all, the DMA transfers can be set to take place whenever the processor is operating at one of the four priority levels, 0–3 (note that there is a single priority level for all DMA transfers).

Table 24-3. DMA Transfer Priority

DMA Transfers at	Operation
Priority 0	DMA transfers only allowed when processor priority at 0
Priority 1	DMA transfers only allowed when processor priority at 0 or 1
Priority 2	DMA transfers only allowed when processor priority at 0, 1, or 2
Priority 3	DMA transfers allowed at any time

Setting an interrupt priority to something greater than the DMA transfer priority will ensure that no DMA activity occurs during that interrupt handler. Note that when both an interrupt and a DMA transfer are pending, the DMA transfer will be selected for execution first (provided its priority is equal or greater than the current processor priority level).

When a DMA transfer is occurring in the bus-sharing mode, normal code execution will not occur until the transfer is completed. To prevent DMA transfers from excessively blocking interrupts or otherwise interfering with normal code execution, two options can be set in DMTCR. First, the maximum limit of a DMA transfer can be set from 1 to 64 bytes, which sets an upper limit on interrupt latency arising from a DMA transfer. Second, the minimum number of clocks before the DMA can be active again can be set from 12 to 512 clocks, guaranteeing processing time for the application.

The values providing roughly equal access to the memory bus for both the processor and the DMA is eight bytes per burst and 64 clocks between bursts.

If you are using the bus-interleaving mode, set the maximum burst size in DCSTCR.

The DMA requires several cycles of overhead when starting up. This overhead comes about because the DMA actually uses part of the processor to perform the data transfers, and consists of one instruction fetch time plus three clock cycles. The byte fetched during the instruction fetch time is discarded, and will be refetched at the completion of the DMA burst. At the end of the DMA burst, two clock cycles are required before this first instruction fetch starts. An individual DMA channel transfers data without any overhead between bytes, but there is always one clock cycle of dead time when switching between DMA channels. Table 24-4 shows the effective number of clock cycles required per burst, assuming a single DMA channel transfer, 8-bit memory, and no wait states. Access via 16-bit memory would provide up to twice the throughput, depending on the address alignment.

Table 24-4. Maximum DMA Transfer Rates (Bus Sharing Mode)

Setting	Total Clocks	Clocks per Byte Transferred
1 byte per burst	11 clocks	11
2 bytes per burst	15 clocks	7.5
3 bytes per burst	19 clocks	6.3
4 bytes per burst	23 clocks	5.8
8 bytes per burst	39 clocks	4.9
16 bytes per burst	71 clocks	4.4
32 bytes per burst	135 clocks	4.2
64 bytes per burst	263 clocks	4.1

The total number of clocks listed in Table 24-4 is related to the number of bytes per burst by the following formula.

$$\text{Total Clocks} = 4 \times \text{Number of Bytes per Burst} + 7 \text{ (for overhead)}$$

24.3.4 DMA Channel Priority

It is possible to control the priority between separate DMA channels. There are three channel-priority options in the Rabbit 6000. The first is fixed priority after every byte where the priority of each channel is equal to its number, i.e., if both DMA Channels 3 and 4 have a pending transfer request, DMA Channel 4 will always be enabled first. If at any point a channel with higher priority than the one currently transferring has a DMA request pending, the current transfer will be suspended and the new channel's transfer will start. With this setting, DMA Channel 15 will always have priority over all other channels, and DMA Channel 0 will transfer only if no other channels have pending requests.

The other two settings rotate the priority among channels as shown in Table 24-5; after the fifteenth rotation, the priority sequence restarts at the top of the table. One option is to rotate priority after every byte analogous to the fixed-priority setting. The priority list is updated after each byte transferred, and if a higher priority channel has a pending request, the current transfer will be suspended and the new channel transfer will start. The other option is to rotate after every burst; this will guarantee that reasonable amounts of data are transferred by each channel before a switchover occurs.

There is a separate priority setting for both the bus-interleaving and bus-sharing modes, since both DMA modes may be occurring depending on the hardware setup.

Table 24-5. Example of Rotating DMA Channel Priority

Rotation	Channel Priority, High to Low
Initial	15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0
First	14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, 15
Second	13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, 15, 14
Third	12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, 15, 14, 13

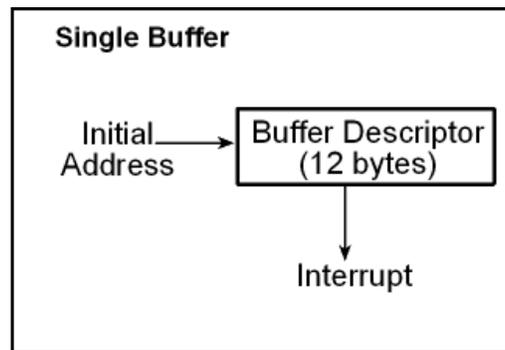
24.3.5 Buffer Descriptor Modes

Flags in the control byte of a buffer descriptor (which gets loaded into DyCR) describe whether to halt on completion of the transfer (or load another descriptor) and whether the next descriptor is adjacent in memory (which implies that the current descriptor is only 12 bytes long) or located at the link address. Each descriptor can also be set to generate an interrupt on completion of the transfer. By using these options in various ways, the Rabbit 6000 DMA can be operated in a number of conventional DMA modes.

The most common options are described here; others are certainly possible by different use of the available linking methods.

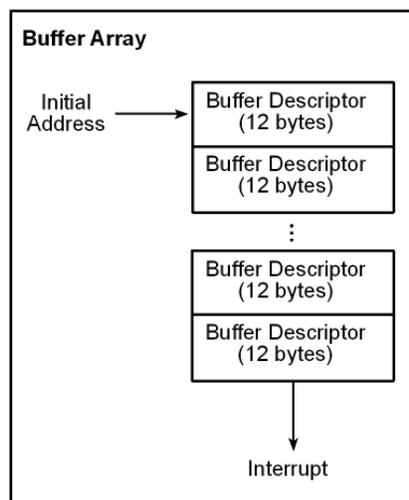
24.3.5.1 Single Buffer

In the simplest mode, a single descriptor is set to halt and interrupt on completion.



24.3.5.2 Buffer Array

In this mode, an array of 12-byte descriptors is set up adjacent in memory; only the last buffer is set to halt on completion. The last buffer is also typically set to interrupt on completion, but other buffer descriptors in the array can also generate interrupts.

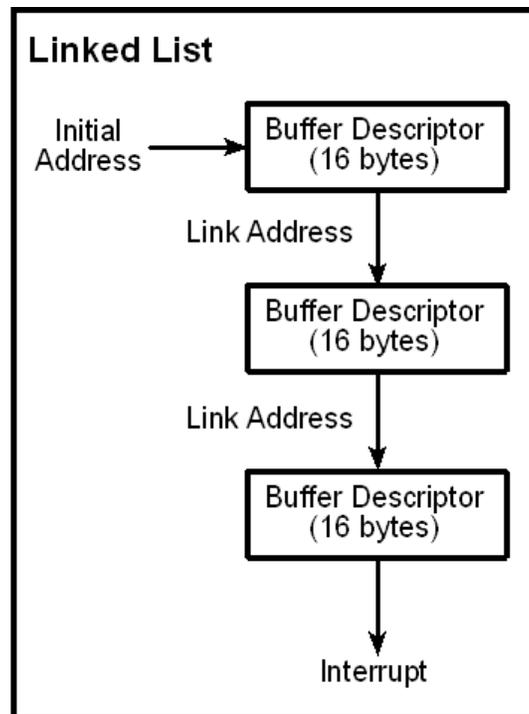


The advantage of the buffer array is that its descriptors require less memory than a full 16-byte descriptor.

The simplest version of the buffer array is a double buffer, which is frequently used to provide a reserve buffer in case the application is slow in handling the first buffer once received (in this case, both buffers are enabled to interrupt on completion).

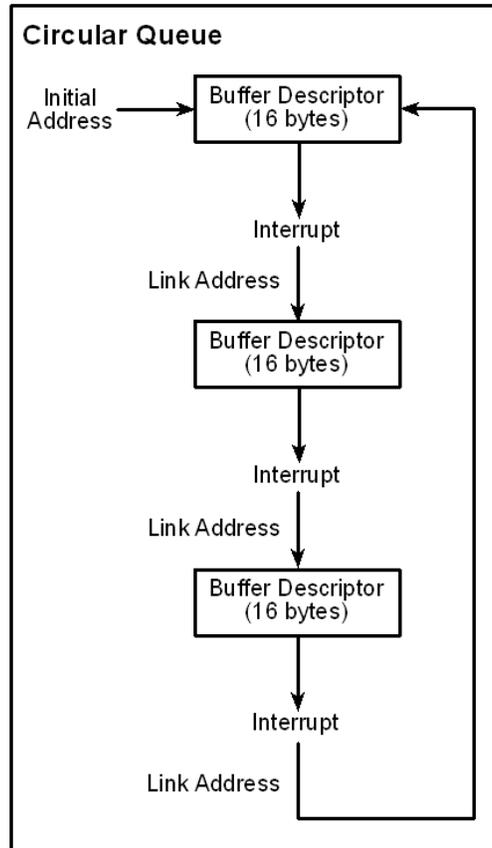
24.3.5.3 Linked List

A linked list is similar to a buffer array, except that 16-byte descriptors are used and the descriptors are not necessarily adjacent in memory. The advantage of this mode is the ability to spread descriptors.



24.3.5.4 Circular Queue

A circular queue is a buffer array or linked list where the final buffer is linked back to the first buffer in the sequence. This method allows for continuous reception of transfers without having to reload the initial address for the DMA buffer descriptor sequence.



The “ping-pong buffer,” where there are only two buffers, is the simplest version of a circular queue. The application can operate on one buffer while the other buffer is being loaded.

24.3.5.5 Linked Array

The linked array is simply a linked list of buffer arrays, where the last buffer in each array is linked to the first buffer in the next array (which can be located anywhere in memory). This method could be useful where a message is broken down into separate transfers, but entire messages could be scattered/gathered from anywhere in memory.

24.3.6 DMA with Peripherals

When the DMA is directed towards an internal I/O address, the DMA transfer request signals will be connected as appropriate for that peripheral. For example, when a DMA transfer is performed to Serial Port D's data register, the transfer request will be enabled whenever the serial port transmit buffer is empty, and will be disabled whenever it is not.

24.3.6.1 DMA with HDLC Serial Ports

The HDLC serial ports receive special handing by the DMA. When the DMA destination is Serial Port E's or Serial Port F's data register (SxDR), the final byte of the transfer will be written to the appropriate last data register (SxLDR) as required to complete an HDLC packet and append the CRC value. In addition, the value in the appropriate status register (SxSR) will be written to the status byte in the buffer descriptor pointed to by the initial address registers (not necessarily the buffer descriptor that is currently being used). These features allow an application to automatically send and receive packets via DMA, only requiring direct handling of a packet when an error occurs.

24.3.6.2 DMA with Ethernet

The Ethernet network peripheral also receives special handing by the DMA. When the DMA destination is the network data register (NBDR), the final byte of the transfer will be written to the last data register (NBLDR) as required to complete an Ethernet packet and append the CRC value. The Ethernet network peripheral also has support for DMA fly-by transfers between the peripheral and external memory.

24.3.6.3 DMA with Wi-Fi

The Wi-Fi network peripheral has support for DMA fly-by transfers between the peripheral and memory. However, the Wi-Fi peripheral has a minimum access time of 75 ns and typically requires wait states, so fly-by DMA may not be the most efficient access method. There are two registers, NCCWR and NCDWR, that set the wait states for access to the Wi-Fi peripheral, both directly and via DMA.

24.3.6.4 DMA with USB

The USB network peripheral has support for DMA fly-by transfers between the peripheral and memory. However, the USB peripheral has a minimum access time of 250 ns and typically requires wait states, so fly-by DMA may not be the most efficient access method.

24.3.6.5 DMA with PWM and Timer C

The PWM and Timer C peripherals have special support for DMA — the block access and pointer registers in each of these peripherals provide a means for the DMA to update the settings of these peripherals at some desired rate. This allows complex PWM waveforms to be generated by using the DMA timed request to update the PWM duty cycles at regular intervals.

24.4 Register Descriptions

DMA Master Control/Status LSB Register (DMCSLR) (Address = 0x0100)		
Bit(s)	Value	Description
7:0 (Write-only)	0	No effect on the corresponding DMA channel (7–0).
	1	Start (or restart) the corresponding DMA channel (7–0) using the contents of the DMA channel registers. This command should only be issued after all the DMA channel registers (source, destination, length, and link if applicable) have been loaded.
7:0 (Read-only)	0	The corresponding DMA channel (7–0) is either disabled or has completed the last buffer descriptor.
	1	The corresponding DMA channel (7–0) is enabled and active. These bits are set by the start command and remain set until the completion of the last buffer.

DMA Master Control/Status MSB Register (DMCSMR) (Address = 0x0101)		
Bit(s)	Value	Description
7:0 (Write-only)	0	No effect on the corresponding DMA channel (15–8).
	1	Start (or restart) the corresponding DMA channel (15–8) using the contents of the DMA channel registers. This command should only be issued after all the DMA channel registers (source, destination, length, and link if applicable) have been loaded.
7:0 (Read-only)	0	The corresponding DMA channel (15–8) is either disabled or has completed the last buffer descriptor.
	1	The corresponding DMA channel (15–8) is enabled and active. These bits are set by the start command and remain set until the completion of the last buffer.

DMA Master Auto-Load LSB Register (DMALLR) (Address = 0x0110)		
Bit(s)	Value	Description
7:0 (wr-only)	0	No effect on the corresponding DMA channel (7–0).
	1	Start (using auto-load) the corresponding DMA channel (7-0), using the buffer descriptor in memory addressed by the channel Initial Address Register. This command should only be issued after the Initial Address has been loaded.
7:0 (rd-only)	0	The corresponding DMA channel (7-0) is either disabled or has completed the last buffer descriptor.
	1	The corresponding DMA channel (7-0) is enabled and active. These bits are set by the Start command and remain set until the completion of the last buffer or receipt of a Halt command.

DMA Master Auto-Load MSB Register (DMALMR) (Address = 0x0111)		
Bit(s)	Value	Description
7:0 (wr-only)	0	No effect on the corresponding DMA channel (15–8).
	1	Start (using auto-load) the corresponding DMA channel (15-8), using the buffer descriptor in memory addressed by the channel Initial Address Register. This command should only be issued after the Initial Address has been loaded.
7:0 (rd-only)	0	The corresponding DMA channel (15-8) is either disabled or has completed the last buffer descriptor.
	1	The corresponding DMA channel (15-8) is enabled and active. These bits are set by the Start command and remain set until the completion of the last buffer or receipt of a Halt command.

DMA Master Halt LSB Register (DMHLR) (Address = 0x0120)		
Bit(s)	Value	Description
7:0	0	No effect on the corresponding DMA channel (7–0).
	1	Halt the corresponding DMA channel (7–0). The DMA registers retain the current state, and the DMA can be restarted using DMCSLR.

DMA Master Halt MSB Register (DMHMR) (Address = 0x0121)		
Bit(s)	Value	Description
7:0	0	No effect on the corresponding DMA channel (15–8).
	1	Halt the corresponding DMA channel (15–8). The DMA registers retain the current state, and the DMA can be restarted using DMCSMR.

DMA y Buffer Complete Register		
(D0BCR)	(Address = 0x0103)	
(D1BCR)	(Address = 0x0113)	
(D2BCR)	(Address = 0x0123)	
(D3BCR)	(Address = 0x0133)	
(D4BCR)	(Address = 0x0143)	
(D5BCR)	(Address = 0x0153)	
(D6BCR)	(Address = 0x0163)	
(D7BCR)	(Address = 0x0173)	
(D8BCR)	(Address = 0x0903)	
(D9BCR)	(Address = 0x0913)	
(D10BCR)	(Address = 0x0923)	
(D11BCR)	(Address = 0x0933)	
(D12BCR)	(Address = 0x0943)	
(D13BCR)	(Address = 0x0953)	
(D14BCR)	(Address = 0x0963)	
(D15BCR)	(Address = 0x0973)	
Bit(s)	Value	Description
7:0	Read	The DMA increments a counter at the start of each buffer. This count is latched in this register and can be used, along with the <i>buffer unused</i> count, to determine the actual amount of data transferred by the DMA. This counter is initialized by a start command or when the DMA is automatically rewound to the initial address.
	Write	Writing to this register loads the counter. This feature is intended only for testing, because the DMA automatically resets the counter to all ones when fetching from the initial address. The counter is incremented whenever the DMA fetches a new buffer length value from a descriptor.

DMA Master Control Register (DMCR) (Address = 0x0104)		
Bit(s)	Value	Description
7:4		These bits are reserved and should be written with zeros.
3:2	00	DMA transfers at Priority 0. No DMA transfers while CPU operates at Priority 3, 2, or 1.
	01	DMA transfers at Priority 1. No DMA transfers while CPU operates at Priority 3 or 2.
	10	DMA transfers at Priority 2. No DMA transfers while CPU operates at Priority 3.
	11	DMA transfers at Priority 3. DMA transfers at any time.
1:0	00	DMA interrupts are disabled.
	01	DMA interrupts use Interrupt Priority 1.
	10	DMA interrupts use Interrupt Priority 2.
	11	DMA interrupts use Interrupt Priority 3.

DMA Master Timing Control Register (DMTCR) (Address = 0x0105)		
Bit(s)	Value	Description
7:6	0x	Fixed DMA channel priority. Higher channel number has higher priority.
	10	Rotating DMA channel priority. Priority rotates highest channel number to lowest channel number after every byte is transferred.
	11	Rotating DMA channel priority. Priority rotates highest channel number to lowest channel number after the current channel request is serviced.
5:3	000	Maximum one byte per burst.
	001	Maximum two bytes per burst.
	010	Maximum three bytes per burst.
	011	Maximum four bytes per burst.
	100	Maximum eight bytes per burst.
	101	Maximum 16 bytes per burst.
	110	Maximum 32 bytes per burst.
	111	Maximum 64 bytes per burst.
2:0	000	Minimum 12 clocks between bursts.
	001	Minimum 16 clocks between bursts.
	010	Minimum 24 clocks between bursts.
	011	Minimum 32 clocks between bursts.
	100	Minimum 64 clocks between bursts.
	101	Minimum 128 clocks between bursts.
	110	Minimum 256 clocks between bursts.
	111	Minimum 512 clocks between bursts.

DMA Master Request 0 Control Register (DMR0CR) (Address = 0x0106)		
Bit(s)	Value	Description
7:6	00	External DMA Request 0 disabled.
	01	External DMA Request 0 enabled from Parallel Port PD2.
	10	External DMA Request 0 enabled from Parallel Port PE2.
	11	External DMA Request 0 enabled from Parallel Port PE6.
5:4	00	External DMA Request 0 falling-edge triggered. One transfer per request.
	01	External DMA Request 0 rising-edge triggered. One transfer per request.
	10	External DMA Request 0 active low. Transfers continue while low.
	11	External DMA Request 0 active high. Transfers continue while high.
3:0	0000	External DMA Request 0 supplied to DMA Channel 0.
	0001	External DMA Request 0 supplied to DMA Channel 1.
	0010	External DMA Request 0 supplied to DMA Channel 2.
	0011	External DMA Request 0 supplied to DMA Channel 3.
	0100	External DMA Request 0 supplied to DMA Channel 4.
	0101	External DMA Request 0 supplied to DMA Channel 5.
	0110	External DMA Request 0 supplied to DMA Channel 6.
	0111	External DMA Request 0 supplied to DMA Channel 7.
	1000	External DMA Request 0 supplied to DMA Channel 8.
	1001	External DMA Request 0 supplied to DMA Channel 9.
	1010	External DMA Request 0 supplied to DMA Channel 10.
	1011	External DMA Request 0 supplied to DMA Channel 11.
	1100	External DMA Request 0 supplied to DMA Channel 12.
	1101	External DMA Request 0 supplied to DMA Channel 13.
	1110	External DMA Request 0 supplied to DMA Channel 14.
	1111	External DMA Request 0 supplied to DMA Channel 15.

DMA Master Request 1 Control Register (DMR1CR) (Address = 0x0107)		
Bit(s)	Value	Description
7:6	00	External DMA Request 1 disabled.
	01	External DMA Request 1 enabled from Parallel Port PD3.
	10	External DMA Request 1 enabled from Parallel Port PE3.
	11	External DMA Request 1 enabled from Parallel Port PE7.
5:4	00	External DMA Request 1 falling-edge triggered. One transfer per request.
	01	External DMA Request 1 rising-edge triggered. One transfer per request.
	10	External DMA Request 1 active low. Transfers continue while low.
	11	External DMA Request 1 active high. Transfers continue while high.
3:0	0000	External DMA Request 1 supplied to DMA Channel 0.
	0001	External DMA Request 1 supplied to DMA Channel 1.
	0010	External DMA Request 1 supplied to DMA Channel 2.
	0011	External DMA Request 1 supplied to DMA Channel 3.
	0100	External DMA Request 1 supplied to DMA Channel 4.
	0101	External DMA Request 1 supplied to DMA Channel 5.
	0110	External DMA Request 1 supplied to DMA Channel 6.
	0111	External DMA Request 1 supplied to DMA Channel 7.
	1000	External DMA Request 1 supplied to DMA Channel 8.
	1001	External DMA Request 1 supplied to DMA Channel 9.
	1010	External DMA Request 1 supplied to DMA Channel 10.
	1011	External DMA Request 1 supplied to DMA Channel 11.
	1100	External DMA Request 1 supplied to DMA Channel 12.
	1101	External DMA Request 1 supplied to DMA Channel 13.
	1110	External DMA Request 1 supplied to DMA Channel 14.
	1111	External DMA Request 1 supplied to DMA Channel 15.

DMA Timed Request Control Register (DTRCR) (Address = 0x0115)		
Bit(s)	Value	Description
7	0	Timed DMA request disabled.
	1	Timed DMA request enabled.
6		These bits are reserved and should be written with zeros.
5:4	00	Timed DMA request transfers one byte per request.
	01	This bit combination is reserved and should not be used.
	10	Timed DMA request triggers transfers until current descriptor is complete. DMA channel fetches the next descriptor if appropriate.
	11	This bit combination is reserved and should not be used.
3:0	0000	Timed DMA request supplied to DMA Channel 0.
	0001	Timed DMA request supplied to DMA Channel 1.
	0010	Timed DMA request supplied to DMA Channel 2.
	0011	Timed DMA request supplied to DMA Channel 3.
	0100	Timed DMA request supplied to DMA Channel 4.
	0101	Timed DMA request supplied to DMA Channel 5.
	0110	Timed DMA request supplied to DMA Channel 6.
	0111	Timed DMA request supplied to DMA Channel 7.
	1000	Timed DMA request supplied to DMA Channel 8.
	1001	Timed DMA request supplied to DMA Channel 9.
	1010	Timed DMA request supplied to DMA Channel 10.
	1011	Timed DMA request supplied to DMA Channel 11.
	1100	Timed DMA request supplied to DMA Channel 12.
	1101	Timed DMA request supplied to DMA Channel 13.
	1110	Timed DMA request supplied to DMA Channel 14.
	1111	Timed DMA request supplied to DMA Channel 15.

DMA Timed Request Divider Low Register (DTRDLR) (Address = 0x0116)		
Bit(s)	Value	Description
7:0	Write	The eight LSBs of the limit value for the DMA timed request timer are stored.

DMA Timed Request Divider High Register (DTRDHR) (Address = 0x0117)		
Bit(s)	Value	Description
7:0	Write	The eight MSBs of the limit value for the DMA timed request timer are stored.

DMA Cycle-Steal Timing Control Register (DCSTCR) (Address = 0x0125)		
Bit(s)	Value	Description
7:6	0x	Fixed cycle-steal DMA channel priority. Higher channel number has higher priority.
	10	Rotating cycle-steal DMA channel priority. Priority rotates highest channel number to lowest channel number, after every transfer.
	11	Rotating cycle-steal DMA channel priority. Priority rotates highest channel number to lowest channel number, after the current channel request is serviced.
5:3	000	Maximum one transfer per burst.
	001	Maximum two transfers per burst.
	010	Maximum three transfers per burst.
	011	Maximum four transfers per burst.
	100	Maximum eight transfers per burst.
	101	Maximum sixteen transfers per burst.
	110	Maximum thirty-two transfers per burst.
	111	Maximum sixty-four transfers per burst.
2:0		These bits are reserved and should be written with zeros.

DMA y Termination Byte Register		
(D0TBR)	(Address = 0x0108)	
(D1TBR)	(Address = 0x0118)	
(D2TBR)	(Address = 0x0128)	
(D3TBR)	(Address = 0x0138)	
(D4TBR)	(Address = 0x0148)	
(D5TBR)	(Address = 0x0158)	
(D6TBR)	(Address = 0x0168)	
(D7TBR)	(Address = 0x0178)	
(D8TBR)	(Address = 0x0908)	
(D9TBR)	(Address = 0x0918)	
(D10TBR)	(Address = 0x0928)	
(D11TBR)	(Address = 0x0938)	
(D12TBR)	(Address = 0x0948)	
(D13TBR)	(Address = 0x0958)	
(D14TBR)	(Address = 0x0968)	
(D15TBR)	(Address = 0x0978)	
Bit(s)	Value	Description
7:0		Byte value that, if matched, will terminate a buffer.

DMA y Termination Mask Register		
(D0TMR)	(Address = 0x0109)	
(D1TMR)	(Address = 0x0119)	
(D2TMR)	(Address = 0x0129)	
(D3TMR)	(Address = 0x0139)	
(D4TMR)	(Address = 0x0149)	
(D5TMR)	(Address = 0x0159)	
(D6TMR)	(Address = 0x0169)	
(D7TMR)	(Address = 0x0179)	
(D8TMR)	(Address = 0x9109)	
(D9TMR)	(Address = 0x0919)	
(D10TMR)	(Address = 0x0929)	
(D11TMR)	(Address = 0x0939)	
(D12TMR)	(Address = 0x0949)	
(D13TMR)	(Address = 0x0959)	
(D14TMR)	(Address = 0x0969)	
(D15TMR)	(Address = 0x0979)	
Bit(s)	Value	Description
7:0		Mask for termination byte. A one in a bit position enables the corresponding bit of the termination byte to be used in the compare to generate the termination condition. A zero in a bit position disables the corresponding bit from contributing to the termination condition. A value of all zeros in this register disables the termination-byte match feature.

DMA y Buffer Unused[7:0] Register		
(D0BU0R)	(Address = 0x010A)	
(D1BU0R)	(Address = 0x011A)	
(D2BU0R)	(Address = 0x012A)	
(D3BU0R)	(Address = 0x013A)	
(D4BU0R)	(Address = 0x014A)	
(D5BU0R)	(Address = 0x015A)	
(D6BU0R)	(Address = 0x016A)	
(D7BU0R)	(Address = 0x017A)	
(D8BU0R)	(Address = 0x090A)	
(D9BU0R)	(Address = 0x091A)	
(D10BU0R)	(Address = 0x092A)	
(D11BU0R)	(Address = 0x093A)	
(D12BU0R)	(Address = 0x094A)	
(D13BU0R)	(Address = 0x095A)	
(D14BU0R)	(Address = 0x096A)	
(D15BU0R)	(Address = 0x097A)	
Bit(s)	Value	Description
7:0		Bits 7:0 of the buffer unused length value are stored in this register. The DMA copies the buffer remaining length to this register at the completion of the transfer. Normally the buffer remaining length is zero, but if the transfer terminates early, under source control or because of a termination-byte match, the number of unused bytes in the buffer is written.

DMA y Buffer Unused[15:8] Register		
(D0BU1R)	(Address = 0x010B)	
(D1BU1R)	(Address = 0x011B)	
(D2BU1R)	(Address = 0x012B)	
(D3BU1R)	(Address = 0x013B)	
(D4BU1R)	(Address = 0x014B)	
(D5BU1R)	(Address = 0x015B)	
(D6BU1R)	(Address = 0x016B)	
(D7BU1R)	(Address = 0x017B)	
(D8BU1R)	(Address = 0x090B)	
(D9BU1R)	(Address = 0x091B)	
(D10BU1R)	(Address = 0x092B)	
(D11BU1R)	(Address = 0x093B)	
(D12BU1R)	(Address = 0x094B)	
(D13BU1R)	(Address = 0x095B)	
(D14BU1R)	(Address = 0x096B)	
(D15BU1R)	(Address = 0x097B)	
Bit(s)	Value	Description
7:0		Bits 15:8 of the buffer unused-length value are stored in this register.

DMA y Initial Addr[7:0] Register		
(D0IA0R)	(Address = 0x010C)	
(D1IA0R)	(Address = 0x011C)	
(D2IA0R)	(Address = 0x012C)	
(D3IA0R)	(Address = 0x013C)	
(D4IA0R)	(Address = 0x014C)	
(D5IA0R)	(Address = 0x015C)	
(D6IA0R)	(Address = 0x016C)	
(D7IA0R)	(Address = 0x017C)	
(D8IA0R)	(Address = 0x090C)	
(D9IA0R)	(Address = 0x091C)	
(D10IA0R)	(Address = 0x092C)	
(D11IA0R)	(Address = 0x093C)	
(D12IA0R)	(Address = 0x094C)	
(D13IA0R)	(Address = 0x095C)	
(D14IA0R)	(Address = 0x096C)	
(D15IA0R)	(Address = 0x097C)	
Bit(s)	Value	Description
7:0		Bits 7:0 of the initial address are stored in this register.

DMA y Initial Addr[15:8] Register		
(D0IA1R)	(Address = 0x010D)	
(D1IA1R)	(Address = 0x011D)	
(D2IA1R)	(Address = 0x012D)	
(D3IA1R)	(Address = 0x013D)	
(D4IA1R)	(Address = 0x014D)	
(D5IA1R)	(Address = 0x015D)	
(D6IA1R)	(Address = 0x016D)	
(D7IA1R)	(Address = 0x017D)	
(D8IA1R)	(Address = 0x090D)	
(D9IA1R)	(Address = 0x091D)	
(D10IA1R)	(Address = 0x092D)	
(D11IA1R)	(Address = 0x093D)	
(D12IA1R)	(Address = 0x094D)	
(D13IA1R)	(Address = 0x095D)	
(D14IA1R)	(Address = 0x096D)	
(D15IA1R)	(Address = 0x097D)	
Bit(s)	Value	Description
7:0		Bits 15:8 of the initial address are stored in this register.

DMA y Initial Addr[23:16] Register		
(D0IA2R)	(Address = 0x010E)	
(D1IA2R)	(Address = 0x011E)	
(D2IA2R)	(Address = 0x012E)	
(D3IA2R)	(Address = 0x013E)	
(D4IA2R)	(Address = 0x014E)	
(D5IA2R)	(Address = 0x015E)	
(D6IA2R)	(Address = 0x016E)	
(D7IA2R)	(Address = 0x017E)	
(D8IA2R)	(Address = 0x090E)	
(D9IA2R)	(Address = 0x091E)	
(D10IA2R)	(Address = 0x092E)	
(D11IA2R)	(Address = 0x093E)	
(D12IA2R)	(Address = 0x094E)	
(D13IA2R)	(Address = 0x095E)	
(D14IA2R)	(Address = 0x096E)	
(D15IA2R)	(Address = 0x097E)	
Bit(s)	Value	Description
7:0		Bits 23:16 of the initial address are stored in this register.

DMA y Special Control Register		
(D0SCR)	(Address = 0x0180)	
(D1SCR)	(Address = 0x0190)	
(D2SCR)	(Address = 0x01A0)	
(D3SCR)	(Address = 0x01B0)	
(D4SCR)	(Address = 0x01C0)	
(D5SCR)	(Address = 0x01D0)	
(D6SCR)	(Address = 0x01E0)	
(D7SCR)	(Address = 0x01F0)	
(D8SCR)	(Address = 0x0980)	
(D9SCR)	(Address = 0x0990)	
(D10SCR)	(Address = 0x09A0)	
(D11SCR)	(Address = 0x09B0)	
(D12SCR)	(Address = 0x09C0)	
(D13SCR)	(Address = 0x09D0)	
(D14SCR)	(Address = 0x09E0)	
(D15SCR)	(Address = 0x09F0)	
Bit(s)	Value	Description
7:6	00	Normal DMA operation.
	01	Normal DMA operation;
	10	Enable DMA for automatic Network Port D (USB) receive channel operation.
	11	Enable DMA for automatic Network Port D (USB) transmit channel operation.
5	—	This bit is reserved and must always be read as zero.
4	0	Enable Bus-Sharing Mode.
	1	Enable Bus Interleaving Mode.
3	0	Auto-connect source DMA request. DMA will only transfer when source's DMA transfer request is active.
	1	Disconnect source DMA request. DMA will transfer full buffer size.
2	0	Normal source address.
	1	Source address fixed, independent of type.
1	0	Auto-connect destination DMA request.
	1	Disconnect destination DMA request (full buffer transfer).
0	0	Normal destination address.
	1	Destination address fixed, independent of type.

DMA y Control Register		
(D0CR)	(Address = 0x0181)	
(D1CR)	(Address = 0x0191)	
(D2CR)	(Address = 0x01A1)	
(D3CR)	(Address = 0x01B1)	
(D4CR)	(Address = 0x01C1)	
(D5CR)	(Address = 0x01D1)	
(D6CR)	(Address = 0x01E1)	
(D7CR)	(Address = 0x01F1)	
(D8CR)	(Address = 0x0981)	
(D9CR)	(Address = 0x0991)	
(D10CR)	(Address = 0x09A1)	
(D11CR)	(Address = 0x09B1)	
(D12CR)	(Address = 0x09C1)	
(D13CR)	(Address = 0x09D1)	
(D14CR)	(Address = 0x09E1)	
(D15CR)	(Address = 0x09F1)	
Bit(s)	Value	Description
7	0	Continue to next buffer descriptor.
	1	Final buffer descriptor. Stop DMA operation upon completion of this transfer.
6	0	Use sequential address for next buffer descriptor. The link address field is not present in this buffer descriptor, which is now 12 bytes long.
	1	Use the link address field as a pointer to the next buffer descriptor. This buffer descriptor is 16 bytes long.
5	0	No special treatment for last byte.
	1	Internal Source: status byte written to initial buffer descriptor before last data. Internal Destination: Last byte written to offset address for frame termination. All others: No effect.
4	0	No interrupt on completing this transfer.
	1	Interrupt on completing this transfer.
3:2	00	Source address is fixed internal I/O (two-byte) address.
	01	Source address is fixed external I/O (two-byte) address.
	10	Source address is memory (three-byte) address, auto-decrement.
	11	Source address is memory (three-byte) address, auto-increment.
1:0	00	Destination address is fixed internal I/O (two-byte) address.
	01	Destination address is fixed external I/O (two-byte) address.
	10	Destination address is memory (three-byte) address, auto-decrement.
	11	Destination address is memory (three-byte) address, auto-increment.

DMA y Length[7:0] Register		
(D0L0R)	(Address = 0x0182)	
(D1L0R)	(Address = 0x0192)	
(D2L0R)	(Address = 0x01A2)	
(D3L0R)	(Address = 0x01B2)	
(D4L0R)	(Address = 0x01C2)	
(D5L0R)	(Address = 0x01D2)	
(D6L0R)	(Address = 0x01E2)	
(D7L0R)	(Address = 0x01F2)	
(D8L0R)	(Address = 0x0982)	
(D9L0R)	(Address = 0x0992)	
(D10L0R)	(Address = 0x09A2)	
(D11L0R)	(Address = 0x09B2)	
(D12L0R)	(Address = 0x09C2)	
(D13L0R)	(Address = 0x09D2)	
(D14L0R)	(Address = 0x09E2)	
(D15L0R)	(Address = 0x09F2)	
Bit(s)	Value	Description
7:0		Bits 7:0 of the buffer length value are stored in this register.

DMA y Length[15:8] Register		
(D0L1R)	(Address = 0x0183)	
(D1L1R)	(Address = 0x0193)	
(D2L1R)	(Address = 0x01A3)	
(D3L1R)	(Address = 0x01B3)	
(D4L1R)	(Address = 0x01C3)	
(D5L1R)	(Address = 0x01D3)	
(D6L1R)	(Address = 0x01E3)	
(D7L1R)	(Address = 0x01F3)	
(D8L1R)	(Address = 0x0983)	
(D9L1R)	(Address = 0x0993)	
(D10L1R)	(Address = 0x09A3)	
(D11L1R)	(Address = 0x09B3)	
(D12L1R)	(Address = 0x09C3)	
(D13L1R)	(Address = 0x09D3)	
(D14L1R)	(Address = 0x09E3)	
(D15L1R)	(Address = 0x09F3)	
Bit(s)	Value	Description
7:0		Bits 15:8 of the buffer length value are stored in this register.

DMA y Source Addr[7:0] Register		
(D0SA0R)	(Address = 0x0184)	
(D1SA0R)	(Address = 0x0194)	
(D2SA0R)	(Address = 0x01A4)	
(D3SA0R)	(Address = 0x01B4)	
(D4SA0R)	(Address = 0x01C4)	
(D5SA0R)	(Address = 0x01D4)	
(D6SA0R)	(Address = 0x01E4)	
(D7SA0R)	(Address = 0x01F4)	
(D8SA0R)	(Address = 0x0984)	
(D9SA0R)	(Address = 0x0994)	
(D10SA0R)	(Address = 0x09A4)	
(D11SA0R)	(Address = 0x09B4)	
(D12SA0R)	(Address = 0x09C4)	
(D13SA0R)	(Address = 0x09D4)	
(D14SA0R)	(Address = 0x09E4)	
(D15SA0R)	(Address = 0x09F4)	
Bit(s)	Value	Description
7:0		Bits 7:0 of the source address are stored in this register.

DMA y Source Addr[15:8] Register		
(D0SA1R)	(Address = 0x0185)	
(D1SA1R)	(Address = 0x0195)	
(D2SA1R)	(Address = 0x01A5)	
(D3SA1R)	(Address = 0x01B5)	
(D4SA1R)	(Address = 0x01C5)	
(D5SA1R)	(Address = 0x01D5)	
(D6SA1R)	(Address = 0x01E5)	
(D7SA1R)	(Address = 0x01F5)	
(D8SA1R)	(Address = 0x0985)	
(D9SA1R)	(Address = 0x0995)	
(D10SA1R)	(Address = 0x09A5)	
(D11SA1R)	(Address = 0x09B5)	
(D12SA1R)	(Address = 0x09C5)	
(D13SA1R)	(Address = 0x09D5)	
(D14SA1R)	(Address = 0x09E5)	
(D15SA1R)	(Address = 0x09F5)	
Bit(s)	Value	Description
7:0		Bits 15:8 of the source address are stored in this register.

DMA y Source Addr[23:16] Register		
(D0SA2R)	(Address = 0x0186)	
(D1SA2R)	(Address = 0x0196)	
(D2SA2R)	(Address = 0x01A6)	
(D3SA2R)	(Address = 0x01B6)	
(D4SA2R)	(Address = 0x01C6)	
(D5SA2R)	(Address = 0x01D6)	
(D6SA2R)	(Address = 0x01E6)	
(D7SA2R)	(Address = 0x01F6)	
(D8SA2R)	(Address = 0x0986)	
(D9SA2R)	(Address = 0x0996)	
(D10SA2R)	(Address = 0x09A6)	
(D11SA2R)	(Address = 0x09B6)	
(D12SA2R)	(Address = 0x09C6)	
(D13SA2R)	(Address = 0x09D6)	
(D14SA2R)	(Address = 0x09E6)	
(D15SA2R)	(Address = 0x09F6)	
Bit(s)	Value	Description
7:0		Bits 23:16 of the source address are stored in this register.

DMA y Destination Addr[7:0] Register		
(D0DA0R)	(Address = 0x0188)	
(D1DA0R)	(Address = 0x0198)	
(D2DA0R)	(Address = 0x01A8)	
(D3DA0R)	(Address = 0x01B8)	
(D4DA0R)	(Address = 0x01C8)	
(D5DA0R)	(Address = 0x01D8)	
(D6DA0R)	(Address = 0x01E8)	
(D7DA0R)	(Address = 0x01F8)	
(D8DA0R)	(Address = 0x0988)	
(D9DA0R)	(Address = 0x0998)	
(D10DA0R)	(Address = 0x09A8)	
(D11DA0R)	(Address = 0x09B8)	
(D12DA0R)	(Address = 0x09C8)	
(D13DA0R)	(Address = 0x09D8)	
(D14DA0R)	(Address = 0x09E8)	
(D15DA0R)	(Address = 0x09F8)	
Bit(s)	Value	Description
7:0		Bits 7:0 of the destination address are stored in this register.

DMA y Destination Addr[15:8] Register		
(D0DA1R)	(Address = 0x0189)	
(D1DA1R)	(Address = 0x0199)	
(D2DA1R)	(Address = 0x01A9)	
(D3DA1R)	(Address = 0x01B9)	
(D4DA1R)	(Address = 0x01C9)	
(D5DA1R)	(Address = 0x01D9)	
(D6DA1R)	(Address = 0x01E9)	
(D7DA1R)	(Address = 0x01F9)	
(D8DA1R)	(Address = 0x0989)	
(D9DA1R)	(Address = 0x0999)	
(D10DA1R)	(Address = 0x09A9)	
(D11DA1R)	(Address = 0x09B9)	
(D12DA1R)	(Address = 0x09C9)	
(D13DA1R)	(Address = 0x09D9)	
(D14DA1R)	(Address = 0x09E9)	
(D15DA1R)	(Address = 0x09F9)	
Bit(s)	Value	Description
7:0		Bits 15:8 of the destination address are stored in this register.

DMA y Destination Addr[23:16] Register		
(D0DA2R)	(Address = 0x018A)	
(D1DA2R)	(Address = 0x019A)	
(D2DA2R)	(Address = 0x01AA)	
(D3DA2R)	(Address = 0x01BA)	
(D4DA2R)	(Address = 0x01CA)	
(D5DA2R)	(Address = 0x01DA)	
(D6DA2R)	(Address = 0x01EA)	
(D7DA2R)	(Address = 0x01FA)	
(D8DA2R)	(Address = 0x098A)	
(D9DA2R)	(Address = 0x099A)	
(D10DA2R)	(Address = 0x09AA)	
(D11DA2R)	(Address = 0x09BA)	
(D12DA2R)	(Address = 0x09CA)	
(D13DA2R)	(Address = 0x09DA)	
(D14DA2R)	(Address = 0x09EA)	
(D15DA2R)	(Address = 0x09FA)	
Bit(s)	Value	Description
7:0		Bits 23:16 of the destination address are stored in this register.

DMA y Link Addr[7:0] Register		
(D0LA0R)	(Address = 0x018C)	
(D1LA0R)	(Address = 0x019C)	
(D2LA0R)	(Address = 0x01AC)	
(D3LA0R)	(Address = 0x01BC)	
(D4LA0R)	(Address = 0x01CC)	
(D5LA0R)	(Address = 0x01DC)	
(D6LA0R)	(Address = 0x01EC)	
(D7LA0R)	(Address = 0x01FC)	
(D8LA0R)	(Address = 0x098C)	
(D9LA0R)	(Address = 0x099C)	
(D10LA0R)	(Address = 0x09AC)	
(D11LA0R)	(Address = 0x09BC)	
(D12LA0R)	(Address = 0x09CC)	
(D13LA0R)	(Address = 0x09DC)	
(D14LA0R)	(Address = 0x09EC)	
(D15LA0R)	(Address = 0x09FC)	
Bit(s)	Value	Description
7:0		Bits 7:0 of the link address are stored in this register.

DMA y Link Addr[15:8] Register		
(D0LA1R)	(Address = 0x018D)	
(D1LA1R)	(Address = 0x019D)	
(D2LA1R)	(Address = 0x01AD)	
(D3LA1R)	(Address = 0x01BD)	
(D4LA1R)	(Address = 0x01CD)	
(D5LA1R)	(Address = 0x01DD)	
(D6LA1R)	(Address = 0x01ED)	
(D7LA1R)	(Address = 0x01FD)	
(D8LA1R)	(Address = 0x098D)	
(D9LA1R)	(Address = 0x099D)	
(D10LA1R)	(Address = 0x09AD)	
(D11LA1R)	(Address = 0x09BD)	
(D12LA1R)	(Address = 0x09CD)	
(D13LA1R)	(Address = 0x09DD)	
(D14LA1R)	(Address = 0x09ED)	
(D15LA1R)	(Address = 0x09FD)	
Bit(s)	Value	Description
7:0		Bits 15:8 of the link address are stored in this register.

DMA y Link Addr[23:16] Register		
(D0LA2R)	(Address = 0x018E)	
(D1LA2R)	(Address = 0x019E)	
(D2LA2R)	(Address = 0x01AE)	
(D3LA2R)	(Address = 0x01BE)	
(D4LA2R)	(Address = 0x01CE)	
(D5LA2R)	(Address = 0x01DE)	
(D6LA2R)	(Address = 0x01EE)	
(D7LA2R)	(Address = 0x01FE)	
(D8LA2R)	(Address = 0x098E)	
(D9LA2R)	(Address = 0x099E)	
(D10LA2R)	(Address = 0x09AE)	
(D11LA2R)	(Address = 0x09BE)	
(D12LA2R)	(Address = 0x09CE)	
(D13LA2R)	(Address = 0x09DE)	
(D14LA2R)	(Address = 0x09EE)	
(D15LA2R)	(Address = 0x09FE)	
Bit(s)	Value	Description
7:0		Bits 23:16 of the link address are stored in this register.

25. 10/100BASE-T ETHERNET

25.1 Overview

Network Port B implements a full 10/100Base-T Ethernet MAC and PHY; no external PHY chip is required. The MAC is fully compliant with the IEEE 802.3 Ethernet standard, including support for auto-negotiation, link detection, multicast filtering, and broadcast addresses. A wide variety of transmit and receive options is available, including control over frame size, CRC attachment, maximum allowed frame size, and interpacket gap length. The receiver and transmitter each have a dedicated 2048-byte FIFO.

The Network Port B receiver transfers both data and status information to memory via the DMA, eliminating the need for receive data or status interrupts and dedicated receive status registers. The network port appends six bytes of status information to the last byte of the received data. Buffer and byte counts in the DMA can be used to find this status information in memory. In cases where a received frame has been discarded because of an error, only these six bytes of status will be transferred to memory. The DMA must be programmed to close a buffer on end-of-frame, as the network port marks the last byte of status this way.

The Network Port B transmitter uses interrupts because the DMA has no way of knowing when (or if) the frame has successfully been sent. Both the receive and transmit FIFOs are capable of DMA fly-by operation.

The network port requires an accurate 25 MHz clock to generate the 100 Mbit/s serial rate of 100Base-T. This clock can come from dedicated pins in the PHY interface, or from the main clock if a 25 MHz input is used. The clock for the network port may also be disabled to conserve power.

The network port transmitter precedes the transmit data automatically with a preamble and start-frame-delimiter, and appends CRC and the end-frame delimiter after the last byte. Frame transmission starts automatically once the transmit FIFO load is completed and any interframe gap time or back-off time has expired. Transmission is aborted if a collision is detected, and is retried up to 16 times using the standard random back-off time algorithm. Detection of a collision causes the transmitter to send a 32-bit “jam” pattern of all ones to guarantee that all receivers in the network recognize the collision.

The network port receiver uses the received preamble to synchronize to the phase of the incoming frame, and then waits for the start-frame delimiter. Character assembly begins at this point, and each byte is transferred to the receive FIFO. However, no interrupt or DMA request will occur until after the first six bytes of the frame have been received and checked for an address match.

The receiver can receive frames independent of the address (promiscuous mode), or it can receive frames with a physical address match, a broadcast address match, or a multicast address match.

Normal DMA transfers of data begin once an address match occurs, and continue until the end-frame delimiter is recognized or the line goes idle because of a collision. The network receiver calculates the CRC across the entire frame in parallel with character assembly, and reports the result when the end-frame delimiter is recognized. Normally frames with bad CRC are discarded. The receiver also reports misaligned end-frame delimiters (those that do not occur on byte boundaries).

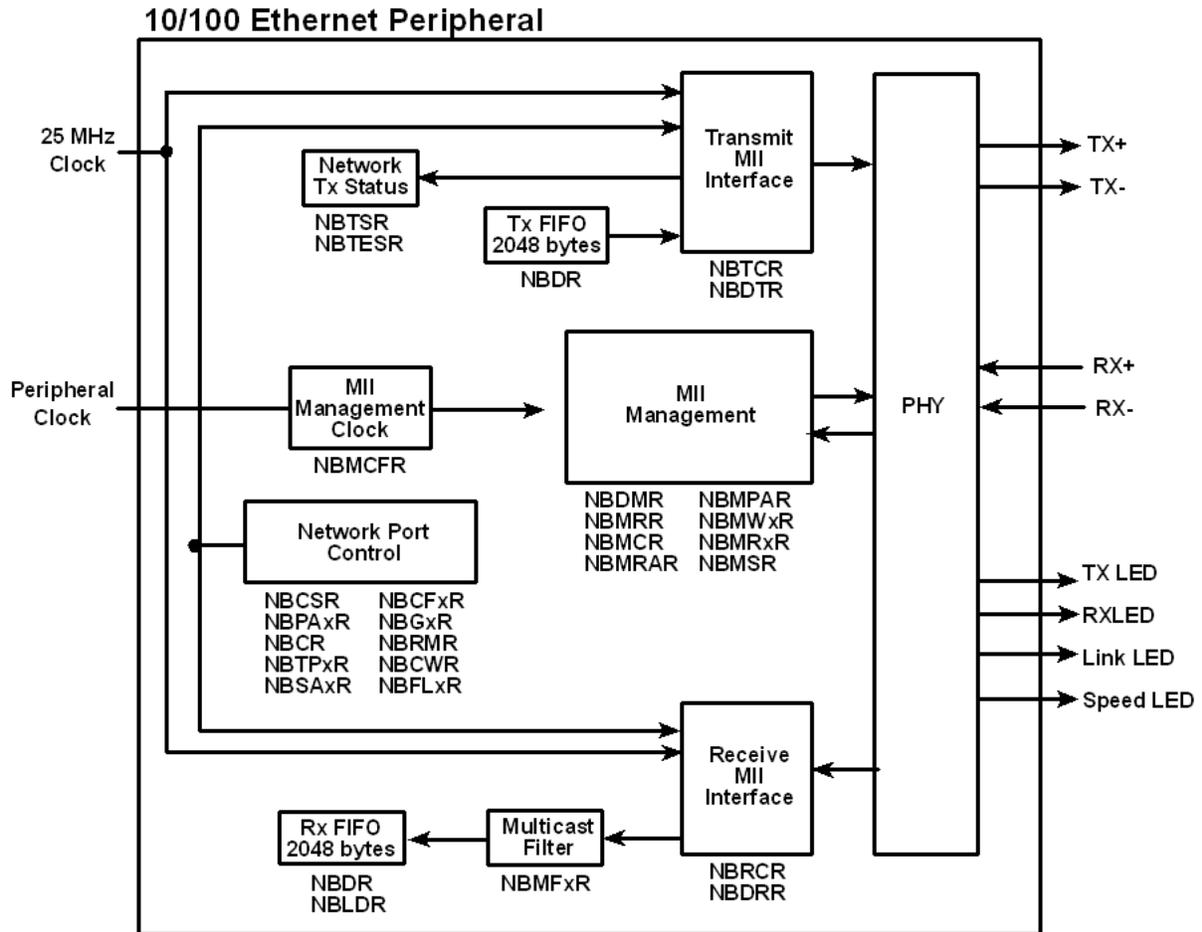
The network port implements the NLP receive link integrity test state machine, which requires link integrity pulses to be detected at certain intervals in the absence of other network activity. If the network receiver enters the NLP Link Test Fail state because of missing link-test pulses, this state machine requires seven successive properly timed link test pulses (or an equal number of FLP bursts) before reporting that the link is again active. The reset state of this state machine is link-inactive. Note that this is a subtle difference relative to the normal 10Base-T receive link-integrity state machine, which requires either link test pulses or carrier sense to make the link active.

The network port implements the auto-negotiation algorithm to determine half-duplex or full-duplex operation. In addition to its normal automatic operation, this feature can be disabled or commanded to execute under software control.

There is a dedicated 2.5 V regulator in the Rabbit 6000 to power the Ethernet PHY. Several pins come off the chip to allow for bypass capacitors. The regulator is disabled if Network Port B is disabled.

The I/O interface consists of differential pair circuits for transmit and receive and four LED outputs for link, TX, RX, and speed status.

25.1.1 Block Diagram



25.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Network Port B Data Register	NBDR	0x0200	R/W	xxxxxxxx
Network Port B Last Data Register	NBLDR	0x0201	W	xxxxxxxx
Network Port B Transmit Status Register	NBTSR	0x0202	R	00000000
Network Port B Control/Status Register	NBCSR	0x0204	R/W	00000000
Network Port B Command Register	NBCR	0x0206	W	00000000
Network Port B Transmit Pause LSB Register	NBTPLR	0x0208	R/W	00000000
Network Port B Transmit Pause MSB Register	NBTPMR	0x0209	R/W	00000000
Network Port B Transmit Control Register	NBTCR	0x020A	R/W	00000000
Network Port B Receive Control Register	NBRCR	0x020B	R/W	00000000
Network Port B Transmit Extra Status Register	NBTESR	0x020C	R/W	00000000
Network Port B Phys. Addr. [7:0] Register	NBPA0R	0x0210	W	xxxxxxxx
Network Port B Phys. Addr. [15:8] Register	NBPA1R	0x0211	W	xxxxxxxx
Network Port B Phys. Addr. [23:16] Register	NBPA2R	0x0212	W	xxxxxxxx
Network Port B Phys. Addr. [31:24] Register	NBPA3R	0x0213	W	xxxxxxxx
Network Port B Phys. Addr. [39:32] Register	NBPA4R	0x0214	W	xxxxxxxx
Network Port B Phys. Addr. [47:40] Register	NBPA5R	0x0215	W	xxxxxxxx
Network Port B Multicast Filter [7:0] Register	NBMF0R	0x0218	R/W	xxxxxxxx
Network Port B Multicast Filter [15:8] Register	NBMF1R	0x0219	R/W	xxxxxxxx
Network Port B Multicast Filter [23:16] Register	NBMF2R	0x021A	R/W	xxxxxxxx
Network Port B Multicast Filter [31:24] Register	NBMF3R	0x021B	R/W	xxxxxxxx
Network Port B Multicast Filter [39:32] Register	NBMF4R	0x021C	R/W	xxxxxxxx
Network Port B Multicast Filter [47:40] Register	NBMF5R	0x021D	R/W	xxxxxxxx
Network Port B Multicast Filter [55:48] Register	NBMF6R	0x021E	R/W	xxxxxxxx
Network Port B Multicast Filter [63:56] Register	NBMF7R	0x021F	R/W	xxxxxxxx
Network Port B Direct Rx Register	NBDRR	0x0228	R	xxxxxxxx
Network Port B Direct Tx Register	NBDTR	0x0229	W	xxxxxxxx
Network Port B Direct MII Register	NBDMR	0x022A	R/W	xxxxxxxx
Network Port B Configuration 0 Register	NBCF0R	0x0240	R/W	00000000
Network Port B Configuration 1 Register	NBCF1R	0x0241	R/W	00000000
Network Port B Configuration 2 Register	NBCF2R	0x0242	R/W	00000000

Register Name	Mnemonic	I/O Address	R/W	Reset
Network Port B Configuration 3 Register	NBCF3R	0x0243	R/W	00000000
Network Port B Gap 0 Register	NBG0R	0x0244	R/W	00000000
Network Port B Gap 2 Register	NBG2R	0x0246	R/W	00000000
Network Port B Gap 1 Register	NBG1R	0x0247	R/W	00000000
Network Port B Retransmit Max Register	NBRMR	0x0248	R/W	00000000
Network Port B Collision Window Register	NBCWR	0x0249	R/W	00000000
Network Port B Frame Limit LSB Register	NBFLLR	0x024A	R/W	00000000
Network Port B Frame Limit MSB Register	NBFMLR	0x024B	R/W	00000000
Network Port B MII Configuration Register	NBMCFR	0x0250	R/W	00000000
Network Port B MII Reset Register	NBMRR	0x0251	R/W	00000000
Network Port B MII Command Register	NBMCR	0x0252	R/W	00000000
Network Port B MII Register Address Register	NBMRAR	0x0254	R/W	00000000
Network Port B MII PHY Address Register	NBMPAR	0x0255	R/W	00000000
Network Port B MII Write LSB Register	NBMWLR	0x0256	W	00000000
Network Port B MII Write MSB Register	NBMWMR	0x0257	W	00000000
Network Port B MII Read LSB Register	NBMRLR	0x0258	R	00000000
Network Port B MII Read MSB Register	NBMRMR	0x0259	R	00000000
Network Port B MII Status Register	NBMSR	0x025A	R/W	00000000
Network Port B Station Address 0 Register	NBSA0R	0x0260	R/W	00000000
Network Port B Station Address 1 Register	NBSA1R	0x0261	R/W	00000000
Network Port B Station Address 2 Register	NBSA2R	0x0262	R/W	00000000
Network Port B Station Address 3 Register	NBSA3R	0x0263	R/W	00000000
Network Port B Station Address 4 Register	NBSA4R	0x0264	R/W	00000000
Network Port B Station Address 5 Register	NBSA5R	0x0265	R/W	00000000

25.2 Dependencies

25.2.1 I/O Pins

The Ethernet port interface has 11 dedicated signal pins, which are listed in Table 25-1.

Table 25-1. Network Port B Interface

Section	Signal	Direction	Function
Data	TX+	Output	Differential transmit data
	TX-	Output	
	RX+	Input	Differential receive data
	RX-	Input	
Clock	XTL_25MI	—	Optional 25MHz crystal input
	XTL_25MO		
LEDs	/LINK_LED	Output	Link status, active low
	/TX_LED	Output	TX status, active low
	/RX_LED	Output	RX status, active low
	/SPEED_LED	Output	Speed status, low=10MBit
Power	RSET	—	Bias resistor (13Ω to ground optimal)
	ETH_2.5V	—	2.5V supply

25.2.2 Clocks

The network port requires a 25 MHz clock input for 10/100Base-T operation; the standard operation is to install a 25 MHz main clock and select the internal clock sharing option in MSCR. If a main clock other than 25 MHz is desired, a separate 25 MHz oscillator exists on the XTL_25MI and XTL_25MO clocks. An external crystal can be attached, or a 25 MHz clock can be applied directly to XTL_25MO.

For optimal power reduction, the XTL_25MO pin should be attached to the ETH_2.5V signal if the external 25 MHz clock interface is not used.

25.2.3 Other Registers

Register	Function
MSCR	Select shared or external 25 MHz clock. Reset PHY.
ENPR	Enable 10/100 Ethernet functionality.

25.2.4 Interrupts

The network interrupt can be generated by an Ethernet frame being transmitted correctly, transmitted with an error, or if a transmit pause occurs (control frame is transmitted but not the data). The events that generate an interrupt can be selected in NBCSR.

The receive frame status is attached to the end of the data frame itself, so the DMA interrupt can be used to handle received frame. See Section 25.3 for more details.

The network port interrupt vector is located in the IIR at offset 0x1E0. It can be set at Priority 1, 2, or 3 by writing to NBCSR.

25.3 Operation

High-level support for TCP/IP and other protocols is beyond the scope of this manual, but this section will describe the low-level setup and operation of the 10/100Base-T Ethernet peripheral. Dynamic C has the necessary drivers.

The contents of the six status bytes are shown below. Note that any status block marked with RxOV (receive overflow) is invalid, as the FIFO could not hold the entire frame. Only the marked frame is invalid, so any previous frames read from the FIFO are fine. Once an overflow is detected, no subsequent frames can be buffered to the FIFO until a FIFO purge command is written to the NBCR.

Status Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
First	LSB of Rx Checksum							
Second	MSB of Rx Checksum							
Third	Receive Status Vector [7:0] (LSB of receive frame length)							
Fourth	Receive Status Vector [15:8] (MSB of receive frame length)							
Fifth	Receive Status Vector [23:16]							
Last	RxOV	Receive Status Vector [30:24]						

25.3.1 Setup

The following steps explain how to set up Network Port B.

1. In MSCR, select shared clock if the main clock is 25 MHz, and reset the PHY if desired.
2. Enable Network Port B by writing to ENPR.
3. Write the interrupt vector for the interrupt service routine to the external interrupt table.
4. Select the desired interrupts and interrupt priority by writing to NBCSR.
5. Select the MII interface settings by writing to NBMCFR, NBMRAR, and NBMPAR.

6. Select the desired configuration of transmit and receive operation by writing to NBTCR, NBTESR, and MBRCR.
7. Write the device's physical MAC address to the physical address (NBPAxR) and station address registers (NBSAxR).
8. If desired, write to the multicast filter registers (NBMFxR) to generate a multicast filter.
9. Select other options in the configuration registers NBCFxR, NBGxR, NBRMR, NBCWR, and NBFLxR.
10. Enable the network port transmitter by writing to NBTCR.
11. Enable the network port receiver by writing to NBRCR.

25.3.2 Transmit

The following steps explain how to transmit an Ethernet packet.

1. Set up a DMA buffer descriptor that will read the packet data from memory and write it to NBDR. Write the buffer descriptor's address to the DMA's initial address registers (see Chapter 24 for more information).
2. Enable the DMA transfer by auto-loading the buffer.
3. The packet transmission will proceed automatically. If any interrupts were enabled for any transmitted packet events, they will occur upon completion (or error).

Note that network interrupts will occur when the data appears in the network peripheral, but DMA interrupts will occur when the DMA transfer is complete.

25.3.3 Receive

The following steps explain how to receive an Ethernet packet.

1. Set up a DMA buffer descriptor that will read the packet data from NBDR and write it to memory. Write the buffer descriptor's address to the DMA's initial address registers (see Chapter 24 for more information).
2. Set up a DMA interrupt to handle the packet once it has been received and copied to memory.
3. Enable the DMA transfer by auto-loading the buffer.
4. The packet transmission will proceed automatically when data come in. When the DMA transfer is complete, the DMA interrupt can be used to start the packet processing. The status of the received packet is appended to the received data.

25.3.4 Handling Interrupts

The network port transmit interrupt is automatically cleared by reading NBCSR; received packets are handled via the DMA interrupt, which is automatically cleared when the ISR is called.

A sample packet transmit interrupt handler is shown below.

```
network_isr::
    push af
    ioi ld a, (NBCSR)      ; read the interrupt status
    push af               ; save status byte for later
    bit 4,a               ; did transmit error occur?
    jp nz, handle_tx_err
    bit 4,a               ; did transmit pause occur?
    jp nz, handle_pause_err
done:
    pop af
    ipres
    ret
handle_tx_err:
    ioi ld a, (NBTSR)     ; get transmitter status
    ; check why error occurred and respond accordingly
    pop af
    pop af
    ipres
    ret
handle_pause_err:
    ; handle transmit pause
    pop af
    ipres
    ret
```

A sample packet receive interrupt handler is shown below.

```
dma_eth_rx_isr::
    ; interrupt is automatically cleared
    ; check status bytes appended to packet just received
    ipres
    ret
```

25.3.5 Multicast Addressing

A physical address match requires that the received frame address is a physical address that matches every bit of the programmed receive address. A broadcast address match requires that all 48 bits of the received frame address be “ones.” A multicast address match requires the received frame address to be a multicast address (LSB of the address is one) and a match in the multicast address filter. The multicast address filter uses the six most significant bits of the CRC calculated on the receive address as an index into a 64-by-1 bit table written under program control. A one in the corresponding table entry constitutes a multicast address match as far as the network port is concerned. A table of one set of unique multicast addresses corresponding to each filter bit is shown below. The table shows the least significant byte of the multicast address; the remaining five bytes of the address are all zeros for this set of multicast addresses.

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
NBMF7R	0x17	0x0B	0x05	0x19	0x85	0x99	0x97	0x8B
NBMF6R	0xD9	0xC5	0xCB	0xD7	0x4B	0x57	0x59	0x45
NBMF5R	0xCF	0xD3	0xDD	0xC1	0x5D	0x41	0x4F	0x53
NBMF4R	0x01	0x1D	0x13	0x0F	0x93	0x8F	0x81	0x9D
NBMF3R	0x5F	0x43	0x4D	0x51	0xCD	0xD1	0xDF	0xC3
NBMF2R	0x91	0x8D	0x83	0x9F	0x03	0x1F	0x11	0x0D
NBMF1R	0x87	0x9B	0x95	0x89	0x15	0x09	0x07	0x1B
NBMF0R	0x49	0x55	0x5B	0x47	0xDB	0xC7	0xC9	0xD5

25.4 Register Descriptions

Network Port B Data Register (NBDR) (Address = 0x0200)		
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer. This register is not normally accessed by the processor, but is accessed by the DMA channels.
	Write	Loads the transmit buffer with a data byte for transmission.

Network Port B Last Data Register (NBLDR) (Address = 0x0201)		
Bit(s)	Value	Description
7:0	Read	Returns the contents of the receive buffer. This register is not normally accessed by the processor, but is accessed by the DMA channels.
	Write	Loads the transmit buffer with the last data byte of a frame to enable the subsequent transmission of the CRC. The DMA automatically writes the last byte of the frame to this address.

Network Port B Transmit Status Register (NBTSR) (Address = 0x0202)		
Bit(s)	Value	Description
7	0	Frame transmission not complete.
	1	Frame transmission complete.
6	0	Frame transmission is not deferring.
	1	Frame transmission is deferring.
5	0	No excessive collisions.
	1	Frame transmission aborted due to excessive collisions.
4	0	No transmit underrun.
	1	Frame transmission aborted because of a FIFO underrun.
3	0	Frame transmission not too long.
	1	Frame transmission too long.
2	0	No excessive defers.
	1	Frame transmission deferred excessively.
1	0	No collisions.
	1	Frame transmission encountered at least one collision.
0	0	No late collisions.
	1	Frame transmission encountered a late collision (later than one slot time).

Network Port B Control/Status Register (NBCSR) (Address = 0x0204)		
Bit(s)	Value	Description
7:6		These bits are reserved and will always read as zero.
5:3 (Write-only)	0	The corresponding interrupt is disabled.
	1	The corresponding interrupt is enabled.
5:3	Read	These bits, and the Network Port interrupt, are automatically cleared by a read of this register. The individual interrupt enables are not affected.
5 (Read-only)	0	No transmit okay interrupt.
	1	Transmit okay interrupt.
4 (Read-only)	0	No transmit error interrupt.
	1	Transmit error interrupt.
3 (Read-only)	0	No transmit pause interrupt.
	1	Transmit pause interrupt (control frame complete).
2	0	This bit is reserved and will always read as zero.
1:0	00	The Network Port interrupt is disabled.
	01	The Network Port uses Interrupt Priority 1.
	10	The Network Port uses Interrupt Priority 2.
	11	The Network Port uses Interrupt Priority 3.

Network Port B Command Register (NBCR) (Address = 0x0206)		
Bit(s)	Value	Description
7	0	No operation.
	1	Transmit start command.
6	0	No operation.
	1	Transmit PAUSE control frame command.
5	0	No operation.
	1	Transmit half-duplex backpressure.
4	0	No operation.
	1	Transmit FIFO purge command.
3:1		These bits are ignored and should always be written as zeros.
0	0	No operation.
	1	Receive FIFO purge command.

Network Port B Transmit Pause LSB Register (NBTPLR) (Address = 0x0208)		
Bit(s)	Value	Description
7:0		LSB of parameter sent in PAUSE control frame.

Network Port B Transmit Pause MSB Register (NBTPMR) (Address = 0x0209)		
Bit(s)	Value	Description
7:0		MSB of parameter sent in PAUSE control frame.

Network Port B Transmit Control Register (NBTCCR) (Address = 0x020A)		
Bit(s)	Value	Description
7:6	00	Disable transmit FIFO.
	01	DMA request when frame transmission is complete.
	10	Reserved.
	11	Reserved.
5:4	00	Start transmit on command only.
	01	Start transmit on command or Last Byte written.
	10	Start transmit on command, when FIFO is half full, or Last Byte written.
	11	Start transmit on command, when FIFO is one-fourth full, or Last Byte written.
3:0		These bits are reserved and should be written with zeros.

Network Port B Receive Control Register (NBRCCR) (Address = 0x020B)		
Bit(s)	Value	Description
7:6	00	Disable receive FIFO.
	01	DMA request when frame reception is complete.
	10	DMA request when FIFO is half full or frame reception is complete.
	11	DMA request when FIFO is one-fourth full or frame reception is complete.
5	0	Normal receiver operation.
	1	Place receiver in Monitor Mode. Receiver operates normally, but does not buffer frames to memory.
4	0	Receive frames less than 64 bytes in length discarded.
	1	Receive frames as short as 8 bytes accepted.
3	0	Receive frames with errors discarded. Reclaim buffer space.
	1	Receive frames with errors accepted. Do not reclaim buffer space.
2	0	Receive frames with broadcast address ignored.
	1	Receive frames with broadcast address accepted
1	0	Receive frames with multicast addresses ignored.
	1	Receive frames with multicast addresses accepted if passing hashing filter.
0	0	Receive frames with mismatched physical addresses are ignored.
	1	Receive frames with any physical address accepted. Promiscuous mode.

Network Port B Transmit Extra Status Register (NBTESR)		(Address = 0x020C)
Bit(s)	Value	Description
7		This bit is reserved and will always be read as zero.
6	0	No transmit length out-of-range, or not checked.
	1	Transmit frame had length out-of-range error.
5	0	No transmit length check error, or transmit length not checked.
	1	Transmit frame had length check error.
4	0	No transmit CRC error, or transmit CRC not checked.
	1	Transmit frame had CRC error.
3:0		Transmit frame collision count.

Network Port B Physical Address x Register		
(NBPA0R)	(Address = 0x0210)	
(NBPA1R)	(Address = 0x0211)	
(NBPA2R)	(Address = 0x0212)	
(NBPA3R)	(Address = 0x0213)	
(NBPA4R)	(Address = 0x0214)	
(NBPA5R)	(Address = 0x0215)	
Bit(s)	Value	Description
7:0	Write	Byte of physical address for receive address filtering.

Network Port B Multicast Filter x Register		
(NBMF0R)	(Address = 0x0218)	
(NBMF1R)	(Address = 0x0219)	
(NBMF2R)	(Address = 0x021A)	
(NBMF3R)	(Address = 0x021B)	
(NBMF4R)	(Address = 0x021C)	
(NBMF5R)	(Address = 0x021D)	
(NBMF6R)	(Address = 0x021E)	
(NBMF7R)	(Address = 0x021F)	
Bit(s)	Value	Description
7:0	Write	Eight bits of the multicast filter. At the end of a received multicast address, the upper six bits of CRC are used as an index into this 64-bit table. If the corresponding bit is zero, the frame is discarded. If the corresponding bit is one, the frame is accepted.

Network Port B Configuration 0 Register (NBCF0R) (Address = 0x0240)		
Bit(s)	Value	Description
7:5		These bits are ignored and will always return zeros when read.
4	0	Disable loopback.
	1	Enable loopback.
3	0	Disable transmit flow control.
	1	Enable transmit flow control (PAUSE control frames).
2	0	Disable receive flow control.
	1	Enable receive flow control (PAUSE control frames).
1	0	Pass normal receive frames only.
	1	Pass all receive frames (normal or control).
0	0	Disable receiver.
	1	Enable receiver.

Network Port B Configuration 1 Register (NBCF1R) (Address = 0x0241)		
Bit(s)	Value	Description
7	0	No operation.
	1	Reset entire MAC.
6	0	No operation.
	1	Reset transmit random number generator.
5:4		These bits are ignored and will always return zeros when read.
3	0	No operation.
	1	Reset MAC control sublayer/receive domain logic.
2	0	No operation.
	1	Reset receiver.
1	0	No operation.
	1	Reset MAC control sublayer/transmit domain logic.
0	0	No operation.
	1	Reset transmitter.

Network Port B Configuration 2 Register (NBCF2R) (Address = 0x0242)		
Bit(s)	Value	Description
7:5	xx0	Disable transmit pad operation. Check CRC if not appended.
	001	Pad transmit frames to 60 bytes, append CRC.
	x11	Pad transmit frames to 64 bytes, append CRC.
	101	Pad transmit frames to 60 bytes (not VLAN tagged) or 64 bytes (VLAN tagged), append CRC.
4	0	Disable transmit CRC insertion.
	1	Enable transmit CRC insertion. Must be set if bit 5 is set.
3	0	Normal 802.3 frame structure.
	1	Enable 4-byte header (ignored by CRC).
2	0	Normal 802.3 frame length restrictions.
	1	Enable huge frames (transmit and receive).
1	0	Disable frame length checking.
	1	Enable frame length checking (transmit and receive).
0	0	Enable half-duplex.
	1	Enable full-duplex.

Network Port B Configuration 3 Register (NBCF3R) (Address = 0x0243)		
Bit(s)	Value	Description
7		This bit is ignored and will always return zero when read.
6	0	Abort transmit on excessive deferral.
	1	Defer to carrier indefinitely.
5	0	Normal transmit operation after back-pressure collision.
	1	Enable immediate transmission after back-pressure collision.
4	0	Normal 802.3 back-off operation.
	1	Enable immediate retransmit (no back-off).
3:2		These bits are ignored and will always return zeros when read.
1	0	Disable preamble length limit checking.
	1	Enable preamble length limit checking (12 bytes or less only).
0	0	Disable preamble checking.
	1	Enable preamble checking.

Network Port B Gap 0 Register (NBG0R) (Address = 0x0244)		
Bit(s)	Value	Description
7		This bit is ignored and will always return zero when read.
6:0		Back-to-back interpacket gap. Recommended values are 0x15 for full-duplex operation, and 0x12 for half-duplex operation. These values result in 9.6 μ s for 10 Mbit/s and 0.96 μ s for 100 Mbit/s, as specified by 802.3.

Network Port B Gap 2 Register (NBG2R) (Address = 0x0246)		
Bit(s)	Value	Description
7		This bit is ignored and will always return zero when read.
6:0		Non-back-to-back interpacket gap for carrier deference. Recommended value is 0x0C, as specified by 802.3.

Network Port B Gap 1 Register (NBG1R) (Address = 0x0247)		
Bit(s)	Value	Description
7		This bit is ignored and will always return zero when read.
6:0		Non-back-to-back interpacket gap. Recommended value is 0x12. This value results in 9.6 μ s for 10 Mbits/s and 0.96 μ s for 100 Mbits/s, as specified by 802.3.

Network Port B Retransmit Max Register (NBRMR) (Address = 0x0248)		
Bit(s)	Value	Description
7:4		These bits are ignored and will always return zero when read.
3:0		Number of retransmission attempts after a collision before aborting. Default (and value specified by 802.3) is 0xF.

Network Port B Collision Window Register (NBCWR) (Address = 0x0249)		
Bit(s)	Value	Description
7:6		These bits are ignored and will always return zero when read.
5:0		Collision window (slot time). Default (and value specified by 802.3) is 0x37.

Network Port B Frame Limit LSB Register (NBFLLR) (Address = 0x024A)		
Bit(s)	Value	Description
7:0		LSB of maximum frame length.

Network Port B Frame Limit MSB Register (NBFLMR) (Address = 0x024B)		
Bit(s)	Value	Description
7:0		MSB of maximum frame length. Default (and value specified by 802.3) is 0x0600.(1536), including preamble, address, length, and CRC fields. Should not be less than 0x05EE (1518) for normal operation.

Network Port B MII Configuration Register (NBMCFR) (Address = 0x0250)		
Bit(s)	Value	Description
7:5		These bits are ignored and will always return zeros when read.
4:2	000	MII Management Clock is system clock divided by 4.
	001	This value is reserved and should not be used.
	010	MII Management Clock is system clock divided by 6.
	011	MII Management Clock is system clock divided by 8.
	100	MII Management Clock is system clock divided by 10.
	101	MII Management Clock is system clock divided by 20.
	110	MII Management Clock is system clock divided by 40.
	111	MII Management Clock is system clock divided by 80.
1	0	Enable MII frame preambles.
	1	Disable MII frame preambles.
0	0	Disable MII scan function.
	1	Enable MII scan function.

Network Port B MII Reset Register (NBMRR) (Address = 0x0251)		
Bit(s)	Value	Description
7	0	No operation.
	1	Reset the MII management module.
6:0		These bits are ignored and will always return zeros when read.

Network Port B MII Command Register (NBMCRR) (Address = 0x0252)		
Bit(s)	Value	Description
7:2		These bits are ignored and will always return zeros when read.
1	0	No operation.
	1	Enable scan. MII module performs continuous read cycles.
0	0	No operation.
	1	Perform one MII read cycle.

Network Port B MII Register Address Register (NBMRAR) (Address = 0x0254)		
Bit(s)	Value	Description
7:5		These bits are ignored and will always return zeros when read.
4:0		MII register address.

Network Port B MII PHY Address Register (NBMPAR) (Address = 0x0255)		
Bit(s)	Value	Description
7:5		These bits are ignored and will always return zeros when read.
4:0		MII PHY address.

Network Port B MII Write LSB Register (NBMWLR) (Address = 0x0256)		
Bit(s)	Value	Description
7:0		LSB of MII write data.

Network Port B MII Write MSB Register (NBWWMR) (Address = 0x0257)		
Bit(s)	Value	Description
7:0		MSB of MII write data. Writing to this register triggers an MII write cycle.

Network Port B MII Read LSB Register (NBMLR) (Address = 0x0258)		
Bit(s)	Value	Description
7:0		LSB of MII read data.

Network Port B MII Read MSB Register (NBMRMR) (Address = 0x0259)		
Bit(s)	Value	Description
7:0		MSB of MII read data.

Network Port B MII Status Register (NBMSR) (Address = 0x025A)		
Bit(s)	Value	Description
7:4		These bits are ignored and will always return zeros when read.
3	0	MII link okay.
	1	MII link fail.
2	0	MII read data valid.
	1	MII read data not valid.
1	0	MII not busy scanning.
	1	MII scan operation in progress.
0	0	MII not busy performing a read or write cycle.
	1	MII busy performing a read or write cycle.

Network Port B Station Address x Register		
(NBSA0R) (Address = 0x0260)		
(NBSA1R) (Address = 0x0261)		
(NBSA2R) (Address = 0x0262)		
(NBSA3R) (Address = 0x0263)		
(NBSA4R) (Address = 0x0264)		
(NBSA5R) (Address = 0x0265)		
Bit(s)	Value	Description
7:0		Byte of physical address for transmit control frames.

Master System Configuration Register (MSCR) (Address = 0x0434)		
Bit(s)	Value	Description
7	0	CPU clock direct from oscillator.
	1	CPU clock from system PLL output (divided by two). Response to this setting may be delayed until the PLL output is stable (roughly 200 μ s after enabling the system PLL, uses 32 kHz clock to generate delay).
6		This bit is reserved and should be written as zero.
5	0	Clock on-chip 10/100 PHY from system oscillator.
	1	Enable embedded oscillator in the internal 10-100 PHY. If using this option, the oscillator must be enabled at least 500 ns before the PHY is enabled in ENPR. This delay must be created in software.
4 (Write-only)	0	No reset of the internal 10/100 PHY. Reads always return zero.
	1	Reset the internal 10/100 PHY hardware. This command must not be issued until at least 600 ms after the internal PHY has been enabled in ENPR. This delay must be created in software.
3:2	00	FIMB clock is disabled.
	01	FIMB clock is identical to the CPU clock.
	10	This bit combination is reserved and should not be used.
	11	FIMB clock from system PLL output. Response to this setting may be delayed until the PLL output is stable (roughly 200 μ s after enabling the system PLL, uses 32 kHz clock to generate delay).
1:0	00	FIMA clock is disabled.
	01	FIMA clock is identical to the CPU clock.
	10	This bit combination is reserved and should not be used.
	11	FIMA clock from system PLL output. Response to this setting may be delayed until the PLL output is stable (roughly 200 μ s after enabling the system PLL, uses 32 kHz clock to generate delay).

Enable Network Port Register (ENPR) (Address = 0x0430)		
Bit(s)	Value	Description
7	0	Disable Network Port C (the Wi-Fi port).
	1	Enable Network Port C (the Wi-Fi port).
6	0	Disable Network Port B (the 10/100Base-T Ethernet port).
	1	Enable Network Port B (the 10/100Base-T Ethernet port).
5	0	Disable Network Port D (the USB port).
	1	Enable Network Port D (the USB port).
4	0	Internal 10/100 PHY. This bit is ignored unless bit 6 of this register is also set, at which point the internal PHY is powered up.
	1	External 10/100 PHY.
3:2	00	Network Port D interrupts are disabled.
	01	Network Port D interrupts use Interrupt Priority 1.
	10	Network Port D interrupts use Interrupt Priority 2.
	11	Network Port D interrupts use Interrupt Priority 3.
1:0	00	Network Port C interrupts are disabled.
	01	Network Port C interrupts use Interrupt Priority 1.
	10	Network Port C interrupts use Interrupt Priority 2.
	11	Network Port C interrupts use Interrupt Priority 3.

26. 802.11A/B/G WIRELESS

26.1 Overview

Network Port C implements an 802.11a/b/g compatible wireless LAN radio. It consists of a baseband module, dedicated processor, high-speed A/D and D/A converters, and an interface for one of several external radio-frequency (RF) transceivers. The external transceiver is responsible for the up-conversion and down-conversion of the RF signal. The receiver and transmitter each have a dedicated 2048-byte FIFO.

Communication with the external transceiver is accomplished through a 3-wire serial interface. Support is also provided for a parallel automatic gain control feedback loop. Control for multiple antennas is available, providing support for separate receive and transmit antennas or switched antenna diversity reception.

The MAC processing is handled by a combination of the baseband processor and software on the Rabbit; any timing-critical MAC operations are handled automatically by the baseband. These operations include time management and transmission-interval spacing. The MAC also performs the CRC check of all received frames and handles the virtual carrier sense functionality.

The Rabbit 6000 supports both the infrastructure and the ad-hoc modes. Multicast transmissions are supported as well.

The interface to the external transceiver consists of 19 digital pins and 17 analog pins. A 20 MHz clock is required as an input; either a crystal or an external clock can be used. A separate low-speed A/D converter is available to monitor the transmit power.

The wireless peripheral also contains an AES encryption/decryption engine for both transmitted and received packets. Up to four expanded keys can be stored in the peripheral at one time.

There is a dedicated 2.5 V regulator in the Rabbit 6000 to power the Wi-Fi D/A converter. Several pins come off the chip to allow for bypass capacitors. The regulator is disabled if Network Port C is disabled.

The high-speed differential A/D and D/A converters are available for customer use if the Wi-Fi is disabled; see Chapter 23 for additional details.

26.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Enable Network Port Register	ENPR	0x0430	R/W	00000000
Network Port C Version 0 Register	NCV0R	0x0A00	R	00000000
Network Port C Version 1 Register	NCV1R	0x0A01	R	00000001
Network Port C General Control 0 Register	NCGC0R	0x0A04	R/W	00000000
Network Port C General Control 1 Register	NCGC1R	0x0A05	R/W	01000000
Network Port C General Control 2 Register	NCGC2R	0x0A06	R/W	01111111
Network Port C General Control 3 Register	NCGC3R	0x0A07	R	00110111
Network Port C General Status 0 Register	NCGS0R	0x0A08	R	00010000
Network Port C General Status 1 Register	NCGS1R	0x0A09	R/W	00000000
Network Port C General Status 2 Register	NCGS2R	0x0A0A	R/W	00000000
Network Port C General Status 3 Register	NCGS3R	0x0A0B	R/W	00110000
Network Port C RSSI 0 Register	NCRSSI0R	0x0A0C	R	01111111
Network Port C RSSI 1 Register	NCRSSI1R	0x0A0D	R	00000000
Network Port C RSSI 2 Register	NCRSSI2R	0x0A0E	R	00000000
Network Port C RSSI 3 Register	NCRSSI3R	0x0A0F	R	00000000
Network Port C Interrupt Mask Register	NCIMR	0x0A10	R/W	00000000
Network Port C Interrupt Status Register	NCISR	0x0A14	R/W	00000000
Network Port C SPI Data 0 Register	NCSPID0R	0x0A18	W	00000000
Network Port C SPI Data 1 Register	NCSPID1R	0x0A19	W	00000000
Network Port C SPI Data 2 Register	NCSPID2R	0x0A1A	W	00000000
Network Port C SPI Data 3 Register	NCSPID3R	0x0A1B	W	00000000
Network Port C SPI Control Register	NCSPICR	0x0A1C	R/W	00011000
Network Port C Data FIFO 0 Register	NCDFR	0x0A20	R/W	00000000
Network Port C Configuration-1 Register 0	NCC1R0	0x0A28	R/W	00101100
Network Port C Configuration-1 Register 1	NCC1R1	0x0A29	R/W	00000000
Network Port C Configuration-1 Register 2	NCC1R2	0x0A2A	R/W	01000011
Network Port C Configuration-1 Register 3	NCC1R3	0x0A2B	R/W	10000000
Network Port C Configuration-2 Register 0	NCC2R0	0x0A2C	R/W	00010100
Network Port C Configuration-2 Register 1	NCC2R1	0x0A2D	R/W	10110011
Network Port C Configuration-2 Register 2	NCC2R2	0x0A2E	R/W	10000010

Register Name	Mnemonic	I/O Address	R/W	Reset
Network Port C Configuration-2 Register 3	NCC2R3	0x0A2F	R/W	00001000
Network Port C AES FIFO Register	NCAFR	0x0A30	R/W	xxxxxxxx
Network Port C AES Mode Register	NCAMR	0x0A38	R/W	00000000
Network Port C Output Control Register 0	NCOCR0	0x0A3C	R/W	00000001
Network Port C Output Control Register 1	NCOCR1	0x0A3D	R/W	00000000
Network Port C Output Control Register 2	NCOCR2	0x0A3E	R/W	00000000
Network Port C Output Control Register 3	NCOCR3	0x0A3F	R/W	00000000
Network Port C Station ID x Register	NCSTAIDxR	0x0A40– 0x0A45	R/W	xxxxxxxx
Network Port C BSS ID x Register	NCBSSIDxR	0x0A48– 0x0A4D	R/W	xxxxxxxx
Network Port C OFDM Basic Rate Set Register	NCOFDMBR SR	0x0A50	R/W	xxxxxxxx
Network Port C PSK Basic Rate Set Register	NCPSKBRSR	0x0A51	R/W	xxxxxxxx
Network Port C SSID Length Register	NCSSIDLR	0x0A53	R/W	xxxxxxxx
Network Port C Backoff 0 Register	NCBO0R	0x0A56	R/W	xxxxxxxx
Network Port C Backoff 1 Register	NCBO1R	0x0A57	R/W	xxxxxxxx
Network Port C DTIM Period Register	NCDTIMPR	0x0A58	R/W	xxxxxxxx
Network Port C CFP Period Register	NCCFPPR	0x0A59	R/W	xxxxxxxx
Network Port C Listen Interval 0 Register	NCLI0R	0x0A5A	R/W	xxxxxxxx
Network Port C Listen Interval 1 Register	NCLI1R	0x0A5B	R/W	xxxxxxxx
Network Port C Beacon Interval 0 Register	NCBI0R	0x0A5C	R/W	xxxxxxxx
Network Port C Beacon Interval 1 Register	NCBI1R	0x0A5D	R/W	xxxxxxxx
Network Port C CFP Max Duration 0 Register	NCCFPMD0R	0x0A5E	R/W	xxxxxxxx
Network Port C CFP Max Duration 1 Register	NCCFPMD1R	0x0A5F	R/W	xxxxxxxx
Network Port C MAC Status Register	NCMACSR	0x0A6C	R/W	xxxxxxxx
Network Port C MAC Control Register	NCMACCR	0x0A67	R/W	xxxxxxxx
Network Port C Remaining Backoff 0 Register	NCRBO0R	0x0A6A	R/W	xxxxxxxx
Network Port C Remaining Backoff 1 Register	NCRBO1R	0x0A6B	R/W	xxxxxxxx
Network Port C Beacon Filter Register	NCBFR	0x0A6D	R/W	xxxxxxxx
Network Port C Beacon Backoff 0 Register	NCBBO0R	0x0A6E	R/W	xxxxxxxx
Network Port C Beacon Backoff 1 Register	NCBBO1R	0x0A6F	R/W	xxxxxxxx

26.2 Dependencies

26.2.1 I/O Pins

The wireless network port interface has 36 dedicated pins, as shown in Table 26-1.

Table 26-1. Wireless Port Interface

Block	Section	Signal	Direction	Function
Analog	Input	VRXQ+	Input	Q channel differential voltage input.
		VRXQ-	Input	
		VRXI+	Input	I channel differential voltage input.
		VRXI-	Input	
	Output	ITXQ+	Output	Q channel differential current output.
		ITXQ-	Output	
		ITXI+	Output	I channel differential current output.
		ITXI-	Output	
	Clock	XTL_20MI	—	20MHz crystal input.
		XTL_20MO		
	Monitor ADC	S_VIN	Input	Monitor ADC input.
		S_AD_REF+	—	Optional A/D converter reference voltage monitors.
		S_AD_REF-		
	Bias	VBG	—	Bandgap voltage (unused)
		AD_RSET	—	Bias resistor for Wi-Fi A/D converter (12.1 kΩ to ground optimal).
		DA_RSET	—	Bias resistor for Wi-Fi D/A converter (9.1 kΩ to ground optimal).
COMP		—	Connect to Wi-Fi_2.5V.	

Table 26-1. Wireless Port Interface

Block	Section	Signal	Direction	Function
Digital	Auto Gain Correction	VGA[4:0]	Output	Variable gain amplifier setting.
		LNA[1:0]	Output	Linear amplifier setting.
	Control	TXON	Output	Transmit enable.
		RXON	Output	Receive enable.
		LOCK	Input	Transceiver PLL lock input.
		RXHP	Output	Reserved for future use, may be used as a general-purpose output.
		ANT1	Output	Antenna select enable.
		ANT2	Output	Antenna select enable.
		PA2G_ON	Output	2G preamplifier enable.
		PA5G_ON	Output	5G preamplifier enable.
		/ACT_LED	Output	Activity LED control, active low.
	Management	SCLK	Output	3-wire serial clock.
		SDATA	Output	3-wire serial data.
		/SEN	Output	3-wire serial enable.

26.3 Clocks

The wireless network port requires a 20 MHz clock input for proper operation. An external crystal can be attached between the XTL_20MI and XTL_20MO pins, or a 20 MHz clock can be applied directly to XTL_20MO. Note that the proper clock operation (crystal or external signal) needs to be enabled in MSSR.

The absolute lower limit for the CPU frequency when accessing Wi-fi peripheral is 50MHz.

The interface for Wi-Fi peripheral does not run at the CPU frequency, but instead uses the 80MHz Wi-Fi clock. This means that Wait states are usually necessary when accessing it from the Rabbit 6000. The Network Port C CPU Wait Register (NCCWR) provides a five-bit field for selecting Wait states for CPU accesses. The Network Port C DMA Wait Register (NCDWR) provides a five-bit field for selecting Wait states for DMA accesses.

To calculate the number of Wait states required, divide 65nS by the period of the main processor clock, round up to the next integer, and subtract two. This is the required number of Wait states, and guarantees that the Wi-Fi cycle time of 65nS is always met.

Note that if software can guarantee that the cycle time will be met and only byte accesses will be performed, a smaller number can be used for CPU Wait states. This smaller number guarantees that the minimum width for the internal Wi-Fi read and write strobes will be met.

CPU/DMA frequency	DMA Waits	CPU Waits (unrestricted)	(only byte access)
> 50.0 MHz	2	2	0
> 61.5 MHz	3	3	0
> 76.9 MHz	4	4	4
> 92.3 MHz	5	5	4
> 107.6 MHz	6	6	4
> 123.0 MHz	7	7	4
> 138.4 MHz	8	8	8
> 153.8 MHz	9	9	8
> 169.2 MHz	10	10	8
> 184.6 MHz	11	11	8
> 200.0 MHz	12	12	12

Although this 65nS cycle time limits the bus bandwidth of the Wi-Fi peripheral to 15MByte/sec, the 2K buffers for both receive and transmit data mean that this limit does not affect overall Wi-Fi throughput.

26.3.1 Other Registers

Register	Function
ENPR	Enable Wi-Fi functionality.
MSSR	Select crystal or external 20 MHz clock.

26.3.2 Interrupts

The wireless network interrupt can be generated for any of the following reasons.

- When data are available in the receive FIFO.
- When the transmit FIFO becomes empty.
- When a receive timeout occurs.
- When a transmit abort occurs.
- When an Announcement Traffic Indication Message (ATIM) is received.
- When the receive FIFO is overrun.
- When a complete packet is received.

The events that generate an interrupt can be selected in NCISR.

The wireless network port interrupt vector is located in the IIR at offset 0x100. It can be set as Priority 1, 2, or 3 by writing to ENPR.

26.4 Operation

At the present time, the wireless peripheral is intended to be used only in Rabbit-branded and other products offered by Digi International. Dynamic C has the necessary drivers. Customers wishing to incorporate the wireless peripheral in their own design should contact the sales representative at Digi International for more information.

27. USB Host

27.1 Overview

Network Port D implements a USB 2.0 compliant host interface and PHY. The USB host in the Rabbit 6000 supports both full-speed (12 Mbit/s) and low-speed (1.5 Mbit/s) operation. It conforms to the Open Host Controller Interface (OHCI) specification, and is fully interfaced with the Rabbit 6000 DMA. Both receive and transmit have a dedicated 2048-byte FIFO.

Network Port D handles all of the DMA data transfer descriptors automatically. Two DMA channels can be allocated for its use via the appropriate DMA Special Control Registers.

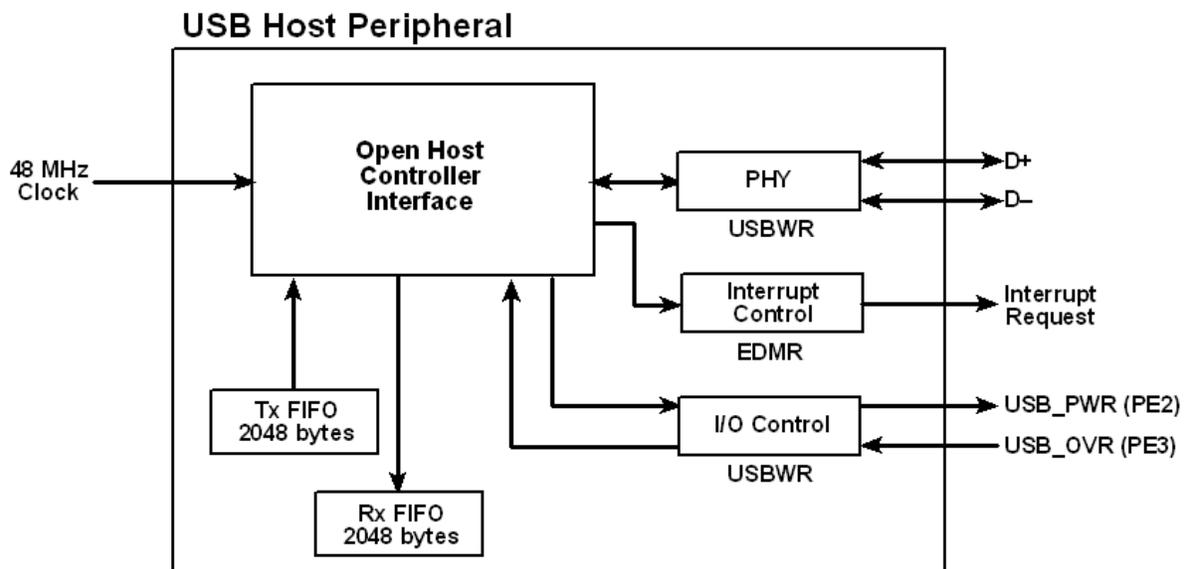
The network port requires an accurate 48 MHz clock to generate the proper USB serial rate. An external crystal can be used to drive the internal oscillator, or an external clock signal can be injected directly.

The USB differential data pins have internal 19.5 k Ω pulldown resistors that may be enabled via register settings.

The I/O interface consists of a bidirectional differential data pair, 48 MHz crystal input/output, and two optional signals for power control and current fault detection that are shared with the Parallel Port E pins.

The interface to Network Port D is actually a 32-bit interface, so some special handling is required for all registers except for USBWR and NDWR. See Section 27.3 for more details.

27.1.1 Block Diagram



27.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
USB Wrapper Register	USBWR	0x1060	R/W	00000010
Network Port D Wait Register	NDWR	0x0433	R/W	00000000

The Open Host Controller Interface (OHCI) registers use I/O addresses ranging from 0x1000 to 0x1057. The official specification, *OpenHCI Open Host Controller Interface Specification for USB*, contains full details of the registers and their proper use, and is available from Compaq.

27.2 Dependencies

27.2.1 I/O Pins

The USB port interface has four dedicated signal pins and two optional ones that are shared with parallel port pins, all of which are listed in Table 27-1.

Table 27-1. Network Port D Interface

Section	Signal	Direction	Function
Data	D+	Bidirectional	Differential data
	D-		
Clock	XTL_48MI	—	48 MHz crystal input / external clock input
	XTL_48MO		
Optional Control	USB_PWR (PE2)	Output	External USB power control
	USB_OVR (PE3)	Input	Overcurrent fault signal

27.2.2 Clocks

The network port requires a 48 MHz clock input for proper full-speed USB operation. A 48 MHz crystal can be attached between XTL_48MI and XTL_48MO, or a 48 MHz clock can be applied directly to XTL_48MO.

The USB peripheral has a fixed 250ns access time, so wait states are usually necessary when accessing it from the Rabbit 6000. The required number of wait states can be determined by dividing 250ns by the period of the main clock and rounding up. NDWR is used to select between 0-63 wait states. The 250nS cycle time for the USB peripheral comes from the 48MHz USB clock (it is twelve cycles of this clock per access).

27.2.3 Other Registers

Register	Function
PEDDR, PEFR, PEALR	Selection of optional power control and overcurrent fault detection signals.
ENPR	Enable USB functionality.
MSSR	Select 48 MHz crystal or external clock.

27.2.4 Interrupts

The network port interrupt vector is located in the IIR at offset 0x110. It can be set as Priority 1, 2, or 3 by writing to ENPR. Details about what events cause interrupts are available in the OHCI specification.

27.3 Operation

High-level support for USB is beyond the scope of this manual, but this section will describe the low-level setup and operation of the USB host peripheral. Dynamic C has the necessary drivers.

27.3.1 32-bit Interface

Network Port D is actually a 32-bit interface, so special handling is required when reading or writing all registers other than USBWR and NDWR.

When writing a 32-bit register, the value is written to the peripheral only when the most-significant byte (uppermost) is written. The three lower bytes will be buffered until that final write occurs. For proper operation, all four bytes in the 32-byte register should be written every time a change to a bit is required.

When reading a 32-bit register, the read of the least-significant (lowest) byte will latch the peripheral's register value for all four bytes. Those values will remain until the next read of the lowest byte, so to avoid stale data all four bytes should be read whenever a 32-bit register is accessed.

27.3.2 Setup

The following steps explain how to set up Network Port D.

1. In MSSR, select the 48 MHz clock source (crystal or external signal).
2. Write the interrupt vector for the interrupt service routine to the external interrupt table.
3. If desired, set up the USB power control and overcurrent fault signals by writing to PEDDR, PEFR, PEALR, and USBWR.
4. Select the optional pulldown resistors on D+ and D- by writing to USBWR.
5. Select two DMA channels for USB transmit and receive by writing to the appropriate DxSCR.
6. Refer to the OHCI specification for details on loading descriptors and further setup.
7. Enable Network Port D and select the interrupt priority by writing to ENPR.

27.3.3 Transmit and Receive

Refer to the OHCI specification for transmission and reception operation.

27.3.4 Handling Interrupts

Refer to the OHCI specification for details on handling interrupts.

27.4 Register Descriptions

USB Wrapper Register		(USBWR)	(Address = 0x1060)
Bit(s)	Value	Description	
7:3		These bits are reserved and should be written with zeros.	
2	0	Disable the 19.5 kΩ pulldown resistor on D+.	
	1	Enable the 19.5 kΩ pulldown resistor on D+.	
1	0	Disable the 19.5 kΩ pulldown resistor on D-.	
	1	Enable the 19.5 kΩ pulldown resistor on D-.	
0	0	Disable the USB overcurrent detection input on PE3.	
	1	Enable the USB overcurrent detection input on PE3.	

Network Port D Wait Register		(NDWR)	(Address = 0x0433)
Bit(s)	Value	Description	
7:6		These bits are reserved and will always be read as zeros.	
5:0		This six-bit field holds the ones complement of the number of wait states to be inserted during Network Port D (internal I/O page 0x0B) reads and writes. That is, 0x00 selects 63 wait states and 0x3F selects zero wait states. Network Port D has a minimum bus cycle time of 250 ns.	

28. INPUT CAPTURE

28.1 Overview

The input capture peripheral consists of two channels, each of which contains a 16-bit counter and edge-detection circuitry. The input capture channels are usually used to determine the time between events. An event is signaled by a rising or falling edge (or optionally by both edges) on one of 12 input pins that can be selected as the input for either of the two channels. A digital low-pass filter is present on the inputs, as explained in Section 28.2.4.

Each channel can be used in one of two modes—input capture or input count.

In the input-capture mode, the channel starts/stops the counter (clocked by Timer A8) according to the signal edges of the selected parallel port pins, providing the ability to measure pulse widths and time intervals between external events, time-stamp signal changes on a pin, and measure time intervals between a software start and an external event.

In the input-count mode the channel simply increments the counter each time the selected edge is detected. The start condition is enabled by the first Timer A8 clock after the mode is selected, and the stop condition is generated when the count matches the value written into the counter registers; this allows an interrupt to be generated when a particular count is reached.

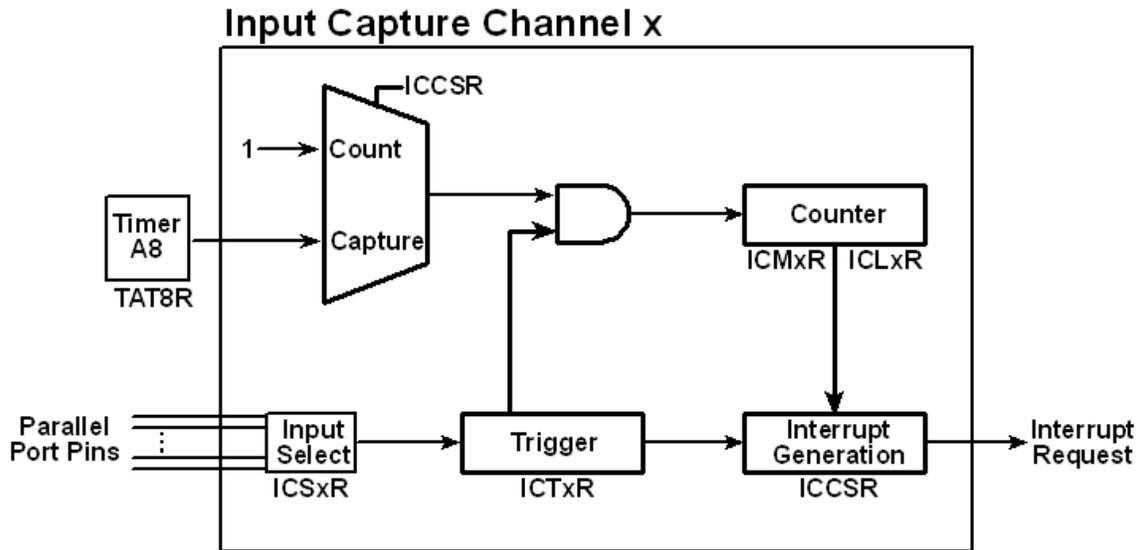
A latch records the value of a 16 bit counter when the event takes place. The counter is driven by the output of Timer A8 which is driven by Timer A12 and the Timer A prescaler. If the counter rolls over to zero, a register bit is set and an interrupt can be generated.

Two events are recognized: a *start condition* and a *stop condition*. The start condition may be used to start counting and the stop condition to stop counting. However, the counter may also run continuously or run until a stop condition is encountered. The start and stop conditions may also be used to latch the current count at the instant the condition occurs rather than actually start or stop the counter. The same pin may be used to detect the start and stop condition—for example a rising edge could be the start condition and a falling edge could be the stop condition. The start and stop condition can also be the input from separate pins.

The input capture channels can be used to measure the width of fast pulses. This is done by starting the counter on the first edge of the pulse and capturing the counter value on the second edge of the pulse. In this case the maximum error in the measurement is approximately 2 periods of the clock used to increment the counter. If there is sufficient time between events for an interrupt to take place the unit can be set up to capture the counter value on either start or stop conditions (or both) and cause an interrupt each time the count is captured. The counter can also be cleared and started under software control and then have its value captured in response to an input.

The capture counter can be synchronized with Timer B outputs to load parallel port output registers. This makes it possible to generate an output signal precisely synchronized with an input signal.

28.1.1 Block Diagram



28.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Input Capture Ctrl/Status Register	ICCSR	0x0056	R/W	00000000
Input Capture Control Register	ICCR	0x0057	W	00000000
Input Capture Trigger 1 Register	ICT1R	0x0058	R/W	00000000
Input Capture Source 1 Register	ICS1R	0x0059	R/W	xxxxxxxx
Input Capture LSB 1 Register	ICL1R	0x005A	R	xxxxxxxx
Input Capture MSB 1 Register	ICM1R	0x005B	R	xxxxxxxx
Input Capture Trigger 2 Register	ICT2R	0x005C	R/W	00000000
Input Capture Source 2 Register	ICS2R	0x005D	R/W	xxxxxxxx
Input Capture LSB 2 Register	ICL2R	0x005E	R	xxxxxxxx
Input Capture MSB 2 Register	ICM2R	0x005F	R	xxxxxxxx

28.2 Dependencies

28.2.1 I/O Pins

Each input-capture channel can accept input from one of the following parallel port pins: PC1, PC3, PC5, PC7, PD1, PD3, PD5, PD7, PE1, PE3, PE5, PE7. Use ICTxR to select which input pin to trigger on.

Note that these pins can be used for other peripherals at the same time as the input-capture peripheral. For example, you can use input capture to measure the pulse width on a serial port input which will allow you to calculate the baud rate.

28.2.2 Clocks

The 16-bit input-capture counters are clocked from the output of Timer A8. Timer A12 can be used as a predivider for Timer A8.

28.2.3 Other Registers

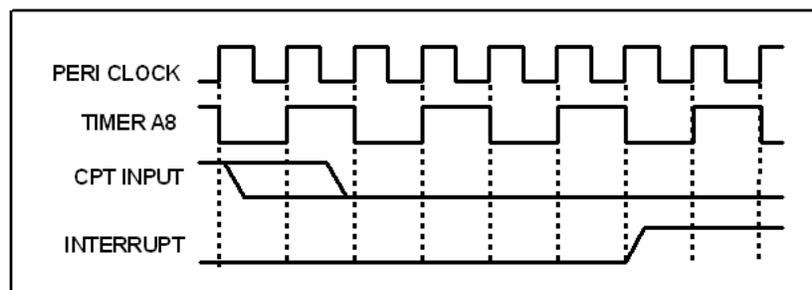
Register	Function
TAT8R	Time constant for input-capture clock.
TAT12R	Optional predivider for Timers A8-11.
TAECR	Enable for Timer A12 prescaling.

28.2.4 Interrupts

Each input capture channel can generate an interrupt whenever a start/stop condition occurs, or when the counter rolls over to zero. The interrupt request is cleared when ICCSR is read.

The input capture interrupt vector is in the IIR at offset 0x1A0. It can be set as Priority 1, 2, or 3.

The input-capture channels synchronize their inputs to Timer A8, so any faster state changes cannot be detected due to the digital low-pass filter functionality on the inputs. Because of this, there is some delay between the input transition and when an interrupt is requested, as shown below. The status bits in ICSxR are set coincident with the interrupt request and are reset when read from the ICSxR.



28.3 Operation

28.3.1 Input-Capture Channel

The following steps explain how to set up an input-capture channel.

1. Configure Timer A8 via TAT8R (and optionally TAT12R) to provide the desired input-capture clock.
2. Configure ICTxR to provide the desired start/stop operation and conditions.
3. Configure ICSxR to select the input pins for the start and stop conditions.
4. Configure ICCR to select either the count or the capture mode.
5. Reset the counter by writing to ICCSR.

28.3.2 Handling Interrupts

The following steps explain how an interrupt is used.

1. Write the vector to the interrupt service routine to the internal interrupt table
2. Configure the Input Capture Control/Status Register (ICCSR) to select events that will generate an interrupt.
3. Configure the Input Capture Control Register (ICCR) to select the interrupt priority (note that interrupts will be enabled once this value is set; this step should be done last).

The following actions occur within the interrupt service routine.

- If needed, the current counter value can be read from ICLxR and ICMxR (reading from ICLxR latches the value of ICMxR, so ICLxR should always be read first)
- If the counter is expected to roll over, determine if that is why the interrupt occurred by reading the status bits in ICCSR and adjusting any software counters accordingly
- The interrupt request should be cleared by reading from ICCSR

28.3.3 Example ISR

A sample interrupt handler is shown below.

```
ic_isr::
    push af
    ioi ld a, (ICCSR)    ; clear the interrupt request and get status
    ; determine which interrupts have occurred
    ; if rollover, perform any necessary software counter adjustments
here
    ; read counter values
    pop af
    ipres
    ret
```

28.3.4 Capture Mode

Pulse Width or Time Between Events

The following steps explain how to measure the pulse width or time between events. Note that for proper operation a start condition needs to be the first event seen once the input capture is enabled, if a stop condition occurs first, the system will stop without taking a measurement.

1. Select the same input pin to perform a pulse-width measurement between the start and stop conditions, or select two different input pins to measure time between events on those pins.
2. Set the counter to start on the start condition and stop on the stop condition, latch on the stop condition, and generate an interrupt on the stop condition.
3. In the interrupt handler, read out the counter to determine the pulse width or time interval between the two events.

Time-Stamp External Events

The following steps explain how to time-stamp external events.

1. Set the trigger for the desired event type.
2. Set the counter to run continuously, latch on the start (and/or stop) condition, and generate an interrupt on the start (and/or stop) condition.
3. In the interrupt handler, read out the counter as an event timestamp.

Measure Time Interval from a Software Start to an External Event

The following steps explain how to measure the time interval between a software start and the occurrence of an external event.

1. Set up the counter to run continuously, latch on the stop condition, and generate an interrupt on the stop condition. The option to not enable the stop condition is not available since those bits would be ignored in the count mode.
2. Set up the stop condition for the event of interest.
3. Reset the counter via ICCSR at the software start.
4. In the interrupt handler, read the counter as a time duration.

28.3.5 Count Mode

The following steps explain how to count pulses when count mode is selected:

1. Set the ICTxR register for the counter to run continuously and to latch the count on either the start or stop condition.
2. If an interrupt is desired at a particular count, write that value into the LSB and MSB registers.
3. Set the start condition for the pulse type desired.
4. Reset the counter by writing to ICCSR.
5. Reading the latch registers at any time after an initial start pulse is received will return the current count. Until an initial start pulse is received, the latch registers will have a residual value.

28.4 Register Descriptions

Input Capture Control/Status Register		(ICCSR)	(Address = 0x0056)
Bit(s)	Value	Description	
7 (Read)	0	The Input Capture 2 Start condition has not occurred.	
	1	The Input Capture 2 Start condition has occurred.	
6 (Read)	0	The Input Capture 2 Stop condition has not occurred.	
	1	The Input Capture 2 Stop condition has occurred.	
5 (Read)	0	The Input Capture 1 Start condition has not occurred.	
	1	The Input Capture 1 Start condition has occurred.	
4 (Read)	0	The Input Capture 1 Stop condition has not occurred.	
	1	The Input Capture 1 Stop condition has occurred.	
3 (Read)	0	The Input Capture 2 counter has not rolled over to all zeros.	
	1	The Input Capture 2 counter has rolled over to all zeros.	
2 (Read)	0	The Input Capture 1 counter has not rolled over to all zeros.	
	1	The Input Capture 1 counter has rolled over to all zeros.	
7:2 (Read)		These status bits (but not the interrupt enable bits) are cleared by the read of this register, as is the Input Capture Interrupt.	
7:4 (Write)	0	The corresponding Input Capture interrupt is disabled.	
	1	The corresponding Input Capture interrupt is enabled.	
3 (Write)	0	No effect on Input Capture 2 counter. This bit always reads as zero.	
	1	Reset Input Capture 2 counter to all zeros and clears the rollover latch.	
2 (Write)	0	No effect on Input Capture 1 counter. This bit always reads as zero.	
	1	Reset Input Capture 1 counter to all zeros and clears the rollover latch.	
1	0	Disable Input Capture 2 interrupt on roll-over to all zeros.	
	1	Enable Input Capture 2 interrupt on roll-over to all zeros.	
0	0	Disable Input Capture 1 interrupt on roll-over to all zeros.	
	1	Enable Input Capture 1 interrupt on roll-over to all zeros.	

Input Capture Control Register (ICCR) (Address = 0x0057)		
Bit(s)	Value	Description
7	0	Input Capture operation for Input Capture 2.
	1	Input Count operation for Input Capture 2.
6	0	Input Capture operation for Input Capture 1.
	1	Input Count operation for Input Capture 1.
5:2		These bits are reserved and should be written with zero.
1:0	00	Input Capture interrupts are disabled.
	01	Input Capture interrupt use Interrupt Priority 1.
	10	Input Capture interrupt use Interrupt Priority 2.
	11	Input Capture interrupt use Interrupt Priority 3.

Input Capture Trigger x Register (ICT1R) (Address = 0x0058) (ICT2R) (Address = 0x005C)		
Bit(s)	Value	Description
7:6	00	Disable the counter. Applies even in Counter operation.
	01	The counter runs from the Start condition until the Stop condition.
	10	The counter runs continuously.
	11	The counter runs continuously, until the Stop condition.
5:4	00	Disable the count latching function. In this case, and with Counter operation only, the ICLxR and ICMxR return the programmed match value.
	01	Latch the count on the Stop condition only.
	10	Latch the count on the Start condition only.
	11	Latch the count on either the Start or Stop condition.
3:2	00	Ignore the starting input.
	01	The Start condition is the rising edge of the starting input.
	10	The Start condition is the falling edge of the starting input.
	11	The Start condition is either edge of the starting input.
1:0	00	Ignore the ending input. These two bits are ignored in Counter operation.
	01	The Stop condition is the rising edge of the ending input.
	10	The Stop condition is the falling edge of the ending input.
	11	The Stop condition is either edge of the ending input.

Input Capture Source x Register (ICS1R) (Address = 0x0059) (ICS2R) (Address = 0x005D)		
Bit(s)	Value	Description
7:6	00	Parallel Port C used for Start condition input.
	01	Parallel Port D used for Start condition input.
	10	Parallel Port E used for Start condition input.
	11	This bit combination is reserved and should not be used.
5:4	00	Use port bit 1 for Start condition input.
	01	Use port bit 3 for Start condition input.
	10	Use port bit 5 for Start condition input.
	11	Use port bit 7 for Start condition input.
3:2	00	Parallel Port C used for Stop condition input.
	01	Parallel Port D used for Stop condition input.
	10	Parallel Port E used for Stop condition input.
	11	This bit combination is reserved and should not be used.
1:0	00	Use port bit 1 for Stop condition input.
	01	Use port bit 3 for Stop condition input.
	10	Use port bit 5 for Stop condition input.
	11	Use port bit 7 for Stop condition input.

Input Capture LSB x Register (ICL1R) (Address = 0x005A) (ICL2R) (Address = 0x005E)		
Bit(s)	Value	Description
7:0	Read	The least significant eight bits of the latched Input Capture count are returned. Reading the LSB of the count latches the MSB of the count to avoid reading stale data. Reading the MSB of the count opens these latches on the MSB of the count. In Counter operation, if no latching condition is specified the value written to this register is returned.
	Write	The eight LSBs of the match value for counter mode are stored.

Input Capture MSB x Register (ICM1R) (Address = 0x005B) (ICM2R) (Address = 0x005F)		
Bit(s)	Value	Description
7:0	Read	The most significant eight bits of the latched Input capture count are returned. In Counter operation, if no latching condition is specified the value written to this register is returned.
	Write	The eight MSBs of the match value for counter mode are stored.

29. QUADRATURE DECODER

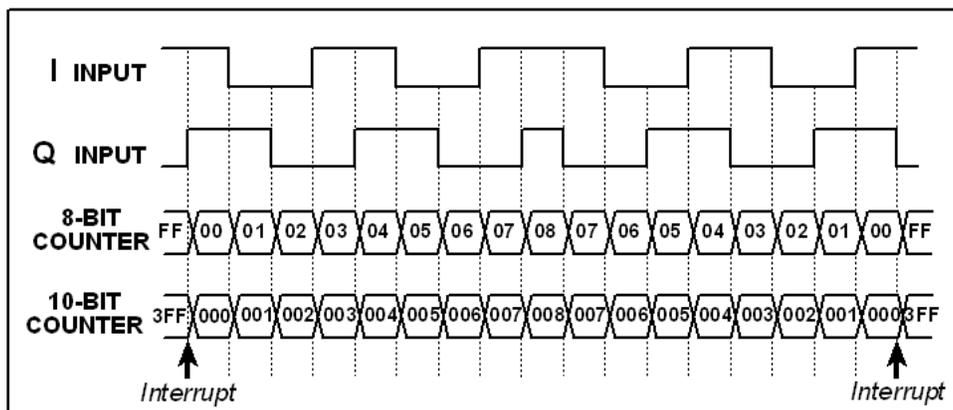
29.1 Overview

The Rabbit 6000 has a two-channel Quadrature Decoder that accepts inputs via specific pins on Parallel Ports D and E. Each channel has two inputs, the in-phase (I) input and the 90 degree or quadrature-phase (Q) input. An 8 or 10-bit up/down counter counts encoder steps in the forward and backward directions, and provides interrupts when the count goes from 0x00 to 0xFF (or 0x3FF) or from 0xFF (or 0x3FF) to 0x00. An interrupt can occur each time the count overflows or underflows. The Quadrature Decoder contains digital filters on the inputs to prevent false counts.

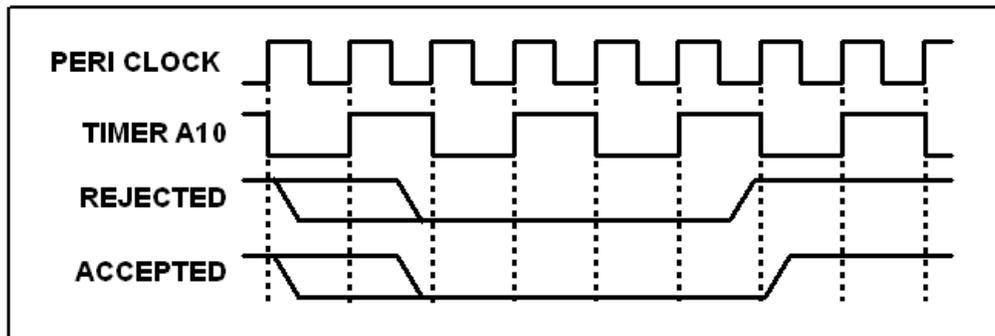
The external signals are synchronized with an internal clock provided by the output of Timer A10.

Each Quadrature Decoder channel accepts inputs from either the upper nibble or lower nibble of Parallel Ports D and E. The I signal is input on an odd-numbered port bit, while the Q signal is input on an even-numbered port bit. There is also a disable selection, which is guaranteed to not generate a count increment or decrement on either entering or exiting the disabled state.

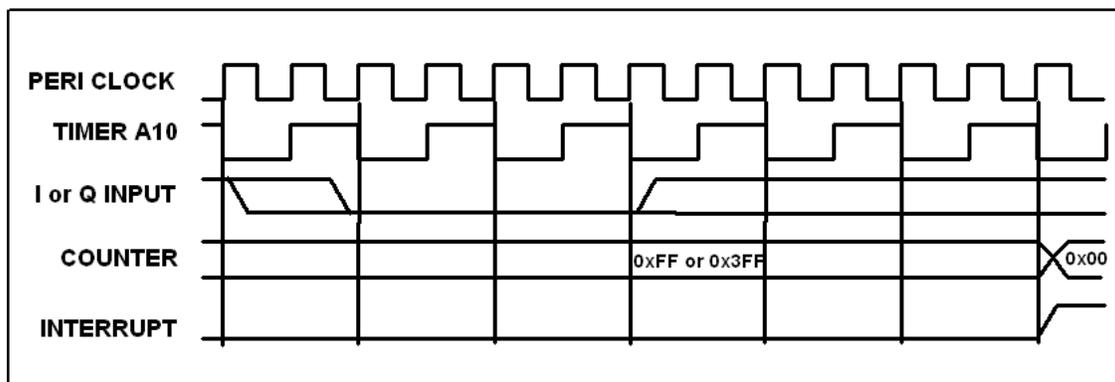
The operation of the counter as a function of the I and Q inputs is shown below.



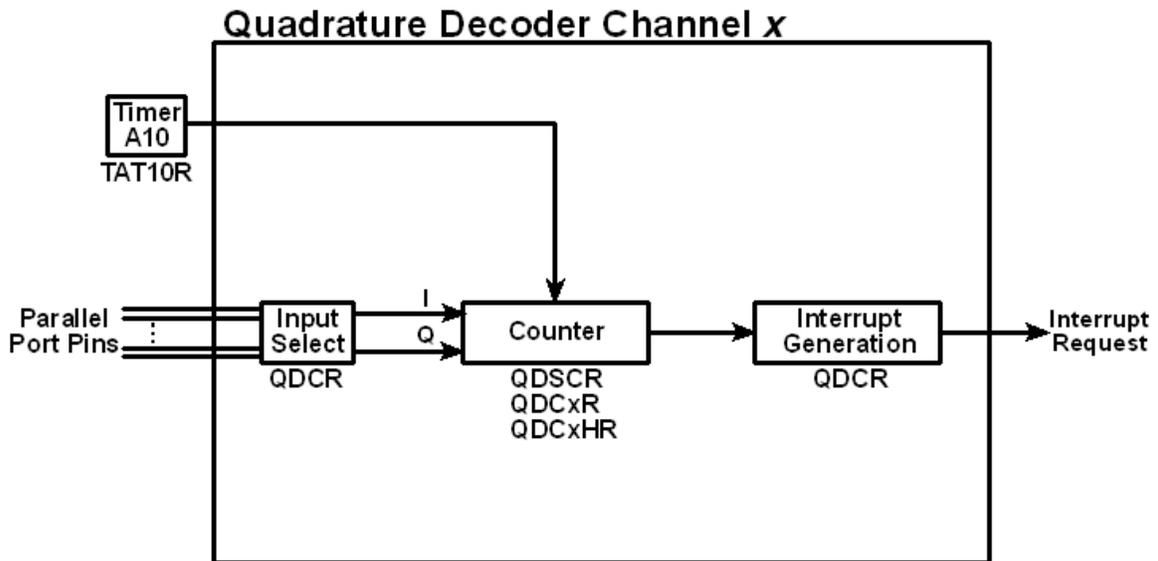
The Quadrature Decoders are clocked by the output of Timer A10, which must be fast enough to sample the inputs properly. Both the I and Q inputs go through a digital filter that rejects pulses shorter than two clock periods wide so that highest detectable input frequency is one-fourth of the frequency set by Timer A10. In addition, the clock rate must be high enough that transitions on the I and Q inputs are sampled in different clock cycles. Input capture may be used to measure the pulse width on the I inputs because they come from the odd-numbered port bits. The operation of the digital filter is shown below.



The Quadrature Decoder generates an interrupt when the counter increments from 0xFF (0x3FF in 10-bit mode) to 0x00, or when the counter decrements from 0x00 to 0xFF (0x3FF in 10-bit mode). The timing for the interrupt is shown below. Note that the status bits in the QDCSR are set coincident with the interrupt, and the interrupt and status bits are cleared by reading the QDCSR.



29.1.1 Block Diagram



29.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Quad Decode Ctrl/Status Register	QDCSR	0x0090	R/W	xxxxxxxx
Quad Decode Control Register	QDCR	0x0091	R/W	00000000
Quad Decode Count 1 Register	QDC1R	0x0094	R	xxxxxxxx
Quad Decode Count 1 High Register	QDC1HR	0x0095	R	xxxxxxxx
Quad Decode Count 2 Register	QDC2R	0x0096	R	xxxxxxxx
Quad Decode Count 2 High Register	QDC2HR	0x0097	R	xxxxxxxx

29.2 Dependencies

29.2.1 I/O Pins

Each Quadrature Decoder channel can accept the two encoder inputs from one of three different locations, as shown in the table below. Each channel can select a different input option. Note that these pins can be used for other peripherals at the same time as the Quadrature Decoder peripheral; one example of this use is to measure pulse width on the I channels with the input capture peripheral.

Inputs	Channel 1		Channel 2	
	I	Q	I	Q
Option 1	PD1	PD0	PD3	PD2
Option 2	PE1	PE0	PE3	PE2
Option 3	PE5	PE4	PE7	PE6

29.2.2 Clocks

The 8/10-bit Quadrature Decoder counters are clocked from the output of Timer A10, and can run at rates from the peripheral clock divided by 2 down to the peripheral clock divided by 512 by writing the appropriate value to TAT10R. Timer A12 can be used as a predivider for Timer A10.

Both the I and Q inputs go through a digital filter that rejects pulses shorter than two clock periods wide.

29.2.3 Other Registers

Register	Function
TAT10R	Time constant for Quadrature Decoder clock
TAT12R	Optional predivider for Timers A8-11.
TAECR	Enable for Timer A12 prescaling.

29.2.4 Interrupts

Each Quadrature Decoder channel can generate an interrupt whenever the counter increments from 0x0FF (0x3FF in 10-bit mode) to 0x00 or when the counter decrements from 0x000 to 0x0FF (0x3FF for 10-bit mode). The interrupt request is cleared when QDCSR is read.

The Quadrature Decoder interrupt vector is in the IIR at offset 0x190. It can be set as Priority 1, 2, or 3.

The status bits in the QDCSR are set coincident with the interrupt request and are reset when QDCSR is read.

29.3 Operation

The following steps explain how to set up a Quadrature Decoder channel.

1. Configure Timer A10 via TAT10R to provide the desired Quadrature Decoder clock speed (and optionally TA12R).
2. Configure QDCR to select the input pins for the two channels.
3. Reset the counters by writing to QDCSR.

29.3.1 Handling Interrupts

The following steps explain how an interrupt is set up and used.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure QDCR to select the interrupt priority (note that interrupts will be enabled once this value is set).

The following actions occur within the interrupt service routine.

- Determine exactly why the interrupt occurred by reading the status bits in QDCSR; if the interrupt occurred due to a counter rollover, adjust any software counters accordingly. Reading QDCSR will also clear the interrupt request.
- The current counter value can be read from QDCxR (and QDCxHR if the 10-bit counter is enabled).

29.3.2 Example ISR

A sample interrupt handler is shown below.

```
qd_isr::
    push af                ; save used registers
    ioi ld a, (QDCSR)     ; clear the interrupt request and get status

    ; perform any necessary software counter adjustments here
    ; read current counter value(s)

    pop af                ; restore used registers
    ipres
    ret
```

29.4 Register Descriptions

Quad Decode Control/Status Register		(QDCSR)	(Address = 0x0090)
Bit(s)	Value	Description	
7 (Read-only)	0	Quadrature Decoder 2 did not increment from the maximum count.	
	1	Quadrature Decoder 2 incremented from the maximum count to 0x000. This bit is cleared by a read of his register.	
6 (Read-only)	0	Quadrature Decoder 2 did not decrement from zero.	
	1	Quadrature Decoder 2 decremented from zero to the maximum count. This bit is cleared by a read of this register.	
5		This bit always reads as zero.	
4 (Write-only)	0	No effect on the Quadrature Decoder 2.	
	1	Reset Quadrature Decoder 2 to all zeros, without causing an interrupt.	
3 (Read-only)	0	Quadrature Decoder 1 did not increment from the maximum count.	
	1	Quadrature Decoder 1 incremented from the maximum count to zero. This bit is cleared by a read of this register.	
2 (Read-only)	0	Quadrature Decoder 1 did not decrement from zero.	
	1	Quadrature Decoder 1 decremented from zero to the maximum count. This bit is cleared by a read of this register.	
1		This bit always reads as zero.	
0 (Write-only)	0	No effect on the Quadrature Decoder 1.	
	1	Reset Quadrature Decoder 1 to all zeros, without causing an interrupt.	

Quad Decode Control Register (QDCR) (Address = 0x0091)		
Bit(s)	Value	Description
7:6	00	Disable Quadrature Decoder 2 inputs. Writing a new value to these bits will not cause Quadrature Decoder 2 to increment or decrement.
	01	Quadrature Decoder 2 inputs from Parallel Port D bits 3 and 2.
	10	Quadrature Decoder 2 inputs from Parallel Port E bits 3 and 2.
	11	Quadrature Decoder 2 inputs from Parallel Port E bits 7 and 6.
5	0	Eight bit quadrature decoder counters (both channels).
	1	Ten bit quadrature decoder counters (both channels).
4		This bit is reserved and should be written as zero.
3:2	00	Disable Quadrature Decoder 1 inputs. Writing a new value to these bits will not cause Quadrature Decoder 1 to increment or decrement.
	01	Quadrature Decoder 1 inputs from Parallel Port D bits 1 and 0.
	10	Quadrature Decoder 1 inputs from Parallel Port E bits 1 and 0.
	11	Quadrature Decoder 1 inputs from Parallel Port E bits 5 and 4.
1:0	00	Quadrature Decoder interrupts are disabled.
	01	Quadrature Decoder interrupt use Interrupt Priority 1.
	10	Quadrature Decoder interrupt use Interrupt Priority 2.
	11	Quadrature Decoder interrupt use Interrupt Priority 3.

Quad Decode Count Register (QDC1R) (Address = 0x0094) (QDC2R) (Address = 0x0096)		
Bit(s)	Value	Description
7:0	Read	The current value of bits 7-0 of the Quadrature Decoder counter is reported.

Quad Decode Count High Register (QDC1HR) (Address = 0x0095) (QDC2HR) (Address = 0x0097)		
Bit(s)	Value	Description
7:2	Read	These bits are reserved and will always read as zeros.
1:0	Read	The current value of bits 9-8 of the Quadrature Decoder counter is reported.

30. PULSE WIDTH MODULATOR

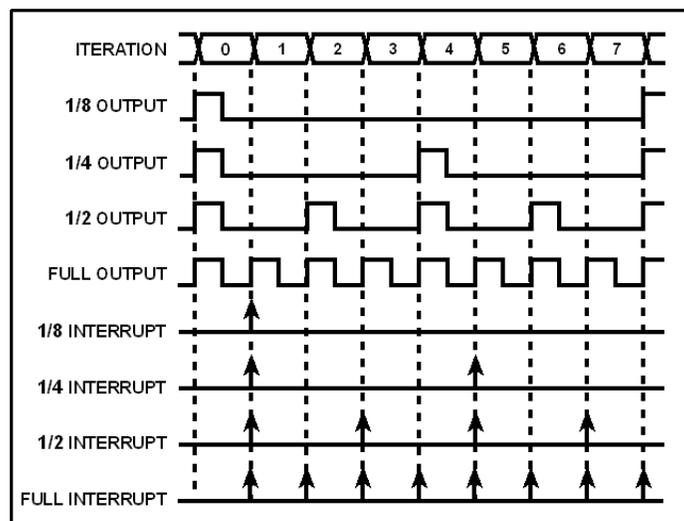
30.1 Overview

The Pulse Width Modulator (PWM) consists of a 10-bit free running counter and four width registers. A PWM output consists of a train of periodic pulses within a 1024-count frame with a duty cycle that varies from 1/1024 to 1024/1024. Each PWM output is high for $n + 1$ counts out of the 1024-clock count cycle starting when the counter is 0, where n is the value held in the width register. Any changes to the width registers will not take effect until the next counter rollover.

The PWM is clocked by the output of Timer A9 which is used to set the period. Timer A9 can be further prescaled by cascading it off of Timer A12.

Each PWM output high time can optionally be spread throughout the cycle to reduce ripple on the externally filtered PWM output. The PWM outputs can be passed through a filter and used as a 10-bit D/A converter. The outputs can also be used to directly drive devices such as motors or solenoids that have intrinsic filtering.

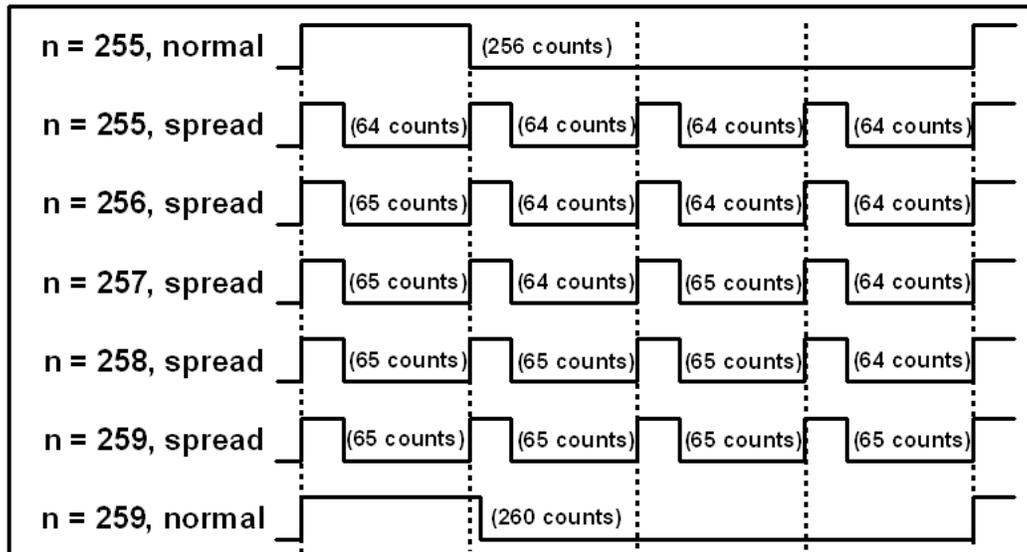
The PWM outputs can trigger a PWM interrupt when the counter rolls over to zero on every PWM cycle, every other cycle, every fourth cycle, or every eighth cycle. In addition, the PWM output can be suppressed every other cycle, three out of every four cycles, or seven out of every eight cycles. These options provide support for driving servos and to generate audio signals. The setup for this interrupt is done in the PWL0R and PWL1R registers. The timing is shown below.



The spreading function is implemented by dividing each 1024-clock cycle into four quadrants of 256 clocks each. Within each quadrant, the Pulse-Width Modulator uses the eight MSBs of each pulse-width register to select the base width in each of the quadrants. This is the equivalent to dividing the contents of the pulse-width register by four and using this value in each quadrant. To get the exact high time, the Pulse-Width Modulator uses the two LSBs of the pulse-width register to modify the high time in each quadrant according to the table below. The “ $n/4$ ” term is the base count, formed from the eight MSBs of the pulse-width register.

Pulse-Width LSBs	1st	2nd	3rd	4th
00	$n/4 + 1$	$n/4$	$n/4$	$n/4$
01	$n/4 + 1$	$n/4$	$n/4 + 1$	$n/4$
10	$n/4 + 1$	$n/4 + 1$	$n/4 + 1$	$n/4$
11	$n/4 + 1$	$n/4 + 1$	$n/4 + 1$	$n/4 + 1$

The diagram below shows a PWM output for several different width values, for both modes of operation. Operation in the spread mode reduces the filtering requirements on the PWM output in most cases.

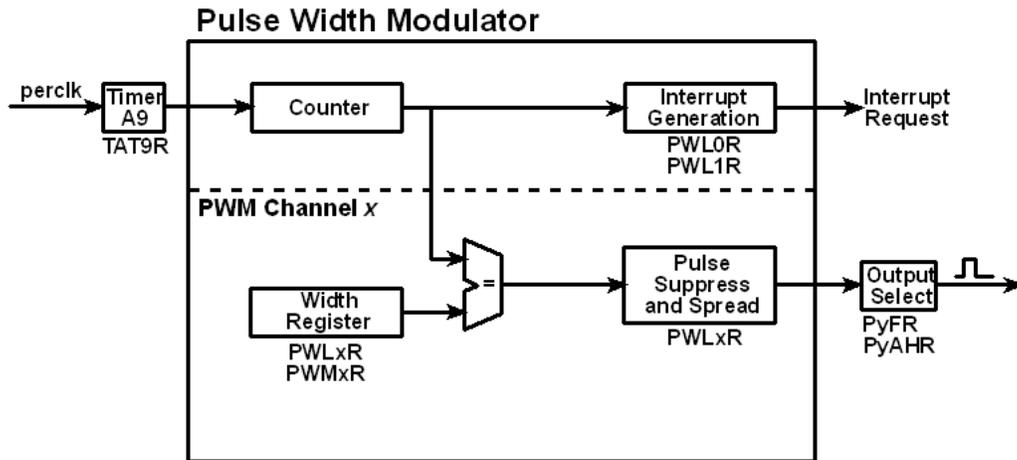


The DMA channels on the Rabbit 6000 are designed to work with fixed I/O addresses. To allow DMA control of the PWM, a separate PWM Block Access Register (PWBAR) and PWM Block Pointer Register (PWBPR) are available. The pointer register contains the address of the PWM register to be accessed via the access register. Each read or write of the access register automatically increments the pointer register through the sequence shown below. Note that only the lower three bits of the pointer register actually change. This allows the DMA to write to a fixed internal I/O location but still program all of the PWM registers. The pointer register can be written and read if necessary. Normally the pointer register is initialized to 0x88 (the first PWM register) and the DMA then transfers blocks of eight bytes to completely reprogram the PWM.

0x88 -> 0x89 -> 0x8A -> 0x8B -> 0x8C -> 0x8D -> 0x8E -> 0x8F ->

When the DMA destination address is the PWBAR, the DMA request from the PWM is automatically connected to the DMA.

30.1.1 Block Diagram



30.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
PWM LSB 0 Register	PWL0R	0x0088	R/W	xxxxx00x
PWM MSB 0 Register	PWM0R	0x0089	R/W	xxxxxxxx
PWM LSB 1 Register	PWL1R	0x008A	R/W	xxxxx00x
PWM MSB 1 Register	PWM1R	0x008B	R/W	xxxxxxxx
PWM LSB 2 Register	PWL2R	0x008C	R/W	xxxxx00x
PWM MSB 2 Register	PWM2R	0x008D	R/W	xxxxxxxx
PWM LSB 3 Register	PWL3R	0x008E	R/W	xxxxx00x
PWM MSB 3 Register	PWM3R	0x008F	R/W	xxxxxxxx
PWM Block Access Register	PWBAR	0x00E8	W	xxxxxxxx
PWM Block Pointer Register	PWBPR	0x00E9	W	10001000

30.2 Dependencies

30.2.1 I/O Pins

Each PWM channel can be output on up one of three pins, which can be selected via the parallel port alternate output registers.

PWM	Output Pins
Channel 0	PC4, PD4, PE4, PF4, PG4, PH4
Channel 1	PC5, PD5, PE5, PF5, PG5, PH5
Channel 2	PC6, PD6, PE6, PF6, PG6, PH6
Channel 3	PC7, PD7, PE7, PF7, PG7, PH7

30.2.2 Clocks

The PWM counter is clocked from the output of Timer A9 which can use both Timer A12 (TAT12R) and the Timer A prescaler (TAPR) as prescalers. See 16.1.1, “Block Diagram” for details.

30.2.3 Other Registers

Register	Function
TAT9R	Time constant for PWM clock
TAT12R	Optional predivider for Timers A8-11.
TAECR	Enable for Timer A12 prescaling.
TAPR	Timer A prescaler.
PCFR, PCAHR PDFR, PDAHR PEFR, PEAHR PFFR, PFAHR PGFR, PGAHR PHFR, PHAHR	Alternate port output selection

30.2.4 Interrupts

The PWM can generate an interrupt for every PWM counter rollover, every second rollover, every fourth rollover, or every eighth rollover. This option is selected in PWL1R. The interrupt request is cleared by a write to any PWM register.

The PWM interrupt vector is in the IIR at offset 0x170. It can be set as Priority 1, 2, or 3 by writing to PWL0R.

30.3 Operation

The following steps explain how to set up a PWM channel.

1. Configure Timer A9 via TAT9R to provide the desired PWM clock frequency.
2. Configure PWLxR to select whether to spread the PWM output throughout the cycle.
3. Configure PWLxR to select whether to suppress the PWM output.
4. Configure the duty cycle by writing to PWLxR and PWMxR. Note that any changes to these registers while the PWM is active will not take effect until the next counter rollover.

30.3.1 Handling Interrupts

The following steps explain how an interrupt is set up and used.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure PWL0R to select the PWM interrupt priority and PWL1R to select PWM interrupt suppression (if an interrupt is desired).

The following actions occur within the interrupt service routine.

- Any PWM values may be updated.
- The interrupt request is cleared by writing to any PWM register.

30.3.2 Example ISR

A sample interrupt handler is shown below.

```
pwm_isr::
    push af                ; save used registers

    ; load next PWM value into HL here

    ioi ld (PWL0R), hl    ; update the PWM value in PWL0R and PWM0R

                                ; note that interrupt request is also
                                ; cleared by register write above

    pop af                ; restore used registers
    ipres
    ret
```

30.4 Register Descriptions

PWM LSB 0 Register (PWL0R) (Address = 0x0088)		
Bit(s)	Value	Description
7:6		Least significant two bits for the Pulse Width Modulator count.
5:4	00	Normal PWM operation.
	01	Suppress PWM output seven out of eight iterations of PWM counter.
	10	Suppress PWM output three out of four iterations of PWM counter.
	11	Suppress PWM output one out of two iterations of PWM counter.
3		This bit is ignored and should be written with zero.
2:1	00	Pulse Width Modulator interrupts are disabled.
	01	Pulse Width Modulator interrupts use Interrupt Priority 1.
	10	Pulse Width Modulator interrupts use Interrupt Priority 2.
	11	Pulse Width Modulator interrupts use Interrupt Priority 3.
0	0	PWM output High for single block.
	1	Spread PWM output throughout the cycle.

PWM LSB 1 Register (PWL1R) (Address = 0x008A)		
Bit(s)	Value	Description
7:6		Least significant two bits for the Pulse Width Modulator count.
5:4	00	Normal PWM operation.
	01	Suppress PWM output seven out of eight iterations of PWM counter.
	10	Suppress PWM output three out of four iterations of PWM counter.
	11	Suppress PWM output one out of two iterations of PWM counter.
3		This bit is ignored and should be written with zero.
2:1	00	Normal PWM interrupt operation.
	01	Suppress PWM interrupts seven out of eight iterations of PWM counter.
	10	Suppress PWM interrupts three out of four iterations of PWM counter.
	11	Suppress PWM interrupts one out of two iterations of PWM counter.
0	0	PWM output High for single block.
	1	Spread PWM output throughout the cycle.

PWM LSB x Register (PWL2R) (Address = 0x008C) (PWL3R) (Address = 0x008E)		
Bit(s)	Value	Description
7:6		Least significant two bits for the Pulse Width Modulator count.
5:4	00	Normal PWM operation.
	01	Suppress PWM output seven out of eight iterations of PWM counter.
	10	Suppress PWM output three out of four iterations of PWM counter.
	11	Suppress PWM output one out of two iterations of PWM counter.
3:1		These bits are ignored and should be written with zero.
0	0	PWM output High for single block.
	1	Spread PWM output throughout the cycle.

PWM MSB x Register (PWM0R) (Address = 0x0089) (PWM1R) (Address = 0x008B) (PWM2R) (Address = 0x008D) (PWM3R) (Address = 0x008F)		
Bit(s)	Value	Description
7:0		Most significant eight bits for the Pulse Width Modulator count. With a count of “n”, the PWM output will be High for “n + 1” clocks out of the 1024 clocks of the PWM counter.

PWM Block Access Register (PWBAR) (Address = 0x00E8)		
Bit(s)	Value	Description
7:0		Access the PWM register pointed to by the PWBPR. The PWBPR is automatically updated to the next PWM register address in the sequence.

PWM Block Pointer Register (PWBPR) (Address = 0x00E9)		
Bit(s)	Value	Description
7:3		These bits are reserved.
2:0		Three least significant bits of the PWM register address for indirect access.

31. EXTERNAL I/O CONTROL

31.1 Overview

The Rabbit 6000's external I/O space consists of 64KB that is accessed by prefixing a read or write instruction with the **IOE** instruction. These accesses can go onto the memory bus or onto the external I/O bus (described below). There are three dedicated signal pins (/IORD, /IOWR, /BUFEN) that toggle for all external I/O accesses, and eight I/O strobes that can be associated with this external I/O space and directed out on Parallel Ports C–H.

In addition, a handshaking signal input can be enabled on any Parallel Port E pin, and can be used to pause an external I/O transaction until the external device is ready to complete the transaction. A timeout period can be defined to ensure that the processor is not held indefinitely by a misbehaving external device.

The drive strength and slew rate can be controlled for the /IORD, /IOWR, and /BUFEN pins. In addition, a 75 k Ω pullup or pulldown resistor can be enabled for the pins.

31.1.1 External I/O Bus

The Rabbit 6000 can enable a separate external I/O bus for external devices to keep bus loading on the memory bus at an acceptable level. This bus consists of eight data lines on Parallel Port A and up to eight address lines on Parallel Port B; two of the address lines are also available on Parallel Port D. If desired, Parallel Port H can be used for an additional eight data lines for 16-bit accesses.

Note that if the 16-bit mode is enabled (using parallel port H as the upper byte), it does not behave the same as 16-bit accesses on the memory bus. The external I/O bus in 16-bit mode is word-addressable, while the memory bus is byte-addressable. Each 16-bit external I/O write goes to a single address, while 16-bit memory bus writes span two bytes.

This functionality is mutually exclusive with the slave port and regular parallel I/O on Parallel Ports A and B.

When enabled, the address lines of the external I/O bus hold their value until a new value is written to them. The data lines return to a tristate mode after each transaction.

See Section 31.1.2 for memory timing for external I/O accesses.

31.1.2 I/O Strobes

There are eight I/O strobes available in the Rabbit 6000. Each has a separate 8KB address range that can be enabled as a chip select, read strobe, write strobe, or a read/write strobe. The number of wait states can be set to 1, 3, 7, or 15, and the signal can be active high or low. The timing can also be adjusted using IBxER to change the frequency of the clock driving the External I/O interface.

Table 31-1. External I/O Strobes

Register	External I/O Address Range
IB0CR	0x0000–0x1FFF
IB1CR	0x2000–0x3FFF
IB2CR	0x5000–0x5FFF
IB3CR	0x6000–0x7FFF
IB4CR	0x8000–0x9FFF
IB5CR	0xA000–0xBFFF
IB6CR	0xC000–0xDFFF
IB7CR	0xE000–0xFFFF

The I/O strobes can be used for devices on the memory bus or the external I/O bus. It is also possible to shorten the read strobe by one clock cycle and the write strobe by one-half a clock cycle by pulling in the trailing edge, which guarantees one clock cycle of hold time for transactions.

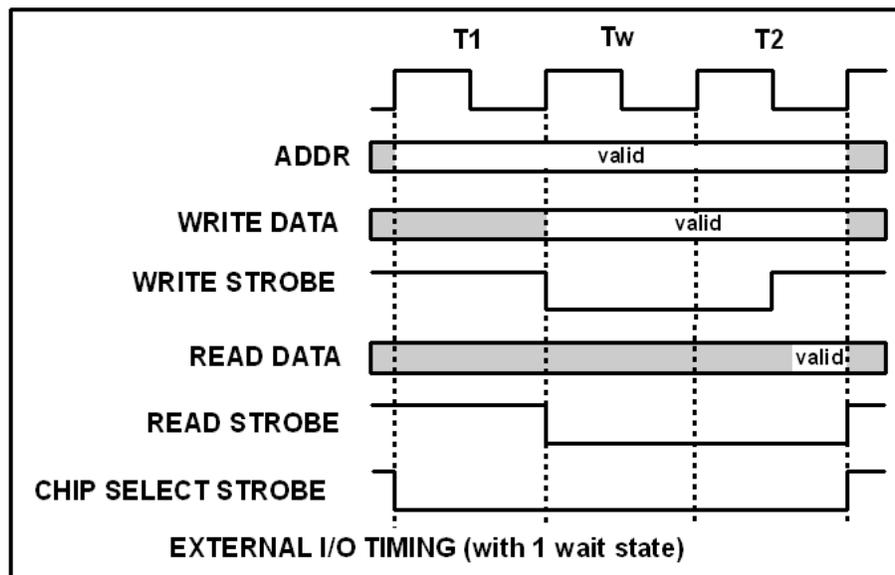


Figure 31.1 External I/O Bus Cycles

The strobes can be enabled to come out on Parallel Ports C, D, E, F, G or H.

By default the I/O strobes are configured as read-only chip selects with 15 wait states and normal timing. These settings will affect the /IORD, /IOWR, and /BUFEN signals for external I/O writes even if no other strobe outputs are enabled in the parallel port registers.

The most common configuration of the I/O strobes is to use them as chip select signals for external devices that share /IORD and /IOWR for the read and write strobes.

31.1.3 I/O Handshake

An external I/O handshake input can be enabled on one of the Parallel Port E pins for any combination of the I/O banks. The external device holds this signal (active high or low) when it is busy and cannot accept a transaction. The Rabbit 6000 will then hold midway through the transaction until either the handshake signal goes inactive or a timeout occurs. The timeout can be defined anywhere from 32 to 2048 clocks. When the timeout occurs, the transaction ends and a status bit is set. This bit must be checked by the program attempting the write; no interrupt is generated.

The I/O handshake signal is sampled at the end of the first wait state (T_w). When the handshake signal is disabled, the transition will start at the beginning of the T_w phase and continue to completion.

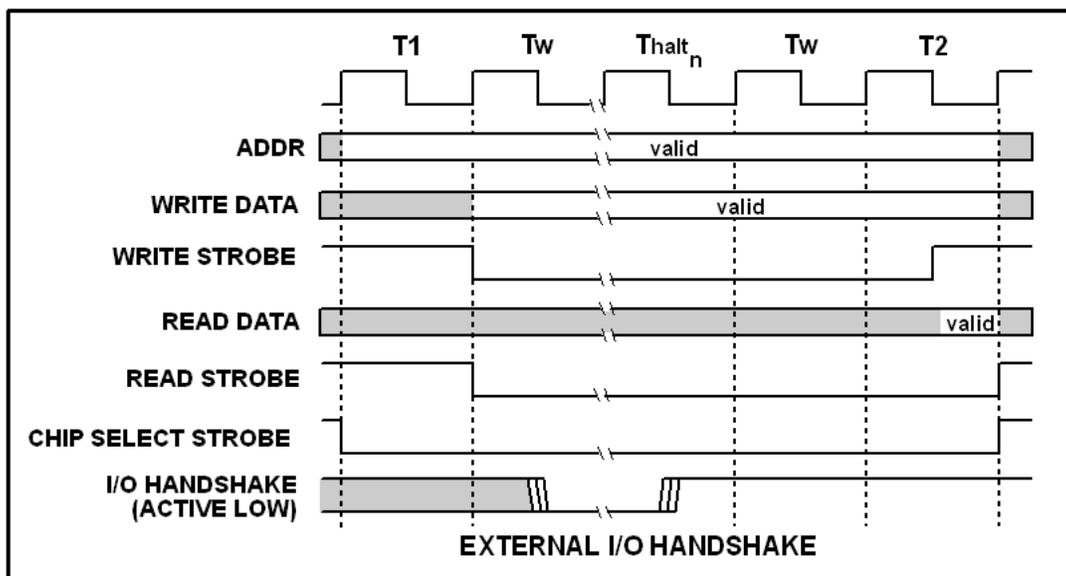
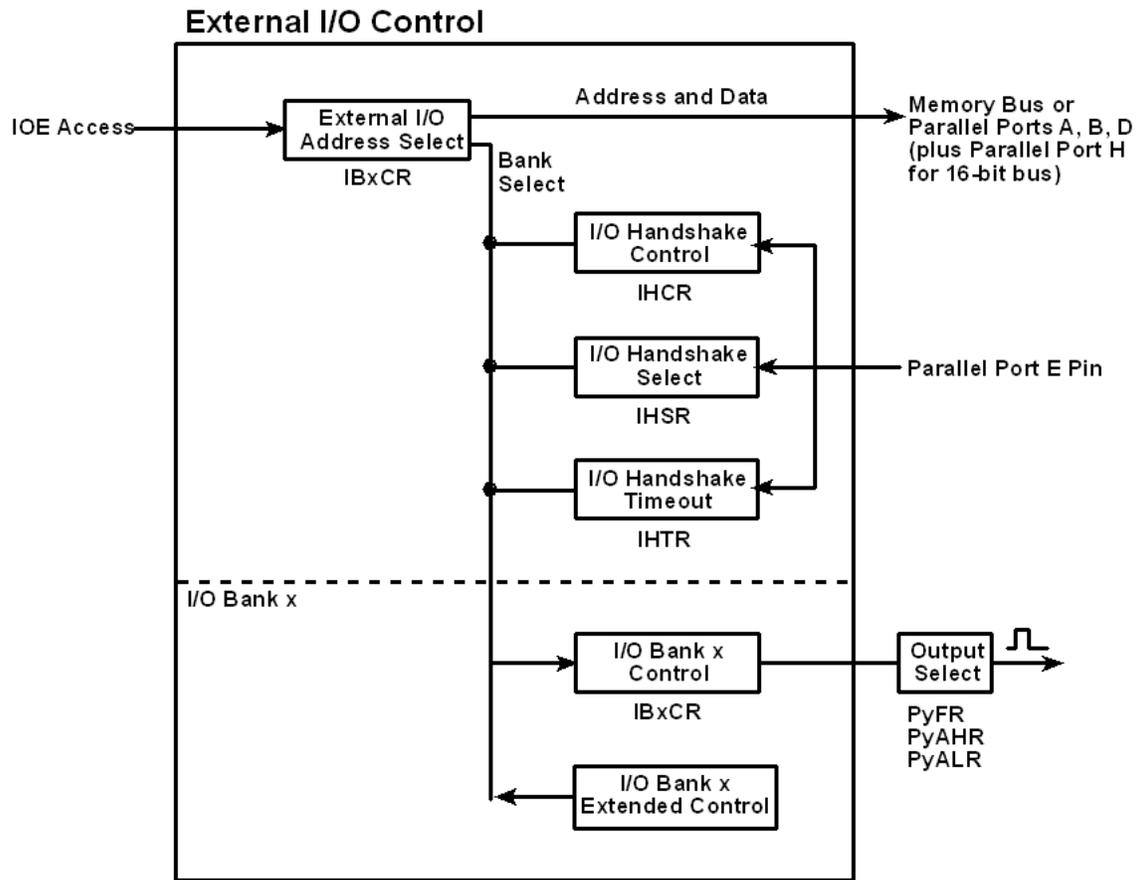


Figure 31.2 External I/O Handshake Timing Diagram

31.1.4 Block Diagram



31.1.5 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
I/O Bank 0 Control Register	IB0CR	0x0080 or 0x0450	W R/W	00000000
I/O Bank 0 Extended Register	IB0ER	0x0451	R/W	00000000
I/O Bank 1 Control Register	IB1CR	0x0081 or 0x0452	W R/W	00000000
I/O Bank 1 Extended Register	IB1ER	0x0453	R/W	00000000
I/O Bank 2 Control Register	IB2CR	0x0082 or 0x0454	W R/W	00000000
I/O Bank 2 Extended Register	IB2ER	0x0455	R/W	00000000
I/O Bank 3 Control Register	IB3CR	0x0083 or 0x0456	W R/W	00000000
I/O Bank 3 Extended Register	IB3ER	0x0457	R/W	00000000
I/O Bank 4 Control Register	IB4CR	0x0084 or 0x0458	W R/W	00000000
I/O Bank 4 Extended Register	IB4ER	0x0459	R/W	00000000
I/O Bank 5 Control Register	IB5CR	0x0085 or 0x045A	W R/W	00000000
I/O Bank 5 Extended Register	IB5ER	0x045B	R/W	00000000
I/O Bank 6 Control Register	IB6CR	0x0086 or 0x045C	W R/W	00000000
I/O Bank 6 Extended Register	IB6ER	0x045D	R/W	00000000
I/O Bank 7 Control Register	IB7CR	0x0087 or 0x045E	W R/W	00000000
I/O Bank 7 Extended Register	IB7ER	0x045F	R/W	00000000
I/O Handshake Control Register	IHCR	0x0028	R/W	00000000
I/O Handshake Select Register	IHSR	0x0029	R/W	00000000
I/O Handshake Timeout Register	IHTR	0x002A	R/W	00000000
I/O Bank 0 Control Register	IB0CR	0x0080 or 0x0450	W R/W	00000000

31.2 Dependencies

31.2.1 I/O Pins

The external I/O bus uses PA0–PA7 for the lower byte of data, and PH0–PH7 for the upper byte if 16-bit mode is enabled in IBxER. All Parallel Port H settings are overridden if the 16-bit I/O bus mode is enabled.

Either PB2–PB7 or PB0–PB7 are used for address lines, depending on the setting in SPCR. Address bits 6 and 7 can also be enabled on pins PD1, PD3, PD5, or PD7, which allows PB0 and PB1 to be used as clocked serial I/O instead of as external I/O.

The /IOWR, /IORD, and /BUFEN pins are dedicated strobes for external I/O accesses. Drive strength, slew rate, and the pullup/down resistor status are selectable via IOPCR.

The I/O strobes can be directed to pins on Parallel Ports C, D, E, F, G, or H; each bank can be directed to the appropriate pin (bank zero on PC0, PD0, or PE0; bank one on PC1, PD1, or PE1; etc.). The settings for each strobe will be reflected on /IOWR, /IORD, and /BUFEN as well whenever that bank is accessed.

The I/O handshake can be input on any one of the Parallel Port E pins (PE0–PE7).

31.2.2 Clocks

All external I/O accesses, strobes, and handshake timeouts are based on the processor clock, which can be taken directly or divided by 2, 4, 8, or 16 separately for each IO bank in the appropriate IBxER to provide slower access times when the main clock is at a high frequency. This is independent of the number of wait states which can also be programmed. Note that this divider setting is ignored when the processor clock is set to run off the 32 kHz clock.

31.2.3 Other Registers

Register	Function
SPCR	Enable the external I/O bus.
PCFR, PCALR, PCAHR PDFR, PDALR, PDAHR, PEFR, PEALR, PEAHR PFFR, PFALR, PFAHR PGFR, PGALR, PGAHR PHFR, PHALR, PHAHR	Select Parallel Port pins as I/O strobe outputs. Select PD1, PD3, PD5, or PD7 as address bits 6–7.

31.2.4 Interrupts

There are no interrupts associated with external I/O.

31.3 Operation

31.3.1 External I/O Bus

The following steps must be taken before using external I/O bus:

1. Enable the external I/O bus by writing to SPCR. Select whether 6 or 8 address bits are desired.
2. If PB0 and PB1 are needed for clocked serial use and eight address bits are required, enable the alternate outputs of address bits 6 and 7 on Parallel Port D by writing to PDALR, PDAHR, and PDFR.
3. Select 8- or 16-bit mode and set the I/O timing for a particular device by writing to the appropriate IBxCR and IBxER registers for the I/O bank desired. Make sure to set bit 3 in IBxCR if write access is desired.
4. If a strobe other than /IORD, /IOWR, or /BUFEN is required, enable the output of the IBxCR register by writing to the appropriate PxALR, PxAHR, and PxFR registers.

Once the external I/O bus is enabled, all memory read/write instructions prefixed with an IOE will go to the memory bus and/or external I/O bus, depending on the setup in that bank's IBxCR register.

31.3.2 I/O Strobes

The following steps must be taken before using an I/O strobe:

1. Set the strobe type and timing for a particular device by writing to the appropriate IBxCR and IBxER registers for the I/O bank desired.
2. If signals other than /IORD, /IOWR, and /BUFEN are required, enable the output of the IBxCR register by writing to the appropriate PxALR, PxAHR, and PxFR registers.

On startup, the I/O strobes default to chip selects with 15 wait states, read-only, active-low signaling, and will use the external I/O bus. These settings will be used for the dedicated I/O strobe pins /IORD, /IOWR, and /BUFEN whenever an external I/O write occurs even if no I/O strobe signals are being output on parallel port pins.

31.3.3 I/O Handshake

The following steps must be taken before using the I/O handshake:

1. Select the active level and desired port E bit to use as input by writing to IHCR.
2. Select which I/O banks the handshake is active for by writing to IHSR.
3. Select the handshake timeout value by writing to IHTR.

Once enabled, the handshake will be checked for every external I/O transaction in a bank that was enabled in IHSR. After these transactions, the program should check for a timeout by reading IHTR.

31.4 Register Descriptions

I/O Handshake Control Register		(IHCR)	(Address = 0x0028)
Bit(s)	Value	Description	
7:5		These bits are reserved and should be written with zeros.	
4	0	I/O handshake is active low (I/O transaction held until signal goes high).	
	1	I/O handshake is active high (I/O transaction held until signal goes low).	
3		This bit is reserved and should be written with zero.	
2:0	000	Use Parallel Port E bit 0 for I/O handshake.	
	001	Use Parallel Port E bit 1 for I/O handshake.	
	010	Use Parallel Port E bit 2 for I/O handshake.	
	011	Use Parallel Port E bit 3 for I/O handshake.	
	100	Use Parallel Port E bit 4 for I/O handshake.	
	101	Use Parallel Port E bit 5 for I/O handshake.	
	110	Use Parallel Port E bit 6 for I/O handshake.	
	111	Use Parallel Port E bit 7 for I/O handshake.	

I/O Handshake Select Register		(IHSR)	(Address = 0x0029)
Bit(s)	Value	Description	
7	0	Disable I/O handshake for I/O Bank 7.	
	1	Enable I/O handshake for I/O Bank 7.	
6	0	Disable I/O handshake for I/O Bank 6.	
	1	Enable I/O handshake for I/O Bank 6.	
5	0	Disable I/O handshake for I/O Bank 5.	
	1	Enable I/O handshake for I/O Bank 5.	
4	0	Disable I/O handshake for I/O Bank 4.	
	1	Enable I/O handshake for I/O Bank 4.	
3	0	Disable I/O handshake for I/O Bank 3.	
	1	Enable I/O handshake for I/O Bank 3.	
2	0	Disable I/O handshake for I/O Bank 2.	
	1	Enable I/O handshake for I/O Bank 2.	
1	0	Disable I/O handshake for I/O Bank 1.	
	1	Enable I/O handshake for I/O Bank 1.	
0	0	Disable I/O handshake for I/O Bank 0.	
	1	Enable I/O handshake for I/O Bank 0.	

I/O Handshake Timeout Register (IHTR) (Address = 0x002A)		
Bit(s)	Value	Description
7	0	No I/O handshake timeout has occurred since the last read of this register.
	1	An I/O handshake timeout has occurred since the last read of this register. This bit is cleared by a read of this register.
6		This bit is reserved and should be written with zero.
5:0		Time constant for the I/O handshake timeout counter. This time constant (times 32) selects the number of peripheral clock cycles that the I/O handshake input may delay completion of an I/O transaction before the I/O transaction will complete automatically.

I/O Bank x Control Register		
(IB0CR)	(Address = 0x0080 or 0x0450)	
(IB1CR)	(Address = 0x0081 or 0x0451)	
(IB2CR)	(Address = 0x0082 or 0x0452)	
(IB3CR)	(Address = 0x0083 or 0x0453)	
(IB4CR)	(Address = 0x0084 or 0x0454)	
(IB5CR)	(Address = 0x0085 or 0x0455)	
(IB6CR)	(Address = 0x0086 or 0x0456)	
(IB7CR)	(Address = 0x0087 or 0x0457)	
Bit(s)	Value	Description
7:6	00	Fifteen wait states for accesses in this bank.
	01	Seven wait states for accesses in this bank.
	10	Three wait states for accesses in this bank.
	11	One wait state for accesses in this bank.
5:4	00	The I signal is an I/O chip select.
	01	The I signal is an I/O read strobe.
	10	The I signal is an I/O write strobe.
	11	The I signal is an I/O data (read or write) strobe.
3	0	Writes are not allowed to this bank. Transactions are normal in every other way; only the write strobe is inhibited.
	1	Writes are allowed to this bank.
2	0	Active-low I signal.
	1	Inverted (active-high) I signal.
1	0	Normal I/O transaction timing.
	1	Shorten read strobe by one clock cycle and write strobe by one-half clock cycle. Transaction length remains the same. This guarantees one clock cycle hold time for both address and data for I/O transactions.
0	0	Use I/O bus if enabled in SPCR.
	1	Always use memory data bus.

I/O Bank x Extended Register		
(IB0ER)	(Address = 0x0451)	
(IB1ER)	(Address = 0x0453)	
(IB2ER)	(Address = 0x0455)	
(IB3ER)	(Address = 0x0457)	
(IB4ER)	(Address = 0x0459)	
(IB5ER)	(Address = 0x045B)	
(IB6ER)	(Address = 0x045D)	
(IB7ER)	(Address = 0x045F)	
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	I/O bank uses 8-bit data bus.
	1	I/O bank uses 16 bit data bus (using parallel port H as the upper byte).
3		This bit is reserved and should be written with zero.
2:0	000	I/O transactions run at CPU clock speed. Note that I/O transactions are always run at the CPU clock speed when running the CPU from the 32 kHz clock.
	001	This bit combination is reserved and should not be used.
	010	This bit combination is reserved and should not be used.
	011	This bit combination is reserved and should not be used.
	100	I/O transactions use the CPU clock divided by 2.
	101	I/O transactions use the CPU clock divided by 4.
	110	I/O transactions use the CPU clock divided by 8.
	111	I/O transactions use the CPU clock divided by 16.

I/O Control Pin Control Register (IOPCR) (Address = 0x04A3)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written with zeros.
4	0	Fast output slew rate.
	1	Slow output slew rate.
3:2	00	4 mA output drive capability.
	01	8 mA output drive capability.
	10	10 mA output drive capability.
	11	14 mA output drive capability.
1:0		These bits are reserved and should be written with zeros.

Slave Port Control Register (SPCR) (Address = 0x0024)		
Bit(s)	Value	Description
7	0	Program fetch as a function of the SMODE pins.
	1	Ignore the SMODE pins program fetch function.
6:5	Read	These bits report the state of the SMODE pins.
	Write	These bits are ignored and should be written with zero.
4:2	000	Disable the slave port. Parallel Port A is a byte-wide input port.
	001	Disable the slave port. Parallel Port A is a byte-wide output port.
	010	Enable the slave port, with /SCS from Parallel Port E bit 7.
	011	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:2] is used for the address bus.
	100	This bit combination is reserved and should not be used.
	101	This bit combination is reserved and should not be used.
	110	Enable the slave port, with /SCS from Parallel Port B bit 6.
	111	Enable the external I/O bus. Parallel Port A is used for the data bus and Parallel Port B[7:0] is used for the address bus.
1:0	00	Slave port interrupts are disabled.
	01	Slave port interrupts use Interrupt Priority 1.
	10	Slave port interrupts use Interrupt Priority 2.
	11	Slave port interrupts use Interrupt Priority 3.

32. BREAKPOINTS

32.1 Overview

The Rabbit 6000 contains seven hardware breakpoints to support debugging. Each hardware breakpoint consists of a 24-bit address match register and a 24-bit mask register. A breakpoint can be generated on an address match for execution, data read, data write, or any combination thereof. The mask register serves to mask off selected bits from the address compare. A “one” in a particular bit position in the mask register inhibits the corresponding bit in the address match register from contributing to the address match condition.

When a match occurs, a Level 3 breakpoint interrupt is generated. Note that this means that breakpoints behave differently when the processor is running at Interrupt Priority 3 — the interrupt is generated but will not be handled until the processor drops to a lower priority.

In most cases, a code execution interrupt will be handled at the end of the instruction in which the match occurred. However, because of the time required to perform a 24-bit address match in the processor, a code execution breakpoint that is set on a single-byte, 2-clock instruction will not be enabled at the end of that instruction, but the interrupt will instead occur at the end of the next instruction.

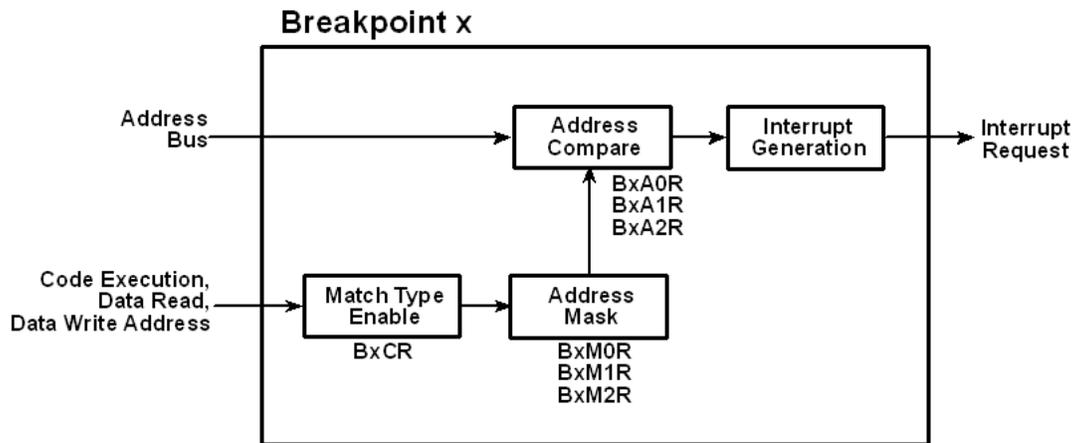
Note that a breakpoint may be forced to be pending by setting the corresponding bit in BDCR. This feature allows a breakpoint request to be used as a virtual single-step request by always setting the appropriate bit in the interrupt handler. There is a particular sequence of instructions required to exit properly when the interrupt is left pending.

DMA transfers are treated as normal data reads and writes, although the DMA transfer will complete before the interrupt is taken.

Breakpoints can be enabled for the User Mode, the System Mode, or both.

Another breakpoint feature is the ability to disable the RST 28h instruction. The RST 28h vector was often used as a breakpoint feature by adding that instruction to code; by enabling a bit in BDCR, the RST 28h instruction will execute as a NOP instead, providing an easy way to disable that type of breakpoint.

32.1.1 Block Diagram



32.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Breakpoint Debug/Control Register	BDCR	0x001C	R/W	00000000
Breakpoint 0 Control Register	B0CR	0x030B	R/W	00000000
Breakpoint 1 Control Register	B1CR	0x031B	R/W	00000000
Breakpoint 2 Control Register	B2CR	0x032B	R/W	00000000
Breakpoint 3 Control Register	B3CR	0x033B	R/W	00000000
Breakpoint 4 Control Register	B4CR	0x034B	R/W	00000000
Breakpoint 5 Control Register	B5CR	0x035B	R/W	00000000
Breakpoint 6 Control Register	B6CR	0x036B	R/W	00000000
Breakpoint x Address 0 Register	BxA0R	0x03xC	R/W	00000000
Breakpoint x Address 1 Register	BxA1R	0x03xD	R/W	00000000
Breakpoint x Address 2 Register	BxA2R	0x03xE	R/W	00000000
Breakpoint x Mask 0 Register	BxM0R	0x03x8	R/W	00000000
Breakpoint x Mask 1 Register	BxM1R	0x03x9	R/W	00000000
Breakpoint x Mask 2 Register	BxM2R	0x03xA	R/W	00000000

32.2 Dependencies

32.2.1 I/O Pins

There are no I/O pins associated with breakpoints.

32.2.2 Clocks

There are no clocks associated with breakpoints.

32.2.3 Other Registers

There are no other registers associated with breakpoints.

32.2.4 Interrupts

When an enabled address match occurs for a given breakpoint, a breakpoint interrupt occurs. The breakpoint that caused the interrupt must be determined by reading BDCR, which also clears the interrupt. Any of the breakpoint interrupts can be enabled by writing to BDCR.

The breakpoint interrupt vector is in the EIR at offset 0x140; note that this is a different vector address than in previous Rabbit processors. It is always set to Interrupt Priority 3, and is the highest priority interrupt; if two Interrupt Priority 3 vectors are pending, the breakpoint interrupt will always be handled first.

32.3 Operation

The following steps must be taken to enable breakpoints:

1. Write the vector to the interrupt service routine to the external interrupt table.
2. Write the desired breakpoint addresses to the appropriate breakpoint address registers (BxAyR, where x is the breakpoint and y is the byte of the address, 0-2).
3. Write an address mask for the given breakpoints (BxMyR).
4. Select the breakpoint address match type (execute, data read, data write) by writing to the appropriate BxCR.
5. Enable the desired breakpoints by writing to BDCR.

32.3.1 Handling Interrupts

The following actions occur within the interrupt service routine.

- Which breakpoints are pending must be determined by reading BDCR. This also clears the pending breakpoints.
- The desired breakpoint action should be taken.
- If single-step functionality is desired, the breakpoint interrupt should be re-enabled by writing the appropriate bit to BDCR. If this is done, the interrupt handler needs to be exited in a particular manner (see below).

32.3.2 Example ISR

A sample interrupt handler is shown below.

```
breakpoint_isr::
    push af
    ioi ld a, (BDCR) ; determine which interrupts are pending and
                    ; clear the interrupt request

    ; handle all breakpoints here
    ; reenale any breakpoints by writing to BDCR
    pop af
    ipres           ; you should exit the handler with these two instruc-
tions
    ret            ; if you reenabled breakpoints, otherwise another
breakpoint

                    ; interrupt may occur inside the ISR
```

32.4 Register Descriptions

Breakpoint/Debug Control Register (BDCR) (Address = 0x001C)		
Bit(s)	Value	Description
7	0	Normal RST 0x28 operation.
	1	RST 0x28h is NOP.
6:0	0	The corresponding Breakpoint request is not pending.
	1	The corresponding Breakpoint request is pending. Reading this register automatically clears all pending breakpoint requests.
6:0	0	No effect on the corresponding Breakpoint request.
	1	Make the corresponding Breakpoint request pending.

Breakpoint x Control Register		
(B0CR)		(Address = 0x030B)
(B1CR)		(Address = 0x031B)
(B2CR)		(Address = 0x032B)
(B3CR)		(Address = 0x033B)
(B4CR)		(Address = 0x034B)
(B5CR)		(Address = 0x036B)
(B6CR)		(Address = 0x037B)
Bit(s)	Value	Description
7:6	00	No Breakpoint x on execute address match.
	01	Breakpoint x on User Mode execute address match.
	10	Breakpoint x on System Mode execute address match.
	11	Breakpoint x on System or User Mode execute address match.
5:4	00	No breakpoint x on data read address match.
	01	Breakpoint x on User Mode data read address match.
	10	Breakpoint x on System Mode data read address match.
	11	Breakpoint x on System or User Mode data read address match.
3:2	00	No breakpoint x on write address match.
	01	Breakpoint x on User Mode write address match.
	10	Breakpoint x on System Mode write address match.
	11	Breakpoint x on System or User Mode write address match.
1:0		These bits are reserved and should be written with zeros.

Breakpoint x Address 0 Register		
(B0A0R)	(Address = 0x030C)	
(B1A0R)	(Address = 0x031C)	
(B2A0R)	(Address = 0x032C)	
(B3A0R)	(Address = 0x033C)	
(B4A0R)	(Address = 0x034C)	
(B5A0R)	(Address = 0x036C)	
(B6A0R)	(Address = 0x037C)	
Bit(s)	Value	Description
7:0		Breakpoint x Address [7:0].

Breakpoint x Address 1 Register		
(B0A1R)	(Address = 0x030D)	
(B1A1R)	(Address = 0x031D)	
(B2A1R)	(Address = 0x032D)	
(B3A1R)	(Address = 0x033D)	
(B4A1R)	(Address = 0x034D)	
(B5A1R)	(Address = 0x036D)	
(B6A1R)	(Address = 0x037D)	
Bit(s)	Value	Description
7:0		Breakpoint x Address [15:8].

Breakpoint x Address 2 Register		
(B0A2R)	(Address = 0x030E)	
(B1A2R)	(Address = 0x031E)	
(B2A2R)	(Address = 0x032E)	
(B3A2R)	(Address = 0x033E)	
(B4A2R)	(Address = 0x034E)	
(B5A2R)	(Address = 0x036E)	
(B6A2R)	(Address = 0x037E)	
Bit(s)	Value	Description
7:0		Breakpoint x Address [23:16].

Breakpoint x Mask 0 Register		
(B0M0R)	(Address = 0x0308)	
(B1M0R)	(Address = 0x0318)	
(B2M0R)	(Address = 0x0328)	
(B3M0R)	(Address = 0x0338)	
(B4M0R)	(Address = 0x0348)	
(B5M0R)	(Address = 0x0368)	
(B6M0R)	(Address = 0x0378)	
Bit(s)	Value	Description
7:0		Breakpoint x Mask [7:0]. (A one in a bit position inhibits the address compare for that bit position.)

Breakpoint x Mask 1 Register		
(B0M1R)	(Address = 0x0309)	
(B1M1R)	(Address = 0x0319)	
(B2M1R)	(Address = 0x0329)	
(B3M1R)	(Address = 0x0339)	
(B4M1R)	(Address = 0x0349)	
(B5M1R)	(Address = 0x0369)	
(B6M1R)	(Address = 0x0379)	
Bit(s)	Value	Description
7:0		Breakpoint x Mask [15:8]. (A one in a bit position inhibits the address compare for that bit position.)

Breakpoint x Mask 2 Register		
(B0M2R)	(Address = 0x030A)	
(B1M2R)	(Address = 0x031A)	
(B2M2R)	(Address = 0x032A)	
(B3M2R)	(Address = 0x033A)	
(B4M2R)	(Address = 0x034A)	
(B5M2R)	(Address = 0x036A)	
(B6M2R)	(Address = 0x037A)	
Bit(s)	Value	Description
7:0		Breakpoint x Mask [23:16]. (A one in a bit position inhibits the address compare for that bit position.)

33. FLEXIBLE INTERFACE MODULES

33.1 Overview

The Rabbit 6000 contains two Flexible Interface Modules, or FIMs. These modules are essentially small independent microcontrollers that can be used to provide a wide range of customized peripherals, such as CAN, SD card, or 1-Wire serial.

Each Flexible Interface Module can run at up to 400 MHz and includes 1024x14 bits of program memory and 256x8 bits of data memory. Most Flexible Interface Module applications are expected to use a single parallel port, so bit-by-bit selection of Flexible Interface Module functionality is available on Parallel Ports F and G. Other Rabbit parallel ports can be accessed to a limited extent using port override modes available on the Flexible Interface Module. If the override is enabled, the entire parallel port is then controlled by the FIM.

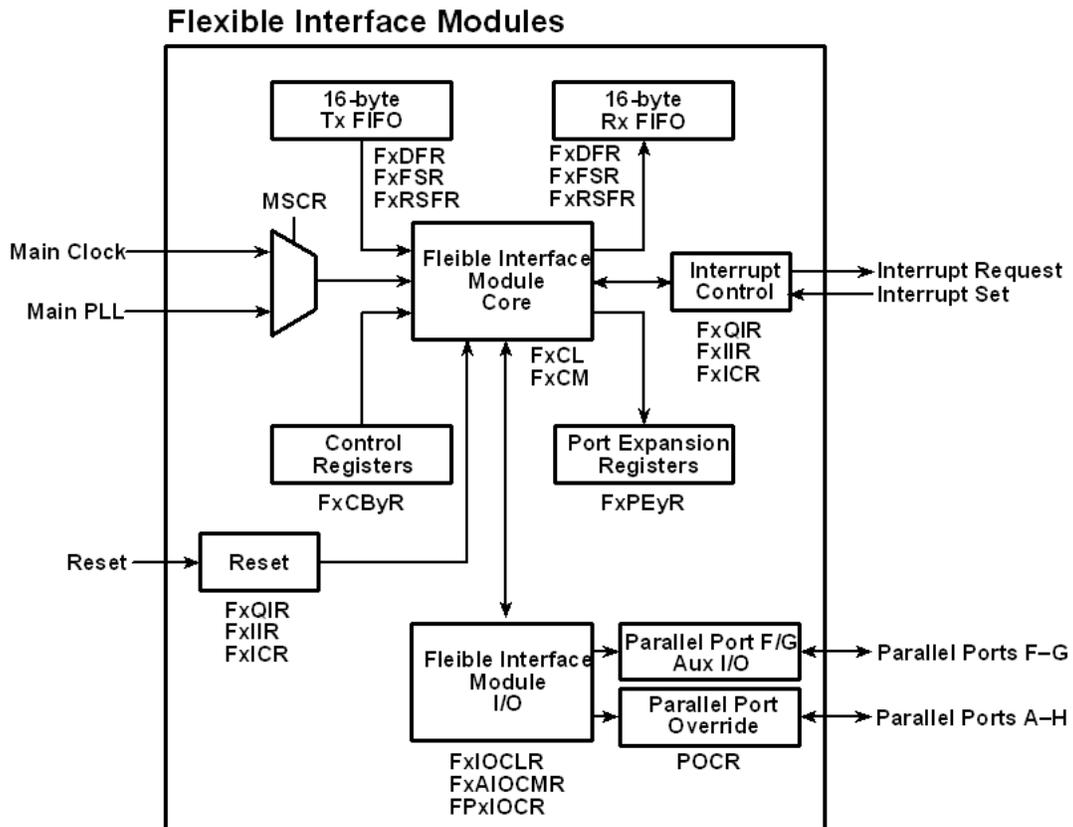
Communication between the Rabbit 6000 and the Flexible Interface Modules is realized in several ways.

- 16-byte TX FIFO from the Rabbit to the Flexible Interface Module
- 16-byte RX FIFO from the Flexible Interface Module to the Rabbit
- 16-byte RX status FIFO from the Flexible Interface Module to the Rabbit that can be used to signal end of packet or an error condition
- 16 “control byte” registers that can be written by the Rabbit and read by the Flexible Interface Module
- 16 “expansion port” registers that can be written by the Flexible Interface Module and read by the Rabbit
- The Rabbit provides an interrupt request line to the Flexible Interface Module
- The Flexible Interface Module provides an interrupt request line to the Rabbit

The FIFOs are DMA-aware.

The interface between the Flexible Interface Modules and the Rabbit 6000 is described in this chapter. Customers wishing to incorporate a custom Flexible Interface Module application in their own design should contact their sales representative at Digi International for more information.

33.2 Block Diagram



33.2.1 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Master System Reset Register	MSRR	0x0436	R/W	xxxxx0x0
Port Override Control Register	POCR	0x0438	R/W	00000000
FIMA				
FIMA Data FIFO Register	FADFR	0x6000	R/W	xxxxxxxx
FIMA Rx Status FIFO Register	FARSFR	0x6001	R	0xxxxxxxx
FIMA FIFO Status Register	FAFSR	0x6002	R	00000000
FIMA Outbound Interrupt Register	FAOIR	0x6003	R	00000000
FIMA Inbound Interrupt Register	FAIIR	0x6004	R/W	00000000
FIMA Master Mode Register	FAMMR	0x6005	R/W	00000000
FIMA Interrupt Control Register	FAICR	0x6006	R/W	00000000
FIMA Control Bytes 0–15	FACBxR	0x6007 + x	R/W	00000000
FIMA Port Expansion Bytes 0–15	FAPEBxR	0x6017 + x	R	00000000
FIMA Code LSB Register	FACLR	0x6800– 0x6BFF	R/W	xxxxxxxx
FIMA Code MSB Register	FACMR	0x6C00– 0x6FFF	R/W	xxxxxxxx
FIMB				
FIMB Data FIFO Register	FBDFR	0x7000	R/W	xxxxxxxx
FIMB Rx Status FIFO Register	FBRsFR	0x7001	R	0xxxxxxxx
FIMB FIFO Status Register	FBFSR	0x7002	R	00000000
FIMB Outbound Interrupt Register	FBOIR	0x7003	R	00000000
FIMB Inbound Interrupt Register	FBIIR	0x7004	R/W	00000000
FIMB Master Mode Register	FBMMR	0x7005	R/W	00000000
FIMB Interrupt Control Register	FBICR	0x7006	R/W	00000000
FIMB Control Bytes 0–15	FBCBxR	0x7007 + x	R/W	00000000
FIMB Port Expansion Bytes 0–15	FBPEBxR	0x7017 + x	R	00000000
FIMB Code LSB Register	FBCLR	0x7800– 0x7BFF	R/W	xxxxxxxx
FIMB Code MSB Register	FBCMR	0x7C00– 0x7FFF	R/W	xxxxxxxx

33.3 Dependencies

33.3.1 I/O Pins

Each Flexible Interface Module has a single parallel port that can be enabled for its use bit-by-bit in that parallel port's alternate output registers. The individual bits of Parallel Port F are available to FIMA, and the individual bits of Parallel Port G are available to FIMB.

The Flexible Interface Modules also have the capability of overriding the normal functionality of any other parallel port via the Port Override Control Register. This overrides control of the entire parallel port, however, meaning that any other functionality on that port is no longer available. The use of Rabbit parallel ports in an override mode is very function-specific and is used predominantly for parallel bus applications. The use and restrictions of the override mode are not covered in this document.

33.3.2 Clocks

The Flexible Interface Modules have two clocking options, selectable in the Master System Configuration Register. One option is to use the main clock output, just like the Rabbit processor; the other is to use the output of the main PLL.

33.3.3 Other Registers

Register	Function
MSCR	Select the Flexible Interface Module clocks.
POCR	Override parallel port registers for Flexible Interface Module operation.

33.3.4 Interrupts

Each Flexible Interface Module can generate an interrupt to the Rabbit 6000, as well as receive an interrupt from the Rabbit 6000. In each case, a 7-bit value can be passed, effectively providing 127 different interrupts without requiring additional information to be passed (sending 0 clears the interrupt request).

The FIMA interrupt vector is in the IIR at offset 0x130. It can be set as Priority 1, 2, or 3 by writing to FAICR.

The FIMB interrupt vector is in the IIR at offset 0x140. It can be set as Priority 1, 2, or 3 by writing to FBICR.

33.4 Operation

While the detailed operation of the Flexible Interface Modules is beyond the scope of this manual, this section will describe how to initialize and start the Flexible Interface Modules.

The following steps explain how to load and start a Flexible Interface Module application.

1. If desired, write the appropriate interrupt vector for the interrupt service routine to the internal interrupt table.
2. Enable the appropriate Flexible Interface Module clock in MSCR.
3. Write a 0 to bit 7 of FxICR to disable the Flexible Interface Module and allow loading of the application.
4. Write the Flexible Interface Module application to the address range starting at FxCLR and FxCMR.
5. Write a 1 to bit 7 of FxICR to enable the Flexible Interface Module. If interrupts from the module are to be used, set the priority level in bits 0–1 of FxICR as well.
6. The Flexible Interface Module is now running the loaded application.

33.4.1 Handling Interrupts

The interrupt receive/acknowledge handshaking between the Flexible Interface Module and the Rabbit 6000 has to be handled manually for both the Flexible Interface Module interrupting the Rabbit and vice versa. Sample code for each is shown below.

33.4.1.1 Rabbit Interrupt Request to Flexible Interface Module

```
ld a, 0x55
ioi ld (FAIIR), a          ; send interrupt 0x55 to FIMA

ld b, 255                  ; timeout counter for FIM ack
waitForFIM:
dec b                      ; decrement timeout counter
jp z, timeout             ; exit to timeout handling routine

ioi ld a, (FAIOR)         ; get interrupt status from FIMA
bit 7, a                  ; check interrupt ack bit
jr z, waitForFIM         ; loop until FIMA ack's the interrupt

ld a, 0x00
ioi ld (FAIIR), a        ; FIMA has ack'd, so clear interrupt
request
```

33.4.1.2 Flexible Interface Module Interrupt Request to Rabbit

```
FIM_A_ISR:
    push af                ; save registers
    push bc

    ioi ld a, (FAIOR)     ; get interrupt value that FIMA sent
    ld a, 0x80
    ioi ld (FAIIR), a    ; set acknowledge bit for FIMA

    ld b, 255             ; timeout counter for FIM ack
waitForFIM:
    dec b                 ; decrement timeout counter
    jp z, timeout        ; exit to timeout handling routine

    ioi ld a, (FAIOR)
    bit 7, a              ; check for FIMA clearing interrupt bit
    jr jz, waitForFIM
    jp done

timeout:
    ; handle timeout here by setting flag, calling exception, etc.

done:
    pop bc                ; restore registers
    pop af
    ipres                 ; restore IP stack
    ret
```

33.5 Register Descriptions

FIMA Data FIFO Register (FADFR) (Address = 0x6000)		
Bit(s)	Value	Description
7:0	write	Loads the transmit FIFO buffer.
	read	Returns the contents of the receive FIFO buffer.

FIMA Rx Status FIFO Register (FARSFR) (Address = 0x6001)		
Bit(s)	Value	Description
7		This bit is reserved and always returns zero.
6:0	read	Returns the contents of the receive status FIFO buffer.

FIMA FIFO Status Register (FAFSR) (Address = 0x6002)		
Bit(s)	Value	Description
7:4		These bits are reserved and always returns zeros.
3 (Read-only)	0	Rx FIFO not full.
	1	Rx FIFO full.
2 (Read-only)	0	Rx FIFO not empty.
	1	Rx FIFO empty.
1 (Read-only)	0	Tx FIFO not full.
	1	Tx FIFO full.
0 (Read-only)	0	Tx FIFO not empty.
	1	Tx FIFO empty.

FIMA Outbound Interrupt Register (FAOIR) (Address = 0x6003)		
Bit(s)	Value	Description
7 (Read-only)	0	The Interrupt code to the Flexible Interface Module processor has been cleared by the FIM.
	1	Flexible Interface Module processor interrupt acknowledge.
6:0	read	Interrupt value from the Flexible Interface Module processor. The Flexible Interface Module processor writes a non-zero value, which causes an interrupt request. The Flexible Interface Module processor will wait for the main processor to set bit 7 of the Inbound Interrupt Register before clearing the interrupt code. The code values are user-defined.

FIMA Inbound Interrupt Register (FAIIR) (Address = 0x6004)		
Bit(s)	Value	Description
7	0	Clear this bit after the interrupt code from the Flexible Interface Module processor has been cleared by the FIM.
	1	Acknowledge interrupt request. This bit must remain set until the interrupt code from the Flexible Interface Module processor has been cleared.
6:0	write	Interrupt value to the Flexible Interface Module processor. Writing a non-zero value to this field causes an interrupt to be generated to the Flexible Interface Module processor. This field should not be cleared until bit 7 of the Outbound Interrupt Register is set by the Flexible Interface Module processor. The code values are user-defined.

FIMA Interrupt Control Register (FAICR) (Address = 0x6006)		
Bit(s)	Value	Description
7	0	The main processor has read/write access to the Flexible Interface Module program memory.
	1	The Flexible Interface Module processor has read access to the Flexible Interface Module program memory.
6:2		These bits are reserved and should always be written with zeros.
1:0	00	Flexible Interface Module interrupt disabled.
	01	Flexible Interface Module interrupt uses priority 1.
	10	Flexible Interface Module interrupt uses priority 2.
	11	Flexible Interface Module interrupt uses priority 3.

FIMA Control Byte x Register		
(FACB0R)	(Address = 0x6007)	
(FACB1R)	(Address = 0x6008)	
(FACB2R)	(Address = 0x6009)	
(FACB3R)	(Address = 0x600A)	
(FACB4R)	(Address = 0x600B)	
(FACB5R)	(Address = 0x600C)	
(FACB6R)	(Address = 0x600D)	
(FACB7R)	(Address = 0x600E)	
(FACB8R)	(Address = 0x600F)	
(FACB9R)	(Address = 0x6010)	
(FACB10R)	(Address = 0x6011)	
(FACB11R)	(Address = 0x6012)	
(FACB12R)	(Address = 0x6013)	
(FACB13R)	(Address = 0x6014)	
(FACB14R)	(Address = 0x6015)	
(FACB15R)	(Address = 0x6016)	
Bit(s)	Value	Description
7:0		User-defined control bytes that are mapped to the data memory of the Flexible Interface Module processor. Bytes 0–7 are mapped to data memory addresses 0x10–0x17, and bytes 8–15 are mapped to data memory addresses 0x90–0x97. These registers are read-write for the Rabbit, but read-only for the FIM.

FIMA Port Expansion x Register		
(FAPE0R)	(Address = 0x6017)	
(FAPE1R)	(Address = 0x6018)	
(FAPE2R)	(Address = 0x6019)	
(FAPE3R)	(Address = 0x601A)	
(FAPE4R)	(Address = 0x601B)	
(FAPE5R)	(Address = 0x601C)	
(FAPE6R)	(Address = 0x601D)	
(FAPE7R)	(Address = 0x601E)	
(FAPE8R)	(Address = 0x602F)	
(FAPE9R)	(Address = 0x6020)	
(FAPE10R)	(Address = 0x6021)	
(FAPE11R)	(Address = 0x6022)	
(FAPE12R)	(Address = 0x6023)	
(FAPE13R)	(Address = 0x6024)	
(FAPE14R)	(Address = 0x6025)	
(FAPE15R)	(Address = 0x6026)	
Bit(s)	Value	Description
7:0 (Read-only)		User-defined status bytes that are mapped to the data memory of the Flexible Interface Module processor. Bytes 0–7 are mapped to data memory addresses 0x18–0x1F, and bytes 8–15 are mapped to data memory addresses 0x98–0x9F.

FIMA Code LSB Register (FACLR) (Address = 0x6800) through (Address = 0x6BFF)		
Bit(s)	Value	Description
7:0		FIMA code bits [7:0].

FIMA Code MSB Register (FACM000) (Address = 0x6C00) through (Address = 0x6FFF)		
Bit(s)	Value	Description
7:6		These bits are unused.
5:0		FIMA code bits [13:8].

FIMB Data FIFO Register (FBDFR) (Address = 0x7000)		
Bit(s)	Value	Description
7:0	write	Loads the transmit FIFO buffer.
	read	Returns the contents of the receive FIFO buffer.

FIMB Rx Status FIFO Register (FBR5FR) (Address = 0x7001)		
Bit(s)	Value	Description
7		This bit is reserved and always returns zero.
6:0	read	Returns the contents of the receive status FIFO buffer.

FIMB FIFO Status Register		(FBFSR)	(Address = 0x7002)
Bit(s)	Value	Description	
7:4		These bits are reserved and always returns zeros.	
3 (Read-only)	0	Rx FIFO not full.	
	1	Rx FIFO full.	
2 (Read-only)	0	Rx FIFO not empty.	
	1	Rx FIFO empty.	
1 (Read-only)	0	Tx FIFO not full.	
	1	Tx FIFO full.	
0 (Read-only)	0	Tx FIFO not empty.	
	1	Tx FIFO empty.	

FIMB Outbound Interrupt Register		(FBOIR)	(Address = 0x7003)
Bit(s)	Value	Description	
7 (Read-only)	0	The Interrupt code to the Flexible Interface Module processor has been cleared by the FIM	
	1	Flexible Interface Module processor interrupt acknowledge.	
6:0	read	Interrupt value from the Flexible Interface Module processor. The Flexible Interface Module processor writes a non-zero value, which causes an interrupt request. The Flexible Interface Module processor will wait for the main processor to set bit 7 of the Inbound Interrupt Register before clearing the interrupt code. The code values are user-defined.	

FIMB Inbound Interrupt Register (FBIIR) (Address = 0x7004)		
Bit(s)	Value	Description
7	0	Clear this bit after the interrupt code from the Flexible Interface Module processor has been cleared by the FIM.
	1	Acknowledge interrupt request. This bit must remain set until the interrupt code from the Flexible Interface Module processor has been cleared.
6:0	write	Interrupt value to the Flexible Interface Module processor. Writing a non-zero value to this field causes an interrupt to be generated to the Flexible Interface Module processor. This field should not be cleared until bit 7 of the Outbound Interrupt Register is set by the Flexible Interface Module processor. The code values are user-defined.

FIMB Master Mode Register (FBMMR) (Address = 0x7005)		
Bit(s)	Value	Description
7:0		These bits are reserved and should always be written with zeros.

FIMB Interrupt Control Register (FBICR) (Address = 0x7006)		
Bit(s)	Value	Description
7	0	The main processor has read/write access to the Flexible Interface Module program memory.
	1	The Flexible Interface Module processor has read access from the Flexible Interface Module program memory.
6:2		These bits are reserved and should always be written with zeros.
1:0	00	Flexible Interface Module interrupt disabled.
	01	Flexible Interface Module interrupt uses priority 1.
	10	Flexible Interface Module interrupt uses priority 2.
	11	Flexible Interface Module interrupt uses priority 3.

FIMB Control Byte x Register		
(FBCB0R)	(Address = 0x7007)	
(FBCB1R)	(Address = 0x7008)	
(FBCB2R)	(Address = 0x7009)	
(FBCB3R)	(Address = 0x700A)	
(FBCB4R)	(Address = 0x700B)	
(FBCB5R)	(Address = 0x700C)	
(FBCB6R)	(Address = 0x700D)	
(FBCB7R)	(Address = 0x700E)	
(FBCB8R)	(Address = 0x700F)	
(FBCB9R)	(Address = 0x7010)	
(FBCB10R)	(Address = 0x7011)	
(FBCB11R)	(Address = 0x7012)	
(FBCB12R)	(Address = 0x7013)	
(FBCB13R)	(Address = 0x7014)	
(FBCB14R)	(Address = 0x7015)	
(FBCB15R)	(Address = 0x7016)	
Bit(s)	Value	Description
7:0		User-defined control bytes that are mapped to the data memory of the Flexible Interface Module processor. Bytes 0–7 are mapped to data memory addresses 0x10–0x17, and bytes 8–15 are mapped to data memory addresses 0x90–0x97. These registers are read-write for the main processor.

FIMB Port Expansion x Register		
(FBPE0R)	(Address = 0x7017)	
(FBPE1R)	(Address = 0x7018)	
(FBPE2R)	(Address = 0x7019)	
(FBPE3R)	(Address = 0x701A)	
(FBPE4R)	(Address = 0x701B)	
(FBPE5R)	(Address = 0x701C)	
(FBPE6R)	(Address = 0x701D)	
(FBPE7R)	(Address = 0x701E)	
(FBPE8R)	(Address = 0x702F)	
(FBPE9R)	(Address = 0x7020)	
(FBPE10R)	(Address = 0x7021)	
(FBPE11R)	(Address = 0x7022)	
(FBPE12R)	(Address = 0x7023)	
(FBPE13R)	(Address = 0x7024)	
(FBPE14R)	(Address = 0x7025)	
(FBPE15R)	(Address = 0x7026)	
Bit(s)	Value	Description
7:0 (Read-only)		User-defined status bytes that are mapped to the data memory of the Flexible Interface Module processor. Bytes 0–7 are mapped to data memory addresses 0x18–0x1F, and bytes 8–15 are mapped to data memory addresses 0x98–0x9F.

FIMB Code LSB Register (FBCLR) (Address = 0x7800) through (Address = 0x7BFF)		
Bit(s)	Value	Description
7:0		FIMB code bits [7:0].

FIMB Code MSB Register (FBCMR) (Address = 0x7C00) through (Address = 0x7FFF)		
Bit(s)	Value	Description
7:6		These bits are unused.
5:0		FIMB code bits [13:8].

Master System Reset Register (MSRR) (Address = 0x0436)		
Bit(s)	Value	Description
7:3		These bits are reserved and should be written with zeros.
2 (wr-only)	0	No reset of Flexible Interface Module B. Reads always return zero.
	1	Reset Flexible Interface Module B. This bit holds FIMB in Reset while set.
1		This bit is reserved and should be written with zero.
0 (wr-only)	0	no reset of Flexible Interface Module A. Reads always return zero.
	1	Reset Flexible interface Module A. This bit holds FIMA in Reset while set.

Master Override Control Register (POCR) (Address = 0x0438)		
Bit(s)	Value	Description
7	0	Normal operation for Port H.
	1	Override Port H operation (FIM A or FIM B controls the port).
6	0	Normal operation for Port G.
	1	Override Port G operation (FIM A or FIM B controls the port).
5	0	Normal operation for Port F.
	1	Override Port F operation (FIM A or FIM B controls the port).
4	0	Normal operation for Port E.
	1	Override Port E operation (FIM A or FIM B controls the port).
3	0	Normal operation for Port D.
	1	Override Port D operation (FIM A or FIM B controls the port).
2	0	Normal operation for Port C.
	1	Override Port C operation (FIM A or FIM B controls the port).
1	0	Normal operation for Port B.
	1	Override Port B operation (FIM A or FIM B controls the port).
0	0	Normal operation for Port A.
	1	Override Port A operation (FIM A or FIM B controls the port).

34. ERROR CHECK AND CORRECTION

34.1 Overview

The Rabbit 6000 contains a hardware-assist Error Check and Correction (ECC) peripheral to aid in generating and checking various check codes. It consists of a 32-bit counter and the required circuitry for the operations listed in Table 34-1.

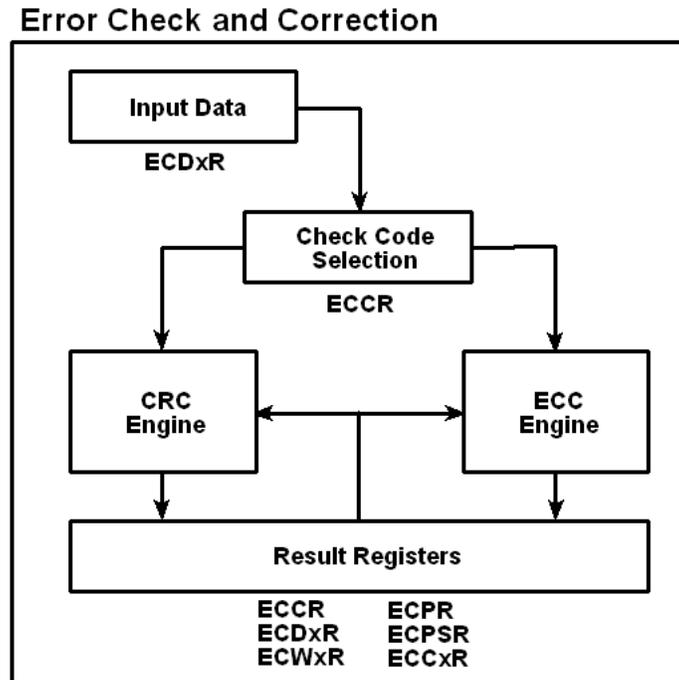
Table 34-1. Rabbit 6000 Error Check Operations

Operation	Commonly Used For
Hamming Error Check and Correction (ECC)	NAND flash error detection and correction
CRC-32	IEEE 802.3 (Ethernet, Wi-Fi), MPEG-2
CRC-16 IBM	USB
CRC-16 CCITT	802.15.4, Bluetooth, PPP, IrDA, SecureDigital
CRC-15	CAN

Data can be written 32 bits at a time, and the resulting counter value can be read out at any point. Both the line and column parity values are available for ECC, allowing for 1-bit error correction and 2-bit error detection. Data can be read in both normal or reverse bit order.

The ECC peripheral is designed for use with the DMA.

34.1.1 Block Diagram



34.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
ECC Data 0 Register	ECD0R	0x05C0	R/W	00000000
ECC Data 1 Register	ECD1R	0x05C1	R/W	00000000
ECC Data 2 Register	ECD2R	0x05C2	R/W	00000000
ECC Data 3 Register	ECD3R	0x05C3	R/W	00000000
ECC Control Register	ECCR	0x05C4	R/W	00000000
ECC CP Read Register	ECPR	0x05C4	R/W	00000000
ECC CP Read Shifted Register	ECPSR	0x05C6	R/W	00000000
ECC Write 0 Register	ECW0R	0x05C7	R/W	00000000
ECC Write 1 Register	ECW1R	0x05C8	R/W	00000000
ECC Write 2 Register	ECW2R	0x05C9	R/W	00000000
ECC Write 3 Register	ECW3R	0x05CA	R/W	00000000
ECC Count 0 Register	ECC0R	0x05CB	R/W	00000000
ECC Count 1 Register	ECC1R	0x05CC	R/W	00000000

34.2 Dependencies

34.2.1 I/O Pins

There are no I/O pins associated with the Error Check and Correction peripheral.

34.2.2 Clocks

There are no clocks associated with the Error Check and Correction peripheral.

34.2.3 Other Registers

There are no other registers associated with the Error Check and Correction peripheral.

34.3 Operation

Before starting an operation, clear the internal counter by writing a 0 and then a 1 to bit 7 of ECCR. The internal counter will not be cleared until this is done.

34.3.1 ECC

The following steps must be taken to perform Error Check and Correction calculations.

1. Enable the ECC peripheral and select the Error Check and Correction peripheral by writing to ECCR. Select the initial value and read data direction if desired.
2. If desired, the initial state of the line parity bits can be set by writing to ECWxR, and the column parity bits by writing to ECPR or ECPSR.
3. Start writing data to ECDxR.
4. When all data have been written for that block, read the line parity bit values from ECDxR for normal bit order, or ECWxR for reverse bit order. Read the column parity bit values from ECPR or ECPSR.

34.3.2 CRC

The following steps must be taken to perform a CRC calculation.

1. Enable the Error Check and Correction peripheral and select the desired CRC operation by writing to ECCR. Select the initial value and read data direction if desired.
2. If desired, the initial state of the CRC counter can be set by writing to ECWxR.
3. Start writing data to ECDxR.
4. When all data have been written for that block, read the CRC counter from ECDxR for normal bit order, or ECWxR for reverse bit order.

34.4 Register Descriptions

ECC Data 0 Register		(ECD0R)	(Address = 0x05C0)
Bit(s)	Value	Description	
7:0	Read	LP/CRC bits 7–0.	
	Write	Data byte for ECC/CRC calculation.	

ECC Data 1 Register		(ECD1R)	(Address = 0x05C1)
Bit(s)	Value	Description	
7:0	Read	LP/CRC bits 15–8.	
	Write	Data byte for ECC/CRC calculation.	

ECC Data 2 Register		(ECD2R)	(Address = 0x05C2)
Bit(s)	Value	Description	
7:0	Read	LP/CRC bits 23–16.	
	Write	Data byte for ECC/CRC calculation.	

ECC Data 3 Register		(ECD3R)	(Address = 0x05C3)
Bit(s)	Value	Description	
7:0	Read	LP/CRC bits 31–24.	
	Write	Data byte for ECC/CRC calculation.	

ECC Control Register (ECCR) (Address = 0x05C4)		
Bit(s)	Value	Description
7	0	Disable (and initialize) ECC/CRC
	1	Enable ECC/CRC.
6	0	Read data not inverted.
	1	Read data inverted.
5	0	Initial value is all zeros.
	1	Initial value is all ones.
4:3		These bits are reserved and must be written as zero. Reads return zero.
2:0	000	ECC, 256 to 64 KB blocks.
	001	CRC-32 (IEEE 802).
	010	CRC-16 IBM (USB).
	011	CRC-16 CCITT.
	100	CRC-15 CAN.
	101	This bit combination is reserved and should not be used.
	110	This bit combination is reserved and should not be used.
	111	This bit combination is reserved and should not be used.

ECC CP Read Register (ECPR) (Address = 0x05C5)		
Bit(s)	Value	Description
7:6		These bits are reserved and should be written with zeros.
7:0	Read	{00, CP value}.
	Write	{00, CP set value}

ECC CP Read Shifted Register (ECPSR) (Address = 0x05C6)		
Bit(s)	Value	Description
7:0	Read	{CP value, 00}.
	Write	{00, CP set value}.

ECC Write 0 Register (ECW0R) (Address = 0x05C7)		
Bit(s)	Value	Description
7:0	Read	LP/CRC bits 24–31 (used for reverse bit order cases).
	Write	Set the state of LP/CRC bits 7–0.

ECC Write 1 Register (ECW1R) (Address = 0x05C8)		
Bit(s)	Value	Description
7:0	Read	LP/CRC bits 16–23 (used for reverse bit order cases).
	Write	Set the state of LP/CRC bits 15–8.

ECC Write 2 Register (ECW2R) (Address = 0x05C9)		
Bit(s)	Value	Description
7:0	Read	LP/CRC bits 8–15 (used for reverse bit order cases).
	Write	Set the state of LP/CRC bits 23–16.

ECC Write 3 Register (ECW3R) (Address = 0x05CA)		
Bit(s)	Value	Description
7:0	Read	LP/CRC bits 0–7 (used for reverse bit order cases).
	Write	Set the state of LP/CRC bits 31–24.

ECC Count 0 Register (ECC0R) (Address = 0x05CB)		
Bit(s)	Value	Description
7:0	Read	Returns bits 7–0 of the ECC counter.
	Write	Set bits 7–0 of the ECC counter.

ECC Count 1 Register (ECC1R) (Address = 0x05CC)		
Bit(s)	Value	Description
7:0	Read	Returns bits 15–8 of the ECC counter.
	Write	Set bits 15–8 of the ECC counter.

35. I²C PERIPHERAL (SERIAL PORT G)

35.1 Overview

Serial Port G in the Rabbit 6000 is a fully featured I²C peripheral. It supports the following features of the Phillips I²C standard:

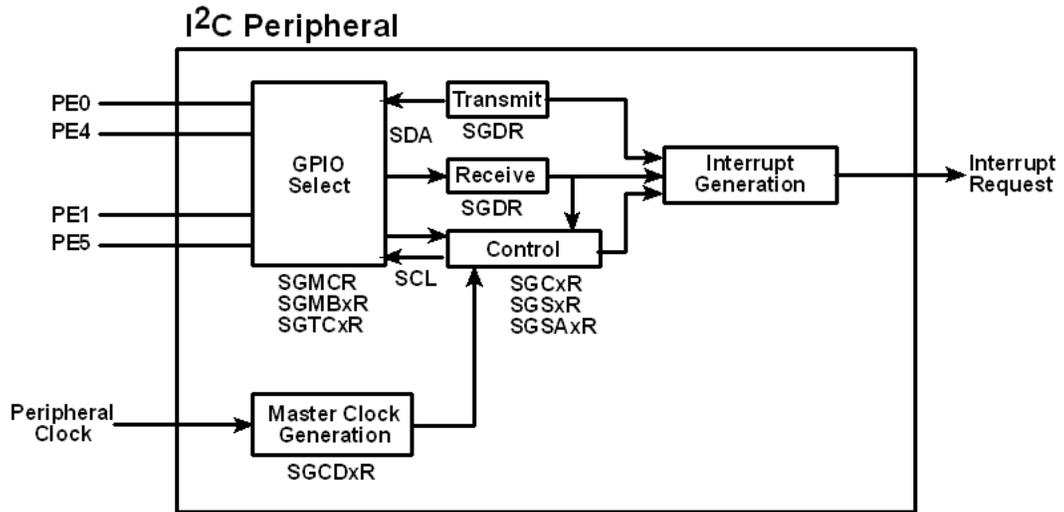
- Master or slave mode
- Standard (100 kbit/s) and fast (400 kbit/s) clock modes
- 7-bit, 10-bit, and general call addressing modes
- Programmable slave address
- Master-transmit, master-receive, slave-transmit, and slave-receive modes
- Multi-master mode
- General-call address detection in slave mode

The I²C peripheral does not support the high-speed (3.4 Mbit/s) mode.

The I²C peripheral contains additional glitch-suppression circuitry to further improve noise rejection. It can generate an interrupt on a variety of master and slave mode conditions.

The interface to the I²C peripheral is actually a 32-bit interface, so some special handling is required for all the registers, except SGDR and SGMCR. See Section 35.3 for more details.

35.1.1 Block Diagram



35.1.2 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Serial Port G Control Registers	SGC0R	0x0580	R/W	00000000
	SGC1R	0x0581		00000000
	SGC2R	0x0582		00000000
	SGC3R	0x0583		00000000
Serial Port G Status Registers	SGS0R	0x0584	R/W	00000000
	SGS1R	0x0585		00000000
	SGS2R	0x0586		00000000
	SGS3R	0x0587		00000000
Serial Port G Clock Divider Registers	SGCD0R	0x0588	R/W	00000000
	SGCD1R	0x0589		00000000
	SGCD2R	0x058A		00000000
	SGCD3R	0x058B		00000000
Serial Port G Data Register	SGDR	0x058C	R/W	00000000
Serial Port G Slave Address Registers	SGSA0R	0x0590	R/W	00000000
	SGSA1R	0x0591		00000000
	SGSA2R	0x0592		00000000
	SGSA3R	0x0593		00000000
Serial Port G Timing Control Registers	SGTC0R	0x0594	R/W	00000001
	SGTC1R	0x0595		00000100
	SGTC2R	0x0596		00000000
	SGTC3R	0x0597		00000000
Serial Port G Bus Monitor Registers	SGSBM0R	0x0598	R	00000011
	SGSBM1R	0x0599		00000000
	SGSBM2R	0x059A		00000000
	SGSBM3R	0x059B		00000000
Serial Port G Main Control Register	SGMCR	0x059F	R/W	00000000

35.2 Dependencies

35.2.1 I/O Pins

The I²C peripheral can transmit and receive data on parallel port pins E0 or E4, and can transmit a clock on E1 or E5. These options are selected in SGMCR.

Table 35-1. Pin Usage I²C

Function	Parallel Port Pin Options
Data (SDA)	PE0, PE4
Clock (SCL)	PE1, PE5

The glitch filtering built in to the I²C peripheral does not meet the 50 ns requirement at system clocks over 140 MHz. When using clock speeds above 140 MHz, it is recommended to add a ferrite bead rated at 1000 Ω at 100 MHz to both the SCL and SDA lines to provide additional glitch filtering. See Texas Instruments Application Report SLEA053 for more information.

35.2.2 Clocks

In the master mode, the data clock for the I²C peripheral is based on the peripheral clock and is divided by the 16-bit divider in SGCDxR. In the slave mode, the external master provides the clock.

35.2.3 Other Registers

Register	Function
PEFR, PEAHR, PEALR	Alternate port output selection

35.2.4 Interrupts

An I²C interrupt can be generated whenever one of the following occurs.

- Start condition detected
- Stop condition detected
- Slave address match or general call
- Byte received
- Byte transmitted
- Arbitration lost (master mode)
- non-ACK response (master mode)

The interrupt selection is in SGC1R.

The I²C interrupt vector is located in the IIR at offset 0x150. It can be set as Priority 1, 2, or 3 in SGMCR.

35.3 Operation

35.3.1 32-bit Interface

The I²C peripheral is actually a 32-bit interface, so special handling is required when reading or writing all registers other than SGDR and SGMCR.

When writing a 32-bit register, the value is written to the peripheral only when the most-significant byte (uppermost) is written. The three lower bytes will be buffered until that final write occurs. For proper operation, all four bytes in the 32-byte register should be written every time a change to a bit is required.

When reading a 32-bit register, the read of the least-significant (lowest) byte will latch the peripheral's register value for all four bytes. Those values will remain until the next read of the lowest byte, so to avoid stale data all four bytes should be read whenever a 32-bit register is accessed.

35.3.2 Interrupts

To enable interrupts for the I²C peripheral, the following steps should be taken before performing any other actions.

1. Write the vector to the interrupt service routine to the internal interrupt table.
2. Configure SGMCR to select the I²C interrupt priority and SGC1R to select which interrupts will occur.

In the interrupt service routine, read SGC1R to identify the reason for interrupt and clear the pending status.

All of the sequences below can be used as interrupt-driven routines as well by replacing the polling steps with responses to interrupts.

35.3.3 Master Mode, Data Write

To write data in master mode, perform the following operations.

1. Set the clock speed by writing to SGCDxR.
2. Set the target slave address and R/W bit by writing to SGDR.
3. Set the master mode and enable the controller by setting bits 1 and 2 of SGC0R.
4. Send the first byte by setting bits 4 and 7 of SGC0R. This can be combined with the previous operation.
5. Monitor bit 4 of SGSxR to determine when the byte has been sent.
6. Send the next byte by clearing bit 4 and setting bit 7 of SGC0R. If this is the final byte to be sent, set bit 5 as well to follow it with a Stop condition.
7. Monitor bit 4 of SGSxR to determine when the byte has been sent.
8. Repeat Steps 6–8 until all data have been sent.

To start communicating with a new slave, restart at Step 2.

35.3.4 Master Mode, Data Read

To read data in master mode, perform the following operations.

1. Set the clock speed by writing to SGCDxR.
2. Set the target slave address and R/W bit by writing to SGSAxR.
3. Set the master mode and enable the controller by setting bits 1 and 2 of SGC0R.
4. Send the first byte by setting bits 4 and 7 of SGC0R. This can be combined with the previous operation.
5. Monitor bit 4 of SGSxR to determine when the byte has been sent. Bit 0 should be high as well.
6. Load the next (data) byte into SGCDxR.
7. Receive the first data byte by clearing bit 4 and setting bit 7 of SGC0R. If this is the final byte, set bit 5 as well to follow it with a Stop condition.
8. Monitor bit 4 of SGSxR to determine when byte has been received. Bit 1 will also be set if this is the final byte.
9. Read SGDR to get the data.
10. Repeat Steps 6–8 until all data have been received.

To start communicating with a new slave, restart at Step 2.

35.3.5 Slave Mode, Data Write

To write data in slave mode, perform the following operations.

1. Set the slave address by writing to SGSAxR.
2. Set slave mode by clearing bit 2 and enable the controller by setting bit 1 of SGC0R.
3. Monitor bits 5 and 8 of SGSxR to determine when byte has been received for the correct slave address. Bits 1 and 2 should also be set, and bit 0 clear.
4. Load the byte to be sent into SGDR and send it by setting bit 7 of SGC0R.
5. Monitor bit 4 of SGSxR to determine when byte has been sent. Bit 0 should also be set.
6. If bits 1 or 7 of SGSxR are set, then an ACK or STOP condition occurred and the slave can go back to step 1. If not, it should go back to step 5 to send the next byte.

35.3.6 Slave Mode, Data Read

To read data in slave mode, perform the following operations.

1. Set the slave address by writing to SGSAxR.
2. Set slave mode by clearing bit 2 and enable the controller by setting bit 1 of SGC0R.
3. Monitor bits 5 and 8 of SGSxR to determine when byte has been received for the correct slave address. Bit 2 should also be set, and bits 0 and 1 clear.
4. Set bit 7 of SGC0R to start byte read. Also set bit 6 if this is the final byte to be read.
5. Monitor bit 5 of SGSxR to determine when the byte has been received.
6. Read the data byte from SGDR.
7. If bits 1 or 7 of SGSxR are set, then an ACK or STOP condition occurred and the slave can go back to Step 1. If not, it should go back to Step 4 to receive the next byte.

35.4 Register Descriptions

Serial Port G Control 0 Register (SGC0R) (Address = 0x0580)		
Bit(s)	Value	Description
7	0	Insert wait states on the I ² C bus by pulling SCL low.
	1	Ready to receive or transmit one byte. This bit is automatically cleared after one byte is received or transmitted or when a start or stop condition is detected.
6	0	Send ACK when in master-receive or slave-receive mode.
	1	Send NACK when in master-receive or slave-receive mode.
5	0	No effect.
	1	Initiate a stop condition after transferring the next data byte on the I ² C bus (master mode only).
4	0	No effect.
	1	Initiate a start condition when the I ² C bus is idle, or a repeated start condition after transferring the next data byte on the I ² C bus (master mode only).
3	0	No response to a general call.
	1	Enable response to a general call (slave mode only).
2	0	Slave mode operation (I ² C controller clock is an input).
	1	Master mode operation (I ² C controller clock is an output).
1	0	Disable the I ² C controller.
	1	Enable the I ² C controller.
0	0	No effect.
	1	Reset the I ² C controller. This bit is automatically cleared after two clock cycles.

Serial Port G Control 1 Register (SGC1R) (Address = 0x0581)		
Bit(s)	Value	Description
7	0	No effect.
	1	Force SCL low. This is not used in normal operation.
6	0	No interrupt when a start condition is detected.
	1	Enable interrupt when a start condition is detected.
5	0	No interrupt when arbitration is lost.
	1	Enable interrupt when arbitration is lost (master mode).
4	0	No interrupt on slave address match or general call (if enabled).
	1	Enable interrupt on slave address match or general call (if enabled).
3	0	No interrupt when a stop condition is detected.
	1	Enable interrupt when a stop condition is detected.
2	0	No interrupt on non-ACK response.
	1	Enable interrupt on non-ACK response from slave after transmit byte complete (master mode).
1	0	No interrupt on receive byte complete.
	1	Enable interrupt on receive byte complete.
0	0	No interrupt on transmit byte complete.
	1	Enable interrupt on transmit byte complete.

Serial Port G Control 2 Register (SGC2R) (Address = 0x0582)		
Bit(s)	Value	Description
7:1		These bits are reserved and should always be written as zeros.
0	0	No effect.
	1	Force SDA low. This is not used in normal operation.

Serial Port G Control 3 Register (SGC3R) (Address = 0x0583)		
Bit(s)	Value	Description
7:0		These bits are reserved and should always be written as zeros.

Serial Port G Status 0 Register (SGS0R) (Address = 0x0584)		
Bit(s)	Value	Description
7 (Read-only)	0	No stop condition detected.
	1	Stop condition detected. This bit is cleared by the read of this register.
6 (Read-only)	0	No non-ACK response detected.
	1	Non-ACK response from the slave device after transmitting a byte (master mode). This bit is cleared by the read of this register.
5 (Read-only)	0	No byte received.
	1	Byte has been received. This bit is cleared by the read of this register.
4 (Read-only)	0	No byte transmitted.
	1	Byte has been transmitted. This bit is cleared by the read of this register.
3 (Read-only)	0	The I ² C bus is not busy.
	1	The I ² C bus is busy, but the controller is not involved in the transfer.
2 (Read-only)	0	Controller is not busy.
	1	Controller is busy, that is between start and stop.
1 (Read-only)	0	Controller has not received or sent a non-ACK.
	1	Controller has received or sent a non-ACK.
0 (Read-only)	0	Controller is not in master-receive or slave-transmit mode.
	1	Controller is in master-receive or slave-transmit mode.

Serial Port G Status 1 Register		(SGS1R)	(Address = 0x0585)
Bit(s)	Value	Description	
7:4		These bits are reserved and will always return zeros.	
3 (Read-only)	0	No start condition detected on the I ² C bus.	
	1	Start condition detected on the I ² C bus. While the underlying status bit is cleared by the read of SGS0R, the bit latched in the interface remains set until the next read of SGS0R.	
2 (Read-only)	0	No lost arbitration.	
	1	Lost arbitration (master mode). While the underlying status bit is cleared by the read of SGS0R, the bit latched in the interface remains set until the next read of SGS0R.	
1 (Read-only)	0	No general call address match.	
	1	General call address match (slave mode). While the underlying status bit is cleared by the read of SGS0R, the bit latched in the interface remains set until the next read of SGS0R.	
0 (Read-only)	0	No slave address match.	
	1	Slave address match (slave mode). While the underlying status bit is cleared by the read of SGS0R, the bit latched in the interface remains set until the next read of SGS0R.	

Serial Port G Status 2 Register		(SGS2R)	(Address = 0x0586)
Bit(s)	Value	Description	
7:0		These bits are reserved and will always return zeros.	

Serial Port G Status 3 Register		(SGS3R)	(Address = 0x0587)
Bit(s)	Value	Description	
7:0		These bits are reserved and will always return zeros.	

Serial Port G Clock Division 0 Register		(SGCD0R)	(Address = 0x0588)
Bit(s)	Value	Description	
7:0		Bits 7–0 of the divider that generates the I ² C clock on SCL).	

Serial Port G Clock Division 1 Register (SGCD1R) (Address = 0x0589)		
Bit(s)	Value	Description
7:0		Bits 15–8 of the divider that generates the I ² C clock on SCL).

Serial Port G Clock Division 2 Register (SGCD2R) (Address = 0x058A)		
Bit(s)	Value	Description
7:2		These bits are reserved and should always be written with zeros.
1:0		Bits 17–16 of the divider that generates the I ² C clock (on SCL).

Serial Port G Clock Division 3 Register (SGCD3R) (Address = 0x058B)		
Bit(s)	Value	Description
7:0		These bits are reserved and should always be written with zeros.

Serial Port G Data Register (SGDR) (Address = 0x058C)		
Bit(s)	Value	Description
7:0	Read	Returns the byte received from the I ² C bus.
	Write	Data byte for transmission on the I ² C bus.

Serial Port G Slave Address 0 Register (SGSA0R) (Address = 0x0590)		
Bit(s)	Value	Description
7:0		Bits 7–0 of the slave address when operating in the slave mode. In the 7-bit addressing mode only bits 6–0 of this field are used, and bit 7 is ignored.

Serial Port G Slave Address 1 Register (SGSA1R) (Address = 0x0591)		
Bit(s)	Value	Description
7:2		These bits are reserved and should always be written with zeros.
1:0		Bits 9–8 of the slave address when operating in the slave mode. These bits are ignored in the 7-bit addressing mode.

Serial Port G Slave Address 2 Register (SGSA2R) (Address = 0x0592)		
Bit(s)	Value	Description
7:0		These bits are reserved and should always be written with zeros.

Serial Port G Slave Address 3 Register (SGSA3R) (Address = 0x0593)		
Bit(s)	Value	Description
7	0	Use 7-bit addressing (slave mode).
	1	Use 10-bit addressing (slave mode).
6:0		These bits are reserved and should always be written with zeros.

Serial Port G Timing Control 0 Register (SGTC0R) (Address = 0x0594)		
Bit(s)	Value	Description
7:0		Bits 7–0 of the data acknowledgement delay.

Serial Port G Timing Control 1 Register (SGTC1R) (Address = 0x0595)		
Bit(s)	Value	Description
7:5		These bits are reserved and should be written as zeros.
4:2		Glitch suppression delay.
1:0		Bits 9–8 of the data acknowledgement delay.

Serial Port G Timing Control 2 Register (SGTC2R) (Address = 0x0596)		
Bit(s)	Value	Description
7:0		These bits are reserved and should be written as zeros.

Serial Port G Timing Control 3 Register (SGTC3R) (Address = 0x0597)		
Bit(s)	Value	Description
7:0		These bits are reserved and should be written as zeros.

Serial Port G Bus Monitor 0 Register (SGBM0R) (Address = 0x0598)		
Bit(s)	Value	Description
7:2		These bits are reserved and will always return zeros.
1 (Read-only)	0	SCL is low.
	1	SCL is high.
0 (Read-only)	0	SDA is low.
	1	SDA is high.

Serial Port G Bus Monitor 1 Register (SGBM1R) (Address = 0x0599)		
Bit(s)	Value	Description
7:0		These bits are reserved and should be written as zeros.

Serial Port G Bus Monitor 2 Register (SGBM2R) (Address = 0x059A)		
Bit(s)	Value	Description
7:0		These bits are reserved and should be written as zeros.

Serial Port G Bus Monitor 3 Register (SGBM3R) (Address = 0x059B)		
Bit(s)	Value	Description
7:0		These bits are reserved and should be written as zeros.

Serial Port G Main Control Register (SGMCR) (Address = 0x059F)		
Bit(s)	Value	Description
7:4		These bits are reserved and should be written with zeros. Reads return zeros.
3	0	Parallel Port PE1 is used for SCL.
	1	Parallel Port PE5 is used for SCL.
2	0	Parallel Port PE0 is used for SDA.
	1	Parallel Port PE4 is used for SDA.
1:0	00	The serial port interrupt is disabled.
	01	The serial port uses interrupt priority 1.
	10	The serial port uses interrupt priority 2.
	11	The serial port uses interrupt priority 3.

36. LOW-POWER OPERATION

36.1 Overview

The Rabbit 6000 contains several power-saving features. Since the power consumed by the processor is proportional to the clock speed, the Rabbit 6000 provides 12 clock modes that can go as low as 2 kHz. To further reduce power consumption in those ultra-sleepy modes, various shortened chip select strobes are available to reduce current draw by the attached memory devices.

Figure 36-1 shows a typical current draw as a function of the main clock frequency when all of the network ports and analog functions are disabled. The values shown do not include any current consumed by external oscillators or memory. It is assumed that approximately 30 pF is connected to each address line.

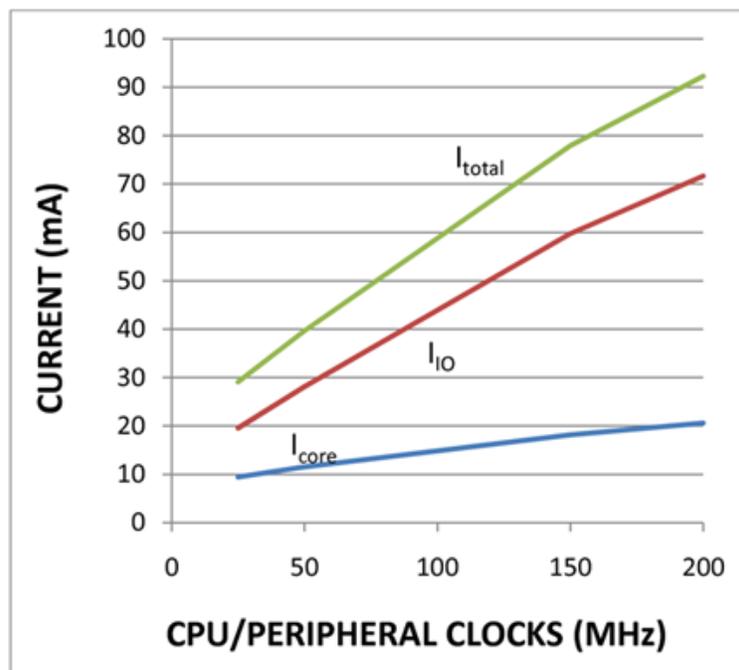


Figure 36-1. Typical Current Draw as a Function of the Main Clock Frequency

The typical current draw in the ultra-sleepy modes is 5 mA for I_{CORE} and 6 mA for I_{IO} , depending on the pin activity.

36.1.1 Registers

Register Name	Mnemonic	I/O Address	R/W	Reset
Global Control/Status Register	GCSR	0x0000	R/W	11000000
Global Power Save Control Register	GPSCR	0x000D	R/W	00000000
Global Clock Double Register	GCDR	0x000F	R/W	00000000

36.2 Operation

36.2.1 Unused Pins

Input (or bidirectional) pins that are unused in a design can pick up noise that may cause the transistors in the input buffer to switch states quickly, causing unnecessary current draw and in the worst case possibly damaging the processor. To avoid this, all unused pins should be connected to a weak pullup or pulldown resistor (approximately 100 k Ω) and left as inputs. This provides protection from noise when the pin is an input, but also limits the current draw if the pin gets inadvertently enabled as an output.

Note that the parallel port pins can all be configured with internal pullup/pulldown resistors. External components are not required if these internal resistors are enabled at startup.

36.2.2 Unused Peripherals

All peripherals in the Rabbit 6000 use gated clocks, which disable the clock input to a peripheral whenever it is not enabled for use. Disabling any peripherals not being used will help reduce power. The A/D converter and D/A converter peripherals have sleep modes that can be enabled when they should remain active but are not being directly used.

The Ethernet and Wi-Fi peripherals in particular can draw a significant amount of current when powered, as shown in Table 36-1. Exercise care that they are only enabled when being used.

Table 36-1. Current Draw by Selected Rabbit 6000 Peripherals

Peripheral	Typical Additional Current
Ethernet	13 mA @ 1.2 V 196 mA @ 3.3 V
Wi-Fi	54 mA @ 1.2 V 9 mA @ 3.3 V

36.2.3 Clock Rates

The processor and peripheral clocks in the Rabbit 6000 can be run in six different modes using the main oscillator or the main PLL: full speed; divided by 2, 4, 6, or 8; and the processor clock divided by 8 with the peripheral clock at full speed. If the clock doubler is enabled, the options also include twice the main oscillator frequency and the main oscillator divided by 3.

In addition, the 32 kHz clock can be used for the processor and peripheral clocks; the 32 kHz clock can also be divided by 2, 4, 8, or 16, which provides dramatically lower power consumption.

Table 36-2 lists the options for the clock modes and the processor clock frequency.

Table 36-2. Clock Modes

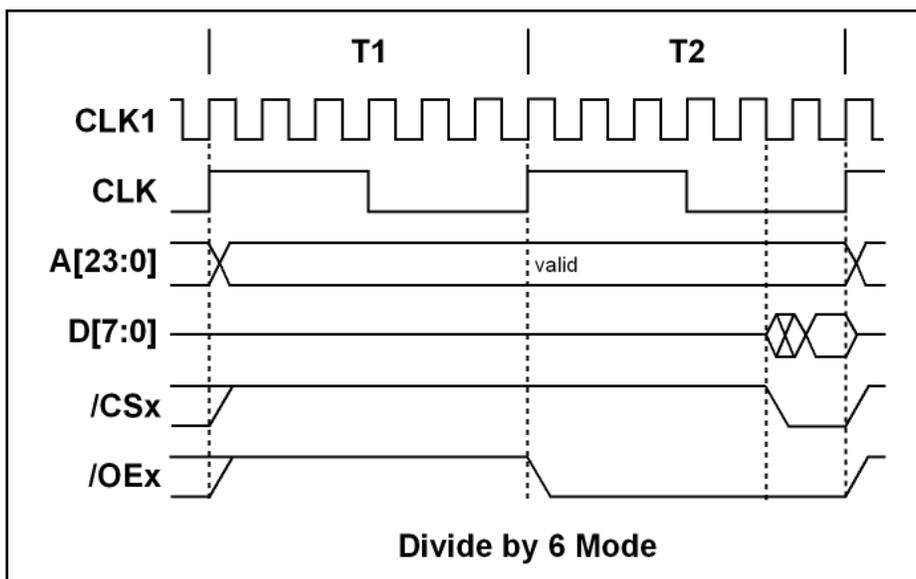
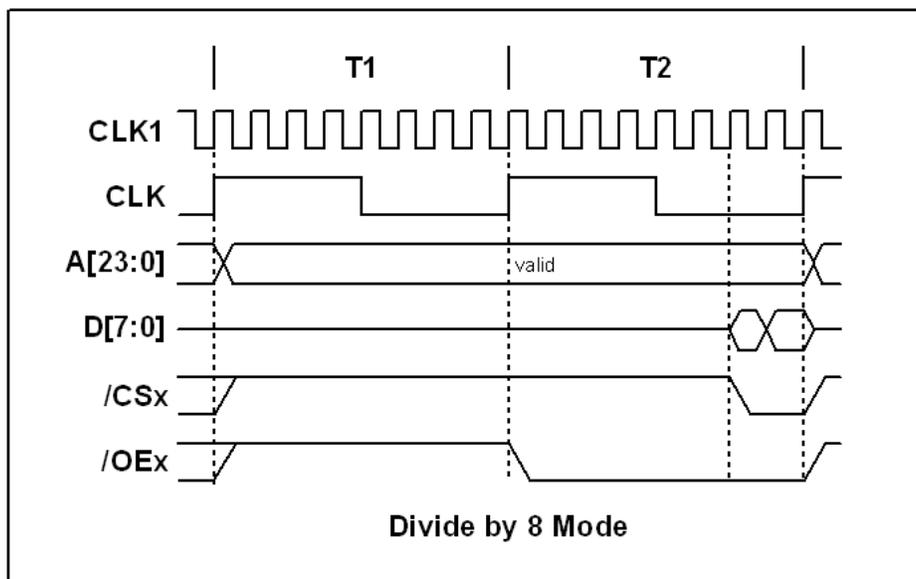
Main Oscillator GCSR Setting	Clock Doubler	32 kHz Divider	Processor Clock Frequency
Full	On	N/A	$2 \times$ Input frequency (main oscillator or PLL)
Full	Off		Input frequency
Divided by 2	On		Input frequency / 2
Divided by 2	Off		Input frequency / 3
Divided by 4	On		Input frequency / 4
Divided by 6	On		Input frequency / 6
Divided by 4	Off		Input frequency / 8
Divided by 8	On		
Divided by 6	Off		
Divided by 8	Off		
Off (32 kHz divider used)	N/A	Disabled	32.768 kHz
		/ 2	16.384 kHz
		/ 4	8.192 kHz
		/ 8	4.096 kHz
		/ 16	2.048 kHz

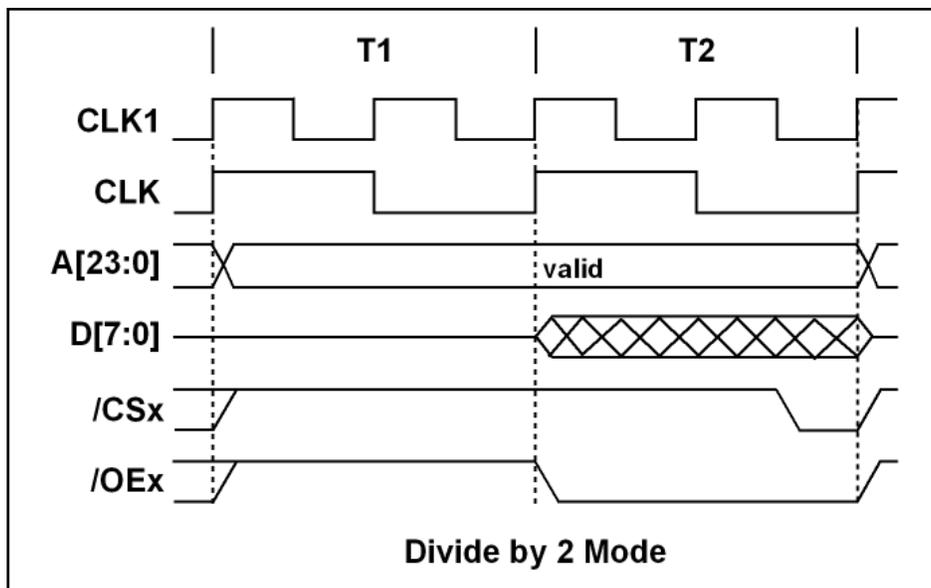
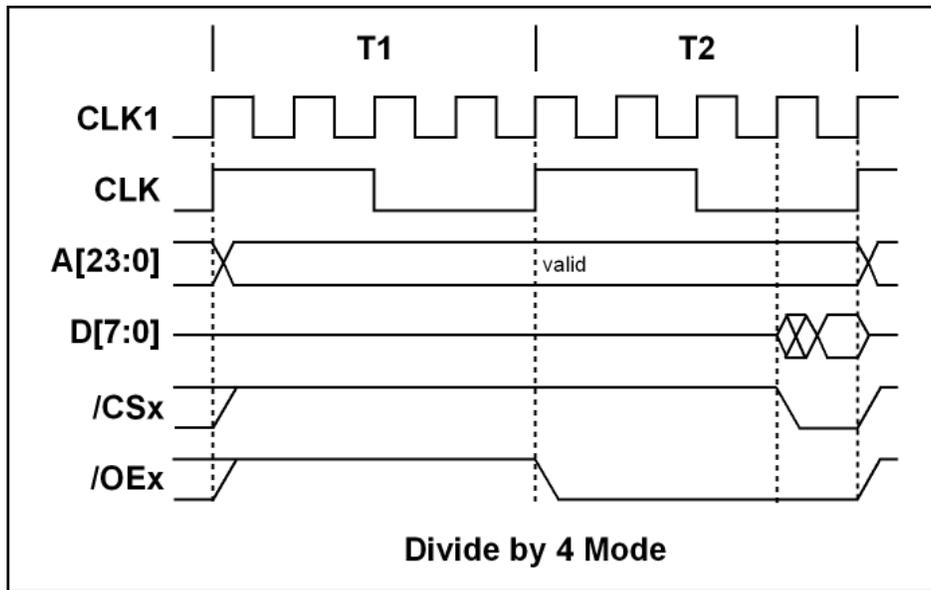
Depending on the application, the processor can continue executing code normally when the main oscillator is divided down to a lower value. However, when the processor clock is running off the 32 kHz clock, the code and data contents of the 1MB RAM will not be preserved. The lowest frequency for the processor clock that will preserve the contents of the 1MB RAM is 12MHz. It is recommended that in that situation the Rabbit 6000 be performing a tight polling loop in another memory device, either SRAM or external parallel flash, waiting for a wake-up event.

36.2.4 Short Chip Selects

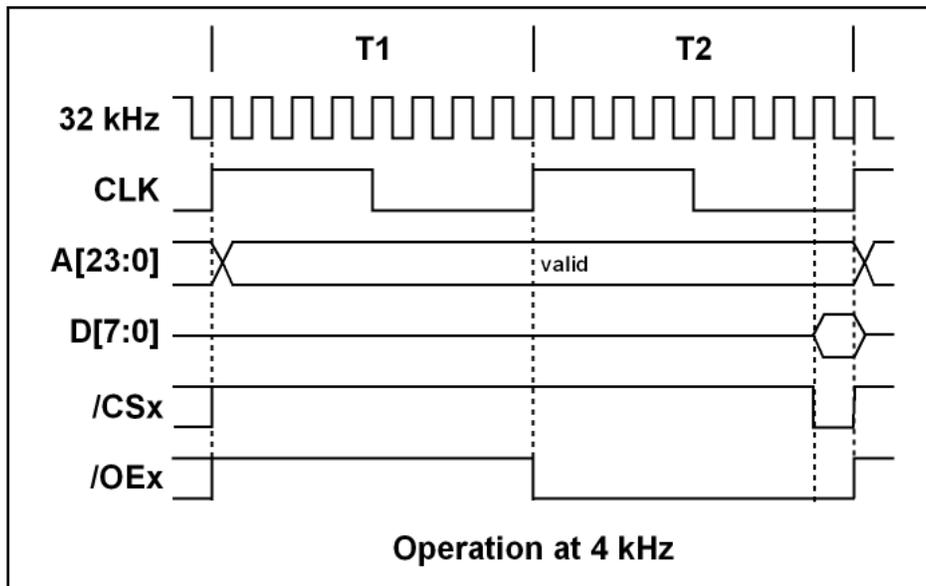
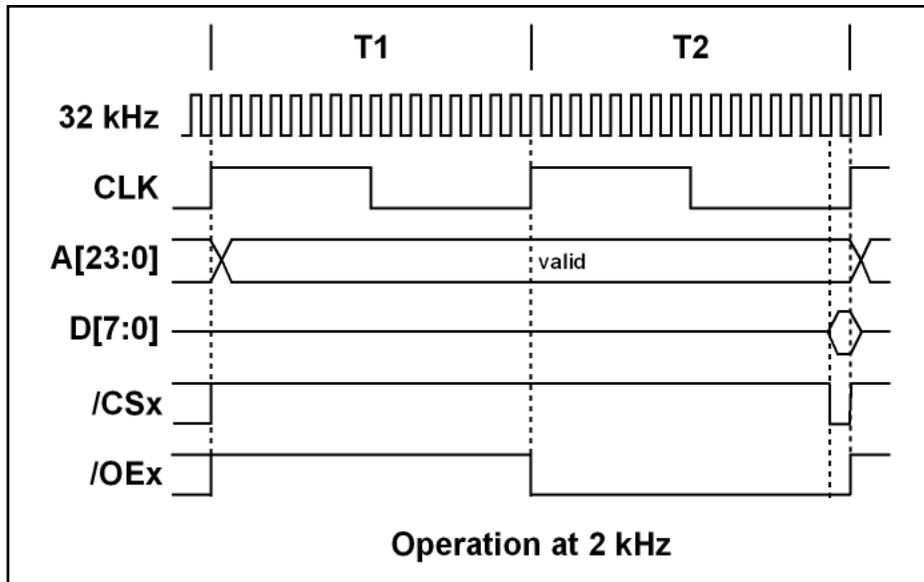
When running at a reduced clock speed, it is likely that the chip selects for external devices will not need to be active for an entire clock cycle. By reducing the width of the chip select, the power consumption of the memory chip can be reduced without having any affect on the processor itself.

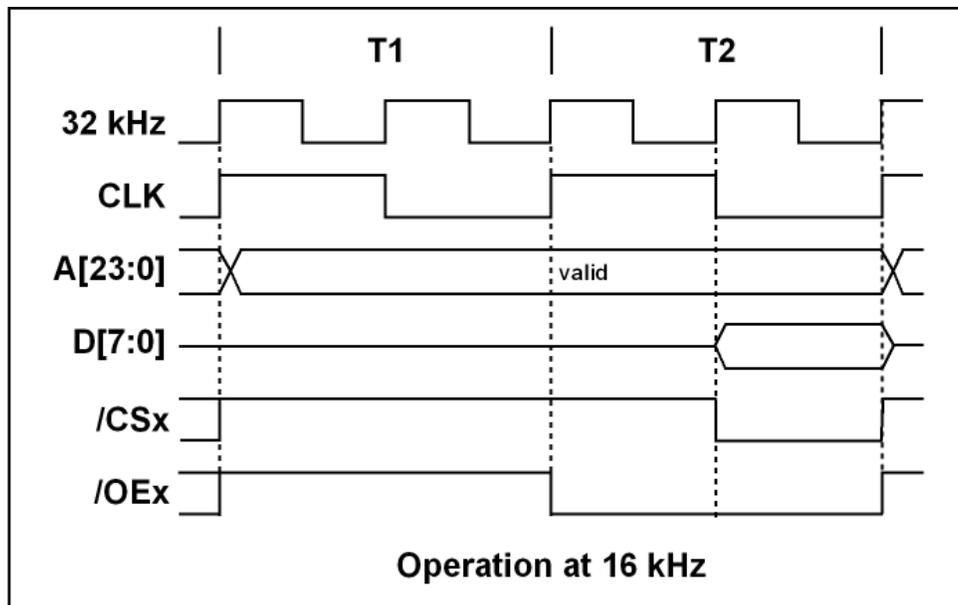
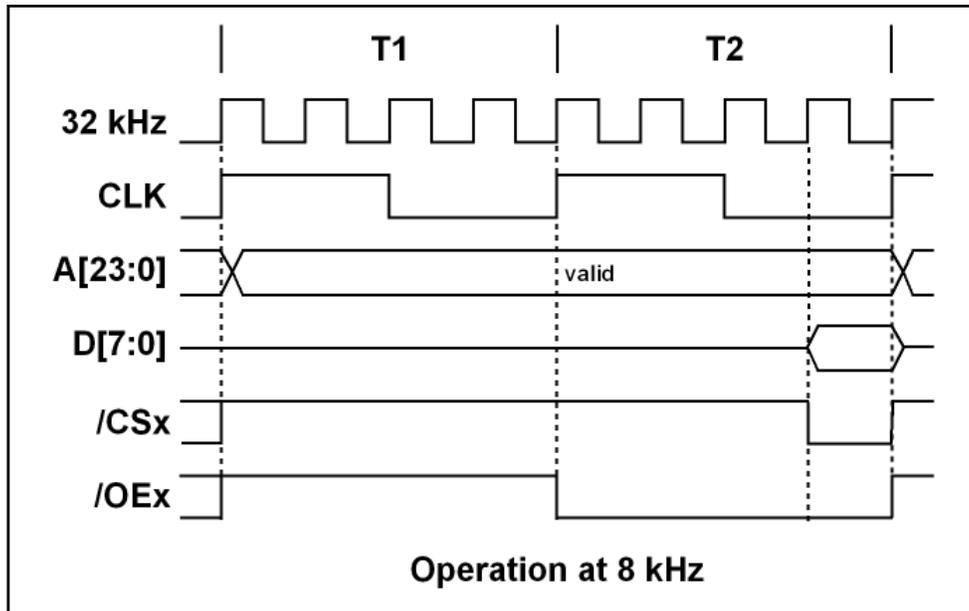
For reduced processor speeds based on the main oscillator, a short chip select can be enabled in GPSCR (this feature is not available when the processor is running at full speed). This feature can be enabled separately for both reads and writes. When enabled, the chip select signals will be the width of two undivided clocks and located at the end of the transaction. The read data in the figures below is sampled by the rising edge of CLKI that terminated the T2 cycle. Wait states are inserted between T1 and T2 so they do not affect the width of the strobe.

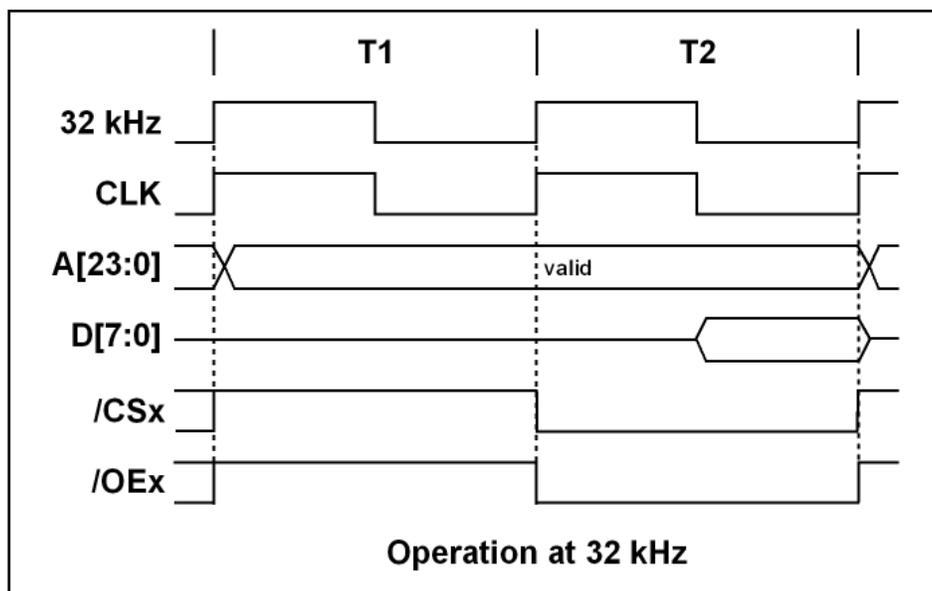




When the processor is running off the 32 kHz clock, the short chip select option will produce chip select signal that is the width of a single 32 kHz clock (30.5 μ s); otherwise the timing is identical to the short chip select options based off the main oscillator. Read strobe figures are shown below.

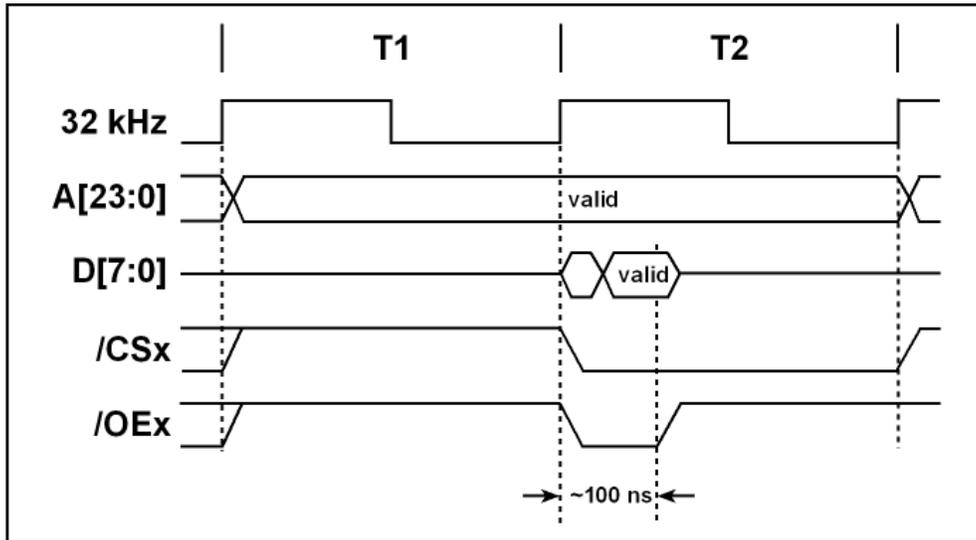






36.2.5 Self-Timed Chip Selects

Self-timed chip selects can be enabled via GPSCR to reduce power consumption even more when running off the 32 kHz oscillator. When self-timed chip selects are enabled, the chip select is only active for a short (selectable) period of time ranging from 165 to 345 nS; this can be enabled for both reads and writes, or reads only. A sample read and write timing diagram is shown below.



36.3 Register Descriptions

Global Control/Status Register (GCSR) (Address = 0x0000)		
Bit(s)	Value	Description
7:6 (Read-only)	00	No reset or watchdog timer timeout since the last read.
	01	The watchdog timer timed out. These bits are cleared by a read of this register.
	10	This bit combination is not possible.
	11	Reset occurred. These bits are cleared by a read of this register.
5 4:2	0	No effect on the periodic interrupt. This bit will always be read as zero.
	1	Force a periodic interrupt to be pending.
	000	Processor clock from the fast clock, divided by 8. Peripheral clock from the fast clock, divided by 8.
	001	Processor clock from the fast clock, divided by 8. Peripheral clock from the fast clock.
	010	Processor clock from the fast clock. Peripheral clock from the fast clock.
	011	Processor clock from the fast clock, divided by 2. Peripheral clock from the fast clock, divided by 2.
	100	Processor clock from the 32 kHz clock, optionally divided via GPSCR. Peripheral clock from the 32 kHz clock, optionally divided via GPSCR.
	101	Processor clock from the 32 kHz clock, optionally divided via GPSCR. Peripheral clock from the 32 kHz clock, optionally divided via GPSCR. The fast clock is disabled.
	110	Processor clock from the fast clock, divided by 4. Peripheral clock from the fast clock, divided by 4.
	111	Processor clock from the fast clock, divided by 6. Peripheral clock from the fast clock, divided by 6.
1:0	00	Periodic interrupts are disabled.
	01	Periodic interrupts use Interrupt Priority 1.
	10	Periodic interrupts use Interrupt Priority 2.
	11	Periodic interrupts use Interrupt Priority 3.

Global Power Save Control Register (GPSCR) (Address = 0x000D)		
Bit(s)	Value	Description
7:5	000	Self-timed chip selects are disabled.
	001	345nS self-timed chip selects for read and write.
	010	255nS self-timed chip selects for read and write.
	011	165nS self-timed chip selects for read and write.
	100	435nS self-timed chip selects for read only.
	101	345nS self-timed chip selects for read only.
	110	255nS self-timed chip selects for read only.
	111	165nS self-timed chip selects for read only.
4	0	Normal Chip Select timing for read cycles.
	1	Short Chip Select timing for read cycles (not available in full speed).
3	0	Normal Chip Select timing for write cycles
	1	Short Chip Select timing for write cycles (not available in full speed).
2:0	000	The 32KHz clock divider is disabled.
	001	This bit combination is reserved and should not be used.
	010	This bit combination is reserved and should not be used.
	011	This bit combination is reserved and should not be used.
	100	32KHz clock divided by two (16.384KHz).
	101	32KHz clock divided by four (8.192KHz).
	110	32KHz clock divided by eight (4.096KHz).
	111	32KHz clock divided by sixteen (2.048KHz).

Global Clock Double Register (GCDR) (Address = 0x000F)		
Bit(s)	Value	Description
7	0	Disable system PLL.
	1	Enable system PLL. Setting this bit does not select the system PLL as the clock source.
6:5		These bits are reserved and should always be written with zeros.
4:0	00000	The clock doubler circuit is disabled.
	00001	9 nS nominal Low time.
	00010	10.5 nS nominal Low time.
	00011	12 nS nominal Low time.
	00100	13.5 nS nominal Low time.
	00101	15 nS nominal Low time.
	00110	16.5 nS nominal Low time.
	00111	18 nS nominal Low time.
	01000	19.5 nS nominal Low time.
	01001	21 ns nominal Low time.
	01010	22.5 ns nominal Low time.
	01011	24 ns nominal Low time.
	01100	25.5 ns nominal Low time.
	01101	27 ns nominal Low time.
	01110	28.5 ns nominal Low time.
	01111	30 ns nominal Low time.
	10001	4.5 nS nominal Low time.
10010	6 nS nominal Low time.	

37. SPECIFICATIONS

37.1 Preliminary DC Characteristics

Table 37-1. DC Electrical Characteristics @VDD = 3.3V

Parameter		Symbol	Min	Typ	Max
Operating Temperature		T_A	-40°C		85°C
Storage Temperature			-55°C		125°C
Core	Core Supply Voltage	$V_{DD_{CORE}}$	1.08 V	1.2 V	1.32 V
	Core Current @ 200 MHz, 25°C Additional current for WiFi, 25°C Additional current for Ethernet, 25°C	I_{CORE}		72 mA +65 mA +75 mA	+115 mA +160 mA
	Core Current @ 32.768 kHz, 25°C			5 mA	
I/O Ring	I/O Ring Supply Voltage, 3.3 V	$V_{DD_{IO}}$	3.0 V	3.3 V	3.6 V
	I/O Current @ 200 MHz, 25°C Additional current for WiFi, 25°C Additional current for Ethernet, 25°C	I_{IO}		21 mA +25 mA +55 mA	+35 mA +60 mA
	I/O Current @ 32.768 kHz, 25°C			6 mA	
	Input Low Voltage	V_{IL}			0.8 V
	Input High Voltage	V_{IH}	2.0 V		
	Output Low Voltage	V_{OL}		0.0 V	0.4 V
	Output High Voltage	V_{OH}	2.4 V	3.3 V	
Output drive: Address and data bus (selectable) /CS1 Other memory strobes (selectable) /IOWR, /IORD, /IOBEN (selectable) All parallel port pins (selectable) CLK, ACK_LED, LED[3:0] All other pins		I_{DRIVE}			4-14 mA 8 mA 4-14 mA 4-14 mA 4-14 mA 16 mA 8 mA

Table 37-2. Battery-Backed DC Electrical Characteristics
(VDD_{CORE} = 1.2V ± 10%, VDD_{IO} = 3.3V ± 10%, T_A = -40°C to 85°C)

	Parameter	Symbol	Min	Typ	Max
VBAT	VBAT Supply Voltage	VBAT	1.08 V	1.2 V	1.32 V
	VBAT Current (rest of device powered) (rest of device powered down)	I _{VBAT}		to be determined	
VBATIO	VBATIO Supply Voltage (rest of device powered) (rest of device powered down)	VBATIO	3.0 V 1.08 V	3.3 V 1.2 V	3.6 V 3.6 V
	VBATIO Current (rest of device powered) (rest of device powered down)	I _{VBATIO}		to be determined	

37.2 AC Characteristics

Table 37-3. AC Electrical Characteristics
 (VDD_{CORE} = 1.2 V ± 10%, VDD_{IO} = 3.3 V ± 10%, T_A = -40°C to 85°C)

Parameter	Symbol	Min	Typ	Max
Main Clock Frequency on CLKI, direct clock	f _{main}	20 MHz		200 MHz
Main Clock Frequency on CLKI, internal oscillator		24 MHz		42 MHz
Main Clock Frequency on CLKI, PLL input		20 MHz	25 MHz	42 MHz
Real-Time Clock Frequency on CLK32K	f _{RTC}		32.768 kHz	
Ethernet Clock Frequency	f _{Eth}	25 MHz ± 100 ppm		
Wi-Fi Clock Frequency	f _{Wi-Fi}	20 MHz ± 100 ppm		
USB Clock Frequency	f _{USB}	48 MHz ± 100 ppm		

37.3 External Memory Access Times

All access time measurements are taken at 50% of signal height.

37.3.1 Memory Reads

Table 37-4. Memory Read Time Delays
($VDD_{CORE} = 1.2\text{ V} \pm 10\%$, $VDD_{IO} = 3.3\text{ V} \pm 10\%$, $T_A = -40^\circ\text{C to }85^\circ\text{C}$)

Parameter	Symbol	Min	Typ	Max
Clock to Address Delay	T_{adr}	3 ns		8 ns
Clock to Memory Chip Select Delay	T_{CSx}	3 ns		6 ns
Clock to Memory Read Strobe Delay	T_{OEx}	3 ns		6 ns
Data Setup Time	T_{setup}		1 ns	
Data Hold Time	T_{hold}		0 ns	

37.3.2 Memory Writes

Table 37-5. Memory Write-Time Delays
($VDD_{CORE} = 1.2\text{ V} \pm 10\%$, $VDD_{IO} = 3.3\text{ V} \pm 10\%$, $T_A = -40^\circ\text{C to }85^\circ\text{C}$)

Parameter	Symbol	Min	Typ	Max
Clock to Address Delay	T_{adr}	3 ns		8 ns
Clock to Memory Chip Select Delay	T_{CSx}	3 ns		6 ns
Clock to Memory Write Strobe Delay	T_{WEx}	3 ns		6 ns
High Z to Data Valid Relative to Clock	T_{DVHZ}	3 ns		8 ns
Data Valid to High Z Relative to Clock	T_{DVHZ}	3 ns		8 ns

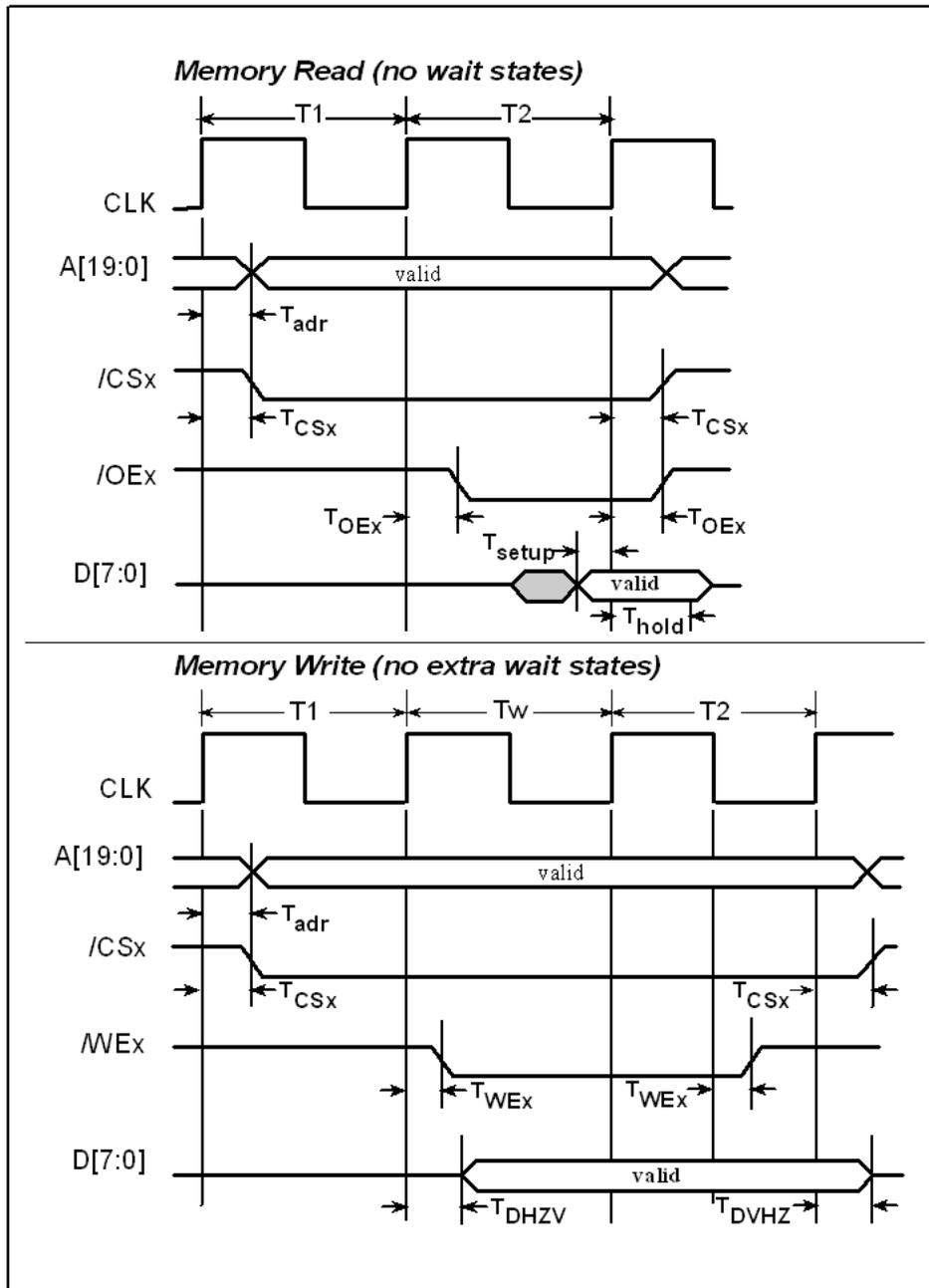


Figure 37.1 Memory Read and Write Cycles

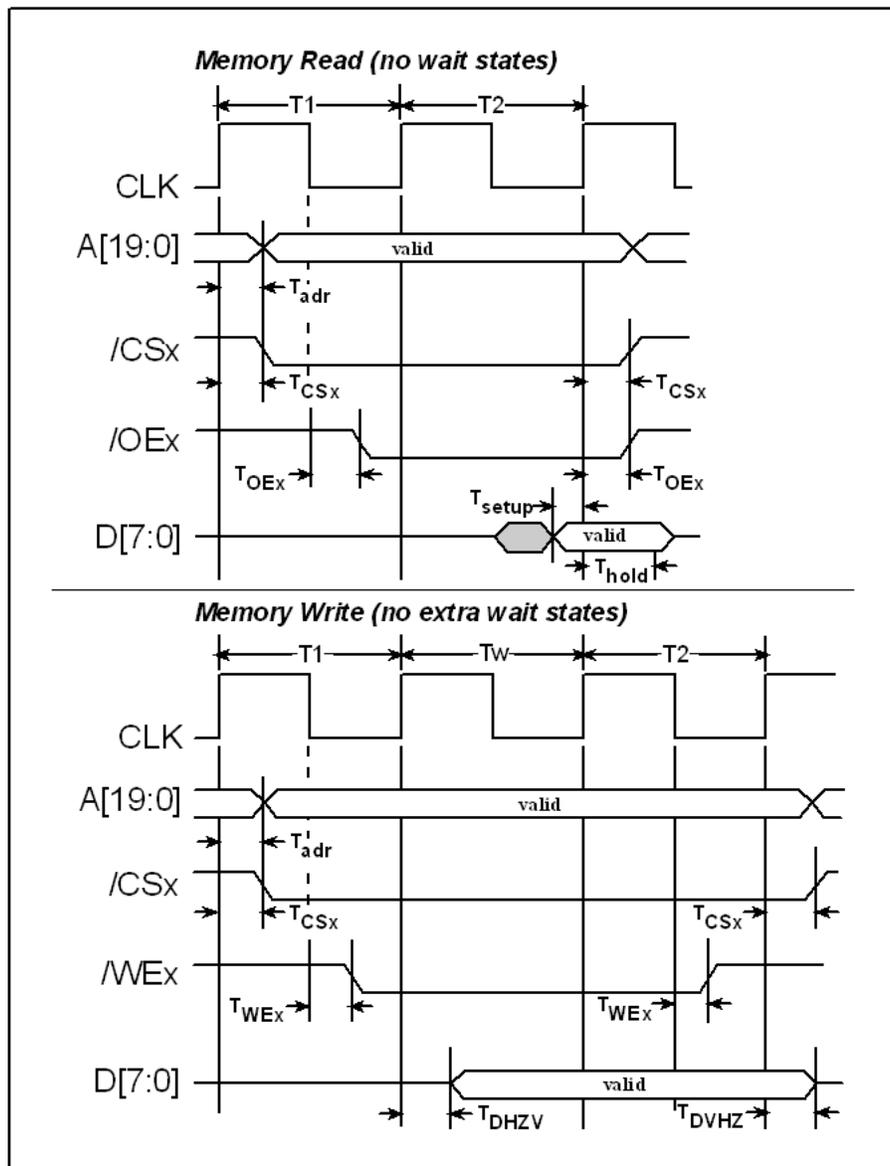


Figure 37.2 Memory Read and Write Cycles—Early Output Enable and Write Enable Timing

37.3.3 External I/O Reads

Table 37-6. External I/O Read Time Delays
($VDD_{CORE} = 1.2\text{ V} \pm 10\%$, $VDD_{IO} = 3.3\text{ V} \pm 10\%$, $T_A = -40^\circ\text{C}$ to 85°C)

Parameter	Symbol	Min	Typ	Max
Clock to Address Delay	T_{adr}	4 ns		8 ns
Clock to Memory Chip Select Delay	T_{CSx}	3 ns		6 ns
Clock to I/O Chip Select Delay	T_{IOCSx}	4 ns		10 ns
Clock to I/O Read Strobe Delay	T_{IORD}	3 ns		7 ns
Clock to I/O Buffer Enable Delay	T_{BUFEN}	3 ns		6 ns
Data Setup Time	T_{setup}		1 ns	
Data Hold Time	T_{hold}		1 ns	

37.3.4 External I/O Writes

Table 37-7. External I/O Write Time Delays
($VDD_{CORE} = 1.2\text{ V} \pm 10\%$, $VDD_{IO} = 3.3\text{ V} \pm 10\%$, $T_A = -40^\circ\text{C}$ to 85°C)

Parameter	Symbol	Min	Typ	Max
Clock to Address Delay	T_{adr}	4 ns		8 ns
Clock to Memory Chip Select Delay	T_{CSx}	3 ns		6 ns
Clock to I/O Chip Select Delay	T_{IOCSx}	4 ns		10 ns
Clock to I/O Write Strobe Delay	T_{IOWR}	3 ns		7 ns
Clock to I/O Buffer Enable Delay	T_{BUFEN}	3 ns		6 ns
High Z to Data Valid Relative to Clock	T_{DHZV}	3 ns		6 ns
Data Valid to High Z Relative to Clock	T_{DVHZ}	1 ns		2 ns

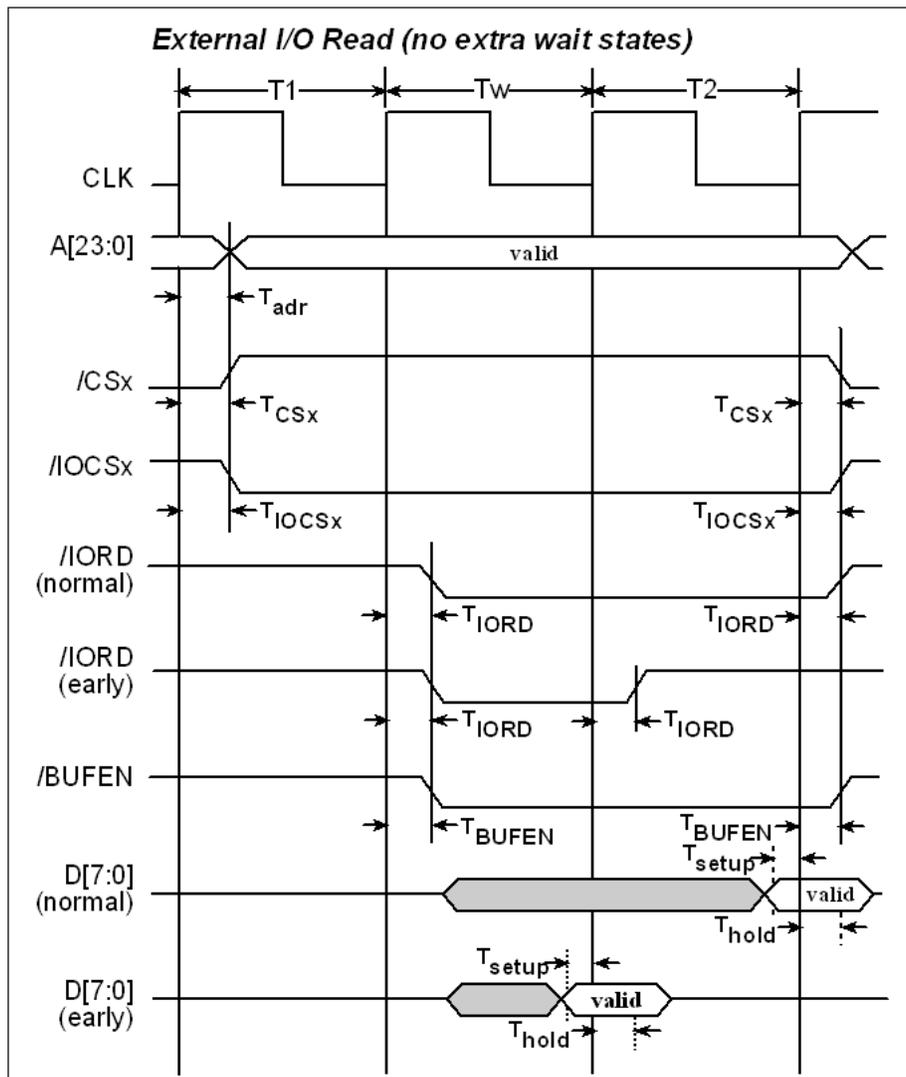


Figure 37.3 I/O Read Cycles—No Extra Wait States

NOTE: **/IOCSx** can be programmed to be active low (default) or active high.

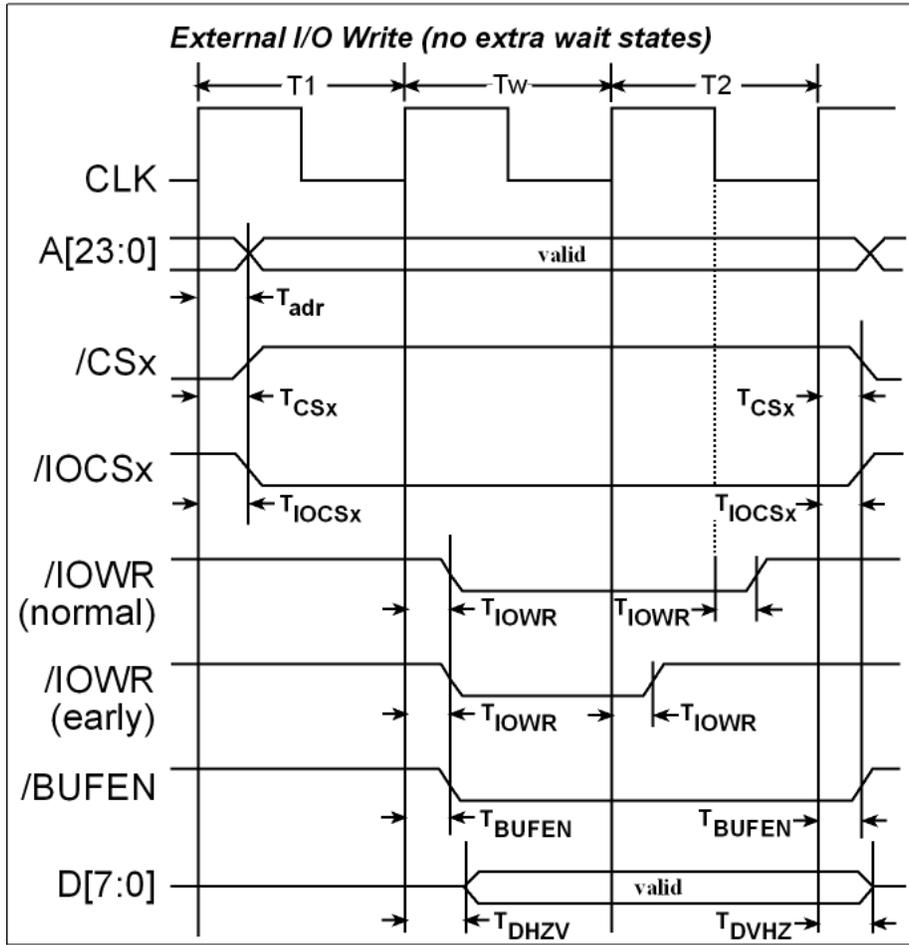


Figure 37.4 I/O Write Cycles—No Extra Wait States

NOTE: /IOCSx can be programmed to be active low (default) or active high.

37.4 Clock Speeds

37.4.1 Recommended Clock/Memory Configurations

Table 37-8 describes some recommended clock and memory configurations for both 8-bit and 16-bit external memory devices in the 10-70ns access time range.

To calculate the required number of Wait states for a given memory access time and a known CPU clock frequency, use the following formula (round the result up to the next integer):

$$\text{Wait states} = ((\text{memory access time} + 10\text{nS}) / (\text{CPU clock cycle time})) - 2$$

Table 37-8. Some Recommended Clock/Memory Configurations

Input Frequency (MHz)	Internal Frequency (MHz)	Recommended Memory Timing	Optimal Use
25	200.0000 (PLL)	10 ns, 2 wait states 12 ns, 3 wait states 15 ns, 3 wait state 45 ns, 9 wait states 55 ns, 11 wait states 70 ns, 14 wait states	10 ns (or faster) devices
25	150.0000 (PLL)	10 ns, 1 wait states 12 ns, 2 wait states 15 ns, 2 wait state 45 ns, 7 wait states 55 ns, 8 wait states 70 ns, 10 wait states	10 ns (or faster) devices
25	100.0000 (PLL)	12 ns, 1 wait states 15 ns, 1 wait state 45 ns, 4 wait states 55 ns, 5 wait states 70 ns, 6 wait states	12 ns (or faster) devices
44.2368	88.4736 (doubler)	12 ns, 0 wait states 15 ns, 1 wait state 45 ns, 3 wait states 55 ns, 4 wait states 70 ns, 5 wait states	12 ns devices
36.8640	73.7280 (doubler)	15 ns, 0 wait states 45 ns, 2 wait states 55 ns, 3 wait states 70 ns, 4 wait states	15 ns devices
18.4320	36.8640 (doubler)	45 ns, 0 wait states 55 ns, 1 wait state 70 ns, 1 wait state	45 ns devices

Table 37-8. Some Recommended Clock/Memory Configurations

Input Frequency (MHz)	Internal Frequency (MHz)	Recommended Memory Timing	Optimal Use
14.7456	29.4912 (doubler)	55 ns, 0 wait states 70 ns, 1 wait state	55 ns devices

37.5 Power and Current Consumption

Several mechanisms contribute to the current consumption of the Rabbit 6000 processor while it is operating. Current that is proportional to the voltage alone is due to the power consumption of the internal logic. The other current draw component is dependent on both voltage and frequency. Since the operating voltage is fixed, the primary way to reduce current consumption is by reducing the clock speed by either adjusting or disabling the PLL, dividing the main clock, or running off the 32kHz oscillator. See Table 36-2 for more details.

The Ethernet and Wi-Fi peripherals in particular can draw a significant amount of current when powered, as shown in Table 37-5. Exercise care that they are only enabled when being used.

37.5.1 Sleepy Mode Current Consumption

The Rabbit 6000 supports designs with very low power consumption by using features such as the ultra-sleepy modes and self-timed chip selects. At the low frequencies possible in the ultra-sleepy modes (as low as 2 kHz), the external memory devices become significant factors in the current consumption unless one of the short or self-timed chip selects is used. The I/O current use will vary with pin activity.

**Table 37-9. Typical Sleepy Mode Current Consumption
(-40°C to +85°C)**

Pin	Voltage	Current
I_{CORE}	1.2 V	5 mA
I_{IO}	3.3 V	6 mA

37.5.2 Battery-Backed Clock Current Consumption

For the battery-backed features of the Rabbit 6000 to operate while the processor is powered down, both the VBAT and VBATIO pins need to be supplied properly. The VBAT pin powers the internal real-time clock and the battery-backed SRAM, while VBATIO powers the /RESET, /CS1, CLK32K, and RESOUT pins.

Note that the VBATIO pin can be powered at 1.2 V during powerdown even if the processor is running at 3.3 V normally. A circuit to switch between a 1.2–2.0 V battery and the main power can use the RESOUT pin to switch the power source for the VBATIO pin. R is a current-limiting resistor that should be adjusted for the battery voltage; a good value to use for a 3.0 V battery is 150 k Ω .

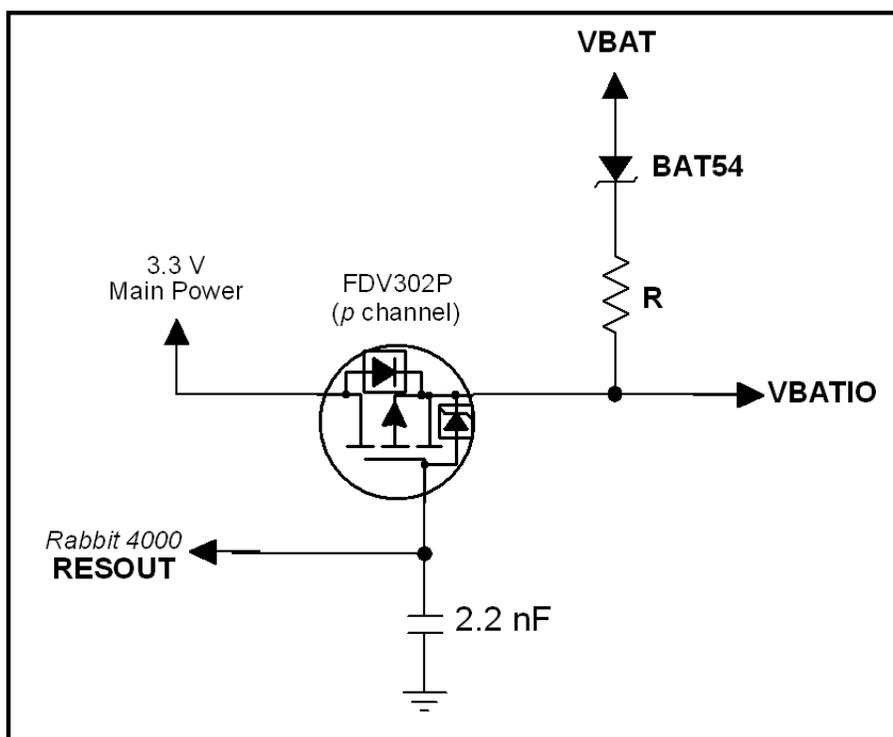


Figure 37.5 Switching Circuit for VBATIO Pin

Table 37-10 shows the typical current consumption for these pins while the remainder of the Rabbit 6000 is powered down.

Table 37-10. Typical Battery-Backed Current Consumption (-40°C to +85°C)

Pin	Voltage	Current
VBAT	1.2 V	to be determined
VBATIO	1.2 V	to be determined

38. PACKAGE SPECIFICATIONS AND PINOUT

38.1 Ball Grid Array Packages

38.1.1 Pinout 17mm × 17mm BGA 292

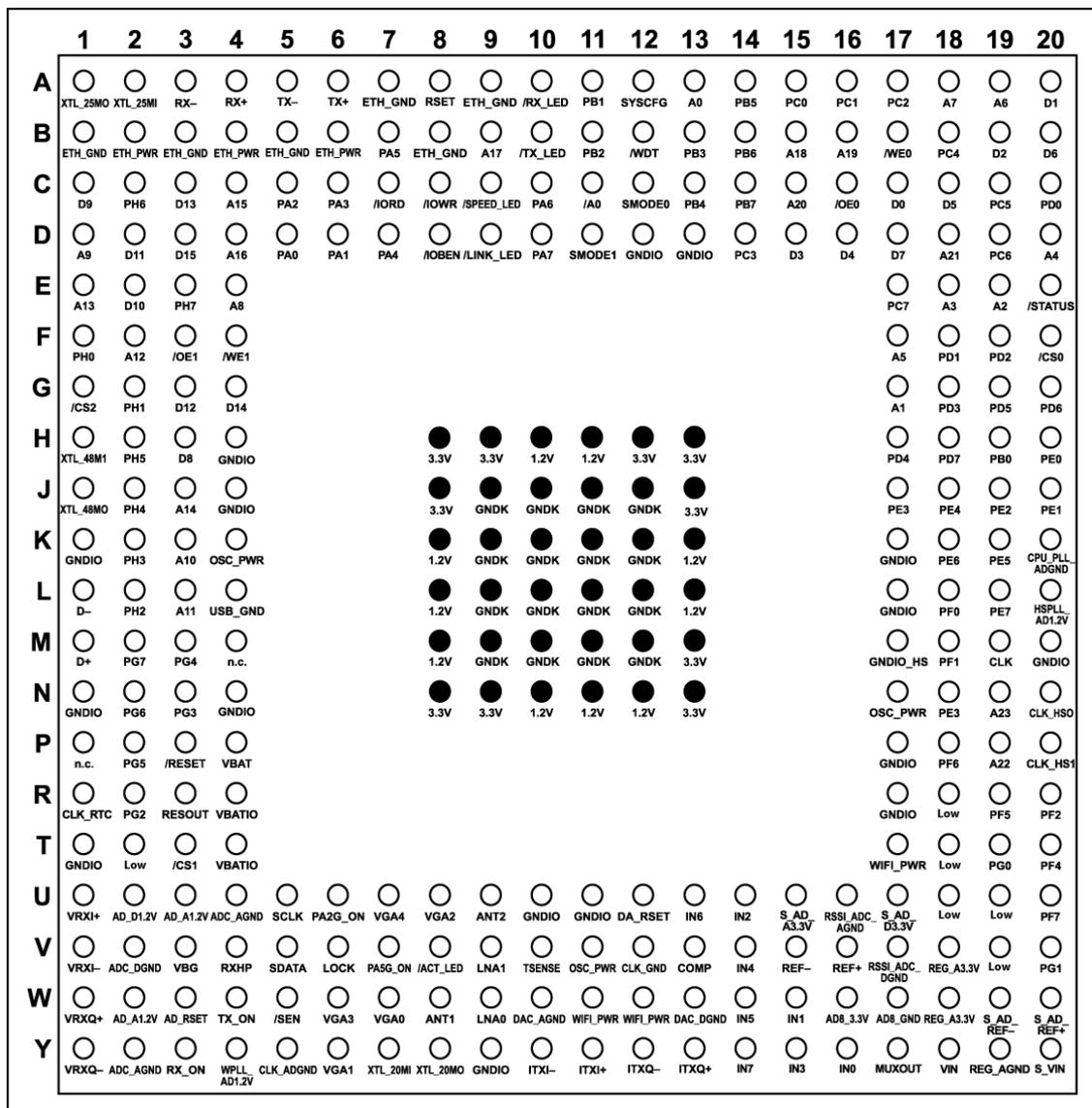


Figure 38.1 BGA 292 Pinout Looking Through the Top of Package

38.1.2 Pinout 15mm × 15mm BGA 233

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	○ XTL_48M1	○ PH5	○ RX+	○ RX-	○ TX+	○ TX-	○ RSET	○ PA3	○ /IORD	○ /SPEED_LED	○ /TX_LED	○ PB2	○ PB4	○ PB6	○ PC2	○ PC7	○ PD1
B	○ XTL_48MO	○ GNDK	○ 1.2V	○ GNDK	○ 3.3V	○ GNDIO	○ PA0	○ PA4	○ /IOWR	○ GNDIO	○ PA7	○ SMODE1	○ 3.3V	○ PC1	○ PC5	○ GNDK	○ PD5
C	○ GNDIO	○ PH2	○ PH6	○ XTL_25MI	○ ETH_PWR	○ ETH_PWR	○ PA1	○ PA5	○ /LINK_LED	○ PA6	○ /WDT	○ PB5	○ PC0	○ PC4	○ PD0	○ PD4	○ PD7
D	○ D+	○ 3.3V	○ PH0	○ XTL_25MO	○ ETH_GND	○ ETH_GND	○ PA2	○ /IOBEN	○ /RX_LED	○ PB1	○ PB3	○ PB7	○ PC3	○ PC6	○ PD2	○ 1.2V	○ PE2
E	○ D-	○ GNDK	○ PH4	○ PH7										○ /STATUS	○ PD6	○ PE1	○ PE3
F	○ GNDIO	○ 3.3V	○ OSC_PWR	○ PH1										○ PD3	○ PE0	○ PE4	○ PE6
G	○ PG5	○ 1.2V	○ USB_GND	○ PH3			● 3.3V	● GNDIO	● 3.3V	● GNDIO	● 3.3V			○ PB0	○ PE5	○ GNDK	○ CLK
H	○ PG2	○ PG4	○ PG6	○ PG7			● 1.2V	● GNDK	● GNDK	● GNDK	● 1.2V			○ PE7	○ PF0	○ CPU_PLL_ADGND	○ HSPLL_AD1.2V
J	○ VBAT	○ VBATIO	○ /RESET	○ PG3			● 1.2V	● GNDK	● GNDK	● 1.2V	● 1.2V			○ GNDIO_HS	○ OSC_PWR	○ 3.3V	○ GNDIO
K	○ GNDIO	○ RESOUT	○ /CS1	○ TEST5			● 1.2V	● GNDK	● GNDK	● GNDK	● 1.2V			○ PF2	○ PF1	○ CLK_HSI	○ CLK_HSO
L	○ n.c.	○ n.c.	○ n.c.	○ AD_A1.2V			● WPLL_AD1.2V	● CLK_ADGND	● 3.3V	● GNDIO	● 3.3V			○ PF7	○ PF5	○ PF4	○ PF3
M	○ CLK_RTC	○ AD_A1.2V	○ ADC_AGND	○ ADC_AGND										○ TEST4	○ PG1	○ GNDIO	○ PF6
N	○ GNDIO	○ AD_D1.2V	○ ADC_DGND	○ RXHP										○ ETH_PWR	○ TEST0	○ TEST3	○ PG0
P	○ VRXI-	○ VBG	○ RX_ON	○ TX_ON	○ PA2G_ON	○ VGA3	○ ANT1	○ TSENSE	○ DA_RSET	○ COMP	○ IN4	○ IN0	○ AD8_GND	○ S_AD_REF+	○ WIFI_PWR	○ 3.3V	○ TEST2
R	○ VRXI+	○ AD_RSET	○ SCLK	○ LOCK	○ VGA2	○ /ACT_LED	○ ANT2	○ OSC_PWR	○ WIFI_PWR	○ WIFI_PWR	○ IN5	○ IN1	○ AD8_3.3V	○ S_AD_REF-	○ RSSI_ADC_AGND	○ OSC_PWR	○ TEST1
T	○ VRXQ+	○ GNDK	○ /SEN	○ VGA4	○ VGA1	○ LNA1	○ LNA0	○ CLK_GND	○ DAC_AGND	○ DAC_DGND	○ IN6	○ IN2	○ REF-	○ REF+	○ S_AD_A3.3V	○ S_AD_D3.3V	○ REG_AGND
U	○ VRXQ-	○ SDATA	○ PA5G_ON	○ VGA0	○ XTL_20MI	○ XTL_20MO	○ ITXI-	○ ITXI+	○ ITXQ-	○ ITXQ+	○ IN7	○ IN3	○ MUXOUT	○ VIN	○ S_VIN	○ RSSI_ADC_DGND	○ REG_A3.3V

Figure 38.2 BGA 233 Pinout Looking Through the Top of Package

38.1.3 Mechanical Dimensions and Land Pattern

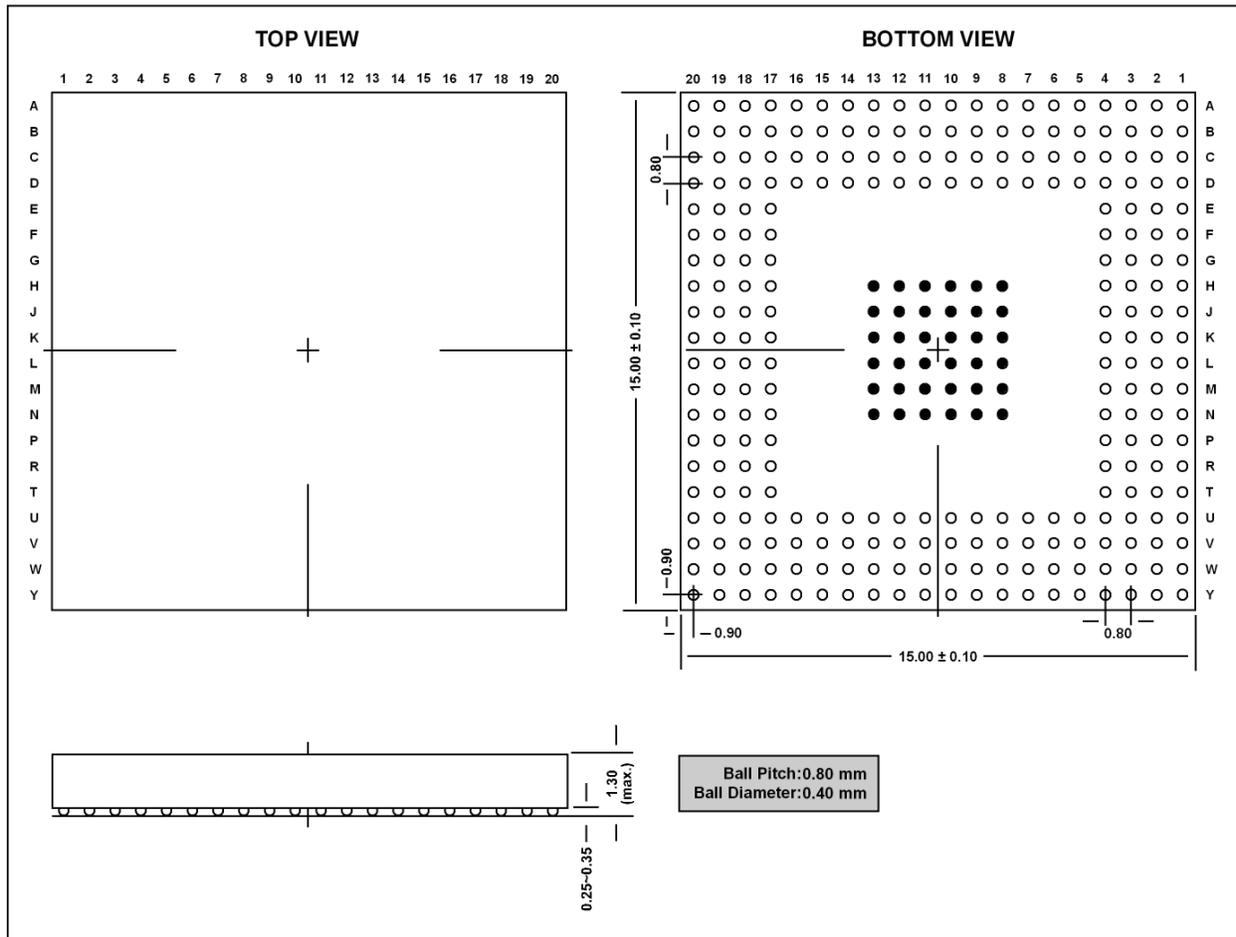


Figure 38-3(a). BGA 292 Package Outline

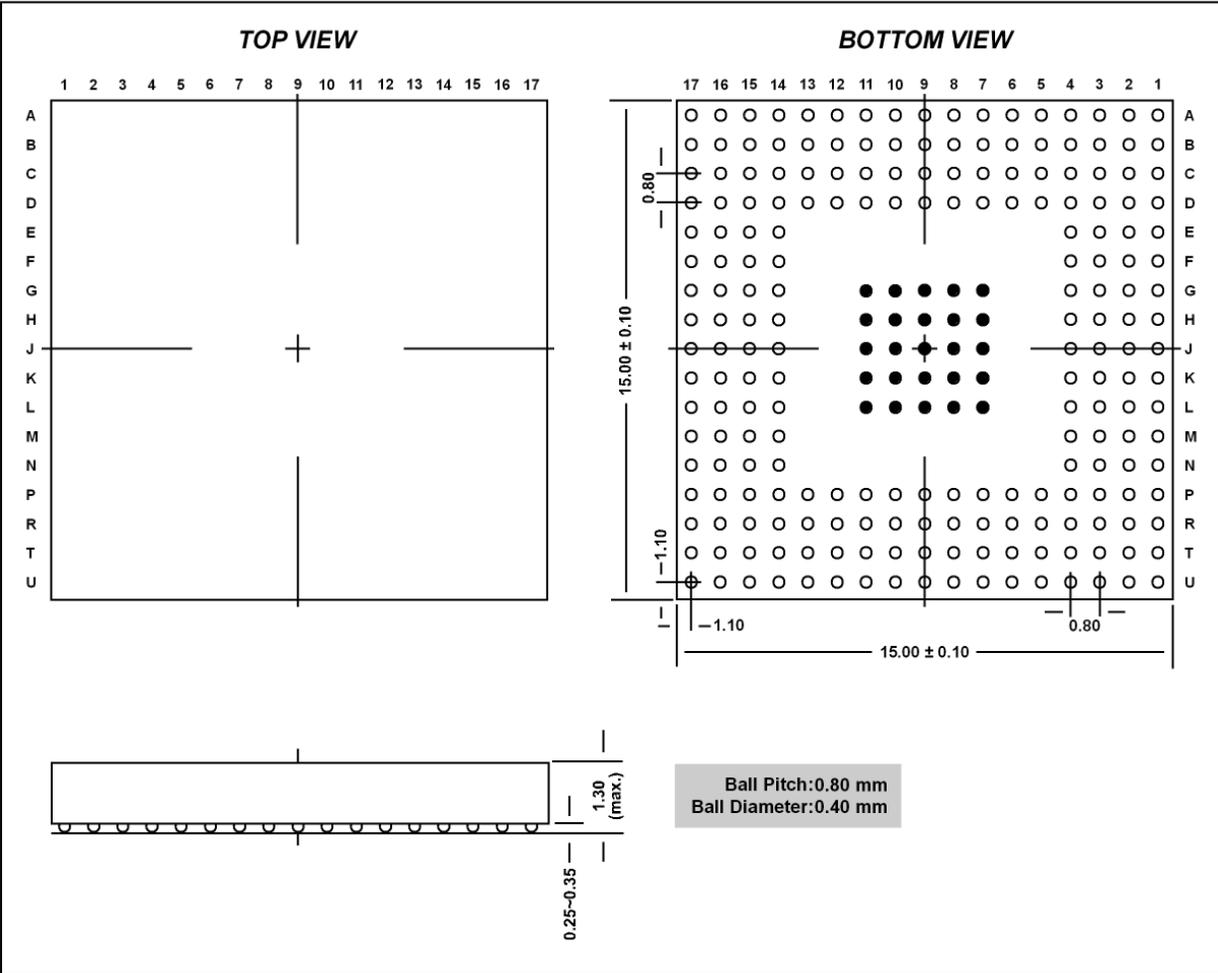


Figure 38-4(b). BGA 233 Package Outline

Table 38-1. Ball and Land Size Dimensions

Nominal Ball Diameter (mm)	Tolerance Variation (mm)	Ball Pitch (mm)	Nominal Land Diameter (mm)	Land Variation (mm)
0.40	0.45-0.35	0.80	0.35	0.35-0.30

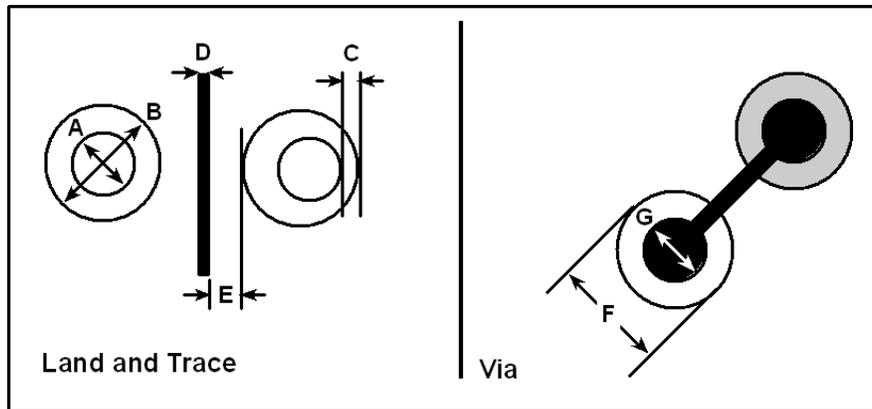
The design considerations in Table 38-2 are based on 5 mil design rules and assume a single conductor between solder lands.

Table 38-2. Design Considerations (all dimensions in mm)

Key	Feature	Recommendation
A	Solder Land Diameter	0.356 (0.014)

Table 38-2. Design Considerations
(all dimensions in mm)

Key	Feature	Recommendation
B	NSMD Defined Land Diameter	0.406 (0.016)
C	Land to Mask Clearance (min.)	0.076 (0.003)
D	Conductor Width (max.)	0.127 (0.005)
E	Conductor Spacing (typ.)	0.127 (0.005)
F	Via Capture Pad (max.)	0.406 (0.016)
G	Via Drill Size (max.)	0.203 (0.008)



38.2 Rabbit Pin Descriptions

Table 38-3 lists all the pins on the Rabbit 6000 along with the data direction of the pin, its function, and the pin number on the die.

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
Hardware	CLK	Output	Internal Clock Output	M19	G17
	CLK_RTC	Input	32KHz Clock	R1	M1
	CLK_HSI	Input	Main Clock Crystal In	P20	K16
	CLK_HSO	Bidirectional	Main Clock Crystal Out	N20	K17
	/RESET	Input	Master Reset	P3	J3
	RESOUT	Output	Reset Output	R3	K2
	ETH_PWR	Output	PHY Regulator Out	B2, B4, B6	C5, C6, N14
	OSC_PWR	Output	Oscillator Regulator Out	K4, N17, V11	F3, J15, R8
	WIFI_PWR	Output	Wi-Fi Regulator Out	W11, W12, T17	P15, R9, R10

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
CPU Buses	A23	Output	Address Bus	N19	N/A
	A22			P19	
	A21			D18	
	A20			C15	
	A19			B16	
	A18			B15	
	A17			B9	
	A16			D4	
	A15			C4	
	A14			J3	
	A13			E1	
	A12			F2	
	A11			L3	
	A10			K3	
	A9			D1	
	A8			E4	
	A7			A18	
	A6			A19	
	A5			F17	
	A4			D20	
A3	E18				
A2	E19				
A1	G17				
A0	A13				
	/A0	Output	Address Bus 0 Bar	C11	N/A
	D15	Bidirectional	Data Bus	D3	N/A
	D14			G4	
	D13			C3	
	D12			G3	
	D11			D2	
	D10			E2	
	D9			C1	
	D8			H3	
	D7			D17	
	D6			B20	
	D5			C18	
	D4			D16	
	D3			D15	
	D2			B19	
	D1			A20	
	D0			C17	
Real-Time Clock	VBAT	Input	1.2V	P4	J1
	VBATIO	Input	2.0V - 3.3V	R4, T4	J2

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
Status & Control	/WDT	Output	WDT Time-Out	B12	C11
	STATUS	Output	IFetch First Byte	E20	E14
	SYSCFG	Input	System Config.	A12	N/A
	SMODE1, SMODE0	Inputs	Bootstrap Mode & Tamper Detect	D11 C12	B12 N/A
	TSENSE	Input	Die Temp Monitor	V10	P8
Chip Selects	/CS0	Output	Memory Chip Select	F20	N/A
	/CS1	Output	Memory Chip Select	T3	K3
	/CS2	Output	Memory Chip Select	G1	N/A
Output Enables	/OE0	Output	Memory Output Enable	C16	N/A
	/OE1	Output	Memory Output Enable	F3	N/A
Write Enables	/WE0	Output	Memory Write Enable	B17	N/A
	/WE1	Output	Memory Write Enable	F4	N/A
I/O Control	/IOBEN	Output	I/O Buffer Enable	D8	D8
	/IORD	Output	I/O Read Enable	C7	A9
	/IOWR	Output	I/O Write Enable	C8	B9

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
I/O Ports	PA7 PA6 PA5 PA4 PA3 PA2 PA1 PA0	Input / Output	Parallel Port A	D10 C10 B7 D7 C6 C5 D6 D5	B11 C10 C8 B8 A8 D7 C7 B7
	PB7 PB6 PB5 PB4 PB3 PB2 PB1 PB0	Input / Output	Parallel Port B	C14 B14 A14 C13 B13 B11 A11 H19	D12 A14 C12 A13 D11 A12 D10 G14
	PC7 PC6 PC5 PC4 PC3 PC2 PC1 PC0	Input / Output	Parallel Port C	E17 D19 C19 B18 D14 A17 A16 A15	A16 D14 B15 C14 D13 A15 B14 C13
	PD7 PD6 PD5 PD4 PD3 PD2 PD1 PD0	Input / Output	Parallel Port D	H18 G20 G19 H17 G18 F19 F18 C20	C17 E15 B17 C16 F14 D15 A17 C15
	PE7 PE6 PE5 PE4 PE3 PE2 PE1 PE0	Input / Output	Parallel Port E	L19 K18 K19 J18 J17 J19 J20 H20	H14 F17 G15 F16 E17 D17 E16 F15
	PF7 PF6 PF5 PF4 PF3 PF2 PF1 PF0	Input / Output	Parallel Port F	U20 P18 R19 T20 N18 R20 M18 L18	L14 M17 L15 L16 L17 K14 K15 H15

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
I/O Ports (cont'd)	PG7 PG6 PG5 PG4 PG3 PG2 PG1 PG0	Input / Output	Parallel Port G	M2 N2 P2 M3 N3 R2 V20 T19	H4 H3 G1 H2 J4 H1 M15 N17
	PH7 PH6 PH5 PH4 PH3 PH2 PH1 PH0	Input / Output	Parallel Port H	E3 C2 H2 J2 K2 L2 G2 F1	E4 C3 A2 E3 G4 C2 F4 D3
Ethernet	TX+ TX-	Output	Transmit	A6 A5	A5 A6
	RX+ RX-	Input	Receive	A4 A3	A3 A4
	/SPEED_LED /TX_LED /LINK_LED /RX_LED	Output	LEDs	C9 B10 D9 A10	A10 A11 C9 D9
	RSET XTL_25MI XTL_25MO		Circuit Interface	A8 A2 A1	A7 C4 D4

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
WiFi	/WIFI_ACT_LED	Output	Link Activity	V8	R6
	ANT1 ANT2	Outputs	Antenna Select	W8 U9	P7 R7
	LNA1 LNA0	Outputs	LNA Control	V9 W9	T6 T7
	PA2G_ON	Output	2GHz PA Enable	U6	P5
	PA5G_ON	Output	5GHz PA Enable	V7	U3
	RX_ON	Output	Receiver Enable	Y3	P3
	RXHP	Output	Receiver High Power	V4	N4
	SCLK	Output	Serial Bus Clock	U5	R3
	SDATA	Output	Serial Bus Data	V5	U2
	/SEN	Output	Serial Bus Enable	W5	T3
	TX_ON	Output	Transmitter Enable	W4	P4
	VGA4 VGA3 VGA2 VGA1 VGA0	Output	Amp Gain Control	U7 W6 U8 Y6 W7	T4 P6 R5 T5 U4
	XTL_20MI XTL_20MO	Input Bidirectional	Wi-Fi 20MHz Crystal	Y7 Y8	U5 U6
	LOCK	Input	Locked	V6	R4

Table 38-3. Rabbit 6000 Pin Descriptions

Pin Group	Pin Name	Direction	Function	BGA 292 Ball	BGA 233 Ball
Analog	VRXI+	Input	Inphase + Input	U1	R1
	VRXI-	Input	Inphase - Input	V1	P1
	VRXQ+	Input	Quadrature + Input	W1	T1
	VRXQ-	Input	Quadrature - Input	Y1	U1
	VBG	Input	A/D Ext Bandgap	V3	P2
	AD_RSET	Output	A/D resistor	W3	R2
	ITXI+	Output	Inphase + Output	Y11	U8
	ITXI-	Output	Inphase - Output	Y10	U7
	ITXQ+	Output	Quadrature + Output	Y13	U10
	ITXQ-	Output	Quadrature - Output	Y12	U9
	COMP	Bidirectional	D/A Compensation	V13	P10
	DA_RSET	Bidirectional	D/A resistor	U12	P9
	S_VIN	Input	RSSI A/D Input	Y20	U15
	S_AD_REF+	Input	RSSI A/D Top Ref	W20	P14
	S_AD_REF-	Input	RSSI A/D Bottom Ref	W19	R14
	IN7 IN6 IN5 IN4 IN3 IN2 IN1 IN0	Input	A/D Inputs	Y14 U13 W14 V14 Y15 U14 W15 Y16	U11 T11 R11 P11 U12 T12 R12 P12
	MUXOUT	Output	Multiplexer Output	Y17	U13
	VIN	Input	Actual ADC Input	Y18	U14
	REF+	Input	A/D Top Ref	V16	T14
	REF-	Input	A/D Bottom Ref	V15	T13
USB	XTL_48MI XTL_48MO	Input Bidirectional	USB 48MHz Crystal	H1 J1	A1 B1
	D+	Bidirectional	USB Data	M1	D1
	D-			L1	E1

APPENDIX A. PARALLEL PORT PINS WITH ALTERNATE FUNCTIONS

A.1 Alternate Parallel Port Pin Outputs

Table A-1. Alternate Parallel Port A and B Pin Outputs

Pin	Alternate Output Options		
	Serial Clock	External I/O Bus	Slave Port
PA[7:0]	—	ID[7:0]	SD[7:0]
PB7	—	IA5	/SLVATTN
PB6	—	IA4	/SCS
PB5	—	IA3	SA1
PB4	—	IA2	SA0
PB3	—	IA1	/SRD
PB2	—	IA0	/SWR
PB1	SCLKA	IA7	—
PB0	SCLKB	IA6	—

Table A-2. Alternate Parallel Port C, D, E, F, G, and H Pin Outputs

Pin	Alternate Output Option				External I/O 16-bit Data
	0	1	2	3	
PC7	TXA	I7	PWM3	SCLKC	—
PC6	TXA	I6	PWM2	TXE	—
PC5	TXB	I5	PWM1	RCLKE	—
PC4	TXB	I4	PWM0	TCLKE	—
PC3	TXC	I3	TIMER C3	SCLKD	—
PC2	TXC	I2	TIMER C2	TXF	—
PC1	TXD	I1	TIMER C1	RCLKF	—
PC0	TXD	I0	TIMER C0	TCLKF	—
PD7	IA7	I7	PWM3	SCLKC	—
PD6	TXA	I6	PWM2	TXE	—
PD5	IA6	I5	PWM1	RCLKE	—
PD4	TXB	I4	PWM0	TCLKE	—
PD3	IA7	I3	TIMER C3	SCLKD	—
PD2	SCLKC	I2	TIMER C2	TXF	—
PD1	IA6	I1	TIMER C1	RCLKF	—
PD0	SCLKD	I0	TIMER C0	TCLKF	—
PE7	I7	—	PWM3	SCLKC	—
PE6	I6	—	PWM2	TXE	—
PE5	I5	SCLKG	PWM1	RCLKE	—
PE4	I4	SDATG	PWM0	TCLKE	—
PE3	I3	—	TIMER C3	SCLKD	—
PE2	I2	USB_PWR	TIMER C2	TXF	—
PE1	I1	SCLKG	TIMER C1	RCLKF	—
PE0	I0	SDATG	TIMER C0	TCLKF	—
PF7	FIMA7	I7	PWM3	SCLKC	—
PF6	FIMA6	I6	PWM2	TXE	—

Table A-2. Alternate Parallel Port C, D, E, F, G, and H Pin Outputs

Pin	Alternate Output Option				External I/O 16-bit Data
	0	1	2	3	
PF5	FIMA5	I5	PWM1	RCLKE	—
PF4	FIMA4	I4	PWM0	TCLKE	—
PF3	FIMA3	I3	TIMER C3	SCLKD	—
PF2	FIMA2	I2	TIMER C2	TXF	—
PF1	FIMA1	I1	TIMER C1	RCLKF	—
PF0	FIMA0	I0	TIMER C0	TCLKF	—
PG7	FIMB7	I7	PWM3	SCLKC	—
PG6	FIMB6	I6	PWM2	TXE	—
PG5	FIMB5	I5	PWM1	RCLKE	—
PG4	FIMB4	I4	PWM0	TCLKE	—
PG3	FIMB3	I3	TIMER C3	SCLKD	—
PG2	FIMB2	I2	TIMER C2	TXF	—
PG1	FIMB1	I1	TIMER C1	RCLKF	—
PG0	FIMB0	I0	TIMER C0	TCLKF	—
PH7	—	I7	PWM3	SCLKC	D15
PH6	—	I6	PWM2	TXE	D14
PH5	—	I5	PWM1	RCLKE	D13
PH4	—	I4	PWM0	TCLKE	D12
PH3	—	I3	TIMER C3	SCLKD	D11
PH2	—	I2	TIMER C2	TXF	D10
PH1	—	I1	TIMER C1	RCLKF	D9
PH0	—	I0	TIMER C0	TCLKF	D8

A.2 Alternate Parallel Port Pin Inputs

Table A-3. Parallel Port Pin Input Functions

Pin	Input Capture	I/O Handshake	DMA	External Interrupt	USB	Quadrature Decoder	Slave Port	Serial Ports A–D	Serial Ports E–F
PA[7:0]	—	—	—	—	—		SD[7:0]	—	—
PB7	—	—	—	—	—	—	—	—	—
PB6	—	—	—	—	—	—	/SCS	—	—
PB5	—	—	—	—	—	—	SA1	—	—
PB4	—	—	—	—	—	—	SA0	—	—
PB3	—	—	—	—	—	—	/SRD	—	—
PB2	—	—	—	—	—	—	/SWR	—	—
PB1	—	—	—	—	—	—	—	SCLKA	—
PB0	—	—	—	—	—	—	—	SCLKB	—
PC7	yes	—	—	—	—	—	—	RXA	RXE
PC6	—	—	—	—	—	—	—	—	—
PC5	yes	—	—	—	—	—	—	RXB	RCLKE
PC4	—	—	—	—	—	—	—	—	TCLKE
PC3	yes	—	—	—	—	—	—	RXC	RXF
PC2	—	—	—	—	—	—	—	—	—
PC1	yes	—	—	—	—	—	—	RXD	RCLKF
PC0	—	—	—	—	—	—	—	—	TCLKF
PD7	yes	—	—	—	—	—	—	RXA	RXE
PD6	—	—	—	—	—	—	—	—	—
PD5	yes	—	—	—	—	—	—	RXB	RCLKE
PD4	—	—	—	—	—	—	—	—	TCLKE
PD3	yes	—	DREQ1	—	—	QD2A	—	RXC	RXF
PD2	—	—	DREQ0	—	—	QD2B	—	SCLKC	—
PD1	yes	—	—	INT1	—	QD1A	—	RXD	RCLKF
PD0	—	—	—	INT0	—	QD1B	—	SCLKD	TCLKF
PE7	yes	yes	DREQ1	—	—	QD2A	/SCS	RXA	RXE

Table A-3. Parallel Port Pin Input Functions

Pin	Input Capture	I/O Handshake	DMA	External Interrupt	USB	Quadrature Decoder	Slave Port	Serial Ports A–D	Serial Ports E–F
PE6	—	yes	DREQ0	—	—	QD2B	—	—	—
PE5	yes	yes	—	INT1	—	QD1A	—	RXB	RCLKE
PE4	—	yes	—	INT0	—	QD1B	—	—	TCLKE
PE3	yes	yes	DREQ1	—	OVCR	QRD2A	—	RXC	RXF
PE2	—	yes	DREQ0	—	—	QRD2B	—	SCLKC	—
PE1	yes	yes	—	INT1	—	QRD1A	—	RXD	RCLKF
PE0	—	yes	—	INT0	—	QRD1B	—	SCLKD	TCLKF

Pin	Input Capture	I/O Handshake	DMA	External Interrupt	FIM	Slave Port	Serial Ports A–D	Serial Ports E–F
PF7	—	—	—	INT2–7	FIMA7	—	—	—
PF6	—	—	—	INT2–7	FIMA6	—	—	—
PF5	—	—	—	INT2–7	FIMA5	—	—	—
PF4	—	—	—	INT2–7	FIMA4	—	—	—
PF3	—	—	—	INT2–7	FIMA3	—	—	—
PF2	—	—	—	INT2–7	FIMA2	—	—	—
PF1	—	—	—	INT2–7	FIMA1	—	—	—
PF0	—	—	—	INT2–7	FIMA0	—	—	—
PG7	—	—	—	INT2–7	FIMB7	—	—	—
PG6	—	—	—	INT2–7	FIMB6	—	—	—
PG5	—	—	—	INT2–7	FIMB5	—	—	—
PG4	—	—	—	INT2–7	FIMB4	—	—	—
PG3	—	—	—	INT2–7	FIMB3	—	—	—
PG2	—	—	—	INT2–7	FIMB2	—	—	—
PG1	—	—	—	INT2–7	FIMB1	—	—	—
PG0	—	—	—	INT2–7	FIMB0	—	—	—

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