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LH7A400
User's Guide

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Content Revisions

This document contains the following changes to content, causing it to differ from previous versions. Minor typographical changes, where they do not affect content, are not tracked here.

Record of Revisions

DATE	PAGE NO.	SECTION, TABLE, OR ILLUSTRATION	SUMMARY OF CHANGES
10-11-04	Book	All	Rolled version from Preliminary to Version 1.0
	Preface	Text	Clarified
	3-12, 3-13	3.2.1.4 and 3.2.1.5.1	Synchronous Bus Mode definition clarified; corrected ‘Synchronous Bus Mode’ to ‘Asynchronous Bus Mode’
	4-16	Figure 4-7	Figure corrected
	4-17	Note	Note added to clarify address connection for configurable-width data bus memory devices.
	5-17, 5-28	Section 5.1.4.7; Table 5-22	Clarified that programming the GBLCNFG:CKSD bit to 1 causes the SCKEx clock to free-run only when the SDMC controls the EBI, and that it stops when the SMC controls the EBI.
	5-23	Section 5.1.6	Synchronous Flash section removed.
	6-4	Table 6-2	Divisor for Timer1/Timer2 corrected to 7395; Timer3 entry in table added
	6-4	6.1.1.4	Section added to describe TICK interrupt
	6-6	6.1.2.1.1	Standby to Run transition process clarified
	6-8	Table 6-6	CHIPID bit definitions corrected
	6-11	Table 6-8	PGMCLK and WDTSEL bit definitions clarified
	6-13	Table 6-16	Definition of STFCLR bit corrected
	6-15	Table 6-18	HCKL Divisor: Corrected 00 definition to ‘FASTBUS’; also corrected definition to ‘FASTBUS’.
	9-9	9.1.6	Updated DMA priority list
	10-13	Figure 10-5	Clock source corrected to ‘HCLK’
	10-25	Table 10-16	CSEL bit added
	11-2	11.1.1	References to invalid settings of WDTSEL removed
	Chapter 17	All	SPI mode removed from document
	21-40	Table 21-26	DIVFACT bit definition corrected

Record of Revisions (Cont'd)

DATE	PAGE NO.	SECTION, TABLE, OR ILLUSTRATION	SUMMARY OF CHANGES
3-23-06	Book	All	Rolled Version to 1.1
	4-13	Section 4.1.6.1.1	Removed requirement to have pull-up resistors
	5-2	Text	Corrected description of SDRAM memory banks
	10-3	Section 10.1.2	Corrected Feature List
	10-24	Table 10-15	Corrected CSEL bit (was marked RESERVED)
	10-29	Table 10-24	Corrected definition of WATERMARK bit
	11-2	Section 11.1.1.1	Added step 1
	11-2	Section 11.1.1.2	Added section
	21-28	Text	Corrected base address from 0x80000.0F00 to 0x8000.0F00
	Chapter 21	All	Corrected register naming errors
4-4-07	Book	All	Rolled version to Version 1.2
	1-2	Section 1.2	Removed pin list table; duplicated from Data Sheet.
	7-3	Section 7.1.2	Corrected register name 'CON3' to 'CON'.
	16-19	Section 16.2.2.5	Corrected register name 'UARTCON3' to 'CON'.
5-15-07	Book	All	Rolled version to Version 1.3
	6-11	Table 6-7 & Table 6-8	Corrected bit 0 to "Reserved".
	Chapter 11	Various	"system reset" corrected to "WDT reset"
	21-27, 21-44, 21-47	Table 21-4, Table 21-32, Table 21-34	Clarified condition that asserts the MTCI interrupt.
8-27-07	All	—	All references to Sharp replaced with NXP. Revision number rolled to Version 1.3.

Table of Contents

Chapter 4 – Static Memory Controller (SMC)

Chapter 5 – Synchronous Dynamic Memory Controller

Chapter 6 – Clock and State Controller (CSC)

Chapter 7 – Pin and Signal Multiplexing

Chapter 8 – Interrupt Controller

Chapter 9 – Direct Memory Access (DMA) Controller

Chapter 10 – Color LCD Controller

List of Figures

Chapter 10 – Color LCD Controller

Chapter 12 – Real Time Clock (RTC)

Chapter 14 – Synchronous Serial Port (SSP)

Chapter 15 – Universal Asynchronous Receiver/Transmitter (UART)

Chapter 16 – GPIO and External Interrupts

Chapter 17 – MultiMediaCard (MMC) Controller

Chapter 18 – Universal Serial Bus (USB) Device

Chapter 19 – AC97 Controller

Chapter 21 – Battery Monitor Interface (BMI)

Chapter 22 – Direct Current to Direct Current (DC-DC) Converter Interface

List of Tables

Chapter 6 – Clock and State Controller (CSC)

Chapter 7 – Pin and Signal Multiplexing

Chapter 8 – Interrupt Controller

Chapter 9 – Direct Memory Access (DMA) Controller

Chapter 10 – Color LCD Controller

Chapter 11 – Watchdog Timer (WDT)

Chapter 12 – Real Time Clock (RTC)

Chapter 13 – Timers

Chapter 14 – Synchronous Serial Port (SSP)

Chapter 15 – Universal Asynchronous Receiver/Transmitter (UART)

Chapter 16 – GPIO and External Interrupts

Chapter 17 – MultiMediaCard (MMC) Controller

Chapter 18 – Universal Serial Bus (USB) Device

Chapter 19 – AC97 Controller

Chapter 20 – Audio Codec Interface (ACI)

Chapter 21 – Battery Monitor Interface (BMI)

Chapter 22 – Direct Current to Direct Current (DC-DC) Converter Interface

Chapter 23 – Smart Card Interface (SCI)

Preface

The NXP LH7A400 is a complete MCU. This User's Guide is the principal technical reference for this device. This document assumes the reader is familiar with ARM922T programming. For more information on programming the ARM922T core, see the library of methods and downloads available from ARM Ltd., at http://www.nxp.com/redirect/arm.com.

For an abridged version of this User's Guide, consult the LH7A400 Data Sheet and the single page Product Brief. For details, contact a NXP representative or see the NXP Semiconductors website (http://www.nxp.com).

Application Notes and further information on connecting, programming and implementing the LH7A400, along with suggestions for companion parts, can be found on NXP's website (http://www.nxp.com).

IMPORTANT: The following sections contain important design information about the LH7A400. Please take a moment to read the 'Conventions and Terms' section in its entirety.

Conventions and Terms

For information on specific terms and acronyms see the Glossary in this User's Guide.

Unconnected (Floating) Inputs

Many applications employing the LH7A400 require extremely low standby and operating current consumption, especially in battery operated devices. To achieve minimum current, unused inputs must never be left floating (unconnected). Each input must be pulled up or pulled down with a 33 kΩ resistor (or smaller). In addition to terminating input pins, this also allows the designer to specify the reset state of input pins by selecting pull up (logical 1 at reset) or pull down (logical 0 at reset) resistors.

Multiplexed Pins

The LH7A400 is manufactured in a BGA package with 255 pins. Some pins have only one function, but others are multiplexed and may carry as many as three functions. Designers must be aware that multiplexed pins cannot simultaneously support more than one function; a choice is required prior to designing the MCU into an application.

Pins Listed in Diagrams

Pin numbers listed in any diagrams are for reference only, and represent the PBGA package pin number. For CABGA pin numbers, refer to the pin listing table in Chapter 1.

Pin Names

Package pins are named to indicate the signal(s) or functionality available at the pin. If the signal or function is active LOW, the name is prefixed with a lower-case 'n', such as nSCS2. Multiplexed pins are named to indicate all available functions, such as Pin L10: LCDVD5/PE1, which can function as either LCD Data bit 5, or GPIO Port E bit 1.

These naming conventions help designers recognize and avoid collisions between multiplexed functions but can complicate explanatory text, so this User's Guide uses the name appropriate to the context. A discussion of LCD data, for example, would refer to signal LCDVD5, but information about Port E bit 1 would use PE1. Readers must be aware that these are separate signals, with distinctly different functionality, which happen to be available on the same pin. Such signals are not simultaneously available at the pin.

Peripheral Devices

The LH7A400 is an MCU built using the ARM922T RISC core as a base. Objects within the chip but external to the core processor and its support devices are referred to throughout this User's Guide as 'blocks' or 'Peripheral Devices'.

The LH7A400 includes two buses: an Advanced High-Performance Bus (AHB) and an Advanced Peripheral Bus (APB). The devices shown on the APB in the block diagrams are an example of Peripheral Devices in this document. Devices that are external to the chip are referred to as 'External Devices'.

Register Addresses

The LH7A400 is a memory-mapped device with programmable, internal registers that control its operation. Each internal register is located at a unique address in the memory map and the registers are generally grouped in the map by subsystem.

In this User's Guide, the addresses for all registers are expressed as a base address and an offset from that base. The base address indicates where in the map a group of registers begins and the offset locates a particular register, relative to its base address. Thus, any register's absolute address is the sum of its base address and its offset. Programmers will find this base+offset representation convenient for creating software structures to access the registers. The absolute addresses are also provided for convenient reference.

Register Tables

All Registers are presented in tabular format. A primary table presents each register's name, address, permissions, bit-field names and the register's contents at reset. Subsequent tables detail the specific names and function(s) of all bit fields in the register and explain any important variations that may exist.

An important detail to note is that all registers are not perfectly writable and readable. Some will exhibit different characteristics on a write, while a read may not return the expected result. At the same time, there will be registers whose function on a write is to clear a value or a set of stored values, while on a read will return a specific set of values. This is particularly true in registers that handle interrupts. Writing to a specific register may clear a set of interrupts, while reading that same register will yield which interrupts are set.

Similarly, not all bit fields in all registers can be written, nor can all register bit fields yield useful information when read. These restricted register bit fields will be specifically called out with three slashes (///) and the word 'Reserved', along with their special conditions in the bit field tables. See Table 1 and Table 2 for examples of this practice.

Table 1. Register Name

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///						F25	///								
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RW	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	—															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F07	F06	F05	F04	F03	F02	F01	F00
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	REGISTERBASE + 0x0004															

Table 2. Bit Fields

BITS	FIELD	FUNCTION
31:26	///	**Reserved** Reading returns 0. Values written cannot be read.
25	F25	**Field 25** A description of this bit's functionality will be found in this space.
24:8	///	**Reserved** Reading returns 0. Writing to this field will have no effect.
7:0	F7:F0	**Field Bits [7:0]** A description of these bits' functionality will be found in this space.

Numeric Values

Binary values are prefixed with 0b; for example, 0b00001000.

Hexadecimal values are expressed with UPPERCASE letters and prefixed with 0x; for example, 0x0FBC.

All numeric values not specifically identified with the above prefixes as either binary or hexadecimal are decimal values.

Registers and bit fields with 0b0 in all bits are referred to as cleared or as 0. Registers and bit fields with 0b1 values in all bits are referred to as set or as the binary, hexadecimal, or decimal value of the entire field or register. When truth tables are used, the '0b' prefix is omitted for textual clarity.

Block Diagrams

The functional descriptions in this User's Guide include block diagrams with symbols representing logical or mathematical operations or selections, usually the result of writing a value to a register. Figure 1 shows one such multiplexer with three inputs and one output (the result).

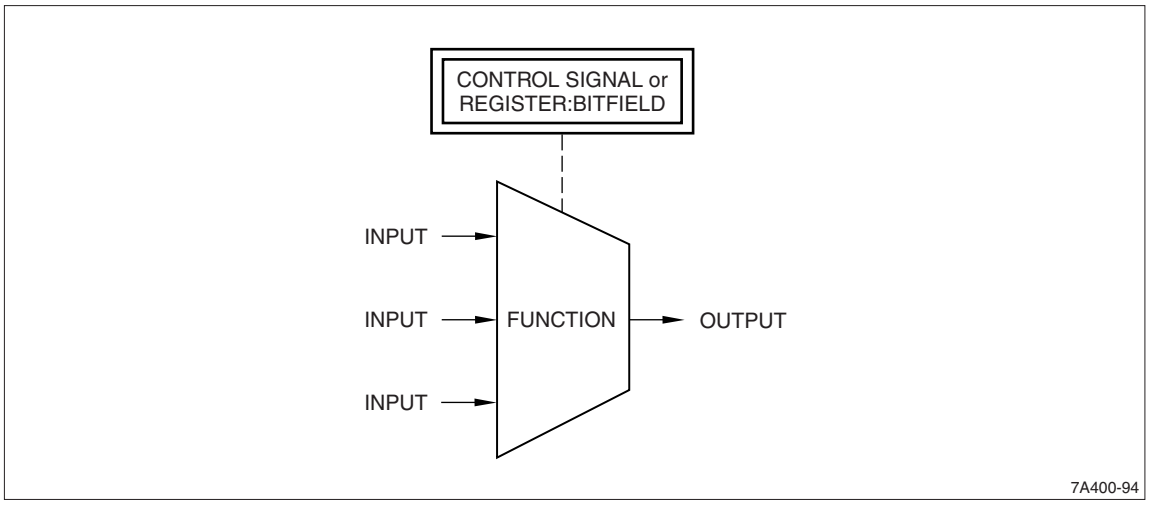


Figure 1. Multiplexer

Block diagrams can include symbols representing Registers and the bit fields within them. Figure 2 shows that the BITFIELDNAME bit field in the REGISTERNAME register enables or disables the signal named OUTPUT.

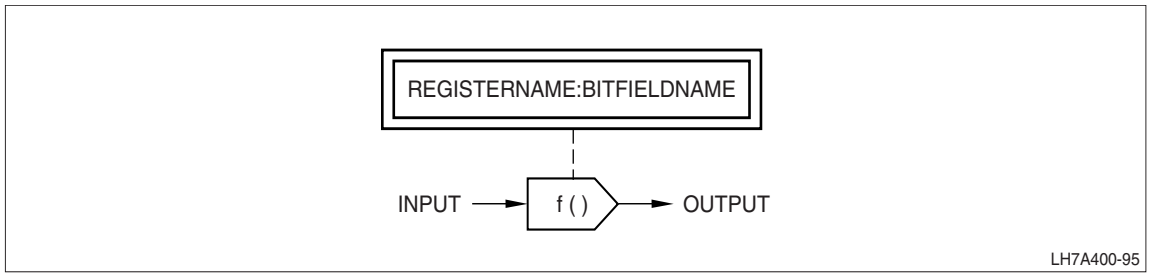


Figure 2. Register with Bit-Field Named

Figure 4 is similar to Figure 2 except that Figure 4 references multiple (different) BITFIELDS in the REGISTERNAME register.

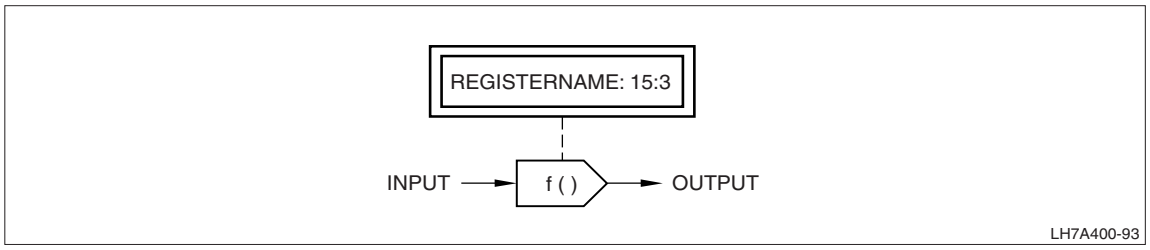


Figure 3. Register with Multiple Bit-Fields Named

Not all bit fields are named. If a bit field has no name, the Register is shown with numbers indicating the appropriate bit positions, with the least significant bit on the right, as in Figure 4. This bit ordering matches that of the Register tables, shown in Table 1.

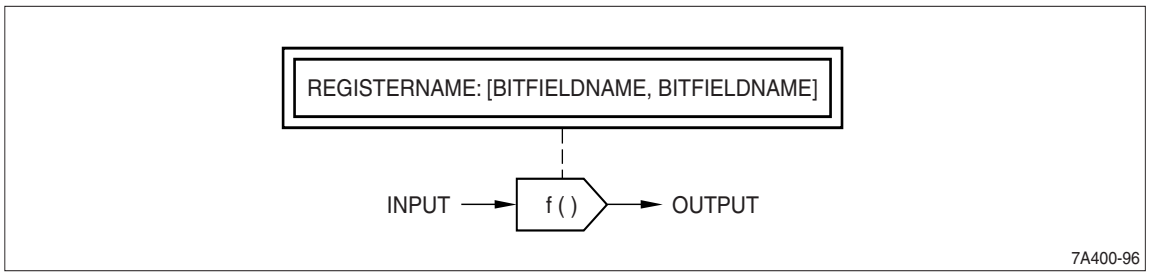


Figure 4. Register with Bit-Field Numbered

What's in This User's Guide

Chapter 1 – Introduction

This contains the complete LH7A400 BGA pinout is presented in tabular format. Included is the pin description, reset state, standby state, and output drive current (for output pins).

Chapter 2 – System Overview

This Chapter lists the features of the LH7A400 MCU and presents a simplified block diagram of the device, with the major architectural features identified.

Chapter 3 – Core and Memory Systems

This Chapter presents the theory of operation of the LH7A400 MCU, including an overview of the ARM922T processor and MMU. The theory of operation covers bus architecture, bus arbitration, and the base addresses for each of the Advanced High-Performance Bus (AHB) and Advanced Peripheral Bus (APB) devices and the APB Bridge. Coverage of the memory system includes memory mapping, memory remapping, and the External Bus Interface (EBI). This Chapter provides programmer's models, programmable parameters, default memory widths, address mapping, and includes a register summary and register descriptions for the core and memory map.

Chapter 4 – Static Memory Controller

This Chapter presents the theory of operation of the LH7A400 Static Memory Controller (SMC), including programmable parameters, default memory widths, and address mapping. Also included in this chapter is operational description fo the PCMCIA and CompactFlash cards. This Chapter includes a register summary and register descriptions for the SMC.

Chapter 5 – SDRAM Controller

This Chapter presents the theory of operation of the LH7A400 Synchronous Dynamic RAM Memory (SDRAM) Controller, including programmable parameters, device selection, memory widths, and address mapping. This Chapter includes a register summary and register descriptions for the SDRAM Controller.

Chapter 6 – Clock Domains and State Machine

This Chapter presents an overview of the LH7A400 Clock and State Controller (CSC), including a block diagram, a list of clock signals, power control modes, programmer's model, register summaries, state diagram, and register descriptions.

Chapter 7 – I/O Control and Multiplexing

This Chapter is an overview of the LH7A400 I/O Controls and pin Multiplexing. The Chapter provides a block diagram, programmer's model, register summary and descriptions.

Chapter 8 – Interrupt Controller

This Chapter describes the LH7A400 Interrupt Controller. The Chapter includes a short overview, a block diagram, programmer's model, interrupt channel list, register summaries, and register descriptions.

Chapter 9 – DMA Controller

This Chapter describes the DMA operations available in the LH7A400 MCU, latencies from one process to another, and the interrupts involved.

Chapter 10 – Color LCD Controller

This Chapter describes the Color LCD Controller (CLCDC) and the HR-TFT Controller (HRTFTC) functional blocks within the LH7A400. The Chapter includes a brief overview, lists the types of panels supported, and at what bit-depths. The Chapter also lists and explains the programmable parameters, presents a programmer's model, and includes a register summary. Register descriptions, with reset values, and horizontal timing restrictions are provided.

Chapter 11 – Watchdog Timer

This Chapter describes the LH7A400 Watchdog Timer (WDT). The Chapter includes a short overview, block diagram, programmer's model, signal descriptions, operating sequences, register summaries and register descriptions.

Chapter 12 – Real Time Clock

This Chapter describes the LH7A400 Real Time Clock (RTC). The Chapter includes a short overview, a block diagram, a list of clock signals, programmer's model, signal descriptions, operating sequences, register summaries, register descriptions and interface signals.

Chapter 13 – Timer Counters

This Chapter describes the LH7A400 Timer Counters. The Chapter includes a short overview and block diagram, signal descriptions, operation sequences, register summaries, register descriptions, and interface signals.

Chapter 14 – Synchronous Serial Ports

This Chapter presents an overview of the LH7A400 Synchronous Serial Ports, a block diagram, programmer's model, register summary, register descriptions, Interrupts, and register locations.

Chapter 15 – UARTs

This Chapter presents the LH7A400 UART blocks. The Chapter includes a brief overview, block diagram, programmer's model, programmable parameters, register summary and register descriptions.

Chapter 16 – General Purpose Input/Output

This Chapter presents the LH7A400 General Purpose Input/Output (GPIO) systems, beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 17 – Multi-Media Card Adapter

This Chapter presents the LH7A400 Multi-Media Card (MMC) adapter, beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 18 – USB Device

This Chapter presents the LH7A400 USB Device, beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 19 – AC97 Codec

This Chapter presents the LH7A400 AC97 Codec, beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 20 – Audio Codec

This Chapter presents the LH7A400 Audio Codec, beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 21 – Battery Monitor Interface

This Chapter presents the LH7A400 Battery Monitor Interface (BMI), beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 22 – DC-DC Converter Interface

This Chapter presents the LH7A400 DC-DC Converter interface, beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 23 – Smart Card Interface

This Chapter presents the LH7A400 Smart Card Interface (SCI), beginning with a brief overview, and including a block diagram, programmer's model, register summary, and register descriptions.

Chapter 24 – Glossary

This Chapter contains an alphabetical listing of common terminology appearing in this User's Guide.

Chapter 1
Introduction

1.1 Description

The LH7A400 is a fully-integrated MCU based on the 32-bit ARM922TDMI™ core. The core comprises an ARM9TDMI™ RISC CPU, Cache RAM, a Write buffer, Memory Management Unit (MMU), and Translation Lookaside Buffer (TLB). Complementing the core are a Direct Memory Access Controller, Interrupt Controller, Color LCD Controller, 80K of internal SRAM, and high performance functional blocks that provide a glueless interface to external memory. A fully static design provides low voltage operation and a complete set of power management features.

Features of the LH7A400 include:

- Serial and Parallel interfaces
- Three Programmable Timers
- Real Time Clock
- Watchdog Timer
- Three UARTs; one with Infrared support (IrDA)
- AC97 and standard Audio Codec
- USB device interface
- Battery Monitor interfaces
- MultiMediaCard/Secure Digital
- Smart Card interface (ISO7816)
- Up to 60 General Purpose I/O
- Two DC-DC Converters (Pulse Width Modulators)

On-chip phase lock loops (PLLs) supply a Clock Tree for core, Advanced High-speed Bus (AHB) and Advanced Peripheral Bus (APB) communication. JTAG support is provided to simplify debugging.

1.2 Functional Pin List

The current pin listings are located in the LH7A400 Data Sheet.

Chapter 2
System Overview

2.1 Introduction

This Chapter introduces the NXP LH7A400 Universal MCU, lists the features, and describes the internal architecture and operation in general terms. Subsequent chapters of this User's Guide explain the major features and functions in more detail. This chapter and the Terms and Conventions in the Preface provide a foundation for subsequent chapters.

2.2 Features

The NXP LH7A400, powered by an ARM922T core, is a complete MCU designed with a high level of integration to satisfy a wide range of requirements and expectations. This design lowers overall system costs, reduces development cycle time, and accelerates product introduction. The LH7A400 includes the following features:

- ARM922T Core
  - 32-bit ARM9TDMI RISC Core
  - 16KB Cache: 8KB Instruction Cache
  - 8KB Data Cache
  - MMU (WinCE™ Enabled)
- High Performance (200 MHz)
- 80KB On-Chip Memory
- External Bus Interface
  - 100 MHz
  - Asynchronous SRAM/ROM/Flash
  - Synchronous DRAM/Flash
  - PCMCIA
  - CompactFlash
- Clock and Power Management
  - 32.768 kHz and 14.7456 MHz Oscillators
  - Programmable System Clocks
  - Programmable Clock Divider Output
- Low Power Modes
  - Run (147 mA)
  - Halt (41 mA)
  - Standby (42 μA)

- Programmable LCD Controller
  - Up to 1,024 × 768 Resolution
  - Supports STN, Color STN, TFT, HR-TFT, AD-TFT
  - Up to 64,000 Colors and 15 Gray Shades
- DMA (10 Channels)
  - AC97
  - MMC
  - USB
- USB Device Interface (USB 1.1)
- Synchronous Serial Port (SSP)
  - Motorola SPI™
  - Texas Instruments SSI
  - National MICROWIRE™
- Three Programmable Timers
- Three UARTs
  - 16C550-like
  - Classic IrDA (115 kbit/s)
- Smart Card Interface (ISO7816)
- DC-to-DC Converters
- MultiMediaCard™ Interface
- AC97 Codec Interface
- Smart Battery Monitor Interface
- Real Time Clock (RTC)
- Up to 60 General Purpose I/Os
- Programmable Interrupt Controller
- Watchdog Timer
- JTAG Debug Interface and Boundary Scan
- Operating Voltage
  - 1.8 V Core
  - 3.3 V Input/Output (1.8 V I/O Optional)
- Operating Temperature
  - -40°C to +85°C
- 256-Ball PBGA or 256-ball CABGA Packages

2.3 Block Diagram

The LH7A400, shown in Figure 2-1, is organized around two 32-bit internal buses and operates with two external crystals, as described below and shown in Figure 2-1:

- 32.768 kHz crystal to control power-down operations and the Real Time Clock (RTC)
- 14.7456 MHz crystal to generate the main system clock domains.

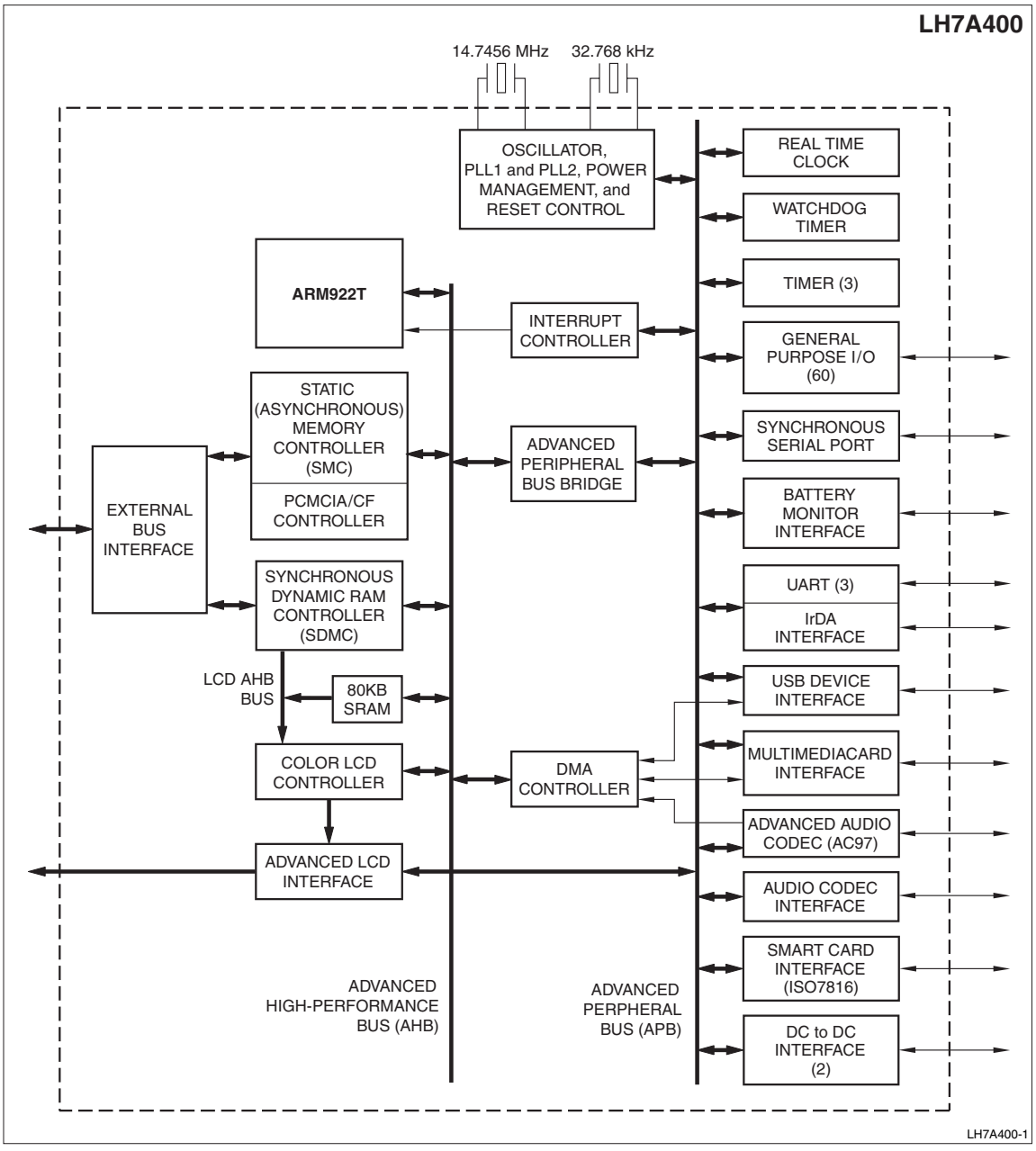


Figure 2-1. LH7A400 Block Diagram

The LH7A400 includes an ARM922T core, a 10-channel Direct Memory Access (DMA) controller (DMAC) and a DMA-enabled Color LCD Controller (CLCDC) on a 32-bit Advanced High-Performance Bus (AHB). This high level of integration promotes the concurrency of tasks such as LCD flat-panel refresh while the core is operating in cache.

The LH7A400 on-chip memory resources include 80KB of internal Static RAM (SRAM) embedded memory, a Static (asynchronous) Memory Controller (SMC), and a Synchronous Dynamic RAM (SDRAM) Controller for interfacing to external memory devices. The embedded memory is designed to be used for storing code, data, or LCD frame data and to be contiguous with external SDRAM. The 80KB is large enough to store a QVGA panel (320 × 240) at eight bits per pixel, equivalent to 70KB of information. Speed-critical memory interface control signals are pipelined to facilitate the use of the fast, local modes offered by industry-standard dynamic RAM (DRAM) devices.

Essential on-chip peripherals are accessed via a 32-bit Advanced Peripheral Bus (APB) connected to the Advanced High speed Bus (AHB) by a 32-bit Bridge. The AHB, APB, and Bridge conform to the ARM Advanced Microcontroller Bus Architecture (AMBA) specification. The 10-channel DMAC can transfer data between memory and peripherals to promote efficient AHB bandwidth utilization.

The LH7A400 can respond to interrupts from 28 different sources, 8 of which are external. All external interrupts can be conditioned in software for level or edge sensitivity. The Watchdog Timer (WDT), Battery Low, Media Change (MEDCH), and one of the external interrupt sources are treated as Fast Interrupt Request (FIQ) interrupts, reducing the hardware overhead in responding to these interrupts.

The LH7A400 can be reset by external input or by an internal signal from the WDT. The active LOW Power On Reset (nPOR), active LOW Power Failure (nPWRFL), and active LOW User Reset (nURESET) external signals generate system resets. The nPOR signal generates a full system reset. The nPWRFL and nURESET signals allow the system to maintain the Real Time Clock and SDRAM contents.

The LH7A400 has three operational states for power efficiency:

- In Run State, all clocks can be active including the processor clock. Software can activate and deactivate individual clocks.
- In Halt State, the device is functioning but the processor clock is halted, waiting for an event such as a key press.
- In Standby State, the main oscillator is shut down, shutting down all peripheral clocks, and the LCD is disabled. Only the 32.768 kHz oscillator, the RTC, and the State Controller remain active. This is the lowest power state of the chip.

Additional information and documentation about AMBA, AHB, APB, and other ARM concepts is available from ARM at http://www.nxp.com/redirect/arm.com.

Chapter 3
Core and Data Paths

3.1 Theory of Operation

The LH7A400 includes an ARM922T Core, 80KB of embedded SRAM (eSRAM), and on-chip memory controllers for a glueless interface to external memories. The Core and memory controllers use a 32-bit AHB for system interfaces and an External Bus Interface (EBI) for external interfaces. On-chip peripherals are accessed via a 32-bit APB, connected to the AHB through a 32-bit Bridge. Figure 3-1 shows the Core, buses, memory controllers, EBI, DMA paths, and eSRAM.

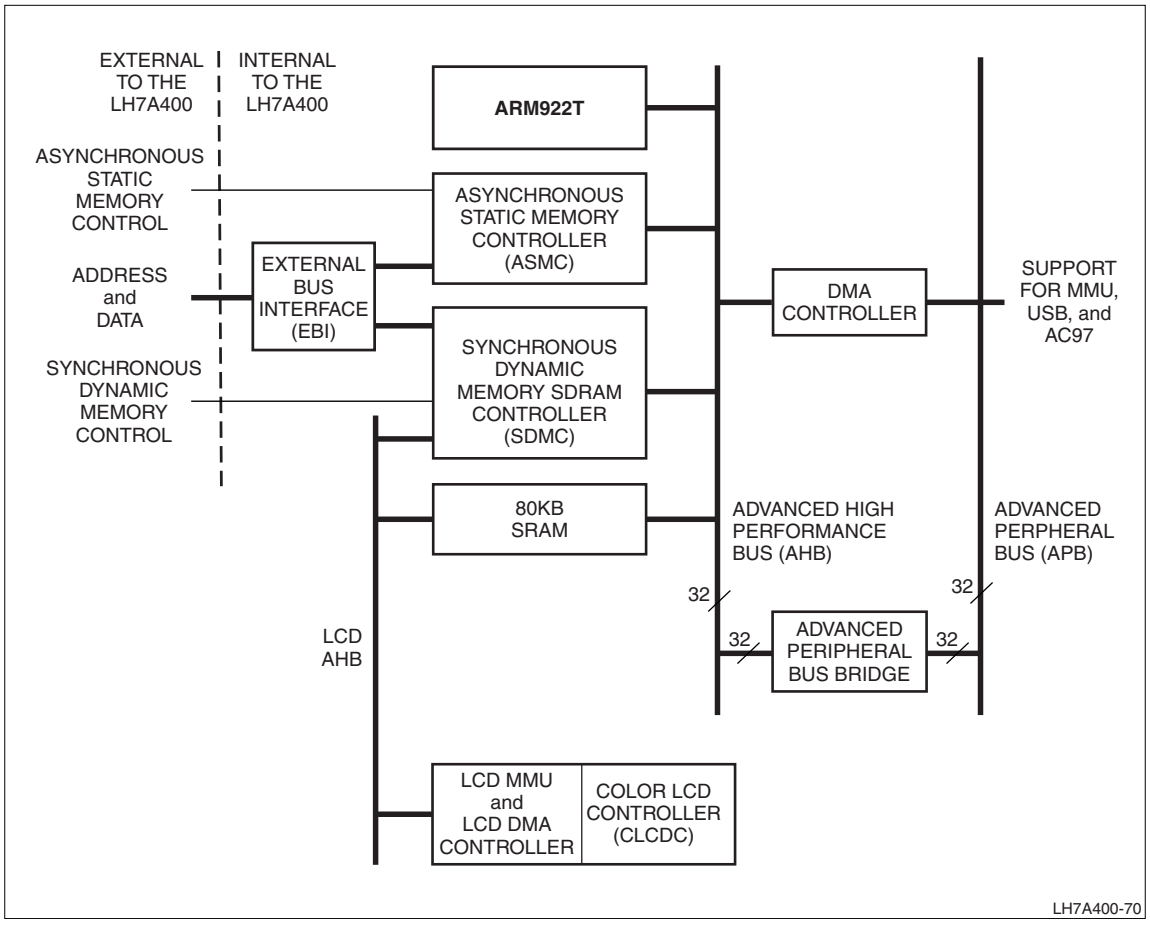


Figure 3-1. LH7A400 ARM Core and Memory Interfaces

The address bus is 32 bits wide, allowing the LH7A400 to address up to 4GB of memory. This memory space is divided into banks allocated to the Static Memory Controller (SMC) or to the Synchronous Dynamic RAM Controller (SDMC). Multiple boot modes are available for booting from Synchronous or Asynchronous ROM or Flash. Little-endian storage is used throughout the LH7A400.

The LH7A400 includes two AHB Masters, the ARM922T Core and the on-chip DMA Controller, with a fixed hardware priority. The DMA Controller supports streams from the MultiMediaCard Controller (MMC), AC97 Codec (AC97), and Universal Serial Bus (USB) peripherals. The Color LCD Controller (CLCDC) includes a separate, dedicated LCD AHB for specific CLCDC accesses to the 80KB of eSRAM and to the SDMC.

Because the ARM922T is a fully static design, the LH7A400 Core and bus clock signals can be stopped indefinitely, with no loss of internal data.

3.1.1 Operating States

The LH7A400 operates in three possible states: Run, Standby, and Halt.

The Run state is the normal operation of the system. All clocks can be active; the CPU may set some clocks to inactive in the Run state. All peripherals and controllers can also be active in the Run state.

The Halt state provides a low-power option when the system is waiting for an event, such as a keyboard input. In this mode, processor clocks are deactivated and other clocks may be deactivated by software. The LCD and all other peripherals remain active.

The Halt state can only be entered from Run by the CPU reading the Halt memory location 0x8000.0408. Halt exit and return to Run is triggered by:

- IRQ
- FIQ
- User Reset
- Power Fail signal.

In the Standby state, only the clocks derived from the 32.768 kHz clock are active. With these clocks enabled, only the Real Time Clock and state controller remain active. Although the other clocks are disabled, the internal chip state is maintained so normal program flow can continue upon exiting Standby. This is the lowest power consumption state.

Standby can be entered by:

- Read from STBY location, 0x8000.040C
- LOW nPWRFL (Power Fail) signal
- LOW nURESET (User Reset) signal
- LOW nPOR (Power On Reset) signal
- Write to CLKSET register

Standby exits to Run when an interrupt occurs (except as described below), on a rising edge on the Wakeup pin, or upon exit from a CLKSET Write. When transitioning from Reset to Run, a delay of 8 - 16 ms occurs to allow the PLL to stabilize. If Standby was entered due to a nPOR signal, interrupts will be disabled and cannot trigger an exit from Standby to Run.

3.1.2 Instruction and Data Cache

The ARM922T Core includes separate 8KB Instruction and Data Caches, Cache Controllers, MMU, and a Write Buffer. These elements and the associated information flows are shown in Figure 3-2.

The Cache is an important Core feature because the AHB carries all Core, DMA, SMC, SDMC, and eSRAM traffic. For best bandwidth utilization, structure software to ensure the Core runs from within cache whenever possible. When the MMU is used, software can specify memory cachability by segment or by page.

At reset, the Write Buffer, Caches and MMUs are disabled and the MMU Translation Lookaside Buffers (TLB) are flushed.

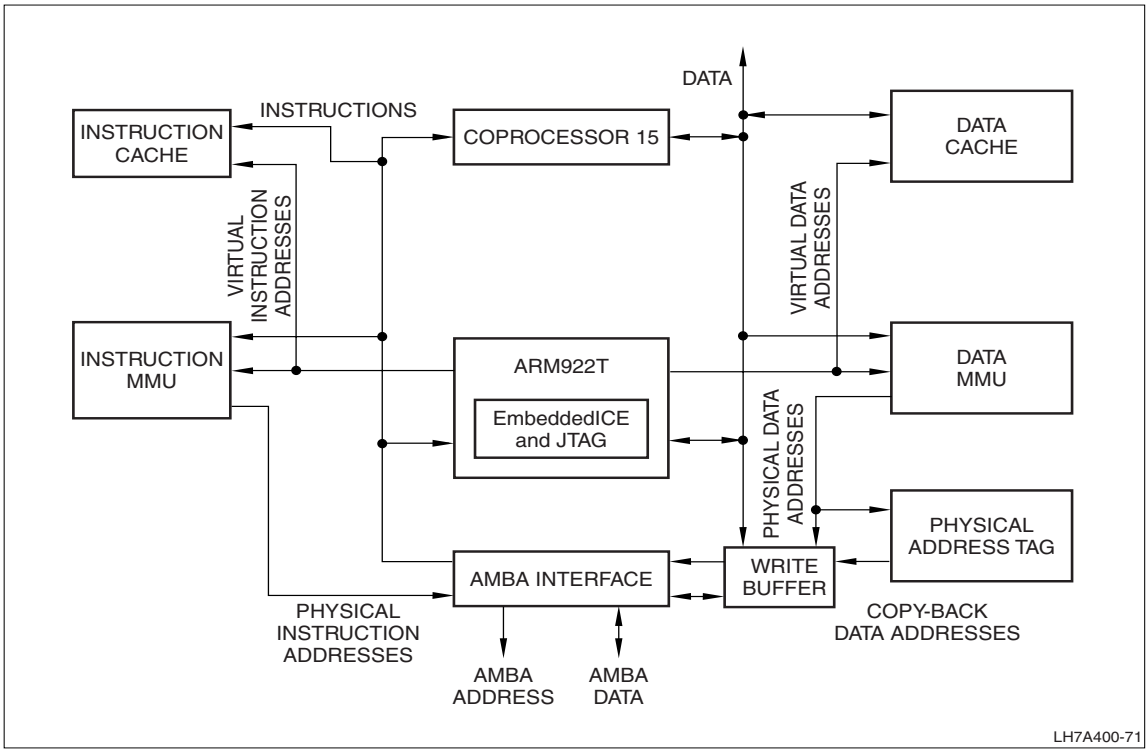


Figure 3-2. ARM922T Core Organization

3.1.3 Memory Management Unit

The ARM922T Data and Instruction MMUs perform the following primary functions:

- Translate virtual addresses into physical addresses
- Enable cache and write buffering for particular ranges of virtual addresses
- Control memory access permissions.

The MMU is turned off at reset. When the MMU is turned off, all virtual addresses are output directly onto the physical address bus (the AHB).

Each MMU supports memory accesses based on the following memory block sizes:

- Sections are 1MB blocks of memory
- Tiny pages are 1KB blocks of memory
- Small pages are 4KB blocks of memory
- Large pages are 64KB blocks of memory.

Large pages allow mapping a large region with a single entry in the Translation Lookaside Buffer (TLB). Additional access control mechanisms are extended to 16KB subpages.

For information on the ARM922T MMU, see the ARM922T Technical Reference Manual, available from ARM, Ltd.

3.1.4 Internal and External Memory

The LH7A400 can use both on-chip and external memory. The on-chip eSRAM is 80KB. The amount and type of external memory depends on the application.

The LH7A400 External Bus Interface (EBI) and memory controllers provide access for the following external memory technologies:

- The SDMC provides the Chip Selects and other interface signals for external SDRAM, often the only external volatile memory used in a system.
- The SMC provides the chip selects and interface signals for other types of external memory such as RAM, ROM, and Flash memory; and for external devices with similar memory interfaces. The byte-lane signals interface with 8-, 16-, and 32-bit wide devices. Synchronous Banks can include memory of varying technologies and widths. However, all devices within a Bank controlled by the LH7A400 SMC must have similar access characteristics, such as bus width, access time, and number of wait states. The SMC includes PCMCIA and Compact Flash (CF) PC card support.

3.1.4.1 Memory Map

The 32-bit wide address bus can address up to 4GB of memory. This space is subdivided into a number of memory banks and control registers (see Figure 3-3):

- Four 256MB banks are allocated to the SDMC.
- Eight 256MB banks are allocated to the SMC. Two of these banks support PCMCIA and CF PC Card systems.
- Part of the remaining memory space is allocated to the eSRAM and the bus control registers.
- The remainder of the space is reserved.

Each Memory Controller and peripheral controller in the LH7A400 is assigned to a specific range of the memory map, as shown in Figure 3-3. For external memory, this assignment determines the range of addresses over which each chip select signal is valid. This assignment provides the following flexibility:

- Two versions of the memory map are available as default configurations after reset, to support booting from synchronous or asynchronous memory. (See Section 3.1.5.)
- Software can reconfigure the memory map via the ARM MMU Coprocessor 15 (CP15) commands. Designers can use this flexibility to optimize system performance at low cost.

When memory is addressed on word (4 byte) boundaries, both the SMC and the SDMC provide sequential Load and Store contiguity between the external memory banks. In addition to programmable wait states, the LH7A400 provides an nWAIT input for peripherals with very long or indeterminate access times.

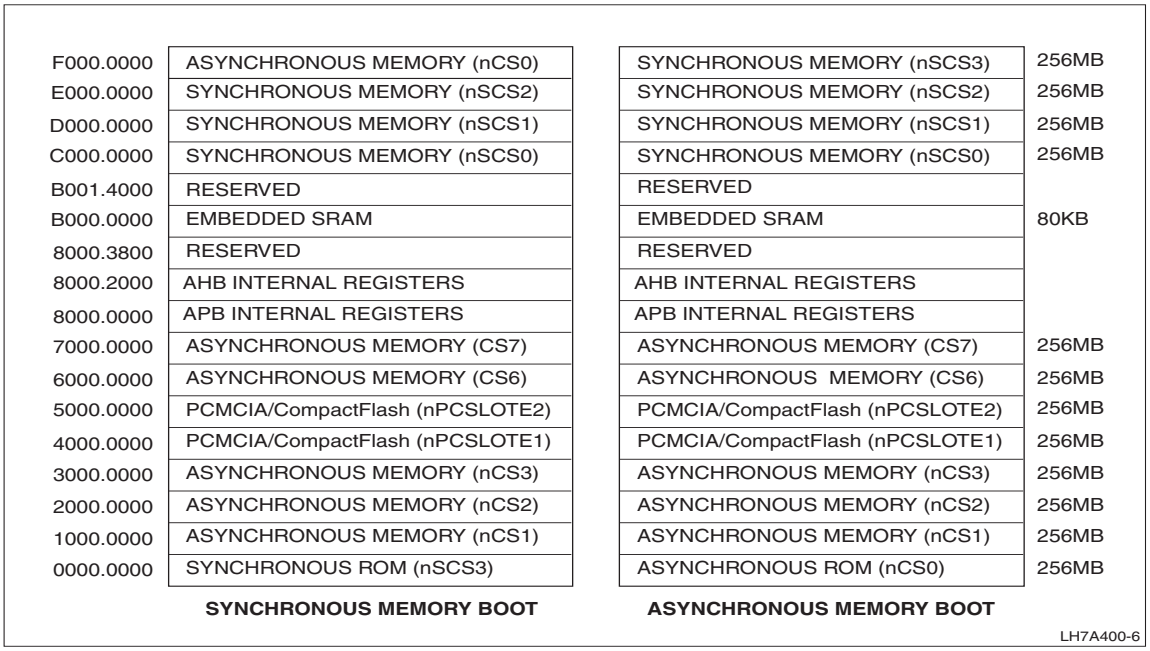


Figure 3-3. Memory Controller Address Range

3.1.5 Boot Modes

The LH7A400 can boot from either Synchronous or Asynchronous ROM or Flash memory. The boot mode is specified at power-on reset by the Media Change signal (MEDCHG, pin C3) and the Boot Width signals (WIDTH[1:0], pins P11 and R12, respectively). The signal values for each boot mode are shown in Table 3-1.

The boot mode determines the memory mapping, as shown in Figure 3-4. To boot from Synchronous memory, configure the WIDTH and MEDCHG signals to map SDMC Bank 3 (nSCS3, pin A12) to memory location 0x0000.0000. To boot from Asynchronous memory, map SMC Bank 0 (nCS0, pin K11) to memory location 0x0000.0000. After the LH7A400 has booted, software can reconfigure the mapping.

Table 3-1. Boot Mode Signals

BOOT MODE	WIDTH[1:0]	MEDCHG
8-bit ROM	00	0
16-bit ROM	01	0
32-bit ROM	10	0
Invalid: Do not allow this condition.	11	0
16-bit SFlash (Initializes device MODE Register)	00	1
16-bit SROM (Initializes device MODE Register)	01	1
32-bit SFlash (Initializes device MODE Register)	10	1
32-bit SROM (Initializes device MODE Register)	11	1

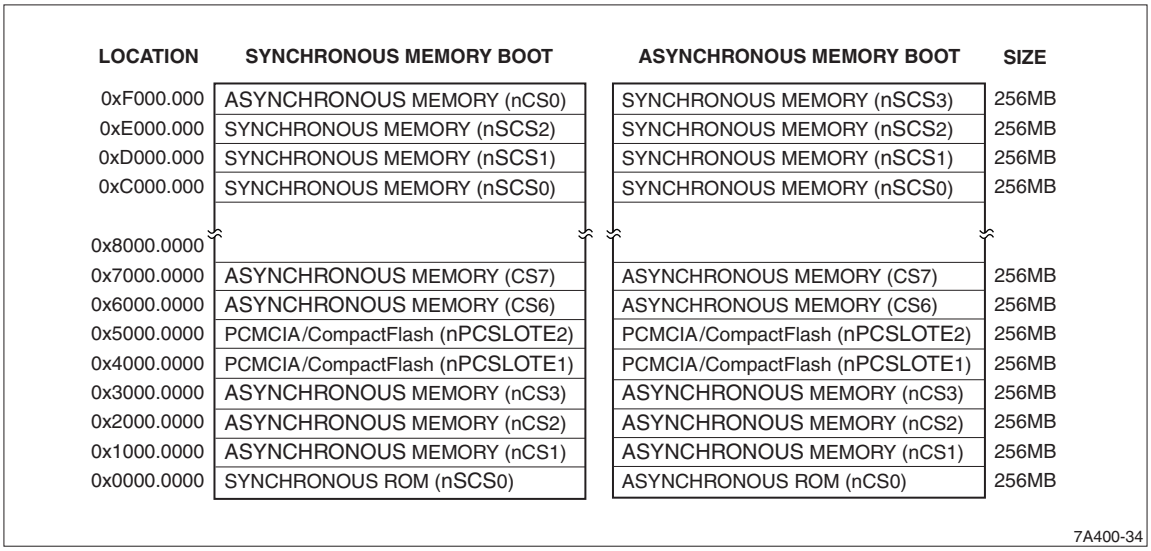


Figure 3-4. Synchronous and Asynchronous Boot Mode Memory Maps

3.2 Buses

The LH7A400 AMBA bus backbone is shown in Figure 3-1. The Color LCD Controller (CLCDC), DMA controller, eSRAM, external Synchronous and Asynchronous Memory Controllers (SDMC and SMC), and the ARM922T Core are connected to the AMBA AHB. The other peripheral interface blocks are connected to the AMBA APB. The AHB and APB are connected together via the Bridge. The EBI provides a 32-bit wide gateway to external memory, supporting the Synchronous and Asynchronous external memories.

Additional data paths within the system include:

- The LCD AHB. This bus connects the CLCDC to the eSRAM and the SDMC, allowing the CLCDC to automatically refresh the video screen from eSRAM, external DRAM, or both without using the system AHB.
- The DMA controller provides AHB access for the higher speed USB, MMC and AC97 peripherals. This allows data to be quickly and efficiently transferred to these blocks without the intervention of the ARM922T Core.

3.2.1 Advanced High-Performance Bus (AHB)

The LH7A400 includes an AHB for high-performance, high clock frequency system modules. The AHB connects the Core and all other on-chip blocks capable of mastering the AHB with all memory resources and peripherals. The main AHB data and address lines are configured using a multiplexed bus, removing the need for tristate buffers and bus holders and simplifying bus arbitration.

The AHB allows connection of CPUs, on-chip memory, and off-chip external memory interfaces with low-power peripherals. The APB Bridge transparently converts AHB access into the slower speed APB accesses. All control registers for the APB peripherals are programmed using the AHB Bridge.

3.2.1.1 Arbitration

Two blocks can act as AHB bus Masters or Slaves:

- DMA Controller
- ARM922T Core

Other blocks can act as AHB slaves:

- Color LCD Controller (CLCDC)
- embedded SRAM (eSRAM)
- Synchronous Dynamic RAM Controller (SDMC)
- Static Memory Controller (SMC)

Table 3-2 and Figure 3-5 show the blocks residing on the AHB.

Arbitration ensures only one Master has access to the bus at any one time. The arbiters observe all concurrent bus requests and identify the highest priority Master requesting the bus. The following comprise the LH7A400 arbitration scheme, as shown in Figure 3-5:

- The main AHB system bus arbiter controls system AHB access for the ARM922T Core and the DMA controller. The ARM922T Core and the DMA Controller have the following order of priority, corresponding to the system clocking and power states:
  - In Halt and Standby, the arbiter grants bus mastery to the default bus Master, the ARM922T Core. Default bus mastery applies only during Halt and Standby.
  - The DMA Controller Halt request has a higher priority than the ARM922T Core request. In normal operation, when the ARM922T has bus mastery and a Halt request occurs, the ARM922T loses bus mastery. The DMA Controller bus can be used during Halt, but is shut down while the LH7A400 is entering Standby.
- The eSRAM Slave arbiter, controlling system AHB and LCD AHB access for the eSRAM. The LCD AHB has priority.
- The SDMC Slave arbiter, controlling system AHB and LCD AHB access for the SDMC. The LCD AHB has priority.
- The SMC slave interface arbiter, controlling system AHB access for the SMC.
- The EBI arbiter, controlling SDMC and SMC access for the EBI. The SDMC has priority.

Table 3-2. AHB Blocks

ADDRESS RANGE	REGISTER WIDTH	BLOCK
0x8000.3000 - 0x8000.37FC	32 bits	Color LCD Controller (CLCDC), including palette
0x8000.2800 - 0x8000.2BFC	32 bits	DMA Controller
0x8000.2400 - 0x8000.27FC	32 bits	Synchronous DRAM Controller (SDMC)
0x8000.2000 - 0x8000.23FC	32 bits	Static (Asynchronous) Memory Controller (SMC)

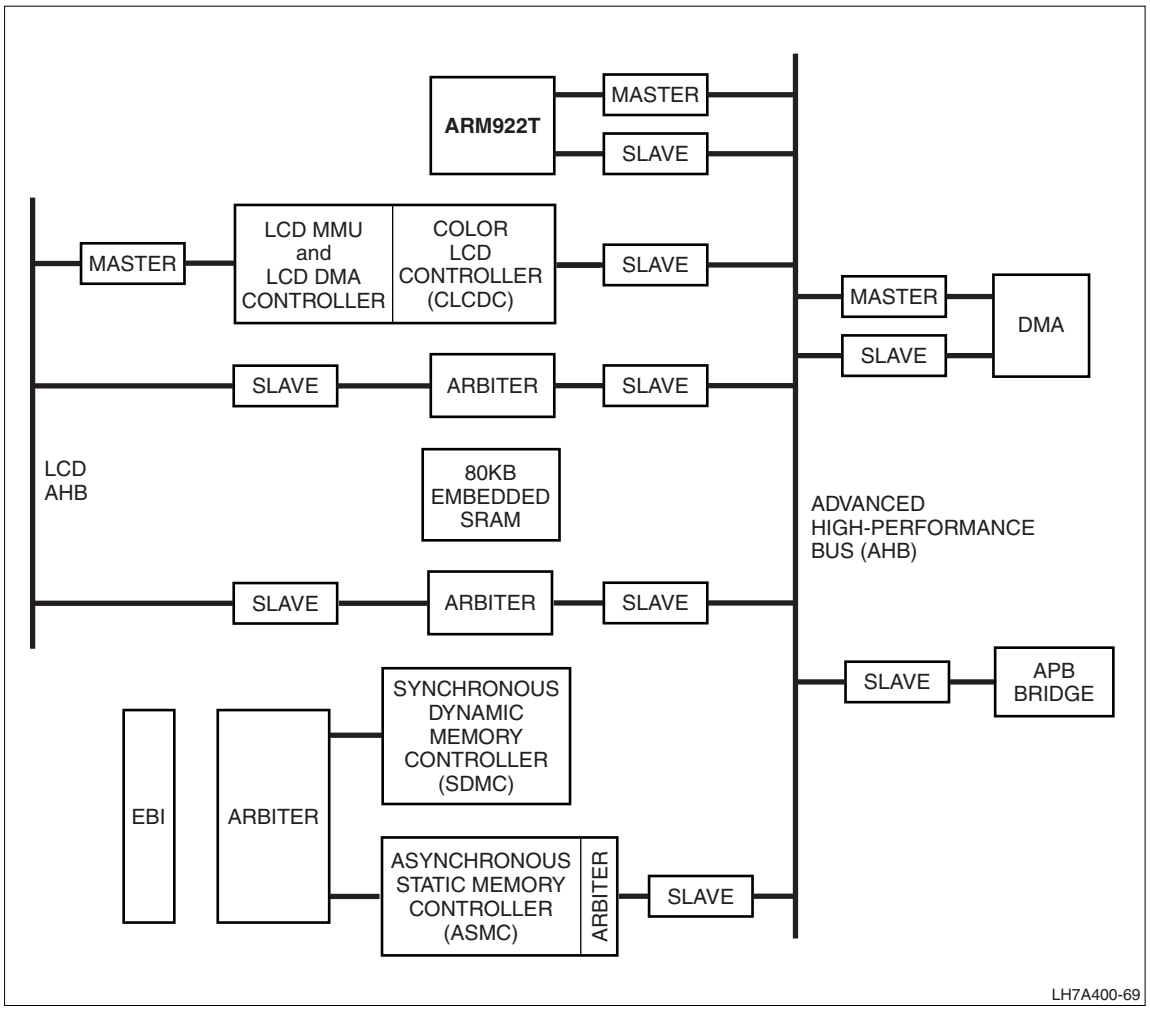


Figure 3-5. AHB Masters and Slaves

3.2.1.2 External Bus Interface

The 32-bit wide EBI, shown in Figure 3-6, provides external memory access for the ARM922T Core, the CLCDC, and the DMA controller. Memory devices supported:

- Asynchronous RAM, ROM, and Flash
- Synchronous DRAM and Flash
- PC Cards (PCMCIA and Compact Flash)

The SDMC and SMC use the EBI for activity involving the ARM922T Core, the DMA controller, and the CLCDC. The ARM922T Core and the DMA Controller share the system AHB, providing access to eSRAM and via the SDMC and SMC to all external memory devices. The CLCDC can use an internal frame buffer in the eSRAM and an extension buffer in external SDRAM, accessed via the SDMC, for dual panel or large displays. The EBI arbiter grants control only when an existing access has been completed.

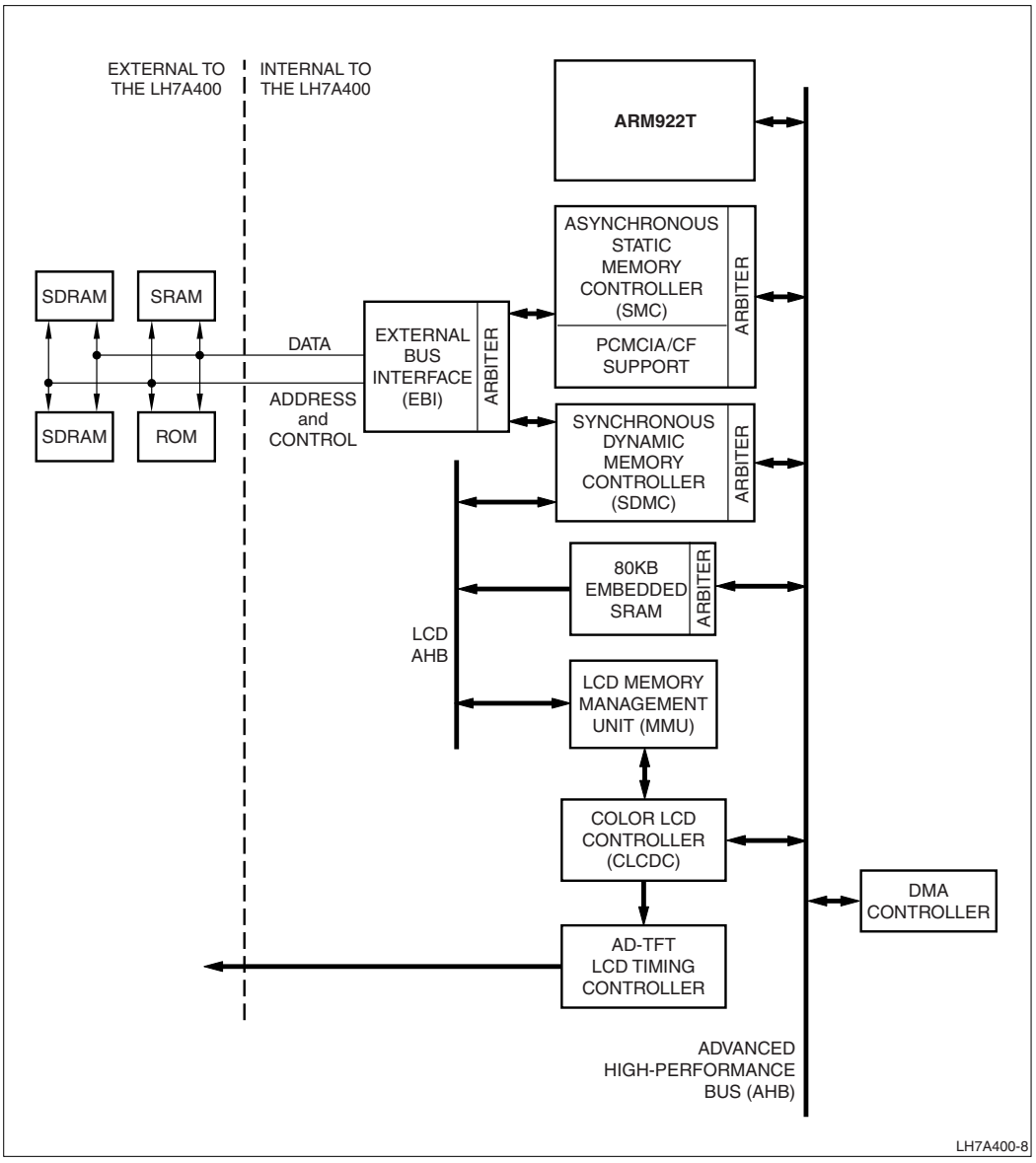


Figure 3-6. LH7A400 External Memory Interface

3.2.1.3 Clock Generation and Bus Clocking Modes

The AHB clocking modes determine the relative operating frequencies of the ARM922T Core and the AHB, and the associated AHB access considerations. The Core and Cache and the AHB interface can operate in any of the clocking modes, summarized in Table 3-3:

- Fastbus Extension
- Synchronous Bus
- Asynchronous Bus

The clocking modes can have significant impact on power consumption and system throughput, depending on the application and the speed of external memory. For example:

- Separate signals clock the Core and the AHB. The Core can operate at a much higher frequency than the AHB. This higher Core speed benefits applications running from the Cache more than applications needing frequent AHB access, because each AHB access requires resynchronizing the Core and AHB.
- Core and AHB activity can operate in parallel with buffered writes to the AHB. However, all read accesses stall the Core until bus access is completed. Software can use the bus clocking modes to maximize throughput by reducing the resynchronization delays; that is, by minimizing the number of wait states.

Table 3-3. Clocking Mode Comparisons

ITEM	STANDARD		FASTBUS EXTENSION
	SYNCHRONOUS BUS	ASYNCHRONOUS BUS	
Clock Signals	HCLK, FCLK	HCLK, FCLK	HCLK, HCLK_CPU
Function	HCLK clocks the AHB. FCLK clocks the Core.	HCLK clocks the AHB. FCLK clocks the Core.	HCLK clocks the AHB. HCLK_CPU clocks the Core.
Clock Signal Frequency Limitations	Requires FCLK ≥ HCLK. FCLK must be an integer multiple (harmonic) of HCLK.	Requires FCLK ≥ HCLK.	The Core operating speed is limited by the maximum AHB speed.
Synchronization	The Core and the AHB are always synchronized, but can be operated at different frequencies.	The Core and the AHB operate asynchronously.	The Core and the AHB are inherently synchronized. No additional synchronization logic is required.
AHB Access	1 wait state minimum.	2 wait states minimum.	No wait states.
Advantages	The Core can operate much faster than the AHB, but the Core speed must be an even integer multiple (harmonic) of the AHB frequency. Using a slower HCLK can reduce the power consumption.	The Core can operate much faster than the AHB. The Core and the AHB can operate at different, unrelated frequencies. Using a slower HCLK can reduce the power consumption. The bus frequency can be optimized for a specific peripheral. Clocking requirements depend on the Core operating speed.	The Core and the AHB operate at the same frequency, driven by the same clock. Inherent synchronization avoids the logic required in the other two bus clocking modes and requires no wait states.
Limitations	The Core operating speed is limited by the maximum Core and AHB speeds. Memory accesses impose delays when the Core and bus operate at different speeds.	Memory access imposes delays, because the Core and the AHB must be re-synchronized whenever the Core accesses the bus.	The Core operating speed is limited by the maximum AHB speed. Memory access imposes no synchronization delays.
Uses	For CPU-intensive applications	For CPU-intensive applications requiring a specific source clock frequency for on-chip peripherals. The peripheral clocks are derived from the bus clock.	For memory-access intensive applications

3.2.1.4 Standard Bus Clocking Modes

The standard Synchronous and Asynchronous bus clocking modes are useful for designs involving low-cost, low-speed memory, when the Core must operate at higher speed than the AHB. These modes involve the following:

- A programmable choice of Synchronous or Asynchronous operation
- Two clocks: HCLK and FCLK

For information on clock generation and clock domains, see the chapter in this User's Guide entitled Clock and State Control.

The AHB interface is clocked by HCLK, qualified by a WAIT signal. Figure 3-7 shows the Standard mode clocking. FCLK drives the Core and Cache, while HCLK drives the bus. FCLK must always be ≥ HCLK, on a cycle-by-cycle basis.

Although the frequency of FCLK must always be greater than or equal to HCLK, the Standard modes vary the relationship between these two clock signals:

- In Synchronous Bus mode, the FCLK frequency must be programmed as an integer multiple of the HCLK frequency. Synchronous Bus mode accesses require a re-synchronization delay of at least one wait state.
- In Asynchronous Bus mode, the harmonic relationship between the clocks need not be maintained. The two clock signals can have unrelated frequencies. Asynchronous Bus mode accesses require a minimum re-synchronization delay of two wait states.

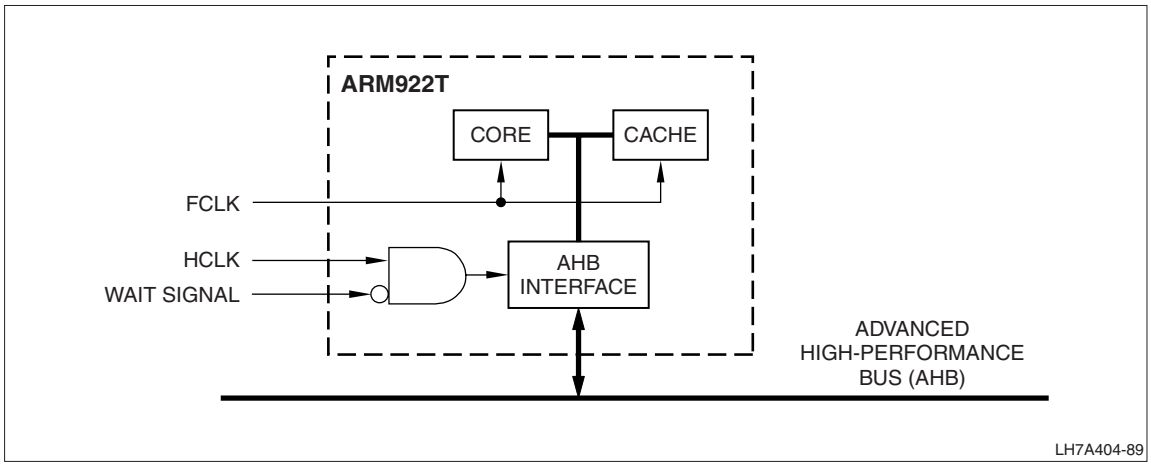


Figure 3-7. Standard Mode Clocking

3.2.1.5 Fastbus Extension Bus Clocking Mode

Designs involving frequent high-speed memory accesses can benefit from the Fastbus Extension mode. This inherently synchronous mode clocks the Core, Cache, and AHB at the same frequency. In contrast to the Standard mode usage of two different clocks, the Fastbus Extension mode operates the Core, Cache, and AHB interface using two signals derived from the same source — essentially, the same clock. Figure 3-8 shows the Fastbus Extension clocking. Fastbus Extension mode accesses require no re-synchronization delays.

The Fastbus Extension mode is useful for applications involving frequent AHB accesses. Although the Core frequency is limited by the AHB maximum frequency, the Fastbus Extension mode avoids the wait state penalties imposed by the Standard modes.

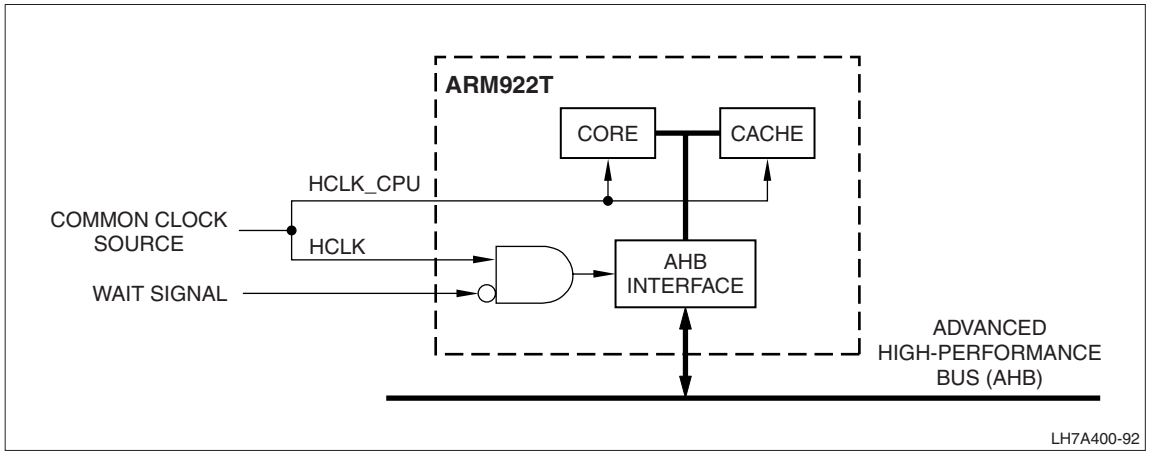


Figure 3-8. Fastbus Mode Clocking

3.2.1.5.1 Reset Condition

After reset, the LH7A400 is in Fastbus Extension mode, using only HCLK and not FCLK. Switch to Synchronous Bus mode to use FCLK for internal cached operations and HCLK for external (AHB) operations. In Asynchronous Bus mode, the LH7A400 can operate at any ratio of FCLK to HCLK. However, when FCLK = HCLK, maximum performance can be obtained by running in Fastbus Extension mode.

To switch modes, use Coprocessor 15 (CP15) Register 1, as described in the ARM documentation. The programming sequence depends on the switching direction:

- When switching from a divide ratio of 1 to 2 or more, change the bus mode to Synchronous Bus mode before writing the CLKSET register.
- When switching from a divide ratio of 2 or more to 1, change the bus mode to Fastbus Extension mode after writing to the CLKSET register and returning out of Standby.

3.2.2 Advanced Peripheral Bus (APB)

The LH7A400 includes an APB for on-chip peripherals. The APB peripherals communicate with the AHB through a Bridge. The APB is designed for low-speed peripherals requiring lower performance than a pipelined interface such as the AHB. Table 3-4 shows the addresses of the peripherals on the APB.

Table 3-4. APB Peripheral Address Map

ADDRESS RANGE	REGISTER WIDTH	PERIPHERAL
0x8000.1500 - 0x8000.1FFC	16 bits	Reserved
0x8000.1400 - 0x8000.14EC	32 bits	Watchdog Timer (WDT)
0x8000.1000 - 0x8000.13EC	16 bits	Reserved
0x8000.0F00 - 0x8000.0FFC	32 bits	Battery Monitor Interface (BMI)
0x8000.0E00 - 0x8000.0EFC	16 bits	General Purpose Input and Output (GPIO Ports A through H)
0x8000.0D00 - 0x8000.0DFC	32 bits	Real Time Clock (RTC)
0x8000.0C00 - 0x8000.0CFC	16 bits	Timer Counters (TC1, TC2, TC3)
0x8000.0B00 - 0x8000.0BFC	16 bits	Synchronous Serial Port Controller (SSP)
0x8000.0A00 - 0x8000.0AFC	16 bits	Audio Codec Interface
0x8000.0900 - 0x8000.09FC	16 bits	DC-DC Converters (PWM0, PWM1)
0x8000.0800 - 0x8000.08FC	16 bits	Universal Asynchronous Receiver and Transmitter (UART3)
0x8000.0700 - 0x8000.07FC	16 bits	UART2
0x8000.0600 - 0x8000.06FC	16 bits	UART1 and Infrared Interface
0x8000.0500 - 0x8000.05FC	32 bits	Interrupt Controller
0x8000.0400 - 0x8000.04FC	16 bits	Clock and State Controller (CSC)
0x8000.0300 - 0x8000.03FC	32 bits	Smart Card Interface (SCI)
0x8000.0200 - 0x8000.02FC	32 bits	Universal Synchronous Bus Client (USB)
0x8000.0100 - 0x8000.01FC	32 bits	Multi-Media Card Controller (MMC)
0x8000.0000 - 0x8000.00FC	16 bits	AC97 Codec Interface (AC97)

3.2.3 The DMA Controller

The DMA Controller provides alternative Core access for the MMU, USB, and AC97 peripheral blocks. Using a DMA operation to access a peripheral block can improve system performance, when the software is structured to ensure the Core runs in Cache during the DMA operation. The DMA Controller can block Core AHB or APB access.

Chapter 4
Static Memory Controller (SMC)

4.1 Theory of Operation

The Static Memory Controller (SMC) is an AHB slave device, providing an interface between the LH7A400 Advanced High-Speed Bus (AHB) and external memory devices. Figure 4-1 shows a block diagram of the LH7A400 SMC.

The SMC provides access to static memory devices on the external bus and can be used to interface to a wide variety of external device types, including SRAM, ROM, and PC Cards. The LH7A400 includes separate memory controllers for SDRAM devices and for the 80KB of embedded SRAM.

The SMC supports eight independently configurable memory banks:

- Two banks dedicated to PCMCIA and CompactFlash (CF) interfaces
- Six banks of external memory, each addresses up to 256MB using external chip select signals.

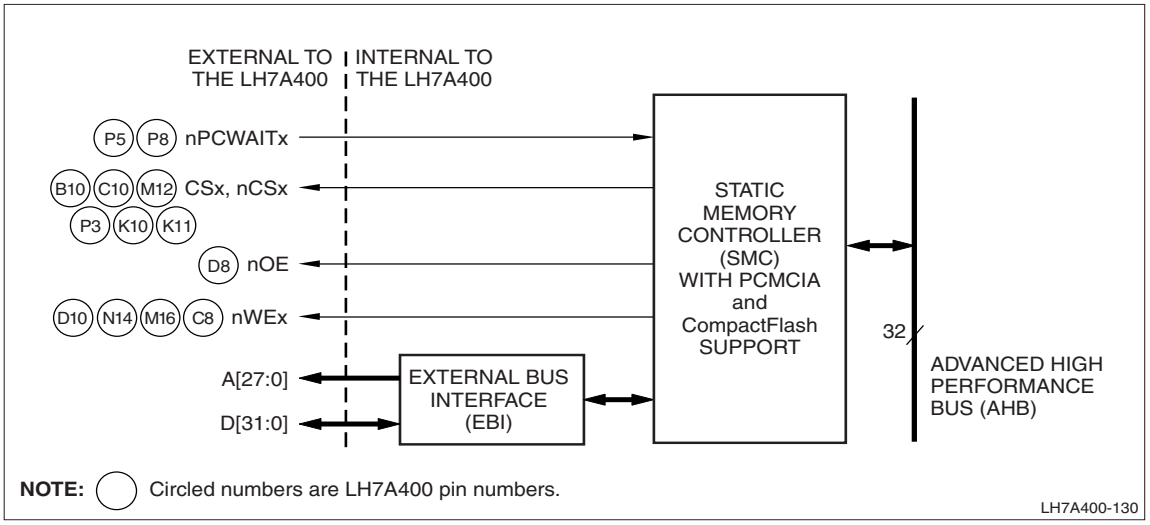


Figure 4-1. SMC Block Diagram

Each memory bank can use devices with either 8-, 16-, or 32-bit external data paths. The SMC supports asynchronous page mode and burst mode read operations and allows up to 32 programmable wait states and programmable bus turnaround cycles.

The following parameters are programmable for each bank of external memory controlled by the SMC:

- Bus turnaround (idle) cycles
- Read and Write wait states, for static RAM devices
- Initial and subsequent burst read wait states
- Write protection
- Burst mode operation for burst ROM devices
- 8-, 16-, or 32-bit external memory width
- Byte lane enable controls
- nWAIT handshake for PCMCIA and CF.

The base address of each bank is hard-coded by the address decoder. A separate SMC Chip Select signal (nCS[3:0] and CS[7:6]) is provided for each bank of memory.

Byte-Lane Enable signals (nWE[3:0]) are available for use with memory devices of varying widths. Each SMC memory bank has an associated configuration register specifying memory width.

4.1.1 Operation Overview

The SMC performs six primary functions:

- Memory bank selection
- Access sequencing
- Wait state generation
- Byte lane write control
- External bus interface
- CF or PCMCIA interfacing.

Upon power-on reset, the software must configure the SMC for the external devices connected to the system. Configuring and operating the SMC is outlined here.

4.1.1.1 Configuring the Multiplexed Pins

Many of the pins used by the SMC are multiplexed with other LH7A400 functional blocks. Application design must take into account which functions will be used and the pins required for those functions.

Upon reset, software must configure the pins used by the SMC by writing to the PINMUX register (see Chapter 7 and Chapter 16).

4.1.1.2 Using External Memory

After the pin multiplexing is complete, software must set up the memory bank registers to be compatible with the hardware present. The SMC can interface with external static memory of a variety of data widths and timing requirements. This is done by programming the Bank Configuration registers (BCRx) for each bank with the memory width (8-, 16-, or 32-bit), wait states, read/write turnaround times, and specific SRAM and ROM parameters.

External memory is mapped into up to six banks, each with 256MB of addressable space. Addressing within each bank takes place on the 28 external address pins of the LH7A400. Bank selection is determined with four active LOW chip select pins (nCS[3:0]) and two active HIGH chip select pins (CS6 and CS7). The hardware design determines memory bank addressing and memory device type.

Once set up, the SMC then handles all necessary timing, including the logic for making transfers of disparate width data between the external memory bus and the internal AHB. For example, if the external data path is 8 bits, when reading the SMC will assemble four 8-bit bytes into one 32-bit word for transfer on the AHB. When writing, the SMC parses a 32-bit word from the AHB into four 8-bit bytes to be sequentially sent over the external data bus to the external memory devices.

4.1.2 Using PCMCIA and CompactFlash

Two of the eight addressable banks are configured to support PC Cards (PCMCIA and CF devices). The two PC Card slots are selected by the CF and PCMCIA address pins (CFA[10:8] and PCMCIA[25:24]). Three sets of parameters must be programmed by software for each of the two PC Card slots. These three registers contain parameters for the PC Card Attribute address space, Common Memory address space, and I/O address space. If a PCMCIA device is used in one or both slots, parameters specific to the PCMCIA must be programmed by software writing to the PCMCIA Control register (PCMCIACON).

The PCDIR pin (N4) signals whether a data transaction is a read or write. This pin is LOW during reads, and HIGH during writes. See the LH7A400 datasheet for timing diagrams.

Once configured, the SMC handles all timing, data sequencing, and PC Card access logic.

4.1.3 Pin Multiplexing

The SMC BGA pin assignments and multiplexing are shown in Table 4-1. Software must configure the pins using the PINMUX register prior to using any external memory devices. Note that address lines multiplexed with synchronous memory address lines are not shown, as these do not need to be configured.

Table 4-1. SMC Multiplexing

PIN	SIGNAL	DESCRIPTION	MULTIPLEXING
A8	A27	Address line bit 27	Smart Card Reset
F8	A26	Address line bit 26	Smart Card Clock
G8	A25	Address line bit 25	Smart Card I/O
N14	A1	Address Line bit 1 for 8 and 16-bit external systems, used as Write Enable for 32-bit systems.	SMC nWE2
M16	A0	Address Line bit 0 for 8-bit external systems, used as Write Enable for 16-bit and 32-bit systems	SMC nWE1
P5	CFA10	CF address bit 10, in single card mode	GPIO Port H5
	PCMCIAA24	PCMCIA address bit 24, in single card mode	
	nPCWAIT2	CF and PCMCIA, in dual card mode, wait state extension for Card 2	
N7	CFA9	CF address bit 9, in single card mode	GPIO Port H3
	PCMCIAA25	PCMCIA address bit 25, in single card mode	
	nPCSLOTE2	CF and PCMCIA Card 2 Enable, in dual card mode, gating other control signals to the PC Card in Bank 5	
R4	CFA8	CF address bit 8, in single card mode	GPIO Port H1
	PCRESET2	CF and PCMCIA, in dual card mode, Reset Card 2	
C10	CS7	Chip Select for Bank 7	Synchronous Memory Clock Enable 0
B10	CS6	Chip Select for Bank 6	Synchronous Memory Clock Enable 1 and 2
M12	nCS3	Chip Select for Bank 3	Multi-Media Card SPI Select
N14	nWE2	Write Enable for 32-bit external systems, provided as bit 1 of such addresses	SMC A1
M16	nWE1	Write Enable for 16- and 32-bit external systems, provided as bit 0 of such addresses	SMC A0
M7	nPCCE1	CF and PCMCIA Card Enable 1, used with nPCCE2 by both PC Cards for decoding low and high byte accesses	GPIO Port G5
M8	nPCCE2	CF and PCMCIA Card Enable 2, used with nPCCE1 by both PC Cards for decoding low and high byte accesses	GPIO Port G6
T4	nPCSLOTE1	CF and PCMCIA Card 1 Enable, in single or dual card mode, gating other control signals to the PC Card in Bank 4	GPIO Port H2
R3	nPCOE	CF and PCMCIA Output Enable Attribute and Common Memory space read control	GPIO Port G0
T5	nPCSTATRE	CF and PCMCIA Status Enable, for enabling a data bus buffer to read the Battery Voltage Detect and Voltage Sense card signals	GPIO Port H7
T3	nPCWE	CF and PCMCIA Write Enable, Attribute and Common Memory space write control	GPIO Port G1

Table 4-1. SMC Multiplexing (Cont'd)

PIN	SIGNAL	DESCRIPTION	MULTIPLEXING
E6	PCRDY1	CF and PCMCIA, in single or dual card mode, ready for Card 1	GPIO Port F6 or External IRQ Interrupt 5
C5	PCRDY2	CF and PCMCIA, in dual card mode, ready for Card 2	GPIO Port F7 or External IRQ Interrupt 6
N6	nPCREG	CF and PCMCIA Attribute or Common Memory space selection	GPIO Port G4
P8	nPCWAIT1	CF and PCMCIA, in single or dual card mode, wait state extension for Card 1	GPIO Port H4
L6	nPCIOR	CF and PCMCIA I/O space read control	GPIO Port G2
M6	nPCIOW	CF and PCMCIA I/O space write control	GPIO Port G3
N4	PCDIR	CF and PCMCIA Data Direction	GPIO Port G7
P4	PCRESET1	CF and PCMCIA, in single or dual card mode, Reset Card 1	GPIO Port H0

4.1.3.1 Non-SMC Systems

The Synchronous Dynamic RAM Controller (SDRAMC) SCKE1_2 and SCKE0 output signals are multiplexed with the SMC CS6 and CS7 signals on pins B10 and C10, respectively. The GPIO Pin Multiplexing register Clock 1 and 2 Enable and Clock 0 Enable fields (PINMUX:CLK1_2EN and PINMUX:CLK0EN — see Chapter 16 for description of PINMUX) select between CS and SCKE multiplexing, shown in Table 4-2 and Table 4-3.

When the MultiMediaCard (MMC) adapter is enabled, the SMC Bank 3 Chip Select pin (M12) is used by the MMC for the SPI Chip Select signal.

When the Smart Card Interface (SCI) is enabled, some SMC address pins A[27:25] (A8, F8, and G8, respectively) are used by the SCI for the I/O, Clock, and Reset signals.

Table 4-2. Pin B10 Multiplexing

CLK12EN	PIN B10
1	SCKE1_2
0	CS6

Table 4-3. Pin C10 Multiplexing

CLK0EN	PIN C10
1	SCKE0
0	CS7

4.1.3.2 General Purpose I/O and SMC PC Card Multiplexing

The PCMCIA and CompactFlash (CF) signals are multiplexed with GPIO Ports G, H, F6, and F7. To select between Card or GPIO operation, and to configure the system for one or two cards (any combination of PCMCIA and CF Cards), set the PCMCIA Control register PC Cards 1 and 2 Enable field (PCMCIACON:PC12EN[1:0]):

- 00 disables both cards, configuring ports G and H as GPIO.
- 01 enables one card in CF mode at 0x4000.0000 (Slot 0).
- 10 enables one card in PCMCIA mode at Slot 0.
- 11 enables two cards, with Card 1 at Slot 0 and Card 2 at 0x5000.0000 (Slot 1). Either card can be CF or PCMCIA.

At reset, all pins default to GPIO, and Port G and H pin states at reset are:

- Port G Output LOW
- Port H Input
- No cards enabled; Ports G and H configured as GPIO (PC12EN = 00).

Figure 4-2 shows an example of a single card configuration with a CompactFlash card (PC12EN = 01).

Figure 4-3 shows an example of a dual card configuration (PC12EN = 11) with a PCMCIA card in Slot 0 (Card 1) and a CompactFlash card in Slot 1 (Card 2).

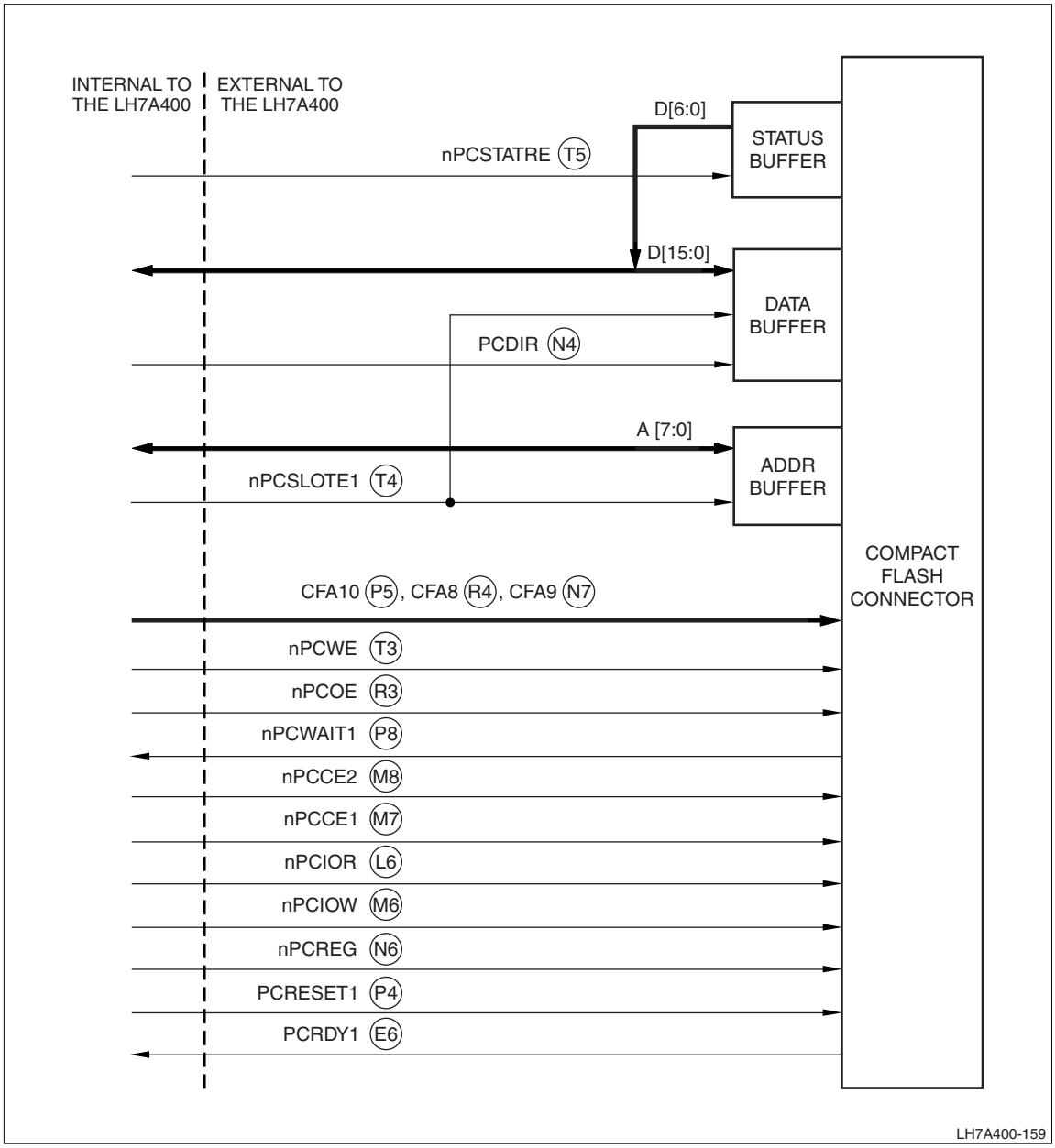


Figure 4-2. CompactFlash Single Card Example (PC12EN = 01)

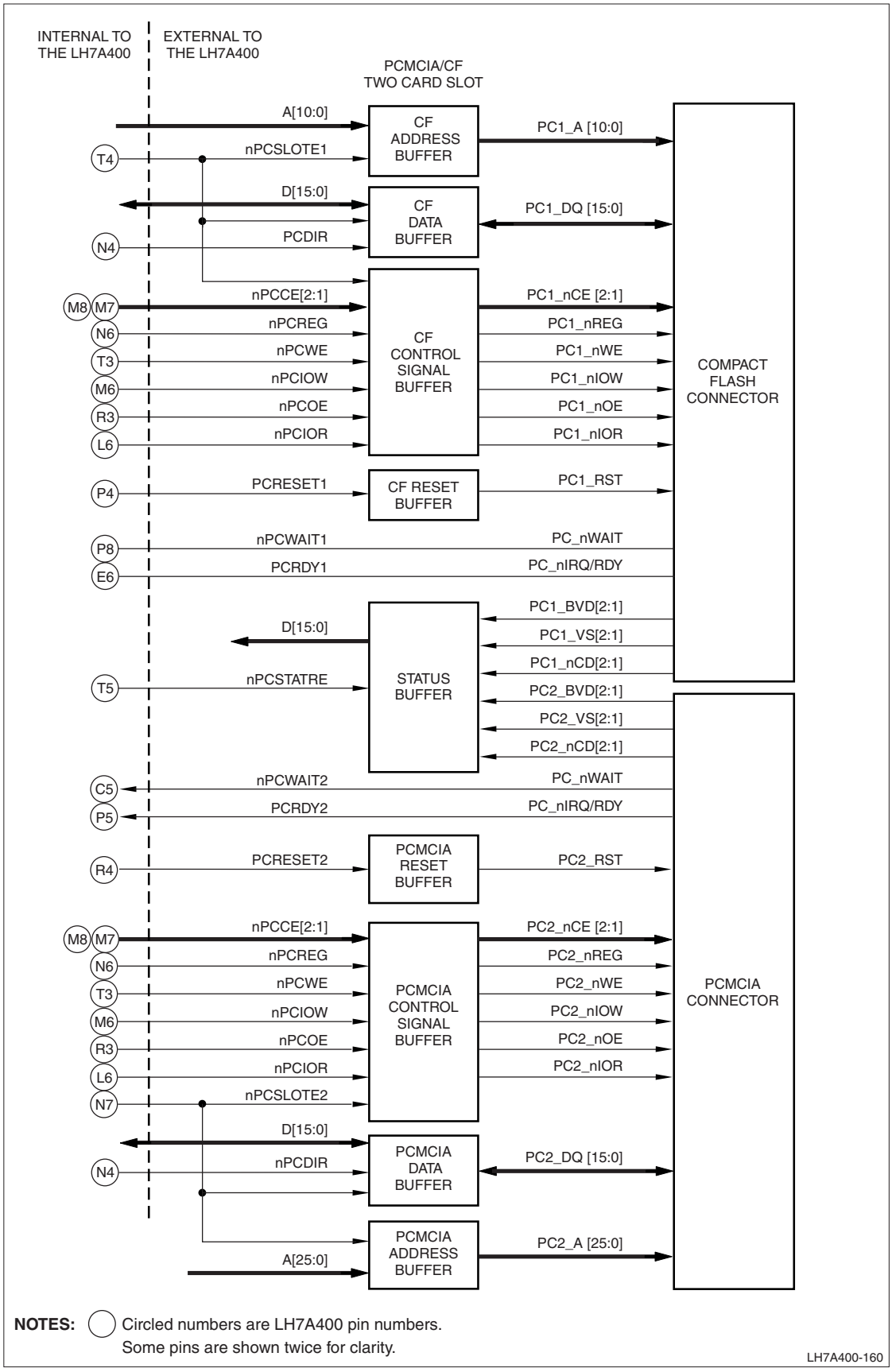


Figure 4-3. PCMCIA and CompactFlash Dual Card Example (PC12EN = 11)

When selected by PCMCIACON programming for SMC use, the PC Card signals are further multiplexed for PCMCIA or CF configuration and for one card or two card configuration, as shown in Table 4-4.

When two cards are present, the following control signals are gated for the appropriate card by asserting nPCSLOTE1 (for the card in Bank 4) or nPCSLOTE2 (for the card in Bank 5):

- nPCOE
- nPCREG
- nPCWE
- nPCCE1
- nPCIOR
- nPCCE2
- nPCIOW.

When only one card is present, the CompactFlash address lines CFA8, CFA9, and CFA10 and the PCMCIA addresses PCMCIAA24 and PCMCIAA25 are also gated with PCSLOTE1, based on whether the card is PCMCIA or CompactFlash. In a two card system, buffer these signals from the main address bus.

The nPREG signal can be independently configured for GPIO or PCMCIA control of the rest of the PCMCIA multiplexing configuration. Setting PCMCIACON:MPREG configures nPREG for control via the GPIO interface.

Table 4-4. PC Card Signal Multiplexing

PIN	GPIO PORT	ONE CARD, CF MODE	ONE CARD, PCMCIA MODE	TWO CARDS*
E6	F6	PCRDY1	PCRDY2	PCRDY1
C5	F7			PCRDY2
R3	G0	nPCOE	nPCOE	nPCOE
T3	G1	nPCWE	nPCWE	nPCWE
L6	G2	nPCIOR	nPCIORD	nPCIORD
M6	G3	nPCIOW	nPCIOWR	nPCIOWR
N6	G4	nPCREG	nPCREG	nPCREG
M7	G5	nPCCE1	nPCCE1	nPCCE1
M8	G6	nPCCE2	nPCCE2	nPCCE2
N4	G7	PCDIR	PCDIR	PCDIR
P4	H0	PCRESET1	PCRESET1	nPCRESET1
R4	H1	CFA8		PCRESET2
T4	H2	nPCSLOTE1	nPCSLOTE1	nPCSLOTE1
N7	H3	CFA9	PCMCIAA25	nPCSLOTE2
P8	H4	nPCWAIT1	nPCWAIT1	nPCWAIT1
P5	H5	CFA10	PCMCIAA24	nPCWAIT2
T5	H7	nPCSTATRE	nPCSTATRE	nPCSTATRE

NOTE: *Any Combination of PCMCIA/CF

4.1.4 Memory Bank Selection

Of the eight independently configurable memory banks, Chip Select outputs are available for Banks 0 through 3, 6, and 7. These outputs are the Chip Select signals nCS[3:0] and CS[7:6], respectively. Instead of Chip Select signals, the PC card control uses Slot Select signals:

- nPCSLOTE1 gates control signals to Card 1 in Bank 4, in both single card and dual card PCMCIA and CF configurations.
- nPCSLOTE2 gates control signals to Card 2 in Bank 5, in dual card PCMCIA and CF configurations.

nCS[3:0] are active LOW and CS[7:4] are active HIGH. Both nPCSLOTEx signals are active LOW (where x is 1 for Card 1 and 2 for Card 2). The physical address ranges for each Chip Select and Slot Select are fixed, as shown in Table 4-5. Table 4-6 shows the address spaces of PC cards.

Table 4-5. SMC Memory Bank Selection

ADDRESS RANGE	CS[7:6]	nCS[3:0]	nPCSLOTE[2:1]	MEMORY CONFIGURATION
0x0000.0000 - 0x0FFF.FFFF	00	1110	xx	Bank 0
0x1000.0000 - 0x1FFF.FFFF	00	1101	xx	Bank 1
0x2000.0000 - 0x2FFF.FFFF	00	1011	xx	Bank 2
0x3000.0000 - 0x3FFF.FFFF	00	0111	xx	Bank 3
0x4000.0000 - 0x4FFF.FFFF	00	1111	10	PC Card Slot 0 Select (Bank 4)
0x5000.0000 - 0x5FFF.FFFF	00	1111	01	PC Card Slot 1 Select (Bank 5)
0x6000.0000 - 0x6FFF.FFFF	01	1111	xx	Bank 6
0x7000.0000 - 0x7FFF.FFFF	10	1111	xx	Bank 7

NOTE: x = 'don't care'.

4.1.4.1 PC Card Address Space

Table 4-6 shows the PC Card (PCMCIA card) address space. In addition to the linear addressing, the status of PCMCIA signals may be read by asserting the nPCSTATRE (PC Card Status Read Enable) pin. Software issues a Read command to the first location in the reserved space for the appropriate card (0x4400.0000 for PC Card 0, or 0x5400.000 for PC Card 1). This asserts nPCSTATRE for five clock cycles and returns the current value of the data bus. This may be used for sensing the Card Detect, and Voltage signals, and to enable the correct application of power to the card.

Because the data I/O enables may not be configured for a read, software must first perform a dummy read of either attribute memory, common memory, or I/O memory, then execute a status read. This dummy read must be inserted before every status read for proper operation.

The number of status signals depends on the board design. If eight or fewer status signals are used, AHB byte-reads may be used. If more than eight status signals are used, a 16-bit AHB read must be used.

CAUTION

With wait states enabled, an attempt to read a slot without a card present will result in the CPU hanging (continuing to wait for data).

Table 4-6. PC Card Address Space

ADDRESS	SPACE
0X5C00.0000	Socket 2 common memory space
0X5800.0000	Socket 2 attribute space
0X5400.0004	Reserved
0X5400.0000	nPCSTATRE
0X5000.0000	Socket 2 I/O space
0X4C00.0000	Socket 1 common memory space
0X4800.0000	Socket 1 attribute space
0X4400.0004	Reserved
0X4400.0000	nPCSTATRE
0X4000.0000	Socket 1 I/O space

4.1.5 Byte Lane Write Control

Since each bank of external memory must be configured according to the hardware design, the LH7A400 accommodates this through the use of the SMC Bank Configuration Register (BCRx, where x is 0 through 3, 6, or 7). This register allows programming the Chip Select signals (nCS[3:0] and CS[7:6]) and write enable signals (nWE[3:0]) for each bank. The write enable signal operation depends on:

- The bank width programmed in the Bank Configuration Register (BCRx:MW)
- The required transfer width (an 8-bit, 16-bit, or 32-bit access)

The nWE1 signal is multiplexed with A0, and nWE2 is multiplexed with A1. Care must be used when designing 16- and 32-bit memory systems, as these signals do not act as address lines when the SMC uses them as nWE[2:1]. Application examples appear in subsequent sections (the SMC supports the example little-endian memory systems). Table 4-7 shows the signal coding for 8-bit, 16-bit, and 32-bit little-endian external memory systems. For a PC Card, the two Card Enable (CE) signals (nPCCE[2:1]) select the access as high or low byte, as shown in Table 4-8.

External memory can be composed of 8-bit devices or devices partitioned into multiples of a byte. The type of memory devices used for each bank determine how the interface signals must be connected in order to provide byte, half-word or word-wide accesses.

Table 4-7. SMC Byte Lane Write Control

BCRx:MW	ACCESS	EXTERNAL MEMORY DEVICE WIDTH						
		8-BIT			16-BIT			32-BIT
		A1	A0	nWE[0]	A1	A0	nWE0	nWE[3:0]
0b10	Word	nWE2	nWE1	0	nWE2=x	nWE1=0	0	0000
0b01	Half Word	A1	nWE1	0	A1	nWE1	0	0011
0b01	Half Word	A1	nWE1	0	A1	nWE1	0	1100
0b00	Byte	A1	A0	0	A1	nWE1	0	0111
0b00	Byte	A1	A0	0	A1	nWE1	1	1011
0b00	Byte	A1	A0	0	A1	nWE1	0	1101
0b00	Byte	A1	A0	0	A1	nWE1	1	1110

Table 4-8. PC Card Access Enable

nPCCE2	nPCCE1	A[0]	D[15:8]	D[7:0]	MODE	ACCESS
1	1	x	High-Z	High-Z	Standby	No Access
1	0	0	High-Z	Even Byte	8- or 16-bit	Even Byte
1	0	1	High-Z	Odd Byte	8- or 16-bit	Odd Byte
0	1	x	Odd Byte	High-Z	16-bit	Odd Byte
0	0	x	Odd Byte	Even byte	16-bit	Even and Odd Byte

4.1.6 Memory Example With 8-Bit Devices

Memory systems using 8-bit devices can be configured for byte (8 bits), half-word (16 bits), or word (32 bits) accesses by the LH7A400. In the sections that follow, examples illustrate pin connection and register programming for each possible configuration with 8-bit devices.

The examples use Bank 0, but other banks work the same; just ensure the proper BCRx is programmed for that bank, and that the Chip Select signals are connected as shown in Table 4-5.

The SMC uses the programmed width of each bank (BCRx:MW) to determine how many bytes of the external bus to drive. For example, a byte write to a bank of external memory programmed to be 16 bits wide drives only the lower 16 external data lines. To ensure the external data bus never floats, tie unused pins HIGH or LOW through a resistor.

4.1.6.1 Byte-Wide Bank Configuration

Design of a byte-wide bank with 8-bit devices is quite straight forward. Refer to Figure 4-4 for this example. This example will configure the LH7A400 for 8-bit external accesses to Bank 0.

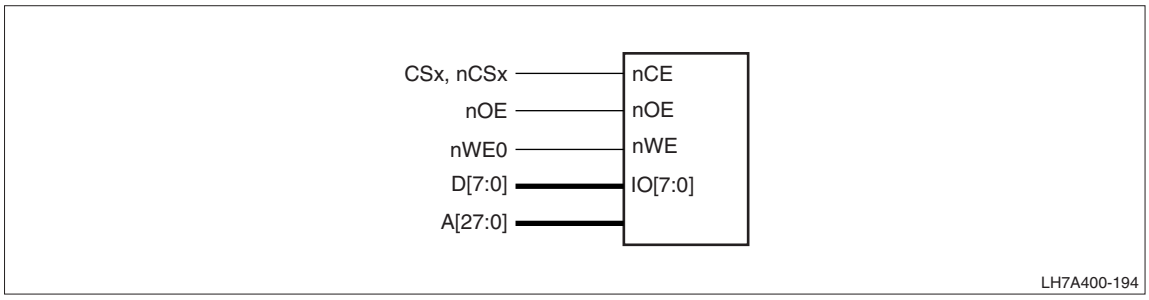


Figure 4-4. Byte-Wide Memory Bank Constructed from 8-bit Devices

4.1.6.1.1 Signal Connection

The signal connection between the LH7A400 and the memory devices, as shown in Figure 4-4, is:

1. Referring to Table 4-5, Chip Select for Bank 0 is nCS0. This signal should be wired to nCE on the memory device.
2. Only nWE0 is valid for 8-bit transfers, and is connected to nWE on the memory device.
3. The LH7A400 nOE is connected to nOE on the memory device.
4. The full address bus can be used, with the LH7A400 A0 pin connected to the A0 address on the memory device.

4.1.6.1.2 Configuration Registers

The SMC interface requires programming two registers: the PINMUX and the BCRx.

1. The PINMUX register is described in Chapter 16. It requires that PINMUX:CLK0EN=0 and PINMUX:CLK1_2EN=0. This is the default value of those bits following reset.
2. Program BCR0:MW (see Section 4.2.2.1) to 0b00 to select 8-bit memory width. Program the remaining bits for parameters required by the specific memory devices.

4.1.6.2 Half-Word-Wide Bank Configuration

Design of a half-word-wide bank with 16-bit devices is slightly more complex. Refer to Figure 4-5 for this example. This example will configure the LH7A400 for 16-bit external accesses to Bank 0, and requires two 8-bit devices per half word.

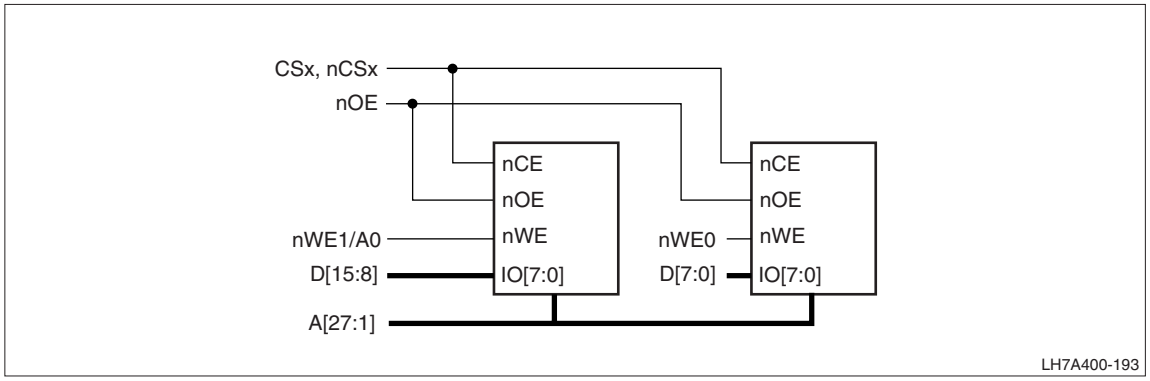


Figure 4-5. Half-Word Memory Bank Constructed from 8-bit Devices

4.1.6.2.1 Signal Connection

The signal connection between the LH7A400 and the memory devices, as shown in Figure 4-5, is:

1. Referring to Table 4-5, Chip Select for Bank 0 is nCS0. This signal should be wired to nCE on the memory devices.
2. Two byte lane enables, nWE0 and nWE1 are required for 16-bit devices. The nWE0 signal connects to nWE on the low-byte device, and nWE1 connects to the high-byte memory device as shown. Note that nWE1 does not function as A0 during SMC accesses, and care should be taken when using A0 for another bank to avoid spurious accesses when A0 is configured as nWE1. When the SMC is active in 16-bit width, A0 does not contain address values.
3. The LH7A400 nOE is connected to nOE on the memory device.
4. Only A[27:1] are used for 16-bit accesses, with the LH7A400 A1 pin connected to the A0 address on the memory device.
5. LH7A400 data bus signals D[7:0] are connected to IO[7:0] on the low-byte memory device, and D[15:8] are connected to IO[7:0] on the high-byte device. The remaining LH7A400 data signals (D[31:16]) must have a pull-up or pull-down resistor to prevent the data bus from floating when accesses are made by the SMC.

4.1.6.2.2 Configuration Registers

The SMC interface requires programming two registers: the PINMUX and the BCRx.

1. The PINMUX register is described in Chapter 16. It requires that PINMUX:CLK0EN=0 and PINMUX:CLK1_2EN=0. This is the default value of those bits following reset.
2. Program BCR0:MW (see Section 4.2.2.1) to 0b01 to select 16-bit memory width. Program the remaining bits for parameters required by the specific memory devices.

4.1.6.3 Word-Wide Bank Configuration

When using 8-bit devices for a word-wide bank, additional parameters must be considered. Refer to Figure 4-6 for this example. This example will configure the LH7A400 for 32-bit external accesses to Bank 0, and requires four 8-bit devices per word.

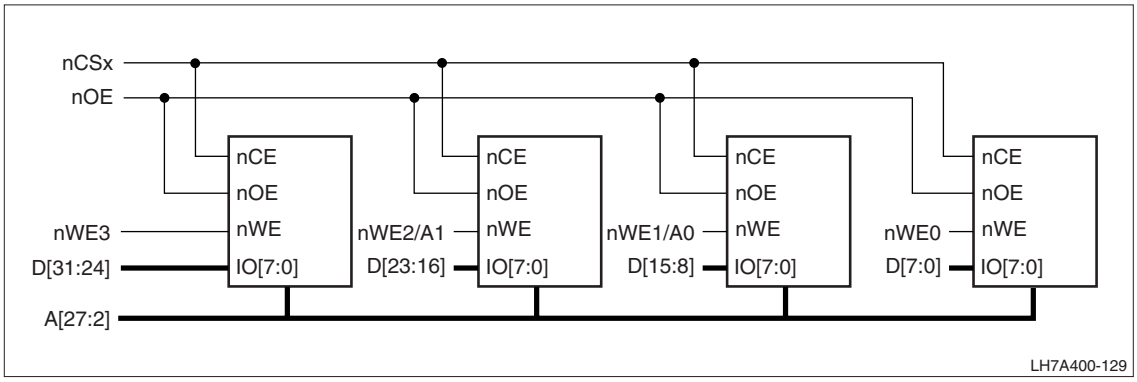


Figure 4-6. Word-Wide Memory Bank Constructed from 8-bit Devices

4.1.6.3.1 Signal Connection

The signal connection between the LH7A400 and the memory devices, as shown in Figure 4-6, is:

1. Referring to Table 4-5, Chip Select for Bank 0 is nCS0. This signal should be wired to nCE on the memory devices.
2. All four byte lane enables, nWE[3:0] are active for 32-bit banks. The nWE0 signal connects to nWE on the LSB device, nWE1 to the next-most significant byte, nWE2 to the next, and nWE3 to the MSB device. Note that nWE1 does not function as A0 and nWE2 does not function as A1 during SMC accesses. Care should be taken when using A0 and A1 for another bank to avoid spurious accesses when A0 is configured as nWE1 and A1 as nWE2. When the SMC is active in 32-bit width, A0 and A1 do not contain address values.
3. The LH7A400 nOE is connected to nOE on the memory device.
4. Only A[27:2] are used for 32-bit accesses, with the LH7A400 A2 pin connected to the A0 address on the memory device.
5. LH7A400 data bus signals D[7:0] are connected to IO[7:0] on the low-byte memory device; D[15:8] are connected to IO[7:0] on the next most-significant device; D[23:16] to the next, and D[31:24] to the MSB device. No pull-up/pull-down resistors are required by the SMC in 32-bit-wide mode.

4.1.6.3.2 Configuration Registers

The SMC interface requires programming two registers: the PINMUX and the BCRx.

1. The PINMUX register is described in Chapter 16. It requires that PINMUX:CLK0EN=0 and PINMUX:CLK1_2EN=0. This is the default value of those bits following reset.
2. Program BCR0:MW (see Section 4.2.2.1) to 0b10 to select 16-bit memory width. Program the remaining bits for parameters required by the specific memory devices.

4.1.7 Memory Example With 16-Bit Devices

Memory systems using 16-bit devices can be configured for byte (8 bits), half-word (16 bits), or word (32 bits) accesses by the LH7A400. In the sections that follow, examples illustrate pin connection and register programming for each possible configuration with 16-bit devices. Figure 4-7 shows 16-bit-wide memory devices connected to the LH7A400 in two different width bank configurations.

The examples use Bank 0, but other banks work the same; just ensure the proper BCRx is programmed for that bank, and that the Chip Select signals are connected as shown in Table 4-5.

The SMC uses the programmed width of each bank (BCRx:MW) to determine how many bytes of the external bus to drive. For example, a byte write to a bank of external memory programmed to be 16 bits wide drives only the lower 16 external data lines. To ensure the external data bus never floats, tie unused pins HIGH or LOW through a resistor.

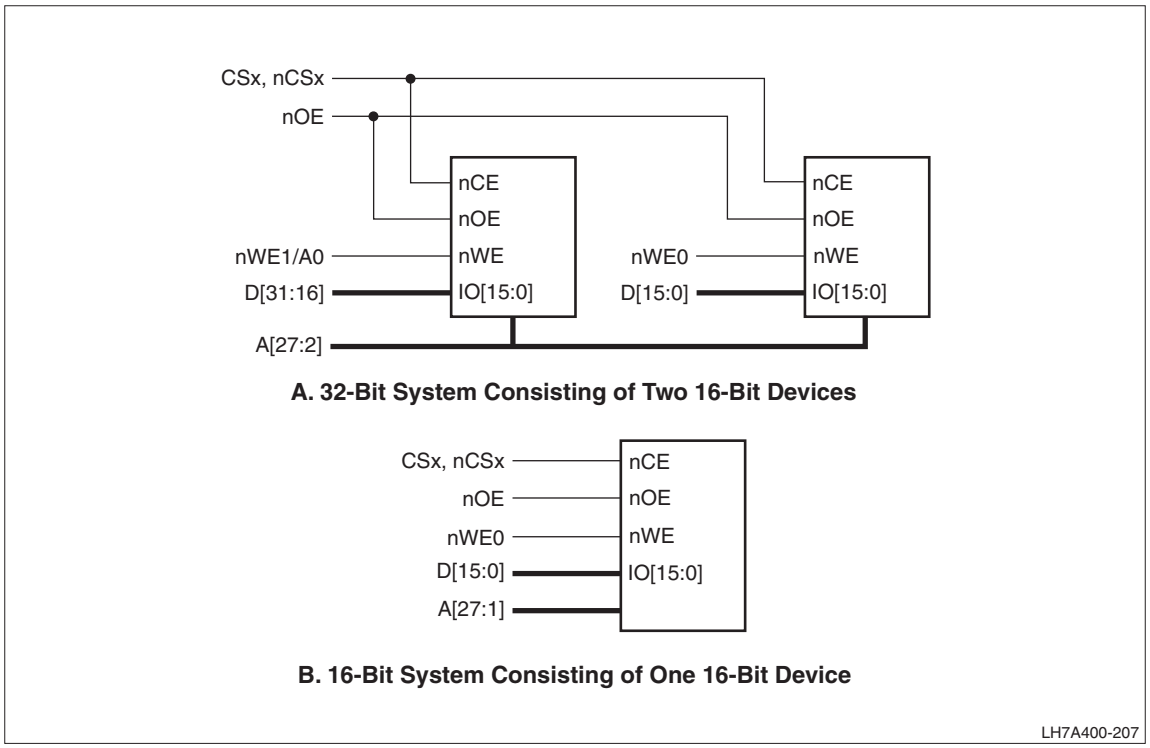


Figure 4-7. Memory Banks Constructed from 16-bit Memory

4.1.7.1 Byte-Wide Bank Configuration

Memory systems using 16-bit-wide devices can be used with byte-wide data transfers by programming the BCRx:MW field to 0b00. Multiple configurations are possible for this architecture, depending on the application. Because of this, no examples are presented.

4.1.7.2 Half-Word-Wide Bank Configuration

Design of a half-word-wide bank with 16-bit devices is straight forward. Refer to Figure 4-7, part B for this example. This example will configure the LH7A400 for 16-bit external accesses to Bank 0, and requires one 16-bit device per half word.

4.1.7.2.1 Signal Connection

The signal connection between the LH7A400 and the memory devices, as shown in Figure 4-7, part B, is:

1. Referring to Table 4-5, Chip Select for Bank 0 is nCS0. This signal should be wired to nCE on the memory devices.
2. Two byte lane enables, nWE0 and nWE1 are required for 16-bit devices. With just a single 16 bit device, nWE0 connects to nWE on the memory device, and nWE1 is unconnected. Note that nWE1 does not function as A0 during SMC accesses, and care should be taken when using A0 for another bank to avoid spurious accesses when A0 is configured as nWE1. When the SMC is active in 16-bit width, A0 does not contain address values.
3. The LH7A400 nOE is connected to nOE on the memory device.
4. Only A[27:1] are used for 16-bit accesses, with the LH7A400 A1 pin connected to the A0 address on the memory device.
5. LH7A400 data bus signals D[15:0] are connected to IO[15:0] on the memory device. The remaining LH7A400 data signals (D[31:16]) must have a pull-up or pull-down resistor to prevent the data bus from floating when accesses are made by the SMC.

4.1.7.2.2 Configuration Registers

The SMC interface requires programming two registers: the PINMUX and the BCRx.

1. The PINMUX register is described in Chapter 16. It requires that PINMUX:CLK0EN=0 and PINMUX:CLK1_2EN=0. This is the default value of those bits following reset.
2. Program BCR0:MW (see Section 4.2.2.1) to 0b01 to select 16-bit memory width. Program the remaining bits for parameters required by the specific memory devices.

NOTE: Figure 4-7 and its accompanying text describe the general case of a fixed, 16-bit data bus. Some devices have configurable-width data buses, for example the NXP Multi-Level Cell (MLC) Flash memories. These MLC devices can be configured for either 8-bit or 16-bit data buses. Because of this, the MLC device's A0 address is a byte address, used only when configured for an 8-bit data bus. When using it configured as a 16-bit device, the LH7A400 address bus is connected in a one-to-one mapping (that is, A1 on the LH7A400 to A1 on the MLC Flash; A2 to A2 and so on). Thus, when configured as a 16-bit device, A0 on the device is not connected since all data accesses are on 16-bit address boundaries. Other data-bus-configurable devices may also exist that require connection of the LH7A400 address bus in a different mapping than the general case. Connection must be determined by studying the particular device's data sheet.

4.1.7.3 Word-Wide Bank Configuration

When using 16-bit devices for a word-wide bank, additional parameters must be considered. Refer to Figure 4-7, part A for this example. This example will configure the LH7A400 for 32-bit external accesses to Bank 0, and requires two 16-bit devices per word.

4.1.7.3.1 Signal Connection

The signal connection between the LH7A400 and the memory devices, as shown in Figure 4-7, part A, is:

1. Referring to Table 4-5, Chip Select for Bank 0 is nCS0. This signal should be wired to nCE on the memory devices.
2. All four byte lane enables, nWE[3:0] are active for 32-bit banks. The nWE0 signal connects to nWE on the least-significant half-word device and A1/nWE2 is connected to nWE on the most-significant half-word device. With 16-bit wide memory devices, A0/nWE1 and nWE3 are not required and not connected. Note that nWE1 does not function as A0 and nWE2 does not function as A1 during SMC accesses. Care should be taken when using A0 and A1 for another bank to avoid spurious accesses when A0 is configured as nWE1 and A1 as nWE2. When the SMC is active in 32-bit width, A0 and A1 do not contain address values.
3. The LH7A400 nOE is connected to nOE on the memory device.
4. Only A[27:2] are used for 32-bit accesses, with the LH7A400 A2 pin connected to the A0 address on the memory devices.
5. LH7A400 data bus signals D[15:0] are connected to IO[15:0] on the least-significant half-word memory device, and D[31:16] to the most-significant half-word device. No pull-up/pull-down resistors are required by the SMC in 32-bit-wide mode.

4.1.7.3.2 Configuration Registers

The SMC interface requires programming two registers: the PINMUX and the BCRx.

1. The PINMUX register is described in Chapter 16. It requires that PINMUX:CLK0EN=0 and PINMUX:CLK1_2EN=0. This is the default value of those bits following reset.
2. Program BCR0:MW (see Section 4.2.2.1) to 0b10 to select 32-bit memory width. Program the remaining bits for parameters required by the specific memory devices.

4.1.8 Memory Example With 32-Bit Devices

4.1.8.1 Word-Wide Bank Configuration

A system with 32-bit memory devices used as a word-wide bank is straight forward, although attention needs to be given to the A0/nWE1 and A1/nWE2 signals. Refer to Figure 4-8 for this example. This example will configure the LH7A400 for 32-bit external accesses to Bank 0, and requires one 32-bit device per word.

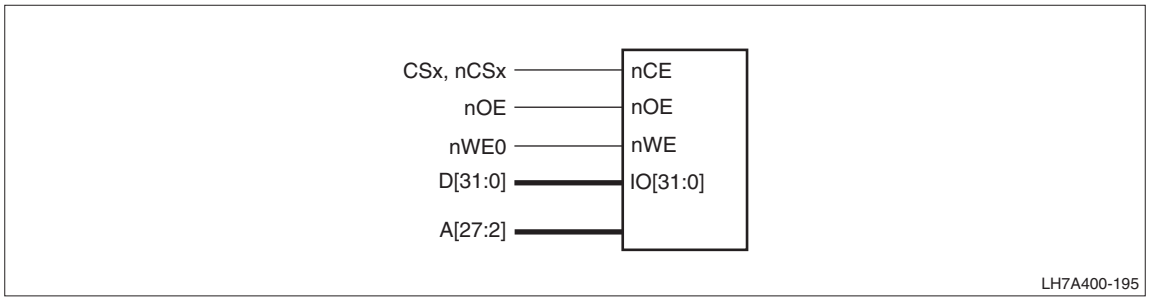


Figure 4-8. Word-wide bank with 32-bit memory devices

4.1.8.1.1 Signal Connection

The signal connection between the LH7A400 and the memory devices, as shown in Figure 4-8, is:

1. Referring to Table 4-5, Chip Select for Bank 0 is nCS0. This signal should be wired to nCE on the memory devices.
2. All four byte lane enables, nWE[3:0] are active for 32-bit banks. The nWE0 signal connects to nWE on the memory device. With 32-bit devices, nWE1 and nWE3 are not required and not connected. Note that nWE1 does not function as A0 and nWE2 does not function as A1 during SMC accesses. Care should be taken when using A0 and A1 for another bank to avoid spurious accesses when A0 is configured as nWE1 and A1 as nWE2. When the SMC is active in 32-bit width, A0 and A1 do not contain address values.
3. The LH7A400 nOE is connected to nOE on the memory device.
4. Only A[27:2] are used for 32-bit accesses, with the LH7A400 A2 pin connected to the A0 address on the memory devices.
5. LH7A400 data bus signals D[31:0] are connected to IO[315:0] on the memory device. No pull-up/pull-down resistors are required by the SMC in 32-bit-wide mode.

4.1.8.1.2 Configuration Registers

The SMC interface requires programming two registers: the PINMUX and the BCRx.

1. The PINMUX register is described in Chapter 16. It requires that PINMUX:CLK0EN=0 and PINMUX:CLK1_2EN=0. This is the default value of those bits following reset.

Program BCR0:MW (see Section 4.2.2.1) to 0b10 to select 32-bit memory width. Program the remaining bits for parameters required by the specific memory devices.

More detailed memory system design examples can be found in the application note "Designing an SRAM Memory System for the LH7A400: A 16-bit Example."

4.1.9 Access Sequencing for Different Width Memory Systems

The LH7A400 SMC can automatically use the system hardware for any size data word. The number of cycles required to complete an AMBA transfer depends on the access width and the external memory width.

An internal bus transfer can require several external bus transfers when the external memory bus is narrower than the transfer initiated from the SMC. For example, a 32-bit AMBA transfer to an 8-bit external memory system (BCRx:MW=0b00) requires four external accesses. When Bank 0 is configured as 8-bit-wide memory, and a 32-bit read is initiated, the AHB stalls while the SMC reads four consecutive bytes from memory and the four bytes are assembled into one 32-bit word.

Access sequencing supports little endian operation.

4.1.10 Wait State Generation

Wait State control refers to external bus transfer wait states. This section discusses timing requirements and programming for the SMC Memory Banks 0 through 3, 6, 7, and PCMCIA and CF Banks 4 and 5.

4.1.10.1 Memory Bank Timing

WST1 is used for both read and write wait state insertion, and results in identical numbers of wait states for both operations. WST2 is only relevent for Page Mode operation. With Page Mode enabled, burst read timing behaves as follows:

2. The first transfer cycle duration is WST1 + 1 clocks
3. The second and third transfer cycle durations are WST2 + 1 clocks
4. The fourth transfer cycle is WST2 + 2 clocks
5. For 16-bit accesses only:
   - The fifth transfer is repeat of the address in the third transfer but for a duration of WST1 + 1 clocks
   - The sixth transfer is a repeat of the fourth transfer
   - The seventh transfer is the one that should have occurred as the fifth, is the first of a new burst and timed at WST1 + 1 clocks
6. For 32-bit accesses only, the fourth transfer is timed at WST2 + 5 clocks
   - For 8-bit accesses only, the third access is timed at WST2 + 2 clocks.

4.1.10.2 PC Card Timing

For the PCMCIA interface, configure the Address Pre-Charge Times, the Read/Write Access Times, and the Hold Times for the Attribute, Common Memory, and I/O Spaces for each card as they may be different for different cards. These Pre-Charge, Access, and Hold Times are configured in the Attribute, Common, and I/O registers for Bank 4, supporting Card 1, and for Bank 5, supporting Card 2:

- The Pre-Charge Delay Time determines the number of clock cycles for the PC card address to be asserted before the PC card nOE or nWE is asserted. Program this value in the PCxATTRIB register Pre-charge delay time for Attribute space field (PCxATTRIB:PA), the PCxCOM register Pre-charge delay time for Common space field (PCxCOM:PC), and the PCxIO register Pre-charge delay time for I/O space field (PCxIO:PI). (Where x in each register name is 1 or 2, corresponding to Card 1 or Card 2.) The time specified by the field value is (value + 1) × HCLK.
- External PC cards can extend the access cycles using wait states. Regardless of external wait states, the Access Delay Time defines the minimum width, in clock cycles, of the PCMCIA nOE or nWE signal. Program this value in the PCxATTRIB register Access time for Attribute space field (PCxATTRIB:AA), the PCxCOM register Access time for Common space field (PCxCOM:AC), and the PCxIO register Access time for I/O space field (PCxIO:AI). The time specified by the field value is (value + 1) × HCLK.
- The Hold Time defines the minimum number of clock cycles between releasing the nOE or nWE signal and releasing the PC card chip select/data/address. Program this value in the PCxATTRIB register, PCxCOM register, and PCxIO register Hold Time fields (PCxATTRIB:HT, PCxCOM:HT, and PCxIO:HT). The time specified by the field value is (value + 1) × HCLK.

Support of nPCWAITx signaling in the controller allows slower cards to stretch the access cycles to the maximum of 12 ms. To protect the system from malfunctioning cards, disable the nPCWAITx signal while reading Attribute memory space, and explicitly re-enable nPCWAITx once the card is verified as functioning correctly. The PCMCIA Control register (PCMCIACON) Wait State Enable 1 (WEN1) and Wait State Enable 2 (WEN2) bits enable and disable nPCWAITx signal acceptance:

- PCMCIACON:WEN1 controls wait states for Card 1.
- PCMCIACON:WEN2 controls wait states for Card 2.

The longest cycle time required by the PCMCIA specification is 600 ns. This cycle time is the mandated access speed for initial reads to attribute memory of an unknown 3.3 VDC card. A 5 VDC card attribute memory is initially read at 300 ns. In both cases, the maximum required programmable delay is half the full cycle time: 300 ns or 150 ns, respectively.

The Card Information Structure (CIS), read from the Attribute space, provides the access times for the remainder of the card structure. The SMC can be configured to generate the appropriate delays. At the fastest expected bus speed of 100 MHz (a 10 ns cycle), the longest output enable access time is 300 ns. The equivalent maximum required Pre-Charge time for the 600 ns cycle time cards is 100 ns.

Care must be exercised when using the nWAIT signal in order to meet PCMCIA specification. A read or write cycle cannot complete while the nWAIT signal is asserted by the PC Card. If the nWAIT signal is de-asserted prior to normal completion of the read or write cycle, the cycle should complete normally. However, the LH7A400 terminates the read or write cycle immediately upon removal of the nWAIT signal, even if it is prior to the minimum-required cycle time. This situation could result in an out-of-compliance bus cycle time.

For proper operation, GPIO bits must be used to detect PC Card presence rather than the nPCSTATRE signal (see Section 4.1.4.1 for nPCSTATRE use). Then, software can first read the GPIO bits, and if a card slot is empty, the software can avoid accessing the empty slot, especially if nWAIT is honored on behalf of the PC Card in the occupied slot.

4.1.11 Write Protection

Each bank of external memory controlled by an SMC Chip Select can be configured for write protection. Although external SRAM is normally unprotected, and ROM devices are normally write-protected, the external SRAM devices can also be write protected. To define a bank as ROM or write-protected RAM, program the corresponding BCR Write Protect bit (BCR:WP) to 1. To define the bank as SRAM, program WP to 0. A write access to a write-protected bank of memory asserts the corresponding BCR Write Protect Error field (BCR:WPERR). A write access to unprotected ROM, for example, causes no error. To clear WPERR, write any value to WPERR.

4.1.12 External Bus Interface

For low power operation, the external address bus transitions are minimized by enabling the address bus transitions only during external memory accesses. The data-out path allows conversion of 32-bit AMBA writes into several external memory half-word or byte writes. The LH7A400 drives all bits of the data bus in accordance with the width programmed for that bank of memory, regardless of the requested width of a data write operation. The data-in path can construct 32-bit AMBA data words from half-word-wide and byte-wide external static memory devices.

4.2 Register Reference

This section describes the SMC registers.

4.2.1 Memory Map

The register offsets shown in Table 4-9 are relative to the SMC base address, 0x8000.2000.

Table 4-9. SMC Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	BCR0	Bank 0 (0x0000.0000) Configuration
0x04	BCR1	Bank 1 (0x1000.0000) Configuration
0x08	BCR2	Bank 2 (0x2000.0000) Configuration
0x0C	BCR3	Bank 3 (0x3000.0000) Configuration
0x10 - 0x17	///	Reserved
0x18	BCR6	Bank 6 (0x6000.0000) Configuration
0x1C	BCR7	Bank 7 (0x7000.0000) Configuration
0x20	PC1ATTIB	PC Card 1 (0x4000.0000) Attribute Space Configuration
0x24	PC1COM	PC Card 1 Common Memory Space Configuration
0x28	PC1IO	PC Card 1 I/O Space Configuration
0x2C	///	Reserved
0x30	PC2ATTIB	PC Card 2 (0x5000.000) Attribute Space Configuration
0x34	PC2COM	PC Card 2 Common Memory Space Configuration
0x38	PC2IO	PC Card 2 I/O Space Configuration
0x3C	///	Reserved
0x40	PCMCIACON	PCMCIA Control

4.2.2 Register Descriptions

The following sections describe the contents and use of the registers.

4.2.2.1 Bank Configuration Registers (BCRx)

To program the parameters and timing for each memory bank, use the corresponding Bank Configuration register, described in Table 4-10 and Table 4-11.

Table 4-10. BCRx Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///		MW		PME	WP	///									
RESET	0	0	WIDTH1	WIDTH0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO		RW	RW	RW	RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	WST2					///	WST1					///	IDCY			
RESET	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RO	RW	RW	RW	RW	RW	RO	RW	RW	RW	RW
ADDR	0x8000.2000 for BCR0, controlling nCS0 0x8000.2004 for BCR1, controlling nCS1 0x8000.2008 for BCR2, controlling nCS2 0x8000.200C for BCR3, controlling nCS3 0x8000.2018 for BCR6, controlling nCS6 0x8000.201C for BCR7, controlling nCS7															

Table 4-11. BCRx Fields

BITS	FIELD	DESCRIPTION
31:30	///	**Reserved** Reading returns 0. Write the reset value.
29:28	MW	**Memory Width** Selects the external device memory width: 00 = 8 bits; nWE0 is the only active write enable; A0 and A1 are the least-significant address signals 01 = 16 bits; nWE0[1:0] are the active write enables; A1 is the least-significant address signal 10 = 32 bits; nWE0[3:0] are the active write enables; A2 is the least-significant address signal 11 = Do not use this value; it can cause unpredictable operation. To support different boot ROM widths, holding MEDCHG LOW after a power-on reset automatically configures this field for nCS0. This configuration programs MW to the state of the WIDTH1 and WIDTH0 pins. When booting from ROM via nCS0, ensure at least one of WIDTH1 or WIDTH0 is LOW.The currently programmed value can be ascertained by reading this field.
27	PME	**Page Mode Enable** 1 = Enables page mode for burst ROM access, providing fast quad-word accesses in burst mode by toggling the least two significant address bits on quad word boundaries. 0 = Disables page mode.

Table 4-11. BCRx Fields (Cont'd)

BITS	FIELD	DESCRIPTION
26	WP	**Write Protect** Selects the memory access protection level: 1 = ROM and write protected RAM 0 = SRAM
25	WPERR	**Write Protect Error** 1 = A write protect error has occurred. 0 = No write protect error. Writing any value to this field clears an existing Write Protect error.
24:16	///	**Reserved** Reading returns 0. Write the reset value.
15:11	WST2	**Wait State 2** WST2 is only relevent for Page Mode operation. With Page Mode enabled, burst read timing behaves as follows: 1. The first transfer cycle duration is WST1 + 1 clocks 2. The second and third transfer cycle durations are WST2 + 1 clocks 3. The fourth transfer cycle is WST2 + 2 clocks 4. For 16-bit accesses only: – The fifth transfer is repeat of the address in the third transfer but for a duration of WST1 + 1 clocks – The sixth transfer is a repeat of the fourth transfer – The seventh transfer is the one that should have occurred as the fifth, is the first of a new burst and timed at WST1 + 1 clocks. 5. For 32-bit accesses only, the fourth transfer is timed at WST2 + 5 clocks 6. For 8-bit accesses only, the third access is timed at WST2 + 2 clocks
10	///	**Reserved** Reading returns 0. Because setting this field can cause anomalous activity on the nWE[3:0] signals (pins C8, N16, M14, and D10, respectively), ensure this bit is 0 when writing to this register.
9:5	WST1	**Wait State 1** Program this value to set the SRAM and ROM read and write access time, and the first access for burst ROM accesses in Page Mode. Access Time = (WST1 + 1) × HCLK. The currently programmed value can be ascertained by reading this field. After reset, this value is 0x1F, to accommodate booting from ROM.
4	///	**Reserved** Reading returns 0. Values written cannot be read.
3:0	IDCY	**Idle Cycle** Program this value to set the memory data bus turnaround time, from a read cycle to a write cycle: (IDCY + 1) × HCLK. The currently programmed value can be ascertained by reading this field.

4.2.2.2 PC Card Attribute Space Registers (PCxATTRIB)

SMC Banks 4 and 5 support PCMCIA and CF PC Cards:

- Bank 4 supports Card 1, addressed at 0x4000.0000.
- Bank 5 supports Card 2, addressed at 0x5000.0000.

In each bank, PC Card Attribute, Common Memory, and I/O Configuration register set controls the wait state and device width for these address spaces. The PC card Attribute configuration registers, described in Table 4-12 and Table 4-13, allows programming the attributes of the two PC Cards. PC1ATTRIB corresponds to Bank 4 and PC2ATTRIB corresponds to Bank 5.

Table 4-12. PCxATTRIB Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	WA	///							AA							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				HT				PA							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.2020 for Card 1, controlling nPCSLOTE1 0x8000.2030 for Card 2, controlling nPCSLOTE2															

Table 4-13. PCxATTRIB Fields

BITS	FIELD	DESCRIPTION
31	WA	**Width of Attribute Address Space** Selects the attribute address space width: 1 = 16 bits 0 = 8 bits.
30:24	///	**Reserved** Reading returns 0. Values written cannot be read.
23:16	AA	**Access Time for Attribute Space** Program this value to set the attribute space access time: (AA+1) × HCLK. The currently programmed value can be ascertained by reading this field.
15:12	///	**Reserved** Reading returns 0. Values written cannot be read.
11:8	HT	**Hold Time** Program this value to set the hold time between the nOE or nWEx signal release and the chip select/address/data signal release: (HT+1) × HCLK. The currently programmed value can be ascertained by reading this field.
7:0	PA	**Pre-charge Delay Time for Attribute Space** Program this value to set the attribute space pre-charge delay time: (PA+1) × HCLK. The currently programmed value can be ascertained by reading this field.

4.2.2.3 PC Card Common Memory Space Registers (PCxCOM)

The PC card Common memory configuration register, described in Table 4-14 and Table 4-15 allows programming the Common Memory space parameters and timing. PC1COM corresponds to Bank 4 and PC2COM corresponds to Bank 5.

Table 4-14. PCxCOM Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	WC	///							AC							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				HT				PC							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.2024 for Card 1, controlling nPCSLOTE1 0x8000.2034 for Card 2, controlling nPCSLOTE2															

Table 4-15. PCxCOM Fields

BITS	FIELD	DESCRIPTION
31	WC	**Width of Common Memory Address Space** Selects the common memory address space width: 1 = 16 bits 0 = 8 bits.
30:24	///	**Reserved** Reading returns 0. Values written cannot be read.
23:16	AC	**Access Time for Common Memory** Program this value to set the common memory space access time: (AC + 1) × HCLK. The currently programmed value can be ascertained by reading this field.
15:12	///	**Reserved** Reading returns 0. Values written cannot be read.
11:8	HT	**Hold Time** Program this value to set the hold time between the common memory space data signal release and the chip select signal release: HT × HCLK. The currently programmed value can be ascertained by reading this field.
7:0	PC	**Pre-charge Delay Time for Common Memory** Program this value to set the common memory space pre-charge delay time: (PC + 1) × HCLK. The currently programmed value can be ascertained by reading this field.

4.2.2.4 PC Card I/O Space Registers (PCxIO)

The PC Card I/O Space Configuration registers, described in Table 4-16 and Table 4-17, allow programming the I/O Space parameters and timing.

Table 4-16. PCxIO Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	WI	///							AI							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				HT				PI							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.2028 for Card 1, controlling nPCSLOTE1 0x8000.2038 for Card 2, controlling nPCSLOTE2															

Table 4-17. PCxIO Fields

BITS	FIELD	DESCRIPTION
31	WI	**Width of I/O Address Space** Selects the I/O address space width: 0 = 8 bits 1 = 16 bits.
30:24	///	**Reserved** Reading returns 0. Values written cannot be read.
23:16	AI	**Access Time for I/O Space** Program this value to set the I/O space access time: (AI + 1) × HCLK. The currently programmed value can be ascertained by reading this field.
15:12	///	**Reserved** Reading returns 0. Values written cannot be read.
11:8	HT	**Hold Time** Program this value to set the hold time between the I/O space data signal release and the chip select signal release: HT × HCLK. The currently programmed value can be ascertained by reading this field.
7:0	PI	**Pre-charge Delay Time for I/O Space** Program this value to set the I/O space pre-charge delay time: (PI + 1) × HCLK. The currently programmed value can be ascertained by reading this field.

4.2.2.5 PCMCIA Control Register (PCMCIACON)

This register, described in Table 4-18 and Table 4-19, allows configuration of the PCMCIA and CF parameters and timing.

Table 4-18. PCMCIACON Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///							MPREG	///		WEN2	WEN1	PC2RST	PC1RST	PC12EN	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RW	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.2040															

Table 4-19. PCMCIACON Fields

BITS	FIELD	DESCRIPTION
31:9	///	**Reserved** Reading returns 0. Values written cannot be read.
8	MPREG	**Manual Control of PCREG** This value selects the source for nPCREG (pin N6) signal generation when PCMCIA operation is enabled: 1 = Allow manual operation of nPCREG, via GPIO Port G4 programming. 0 = Automatically generate nPCREG.
7:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	WEN2	**Wait State Enable for Card 2** 1 = Enable external wait states for Card 2. 0 = Disable external wait states for Card 2.
4	WEN1	**Wait State Enable for Card 1** 1 = Enable external wait states for Card 1. 0 = Disable external wait states for Card 1.
3	PC2RST	**PC Card 2 Reset** 1 = Reset PCMCIA Card 2. 0 = No reset issued.
2	PC1RST	**PC Card 1 Reset** 1 = Reset PCMCIA Card 1. 0 = No reset issued.
1:0	PC12EN	**PC Card 1 and 2 Enable** Enables or disables the PC Cards: 00 = No cards enabled. 01 = One card enabled in CF mode, addressed at 0x4000.0000 10 = One card enabled in PCMCIA mode, addressed at 0x4000.0000 11 = Two cards enabled, each in either CF or PCMCIA mode, addressed at 0x4000.0000 (Card 1) and 0x5000.0000 (Card 2).

Chapter 5
Synchronous Dynamic Memory Controller

5.1 Theory of Operation

SDRAM memory technology is very different from the simpler memory technologies interfaced by the LH7A400 SMC. The SDRAM Memory Controller (SDMC) provides an interface between the AHB and external (off-chip) SDRAM memory devices. The SDMC is for use with all external SDRAM devices. The LH7A400 includes a Static (asynchronous) Memory Controller (SMC) for all other external memory devices and a separate memory controller for the 80KB of embedded SRAM.

The LH7A400 has one external address bus, shared by the SMC and the SDMC. This sharing is automatically coordinated by the External Bus Interface (EBI) block shown in Figure 5-1.

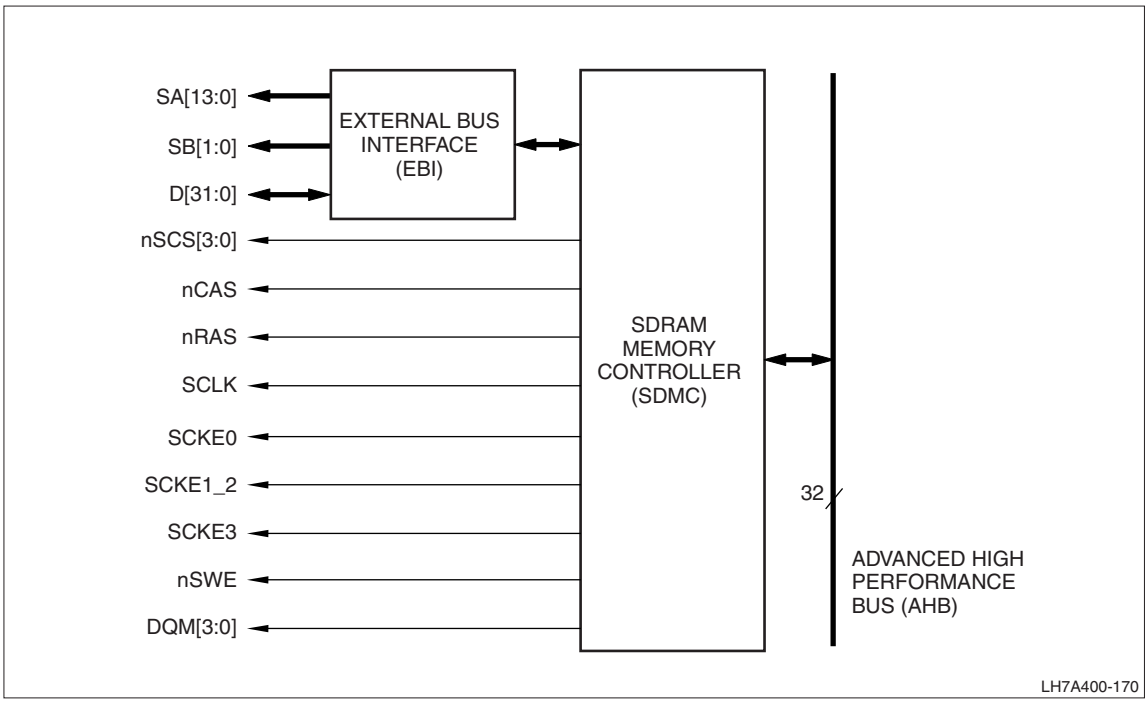


Figure 5-1. SDMC and EBI Block Diagram

The SDMC features include:

- An LCD DMA port for high bandwidth
- Up to four independently configurable, synchronous memory Banks
- Up to 256MB addressable per memory Bank
- Support for Synchronous ROM (SROM), Synchronous Flash (SFLASH), and SDRAM operation
- Synchronous Flash device programming using write and erase commands
- Configuration sequences for booting from SROM or SFLASH, before releasing the processor from reset
- 16-bit or 32-bit data bus
- Two reset domains to preserve SDRAM contents during a user reset (nURESET) or power failure (nPWRFL)
- Power saving synchronous memory clock enable and external clock modes
- Read Buffer and a Merging Write buffer. The Read Buffer can be disabled in software.

Note that it is not possible to read the device ID or the device protect bit from a single 16-bit SyncFlash device.

5.1.1 Memory Banks

The SDMC can accommodate four banks of external SDRAM memory, each with up to 256MB of addressing space. The LH7A404 SDMC provides separate SDRAM Chip Select signals (nSCS[3:0]) for each range of addresses accessed by the SDMC.

Note that the term 'bank', when referring to the LH7A404 bank select signals (SB[1:0]), refers to selection of the particular bank within the SDRAM chip. The SDRAM chips have corresponding Bank Address (BA[0:1]) pins.

For example, a 128 Mb SDRAM may have, internally, four banks of 32 Mb. The ACTIVE, READ, WRITE, and PRECHARGE commands are applied only to the bank selected with the Bank Address signals.

5.1.2 Operational Overview

There are many speed and power advantages to using SDRAM. However, the flexibility as well as lack of complete device standardization, makes design and use more complicated as well. This section provides an overview of designing and using SDRAM with the SDMC; more detailed information appears in following sections.

5.1.2.1 SDMC Operation

Before normal operation can occur, the SDRAM devices must be initialized by the LH7A400 software. The programming is handled by the SDMC writing to the SDRAM Mode register using several address lines to carry the programming data.

As with asynchronous DRAM, SDRAM is addressed with Row and Column addresses, gated on Row Address Strobe (nRAS) and Column Address Strobe (nCAS) signals. (With SDRAM, the data is actually clocked on the SCLK rising edge instead of nRAS and nCAS. Instead of edge-sensitive 'strobes' used for asynchronous DRAM, they actually function as level-sensitive signals.) This requires the linear, physical address transmitted by the CPU over the AHB to the SDMC to be translated to the appropriate Row and Column address, and proper Bank Select and Chip Select signals. The SDMC and the EBI automatically handle the logic, address translation, and timing based on programming for the specific SDRAM devices used. This includes nRAS and nCAS timing required for the specific SDRAM devices.

The total number of address bits necessary to address a specific SDRAM device depends on its size and organization. The Column address is contained in least significant bits on the AHB, and the Row address in the bits immediately more significant than the Column address. A detailed description of address translation appears later in this chapter.

The SDMC enables the row and bank component of the logical address onto the address lines, usually coincident with the appropriate chip select signal (nSCSx) and the row address (nRAS) signal. This is done by the SDMC prior to the next rising edge of SCLK, early enough to allow the address lines time to settle before the SCLK rising edge causes the device to become active and simultaneously latches the row and bank address into the SDRAM device. The RAS-to-CAS delay commences, and then nSCSx and nRAS are driven HIGH, nominally half a bus clock cycle after registration.

After the RAS-to-CAS-delay, the SDMC again drives nSCSx LOW, only this time the column address (nCAS) signal and the column and bank component of the logical address is concurrently LOW. If the action is a READ from the SDRAM device, the nWE signal remains HIGH; if the action is a WRITE to the SDRAM device, the nWE signal goes LOW concurrently with nCSx and nCAS. When SDCLK registers the column address, the CAS latency period commences and then the SDMC sets HIGH nSCSx, nRAS, nCAS, and nWE (if applicable). After the CAS latency period has elapsed, data on the data lines is valid, and is latched into the LH7A400 for a READ, or into the SDRAM device for a WRITE. Both the RAS-to-CAS latency and the CAS latency values are established by the programmer during SDMC and SDRAM Initialization.

5.1.2.2 Designing an SDRAM System

More than any other functional block in the LH7A400, the SDMC requires careful coordination between the external hardware system design, programming of the SDMC, and programming to initialize and use the external SDRAM. Because SDRAM devices are available in a wide range of sizes and organizations (i.e. a 256MB device could be arranged as 16M × 4 × 4 banks, 8M × 8 × 4 banks, or 4M × 16 × 4), and they are not universally standardized in terms of programming, programming the SDMC and the SDRAM is tightly coupled to the particular hardware implementation chosen. In addition, each chip select can access a different memory configuration.

5.1.2.2.1 Hardware System Design

The hardware design depends heavily on the particular devices selected. While this chapter provides documentation regarding the SDMC behavior and physical design, it is impossible to cover all available SDRAM hardware configurations. It is up to the designer to select the SDRAM and refer to the manufacturer's data sheet to complete the interconnection between the LH7A400 and the SDRAM devices.

The major considerations during hardware design include the number of SDRAM devices, specifications of the SDRAM devices, external bus width, and the bus clock frequency that is used. Once the devices have been selected and connected, the addressing and programming become known and the SDMC and SDRAMs can be programmed.

5.1.2.2.2 Programming the SDMC

The SDMC, coupled with the EBI, provide a very intelligent interface to SDRAM once set up. The first task upon power up is to configure the SDMC. The SDMC is programmed with information regarding the external bus structure, bus speed, SDRAM device parameters and specifications, SDMC operating configuration and power modes.

5.1.2.2.3 Initialization of the SDRAM Devices

Unlike conventional memory, SDRAM has onboard intelligence that must be programmed prior to writing to or reading from the memory. Parameters that must be initialized include the bus speed, device parameters (including burst length and type, CAS latency, refresh, precharge, and operating mode), and SDRAM configuration.

5.1.2.3 Read and Write Operation

Once the SDMC and SDRAM have been programmed and initialized, normal read and write operation can commence. Again unlike conventional memory, SDRAM is accessed not only by simple hardware signals, but also by sending commands to the devices. Commands include Read and Write, of course, but also Burst commands, Precharge commands, Refresh, Power down, Clock suspend commands, and others, depending on the particular SDRAM device.

Study of the device manufacturer's data sheet will reveal which commands are compatible with the device used and the optimum implementation. Typically, the ability to transact burst writes and reads using the SDMC onboard buffers increases memory throughput considerably. When running in full burst mode, data can be read or written on each rising HCLK edge after the latency for the first data to appear.

5.1.2.4 Other Functions

The SDMC is also capable of controlling Synchronous Flash and Synchronous ROM memory. These require different setup programming of the SDMC than SDRAM does. This is discussed in detail later in this chapter.

5.1.3 External Hardware System Design

This section describes hardware system design considerations, however, these design factors directly effect SDMC and SDRAM programming as well. The actual SDRAM devices used dictate many of the hardware decisions.

The SDRAM system addressing is decoded from the processor physical memory map into four address domains, each being 256MB. The memory devices used within an address domain must be all of the same type, but different domains can use different memory devices and timing characteristics. Because all the memory devices share a common bus, the total number of devices is limited by the maximum bus capacitance allowable by the SDRAM device manufacturer's specifications, regardless of the Chip Select domain.

5.1.3.1 Control Signals

In addition to the standard address and data signals, SDRAM requires several control signals, some of which have more than one purpose. Table 5-1 describes the control signals and their function.

Table 5-1. SDMC Control Signals

SIGNAL	DESCRIPTION
nSCSx	When LOW, the Chip Select signal selects a given domain of SDRAM devices to which it is connected.
nRAS	The Row Address Strobe is LOW concurrent with nSCSx, causing the device to become 'Active' and the Row Address to be latched on the next SCLK rising edge.
nCAS	The Column Address Strobe is LOW concurrent with nSCSx, causing the Column Address to be latched on the next SCLK rising edge, beginning a Read or Write operation.
nSWE	The Synchronous Write Enable, when LOW concurrently with nSCSx and nCAS causes a Write operation to begin. If it is HIGH concurrently with these two signals, a read operation commences.
DQMx	The Data Mask signals control the width of the Read or Write operation. When connected to an SDRAM DQL input, it enables the LSB in a two-byte wide device, and when connected to the SDRAM DQH input, it enables the MSB. For a word-width operation, both signals are LOW; for a byte-width operation, only the appropriate signal is LOW. These are automatically controlled by the SDMC based on its programming. See the example in Table 5-5.
SCKEx	These four Clock Enable signals allow control of the SDRAM clocks separately for each domain. During normal operation, the SCKEx signal is continuously HIGH. SCKE LOW concurrently with an Auto Refresh command causes the SDRAM to enter Self Refresh Mode. Note that because of pin multiplexing (see Section 5.1.3.2), external hardware is required to uniquely decode all four SCKEx signals; however, it may not be necessary in a particular system design to decode all four uniquely.
SCLK	The Synchronous Clock is based on the LH7A400 HCLK and provides the clock for synchronous operation of all SDRAM devices (except when they are in Self Refresh mode).
SA10	The synchronous address bit SA10 on the LH7A400 is used during the Precharge command and during Read and Write command. If SA10 is HIGH concurrently with a Read or Write command, it causes an Auto Precharge command to be applied automatically at the end of the burst. If it is HIGH during a Precharge command, the devices selected with the Bank Select (SB[1:0]) signal to be precharged. If it is LOW during a Precharge command, all banks are precharged.

5.1.3.2 Pin Multiplexing

Pins B10 and C10 multiplex the SDMC SCKE1_2 and SCKE0 output signals and SMC CS6 and CS7 output signals. GPIO Pin Multiplexing register bits Clock 12 Enable and Clock 0 Enable (PINMUX:CLK12EN and PINMUX:CLK0EN) define the multiplexing:

- When CLK12EN = 0, pin B10 is the SMC CS6 output.
- When CLK0EN = 0, pin C10 is the SMC CS7 output.

The SDMC signal multiplexing is selected with the PINMUX register, as shown in Table 5-2. (See Chapter 7 for more details.) Pin G9 should be configured based on the hardware design. External logic is necessary if the application requires four uniquely decoded Clock Enable signals.

After reset, both CLK0EN and CLK12EN are LOW, resulting in all four SCKE[3:0] signals being ORed together at pin G9. Pin B10 is CS6 and pin C10 is CS7 and both are LOW. Those two pins must be explicitly programmed after reset to be used as SDRAM Clock Enable signals.

Synchronous memory devices require multiplexed address signals for row-column-bank addressing. The addresses placed on the external address bus during memory accesses are automatically multiplexed from the address sent via the AHB by the SDMC. In addition, the SDMC and the SMC share the LH7A400 external address bus. Because the LH7A400 A[1:0] signals are also used as SMC Memory Write Enable (nWE[2:1]) signals, the SDMC Synchronous Address bus (SA[13:0]) and Bank Select (SB[1:0]) signals are multiplexed with SMC pins used as A[17:2], as shown in Table 5-3.

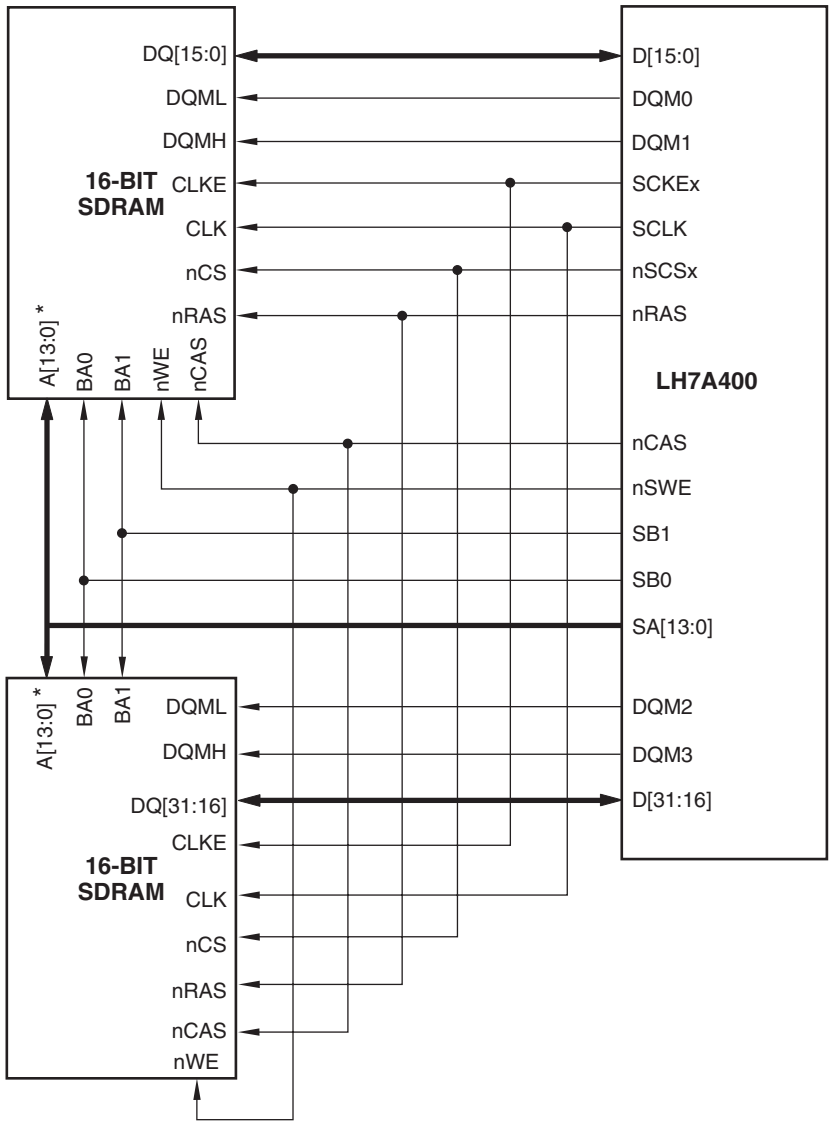
Table 5-2. SDRAM Clock Enable Multiplexing

PINMUX		OUTPUT SIGNAL VALUES		
CLK0EN	CLK12EN	PIN G9	PIN B10	PIN C10
0	0	SCKE0 <OR> SCKE1 <OR> SCKE2 <OR> SCKE3	CS6	CS7
0	1	SCKE1 <OR> SCKE3	SCKE1_2	CS7
1	0	SCKE1 <OR> SCKE2 <OR> SCKE3	CS6	SCKE0
1	1	SCKE3	SCKE1_2	SCKE0

To manage the address multiplexing for particular Synchronous memory devices, consult the data sheets supplied by the device manufacturers. Connect the devices to the LH7A400 and program the SDMC registers according to the device specifications in the data sheets and the SDMC operation described in this chapter. Figure 5-2 shows an example of connecting the LH7A400 SDMC to an external SDRAM memory array.

Table 5-3. Address Line Multiplexing

PIN	SYNCHRONOUS ADDRESS	DESCRIPTION	ASYNCHRONOUS ADDRESS
E16	SB[1]	Synchronous Bank Select	A[17]
F14	SB[0]		A[16]
F16	SA[13]	Synchronous Address Bus	A[15]
G13	SA[12]		A[14]
G14	SA[11]		A[13]
G16	SA[10]		A[12]
H14	SA[9]		A[11]
H16	SA[8]		A[10]
J9	SA[7]		A[9]
J14	SA[6]		A[8]
J16	SA[5]		A[7]
J8	SA[4]		A[6]
K14	SA[3]		A[5]
K15	SA[2]		A[4]
K16	SA[1]		A[3]
M13	SA[0]		A[2]



NOTE: * Depending on the SDRAM size and organization, some address lines may not be used.

LH7A400-171

Figure 5-2. SDRAM Device Interfacing

5.1.3.3 Chip Select Decoding

Each Synchronous Memory address domain is selected by one of the SDMC Chip Select signals (nSCS[3:0], pins A12, E11, D13, and C14, respectively). The SDMC is configured to control each address domain by programming the Synchronous Domain Chip Select Configuration register (SDCSC[3:0], respectively) corresponding to the particular chip select signal. The nSCS[3:0] signals are decoded from the most significant bits of the AHB address bus, as shown in Table 5-4.

Each Synchronous memory domain can be configured as either 16 or 32 bits wide, and to support word, half word, and byte transfers from the AHB. When the external memory system is 16 bits wide, two external bus cycles occur for each 32-bit operand.

Booting can be configured to use SROM located in the nSCS3 address domain. The MEDCHG signal selects the boot source, as shown in the right-most columns in Table 5-4. With MEDCHG programmed to 1, SDMC Bank 3 (nSCS3) becomes the boot location from SROM or SFLASH, mapped to 0x0000.0000. Alternatively, with MEDCHG programmed to 0, SMC Bank 0 (nCS0) becomes the boot location from asynchronous memory, mapped to 0x0000.0000, with SDMC Bank 3 mapped to 0xF000.0000.

Table 5-4. Chip Select Address Coding

CHIP SELECT	A31	A30	A29	A28	MEDCHG	Boot Option
nSCS3	0	0	0	0	1	SROM Bank 3
nSCS3	1	1	1	1	0	SMC Bank 0
nSCS2	1	1	1	0	X	x
nSCS1	1	1	0	1	X	x
nSCS0	1	1	0	0	X	x

5.1.3.4 Address, Data, and Control Requirements

The device type, bank count, and latency timing specifications can vary between the SDMC Chip Select domains, to accommodate various memory devices in each domain. The bank count refers to the number of banks within the SDRAM, addressed as a single SDMC memory domain.

5.1.3.4.1 Data Mask Signals

Depending on the external memory system width and the operand size, one or two memory cycles may be required for operand transfer. The Data Mask signals (DQM[3:0]) select the data phase for each cycle, as shown in Table 5-5.

- For 32-bit wide memory systems, only one memory cycle is required for any data transfer width, with the DQM bits configured on write cycles to disable bytes unaffected by the transfer.
- For 16-bit wide memory systems, DQM[1] is used as the memory system upper data mask (UDQM) and DQM[0] is used as the lower data mask (LDQM).
- For 32-bit transfers in 16-bit wide memory systems, two memory data phases are required to complete the memory cycles. Half word (16-bit) and byte-width transfers complete in one data phase.

Table 5-5. Memory System Examples

MEMORY SYSTEM	SIZE	DATA BUS	AHB PHYSICAL ADDRESS	BYTE ENABLES
16M by 16-bit	32MB	D[15:0]	A[24:1]	DQM[1:0]
16M by 32-bit	64MB	D[31:0]	A[25:2]	DQM[3:0]
64M by 16-bit	128MB	D[15:0]	A[26:1]	DQM[1:0]
64M by 32-bit	256MB	D[31:0]	A[27:2]	DQM[3:0]

5.1.3.4.2 Address Pins

Each nSCS domain can be connected to a variety of device types, provided the total device capacitance on any address, control, or data pin does not exceed the SDRAM manufacturer's specified operating limit.

Addresses from the LH7A400 CPU are presented to the SDMC via the AHB. The addresses are parsed by the SDMC into Row Address, Column Address, Bank Select, and Chip Select signals.

Because of the row-column-bank architecture of Synchronous memory devices, the mapping of such devices into the LH7A400 memory space is not necessarily obvious. The memory in an SDRAM system may appear non-contiguous to the LH7A400 chip. For example, a 32MB SDRAM device can appear as eight blocks of 4 MB each. This non-contiguous appearance is due to the LH7A400 address pin usage, as shown in Table 5-6. The header row of this table shows the Synchronous Address signals (SAx) connected to the SDRAM device. The remaining rows show how the linear address presented to the SDMC on the AHB maps onto the external LH7A400 Synchronous Address pins.

Each device configuration corresponds to a row and column, showing the addresses presented to the synchronous memory device for row and column access. For the specific address lines used in addressing a device, consult the data sheet from the device manufacturer. Because some address lines are unused, the memory appears non-contiguous.

Power consumption can be lowered by ensuring that multiple banks within a device are not always activated. To take maximum advantage of this, use LH7A400 A[26] and A[27] to ensure the memory map appears the same for both Flash and SROM devices and use the 'SROM Lookalike' mode.

Table 5-6. Synchronous Memory Address Decoding

MUXING SCHEME	ADDRESS	SB1	SB0	SA13	SA12	SA11	SA10	SA9	SA8	SA7	SA6	SA5	SA4	SA3	SA2	SA1	SA0
Data Width 16	Row/Bank	A27	A26	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9
	Column	A27	A26				AP*	A25	A24	A8	A7	A6	A5	A4	A3	A2	A1
Data Width 32	Row/Bank	A27	A26	A23	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10
	Column	A27	A26				AP*	A25	A24	A9	A8	A7	A6	A5	A4	A3	A2
2K Page Mode, Data Width 32	Row/Bank	A27	A26	A24	A23	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11
	Column	A27	A26				AP*	A25	A24	A9	A8	A7	A6	A5	A4	A3	A2
SROM512, Data Width 32	Row/Bank	A27	A26	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9
	Column	A27	A26					A25	A24	A23	A8	A7	A6	A5	A4	A3	A2
SROM Lookalike, Data Width 16	Row/Bank	A22	A21	A27	A26	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9
	Column	A22	A21				AP*	A25	A24	A8	A7	A6	A5	A4	A3	A2	A1
SROM Lookalike, Data Width 32	Row/Bank	A23	A22	A27	A26	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10
	Column	A23	A22					A25	A24	A9	A8	A7	A6	A5	A4	A3	A2

NOTE: * AP = SA10 used to control Auto Precharge.

The first two rows of Table 5-6 (reproduced in Table 5-7 for clarity) show the address mapping for an example of a 256MB device:

- 16 bits wide
- 24 address lines: 13 row addresses, nine column addresses, and two bank signals
- Address lines A22, A23, and A25 are unused in this address, because the row and column are 13 and 9, respectively. The non-use of these address lines results in the non-continuous memory map of the SDRAM.

Table 5-7. Address Mapping for 256 Mbit SDRAM

MUXING SCHEME	ADDRESS	SB1	SB0	SA13	SA12	SA11	SA10	SA9	SA8	SA7	SA6	SA5	SA4	SA3	SA2	SA1	SA0
Data Width 16	Row/Bank	A27	A26	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9
	Column	A27	A26	Unused			AP	A25	A24	A8	A7	A6	A5	A4	A3	A2	A1

Set SDCSCx:SROM512 to ensure a linear addressing range for highly rectangular organized devices. Burst accesses must also be prevented from crossing the 512 byte boundry.

To prevent vacant addresses in the AHB address space, set SDCSCx:SROMLL to use a SyncFlash device to mimic an SROM device or to configure a SDRAM device as a flat address space. SDCSCx:EBW specifies the data width. SDCSCx:SROMLL must be programmed to 0 prior to writing to SyncFlash.

Table 5-8 and Table 5-9 show the address ranges used by a variety of different device configurations and sizes, for 32-bit wide data, using two 16-bit-wide devices. The Read addresses shown in these tables are offset from each memory Bank base address specified by the four most significant bits of the address (the Chip Select signals, nSCS[3:0]).

Table 5-8. Address Ranges for 32-bit-wide Devices

DEVICE SIZE (SYSTEM TYPE)	ADDRESS MATRIX	TOTAL DOMAIN SIZE	CONTIGUOUS ADDRESS RANGE*	SEGMENT SIZE
64MB (32-bit-wide device)	12 × 8 × 2 banks	8MB	0xN000.0000-0xN03F.FFFF	4MB
			0xN400.0000-0xN43F.FFFF	
64MB (32-bit-wide device)	11 × 8 × 4 banks	8MB	0xN000.0000-0xN01F.FFFF	2MB
			0xN400.0000-0xN41F.FFFF	
			0xN800.0000-0xN81F.FFFF	
			0xNC00.0000-0xNC1F.FFFF	
64MB (Two 16-bit-wide devices)	12 × 8 × 4 banks	16MB	0xN000.0000-0xN03F.FFFF	4MB
			0xN400.0000-0xN43F.FFFF	
			0xN800.0000-0xN83F.FFFF	
			0xNC00.0000-0xNC3F.FFFF	
128MB (32-bit-wide device)	12 × 8 × 4 banks	16MB	0xN000.0000-0xN03F.FFFF	4MB
			0xN400.0000-0xN43F.FFFF	
			0xN800.0000-0xN83F.FFFF	
			0xNC00.0000-0xNC3F.FFFF	

Table 5-8. Address Ranges for 32-bit-wide Devices (Cont'd)

DEVICE SIZE (SYSTEM TYPE)	ADDRESS MATRIX	TOTAL DOMAIN SIZE	CONTIGUOUS ADDRESS RANGE*	SEGMENT SIZE
128MB (Two 16-bit-wide devices)	12 × 9 × 4 banks	32MB	0xN000.0000-0xN03F.FFFF	4MB
			0xN100.0000-0xN13F.FFFF	
			0xN400.0000-0xN43F.FFFF	
			0xN500.0000-0xN53F.FFFF	
			0xN800.0000-0xN83F.FFFF	
			0xN900.0000-0xN93F.FFFF	
			0xNC00.0000-0xNC3F.FFFF	
			0xND00.0000-0xND3F.FFFF	
256MB (32-bit-wide device)	13 × 8 × 4 banks	32MB	0xN000.0000-0xN07F.FFFF	8MB
			0xN400.0000-0xN47F.FFFF	
			0xN800.0000-0xN87F.FFFF	
			0xNC00.0000-0xNC7F.FFFF	
256MB (Two 16-bit-wide devices)	13 × 9 × 4 banks	64MB	0xN000.0000-0xN07F.FFFF	8MB
			0xN100.0000-0xN17F.FFFF	
			0xN400.0000-0xN47F.FFFF	
			0xN500.0000-0xN57F.FFFF	
			0xN800.0000-0xN87F.FFFF	
			0xN900.0000-0xN97F.FFFF	
			0xNC00.0000-0xNC7F.FFFF	
			0xND00.0000-0xND7F.FFFF	
512MB (Two 16-bit-wide devices)	13 × 10 × 4 banks	128MB	0xN000.0000-0xN07F.FFFF	8MB
			0xN100.0000-0xN17F.FFFF	
			0xN200.0000-0xN27F.FFFF	
			0xN300.0000-0xN37F.FFFF	
			0xN400.0000-0xN47F.FFFF	
			0xN500.0000-0xN57F.FFFF	
			0xN600.0000-0xN67F.FFFF	
			0xN700.0000-0xN77F.FFFF	
			0xN800.0000-0xN87F.FFFF	
			0xN900.0000-0xN97F.FFFF	
			0xNA00.0000-0xNA7F.FFFF	
			0xNB00.0000-0xNB7F.FFFF	
			0xNC00.0000-0xNC7F.FFFF	
			0xND00.0000-0xND7F.FFFF	
			0xNE00.0000-0xNE7F.FFFF	
			0xNF00.0000-0xNF7F.FFFF	

NOTE: *'N' = MSB of particular SDRAM Domain.

Table 5-9. Address Ranges for 16-bit-wide Devices

DEVICE SIZE (SYSTEM TYPE)	ADDRESS MATRIX	TOTAL BANK SIZE	CONTINUOUS ADDRESS RANGE	SEGMENT SIZE
64MB (16-bit-wide device)	12 × 8 × 4 banks	8MB	0xN000.0000-0xN01F.FFFF	2MB
			0xN400.0000-0xN41F.FFFF	
			0xN800.0000-0xN81F.FFFF	
			0xNC00.0000-0xNC1F.FFFF	
128MB (16-bit-wide device)	12 × 9 × 4 banks	16MB	0xN000.0000-0xN01F.FFFF	2MB
			0xN100.0000-0xN11F.FFFF	
			0xN400.0000-0xN41F.FFFF	
			0xN500.0000-0xN51F.FFFF	
			0xN800.0000-0xN81F.FFFF	
			0xN900.0000-0xN91F.FFFF	
			0xNC00.0000-0xNC1F.FFFF	
			0xND00.0000-0xND1F.FFFF	
256MB (16-bit-wide device)	13 × 9 × 4 banks	32MB	0xN000.0000-0xN03F.FFFF	4MB
			0xN100.0000-0xN13F.FFFF	
			0xN400.0000-0xN43F.FFFF	
			0xN500.0000-0xN53F.FFFF	
			0xN800.0000-0xN83F.FFFF	
			0xN900.0000-0xN93F.FFFF	
			0xNC00.0000-0xNC3F.FFFF	
			0xND00.0000-0xND3F.FFFF	
512MB (16-bit-wide device)	13 × 10 × 4 banks	64MB	0xN000.0000-0xN03F.FFFF	4MB
			0xN100.0000-0xN13F.FFFF	
			0xN200.0000-0xN23F.FFFF	
			0xN300.0000-0xN33F.FFFF	
			0xN400.0000-0xN43F.FFFF	
			0xN500.0000-0xN53F.FFFF	
			0xN600.0000-0xN63F.FFFF	
			0xN700.0000-0xN73F.FFFF	
			0xN800.0000-0xN83F.FFFF	
			0xN900.0000-0xN93F.FFFF	
			0xNA00.0000-0xNA3F.FFFF	
			0xNB00.0000-0xNB3F.FFFF	
			0xNC00.0000-0xNC3F.FFFF	
			0xND00.0000-0xND3F.FFFF	
			0xNE00.0000-0xNE3F.FFFF	
			0xNF00.0000-0xNF3F.FFFF	

NOTE: *'N' = MSB of particular SDRAM Domain.

5.1.4 Programming the SDMC

The SDMC is configured by entering the proper parameter values into its four Synchronous Domain Chip Select Configuration registers (SDCSC[3:0]), Global Configuration register (GBLCNFG), and Refresh Timer register (RFSHTMR), in the proper sequence during initialization. This is done by writing the configuration data directly to their memory-mapped location under program control.

The Global Configuration register is programmed with information common to all SDRAM domains. The SDCSC registers contain information specific to each domain, based on the Chip Select signal. Exact use of the registers is described in Section 5.3.2.

The SDRAM devices are configured by programming their onboard Mode Registers. This is done by programming bits [1:0] in the GBLCNFG register to 1 to cause the SDMC to generate the Load Mode Register command to the SDRAM, then performing a read operation to the SDRAM device. The value to be programmed is encoded onto the address signals during the read from the configuration data contained in the SDCSC register associated with the particular SDRAM domain. The coded address is formed by combining the base address of the applicable chip select with the bit pattern with the values to be loaded into corresponding bits of the Mode Register.

5.1.4.1 Determining Parameter Values

For initialization, the user must:

- Decide whether or not to enable Auto Pre-charge.
- Determine the permitted RAS to CAS latency.
- Determine the permitted CAS latency.
- Define the external bus width.
- Determine the necessary burst length.
- Identify the specific type of SDRAM attached to each of the Chip Select signals, that is, determine the number of internal banks in the respective SDRAM devices, and determine the address multiplexing scheme they use.
- Determine the Write Burst Mode: either programmed burst length or single location access should be selected in conjunction with enabling or disabling the SDMC Write Buffers.
- Decide which of the four Clock Enable signals will be used.

5.1.4.2 Auto Precharge

During normal operation, it is desirable to use Auto Precharge, so Auto Precharge would usually be enabled. In general, manual precharge is used for page size bursting transfers under program control.

5.1.4.3 RAS to CAS Latency

The RAS to CAS latency is the number of SCLKs between the ACTIVE command and the READ or WRITE command.

The LH7A400 only allows RAS to CAS latency (RCD) values of 2 or 3.

Of these two values, the RAS to CAS latency is selected by inspecting the SDRAM AC operating conditions in the manufacturer's data sheet.

The RAS-to-CAS setting is specified in integral counts of SCLK. The required count value is the least integral number of SCLKs multiplied by the bus clock period that results in a value greater than or equal to the minimum ACTIVE to READ or ACTIVE to WRITE delay.

That is, the following inequality must be satisfied:

$$\text{Period(SCLK)} \times \text{RCD} \geq \text{tRCD}$$

5.1.4.4 CAS Latency

The CAS latency identifies the number of SCLKs between incidence of the READ or WRITE command and the presence of valid data. A CAS latency of 2 means that data is valid on the second SCLK after the READ or WRITE SCLK.

Understanding CAS latency is somewhat confusing because the actual latency for a WRITE is different than the actual latency for a READ for a specific configured value of CAS latency. If CAS latency is set to 2, then the actual CAS latency for a READ is 2 SCLKs, while the actual CAS latency for a WRITE is 3 SCLKS.

The SDMC can accommodate CAS latencies of 2-8.

5.1.4.5 External Bus Width

External bus width is established by the physical hardware. The External Bus Width (EBW) bit in the SDCSC registers establishes the external bus width from the LH7A400's view-point. The value selected also determines which Burst Length must be programmed into the SDRAM device.

5.1.4.6 Burst Length

The burst length is automatically determined by the value programmed for the GBLCNFG[EBW] bit. If the bus width selected is 16 bits, the burst length is 8. If the bus width selected is 32 bits, the burst length is 4.

5.1.4.7 Clock Enable and Clock Shutdown

Clock Enable and Clock Shutdown are configured using GBLCNFG[CKE] and GBLCNFG[CKSD]. When Clock Enable is programmed to 0, the SDMC drives the SCKEx signal LOW when all SDRAM devices are idle to conserve power. When Clock Enable is programmed to 1, the SCKEx signal is set HIGH to all SDRAM devices continuously. Clock Control affects the SCLK signal. If Clock Control is programmed to 0, SCLK is inhibited when all devices are idle. If Clock Control is programmed to 1, SCLK runs continuously while the SDMC is in control of the EBI. However, it's important to note that SCLK **cannot** be used to clock other peripherals as it stops when the SMC controls the EBI.

Note that programming both Clock Control and Clock Enable to 1 is a forbidden condition. That is, configuring SDCLK to stop when idle while configuring GBLCNFG[CKE] to HIGH continuously must not be done.

5.1.4.8 Configuring the SDRAM device Load Mode Register

Using GBLCNFG under program control, the SDMC can generate one of four specific commands, or resume normal operation. The commands are:

- Generate a NOP command
- Generate a PRECHARGE ALL command
- Generate an SDRAM LOAD MODE REGISTER command
- Generate a Synchronous Flash LOAD COMMAND REGISTER command
- Resume normal operation.

When GBLCNFG[MRS]=1 and GBLCNFG[Initialize]=0, access to the Synchronous Device MODE register is enabled, and the subsequent Read Instruction address on the AHB Address Bus A[23:10] is output on SA[13:0] as the SYNCHRONOUS MODE command. The Read Address specifies the Command Word. The four most significant address bits specify the memory Bank receiving this Command Word. When the LH7A400 is configured to boot from SROM or SFLASH, the four most significant address bits are 0x0, corresponding to Bank 3 (nSDCS[3]).

For Mode register programming, the Command Word put onto the address lines depends on whether the device is SROM, SDRAM, or SFLASH. Table 5-10 shows the Command Word coding for various device types with a 32-bit external bus. After programming the device Mode register for a Chip Select (nSCSx), program the corresponding SDMC SDCSCx register:

- The read Burst Length (BL) shown in Table 5-10 is 4 because the device types covered by this table are 32-bit. The smallest burst length supported by LH7A400 is a quad word. Program the SDMC external device bus width to match the device BL:
  - Program SDCSCx:EBW to 0, specifying a 32-bit external memory system with a BL of 4. In the corresponding Command Word, code BL[2:0] = 0b010 for SDRAM and SFLASH, or BL[1:0] = 0b01 for SROM.
  - Program SDCSCx:EBW to 0, specifying a 16-bit memory system with a BL of 8. In the corresponding Command Word, code BL[2:0] = 0b011 for SDRAM and SFLASH, or BL[1:0] = 0b10 for SROM.

- Enable or disable Auto-Precharge in SDCSCx:AutoPrecharge, to match the Command Word Auto Precharge (AP) coding.
- The Write Burst Length (WBL) varies by device type, as follows:
  - For SDRAM devices, specify single location write accesses by programming SDCSCx:WBL to 1. Specify write burst accesses the same length as BL by programming SDCSCx:WB to 0.
  - SFLASH devices can be written to in only single word writes, not in bursts. For SFLASH devices, program SDCSCx:WBL to 0.
  - For SROM devices, program SDCSCx:WBL to 0, disabling burst write accesses.
- In the Command Word, the device Operating Mode (OPM[1:0]) is 0b00 for normal operation, unless otherwise specified in the device data sheet. No corresponding programming is required for the SDMC.
- Program SDCSCx:CasLat[2:0] with a Column Access Strobe (CAS) latency corresponding to CAS[2:0] in the Command Word, as shown in Table 5-11.
- In the Command Word, the Burst Access Type (BAT) specifies sequential (0) or interleaved (1) burst addressing. No corresponding programming is required for the SDMC.
- For SDRAM and SFLASH devices, program SDCSCx:RasToCas[1:0] for a latency equal to or greater than the latency specified in the device data sheet. Only SROM devices require Command Word RAS coding. For SROM devices, program SDCSCx:RasToCas[1:0]:
  - When Command Word RAS = 0b0, specifying a RAS of 2, program SDCSCx:RasToCas[1:0] = 0b10.
  - When Command Word RAS = 0b1, specifying a RAS of 3, program SDCSCx:RasToCas[1:0] = 0b11.
- Example 1 is for a SDRAM device. The Command Word coding and corresponding SDMC programming are:
  - The Command Word specifies the Write Burst Length is the same as the Read Burst Length (WBL = 0b0). Clear SDCSCx:WBL.
  - The Command Word specifies the CAS latency is 3 (CAS[2:0] = 0b011). Program SDCSCx:CasLat[2:0] = 0b010.
  - The Command Word specifies sequential burst access (BAT = 0b0).
- Example 2 is for a SROM device. The Command Word coding and corresponding SDMC programming are:
  - The Command Word specifies the RAS latency is 2 (RAS = 1). Program SDCSCx:RasToCas[1:0] = 0b10.
  - The Command Word specifies the CAS latency is 5 (CAS[2:0] = 0b100). Program SDCSCx:CasLat[2:0] = 0b100.
  - The Command Word specifies sequential burst access (BAT = 0b0).

Table 5-11, Table 5-12, and Table 5-13 show the standard codings for CAS, RAS, BAT, BL, and WBL. Table 5-15 and Table 5-16 show examples of the Read addresses to configure various parameters on 32-bit wide and 16-bit wide external devices. The Read addresses shown in these tables are offset from each memory Bank base address specified by the four most significant bits of the address (the Chip Select signals, nSCS[3:0]).

Table 5-10. Mode Register Command Coding for 32-bit External Systems

MEMORY TYPE	SDRAM ADDRESS LINES											
	SA11	AP/SA10	SA9	SA8	SA7	SA6	SA5	SA4	SA3	SA2	SA1	SA0
	CORRESPONDING AHB ADDRESS LINES											
	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10
SDRAM or SFLASH	///	///	WBL	OPM[1:0]		CAS[2:0]			BAT	BL[2:0]		
EXAMPLE 1	0	0	0	00		011			0	010		
SROM	///	///	///	///	///	RAS	CAS[2:0]			BAT	BL[1:0] = 0b01	
EXAMPLE 2	0	0	0	0	0	1	100			0	01	

Table 5-11. Synchronous Memory Command Word CAS Coding and SDCSCx CAS Latency Programming

COMMAND WORD CAS[2:0]	SDRAM CAS	SFLASH CAS	SDRAM and SFLASH SDCSCx:CasLat[2:0]	SROM CAS	SROM SDCSCx:CasLat[2:0]
000			000		000
001		1	Unsupported	2	001
010	2	2	001	3	010
011	3	3	010	4	011
100				5	100
101				6	101
110				7	110
111				8	111

Table 5-12. Synchronous Memory RAS and Write Burst Length Coding

COMMAND WORD	SDCSCx REGISTER	SDRAM	SFLASH	SROM
RAS = 0	RAS[1:0] = 0b10			RAS = 2
RAS = 1	RAS[1:0] = 0b11			RAS = 3
BAT = 0		Sequential	Sequential	Sequential
BAT = 1		Interleaved	Interleaved	Interleaved
WBL = 0	WBL = 0	WBL = BL	As Initialized	As Initialized
WBL = 1	WBL = 1	Single Location	Single Location	

Table 5-13. Burst Length for SDRAM and SFLASH

SDCSCx:EBW	COMMAND WORD	SDRAM (SDCSCx:WBL = 0b1) BURST LENGTH (WORDS)	SFLASH (SDCSCx:WBL = 0b0) BURST LENGTH (WORDS)
Unsupported	BL[2:0] = 000	1	1
Unsupported	BL[2:0] = 001	2	2
0 (32-bit)	BL[3:0] = 010	4	4
1 (16-bit)	BL[3:0] = 011	8	8
x	BL[3:0] = 111	Full Page or Reserved	Full Page or Reserved

Table 5-14. Burst Length for SROM

SDCSx:EBW	COMMAND WORD	SROM (SDCSCx:WBL = 0b1) BURST LENGTH (WORDS)
0 (32-bit)	BL[1:0] = 01	4
1 (16-bit)	BL[1:0] = 10	8

Table 5-15. Read Addresses and Parameters for 32-bit External Devices

READ ADDRESS OFFSET	PARAMETERS
SDRAM default Read Address 0x0000.C800	WBL = Same as BL OPM = Normal mode CAS = 3 BAT = Sequential BL = 4
SFLASH default Read Address 0x0008.C800	WBL = Single location access OPM = Normal mode CAS = 3 BAT = Sequential BL = 4
SROM default Read Address 0x0001.8400	RAS = 2 CAS = 5 BAT = Sequential BL = 4

Table 5-16. Read Addresses and Parameters for 16-bit External Devices

READ ADDRESS OFFSET	PARAMETERS
SDRAM default Read Address 0x0000.6600	WBL = Same as BL OPM = Normal mode CAS = 3 BAT = Sequential BL = 8
SFLASH default Read Address 0x0004.6600	WBL = Single location access OPM = Normal mode CAS = 3 BAT = Sequential BL = 8
SROM default Read Address 0x0000.C400	RAS = 2 CAS = 5 BAT = Sequential BL = 8

5.1.4.9 Configuring the Refresh Timer Register

As with any DRAM, Synchronous DRAM must be refreshed periodically to maintain its data integrity. The number of SCLKs between Auto Refreshes is determined by the value in RFSHTMR. This value is dependent upon the required SDRAM refresh rate and the SCLK frequency.

5.1.5 Initializing the SDRAM Devices

After a power-on reset, software must first initialize the SDMC, then initialize each device connected to the SDMC.

Synchronous memory devices must be powered-up and configured as specified by the device manufacturers. The device initialization sequence varies by manufacturer. Sequences other than as specified by the manufacturer can cause unpredictable operation. The initialization sequences in this section are presented as guidelines and examples.

5.1.5.1 Initialization When Debugging

SDRAM accesses attempted before initialization is complete cause an AHB error and the chip must be reset to recover. This Affects debugging if there is an open window for SDRAM space when the chip is reset. The debugger attempts to restore contents of the window after a reset, but before the initialization has completed, and locks up the chip. When debugging code that runs on the chip prior to SDRAM initialization, close windows that show SDRAM.

5.1.5.2 General Initialization Sequence

The following is a general initialization sequence, demonstrating typical steps, times, and effects:

1. Wait 100 µs to allow the device power and clocks to stabilize.
2. Program the External Bus Width field (SDCSCx:EBW), for each memory Bank in use, according to the device width.
3. Program the SDMC Global Configuration register Initialize, MODE Register Select, and Clock Enable bits to 1 (GBLCNFG:Initialize, GBLCNFG:MRS, and GBLCNFG:CKE, respectively), to issue continuous NOP commands.
4. Wait 200 µs, as required by the device.
5. Program the device MODE register.
6. Write 10 to the SDMC Refresh Timer register (RFSHTMR), specifying a refresh every 10 HCLK cycles.
7. Wait at least 80 HCLK cycles, to provide 8 refresh cycles to all devices.
8. Program RFSHTMR to specify normal refresh operation.
9. Program each device MODE register. Clear Initialize and set MRS, to select the MODE Register Update mode, and read each device. The read address specifies the value written to the MODE register, as described in the device data sheet. This address depends on the SDCSCx:EBW configuration, as specified in step 2, because the SDMC address pin mapping to LH7A400 pins differs between 16- and 32-bit wide memory systems.
10. Program each SDCSCx register according to the corresponding device Mode register programming. This step initializes the SDMC timing.
11. Program Initialize and MRS to 0 and program other GBLCNFG fields to normal operating values.

5.1.5.3 JEDEC General SDRAM Initialization Sequence

The following is a general JEDEC initialization sequence:

1. Apply power. Apply VDD/VDDQ equally, and ensure the device clock is stable.
2. Wait at least 200 µs.
3. Select the device PRECHARGE ALL mode.
4. Perform eight AUTO REFRESH commands.
5. Issue a LOAD MODE register command to the SDRAM.

5.1.5.4 Micron SDRAM Initialization Sequence

A stable clock is defined as a signal cycling within the timing constraints specified by the SDRAM device manufacturer for that device's clock pin. When power has been applied and the clock is stable, SDRAM devices usually require a delay prior to issuing any commands other than a COMMAND INHIBIT or a NOP. The COMMAND INHIBIT or NOP commands should be applied to the device throughout this delay.

When the delay has expired, a PRECHARGE ALL command should be issued. All SDRAM banks must then be precharged, thereby placing the SDRAM device in the ALL BANKS IDLE state.

Once the SDRAM device is in the IDLE state, 2 AUTO REFRESH cycles must be performed. When the 2 AUTO REFRESH cycles are completed, the SDRAM device is ready for MODE REGISTER programming. The SDRAM device's MODE register powers up in an unknown state, and should be programmed before any other operational commands are issued to the SDRAM device.

Although Micron SDRAM devices can be initialized with a JEDEC sequence, Micron devices also permit a faster initialization sequence:

1. APPLY POWER (Apply VDD/VDDQ equally, and ensure that the CLK is stable.)
2. Wait at least 100 µs (Begin and continue applying NOP or COMMAND INHIBITs during this delay.)
3. Issue a PRECHARGE ALL command to the SDRAM device.
4. Issue 2 (or more) AUTO REFRESH commands to the SDRAM device. (The order of the AUTO REFRESH and LOAD MODE REGISTER commands can be reversed if preferred.)
5. Issue a LOAD MODE REGISTER to the SDRAM.

The SDRAM is ready for operation.

5.1.6 Self Refresh

When entering Low Power mode (Standby), the SDMC automatically does the following before the processor is stopped:

- Pre-charge all active banks.
- Issue a NOP command.
- Drive Clock Enable (CLKE3, CLKE1_2, and CLKE0) LOW.
- Issue an AUTO REFRESH command.
- Enter SELF REFRESH Mode.

When exiting Standby, the SDMC automatically does the following before the processor is started:

- Allow clock stabilization.
- Drive Clock Enable HIGH.
- Issue 10 NOP commands.
- Issue an AUTO REFRESH command.
- Enter AUTO REFRESH Mode.

5.2 Boot Modes

The LH7A400 can boot from SROM or from SFLASH on Chip Select 3, depending on the Width1, Width0 and MEDCHG signals (pins R12, P11, and C3, respectively). Table 5-17 shows the boot mode control signals.

Table 5-17. Boot Mode Signal Values

BOOT MODE	Width[1:0]	MEDCHG
8-bit ROM	00	0
16-bit ROM	01	0
32-bit ROM	10	0
Invalid: Do not allow this state.	11	0
16-bit SFLASH (Initializes Mode Register)	00	1
16-bit SROM (Initializes Mode Register)	01	1
32-bit SFLASH (Initializes Mode Register)	10	1
32-bit SROM (Initializes Mode Register)	11	1

To support these boot modes, the SDMC Chip Select 3 register (SDCSC3) and GBLCNFG have the following values after an LH7A400 reset:

- When booting from SROM, SDCSC3:CasLat[2:0] is reset to 0b100, specifying a CAS latency of 5.
- When booting from SFLASH, SDCSC3:CasLat[2:0] is reset to 0b010, specifying a CAS latency of 3.
- When booting from SROM or SFLASH, GBLCNFG:CKE is reset to 0b1, driving all clock enable signals (CLKE0, CLKE12, and CLKE3) continuously HIGH.

When booting from SROM, a short configuration sequence occurs before the ARM922T processor is released from RESET. This sequence ensures a known configuration, regardless of the device attached, to accommodate differences in SROM default Burst Lengths. This configuration is:

- SDCSC3:RasToCas[1:0] = 0b10, specifying a RAS latency of 2.
- SDCSC3:CasLat[2:0] = 0b100, specifying a CAS latency of 5.
- SDCSC3:EBW = 0, specifying a 32-bit External Bus Width and Burst Length = 4.

The following automatic sequence occurs on booting from SFLASH:

- SDCSC3:WBL is set, specifying a single word write burst length. SFLASH devices cannot be written in bursts.
- SDCSC3:CasLat[2:0] = 0b010, specifying a CAS latency of 3.
- SDCSC3:EBW = 0, specifying a 32-bit External Bus Width and Burst Length = 4.

This power-up sequence occurs after a power-on reset:

1. Power is applied to the circuit, with the input signals CKE and DQM pulled HIGH to rise with the supply VDD and VDDQ.
2. After power-up, the processor is held in the reset state while the clock runs. A NOP command is put on the Command pins (SA[13:0]) for 200 μs by programming GBLCNFG:Initialize and GBLCNFG:MRS to 1 and programming GBLCNFG:LCR to 0, while the SROM device is clocked.
3. The default configuration is written to the device MODE register, by programming GBLCNFG:Initialize and GBLCNFG:LCR to 0, programming GBLCNFG:MRS to 1, and reading the appropriate address.
4. Three clock cycles after the MODE register configuration cycle, the device is ready for power-up. All data outputs are in a high impedance state. The processor is released from the reset state.

5.2.1 Synchronous Memory Boot Interrupt Behavior

Following a Synchronous Memory boot, the MEDCHG interrupt will be set and pending. Therefore, prior to enabling interrupts, the MEDCHG interrupt should be cleared in the end of interrupt register (EOI:MCEOI). See Chapter 8 for details on this register.

5.3 Register Reference

This section describes the SDRAM Controller registers.

5.3.1 Memory Map

The register offsets shown in Table 5-18 are relative to the SDMC base address, 0x8000.2400.

Table 5-18. SDRAM Controller Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	///	Reserved. Do not access this location.
0x04	GBLCNFG	Global Configuration. Controls SDMC operation and reports SDMC status.
0x08	RFSHTMR	Refresh Timer. Specifies the time period between synchronous memory refresh commands.
0x0C	BOOTSTAT	Boot Status. Reports the boot configuration pin states.
0x10	SDCSC0	Synchronous Domain Chip Select Configuration. Each register (SDCSC[3:0]) configures the SDMC for the specific memory device at the corresponding chip select (nSCS[3:0]).
0x14	SDCSC1	
0x18	SDCSC2	
0x1C	SDCSC3	

5.3.2 Register Descriptions

5.3.2.1 Synchronous Domain Chip Select Configuration Registers (SDCSC)

The Synchronous Domain Chip Select Configuration registers (SDCSC[3:0]), described in Table 5-19 and Table 5-20, configure the SDMC for the characteristics of the external synchronous memory devices connected to the Synchronous Chip Select signals (nSCS[3:0]). Each signal corresponds to a memory Bank. Each Bank can be configured with different device characteristics. The configuration must correspond to the device mode register programming.

Although this chapter describes the memory addressed by each SCS signal as a separate memory Bank, avoid confusing these Banks with the banks of memory internal to Synchronous devices. Each device can contain multiple banks, as specified by the device manufacturer.

In each SDCSC register, only one of the SROM512, SROMLL, and 2KPAGE fields can be set at any one time. For correct SDMC operation, at least two of these fields must be cleared. The SROM512 and 2KPAGE paging methods operate in multiples of 32-bit data width regardless of the external bus width. The RAS latency has one additional clock cycle over the programmed value when performing a write operation.

Changes to the SDCSCx registers take effect only when the SDMC is idle. Disable interrupts and DMA operations before changing these registers.

Table 5-19. SDCSC[3:0] Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///							AutoPrecharge	///		RasToCas		WBL	CasLat		
RESET	0	0	0	0	0	0	0	1	0	0	1	0	0	*	*	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									2KPAGE	SROMLL	SROM512	BankCount	EBW	///	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RO	RO
ADDR	0x8000.2410 for SDCSC0 0x8000.2414 for SDCSC1 0x8000.2418 for SDCSC2 0x8000.241C for SDCSC3															

NOTE: *SDCSCx:CasLat[2:0] reset to 0b010. When the LH7A400 boots from SROM, SDCSC3:CasLat[2:0] resets to 0b100.

Table 5-20. SDCSC[3:0] Fields

BIT	FIELD	DESCRIPTION
31:25	///	**Reserved** Reading returns 0. Values written cannot be read.
24	AutoPrecharge	**AutoPrecharge** Specifies the Auto-Precharge (AP) value. 1 = Enable auto pre-charge. 0 = Disable auto pre-charge.
23:22	///	**Reserved** Reading returns 0. Values written cannot be read.
21:20	RasToCas	**Row Address Strobe To Column Address Strobe** Selects the synchronous memory RAS-to-CAS latency. 00 = Reserved; do not program this value. 01 = Reserved; do not program this value. 10 = RAS latency is 2. 11 = RAS latency is 3. The RAS latencies shown are for read operations. For write operations, RAS latency has one additional clock cycle. This field value resets to 10, to support booting from SROM.
19	WBL	**Write Burst Length** Selects the write burst length. 1 = Writes are single location only, and write bursting is disabled. 0 = Write burst length is the same as the read burst length. The read burst length is specified by the EBW bit of this register. With WBL set to 1 for a device, the SDMC recognizes the device as SFLASH or SROM and issues no auto-refresh command for the corresponding Chip Select.

Table 5-20. SDCSC[3:0] Fields (Cont'd)

BIT	FIELD	DESCRIPTION
18:16	CasLat	**Column Address Strobe Latency** Selects the CAS latency. 000 = Reserved; do not program this value. 001 = CAS latency is 2 010 = CAS latency is 3 011 = CAS latency is 4 100 = CAS latency is 5 101 = CAS latency is 6 110 = CAS latency is 7 111 = CAS latency is 8
15:7	///	**Reserved** Reading returns 0. Values written cannot be read.
6	2KPAGE	**2K PAGE Depth** 1 = Synchronous memory page depth is 2K. The SROMLL and SROM512 bits in this register must be programmed to 0. 0 = Synchronous memory page depth is not 2K.
5	SROMLL	**SROM Lookalike** 1 = Swap the multiplexed bank address SB0 and SB1 signals with the synchronous address signals A12 (pin G16) and A13 (pin G14), respectively. In this configuration, the synchronous flash can mimic a SROM device. The EBW bit must specify the data width. The 2KPAGE and SROM512 bits must be programmed to 0. 0 = Normal operation (no swapping). This bit must be programmed to 0 before writing to SyncFlash.
4	SROM512	**SROM Page Depth 512** The SROM maximum burst size is 512 bytes. This field selects the synchronous memory page. 1 = Synchronous memory page depth is 512. The 2KPAGE and SROMLL bits in this register must be programmed to 0. 0 = Synchronous memory page depth is not 512.
3	BankCount	**Bank Count** Selects the number of banks within the external memory connected to the corresponding Chip Select. 1 = Four bank devices. 0 = Two bank devices. Although this chapter describes the memory addressed by each SDRAM Controller Chip Select signal (nSCS[3:0]) as a separate memory bank, avoid confusing these banks with the banks of memory internal to synchronous devices. The nSCSx signals address separate memory banks. The SB[1:0] signals provide the bank address of the device row-column-bank addressing scheme within each nSCSx address space. The BankCount field specifies how many banks are available to be addressed by SB[1:0].
2	EBW	**External Bus Width** Selects the external memory system width. 1 = Memory device bus widths are 16 bits. The read burst length is 8. The page burst depth is 512 bytes. 0 = Memory device bus widths are 32 bits. The read burst length is 4.
1:0	///	**Reserved** Reading returns 0. Values written cannot be read.

5.3.2.2 SDRAM Global Configuration Register (GBLCNFG)

The Global Memory Configuration register, described in Table 5-21 and Table 5-22, contains additional control and status bits for use during configuration. The Initialize, MRS, and LCR fields provide synchronous memory commands unavailable during normal read and write cycles, as shown in Table 5-23.

Table 5-21. GBLCNFG Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	CKE	CKSD	///													
RESET	0 unless booting from SROM or SFLASH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									LCR	SMEMBust	///			MRS	Initialize
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	Ro	RO	RO	RO	RW	RW
ADDR	0x8000.2404															

Table 5-22. GBLCNFG Fields

BIT	FIELD	DESCRIPTION
31	CKE	**Clock Enable** Controls the synchronous memory clock enables. 1 = Drive all clock enables HIGH. 0 = Set all idle device clock enables LOW, saving power.
30	CKSD	**Clock Shutdown** Controls the synchronous memory clock shutdowns. 1 = CLK is free-running when the SDMC controls the EBI (the clock stops when the SMC controls the EBI). 0 = CLK is gated dynamically when no accesses occur to any device. Before programming CKSD to 1, program the CKE bit to 0.
29:7	///	**Reserved** Reading returns 0. Values written cannot be read.
6	LCR	**Load Command Register** 1 = Output subsequent read instruction addresses on lines A[23:10] as the SFLASH LOAD Command Word on SA[13:0]. The four most significant address bits determine the corresponding memory Bank. 0 = Normal operation. Table 5-23 shows the action of the LCR, MRS, and Initialize bits.

Table 5-22. GBLCNFG Fields (Cont'd)

BIT	FIELD	DESCRIPTION
5	SMEMBust	**Synchronous Memory Busy State** 1 = Synchronous Memory Engine busy 0 = Synchronous Memory Engine idle
4:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	MRS	**MODE Register in Synchronous device** 1 = Next READ instruction output as the MODE Command Word on SA[13:0]. The four most significant address bits determine the corresponding memory bank. 0 = Normal operation. Table 5-23 shows the action of the LCR, MRS, and Initialize bits.
0	Initialize	**Initialize** 1 = Issue a NOP or PRECHARGE ALL command to the Synchronous device. The four most significant address bits determine the corresponding memory bank. 0 = Do not issue a NOP or PRECHARGE ALL command. Table 5-23 shows the action of the LCR, MRS, and Initialize bits.

Table 5-23. Synchronous Memory Command Encoding

INITIALIZE	MRS	LCR	EFFECT
0	0	0	Normal operation
0	0	1	Reserved; do not program this value.
0	1	0	Enable access to Synchronous device MODE register
0	1	1	Enable access to SFLASH Memory device's LOAD COMMAND registers
1	0	0	Issue PRECHARGE ALL to Synchronous memory. Only the first PRECHARGE ALL command is issued. No subsequent PRECHARGE ALL commands are output.
1	0	1	Reserved; do not program this value.
1	1	0	Issue NOP to Synchronous memory
1	1	1	Reserved; do not program this value.

5.3.2.3 Refresh Timer Register (RFSHTMR)

The refresh timer register, described in Table 5-24 and Table 5-25, specifies the period between refresh cycles in multiples of the bus clock period (HCLK). For example, for a 16 μs refresh period based on a 20 ns clock period, program the register to 800 (0x320).

Reset sets the refresh counter to 128 (0x10000000). During initialization, set this register to the correct value for the memory system. Programming to 0 stops the refresh cycles.

Table 5-24. RFSHTMR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	REFCNT															
RESET	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.2408															

Table 5-25. RFSHTMR Fields

BIT	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	REFCNT	**Refresh Count** Controls the refresh counter. Nonzero = The period between refresh cycles in multiples of HCLK. 0 = Stop the refresh counter.

5.3.2.4 Boot Status Register (BOOTSTAT)

The boot status register, described in Table 5-26 and Table 5-27, reports the boot mode option pin states, indicating the device configuration after booting. The field values indicate the levels latched at reset for the corresponding pins.

The Width[1:0] field reports the latched value of the Width1 and Width0 signals (pins P11 and P12, respectively). Booting from asynchronous ROM maps the static (asynchronous) memory Bank 0 (nCS0) to address 0x0000.0000. Booting from synchronous ROM maps the Synchronous memory Bank 3 (nSCS3) to address 0x0000.0000. The boot mapping, shown in Figure 5-3, persists until a reset.

Table 5-26. BOOTSTAT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													MEDCHG	Width[1]	Width[0]
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.240C															

Table 5-27. BOOTSTAT Fields

BIT	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	MEDCHG	**Media Change** This bit reports the latched value of the MEDCHG signal (pin C3). MEDCHG controls the boot source. 1 = Synchronous ROM. 1 = Asynchronous ROM.
1:0	Width[1:0]	**Boot Memory Width** For static (asynchronous) external memory on nCS0, Width[1:0] indicate the memory width: 00 = 8-bit 01 = 16-bit 10 = 32-bit 11 = 32-bit For Synchronous external memory on nSCS3, Width[1:0] indicate the memory width: 00 = 16 bit SFLASH, with WBL=1, CAS=3, and BL=8. 01 = 16 bit SROM, with RAS=2, CAS=5, BL=8. 10 = 32 bit SFLASH, with WBL=1, CAS=3, BL=4. 11 = 32 bit SROM, with RAS=2, CAS=5, BL=4. The 8-bit width is unavailable for SROM.

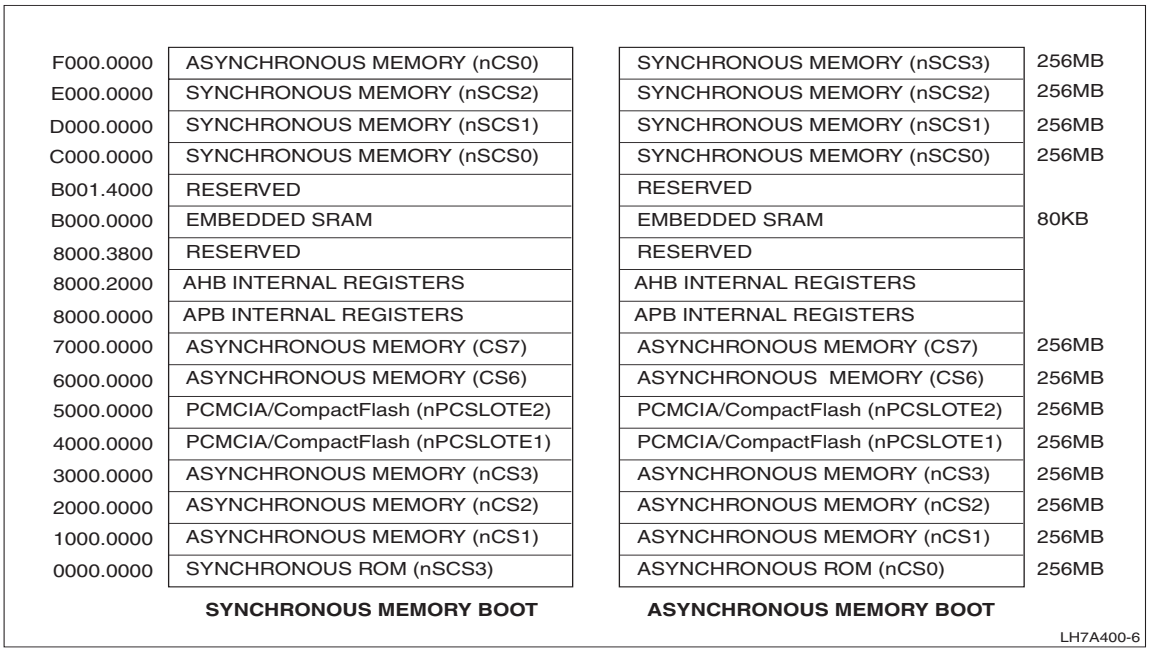


Figure 5-3. Memory Mapping for nSCS3 and nCS0 Boot Sources

Chapter 6
Clock and State Controller (CSC)

6.1 Theory of Operation

The Clock and State Controller (CSC) performs clock generation, clock frequency division, clock gating, and processor state and power mode control. The power mode and clock gating depend on the selected operational state.

6.1.1 Clock Domains

Two primary oscillator inputs provide the timebases for all clock domains:

- 32.768 kHz to control the power-down operations and real time clock (RTC).
- 14.7456 MHz to generate the main system clocks.

These two primary timebases are divided and gated to produce all other required clocks for the CPU and onboard peripherals, as well as and output clock (PGMCLK), as shown in Figure 6-1.

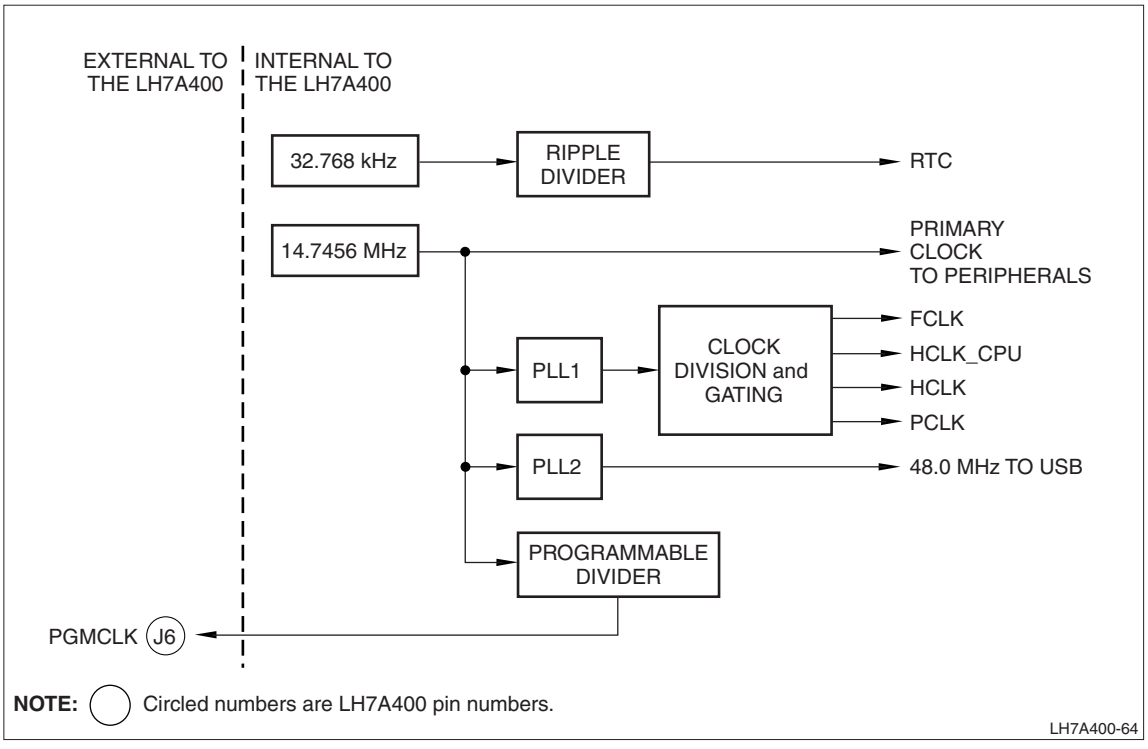


Figure 6-1. Clock Generation

6.1.1.1 32.768 kHz Clock

The 32.768 kHz clock is the only permanently running clock in the LH7A400. In addition to providing the timebase for the RTC, it is used to condition the wakeup signals and control transition between power saving states. The 32.768 kHz-derived clocks also control interlocks to allow the two PLLs to obtain lock before their system clock is supplied.

The 32.768 kHz division uses a ripple divider to conserve power. This two-stage divider produces the 1 Hz signal for the RTC as well as intermediate frequencies of 16 kHz and 8 kHz for the state controller and PLL interlocks (frequencies other than the primary oscillator frequency have been rounded for easier discussion in this chapter). A 64 Hz divided signal provides the TICK interrupt used by wakeup control.

6.1.1.2 14.7456 MHz Clock

The 14.7456 MHz clock provides the timebase for all other LH7A400 peripherals and functions. As shown in Figure 6-2, PLL1 generates an internal clock signal called GCLK, which is the same frequency as FCLK. The clock controller divides GCLK as specified in the CLKSET register, to generate:

- The Synchronous Bus Mode core clocking (FCLK)
- The FASTBUS Mode core clocking (HCLK_CPU)
- APB and peripheral clocking (PCLK)
- AHB and peripheral clocking (HCLK). When optionally gated for low power operation, HCLK is the main clock for:
  - All memory interfaces, including the SDRAM used in the system
  - Bus arbitration
  - All advanced high-performance bus (AHB) peripherals.

These clock signals are all generated as shown in Figure 6-2. Divisor values for Main Divider 1, Main Divider 2, HCLKDIV, PCLKDIV, and the PS exponent are specified by software in the Clock Set register (CLKSET).

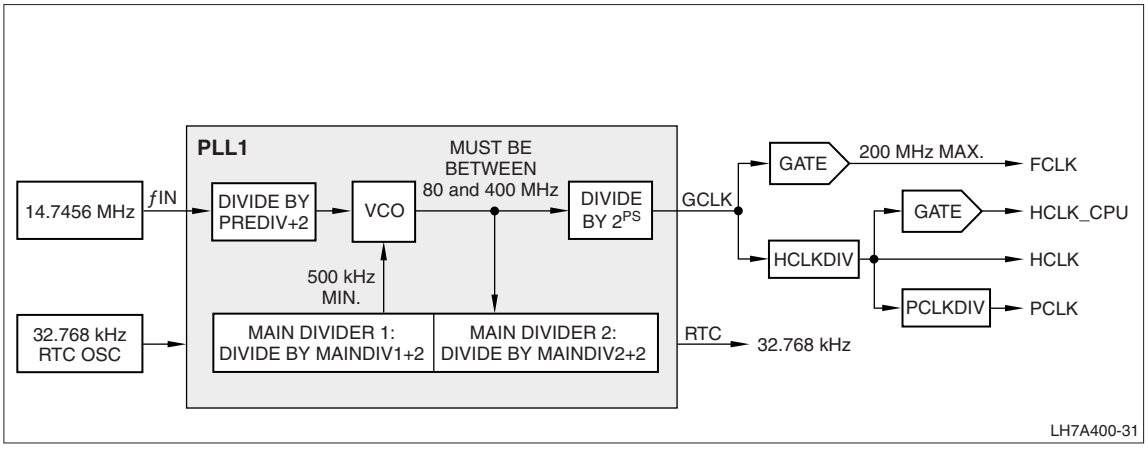


Figure 6-2. Clock Signal Derivation

The equation governing the PLL1 output (GCLK), using the CLKSET register MAINDIV1, MAINDIV2, PREDIV, and PS fields is:

$$GCLK = \frac{(MAINDIV1 + 2) \times (MAINDIV2 + 2) \times 14.7456\ MHz}{(PREDIV + 2) \times (2^{PS})}$$

Software must specify the CLKSET field values such that the feedback frequency to the PLL1 voltage controlled oscillator (VCO) is greater than 500 kHz and the VCO output frequency is within the range of 80 MHz to 400 MHz.

The system clocks generated from GCLK are:

- FCLK, which is the same as GCLK, with a maximum frequency of 200 MHz.
- HCLK, generated from FCLK using CLKSET:HCLKDIV (maximum HCLK = 100 MHz), is:

$$HCLK = \frac{FCLK}{HCLKDIV + 1}$$

- PCLK, generated from HCLK using CLKSET:PCLKDIV is:

$$PCLK = \frac{HCLK}{PCLKDIV}$$

The HCLK frequency must be less than or equal to FCLK. Table 6-1 defines the universe of permissible PCLKDIV divide options and FCKL and HCLK frequencies.

Table 6-1. FCLK and HCLK Allowable Frequencies (in MHz)

FCLK	HCLK	CLKSET:PCLKDIV PERMISSIBLE VALUES
33	33	2 or 4
50	50	2 or 4
66	33	2 or 4
	66	2 or 4
75	75	2 or 4
100	50	2 or 4
	100	2 or 8
132	33	2 or 4
	66	2 or 4
150	75	2 or 4
166	83	2 or 4
200	50	2 or 4
	66	2 or 4
	100	2 or 8

6.1.1.2.1 Peripheral Clocks

Table 6-2 shows the derived clocks for each peripherals and the necessary divisor. Each of these clocks is synchronized to HCLK.

Table 6-2. Peripheral Primary Clock Inputs

PERIPHERAL	PRIMARY CLOCK INPUT	14.7456 MHz DIVISOR
SSI	7.3728 MHz	2
BMI	7.3728 MHz	2
UART1	7.3728 MHz	2
UART2	7.3728 MHz	2
UART3	7.3728 MHz	2
DC-DC Converter	2.9491 MHz	5
CODEC	128.2226 kHz	115
AC97	2.9491 MHz	5
Timer1/Timer2	508.4690 kHz and 1.9940 kHz	29 and 7395
Timer3	3.6864 MHz	4
USB	48 MHz	Output of PLL2
MMC	Derived from HCLK	
SCI	Derived from HCLK	

6.1.1.3 Reset

After a power-on reset, the 32.768 kHz clock is the only valid clock and both PLLs are disabled. On entering the Run state, PLL1 is enabled and the CLKSET register is reset to generate 33 MHz on both FCLK and HCLK. See the State Controller section in this chapter for more information about operating state transitions.

Coming out of reset, the LH7A400 core executes in FASTBUS mode. In this mode, it only uses HCLK_CPU and ignores FCLK. This mode provides fastest code execution when the AHB clock and the core clock have the same frequency, that is, when CLKSET:HCLKDIV value is zero, indicating divide by 1. If CLKSET:HCLKDIV is programmed to be anything other than zero, the core uses FCLK for internal operations and HCLK_CPU for AHB accesses. The LH7A400 core must be switched to Synchronous mode in order to do this. See the Register section for a description of CLKSET:HCLKDIV operation. Reset timing diagrams appear in the LH7A400 Data Sheet.

6.1.1.4 TICK and TICK Timeout Interrupt Generation

The CSC also provides the functionality to generate the 64 Hz TICK Interrupt (TINTR). This interrupt is asserted on every rising edge of the internal 64 Hz clock signal. This 64 Hz clock is derived from the ripple counter that divides the 32.768 kHz oscillator input down to 1 Hz for the real time clock. This interrupt is cleared by writing to the TEOI register.

An extension of the TICK Interrupt is the TICK Timeout Interrupt (TTINT). If the TICK Interrupt is not serviced during the 15.625 ms period of the 64 Hz TICK clock, the TTINT will be asserted on the next 64 Hz rising edge following the TICK interrupt that was not serviced. TTINT is cleared by writing to the TEOI register.

6.1.2 State Controller

The LH7A400 has three operating states: Run, Halt, and Standby. These are used to reduce power consumption. In Halt, some clocks and peripherals are disabled, reducing power from the Run state. In Standby, only the 32.768 kHz clock and state controller are operational, resulting in the minimum power consumption possible. The operational states and state transitions are shown in Figure 6-3. In the figure 'Cold Boot Status' is a short-term Standby state.

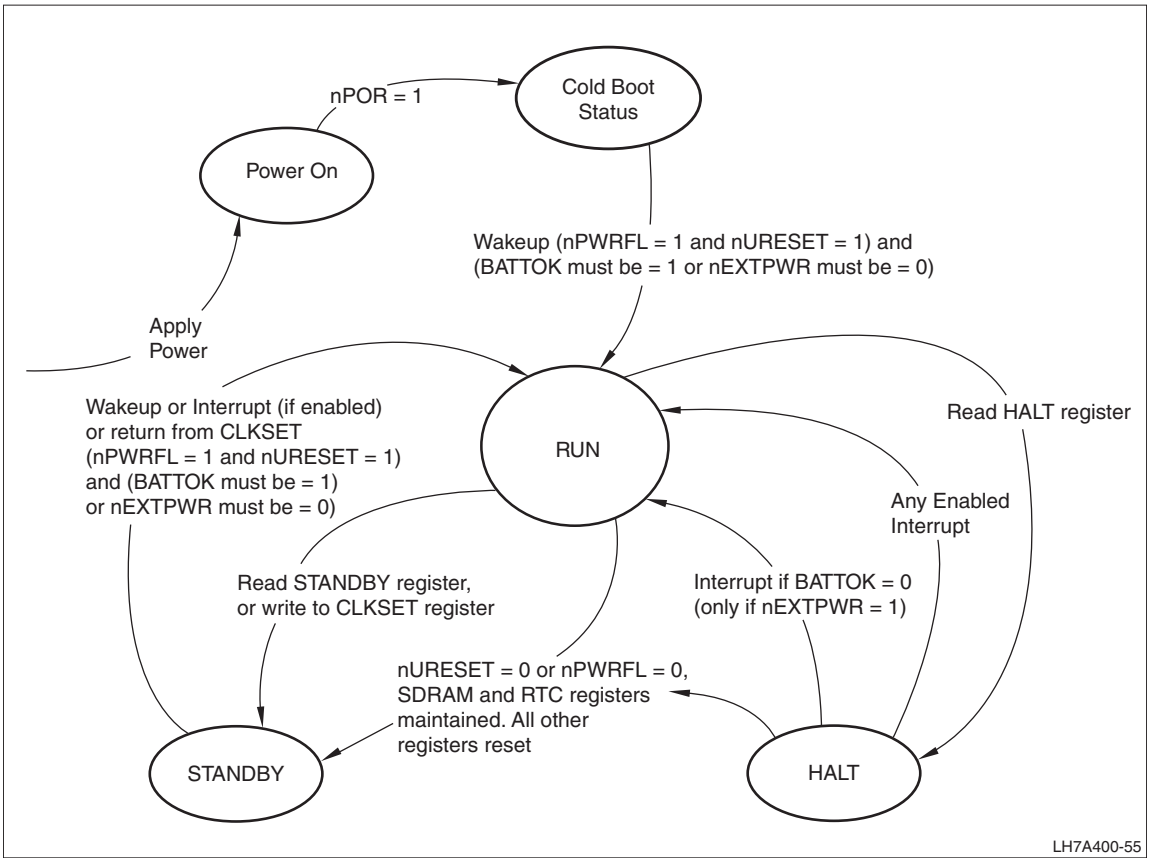


Figure 6-3. State Transition Diagram

6.1.2.1 Run State

In Run state, both oscillator inputs and all clocks are hardware enabled. Software can specify the other active and inactive clocks.

The Run state can be entered from Standby or Halt.

6.1.2.1.1 Standby to Run Transition

The Run state can be entered from Standby through any one of three ways.

- From Standby, Run is entered in response to a rising edge on WAKEUP (pin D4). Because power-on reset disables interrupts, this signal is the only way to enter Run from Standby after power-on reset. This condition is the 'Cold Boot Status' in Figure 6-3.
  - Note that from the rising edge of nPOR, there is a delay of 1-2 seconds before the WAKEUP pin can be asserted. This is to allow sampling the BATOK and nEXTPWR signals. The processor will start executing boot code about 16 msec later. If WAKEUP is asserted (once) before 1-2 seconds, the processor will not wakeup. Pulsing the WAKEUP continuously is acceptable (wakeup edges before 1-2 seconds will just be ignored and the processor will respond to the first wakeup edge it senses after 1-2 sec.). More detailed information is available on the NXP website (http://www.nxp.com) entitled 'Implementing Auto-Wakeup on LH7A4xx Series Devices'.
- From Standby, Run is entered following an exit from a clock set register (CLKSET) write. Writing CLKSET reconfigures PLL1. The LH7A400 automatically enters Standby, providing a delay time for the PLL1 to lock, and returns to Run.
- From Standby, with interrupts enabled, Run is entered in response to an interrupt (IRQ) or fast interrupt (FIQ) falling edge (interrupts are active LOW). This takes approximately 10-15 ms. The TICK interrupt will not cause Standby to exit.

6.1.2.1.2 Halt to Run Transition

The Run state can be entered from Halt:

- From Halt, with interrupts enabled, Run is entered in response to an interrupt (IRQ) or fast interrupt (FIQ) falling edge (interrupts are active LOW). The TICK interrupt will not cause Halt to exit.
- If the interrupt is generated in response to BATOK = 0 (low battery condition), run is entered only if nEXTPWR = 1 (i.e. battery only power). In this instance, BATOK must be stable for at least 61 μs to generate an interrupt.

6.1.2.2 Halt State

The Halt state is designed to reduce system power consumption while the LH7A400 waits for an event such as keyboard input. Although the 14.7456 MHz oscillator input is enabled, the processor clock is halted; software can specify the other active and inactive clocks. The LCD screen image is maintained. Power consumption is reduced from the Run state, but since the 14.7456 MHz oscillator continues to run, Halt consumes more power than when in the Standby state.

6.1.2.2.1 Run to Halt Transition

While in the Run state, reading the HALT register puts the LH7A400 in Halt state. This is the only method to enter the Halt state.

6.1.2.3 Standby State

Standby is the lowest power state. Only the 32.768 kHz oscillator is enabled and the RTC and state controller are the only active functional blocks. The 14.7456 MHz oscillator input is disabled and all associated clocks are halted, and the LCD controller is disabled. When Standby transition is initiated, the CLKEN signal (pin 14) goes LOW and can be used to disable an external 14.7456 oscillator circuit.

The LH7A400 enters the Standby state from the Run state, a reset, or at power on. The SDRAM Controller automatically places the SDRAM in self refresh before the clocks are disabled in Standby, allowing their contents to be maintained.

6.1.2.3.1 Run to Standby Transition

Four conditions transition the LH7A400 from Run to Standby. Two of these are under software control, and two are independent of the LH7A400 software.

- From the Run state, a read of the STBY register allows software to program a transition to the Standby state. Because of ARM922T pipelining, five NOP instructions must follow this read.
- When in Run and the CLKSET register is written (new divisors set for the system clocks), the LH7A400 enters Standby while the PLL stabilizes, then automatically returns to Run.
- From Run state, a valid LOW on nPWRFL (pin E4) changes to the Standby state. After this transition, the state controller will hold the Standby state for one to two 16.384 kHz clocks (61 to 122 μs) before allowing any further state transitions, thus defining a minimum Standby period (allowing clocks to stabilize). The external power (nEXTPWR, pin C2) and battery supply (BATOK, pin D1) signals can block any subsequent transition from Standby to Run, as shown in Table 6-3. The signal sampling is delayed by one or two seconds, to avoid any false good indication caused by alkaline battery recovery (voltage bounce) after a battery low power-off. Note that Standby is entered immediately following the current bus cycle without software cooperation.
- From Run state, a valid LOW level on nURESET (pin H6) changes to the Standby state. After this transition, the state controller will hold the Standby state for one to two 16.384 kHz clocks (61 to 122 μs) before allowing any further state transitions, thus defining a minimum Standby period (allowing clocks to stabilize).

From Standby, the system can enter only the Run state. After transitioning to the Run state, software can read the PWRSR register to identify the reset nature and source.

Table 6-3. Effect of nEXTPWR and BATOK on Standby to Run Transition

nEXTPWR	BATOK	EFFECT
0	0	Using external power supply. Transition is possible.
0	1	
1	0	Using battery. Battery is not OK. No transition is possible.
1	1	Using battery. Battery is OK. Transition is possible.

6.1.2.3.2 Halt to Standby Transition

Standby can also be entered from the Halt state. In the same way as Run to Standby transitions without software intervention, the same two hardware conditions cause a transition from Halt to Standby.

- From Halt state, a valid LOW on nPWRFL (pin E4) changes to the Standby state. After this transition, the state controller will hold the Standby state for one to two 16.384 kHz clocks (61 to 122 μs) before allowing any further state transitions, thus defining a minimum Standby period (allowing clocks to stabilize). The external power (nEXTPWR, pin C2) and battery supply (BATOK, pin D1) signals can block any subsequent transition from Standby to Run, as shown in Table 6-3.
- From Halt state, a valid LOW level on nURESET (pin H6) changes to the Standby state. After this transition, the state controller will hold the Standby state for one to two 16.384 kHz clocks (61 to 122 μs) before allowing any further state transitions, thus defining a minimum Standby period (allowing clocks to stabilize).

6.2 Register Reference

This section describes the CSC registers.

6.2.1 Memory Map

The CSC registers offsets shown in Table 6-4 are relative to the state and power control base address (STPWRBase), 0x8000.0400.

Table 6-4. Clock and State Controller Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	PWRSR	Read to identify the current operational state.
0x04	PWRCNT	Write to specify or read to identify the clock and debug control status.
0x08	HALT	Read to enter Halt.
0x0C	STBY	Read to enter Standby.
0x10	BLEOI	Write to clear a Low Battery interrupt (BLINT). See the Interrupt Controller chapter in this book.
0x14	MCEOI	Write to clear a Media Changed interrupt (MCINT). See the Interrupt Controller chapter in this book.
0x18	TEOI	Write to clear a TICK Interrupt (TINTR). See the Interrupt Controller chapter in this book.
0x1C	STFCLR	Write to clear a New Battery (NBFLG), User Reset (RSTFLG), Power Fail (PFFLG) and Cold Start (CLDFLG) flags. These flags can be read in the PWRSR register.
0x20	CLKSET	Write to specify or read to identify the clock speed.
0x40	SCRREG0	Use for general purpose storage.
0x44	SCRREG1	Use for general purpose storage.
0x48	///	Reserved. Reading returns unpredictable values. Do not write.
0x4C	USBRESET	Write to reset the USB, APB, and I/O controls.

6.2.2 Register Descriptions

The following sections describe the contents and use of the register bit fields.

6.2.2.1 Power Reset Register (PWRSR)

From a reset or power-on, the LH7A400 enters the Standby state and can transition to the Run state on events as described in the State Controller section of this Chapter. In the Run state, read PWRSR to identify the cause of reset and related conditions.

This register is defined in Table 6-5 and Table 6-6.

Table 6-5. PWRSR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	CHIPMAN								CHIPID							
RESET	0	1	0	1	0	0	1	1	*	*	*	*	*	*	*	*
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	WDTFLG	LCKFLG	CLDFLG	PFFLG	RSTFLG	NBFLG	WUON	WUDR	DCDET	MCDR	RTCDIV					
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0X8000.0400															

Table 6-6. PWRSR Bit Fields

BITS	FIELD	DESCRIPTION
31:24	CHIPMAN	**Chip Manufacturer ID** This field contains the ID code for NXP: 0x53.
23:16	CHIPID	**Chip Identification** This field contains the chip revision number. This field changes for each revision. Revision A.0 = 0x00 Revision B.0 = 0x01 Revision B.2 = 0x02 Revision B.3 = 0x03
15	WDTFLG	**Watchdog Flag** If the MCU is reset by an expiration of the WDT, this bit is set to allow software to determine the cause of the reset. 1 = MCU has been reset by the WDT. Clear this bit by writing STFCLR. 0 = The WDT has not reset the MCU
14	LCKFLG	**PLL2 Lock Status** 1 = PLL2 is locked and software enabled. The software enable signal is a logical OR of all peripheral enable signals. 0 = PLL2 is unlocked.
13	CLDFLG	**Cold Start Status Flag** 1 = Power-on reset has occurred. Clear this bit by writing STFCLR. 0 = No power-on reset has occurred since this bit was last cleared.

Table 6-6. PWRSR Bit Fields (Cont'd)

BITS	FIELD	DESCRIPTION
12	PFFLG	**Power Fail Status Flag** 1 = A LOW on nPWRFL has caused a power-fail reset. Clear this bit by writing STFCLR. 0 = No power-fail reset has occurred since this bit was last cleared.
11	RSTFLG	**User Reset Status Flag** 1 = A LOW on nURESET has caused a user reset. Clear this bit by writing STFCLR. 0 = No user reset has occurred since this bit was last cleared.
10	NBFLG	**New Battery Status Flag** 1 = A rising edge on nBATCHG indicates a new battery has been connected. Clear this bit by writing STFCLR. 0 = No battery change signal has occurred since this bit was last cleared.
9	WUON	**Wake Up On** 1 = A rising edge on Wakeup has brought the system out of Standby. Clear this bit with a system reset or by writing HALT, STDBY, or STFCLR. 0 = The system has not entered Standby since this bit was last cleared.
8	WUDR	**Wakeup Direct** This value is the non-latched state of the Wakeup signal.
7	DCDET	**Direct Current Detect** 1 = External power is powering the system. DCDET is the inverted nEXTPWR signal value. 0 = The system is being powered by a battery.
6	MCDR	**Media Change Direct Read** Non-latched value of the media changed (MEDCHG) signal.
5:0	RTCDIV[5:0]	**Real Time Clock Divisor** This value is the number of 64 Hz ticks that have elapsed since the last Real Time Clock Data Register (RTCDR) counter increment. Each bit of RTCDIV is a frequency output: • Bit 5 is the 2 Hz output. • Bit 4 is the 4 Hz output. • Bit 3 is the 8 Hz output. • Bit 2 is the 16 Hz output. • Bit 1 is the 32 Hz output. • Bit 0 is the 64 Hz output. For a 38-bit counter, synchronize RTCDIV with RTCDR.

6.2.2.2 Power Control Register (PWRCNT)

The CSC generates and gates peripheral clocks based on the external 14.7456 MHz oscillator input. Write the power control register to enable the clocks used by the DMA controller and set the programmable clock divider for the PGMCLK (pin J6) output.

The DMACLKEN field enables and disables the DMA clock (HCKL) for DMA to/from the AC97 Controller, MMC Controller, and USB Device. Writing all zeros to this field disables the clock; writing any other value enables the clock. Several clock cycles must transpire between enabling the clock and when the DMA Controller is operational. The number of cycles needed depends on the HCLK and PCLK divisor specified in CLKSET. To save power, ensure all bits in this field are 0 when DMA is not in use.

This register is defined in Table 6-7 and Table 6-8.

Table 6-7. PWRCNT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///						DMACLKEN									
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	PGMCLK								///						WAKEDIS	///
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RO	RO	RO	RO	RO	RO	RW	RW
ADDR	0x8000.0404															

Table 6-8. PWRCNT Fields

BITS	FIELD	DESCRIPTION
31:26	///	**Reserved** Reading returns 0. Values written cannot be read.
25:16	DMACLKEN	**DMA Clock Enable** Non-zero = Enables HCLK for all DMA channels. 0x000 = Disables HCLK to the DMA Controller.
15:8	PGMCLK	**Program Clock Divisor** Specifies the PGMCLK (pin J6) clock divisor. The PGMCLK output frequency is 14.7456 MHz divided by this field value. This field must be set to 1, or an even number. The following examples of the highest and lowest divider values show the output frequency range (0xFF is not an allowable divisor): 0x01 = PGMCLK output is 14.7456/1 = 14.7456 MHz. 0xFE = PGMCLK output is 14.7456/254 = 58.053 kHz. 0 = Disable the PGMCLK output.
7:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	WAKEDIS	**Wakeup Disable** 1 = Disable waking-up from Standby via the WAKEUP (pin D1). 0 = Enable waking-up from Standby via the WAKEUP (pin D1).
0	///	**Reserved** Reading returns 0. Always write as 0.

6.2.2.3 Halt and Standby Read-to-Enter Registers (HALT) (STBY)

Reading STBY or HALT puts the LH7A400 into the Standby or Halt power saving operational state. Five NOP instructions must immediately follow any read from STBY to accommodate ARM922T instruction pipelining.

This register is defined in Table 6-9, Table 6-10, and Table 6-11.

Table 6-9. HALT and STBY Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	HALT or STBY															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	HALT or STBY															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0408 (HALT) or 0x8000.040C (STBY)															

Table 6-10. HALT Field

BITS	FIELD	DESCRIPTION
31:0	HALT	Reading this field causes a transition to the Halt state. Writing this field has no effect on the register contents or on the operational state.

Table 6-11. STBY Field

BITS	FIELD	DESCRIPTION
31:0	STBY	Reading this field causes a transition to the Standby state. Writing this field has no effect on the register contents or on the operational state. After a read, 5 NOP instructions must be executed to accommodate pipelining.

6.2.2.4 Interrupt and Flag Clearing Registers (BLEOI, MCEOI, TEOI, STFCLR)

Writing any value to one of these four registers causes the associated interrupt of flag to be cleared to 0. Reading these registers returns unusable data; do not read. The registers are defined in Table 6-12 through Table 6-16.

Table 6-12. BLEOI, MCEOI, TEOI and STRCLR Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	HALT or STBY															
RESET	0															
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	HALT or STBY															
RESET	0															
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0410 (BLEOI) 0x8000.0414 (MCEOI) 0x8000.0418 (TEOI) 0x8000.041C (STFCLR)															

Table 6-13. BLEOI Fields

BITS	FIELD	DESCRIPTION
31:0	BLEOI	Writing any value clears the Battery Low interrupt (BLINT).

Table 6-14. MCEOI Fields

BITS	FIELD	DESCRIPTION
31:0	MCEOI	Writing any value clears the Media Change interrupt (MCINT).

Table 6-15. TEOI Fields

BITS	FIELD	DESCRIPTION
31:0	TEOI	Writing any value clears the TICK interrupt (TINTR) and the TICK Timeout Interrupt (TTINT).

Table 6-16. STFCLR Fields

BITS	FIELD	DESCRIPTION
31:0	STFCLR	Writing any value clears the New Battery (NBFLG), User Reset (RSTFLG), Power Fail (PFFLG), Watchdog Timer Flag (WDTFLG) and Cold Start (CLDFLG) flags in the PWRSR register.

6.2.2.5 Clock Set Register (CLKSET)

Write this register to enable and specify the divisors and gates used by PLL1 for providing the system and peripheral clocks. Writing this register puts the LH7A400 in Standby state for 8 to 16 msec, allowing time for any PLL1 changes to take effect.

This register is defined in Table 6-17 and Table 6-18.

Table 6-17. CLKSET Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///							SMCROM	///				PS		PCLKDIV	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RW	RO	RO	RO	RO	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	MAINDIV2					MAINDIV1				PREDIV					HCLKDIV	
RESET	0	1	0	0	0	1	1	1	1	1	0	0	0	1	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0420															

Table 6-18. CLKSET Fields

BITS	FIELD	DESCRIPTION
31:25	///	**Reserved** Reading returns 0. Values written cannot be read.
24	SMCROM	1 = Disables the HCLK gate to the static memory controller (SMC) in Halt to save power. In Halt, no instruction code fetches occur. With no DMA operations requiring the SMC, no SMC controller accesses need occur. 0 = HCLK gate to SMC is enabled.
23:20	///	**Reserved** Reading returns 0. Values written cannot be read.
19:18	PS	**PS Divisor** Specifies the divisor (2^{PS}) for the output clock signal from PLL1: 00 = divide-by-1 01 = divide-by-2 10 = divide-by-4 11 = divide-by-8 After a power-on reset, PS = 0b10 (divide-by-4).
17:16	PCLKDIV	**PCLK Divisor** Specifies the divisor for the HCLK AHB clock to generate the PCLK APB clock: 00 = divide-by-2 01 = divide-by-4 10 = divide-by-8 11 = divide-by-8 After power-on reset, PCKLKDIV = 00 (divide-by-2). When specifying PCLKDIV, be sure to maintain the required minimum ratio between PCLK and the peripheral clock. **NOTE:** The SmartCard interface cannot be used with PCLKDIV set to 8.
15:11	MAINDIV2	**Main Divisor 2** Specifies a divisor value used in PLL1. After a power-on reset, MAINDIV2 = 0b01000.
10:7	MAINDIV1	**Main Divisor 1** Specifies a divisor value used in PLL1. After a power-onreset, MAINDIV1 = 0b1111.

Table 6-18. CLKSET Fields (Cont'd)

BITS	FIELD	DESCRIPTION
6:2	PREDIV	**Predivisor** Specifies the pre-divisor value used in PLL1. After a power-on reset, PREDIV = 0b10001.
1:0	HCLKDIV	**HCLK Divisor** Specifies the divisor value for HCLK to generate the FCLK processor clock: 00 = divide-by-1. With FCLK = HCLK, running the processor in FASTBUS mode provides maximum core-to-AHB efficiency. 01 = divide-by-2 10 = divide-by-3 11 = divide-by-4 After a power-on reset, HCLKDIV = 00. For any selection other than divide-by-1, configure LH7A400 in synchronous bus mode. (See the documentation from ARM on coprocessor 15, register 1.) In this mode, the processor core uses FCLK for internal operations, either between registers or within the cache, but uses HCLK_CPU for all external operations involving the AHB bus. This dual clock runs the processor core and cache at maximum speed and the external peripherals at optimum speed. Changing from FASTBUS mode to Synchronous Bus mode must be done: • When switching from a divide ratio of 1 to 2 or more, change to Synchronous Bus mode before writing the CLKSET register. Changing from Synchronous Bus mode to FASTBUS mode must be done: • When switching from a divide ratio of 2 or more to 1, change to FASTBUS mode after writing the CLKSET register and the associated return from Standby. Switching from FCLK to HCLK_CPU introduces a delay of between ½ to 1 HCLK_CPU cycles. Switching back to FCLK introduces a delay of between ½ to 1 FCLK cycles.

6.2.2.6 General Purpose Storage Registers (SCRREG)

SCRREG0 and SCRREG1 are 32-bit RW scratch registers for general purpose storage. A power-on reset clears these registers. Other system resets have no effect on the contents of these registers.

The register field bit positions, names, access types and reset values are shown in Table 6-19.

Table 6-19. SCRREG[1:0] Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	SCRREG1 or SCRREG0															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SCRREG1 or SCRREG0															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0440 SCRREG0 0x8000.0444 SCRREG1															

Table 6-20. SCRREG[1:0] Fields

BITS	FIELD	DESCRIPTION
31:0	SCRREG0 or SCRREG1	**Scratch Register 0 and 1** In both registers, this field can be used as temporary storage at the user's discretion.

6.2.2.7 USB Reset Register (USBRESET)

This register puts the processor in control of resetting the USB controller. Because a USB host controller can send a reset command to the USB peripheral, the LH7A400 must also be able to reset the APB registers. After reset, this register is all zeros.

The register is defined in Table 6-21 and Table 6-22.

Table 6-21. USBRESET Register Description

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														APRESETREG	IORESETREG
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW
ADDR	0x8000.044C															

Table 6-22. USBRESET Fields

BITS	FIELD	FUNCTION
31:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	APBRESETREG	**APB Reset Register** 1 = Reset the USB control side. 0 = No reset.
0	IORESETREG	**I/O Reset Register** 1 = Reset the USB I/O side. 0 = No Reset.

Chapter 7
Pin and Signal Multiplexing

7.1 Theory of Operation

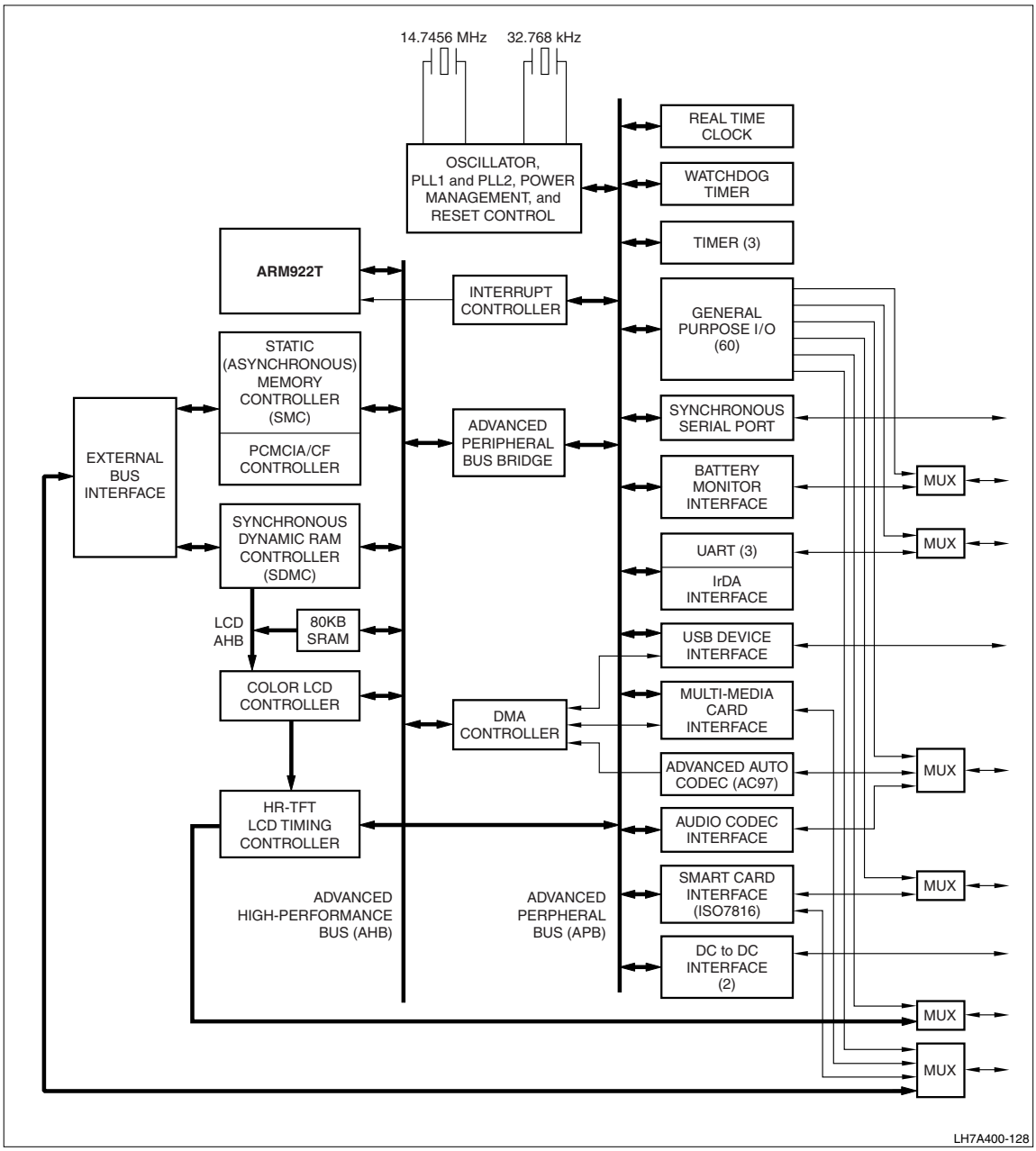


Figure 7-1. LH7A400 Multiplexing Block Diagram

Many pins on the LH7A400 PBGA package are multiplexed to support two or more different signals. This chapter summarizes the multiplexing scheme and describes how to activate each signal for each pin.

After power up or a reset, each multiplexed pin assumes a predetermined function. The function following a reset is defined in Chapter 1. Particular function of a given pin can be changed from the default setting by one of three methods:

- Setting the proper bits in one or more registers specifying the signal operation of the pin
- Enabling or disabling a specific LH7A400 subsystem
- Detection of an external connection on the pins.

All multiplexed signals are represented in the Multiplexing Block Diagram in Figure 7-1.

7.1.1 External Interrupt and GPIO Port F Multiplexing

After reset, the GPIO Port F[7:0] pins are configured as GPIO inputs. Software can configure each pin of Port F independently as an external interrupt source to be handled by the LH7A400 Interrupt Controller. To configure Port F pins as external interrupts, set the corresponding fields in the GPIO Interrupt Enable register (GPIOINTEN), as described in Chapter 16.

When configured as interrupts, the GPIO Port F[7:0] pins correspond to seven externally configurable IRQ interrupts and one externally configurable FIQ interrupt, as shown in Table 7-1.

Table 7-1. GPIO Port F External Interrupt Multiplexing

PIN NUMBER	INTERRUPT NAME	INTERRUPT CONTROLLER REGISTER BIT POSITION	GPIO
C5	INT7	26	PF7
E6	INT6	25	PF6
D6	INT5	24	PF5
B5	INT4	23	PF4
H8	INT3	7	PF3
C6	INT2	6	PF2
B6	INT1	5	PF1
A6	INT0	0	PF0

7.1.2 UART and GPIO Port B and Port C Multiplexing

The UART1 and UART3 data signals along with the UART3 modem status signals are multiplexed with GPIO Ports B[5:0] and C0, as shown in Table 7-2.

To configure the pins for UART3 data and modem status signals:

- Set the UART3 Control register UART Enable field (CON:UARTEN) to enable UART3 operation (See Chapter 15).
- Set the PINMUX register UART3 Configuration field (PINMUX:UART3CON) (See Chapter 16).

Configure the pins for UART1 data signals by setting the UART1 Control register UART Enable field (CON1:UARTEN). Enabling UART1 infrared operation does not automatically reconfigure pins L4 and P1 as GPIO Ports. During infrared operation, UART1 continuously asserts UARTTXD1 and ignores input on UARTRXD1 (See Chapter 15).

Enabling a UART selects the corresponding pins for UART use. To disable UART1 and reconfigure the pins as GPIO, both the UARTEN and SIRD bits in CON1 must be programmed to 0 (See Chapter 15).

Table 7-2. UART Multiplexing

PIN	UART	GPIO
L4	UARTRX1	Port B0
L5	UARTTX3	Port B1
L7	UARTRX3	Port B2
M2	UARTCTS3	Port B3
M4	UARTDCD3	Port B4
N1	UARTDSR3	Port B5
P1	UARTTX1	Port C0

7.1.3 Memory, MultiMediaCard, GPIO Port G, GPIO Port H, and Address Multiplexing

The Static Memory Controller (SMC), Synchronous Dynamic Memory Controller (SDMC), MultiMediaCard (MMC) Interface, GPIO Port G and Port H, Asynchronous Address Line, and Synchronous Address Line signals are multiplexed as shown in Table 7-3.

Table 7-3. Memory and MMC Multiplexing

PIN	SMC	MMC	SDMC	GPIO
R3	nPCOE			Port G0
T3	nPCWE			Port G1
L6	nPCIOR			Port G2
M6	nPCIOW			Port G3
N6	nPCREG			Port G4
M7	nPCCE1			Port G5
M8	nPCCE2			Port G6
N4	PCDIR			Port G7
P4	PCRESET1			Port H0
R4	CFA8/ PCRESET2			Port H1
T4	nPCSLOTE1			Port H2
N7	CFA9/ PCMCIAA25/ nPCSLOTE2			Port H3
P8	nPCWAIT1			Port H4
P5	CFA10/ PCMCIAA24/ nPCWAIT2			Port H5
T5	nPCSTATRE			Port H7
M12	nCS3	nMMS PICS		
B10	CS6		SCKE1_2	
C10	CS7		SCKE0	
M16	A0/nWE1			

PIN	SMC	MMC	SDMC	GPIO
N14	A1/nWE2			
M13	A2		SA0	
K16	A3		SA1	
K15	A4		SA2	
K14	A5		SA3	
J8	A6		SA4	
J16	A7		SA5	
J14	A8		SA6	
J9	A9		SA7	
H16	A10		SA8	
H14	A11		SA9	
G16	A12		SA10	
G14	A13		SA11	
G13	A14		SA12	
F16	A15		SA13	
F14	A16		SB0	
E16	A17		SB1	
G9			SCKE3/ SCKE1_2/ SCKE0	

7.1.3.1 SDRAM Multiplexing

Pins B10 and C10 multiplex the SDMC SCKE1_2 and SCKE0 output signals and SMC CS6 and CS7 output signals. GPIO Pin Multiplexing register fields Clock 12 Enable and Clock 0 Enable (PINMUX:CLK12EN and PINMUX:CLK0EN) define the multiplexing:

- When CLK12EN = 0, pin B10 is the SMC CS6 output.
- When CLK0EN = 0, pin C10 is the SMC CS7 output.

After reset, pin B10 is CS6 and pin C10 is CS7 and both are LOW. The SDMC SCKE1_2 and SCKE0, and SCKE3 (pin G9) output signals are multiplexed SDMC clock enable signals. The SDMC signal multiplexing is also selected with the PINMUX register, as shown in Table 7-4. In this table, each CKE(x) is the corresponding Bank(x) clock enable signal. After reset, both CLK0EN and CLK12EN are LOW, resulting in SCKE[3:0] signals being ORed together at pin G9.

More information on using pins B10, C10, and G9 for external memory access using these multiplexed pins appears in the SDRAM Controller Chapter.

Table 7-4. SDRAM Clock Enable Multiplexing

PINMUX		OUTPUT SIGNAL VALUES		
CLK0EN	CLK12EN	PIN G9	PIN B10	PIN C10
0	0	SCKE0 OR SCKE1_2 OR SCKE3	CS6	CS7
0	1	SCKE0 OR SCKE3	SCKE1_2	CS7
1	0	SCKE1_2 OR SCKE3	CS6	SCKE0
1	1	SCKE3	SCKE1_2	SCKE0

7.1.3.2 PCMCIA/Compact Flash Multiplexing

The PCMCIA and CompactFlash (CF) PC Card support is multiplexed with the GPIO Ports G and H. To select PC Card or GPIO operation, set the PCMCIA Control register PC Cards 1 and 2 Enable fields (PCMCIACON:PC12EN), shown in Table 7-5 (Also see Chapter 4 for more details).

The GPIO Port G and H pin states at reset are:

- Port G Output (all bits driven LOW)
- Port H Input
- No cards enabled; Ports G and H configured as GPIO (PCMCIACON:PC12EN = 0b00).

Table 7-5. PC Card Enable Fields

PC12EN		FUNCTION
BIT 1	BIT 0	
0	0	Disables both cards, configuring Ports G and H as GPIO
0	1	Enables one card in CF mode at 0x4000.0000 (Slot 0)
1	0	Enables one card in PCMCIA mode at Slot 0
1	1	Enables two cards, with the second card at 0x5000.0000 (Slot 1). Either card can be CF or PCMCIA.

7.1.3.3 Static Memory Controller nWE[2:1] Bits Multiplexing

The SMC signals nWE[2:1] are multiplexed with the least significant two Address bits, A[1:0]. The signal present on the LH7A400 external pins depends on the data bus width of the external memory and whether the processor instruction is a word, half-word, or byte access. For more information, see Chapter 4.

7.1.3.4 Synchronous and Asynchronous Memory Controller External Address Bus Multiplexing

The SDMC address signals SA[13:0] and the device bank select signals (SB[1:0]) are multiplexed with SMC address signals A[17:2], as shown in Table 7-3. The signals present on the LH7A400 external pins depends entirely on whether the external memory being accessed is in the Synchronous or Asynchronous memory space. For more information, see the SDRAM Controller Chapter.

7.1.3.5 MultiMediaCard Adapter Signal Multiplexing

When the MultiMediaCard (MMC) Adapter is placed in the SPI mode, pin M12 is used for the MMC Chip Select signal (nMMSPICS), otherwise pin M12 is used for the SMC memory bank Chip Select 3 (nCS3); see Table 7-3. The MMC Adapter is placed in SPI mode by setting the SPI enable bit in the SPI Mode Control register (SPI_REG:SPI_EN). For more information about the MMC Adapter in SPI mode, see Chapter 17.

7.1.4 LCD and GPIO Multiplexing

The Color LCD Controller (CLCDC) and the AD-TFT/HR-TFT Timing Controller (HRTFTC) interface signals are multiplexed with some GPIO signals. Depending on the LCD in use, the interface signals will be different for STN, TFT, or HR-TFT panels. Table 7-6 summarizes the signal multiplexing.

Table 7-6. LCD Signal Multiplexing

PIN	STN SIGNAL	TFT SIGNAL	AD-TFT/HR-TFTSIGNAL	GPIO
P9	LCDM	LCDENAB		
R6	LCDFP (Frame Pulse)	LCDFP (Vertical Sync Pulse)		
R8	LCDLP (Line Sync Pulse)	LCDLP (Horizontal Sync Pulse)		
N9	LCDDCLK (Panel Data Clock)	LCDDCLK (Panel Data Clock)	LCDDCLK (Panel Data Clock)	
P2			LCDPS (Power Save)	PC1
R1	LCDVDDEN (Use PC2) (Digital Supply Enable)	LCDVDDEN (Use PC2) (Digital Supply Enable or High Voltage Supply Control)	LCDVDDEN (Digital Supply Enable)	PC2
K6			LCDREV (AC Bias)	PC3
L8			LCDSPS (Row Reset)	PC4
T1			LCDCLS (Gate Driver Clock)	PC5
T2			LCDHRLP (Horizontal Sync Pulse)	PC6
R2			LCDSPL (Line Start Pulse Left)	PC7
P7	LCDVD0	LCDVD0	LCDVD0	
R7	LCDVD1	LCDVD1	LCDVD1	
T7	LCDVD2	LCDVD2	LCDVD2	
N8	LCDVD3	LCDVD3	LCDVD3	
L10	LCDVD4	LCDVD4	LCDVD4	PE0
N10	LCDVD5	LCDVD5	LCDVD5	PE1
M9	LCDVD6	LCDVD6	LCDVD6	PE2
M10	LCDVD7	LCDVD7	LCDVD7	PE3
M11	LCDVD8	LCDVD8	LCDVD8	PD0
L11	LCDVD9	LCDVD9	LCDVD9	PD1
K8	LCDVD10	LCDVD10	LCDVD10	PD2
N11	LCDVD11	LCDVD11	LCDVD11	PD3
R9	LCDVD12	LCDVD12	LCDVD12	PD4
T9	LCDVD13	LCDVD13	LCDVD13	PD5
P10	LCDVD14	LCDVD14	LCDVD14	PD6
R10	LCDVD15	LCDVD15 (Intensity)	LCDVD15 (Intensity)	PD7
J5			LCDVD16 (always LOW)	PA0
K1			LCDVD 17 (always LOW)	PA1

7.1.4.1 Reset State

Resetting the LH7A400 has the following effects, and software must handle any necessary reconfiguration after reset:

- Reset activates the GPIO signals and deactivates the LCD signals.
- Reset configures the HRTFTC to Bypass mode, for use with STN or TFT panels.

Table 7-7 shows how to configure the CLCDC multiplexed pins.

Table 7-7. CLCDC Mode Configuration

PIN	GPIO	CLCDC	CONFIGURATION METHOD
J5	PA0	LCDVD16	Program the AD-TFT/HR-TFT Setup Register Conversion field (HRTFTCSetup:CR) with the value 0b01.
K1	PA1	LCDVD17	
R1	PC2	LCDVDDEN	Set the HRTFTCSetup register LCD Interface Control Processor Enable field (HRTFTCSetup:LCDICPEN)
P2	PC1	LCDPS	Set HRTFTCSetup:LCDICPEN Program HRTFTCSetup:CR = 0b01.
K6	PC3	LCDREV	
L8	PC4	LCDSPS	
T1	PC5	LCDCLS	
T2	PC6	LCDHRLP	
R2	PC7	LCDSPL	
M11	PD0	LCDVD8	To use these pins for LCD signals, program the PINMUX register Port D Output Control field (PINMUX:PDOCON) to 1
L11	PD1	LCDVD9	
K8	PD2	LCDVD10	
N11	PD3	LCDVD11	
R9	PD4	LCDVD12	
T9	PD5	LCDVD13	
P10	PD6	LCDVD14	
R10	PD7	LCDVD15	
L10	PE0	LCDVD4	To use these pins for LCD signals, program PINMUX register Port E Output Control field (PINMUX:PEOCON) to 1
N10	PE1	LCDVD5	
M9	PE2	LCDVD6	
M10	PE3	LCDVD7	

7.1.5 AC97, ACI, and GPIO Multiplexing

The AC97 Codec Reset signal (nAC97RESET) is multiplexed with GPIO Port H6 on pin R5. To use this pin for nAC97RESET, program the following registers:

- Set the AC97 General Control Register AC97 'Initialize FIFOs and Enable' field (GCR:IFE) to enable the AC97 Codec Interface.
- Clear the GPIO PINMUX register 'Codec On' field (PINMUX:CODECON) to disable the non-AC97 Audio Codec Interface (ACI).

The other AC97 Codec signals are multiplexed with the non-AC97 Audio Codec Interface (ACI) signals on the following pins:

- AC97 or ACI Bit Clock (ACBITCLK) on pin C4
- AC97 or ACI Output (ACOUT) on pin D5
- AC97 or ACI Synchronize (ACSYNC) on pin B4
- AC97 or ACI Input (ACIN) on pin A4

To configure these pins for ACI use, set PINMUX:CODECON. To configure these pins for AC97 use, clear PINMUX:CODECON. See Chapter 16 for details.

After reset, the PINMUX:CODECON will be cleared.

7.1.6 Smart Card Interface, GPIO, and Address Multiplexing

The SCI signals are multiplexed with GPIO, Interrupt, and Address signals, as shown in Table 7-8. Reset, clock, and I/O pin selection for SCI use occurs automatically when the SCI has been enabled by setting the SCI Control register SCI Enable field (SCICON:SCI_EN). The SCVCCEN Smart Card power enable signal and the SCDETECT SCI contact detect signal are individually controlled by fields in the SCICONTROL register:

- To detect when a card is present, set the Multiplexing SCI Card Detection field (SCICONTROL:MUXSCI_Detect). When this field is cleared, pin D6 operates as GPIO Port F5 and is unavailable to the SCI.
- To provide the Smart Card supply voltage enable, program the Multiplexing SCI VCC Enable bit (SCICONTROL:MUXSCI_VCCEN) to 1. When this field is 0, pin B5 operates as GPIO Port F4 and is unavailable to the SCI.

Table 7-8. SCI Multiplexing

PIN	SCI	ADDRESS	GPIO	INT
A8	SCRST	A27		
B5	SCVCCEN		PF4	INT4
D6	SCDETECT		PF5	INT5
F8	SCCLK	A26		
G8	SCIO	A25		

7.1.7 Battery Monitor Interface and GPIO Multiplexing

The following types of Battery Monitor Interfaces (BMI) can be configured under software control on the LH7A400:

- Single Wire Interface (SWI)
- Smart Battery Interface (SBI), a two-wire interface.

The SWI and SBI signals are multiplexed with the GPIO Port B[7:6] signals on pins N3 and N2, as shown in Table 7-9. Enabling either the SWI or the SBI automatically configures these pins as needed for the BMI:

- To enable SWI, set the SWI Control Register SWI Enable field (SWICR:SWIEN). Pin N2 is configured as the SWI Data signal (SWID). Pin N3 is configured as PB7.
- To enable SBI, set the SBI Control Register SBI Enable field (SBICR:SBI_EN). Pin N2 is configured as the SBI System Management Bus Data signal (SMBD). Pin N3 is configured as the SBI System Management Bus Clock signal (SMBCLK).

When both SWI and SBI are enabled, SWI signals take priority on pin N2.

Table 7-9. BMI Multiplexing

PIN	SWI	SBI	GPIO
N2	SWID	SMBD	PB6
N3		SMBCLK	PB7

Chapter 8
Interrupt Controller

8.1 Theory of Operation

The LH7A400 Interrupt Controller collects interrupt request signals from on-chip and off-chip sources and processes the interrupt requests into an IRQ (Interrupt Request) signal and an FIQ (Fast Interrupt Request) signal to the ARM922T core. In this chapter, the term interrupt refers collectively to IRQ and FIQ exceptions in the ARM922T. This section gives a brief description of ARM922T exceptions. For detailed information on ARM922T exceptions, see the literature published by ARM, Ltd., at http://www.nxp.com or http://www.nxp.com/redirect/arm.com.

8.1.1 Interrupt Sources

The 28 sources of interrupt request signals the Interrupt Controller processes are listed in Table 8-2. Source numbers correspond to bit numbers in the Interrupt Controller registers. Interrupts from enabled sources 27 through 4 request an IRQ exception. Interrupts from enabled sources 3 through 0 request an FIQ exception.

Most sources must be configured to generate an interrupt request to the Interrupt Controller. Configuring an external interrupt request from a pin on GPIO Port F is described in the GPIO chapter. Configuring on-chip peripherals to request an interrupt is described in the Chapter of this User's Guide corresponding to that peripheral.

Even if a source is configured to generate an interrupt request, the source cannot cause an IRQ or FIQ exception unless the source's interrupt is enabled at the Interrupt Controller. Enabling a Source at the interrupt controller is described in Section 8.2.

Most sources continue to generate an interrupt request signal to the Interrupt Controller until some action is taken. The action is usually a read from, or a write to a register. If the interrupt handler does not clear the interrupt condition at the source before the interrupt handler (software that executes in response to an interrupt) exits, then the interrupt mechanism will continue to invoke the handler until the condition causing the interrupt is cleared.

8.1.2 Interrupt Priorities

Table 8-2 describes sources capable of generating an FIQ and sources capable of generating an IRQ. The Interrupt Controller provides no other prioritization mechanism for simultaneous interrupt requests. Resolution of simultaneous interrupt requests from multiple peripherals has to be performed by interrupt handler software.

FIQ and IRQ exceptions are prioritized. If an FIQ and an IRQ occur simultaneously, the FIQ will be processed first. Unless an FIQ handler explicitly enables IRQ or FIQ exceptions, FIQ handlers cannot be interrupted. Unless an IRQ handler explicitly enables IRQ exceptions, an IRQ handler cannot be interrupted by another IRQ. Unless an IRQ handler explicitly disables FIQ processing, an FIQ can interrupt an IRQ handler.

8.1.3 ARM922T Exceptions

Interrupts are two types of exceptions in the ARM922T-based LH7A400 architecture. The core does the following when an exception occurs:

1. If possible, completes executing the current instruction. For the interrupts (FIQ and IRQ), the current instruction always completes.
2. Changes the operating mode to the mode associated with the exception category.
3. Saves registers:

   Copies the Program Counter (PC) value to the Link Register (LR), in R14 of the register bank associated with the exception mode.

   Copies the Current Program Status Register (CPSR) to the Saved Program Status Register (SPSR) associated with the exception mode.
4. As appropriate, disables other exceptions by setting bits in the CSPR.
5. Changes the PC to execute at an exception vector address, as listed in Table 8-1.

Table 8-1. ARM Exception Vectors

EXCEPTION CATEGORY	EXCEPTION MODE	ADDRESS
Reset	SVC	0x00000000
Undefined Instruction	UND	0x00000004
SWI (Software Interrupt)	SVC	0x00000008
Prefetch Abort (Instruction Fetch Memory Fault)	Abort	0x0000000C
Data Abort (Data Access Memory Fault)	Abort	0x00000010
IRQ (Normal Interrupt)	IRQ	0x00000018
FIQ (Fast Interrupt)	FIQ	0x0000001C

8.1.4 Interrupt Handling Code Location

IRQ handling starts execution at the exception vector address 0x00000018. For IRQ handlers with multiple instructions, branch from this address to software elsewhere in memory. FIQ handling starts execution at 0x0000001C. FIQ handlers can reside at the exception vector address because no exception vectors are mapped above 0x0000001C. This close location avoids branching latency.

8.1.5 Register Use and Preservation

Most processor registers are shared among all operating modes. For example, Figure 8-1 shows the registers available in System, User, FIQ, and IRQ modes. Dashed arrows indicate shared register locations.

To prevent IRQ or FIQ exception handling software from corrupting the registers that are shared with other operating modes, IRQ and FIQ exception processing software must preserve any shared register the exception processing software modifies.

For example, on entry, IRQ exception handling software must save (usually on the IRQ mode stack) any register it modifies except SP, LR, or the SPSR. The CPSR is automatically moved to the SPSR on entry. On exit, IRQ exception handling software must restore all the registers it previously saved. The ARM922T will automatically move the SPSR to the CPSR if the IRQ exception handler exits properly. FIQ exception handling software operates the same way as IRQ exception handling software except that registers are usually preserved on the FIQ stack and it is not necessary for FIQ exception handling software to preserve registers R12-R8. For details on register sharing on all operation modes, see the literature published by ARM, Ltd., at http://www.nxp.com or http://www.nxp.com/redirect/arm.com.

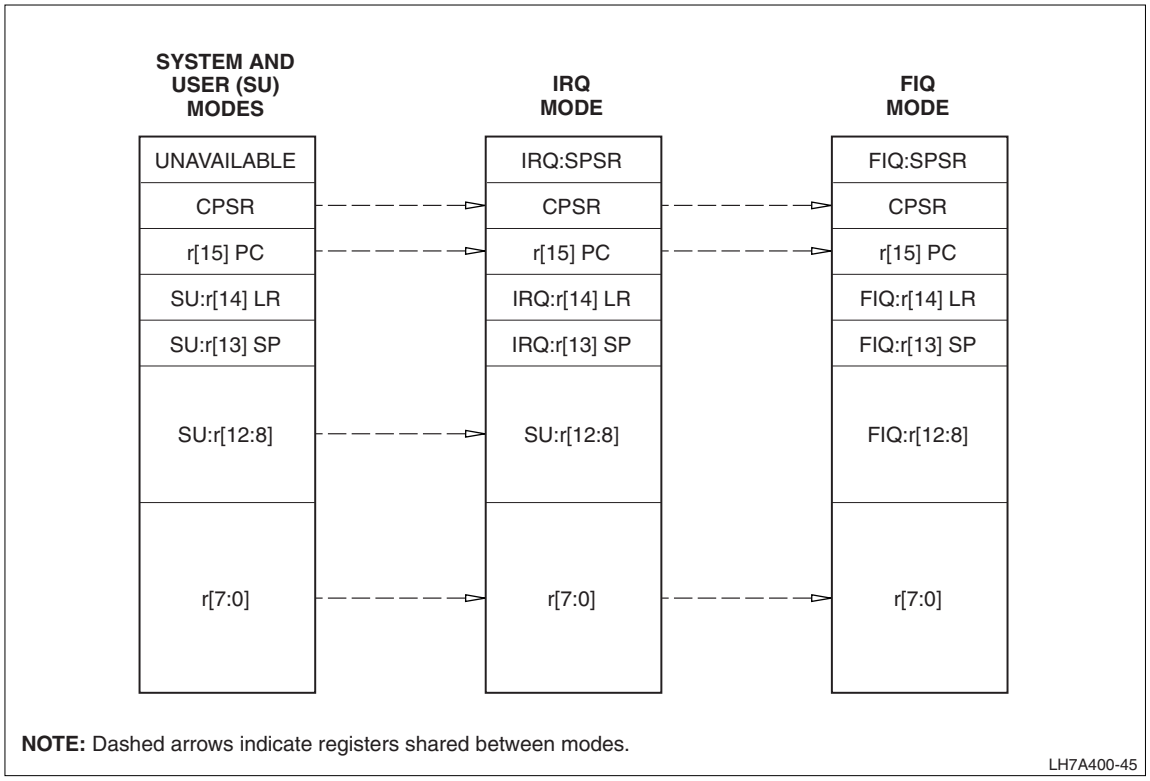


Figure 8-1. FIQ Mode and IRQ Mode Register Sharing

8.1.6 Enabling and Disabling Interrupts

To enable an interrupt source at the Interrupt Controller, set the corresponding Interrupt Enable Set (INTENS) bit to 1. Clearing an INTENS bit has no effect on that bit. To disable an interrupt source, set the corresponding Interrupt Enable Clear register (INTENC) bit to 1. Setting an INTENC bit clears the corresponding INTENS bit. Clearing an INTENC bit has no effect. See Section 8.2 for details.

Enabling the source at the Interrupt Controller does not configure the source to generate interrupt requests. To enable interrupt requests from an on-chip peripheral, see the chapter for that peripheral. To enable external interrupt requests, see the discussion of GPIO port F in the GPIO Chapter.

Enabling the Interrupt Controller to generate an IRQ or an FIQ will not cause a processor exception unless IRQ or FIQ exceptions are enabled in the ARM922T CPSR.

A Power-on Reset disables all interrupts at the Interrupt Controller and the ARM922T CPSR. Whether a particular peripheral is able to generate an interrupt request after Power-on Reset is documented in the Chapter for that peripheral.

8.2 Register Reference

This section describes the Interrupt Controller registers. Each bit in an Interrupt Controller register corresponds to a unique interrupt source. The sequence of bits is identical in all registers. Bit assignments are shown in Table 8-2. In the INTERRUPT SOURCE column of Table 8-2, the chapter that describes how to enable and clear the interrupt at the peripheral source is noted in parentheses. The registers are described in Table 8-3.

Table 8-2. Interrupt Controller Register Bits

BITS	NAME	INTERRUPT SOURCE
31:28	///	**Reserved** Reading returns 0. Values written cannot be read.
27	BMIINTR	Battery Monitor Interface (BMI)
26	GPIO7INTR	Configurable External IRQ Interrupt on the GPIO Port F7 pin (GPIO)
25	GPIO6INTR	Configurable External IRQ Interrupt on the GPIO Port F6 pin (GPIO)
24	GPIO5INTR	Configurable External IRQ Interrupt on the GPIO Port F5 pin (GPIO)
23	GPIO4INTR	Configurable External IRQ Interrupt on the GPIO Port F4 pin (GPIO)
22	TC3OI	Timer3 (Timers)
21	DMAINTR	Direct Memory Access (DMA)
20	USBINTR	Universal Serial Bus (USB)
19	MMCINTR	MultiMediaCard (MMC)
18	AC97INTR	AC97 Audio Codec (AAC)
17	SCIINTR	Smart Card Interface (SCI)
16	UART3INTR	UART3 (UART)
15	SSPINTR	Synchronous Serial Interface (SSI)
14	LCDINTR	Liquid Crystal Display (LCD)
13	UART2INTR	UART2 (UART)
12	UART1INTR	UART1 (UART)
11	TINTR	64 Hz Tick (CSC)
10	RTCINTR	Real Time Clock (RTC)
9	TC2OI	Timer2 (Timers)
8	TC1OI	Timer1 (Timers)
7	GPIO3INTR	Configurable External IRQ Interrupt on the GPIO Port F3 pin (GPIO)
6	GPIO2INTR	Configurable External IRQ Interrupt on the GPIO Port F2 pin (GPIO)
5	GPIO1INTR	Configurable External IRQ Interrupt on the GPIO Port F1 pin (GPIO)
4	ACIINTR	Audio Codec (ACI)
3	MCINT	**Media Change** This FIQ interrupt occurs at least 62.5 μs after a rising edge on the MEDCHG input pin (CSC).
2	WDINTR	**Watchdog Timer** This FIQ interrupt (WDT) occurs when the WDT overflows.
1	BLINT	**Battery Low** This FIQ interrupt occurs at least 62.5 μs after the following signal combination has begun, and remains asserted while these conditions exist: • NEXTPWR is HIGH, indicating no external power supply • BATOK is LOW (CSC)
0	GPIO0FIQ	**GPIO External Interrupt** Configurable External FIQ Interrupt on the GPIO Port F0 pin (GPIO)

8.2.1 Memory Map

The Interrupt Controller registers reside in memory at offsets from the LH7A400 Interrupt Controller base address, 0x8000.0500 as shown in Table 8-3.

Table 8-3. Interrupt Controller Register Bit Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	INTSR	**Interrupt Status Register** 1 = The enabled interrupt source corresponding to the particular bit is requesting an interrupt. 0 = The interrupt source corresponding to the particular bit is not enabled, or is enabled and not requesting an interrupt.
0x04	INTRSR	**Interrupt Raw Status Register** 1 = The interrupt source corresponding to the particular bit is requesting an interrupt, whether enabled or not. 0 = The interrupt source corresponding to the particular bit is not requesting an interrupt.
0x08	INTENS	**Interrupt Enable Set Register** 1 = The enabled interrupt source corresponding to the particular bit is enabled. 0 = The interrupt source corresponding to the particular bit is not enabled.
0x0C	INTENC	**Interrupt Enable Clear Register** 1 = The enabled interrupt source corresponding to the particular bit is cleared; the corresponding bit in INTENS will read 0. 0 = The interrupt source corresponding to the particular bit is not cleared; no change to the corresponding bit in INTENS.
0x10 0x14 0x18	///	**Reserved** Do not read these locations; unpredictable values can be returned.

8.2.2 Register Descriptions

8.2.2.1 Interrupt Controller Status Register (INTSR)

If a bit in INTSR reads back 1, the corresponding enabled interrupt source is requesting an interrupt. If a bit in INTSR reads back 0, the corresponding interrupt source is either disabled or not requesting an interrupt. Values written to this register cannot be read back. INTSR is the bit-wise logical AND of INTRSR with INTENS. Bit field assignments for this register are in Table 8-4 and in Table 8-5. In Table 8-5, the chapter that describes how to enable and clear the interrupt at the peripheral source is noted in parentheses.

Table 8-4. INTSR

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///				BMIINTR	GPIO7INTR	GPIO6INTR	GPIO5INTR	GPIO4INTR	TC3OI	DMAINTR	USBINTR	MMCINTR	AC97INTR	SCIINTR	UART3INTR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SSPINTR	LCDINTR	UART2INTR	UART1INTR	TINTR	RTCINTR	TC2OI	TC1OI	GPIO3INTR	GPIO2INTR	GPIO1INTR	ACIINTR	MCINT	WDINTR	BLINT	GPIO0FIQ
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0500															

Table 8-5. INTSR Bits

BITS	FIELD	INTERRUPT SOURCE
31:28	///	**Reserved** Reading returns 0. Values written cannot be read.
27	BMIINTR	Battery Monitor Interface (BMI)
26	GPIO7INTR	Configurable External IRQ Interrupt on the GPIO Port F7 pin (GPIO)
25	GPIO6INTR	Configurable External IRQ Interrupt on the GPIO Port F6 pin (GPIO)
24	GPIO5INTR	Configurable External IRQ Interrupt on the GPIO Port F5 pin (GPIO)
23	GPIO4INTR	Configurable External IRQ Interrupt on the GPIO Port F4 pin (GPIO)
22	TC3OI	Timer3 (Timers)
21	DMAINTR	Direct Memory Access (DMA)
20	USBINTR	Universal Serial Bus (USB)
19	MMCINTR	MultiMediaCard (MMC)
18	AC97INTR	AC97 Audio Codec (AAC)
17	SCIINTR	Smart Card Interface (SCI)
16	UART3INTR	UART3 (UART)
15	SSPINTR	Synchronous Serial Interface (SSI)
14	LCDINTR	Liquid Crystal Display (LCD)

Table 8-5. INTSR Bits (Cont'd)

BITS	FIELD	INTERRUPT SOURCE
13	UART2INTR	UART2 (UART)
12	UART1INTR	UART1 (UART)
11	TINTR	64 Hz Tick (CSC)
10	RTCINTR	Real Time Clock (RTC)
9	TC2OI	Timer2 (Timers)
8	TC1OI	Timer1 (Timers)
7	GPIO3INTR	Configurable External IRQ Interrupt on the GPIO Port F3 pin (GPIO)
6	GPIO2INTR	Configurable External IRQ Interrupt on the GPIO Port F2 pin (GPIO)
5	GPIO1INTR	Configurable External IRQ Interrupt on the GPIO Port F1 pin (GPIO)
4	ACIINTR	Audio Codec (ACI)
3	MCINT	**Media Change** This FIQ interrupt occurs when the MEDCHG input pin (CSC) is active for at least 62.5 μs. This delay debounces the signal to prevent false interrupt generation.
2	WDINTR	**Watchdog Timer** This FIQ interrupt (WDT) occurs when the WDT overflows.
1	BLINT	**Battery Low** This FIQ interrupt occurs when the following signal combination occurs for at least 62.5 μs, and remains asserted while these conditions exist: • NEXTPWR is HIGH, indicating no external power supply • BATOK is LOW (CSC) The 62.5 μs delay debounces the signal to prevent false interrupt generation.
0	GPIO0FIQ	**GPIO External Interrupt** Configurable External FIQ Interrupt on the GPIO Port F0 pin (GPIO)

8.2.2.2 Interrupt Controller Raw Status Register (INTRSR)

The INTRSR register reports the asserted or deasserted status of interrupts. A bit reading back as 1 indicates an asserted interrupt; a bit reading back as 0 indicates a deasserted interrupt. This register provides the status of interrupts, whether or not software has enabled the particular interrupt.

The values reported in INTRSR are bit-wise-ANDed with the values programmed in INTENS, providing the results of only the enabled interrupts in INTSR.

Values written to this register cannot be read back. Bit field assignments for this register are in Table 8-6 and in Table 8-7. In Table 8-7, the chapter that describes how to enable and clear the interrupt at the peripheral source is noted in parentheses.

Table 8-6. INTRSR

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///				BMIINTR	GPIO7INTR	GPIO6INTR	GPIO5INTR	GPIO4INTR	TC3OI	DMAINTR	USBINTR	MMCINTR	AC97INTR	SCIINTR	UART3INTR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SSPINTR	LCDINTR	UART2INTR	UART1INTR	TINTR	RTCINTR	TC2OI	TC1OI	GPIO3INTR	GPIO2INTR	GPIO1INTR	ACIINTR	MCINT	WDINTR	BLINT	GPIO0FIQ
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0504															

Table 8-7. INTRSR Bits

BITS	FIELD	INTERRUPT SOURCE
31:28	///	**Reserved** Reading returns 0. Values written cannot be read.
27	BMIINTR	Battery Monitor Interface (BMI)
26	GPIO7INTR	Configurable External IRQ Interrupt on the GPIO Port F7 pin (GPIO)
25	GPIO6INTR	Configurable External IRQ Interrupt on the GPIO Port F6 pin (GPIO)
24	GPIO5INTR	Configurable External IRQ Interrupt on the GPIO Port F5 pin (GPIO)
23	GPIO4INTR	Configurable External IRQ Interrupt on the GPIO Port F4 pin (GPIO)
22	TC3OI	Timer3 (Timers)
21	DMAINTR	Direct Memory Access (DMA)
20	USBINTR	Universal Serial Bus (USB)
19	MMCINTR	MultiMediaCard (MMC)
18	AC97INTR	AC97 Audio Codec (AAC)
17	SCIINTR	Smart Card Interface (SCI)
16	UART3INTR	UART3 (UART)

Table 8-7. INTRSR Bits (Cont'd)

BITS	FIELD	INTERRUPT SOURCE
15	SSPINTR	Synchronous Serial Interface (SSI)
14	LCDINTR	Liquid Crystal Display (LCD)
13	UART2INTR	UART2 (UART)
12	UART1INTR	UART1 (UART)
11	TINTR	64 Hz Tick (CSC)
10	RTCINTR	Real Time Clock (RTC)
9	TC2OI	Timer2 (Timers)
8	TC1OI	Timer1 (Timers)
7	GPIO3INTR	Configurable External IRQ Interrupt on the GPIO Port F3 pin (GPIO)
6	GPIO2INTR	Configurable External IRQ Interrupt on the GPIO Port F2 pin (GPIO)
5	GPIO1INTR	Configurable External IRQ Interrupt on the GPIO Port F1 pin (GPIO)
4	ACIINTR	Audio Codec (ACI)
3	MCINT	**Media Change** This FIQ interrupt occurs when the MEDCHG input pin (CSC) is active for at least 62.5 μs. This delay debounces the signal to prevent false interrupt generation.
2	WDINTR	**Watchdog Timer** This FIQ interrupt (WDT) occurs when the WDT overflows.
1	BLINT	**Battery Low** This FIQ interrupt occurs when the following signal combination occurs for at least 62.5 μs, and remains asserted while these conditions exist: • NEXTPWR is HIGH, indicating no external power supply • BATOK is LOW (CSC) • The 62.5 μs delay debounces the signal to prevent false interrupt generation.
0	GPIO0FIQ	**GPIO External Interrupt** Configurable External FIQ Interrupt on the GPIO Port F0 pin (GPIO)

8.2.2.3 Interrupt Controller Enable Set Register (INTENS)

The INTENS registers allows reading the enable status of each interrupt and enabling individual interrupts with a write. If a bit in this register reads back 1, the corresponding interrupt source is enabled. If a bit in this register reads back 0, the corresponding interrupt source is disabled.

Writing a bit as 1 in this register enables the corresponding interrupt source. Clearing a bit by writing a 0 in INTENS will not change that bit nor disable the interrupt. Use the INTENC register to disable interrupt sources.

Bit field assignments for this register are in Table 8-8 and in Table 8-9. In Table 8-9, the chapter that describes how to enable and clear the interrupt at the peripheral source is noted in parentheses.

Table 8-8. INTENS

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///				BMIINTR	GPIO7INTR	GPIO6INTR	GPIO5INTR	GPIO4INTR	TC3OI	DMAINTR	USBINTR	MMCINTR	AC97INTR	SCIINTR	UART3INTR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SSPINTR	LCDINTR	UART2INTR	UART1INTR	TINTR	RTCINTR	TC2OI	TC1OI	GPIO3INTR	GPIO2INTR	GPIO1INTR	ACIINTR	MCINT	WDINTR	BLINT	GPIO0FIQ
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0508															

Table 8-9. INTENS Bits

BITS	FIELD	INTERRUPT SOURCE
31:28	///	**Reserved** Reading returns 0. Values written cannot be read.
27	BMIINTR	Battery Monitor Interface (BMI)
26	GPIO7INTR	Configurable External IRQ Interrupt on the GPIO Port F7 pin (GPIO)
25	GPIO6INTR	Configurable External IRQ Interrupt on the GPIO Port F6 pin (GPIO)
24	GPIO5INTR	Configurable External IRQ Interrupt on the GPIO Port F5 pin (GPIO)
23	GPIO4INTR	Configurable External IRQ Interrupt on the GPIO Port F4 pin (GPIO)
22	TC3OI	Timer3 (Timers)
21	DMAINTR	Direct Memory Access (DMA)
20	USBINTR	Universal Serial Bus (USB)
19	MMCINTR	MultiMediaCard (MMC)
18	AC97INTR	AC97 Audio Codec (AAC)
17	SCIINTR	Smart Card Interface (SCI)
16	UART3INTR	UART3 (UART)

Table 8-9. INTENS Bits (Cont'd)

BITS	FIELD	INTERRUPT SOURCE
15	SSPINTR	Synchronous Serial Interface (SSI)
14	LCDINTR	Liquid Crystal Display (LCD)
13	UART2INTR	UART2 (UART)
12	UART1INTR	UART1 (UART)
11	TINTR	64 Hz Tick (CSC)
10	RTCINTR	Real Time Clock (RTC)
9	TC2OI	Timer2 (Timers)
8	TC1OI	Timer1 (Timers)
7	GPIO3INTR	Configurable External IRQ Interrupt on the GPIO Port F3 pin (GPIO)
6	GPIO2INTR	Configurable External IRQ Interrupt on the GPIO Port F2 pin (GPIO)
5	GPIO1INTR	Configurable External IRQ Interrupt on the GPIO Port F1 pin (GPIO)
4	ACIINTR	Audio Codec (ACI)
3	MCINT	**Media Change** This FIQ interrupt occurs when the MEDCHG input pin (CSC) is active for at least 62.5 μs. This delay debounces the signal to prevent false interrupt generation.
2	WDINTR	**Watchdog Timer** This FIQ interrupt (WDT) occurs when the WDT overflows.
1	BLINT	**Battery Low** This FIQ interrupt occurs when the following signal combination occurs for at least 62.5 μs, and remains asserted while these conditions exist: • NEXTPWR is HIGH, indicating no external power supply • BATOK is LOW (CSC) The 62.5 μs delay debounces the signal to prevent false interrupt generation.
0	GPIO0FIQ	**GPIO External Interrupt** Configurable External FIQ Interrupt on the GPIO Port F0 pin (GPIO)

8.2.2.4 Interrupt Controller Enable Clear Register (INTENC)

Reading this register returns 0. Set a bit to 1 in this register to clear the corresponding bit in INTENS and disable the corresponding interrupt source. An attempt to clear a bit by writing a 0 in this register does not change INTENS. Bit field assignments for this register are in Table 8-10 and in Table 8-11. In Table 8-11, the chapter that describes how to enable and clear the interrupt at the peripheral source is noted in parentheses.

Table 8-10. INTENC

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///				BMIINTR	GPIO7INTR	GPIO6INTR	GPIO5INTR	GPIO4INTR	TC3OI	DMAINTR	USBINTR	MMCINTR	AC97INTR	SCIINTR	UART3INTR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SSPINTR	LCDINTR	UART2INTR	UART1INTR	TINTR	RTCINTR	TC2OI	TC1OI	GPIO3INTR	GPIO2INTR	GPIO1INTR	ACIINTR	MCINT	WDINTR	BLINT	GPIO0FIQ
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.050C															

Table 8-11. INTENC Bits

BITS	FIELD	INTERRUPT SOURCES
31:28	///	**Reserved** Reading returns 0. Values written cannot be read.
27	BMIINTR	Battery Monitor Interface (BMI)
26	GPIO7INTR	Configurable External IRQ Interrupt on the GPIO Port F7 pin (GPIO)
25	GPIO6INTR	Configurable External IRQ Interrupt on the GPIO Port F6 pin (GPIO)
24	GPIO5INTR	Configurable External IRQ Interrupt on the GPIO Port F5 pin (GPIO)
23	GPIO4INTR	Configurable External IRQ Interrupt on the GPIO Port F4 pin (GPIO)
22	TC3OI	Timer3 (Timers)
21	DMAINTR	Direct Memory Access (DMA)
20	USBINTR	Universal Serial Bus (USB)
19	MMCINTR	MultiMediaCard (MMC)
18	AC97INTR	AC97 Audio Codec (AAC)
17	SCIINTR	Smart Card Interface (SCI)
16	UART3INTR	UART3 (UART)
15	SSPINTR	Synchronous Serial Interface (SSI)
14	LCDINTR	Liquid Crystal Display (LCD)
13	UART2INTR	UART2 (UART)
12	UART1INTR	UART1 (UART)
11	TINTR	64 Hz Tick (CSC)

Table 8-11. INTENC Bits

BITS	FIELD	INTERRUPT SOURCES
10	RTCINTR	Real Time Clock (RTC)
9	TC2OI	Timer2 (Timers)
8	TC1OI	Timer1 (Timers)
7	GPIO3INTR	Configurable External IRQ Interrupt on the GPIO Port F3 pin (GPIO)
6	GPIO2INTR	Configurable External IRQ Interrupt on the GPIO Port F2 pin (GPIO)
5	GPIO1INTR	Configurable External IRQ Interrupt on the GPIO Port F1 pin (GPIO)
4	ACIINTR	Audio Codec (ACI)
3	MCINT	**Media Change** This FIQ interrupt occurs when the MEDCHG input pin (CSC) is active for at least 62.5 μs. This delay debounces the signal to prevent false interrupt generation.
2	WDINTR	**Watchdog Timer** This FIQ interrupt (WDT) occurs when the WDT overflows.
1	BLINT	**Battery Low** This FIQ interrupt occurs when the following signal combination occurs for at least 62.5 μs, and remains asserted while these conditions exist: • NEXTPWR is HIGH, indicating no external power supply • BATOK is LOW (CSC) The 62.5 μs delay debounces the signal to prevent false interrupt generation.
0	GPIO0FIQ	**GPIO External Interrupt** Configurable External FIQ Interrupt on the GPIO Port F0 pin (GPIO)

Chapter 9
Direct Memory Access (DMA) Controller

9.1 Theory of Operation

The DMA controller uses ten DMA channels, as shown in Table 9-1, providing an interface for data streams from these peripherals to the system memory:

- For the Universal Serial Bus (USB) controller, one transmit channel and one receive channel.
- For the MultiMediaCard (MMC) controller, one transmit channel and one receive channel.
- For the AC '97 Codec (AC97) controller, three transmit and three receive channels to handle different sample frequency data queues with low software overheads.

Table 9-1. DMA Controller Channel Allocation

CHANNEL	FUNCTION
0	USB Transmit
1	USB Receive
2	MMC Transmit
3	MMC Receive
4	AC97 Receive 0
5	AC97 Transmit 0
6	AC97 Receive 1
7	AC97 Transmit 1
8	AC97 Receive 2
9	AC97 Transmit 2

The DMA controller (shown in Figure 9-1) feature set is summarized here:

- The transmit and receive DMA channels are independent.
- The DMA controller has a dedicated DMA bus to each peripheral, capable of transferring data in both directions simultaneously.
- All memory transfers use the LH7A400 advanced high-performance bus (AHB).
- Each channel has two buffer descriptors to avoid any data underflow or overflow caused by software latency.
- No buffer wrapping occurs.
- The buffer size can be equal to, greater than, or less than the packet size. Transfers can automatically switch between buffers.

- Interrupts for each channel in each direction can be enabled and disabled separately.
- Arbitration is internal between DMA channels and the external bus arbiter.
- DMA transfer sizes can be byte, word, or quad word.
- Control and status registers are provided to initialize and monitor DMA activity.
- A system interrupt can be generated for new buffer allocation requests, transfer errors, and transfer completions.

The subsequent sections describe each of the blocks in the DMA controller and the DMA state machine.

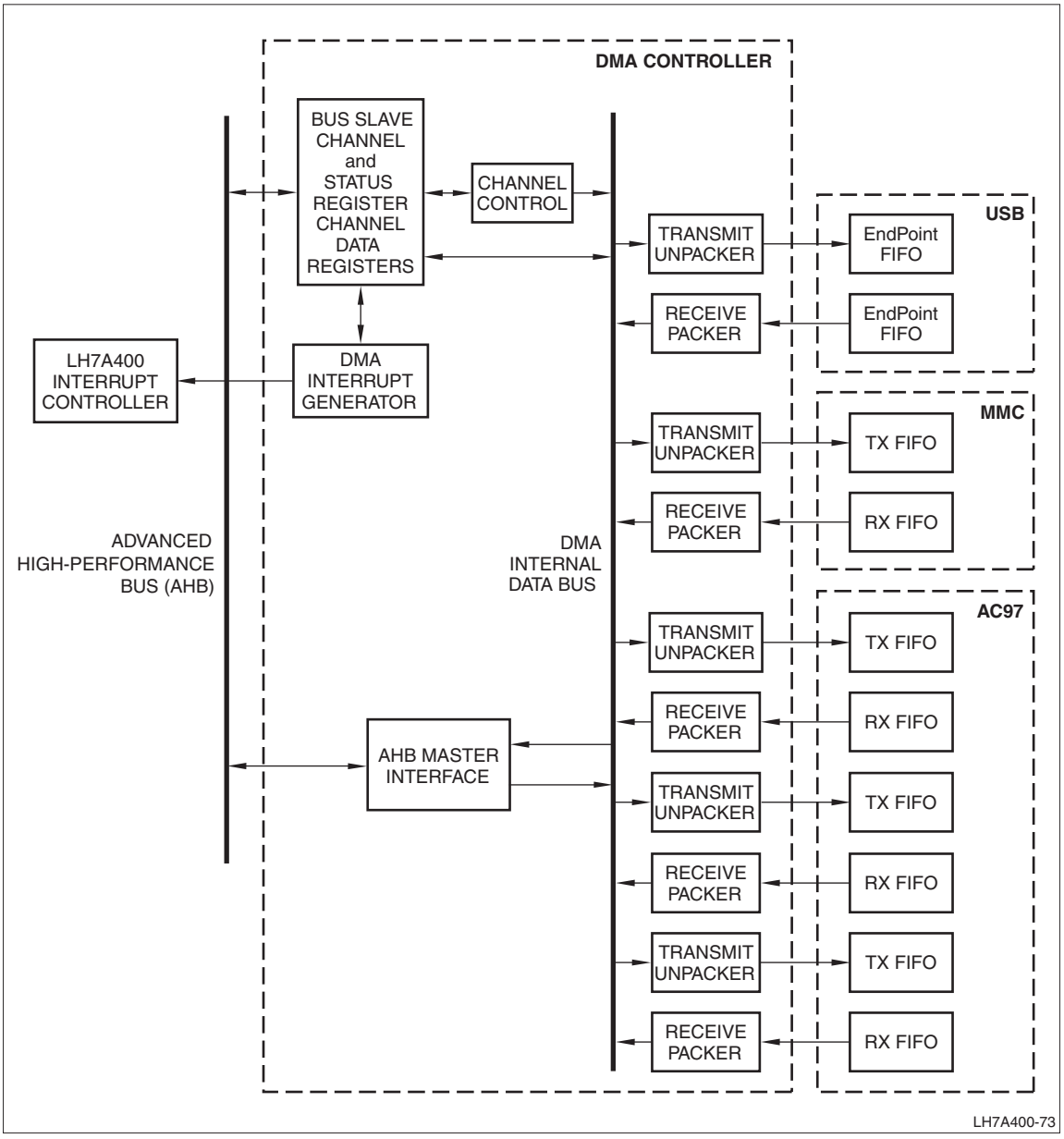


Figure 9-1. DMA Controller Block Diagram

9.1.1 AHB Interface

The AHB Master interface transfers data between the system memory and the DMA Controller. In the receive direction, data is transferred from a packer unit to system memory. In the transmit direction, data is transferred from the system memory to the unpacker unit. Data transfer can be initiated by either:

- A packer unit becoming full, or containing enough data for the next unaligned access
- An unpacker unit becoming empty.

When a peripheral indicates the end of received data or a receiver error or if the number of bytes transferred from a peripheral reaches the maximum transfer count, the AHB Master interface writes any valid data in the receive packer to main memory. Only valid bytes are written. When whole words are present in the packer, word transfers are used. For any remaining bytes, up to a maximum of three, byte transfers are used. Since each packer/unpacker unit can hold four words, potentially, the maximum number of bus transfers performed between the packer/unpacker unit and memory is six. The maximum transfer count can be any arbitrary number of bytes.

9.1.1.1 DMA Addressing

The DMA Controller does not utilize the core's Memory Management Unit. Therefore, all DMA accesses *must* use physical addresses, not virtual addresses.

The start address of a DMA transfer can be aligned to any arbitrary byte boundary. At the start of a receive or transmit data transfer, the AHB Master interface uses the four least-significant bits (LSB) of the current DMA address to determine the data transfer size to use:

- When bits [3:0] are 0, the first transfer is performed by a quad word access.
- When bits [1:0] are zero and bit 3 or bit 2 is nonzero, the first transfer is performed by a word access.

Word transfers continue, until the LSB of the address indicates the address is quad-word aligned. The current address is incremented by one word for each transfer. When the start address is not word aligned, the first transfer is a byte transfer and the current address is incremented by one byte each time until the current address becomes word aligned. Transfers are then performed as word transfers until the address is quad-word aligned. If the address becomes quad-word aligned immediately, quad-word transfers are used.

The end of the transfer is signalled by the transfer count being reached or by the peripheral. In the latter case, any data remaining in a packer unit is written to memory. Any data in an unpacker or the transmit FIFO is considered invalid and therefore discarded.

The data may not form a complete quad-word. When an incomplete quad-word is present, data is transferred to memory by either word or byte accesses. The number of valid bytes remaining to be transferred is used to control the type of access:

- For 16 bytes, a quad word transfer is performed
- For less than 16 and more than four bytes, word transfers are performed until the number of bytes is less than four
- For fewer than four bytes, byte transfers occur until all data has been transferred.

When the peripheral ends the transfer with an error code, an interrupt is generated and operation continues as normal using the next buffer to ensure that a minimal amount of data is lost. The point at which the transfer failed can be determined by reading the channel's current address register for the last buffer.

The AHB slave interface is used to access all control and status registers.

9.1.2 Peripheral DMA Bus Interface

The DMA supports five peripheral interfaces. Data is transferred between the peripheral and the DMA controller using a request/acknowledge handshake. Transfers are synchronous to the rising edge of the system bus clock. Resynchronization is performed within the peripheral if it uses a different clock domain.

The DMA Controller memory access latency is compensated by FIFOs in the peripherals.

For a peripheral-to-DMA controller transfer, the sequence of events that typically occurs is:

- The peripheral places data on the peripheral DMA bus and asserts a transfer request to the DMA controller on the rising edge of the peripheral clock (PCLK).
- The DMA controller recognizes the request, reads data and asserts a transfer acknowledge to the peripheral on the next AHB clock (HCLK) rising edge.
- The peripheral senses the acknowledge on the next PCLK rising edge, deasserts the transfer request signal and invalidates the data on the DMA bus.
- This continues until an end of transfer condition is signalled by the peripheral or the DMA controller.

For a DMA controller-to-peripheral transfer, the sequence of events is typically:

- The DMA controller places data on the peripheral DMA bus and asserts a transfer request to the peripheral on the rising edge of HCLK.
- The peripheral recognizes the request, reads data and asserts a transfer acknowledge to the peripheral on the next PCLK rising edge.
- The DMA controller senses the acknowledge on the next HCLK rising edge, deasserts the transfer request signal and invalidates the data on the DMA bus.
- This continues until an end of transfer condition is signalled by the peripheral or the DMA controller.

PCLK and HCLK are synchronously aligned, with the division of HCLK performed by removing pulses from PCLK. Because PCLK operates at HCLK/2 to HCLK/8, the DMA Controller extends the appropriate signals to allow the slower APB peripheral to respond.

9.1.3 Interrupt Interface

Each of the 10 DMA channels (five channels in each direction) generates a single interrupt signal. All 10 interrupts are combined and passed as a single DMA interrupt to the LH7A400 interrupt controller.

9.1.4 Data Packers and Unpackers

Under normal operating conditions, the DMA controller transfers data to and from the system memory in four-word bursts. The peripheral DMA bus protocol is used to transfer data to and from the peripherals as single bytes. To build the quad word bursts from the single bytes received from the peripheral, the DMA controller uses the Receive Burst Packers. To decompose the quad word bursts into byte transfers to the peripherals, the Transmit Burst Unpackers are used.

The data received on each of the three peripheral receive DMA buses is transferred into an internal receive packer unit. The packer unit converts the byte-wide data, received from the peripheral, into words to be transferred over the AHB to the memory. The packer unit stores four words (one quad word) of data. Memory access latency is compensated by FIFOs within each peripheral.

Transmit data is fetched from system memory by the AHB Master interface and placed into the transmit unpacker. The transmit unpacker converts the quad-word burst of DMA data into byte data for transmission over the transmit peripheral DMA bus. The transmit unpacker contains four words (one quad word) of storage. Memory access latency is compensated by FIFOs within the peripheral.

The number of byte-data transfers over the peripheral DMA bus are counted by the packer or unpacker unit. When the number of bytes transferred reaches the maximum transfer count, the data from the packer unit is flushed to memory or any data remaining in the unpacker unit is invalidated.

9.1.5 DMA State Machine

The DMA Controller initiates data transfer in the receive direction when either:

- A packer unit becomes full
- A packer unit, depending on the next address access, contains enough data for an unaligned byte or word access.

Either of these cases causes the DMA Controller to stop data transfers in the receive direction and move to the next buffer:

- The peripheral indicates the end of received data or a receive error. Regardless of the previous alignment, this indication causes the AHB Master interface to write any valid data in the receive packer to main memory.
- The number of bytes transferred from a receive peripheral reaches the maximum count. This is counted as the number of bytes transferred over the AHB, plus the number of bytes currently in the receive packer written by the peripheral.

When the DMA Controller stops receive data transfers and prepares to move to the next buffer:

- An interrupt is generated to the LH7A400 interrupt controller, if enabled, to request a new buffer allocation.
- The Channel Status Register NEXTBUFFER field is updated to indicate which pair of buffer descriptor registers to be used for the next buffer.

The DMA Controller initiates data transfers in the transmit direction when an unpacker unit becomes empty.

The DMA Controller stops data transfer in the transmit direction and updates the Channel Status Register to specify the next buffer, when either:

- The final transfer in the transmit data stream occurs. Any data remaining in the unpacker unit is considered invalid and flushed.
- The byte count limit is reached.

Bursting across buffers cannot be performed in either the transmit or the receive direction. Buffer pairs can be discontiguous when the address equals the address of the previous transfer plus the transfer size in bytes.

The data transfer size is flexible because the start address of a DMA transfer can be aligned to any arbitrary byte boundary. The maximum transfer count can be any arbitrary number of bytes. At the start of a transmit or receive data transfer, the four LSB of the current DMA address are used to decide on the data transfer size to use, as shown in Table 9-2. Byte or word data transfers are performed until the Current DMA address is quad-word aligned, after which quad-word data transfers are performed.

Each DMA channel is controlled by a state machine, as shown in Figure 9-3, which determines whether the channel is transferring data and whether it is currently generating an interrupt. The states are also described in Table 9-3.

Table 9-2. Data Transfer Size Determination

CURRENTx[3:0]	TRANSFER SIZE
0000	Quad-word access, when four or more word addresses remain.
0100, 1000, 1100	Word access
xx01, xx10, xx11	Byte access

Table 9-3. DMA Operating States

STATE	OPERATION
IDLE	The DMA Channel enters the IDLE state when the channel is disabled via the CONTROL register.
STALL	The DMA Channel enters the STALL state when the channel is enabled. No STALL interrupt is generated for this condition. The DMA Channel enters the STALL state when a buffer completes in the ON state. A STALL interrupt is generated for this condition. The DMA Channel FSM enters the STALL state and terminates the current buffer when a peripheral error occurs in the ON state, when ICE is not enabled. The DMA Channel FSM enters the STALL state and terminates the current buffer when a peripheral error occurs in the NEXT state, with ABORT is active and ICE is not enabled. No STALL interrupt is generated for this condition. No data transfers occur in this state.
ON	The DMA Channel enters this state when a base address is written in the Stall state. Data transfers occur in this state. The DMA Channel enters this state when the current buffer expires in the Next state, and a NFB interrupt is generated.
NEXT	The DMA Channel enters this state when a base address register is written in the ON state. Data transfers occur in this state.

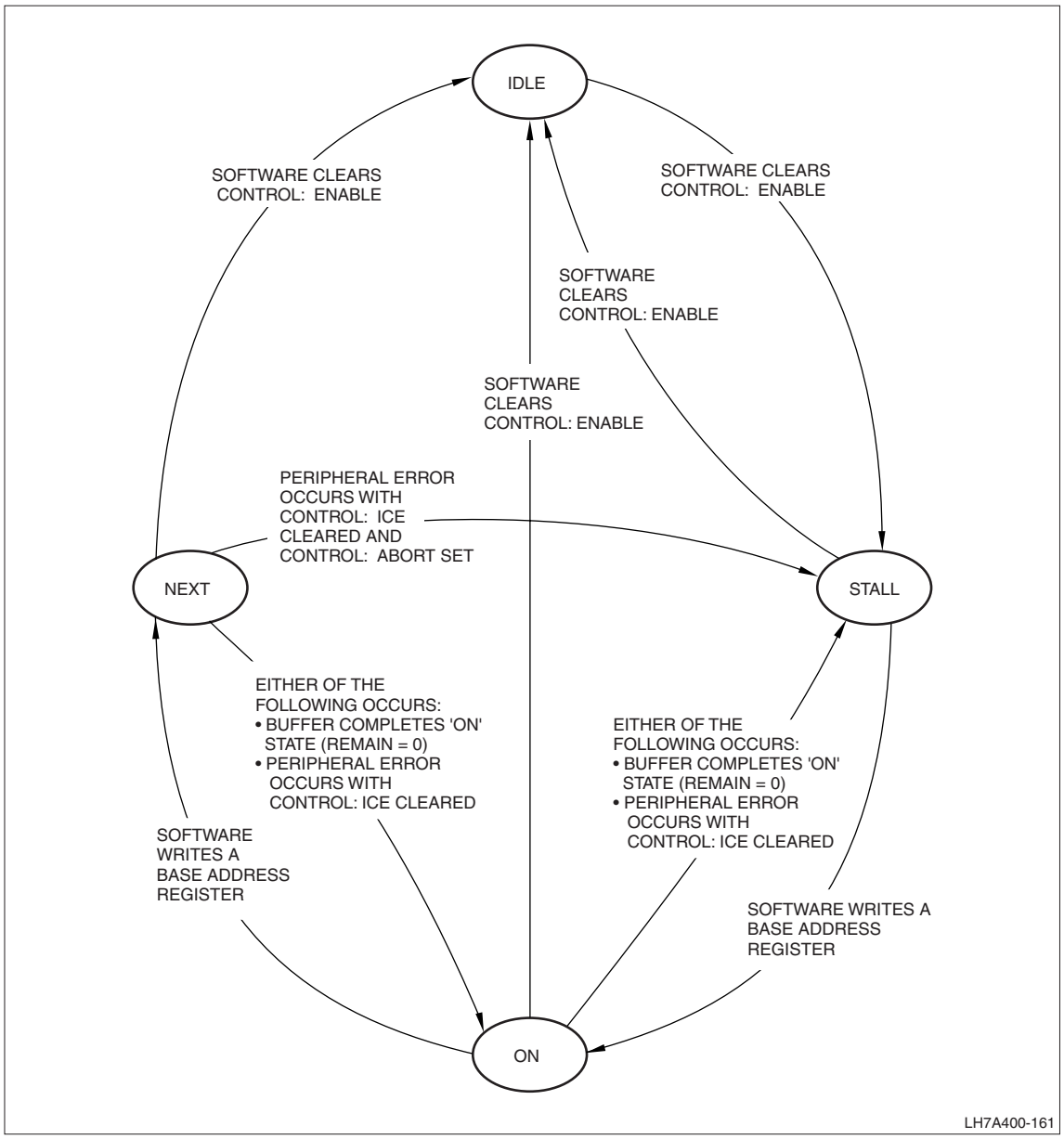


Figure 9-2. DMA State Machine

9.1.6 Bus Arbitration

The bus arbitration logic operates as a slave because an external bus arbiter exists. The DMA Controller generates an external bus request when an internal request is pending. After data initiation, the DMA Controller arbitrates internally between the DMA Channels and then performs AHB bus transfers. The internal arbitration scheme uses a rotating priority, with 1 being the highest priority and 10 the lowest priority. The initial priority list, following Reset, is:

1. MMC Receive
2. MMC Transmit
3. USB Receive
4. USB Transmit
5. AC97 Receive 0
6. AC97 Transmit 0
7. AC97 Receive 1
8. AC97 Transmit 1
9. AC97 Receive 2
10. AC97 Transmit 2

With this rotating priority scheme, the most recent channel to be serviced becomes the lowest priority channel (priority 10) with the others rotating accordingly. In addition, any device requesting service is guaranteed to be recognized after no more than eleven higher priority services occur. This prevents any one channel from monopolizing the system.

The DMA Controller transfers data when it gains ownership of the AHB bus. With the byte, word, and quad-word transfer scheme, the DMA Controller can never burst across a 1KB boundary. The DMA Controller only bursts when the four LSB Address bits are 0000. For a 1KB boundary, the LSB 10 Address bits are 0.

9.2 Register Reference

9.2.1 Memory Map

Table 9-4 defines the DMA controller mapping for each of 10 channels. Each of these channels has an identical set of programming registers, as shown in Table 9-5, using offsets from the individual channel base addresses shown in Table 9-4.

Table 9-4. DMA Channel Memory Map

BASE ADDRESS	DESCRIPTION
0x8000.2800	USB Tx Channel
0x8000.2840	USB Rx Channel
0x8000.2880	MMC Tx Channel
0x8000.28C0	MMC Rx Channel
0x8000.2900 - 0x8000.29FF	Reserved
0x8000.2A00	AC97 Receive Channel 0
0x8000.2A40	AC97 Transmit Channel 0
0x8000.2A80	AC97 Receive Channel 1
0x8000.2AC0	AC97 Transmit Channel 1
0x8000.2B00	AC97 Receive Channel 2
0x8000.2B40	AC97 Transmit Channel 2
0x8000.2B80	Reserved
0x8000.2BC0	DMA Global Interrupt
0x8000.2BC4 - 0x8000.2BFF	Reserved

Table 9-5. Channel Register Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	CONTROL	DMA Channel Control Register
0x04	INTERRUPT	DMA Channel Interrupt Register
0x08	Reserved	Reserved; Do Not Access
0x0C	STATUS	DMA Channel Status Register
0x10	Reserved	Reserved; Do Not Access
0x14	REMAIN	DMA Channel Bytes Remaining Register
0X18	Reserved	Reserved; Do Not Access
0X1C	Reserved	Reserved; Do Not Access
0x20	MAXCNT0	DMA Channel Maximum Bytes Register 0
0x24	BASE0	DMA Channel Base Address Register 0
0x28	CURRENT0	DMA Channel Current Address Register 0
0x2C	Reserved	Reserved; Do Not Access
0x30	MAXCNT1	DMA Channel Maximum Bytes Register 1
0x34	BASE1	DMA Channel Base Address Register 1
0X38	CURRENT1	DMA Channel Current Address Register 1
0X3C	Reserved	Reserved; Do Not Access

9.2.2 Register Descriptions

The following sections describe the contents and use of the register bit fields. Each channel has an individual set of the registers described in this section. The Channel Base Addresses for each register bit diagram are listed in Table 9-4.

9.2.2.1 DMA Channel Control Register (CONTROL)

The channel CONTROL register, described in Table 9-6 and Table 9-7, is provided for configuration of the DMA channel. The Channel Error Interrupt Enable (ChErrorIntEn), New FIFO Buffer Interrupt Enable (NFBIntEn), and Stall Interrupt Enable (STALLIntEn) bits in this register are bit-wise logically ANDed with the corresponding STATUS register bits to assert interrupts in the INTERRUPT register. The ChErrorIntEn status is further qualified by the ICE and ABORT fields.

Table 9-6. CONTROL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									ICE	ABORT	ENABLE	ChErrorIntEn	///	NFBIntEn	STALLIntEn
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW
ADDR	Channel base address + 0x00															

Table 9-7. CONTROL Fields

BITS	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading this field returns 0. Values written cannot be read.
6	ICE	**Interrupt Control Enable** 1 = Suppress ChErrorInt interrupt generation without buffer termination. For example, set ICE for data streams where the end user is intolerant of occasional bit errors. 0 = Do not suppress ChErrorInt generation
5	ABORT	**Abort** Specifies the DMA channel state machine behavior in the NEXT state and after receipt of a peripheral error, as indicated by RxEnd and TxEnd: 1 = NEXT transitions to STALL state, disabling the channel. No STALLInt interrupt is set. 0 = NEXT transitions to ON state When ICE is set, ABORT has no effect.

Table 9-7. CONTROL Fields (Cont'd)

BITS	FIELD	DESCRIPTION
4	ENABLE	**Channel Enable** Enable the channel before writing the base address register. 1 = Enables the channel 0 = Disables the channel, discarding any remaining unpacker or packer data
3	ChErrorIntEn	**Channel Error Interrupt Enable** The ChError interrupt indicates a buffer transfer error. 1 = Enables the ChError interrupt. 0 = ChError interrupt is disabled (masked.)
2	///	**Reserved** Reading this field returns 0. When writing this register, ensure this bit is 0.
1	NFBIntEn	**New FIFO Buffer Interrupt Enable** 1 = Enables NFB interrupt generation in the DMA channel ON state. 0 = Disables NFB interrupt generation. When the channel is enabled, NFBIntEn is set in normal operation. Program this field to 0 in the following situations: • The current buffer is the last buffer. • The transfer consists of a single buffer.
0	STALLIntEn	**Stall Interrupt Enable** 1 = Enables STALL interrupt generation in the DMA channel STALL state. 0 = Disables STALL interrupt generation.

9.2.2.2 DMA Channel Interrupt Register (INTERRUPT)

The channel INTERRUPT register, described in Table 9-8 and Table 9-9, shows the enabled and asserted DMA channel interrupts. The Channel Error Interrupt (ChErrorInt), New FIFO Buffer Interrupt (NFBInt), and Stall Interrupt (STALLInt) fields in this register are a bit-wise logical AND of the corresponding CONTROL and STATUS register fields. The OR of these three fields is sent to the LH7A400 interrupt controller as the DMAINTR IRQ interrupt. The ChErrorInt interrupt is further qualified by the CONTROL:ICE and CONTROL:ABORT fields.

The NFBInt and STALLInt interrupts are cleared automatically when the corresponding cause is resolved. To clear ChErrorInt in both the STATUS and INTERRUPT registers, write any 32-bit value to the INTERRUPT register.

Table 9-8. INTERRUPT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												ChErrorInt	///	NFBInt	STALLInt
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	Controller base address + 0x04															

Table 9-9. INTERRUPT Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading this field returns 0. Values written cannot be read.
3	ChErrorInt	**Channel Error Interrupt** 1 = The peripheral attached to the DMA channel has detected an error in the data stream. A peripheral communicates this situation by ending the current transfer with a TxEnd or RxEnd error response. 0 = No data stream error detected.
2	///	**Reserved** Reading this field returns 0. When writing this register, ensure this bit is 0.
1	NFBInt	**New FIFO Buffer Interrupt** 1 = The channel requires a new buffer. This interrupt is generated on a channel state machine transition from NEXT to ON state, when NFBIntEn is set. 0 = New buffer is not required.
0	STALLInt	**Stall Interrupt** 1 = The channel has stalled. This interrupt is generated on a channel state machine transition from ON to STALL state, when STALLIntEn is set. This critical interrupt indicates an overflow or underflow condition will occur as soon as the peripheral FIFO is full or empty, respectively. 0 = The channel is active; no stall condition.

9.2.2.3 DMA Channel Status Register (STATUS)

The channel STATUS register, described in Table 9-10 and Table 9-11, shows the raw status of the DMA interrupts. If a buffer transfer terminates prior to completion, the Channel Error Interrupt (ChErrorInt) is asserted. The ChErrorInt, New FIFO Buffer Interrupt (NFBInt), and Stall Interrupt (STALLInt) fields in this register are bit-wise logically ANDed with the corresponding CONTROL register fields to assert interrupts in the INTERRUPT register. The ChErrorInt status is further qualified by the CONTROL:ICE and CONTROL:ABORT fields.

The NFBInt and STALLInt interrupts are cleared automatically when the corresponding cause is resolved. To clear ChErrorInt in both the STATUS and INTERRUPT registers, write any 32-bit value to the INTERRUPT register.

Table 9-10. STATUS Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				BYTES					NextBuffer	CurrentState		ChError	///	NFB	STALL
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	Channel base address + 0x0C															

Table 9-11. Status Fields

BITS	FIELD	FUNCTION
31:12	///	**Reserved** Reading this field returns 0. Values written cannot be read.
11:7	BYTES	Number (hex) of valid DMA data bytes currently stored by the channel in the DMA Controller packer or unpacker.
6	NextBuffer	**Next Buffer** Identifies the BASEx and MAXCOUNTx register pair available for update: 1 = Update MAXCNT1 and BASE1. 0 = Update MAXCNT0 and BASE0.
5:4	CurrentState	**Current State** Identifies the current channel state: 11 = NEXT 10 = ON 01 = STALL 00 = IDLE
3	///	**Reserved** Reading this field returns 0. Values written cannot be read.
2	ChError	**Channel Error** 1 = The last buffer transfer terminated with an error 0 = The last buffer transfer completed without an error

Table 9-11. Status Fields (Cont'd)

BITS	FIELD	FUNCTION
1	NFB	**New FIFO Buffer** Announces when the next buffer is ready: 1 = In ON State and ready for the next buffer BASE and MAXCOUNT updates, indicating the channel operation has changed from NEXT state to ON state. The channel is currently transferring data from a DMA buffer but the next base address for the next buffer in the transfer has not been programmed, and can now be programmed. This condition generates the NFB interrupt when the interrupt is unmasked. 0 = Not in ON state and not ready for the next buffer update.
0	Stall	**Stall** 1 = The channel is stalled and cannot currently transfer data because no base address has been programmed. When the channel is first enabled, the Stall bit is suppressed until the first buffer has been transferred. The stall interrupt is generated only when the STALL state is entered from the ON state, not when the STALL state is entered from the IDLE state. To clear the STALL state, write a base address or disable the DMA channel. To find the reason for the STALL, read the REMAIN register. 0 = The channel is not stalled and operating normally.

9.2.2.4 DMA Channel Bytes Remaining Register (REMAIN)

The channel bytes remaining register, described in Table 9-12 and Table 9-13, reports the number of bytes remaining in the current DMA transfer.

Table 9-12. REMAIN Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	REMAIN															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	Channel base address + 0x14															

Table 9-13. REMAIN Fields

BIT	FIELD	FUNCTION
31:16	///	**Reserved** Reading this field returns 0. Values written cannot be read.
15:0	REMAIN	**Channel Bytes Remaining** Nonzero = The DMA transfer was stopped by TxEnd or RxEnd from the peripheral. Software can use this value to determine the data remaining in the buffer. 0 = The buffer transfer has completed, generating TxTC or RxTC. The DMA state machine decrements by one byte for every byte transfer between the DMA controller and the peripheral. When this count reaches 0, the current buffer transfer is complete and the TxTC or RxTC is generated. When the channel enters ON state, the channel MAXCNT value is loaded into REMAIN. Of the two data transfer states, ON and NEXT, only the ON state requires assigning this register. In the ON state, the next buffer to be used is known because only one buffer can be used.

9.2.2.5 DMA Channel Maximum Count Register (MAXCNT[1:0])

The maximum count register, described in Table 9-14 and Table 9-15, specifies the maximum number of bytes in a buffer.

Table 9-14. MAXCNT[1:0] Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0															
TYPE	RO															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	MAXCNT															
RESET	0															
TYPE	RW															
ADDR	Channel base address + 0x20 for MAXCNT0 Channel base address + 0x30 for MAXCNT1															

Table 9-15. MAXCNT[1:0] Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written cannot be read.
15:0	MAXCNT	Maximum byte count for the current (MAXCNT0 register) or next (MAXCNT1 register) buffer, representing the double buffer in each channel. Program each MAXCNT register before programming the corresponding BASE register.

9.2.2.6 DMA Channel Transfer Base Address Register (BASE[1:0])

The transfer base address register, described in Table 9-16 and Table 9-17, specifies the base address for the current and next DMA transfers.

Table 9-16. BASE[1:0] Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	BASE															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	BASE															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	Controller base address + 0x24 for BASE0 Controller base address + 0x34 for BASE1															

Table 9-17. BASE[1:0] Fields

BITS	FIELD	DESCRIPTION
31:0	BASE	The buffer 0 (BASE0 register) and buffer 1 (BASE1 register) DMA transfer addresses. Using this field involves these steps: 1. Enter STALL state by enabling the DMA channel. 2. Enter ON state by loading the start addresses into BASE0 and BASE1.

9.2.2.7 DMA Channel Current Address Register (CURRENT[1:0])

The current address register, described in Table 9-18 and Table 9-19, identifies the base address for the transfer.

Table 9-18. CURRENT[1:0] Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	CURRENT															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	CURRENT															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	Channel base address + 0x28 for CURRENT0 Channel base address + 0x38 for CURRENT1															

Table 9-19. CURRENT[1:0] Fields

BITS	FIELD	DESCRIPTION
31:0	CURRENT	After software enables the DMA channel and writes the base address register (BASE[0] or BASE[1], the DMA loads the base address register value into the corresponding CURRENT[1:0] register. This load activates the DMA buffer [1:0], respectively. After transfer from a buffer completes, the corresponding CURRENT channel address register contains the actual count reached. A software service routine can use this count to discover where in the buffer the transfer terminated.

9.2.2.8 DMA Global Interrupt Register (GLOBALINTERRUPT)

The global interrupt register, described in Table 9-20 and Table 9-21, reports the global interrupt status for each channel. Each interrupt field corresponds to a channel and is a logical OR of the channel interrupt register. No dedicated storage is available for these channel interrupts. To clear a global interrupt for a channel, clear the corresponding channel interrupt register.

Table 9-20. GLOBALINTERRUPT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///						AC97TX2INT	AC97RX2INT	AC97TX1INT	AC97RX1INT	AC97TX0INT	AC97RX0INT	MMCRXINT	MMCTXINT	USBRXINT	USBTXINT
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.2BC0															

Table 9-21. GLOBALINTERRUPT Field

BITS	FIELD	DESCRIPTION
31:10	///	**Reserved** Reading this field returns 0. Values written cannot be read.
9	AC97TX2INT	**AC97 Channel 2 Transmit Interrupt** 1 = The AC97 controller channel 2 transmit interrupt is asserted. 0 = The AC97 controller channel 2 transmit interrupt is not asserted.
8	AC97RX2INT	**AC97 Channel 2 Receive Interrupt** 1 = The AC97 controller channel 2 receive interrupt is asserted. 0 = The AC97 controller channel 2 receive interrupt is not asserted.
7	AC97TX1INT	**AC97 Channel 1 Transmit Interrupt** 1 = The AC97 controller channel 1 transmit interrupt is asserted. 0 = The AC97 controller channel 1 transmit interrupt is not asserted.
6	AC97RX1INT	**AC97 Channel 1 Receive Interrupt** 1 = The AC97 controller channel 1 receive interrupt is asserted. 0 = The AC97 controller channel 1 receive interrupt is not asserted.
5	AC97TX0INT	**AC97 Channel 0 Transmit Interrupt** 1 = The AC97 controller channel 0 transmit interrupt is asserted. 0 = The AC97 controller channel 0 transmit interrupt is not asserted.
4	AC97RX0INT	**AC97 Channel 0 Receive Interrupt** 1 = The AC97 controller channel 0 receive interrupt is asserted. 0 = The AC97 controller channel 0 receive interrupt is not asserted.
3	MMCRXINT	**MMC Receive Interrupt** 1 = The MMC controller channel receive interrupt is asserted. 1 = The MMC controller channel receive interrupt is not asserted.
2	MMCTXINT	**MMC Transmit Interrupt** 1 = The MMC controller channel transmit interrupt is asserted. 0 = The MMC controller channel transmit interrupt is not asserted.
1	USBRXINT	**USB Receive Interrupt** 1 = The USB controller channel receive interrupt is asserted. 0 = The USB controller channel receive interrupt is not asserted.
0	USBTXINT	**USB Transmit Interrupt** 1 = The USB controller channel transmit interrupt is asserted. 0 = The USB controller channel transmit interrupt is not asserted.

Chapter 10
Color LCD Controller

This chapter discusses the LH7A400 Color LCD Controller (CLCDC) and its Advanced LCD Interface Peripheral (ALI) for AD-TFT, HR-TFT panels, and any technology of panel compatible with this signal system. The ALI-specific description begins in section 10.2.1.

10.1 Introduction

The CLCDC provides all necessary control and data signals to interface the LH7A400 directly to a variety of color and monochrome LCD panels, including STN and TFT panels. The ALI modifies the CLCDC output to allow the LH7A400 to connect directly to the Row and Column driver chips on superthin panels, including AD-TFT, HR-TFT, or any panel that supports this method of connection. Figure 10-1 shows a simplified diagram of the two controllers connected to the AHB, to the APB, and to each other.

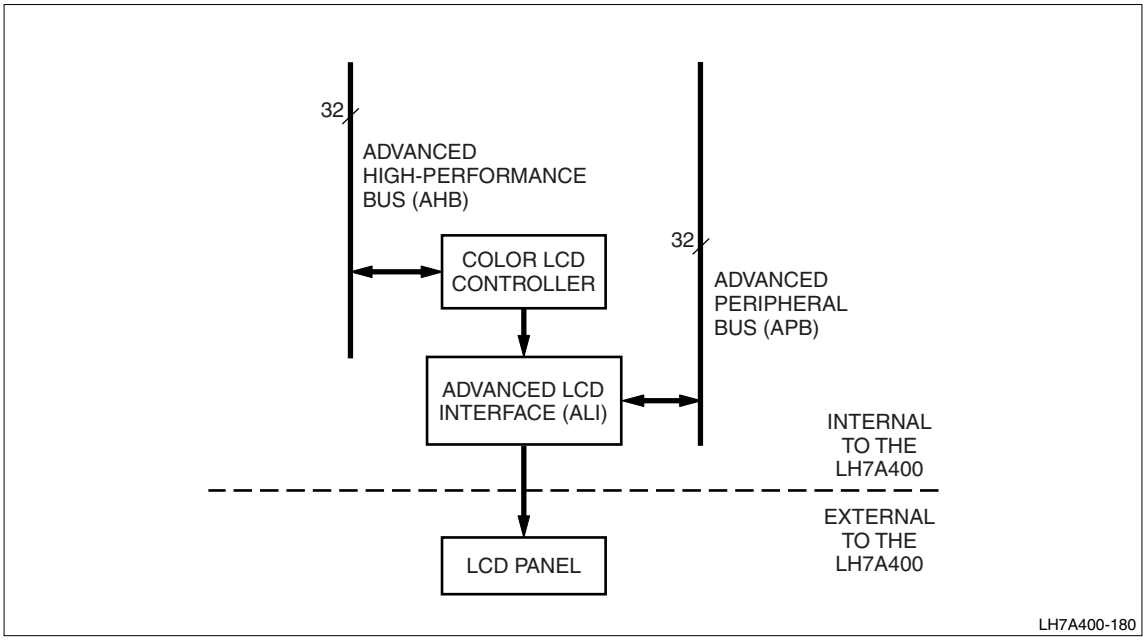


Figure 10-1. LH7A400 LCD System, Simplified Block Diagram

10.1.1 LCD Panel Architecture

The CLCDC has an AHB slave interface to its registers and an AHB master interface for the LCD data. The ALI has an APB slave interface to its registers. Image data flows from the AHB, through the CLCDC and the ALI, to an external LCD panel. Although a particular LCD panel may not require the ALI, the ALI must be correctly programmed because all LCD data passes through it, even if it is set to bypass mode for STN and TFT applications.

Modern technology panels, including AD-TFT and HR-TFT panels, are thinner than ever. To achieve maximum space savings, they are manufactured without the large ASICs and DC-DC converter blocks built into STN and TFT panels. See Figure 10-2.

The ASIC in STN and TFT panels decodes input data into Row and Column information and builds the timing signals. It supplies this information to the panel's Row and Column driver chips to set the proper pixels at the proper intensity and at the proper times. The DC-DC converter runs the panel's power supplies and illuminator. Including these devices in STN and TFT panels, however, comes at the cost of bulk and weight.

The ALI eliminates the need for a separate timing ASIC, since it is able to drive the panel's Row and Column driver chips directly. The DC-DC conversion is also handled off-panel, by a separate device operating the panel's high voltage supplies and illuminator. The DC-DC conversion must be handled by a separate device, since the LH7A400 does not supply this function.

Unless the behavior is different, this User's Guide uses the term TFT to discuss all types of TFT panels whether the panel requires timing support from the ALI or not.

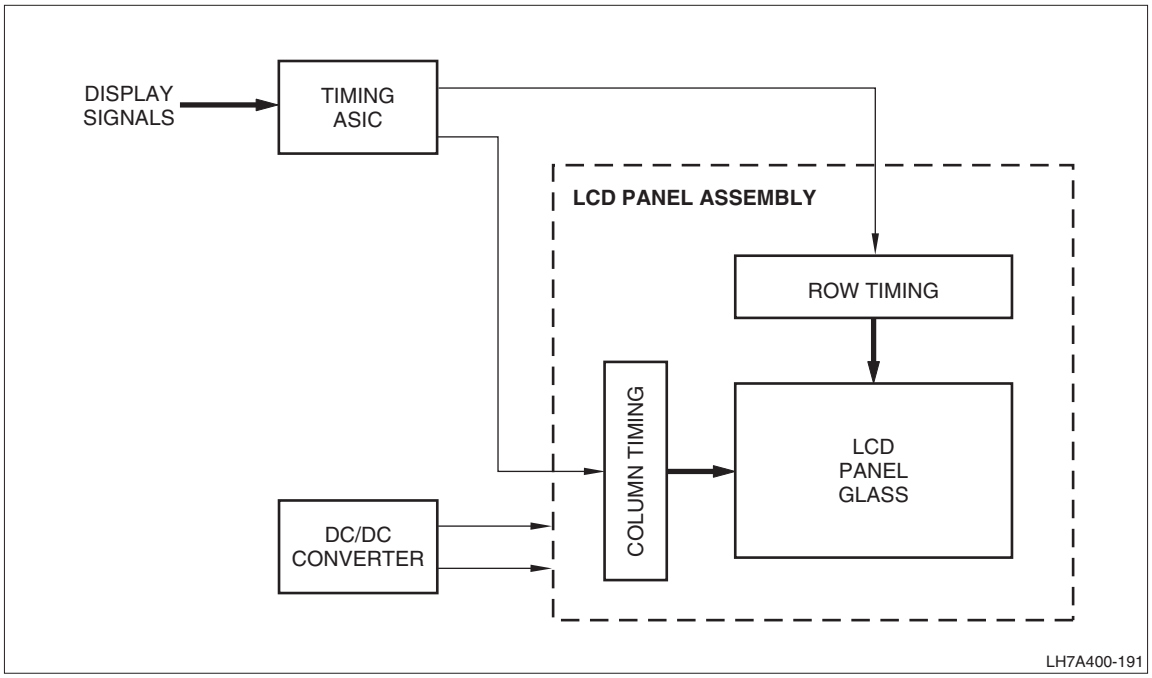


Figure 10-2. Block Diagram of a Typical Advanced LCD Panel

10.1.2 Features

The following parameters can be programmed in the CLCDC:

- Horizontal front and back porch width
- Horizontal synchronization pulse width
- Number of pixels per line
- Vertical front and back porch width
- Vertical synchronization pulse width
- Number of horizontal lines per panel
- Number of panel data clocks per line
- Programmable signal polarities, active HIGH or active LOW
- AC panel bias
- Panel data clock frequency (LCDDCLK)
- Bits-per-pixel
- Little-endian, big-endian, and WinCE™ data formatting
- Interrupt generation.

10.1.3 Theory of Operation

The CLCDC, shown in Figure 10-3, retrieves image data from a frame buffer, formats the data for the LCD panel, and writes it to the panel. The CLCDC also generates the control signals that enable the panel to display the formatted data.

Raw image data is stored in a frame buffer, which can be located in internal static memory or in external SDRAM (external SRAM cannot be used). The CLCDC retrieves raw image data from the frame buffer by its own dedicated two channel DMA and formats the data as programmed. The CLCDC supports little-endian, big-endian, or WinCE pixel ordering in the frame buffer. WinCE pixel ordering is big-endian within a byte and little-endian within a word. The CLCDC can function as an AHB Master, and has the highest priority of the three LH7A400 AHB Masters.

The CLCDC utilizes two clock signals operating at considerably different frequencies. The two clocks need not be synchronous. DMA operations that access the frame buffer use the AHB (fast) clock. A second, slower clock drives the logic that creates the control signals and presents formatted data to the LCD panel. Although DMA operations always occur at the internal AHB rate, the LCD panel logic can be driven by an internally-generated clock or by an external clock source. In either case, the panel operates at a much lower frequency than the AHB. See Section 10.1.7 and Figure 10-5 for more information about the CLCDC clocks.

The CLCDC contains two DMA FIFO buffers for frame buffer data. The CLCDC requests the AHB whenever the level of data in a FIFO falls below the programmed Watermark (four or eight 32-bit words) for that FIFO. The CLCDC will not request the AHB unless a FIFO can accept at least four words. If necessary, the CLCDC will insert AHB busy cycles to ensure that the FIFOs are correctly written. When the CLCDC is granted access to the AHB, it can service either or both FIFOs. Dual panels do not double the overhead associated with mastering the AHB.

In the 1-, 2-, 4- or 8-Bit-Per-Pixel (BPP) modes, the data provides an index into a 16-bit wide color Look-Up Table, called the Palette RAM. In the 16 BPP mode of operation the Palette RAM is bypassed and the data is the actual pixel information. The 16 BPP mode is a direct mode.

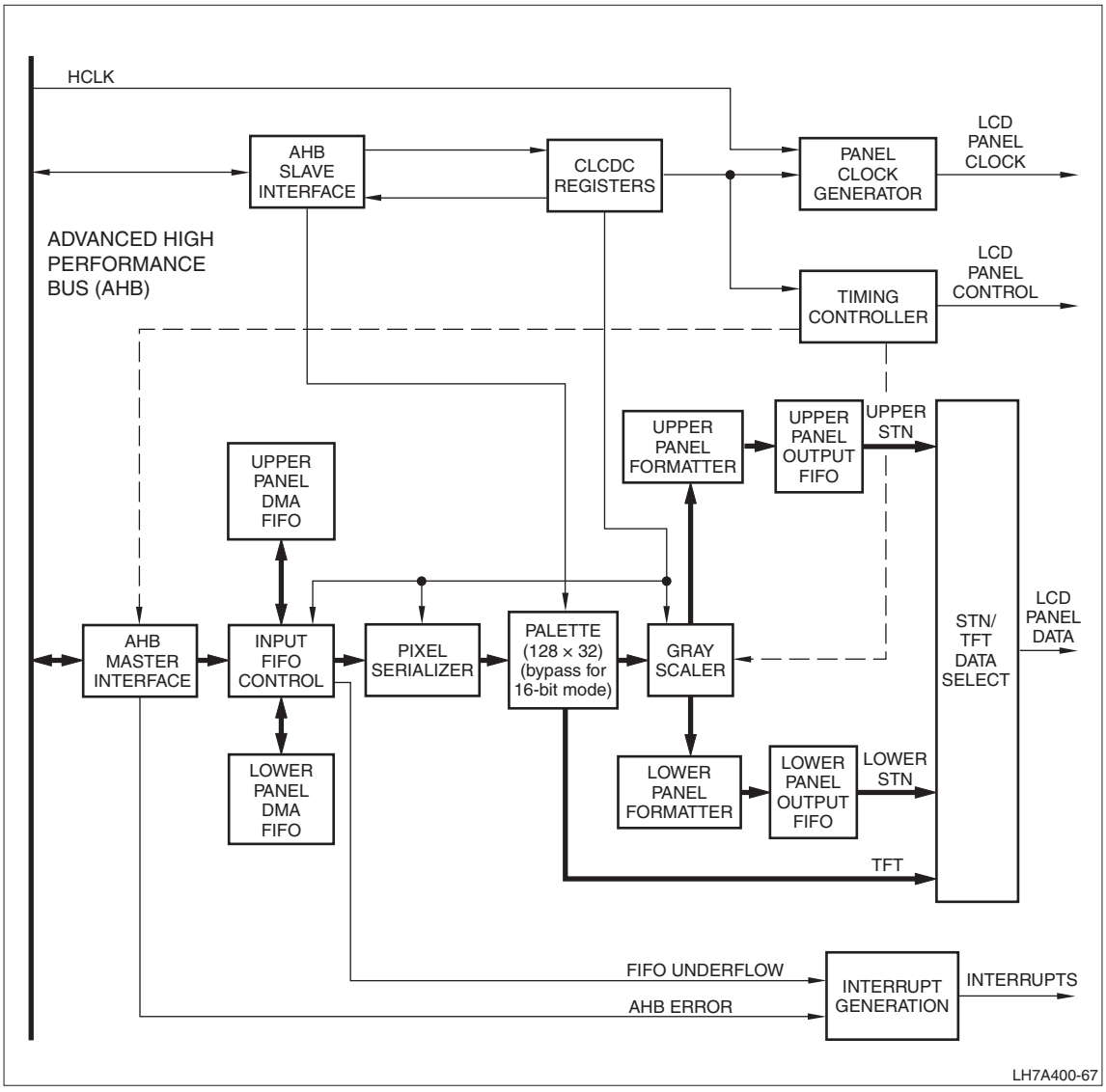


Figure 10-3. CLCDC Block Diagram

10.1.3.1 Memory Management Unit

The CLCDC Memory Management Unit (LCD MMU) contiguously maps the LCD memory areas used in the embedded SRAM (eSRAM) and off-chip SDRAM. Typically the first 40KB of LCD data is stored in eSRAM with the balance stored in SDRAM.

The LCD MMU decodes the physical address generated by the CLCDC. If the addressed area is within 1 MB of the beginning of eSRAM, but beyond the first 40KB, the LCD MMU modifies the address by the address pointer contained in the OVERFLOW register, locating it within external SDRAM. Since the OVERFLOW register pointer is located on a 4KB boundary, the lower three nibbles are unchanged. If the physical address is already within external SDRAM, it is simply passed through unmodified.

In the example in Figure 10-4, a 300KB frame buffer is located with a physical base address at 0xB000.A000 and an overflow area at Synchronous Memory Bank 0 (nSCS0). This base address is the beginning of the upper 40KB of eSRAM, leaving the lower 40KB available for a different application. Memory selected by nSCS0 begins at physical address 0xC000.0000. During CLCDC configuration, software programs the UPBASE register with 0xB000.A000 and OVERFLOW with 0xC000.0000. For the first 40KB of the frame buffer, the LCD MMU accesses the upper 40KB of eSRAM. For the 260KB beyond physical address 0xB001.3FFC, the MMU uses OVERFLOW to offset the address instead of UPBASE.

A convenient design for handling large frame buffers is to use the LH7A400 MMU to map the eSRAM and external parts of the frame buffer as a contiguous address range. For information on the LH7A400 MMU, see the ARM922T MMU documentation available from ARM, Ltd.

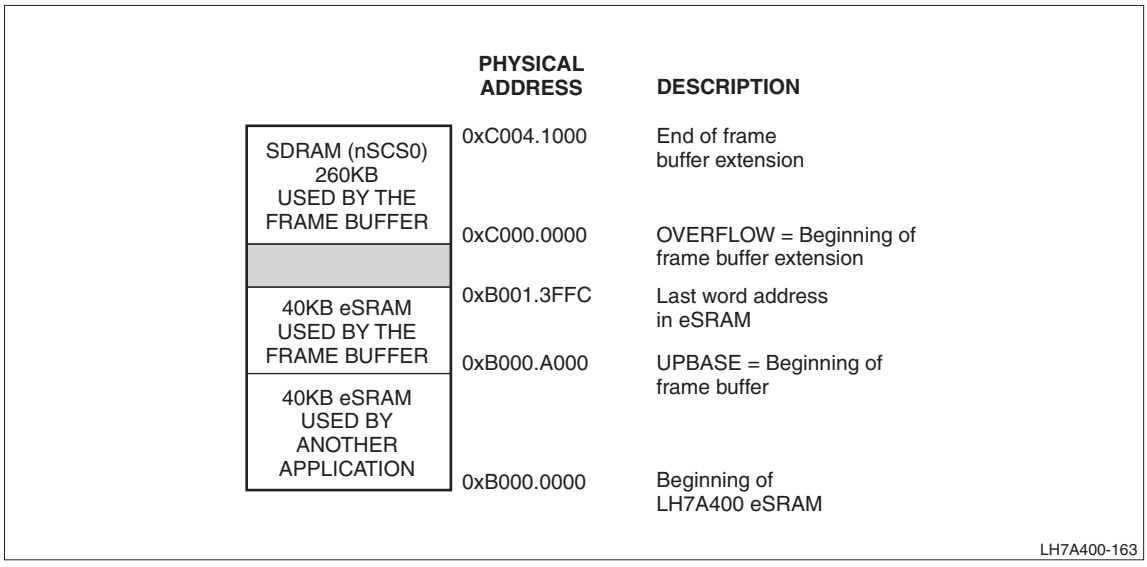


Figure 10-4. Large Frame Buffer Overflow Example

10.1.3.2 Dual-panel Color STN Operation

In the dual-panel color STN mode each FIFO (upper and lower) is fed by a separate DMA channel. The image data to be displayed on the upper and lower panels is read from the upper and lower regions of the frame buffer respectively and placed in the appropriate FIFO. Requests to each DMA channel are independently generated by each FIFO, according to the FIFO's demand. Data in each FIFO is continuously transferred to the Pixel Serializer where the data is separated into 16-, 8-, 4-, or 1-bit sections, according to the mode. The Pixel Serializer extracts the pixel data for the upper and lower panels on alternate clock cycles and passes the pixel data to the Palette RAM. The Palette RAM consists of a 128 × 32-bit dual-port RAM logically organized as 256 × 16 bits.

In the 8, 4, 2, and 1 BPP modes the Palette RAM provides the pixel's physical color value, passing the most significant 4 bits of each color bit field to the Grayscaler.

In the 16 BPP mode the Palette RAM is bypassed and the most significant 4 bits of each color bit field of the Pixel Serializer's output are passed directly to the Grayscaler. The Grayscaler generates a 1-bit pixel for each color. Each 1-bit pixel will be either HIGH or LOW for a particular pixel on the display, in a particular frame. Each color's 1-bit Grayscaler output is passed to the appropriate Formatter, to form an 8-bit data value in the Formatter's FIFO. The final data value for each pixel is output from the FIFO to the panel at 2-2/3 pixels per LCDDCLK cycle.

10.1.3.3 Dual-panel Monochrome STN Operation

In the dual-panel monochrome STN mode, image data is transferred from the frame buffer to the CLCDC input FIFOs by DMA operation, as it is for dual-panel color STN displays. Data also flows from these FIFOs, through the Pixel Serializer, to the Palette RAM in the same manner. In this mode the Palette RAM requires only 16 entries because only 1, 2, and 4 BPP formats are supported. Each Palette RAM entry represents 1 of 16 different displayable levels of gray. The Grayscaler generates 1-bit pixels, each of which will be HIGH or LOW for a particular pixel in a particular frame. The Grayscaler output is passed to the appropriate Formatter, to form a 4-bit or an 8-bit data value in the Formatter's (3 byte) FIFO, depending upon the LCD interface. The final data value is output from the Formatter's FIFO to the LCD panel at a rate of either 4 or 8 pixels per LCDDCLK cycle, depending upon the LCD interface.

10.1.3.4 Single-panel Color STN Operation

In the single-panel color STN mode, the Formatter for the lower panel is disabled and the upper and lower DMA FIFOs are utilized as a single FIFO of twice the capacity. Image data is transferred from the frame buffer to the FIFO by DMA operation. The data in the FIFO is split by the Pixel Serializer into 16-, 8-, 4-, 2-, or 1-bit sections, depending upon the programmed operating mode. The Pixel Serializer extracts the pixel data on every clock cycle and passes it to the Palette RAM or directly to the Grayscaler, depending upon the mode.

In the 8, 4, 2, and 1 BPP modes, the Palette RAM functions in the same manner as for dual-panel color STN displays.

In the 16 BPP mode, the Palette RAM is bypassed and the Pixel Serializer passes the most significant 4 bits of each color bit field to the Grayscaler.

As in dual-panel Color STN operation, the Grayscaler generates a 1-bit pixel for each color. Each 1-bit pixel will be either HIGH or LOW for a particular pixel in a particular frame. The 1-bit pixel is passed to the upper Formatter to form an 8-bit data byte in the Formatter's output (3 byte) FIFO. The final data value is output from the FIFO at a rate of 2-2/3 pixels per LCDDCLK cycle.

10.1.3.5 Single-panel Monochrome STN Operation

In the single-panel monochrome STN mode, the lower panel's Formatter is disabled and the image data is transferred by DMA operation from the frame buffer to the doubled FIFO, as it is for single-panel color STN operation. The Pixel Serializer serializes the data and passes it to the Palette RAM. The Palette RAM provides the physical gray value of the pixel for 4, 2 or 1 BPP modes.

As in dual-panel Monochrome STN operation, the Grayscaler generates 1-bit pixels, each pixel being either HIGH or LOW for a particular pixel in a particular frame. The chosen 1-bit grayscale output is passed to the Formatter to form a 4-bit or 8-bit data byte, depending upon the programmed width of the LCD interface (4 or 8-bits), and written to the (3 byte) FIFO. The final data value for the LCD panel is output at a rate of 4 or 8 pixels per LCDDCLK cycle, depending upon the programmed width of the Interface.

10.1.3.6 TFT Operation

The TFT mode is functionally similar to the single-panel color STN mode except that the Grayscaler and the Formatter are both bypassed. The image data is transferred by DMA operation from the frame buffer to the doubled FIFO. Data from the FIFO is split by the Pixel Serializer into 16-, 8-, 4-, 2-, or 1-bit sections, depending upon the programmed operating mode.

In the 8-, 4-, 2-, or 1-BPP modes, the output of the Pixel Serializer is utilized as the Palette index, to extract the physical color. The Palette data is written to the LCD panel.

In the 16-BPP mode, the Palette RAM is bypassed and the output of the Pixel Serializer is directly utilized as the panel data.

10.1.3.7 Storing Pixels in the Frame Buffer

Tables 10-1 and 10-2 show the physical data structure in each frame buffer corresponding to the BPP combinations. The tables show only the first word of the data. In the tables 'B' represents blue, 'G' represents green, and 'R' represents red.

Table 10-1 describes color mode only. It shows the first word in the frame buffer for 16 BPP direct color, 5:5:5 + intensity bit, and the BGR bit programmed to 0 (see Section 10.3.8 for information about the BGR bit). For CSTN modes, the I bit and the least significant bit of the R, G, and B fields are unused.

Table 10-2 shows the first word in the frame buffer for 16 BPP direct color, 5:6:5 and the BGR bit programmed to 0 (see Section 10.3.8 for information about the BGR bit). It describes TFT modes, including AD-TFT and HR-TFT panels.

Table 10-1. 16 BPP Direct, 5:5:5 + Intensity, BGR = 0

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	I Pixel 2	B Pixel 2					G Pixel 2					R Pixel 2				
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	I Pixel 1	B Pixel 1					G Pixel 1					R Pixel 1				

Table 10-2. 16 BPP Direct, 5:6:5, BGR = 0 (TFT Only; includes AD-TFT and HR-TFT)

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	B Pixel 2					G Pixel 2						R Pixel 2				
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	B Pixel 1					G Pixel 1						R Pixel 1				

10.1.3.8 Pixel Serializer

The pixel serializer reads the 32-bit-wide LCD data from the output port of the LCD DMA FIFO and extracts 12, 8, 4, 2, or 1 bits per pixel (BPP) data, depending on the operating mode. In Dual Panel Mode, data alternately is read from the upper and lower LCD DMA FIFOs. Depending on the operating mode, the extracted data is either used to point to a color/gray scale value in the Palette RAM or directly applied to an LCD panel input.

10.1.4 LCD Panel Resolution

LCD panel resolution is expressed as the addressable number of horizontal pixels with the addressable number of vertical pixels. The CLCDC supports STN, TFT, AD-TFT and HR-TFT LCD panels with a wide range of resolutions, including:

- 120 × 160
- 320 × 200, 320 × 240
- 640 × 200, 640 × 240, 640 × 480
- 800 × 600
- 1,024 × 768 (8 Bits-Per-Pixel MAX.)

10.1.4.1 Color and Gray Scale Selection

TFT, AD-TFT, and HR-TFT LCD panels utilize color palette RAM. For these panels, each 16-bit palette entry is composed of 5 Bits-Per-Pixel plus a common intensity bit. In addition, the total number of supported colors can be doubled from 32,768 to 65,536 if the Intensity bit is utilized and applied simultaneously to all three color components (R, G, and B). The CLCDC can drive up to 16 data lines for standard and thin TFT panel modules. Whether the LCD module requires the ALI to generate additional timing information does not affect the data line usage. The selection of colors that the CLCDC can drive a TFT panel to display is determined by the number of video data lines wired to the panel. If all 16 video data lines are wired to the TFT panel, 65,536 total colors are available. Possible settings are listed in Table 10-3.

The number of different colors displayable on the TFT panel at one time is programmed by the Bits-Per-Pixel (BPP) setting. Color and Monochrome STN panels are driven by a gray-scale algorithm. For Monochrome STN displays, this algorithm provides 15 different levels of gray. In the case of Color STN displays, the three color components (red, green, and blue) are simultaneously gray-scaled. The simultaneous gray-scaling provides 3,375 (15 × 15 × 15) possible levels of gray.

If the BGR bit in the CONTROL register is 0, the CLCDC outputs the color value in the palette entry (for palettized modes) or in the frame buffer entry (direct mode) onto video data lines. If the BGR bit is 1, then bits 4:0 of the palette entry or frame buffer entry are swapped with bits 14:9 before they are output.

Table 10-3. Supported TFT, AD-TFT, and HR-TFT LCD Panels

BPP	SOURCE	TFT, AD-TFT AND HR-TFT (UP TO 16-BIT BUS)
1	Palettized	2 colors selected from 65,536 available colors
2	Palettized	4 colors selected from 65,536 available colors
4	Palettized	16 colors selected from 65,536 available colors
8	Palettized	256 colors selected from 65,536 available colors
16	Direct	65,536 colors are encoded directly in the frame buffer

Table 10-5 shows the bit-depths (Bits-Per-Pixel) supported for Monochrome STN panels.

Table 10-4. Supported Color STN LCD Panels

BPP	SOURCE	COLOR STN (SINGLE AND DUAL PANEL, 8-BIT BUS)
1	Palettized	2 colors selected from 3,375
2	Palettized	4 colors selected from 3,375
4	Palettized	16 colors selected from 3,375
8	Palettized	256 colors selected from 3,375
16	Direct	4:4:4 RGB. Requires 12 data lines, 4 BPP are unused.

NOTE: 3375 colors = (15 RED) × (15 BLUE) × (15 GREEN).

Table 10-5. Supported Mono-STN LCD Panels

BPP	SOURCE	MONO STN (SINGLE AND DUAL, 4- AND 8-BIT BUS)
1	Palettized	2 gray scales selected from 15
2	Palettized	4 gray scales selected from 15
4	Palettized	16 gray scales selected from 15

The grayscaler transforms each 4-bit grayscale value into a sequence-of-activity per pixel, over several frames. The effectiveness of this operation relies on the characteristics of STN LCDs to produce a representation of a grayscale. Table 10-6 shows the intensity that can be obtained from each of the 16 possible 4-bit palette combinations. Only 15 of the combinations are useful because the 2 middle values produce the same result.

Table 10-6. Color STN Intensities From Grayscale Modulation

4-BIT PALETTE VALUE	DUTY CYCLE[1]	RESULTING INTENSITY[2]
0b0000	0/90	00.0%
0b0001	10/90	11.1%
0b0010	18/90	20.0%
0b0011	24/90	26.7%
0b0100	30/90	33.3%
0b0101	36/90	40.0%
0b0110	40/90	44.4%
0b0111	45/90	50.0%
0b1000	45/90	50.0%
0b1001	50/90	55.6%
0b1010	54/90	60.0%
0b1011	60/90	66.6%
0b1100	66/90	73.3%
0b1101	72/90	80.0%
0b1110	80/90	88.9%
0b1111	90/90	100.0%

NOTES:
1. Duty cycle is determined by (pixels on ÷ (pixels on + pixels off)).
2. Resulting intensity: 000% = black, 100% = white.

10.1.5 CLCDC Interface Signals

The LCD interface signals generated by the CLCDC and the ALI are multiplexed with General Purpose I/O (GPIO) functions. These pins are set to GPIO functions at reset; LCD interface signals must be selected by software. LCD interface signals function differently for STN, TFT, AD-TFT, or HR-TFT panels. Table 10-7 lists only the different LCD interface signals without showing the pins carrying LCD data, and shows which signal is utilized by each of the supported types of panels.

Table 10-7. LCD Panel Interface Signals

PBGA PIN	RESET STATE	STN SIGNAL	TFT SIGNAL	AD-TFT/HR-TFT SIGNAL
N9	LCD, Output	LCDDCLK (Panel Data Clock)	LCDDCLK (Panel Data Clock)	LCDDCLK (Panel Data Clock)
P9	LCD, Output	LCDM (MCLK = AC Bias)	LCDENAB (Data Enable)	
R6	LCD, Output	LCDFP (Frame Pulse)	LCDFP (Vertical Sync Pulse)	
R8	LCD, Output	LCDLP (Line Sync Pulse)	LCDLP (Horizontal Sync Pulse)	
P2	PC1, Output			LCDPS (Power Save)
R1	PC2, Output	LCDVDDEN (Digital Supply Enable)	LCDVDDEN (Digital Supply Enable or High Voltage Supply Control)	
K6	PC3, Output			LCDREV (AC Bias)
L8	PC4, Output			LCDSPS (Row Reset)
T1	PC5, Output			LCDCLS (Gate Driver Clock)
T2	PC6, Output			LCDHRLP (Horizontal Sync Pulse)
R2	PC7, Output			LCDSPL (Line Start Pulse Left)
P7	LCD, Output	LCDVD0	LCDVD0	LCDVD0
R7	LCD, Output	LCDVD1	LCDVD1	LCDVD1
T7	LCD, Output	LCDVD2	LCDVD2	LCDVD2
N8	LCD, Output	LCDVD3	LCDVD3	LCDVD3
L10	PE0, Input	LCDVD4	LCDVD4	LCDVD4
N10	PE1, Input	LCDVD5	LCDVD5	LCDVD5
M9	PE2, Input	LCDVD6	LCDVD6	LCDVD6
M10	PE3, Input	LCDVD7	LCDVD7	LCDVD7
M11	PD0, Output	LCDVD8	LCDVD8	LCDVD8
L11	PD1, Output	LCDVD9	LCDVD9	LCDVD9
K8	PD2, Output	LCDVD10	LCDVD10	LCDVD10
N11	PD3, Output	LCDVD11	LCDVD11	LCDVD11
R9	PD4, Output	LCDVD12	LCDVD12	LCDVD12
T9	PD5, Output	LCDVD13	LCDVD13	LCDVD13
P10	PD6, Output	LCDVD14	LCDVD14	LCDVD14
R10	PD7, Output	LCDVD15	LCDVD15 (Intensity)	LCDVD15 (Intensity)
J5	PA0, Output			LCDVD16 (Always LOW)
K1	PA1, Output			LCDVD17 (Always LOW)

NOTE: *Some TFT panels can utilize this signal to control the high-voltage supplies.

10.1.6 LCD Data Multiplexing

When LCD data is written to a LCD panel, the manner in which the LCD data is multiplexed onto the external data bus varies for STN, TFT, AD-TFT, or HR-TFT panels. Table 10-8 shows the data multiplexing for each supported panel.

For example, Table 10-8 shows that a dual-panel, color STN display receives a total of 16 bits of data for each pixel, represented here as CLSTN[7:0] and CUSTN[7:0]. The Table also shows that the display will receive the data for the lower panel on LCDVD[15:8] and the data for the upper panel on LCDVD[7:0].

Table 10-8. LCD Data Multiplexing

PBGA PIN	CABGA PIN	LCD DATA SIGNAL	STN						TFT	AD-TFT HR-TFT
			MONO 4-BIT		MONO 8-BIT		COLOR			
			SINGLE PANEL	DUAL PANEL	SINGLE PANEL	DUAL PANEL	SINGLE PANEL	DUAL PANEL		
K1	K2	LCDVD17								LOW
J5	K1	LCDVD16								LOW
R10	T13	LCDVD15				MLSTN7		CLSTN7	Intensity	Intensity
P10	R12	LCDVD14				MLSTN6		CLSTN6	BLUE4	BLUE4
T9	R11	LCDVD13				MLSTN5		CLSTN5	BLUE3	BLUE3
R9	T12	LCDVD12				MLSTN4		CLSTN4	BLUE2	BLUE2
N11	T11	LCDVD11				MLSTN3		CLSTN3	BLUE1	BLUE1
K8	P10	LCDVD10				MLSTN2		CLSTN2	BLUE0	BLUE0
L11	K10	LCDVD9				MLSTN1		CLSTN1	GREEN4	GREEN4
M11	M9	LCDVD8				MLSTN0		CLSTN0	GREEN3	GREEN3
M10	R10	LCDVD7		MLSTN3	MUSTN7	MUSTN7	CUSTN7	CUSTN7	GREEN2	GREEN2
M9	T10	LCDVD6		MLSTN2	MUSTN6	MUSTN6	CUSTN6	CUSTN6	GREEN1	GREEN1
N10	K9	LCDVD5		MLSTN1	MUSTN5	MUSTN5	CUSTN5	CUSTN5	GREEN0	GREEN0
L10	T9	LCDVD4		MLSTN0	MUSTN4	MUSTN4	CUSTN4	CUSTN4	RED4	RED4
N8	T8	LCDVD3	MUSTN3	MUSTN3	MUSTN3	MUSTN3	CUSTN3	CUSTN3	RED3	RED3
T7	R8	LCDVD2	MUSTN2	MUSTN2	MUSTN2	MUSTN2	CUSTN2	CUSTN2	RED2	RED2
R7	P8	LCDVD1	MUSTN1	MUSTN1	MUSTN1	MUSTN1	CUSTN1	CUSTN1	RED1	RED1
P7	M8	LCDVD0	MUSTN0	MUSTN0	MUSTN0	MUSTN0	CUSTN0	CUSTN0	RED0	RED0

NOTES:
1. The Intensity bit is identically generated for all three colors.
2. MUSTN = Monochrome Upper data bit for STN panel.
3. MLSTN = Monochrome Lower data bit for STN panel.
4. CUSTN = Color Upper data bit for STN panel.
5. CLSTN = Color Lower data bit for STN panel.
6. Connect to the LSB of the Red, Green, and Blue inputs of a 6:6:6 panel.
7. Recommended hookups for TFT 5:5:5 + Intensity and 5:6:5 are shown. This wiring requires the BGR bit in the CONTROL Register to be 0.

10.1.7 CLCDC Clock Generation

The CLCDC and the ALI are driven by a common clock which can be generated from either HCLK or the 14.7456 MHz clock source. Figure 10-5 summarizes the LH7A400 CLCDC clock generation.

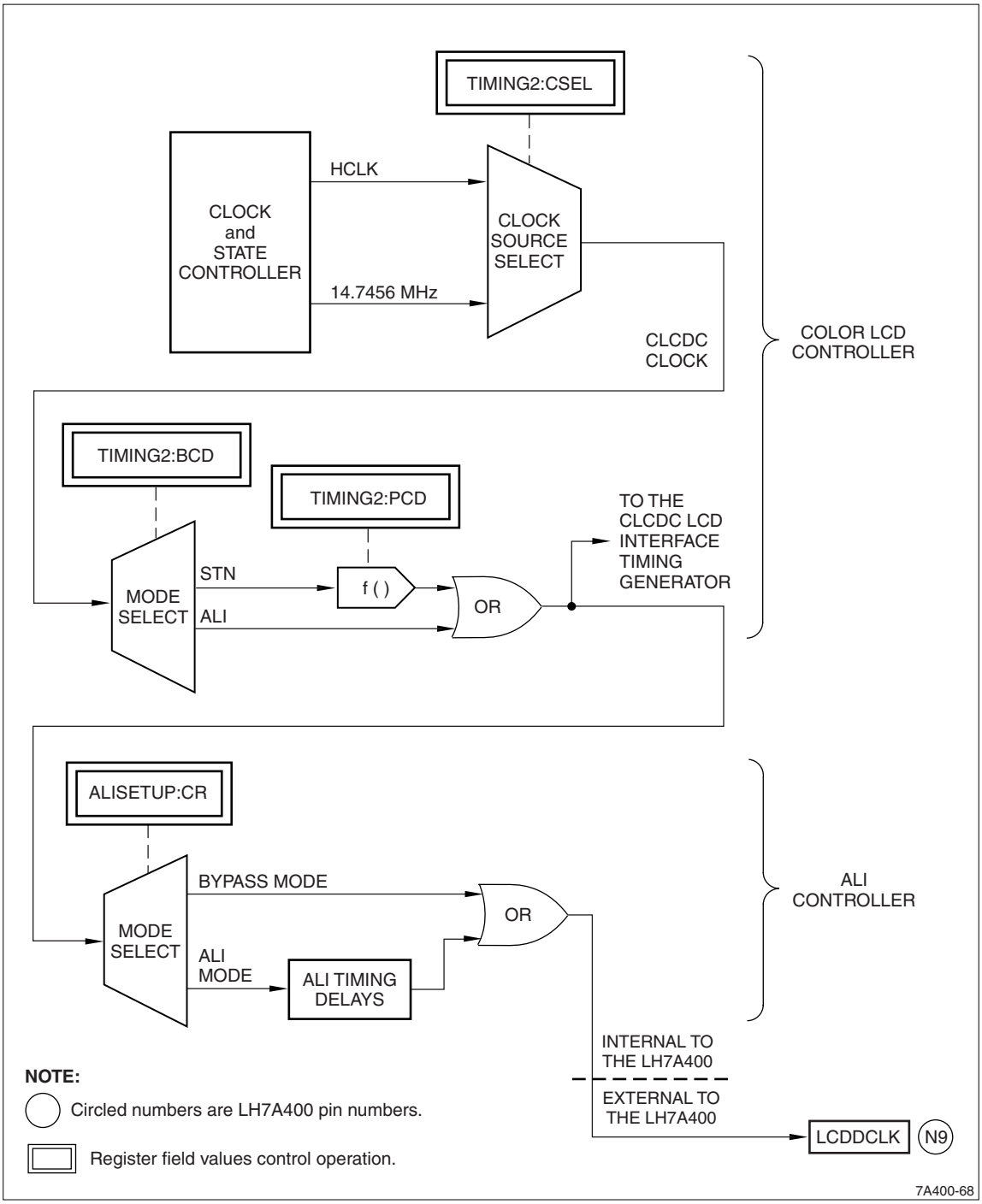


Figure 10-5. LCDDCLK Clock Generation

Together, the LH7A400 CLCDC and ALI generate all clock and timing signals required to drive STN, TFT, AD-TFT, and HR-TFT panels. The CLCDC generates the signals for STN and TFT displays. When enabled, the ALI intercepts the signals from the CLCDC and modifies their timing to drive AD-TFT/HR-TFT panels.

The CLCDC Panel Clock Generator and the CLCDC Timing Controller both receive the CLCDC CLOCK signal from the LH7A400 Clock Generation system.The Timing Controller uses the clock signal to generate frame pulse, line pulse, and AC bias signals for the LCD panel. The Panel Clock Generator creates the LCDDCLK output signal, which has a programmable period. The programmable period can vary the clock's frequency from (CLCDC CLOCK)/2 to (CLCDC CLOCK)/33, with a 50% Duty Cycle. In the Bypass mode, the CLCDC CLOCK is directly used as the LCDDCLK signal.

10.1.8 LCD Interface Timing Signals

LCD interface timing signals are categorized as either horizontal or vertical timing signals. These signals are created by the CLCDC, optionally modified by the ALI, and applied directly to an external LCD panel with no additional external hardware required, except for CGS panels.

10.1.8.1 LCD Horizontal Timing Signals

The horizontal components of LCD timing describe the process of writing one line of LCD data to a LCD panel and include programmable delays before and after the data is written to the panel. A line of data is composed of all pixel information for one displayed line. See Section 10.5 for timing diagrams.

10.1.8.1.1 STN Horizontal Timing Restrictions

The CLCDC's dedicated DMA system requests new data at the start of each horizontal display line. Time must be allowed for the DMA transfer operation to occur. Time must also be allowed for the data to propagate down the FIFO path within the LCD interface. These delays constitute LCD data path latency. The data path latency imposes some restrictions on the usable minimum values for horizontal back porch width when operating in the STN modes. The value restrictions are listed in Table 10-9.

Table 10-9. Usable Minimum Values Affecting STN Back Porch Width

HORIZONTAL TIMING VALUE	SINGLE-PANEL MODE	DUAL-PANEL MODE
TIMING0:HSW	3	3
TIMING0:HBP	5	5
TIMING0:HFP	5	5
TIMING2:PCD	1 × (CLCD CLOCK/3)	5 × (CLCD CLOCK/7)

NOTE: The minimum value for PCD is 4.

10.1.8.2 LCD Vertical Timing Signals

Data is written to an LCD panel in frames. Each frame is composed of a number of horizontal lines. The vertical components of LCD timing describe the process of writing one full frame to an LCD panel.

Each frame begins with a frame pulse or vertical synchronization pulse of programmable duration. Each frame pulse is followed by a programmable delay, the vertical back porch. When the vertical back porch expires, all line information for the frame is presented to the LCD panel. See Section 10.1.8.1. The line information is followed by another programmable delay, the vertical front porch.

10.1.9 LCD Power Sequencing at Turn-On and Turn-Off

Many LCD panels require ground, power for the digital logic, and high-voltage power supplies. To extend the life of these panels, the digital power must be applied before the high voltage is applied, and removed after they are removed. The logic signals driving the panel must be active before the panel voltages are applied, and the panel voltages must be removed before the logic signals are removed. This sequencing ensures that the panel is always operated with a net DC bias of 0 VDC.

Software must ensure that these conditions are met. The requisite delay is usually specified in the LCD panel's data sheet. If the proper power sequencing is not followed, the LSI drivers in the panel can latch and the display will freeze. Typically when this happens, the colors will be incorrect on STN panels. In addition the power down sequence must be followed or LCD life can be degraded.

Figure 10-6 is an example of these timing requirements for the SHARP LM057QCTT03 Color STN LCD Panel, and the accompanying timing specifications. Always refer to your specific LCD panel's Data Sheet to determine the specific turn-on and turn-off requirements for the panel being used in your application.

10.1.9.1 Minimizing a Retained Image on the LCD

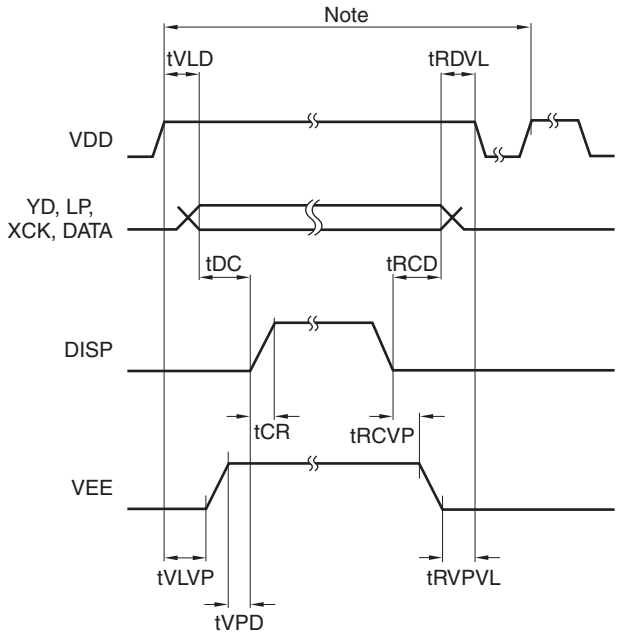
While it is very important to follow the power turn-off sequence to ensure longevity of the LCD panel, this sequence alone will not ensure there is no retained image (ghosting) left on the LCD panel after the LCD has been powered down.

This ghost bleeds away slowly after powering down the LCD panel. It is most noticeable with LCD panels utilizing HR-TFT and AD-TFT technologies for image display. With these types of LCD panels the ambient light alone is enough to make the retained image visible. TFT-type LCD panels also have a retained image, but it is typically not as visible once the backlight source is turned off.

To minimize the appearance of a retained image on HR-TFT and AD-TFT LCD panels, software should write a complete frame of all 1's (white) to the LCD just prior to initiating the turn-off sequence.

To minimize the appearance of a retained image on a TFT LCD panel, software should write a complete frame of all 0's (black) just prior to initiating the turn-off sequence.

In all cases the illumination source should be turned off prior to initiating the turn-off sequence.



POWER ON

SYMBOL	ALLOWABLE VALUE	
tVLD	0 ms MIN.	1 s MAX.
tDC	20 ms MIN.	
tCR		100 ns MAX.
tVPD	0 ms MIN.	
tVLVP	0 ms MIN.	

POWER OFF

SYMBOL	ALLOWABLE VALUE	
tRDVL	0 ms MIN.	1 s MAX.
tRCD	20 ms MIN.	
tRCVP	20 ms MIN.	
tRVPVL	0 ms MIN.	

NOTE: 500 ms MIN. ON/OFF cycle time. All signals and power must be switched in this sequence during power ON/OFF cycles.

LH7A400-173

Figure 10-6. LCD Panel Power Sequencing

10.1.10 CLCDC Interrupts

The CLCDC can generate an interrupt for each of four different conditions:

- Master Bus Error Interrupt
- Vertical Compare Interrupt
- LCD Next Base Address Update Interrupt
- LCD FIFO Underflow Interrupt.

Software must acknowledge the interrupt by writing a 1 to the corresponding status register bit, after which the CLCDC resumes operation from the beginning of the current frame.

Each of the four individually-maskable interrupts is enabled or disabled by the mask bits in the INTREN register. The status of the individual interrupt sources can be read from the STATUS register.

The hardware executes a logical OR of the four interrupts and asserts one combined CLCDINTR interrupt to the Interrupt Controller.

10.1.10.1 Master Bus Error Interrupt — MBEI

The Master Bus Error Interrupt is asserted when an ERROR response is received by the AHB DMA master interface during a transaction with an AHB DMA slave. For example, this error occurs when the UPBASE Register is programmed to an address that is not in the LH7A400's memory map. When such an error is encountered, the master interface enters an error state and remains in this state until clearance of the error has been signalled to it. On completion of the interrupt service routine, clear the Master Bus Error Interrupt by writing a 1 to STATUS:MBEI. This action releases the master interface from its ERROR state, allowing a fresh frame of data display to be initiated.

10.1.10.2 Vertical Compare Interrupt — CVCI

The Vertical Compare Interrupt is asserted when one of four vertical display regions, selected via the CONTROL register, is accessed. This interrupt can be programmed to occur at the start of:

- Vertical Synchronization
- Vertical Back Porch
- Active Video
- Vertical Front Porch.

Clear the Vertical Compare Interrupt by writing a 1 to STATUS:VCI register.

10.1.10.3 LCD Next Base Address Update Interrupt — BUI

The LCD Next Base Address Update Interrupt is asserted when either the UPBASE or the LPBASE values have been transferred to the UPCUR or LPCUR incrementers respectively. This interrupt signals that it is valid to update the UPBASE or the LPBASE registers with new frame base address, if required.

Clear this interrupt by writing a 1 to STATUS:BUI register.

10.1.10.4 LCD FIFO Underflow Interrupt — FUI

The FIFO Underflow Interrupt is asserted when data is requested by the core from an empty CLCDC input FIFO. Clear the FIFO underflow interrupt by writing a 1 to the STATUS:FUI register.

10.2 Advanced LCD Interface

The Advanced LCD Interface (ALI) provides the additional processing required to interface the LH7A400 to AD-TFT, HR-TFT, or any display technology that uses this method of connection. Figure 10-7 shows the ALI between the CLCDC and the LCD output pins.

The ALI is programmed via its16-bit APB interface and receives control signals and display data from the CLCDC. The ALI converts the display data to a format suitable for direct connection to the Row and Column driver ICs in AD-TFT, HR-TFT displays, or any display using similar technology.

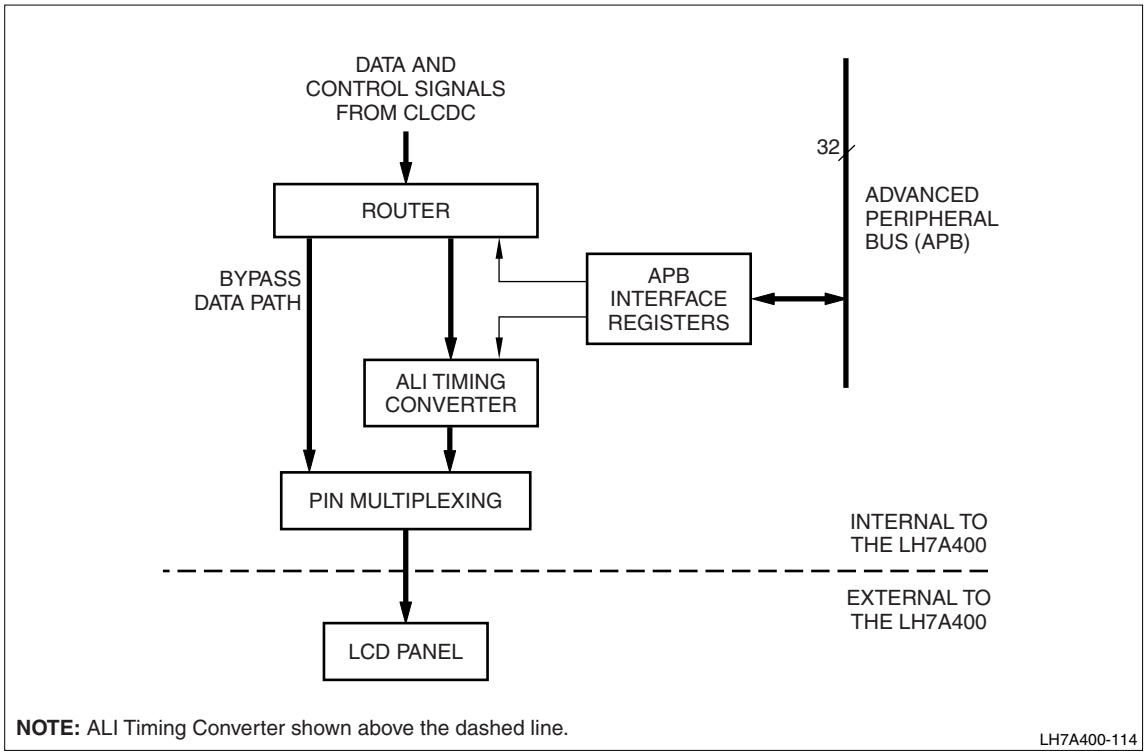


Figure 10-7. ALI Simplified Block Diagram

10.2.1 Theory of Operation

The ALI operates in two modes:

- Bypass Mode
- Active Mode

The ALI operating mode must be selected by software.

10.2.1.1 Bypass Mode

The ALI defaults to Bypass mode following reset. In this mode, signals and data received from the CLCDC simply pass unaltered through the ALI to the LCD output pins. Select the Bypass mode when the CLCDC is driving STN or TFT LCD panels that contain a timing ASIC.

10.2.1.2 Active Mode

In Active mode, the ALI reformats TFT data and control signals from the CLCDC to drive the Row and Column driver circuitry on the LCD panel. When ALISETUP:CR is programmed to select the Active mode, the ALI re-times TFT data from the CLCDC so that it is output on the falling edge of the output clock (LCDDCLK). In the Active mode the ALI also generates source driver, gate driver, and voltage-preparation control signals appropriate for AD-TFT and HR-TFT LCDs.

The correct programming sequence for the CLCDC and ALI registers in Active mode is:

1. Ensure that the CLCDC is not enabled
2. Program the ALISETUP register
3. Program the ALITIMING1 Register
4. Program the ALITIMING2 register
5. Program the ALICONTROL register
6. Enable the CLCDC.

10.2.1.3 CLCDC Setup for AD-TFT or HR-TFT Operation

To supply the correct waveforms, the ALI must receive the correct signals from the CLCDC. Software must:

- Program the CLCDC to scale the internal clock signal routed to the ALI from the CLCDC to a frequency appropriate for the AD-TFT or HR-TFT panel being connected. The ALI will modify this signal's timing but not its frequency. See Section 10.1.7 and Figure 10-5 for additional information regarding the clock frequency setup.
- Program the CLCDC to operate in TFT mode.
- Program the CLCDC to provide an enable signal (LCDSPL).
- Program the CLCDC to provide a continuous clock signal (LCDDCLK).
- Program TIMING0:HSW (Horizontal Sync Width) for the AD-TFT/HR-TFT display.
- Program TIMING1:VSW (Vertical Sync Width) for the AD-TFT/HR-TFT display.
- Program TIMING2:IVS to select the appropriate polarity for the LCDSPS (Row reset) signal.
- Program TIMING2:IHS to select the appropriate polarity for the LCDLP (Horizontal Sync) signal.
- Program TIMING2:IPC to drive data on the falling edge of the LCDDCLK signal.
- Program TIMING2:IOE to 0 to select the appropriate polarity for the LCDSPL signal.

10.3 CLCDC Register Reference

The Register Base Address for the Color LCD Controller is:

CLCDC Base: 0x8000.3000

10.3.1 CLCDC Memory Map

The register offsets shown in Table 10-10 are relative to the CLCDC base address.

Table 10-10. CLCDC Register Summary

ADDRESS	NAME	DESCRIPTION
0x000	TIMING0	Horizontal axis panel control
0x004	TIMING1	Vertical axis panel control
0x008	TIMING2	Clock and signal polarity control
0x00C	///	Reserved. Do not access this location.
0x010	UPBASE	Upper panel frame base address
0x014	LPBASE	Lower panel frame base address
0x018	INTREN	Interrupt enable mask
0x01C	CONTROL	LCD panel pixel parameters
0x020	STATUS	Raw interrupt status
0x024	INTERRUPT	Final masked interrupts
0x028	UPCURR	LCD upper panel current address value
0x02C	LPCURR	LCD lower panel current address value
0x030	OVERFLOW	SDRAM overflow frame buffer address
0x034 - 0x1FC	///	Reserved. Do not access these locations.
0x200 - 0x3FC	PALETTE	256 × 16-bit color palette (128 entries × 2 entries per word)
0x400 - 0x7FF	///	Reserved. Do not access these locations.

10.3.2 CLCDC Register Descriptions

10.3.2.1 LCD Timing 0 Register (TIMING0)

The TIMING0 register sets the LCD panel's horizontal timing. The fields in the TIMING0 register control the Horizontal Synchronization pulse Width (HSW), the Horizontal Front Porch (HFP) period, the Horizontal Back Porch (HBP) period and the Pixels-Per-Line (PPL). Table 10-12 lists the bit assignments for the TIMING0 register.

Table 10-11. TIMING0 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	HBP								HFP							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	HSW								PPL						///	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RO	RO
ADDR	0x8000.3000															

Table 10-12. TIMING0 Fields

BITS	FIELD	DESCRIPTION
31:24	HBP	**Horizontal Back Porch** HBP specifies the number of LCDDCLK periods between the end of the LCDLP signal and the beginning of valid data. HBP can be programmed for a delay of 1 to 256 pixel clock cycles. HBP = (LCDDCLK periods) – 1
23:16	HFP	**Horizontal Front Porch** HFP specifies the number of LCDDCLK periods between the end of valid data and the beginning of the LCDLP signal. HFP can be programmed for a delay of 1 to 256 pixel clock cycles. HFP = (LCDDCLK periods) – 1
15:8	HSW	**Horizontal Synchronization Pulse Width** HSW specifies the width of the LCDLP signal, in LCDDCLK periods. In STN modes, this signal is referred to as the 'line clock'. In TFT modes, this signal is referred to as the 'horizontal synchronization pulse'. HSW = (LCDDCLK periods) – 1
7:2	PPL	**Pixels-Per-Line** PPL specifies the number of pixels in each line of the LCD panel. The PPL value sets the number of pixel clocks that occur before the value in the HFP bit field is applied (that is, before the LCDLP signal is asserted). The PPL bit field is a 6-bit value that represents a number corresponding to the actual pixels-per-line, which can range from 16 to 1,024. At reset this field is 0, which corresponds to 16 actual pixels-per-line. PPL = (Actual pixels-per-line/16) – 1 Actual pixels-per-line = 16 × (PPL + 1)
1:0	///	**Reserved** Reading returns 0. Write the reset value.

NOTE: *The CLCDC DMA system requests new data at the beginning of each horizontal display line. The delays implicit in this operation must be considered when establishing the horizontal display timing. See Section 10.1.8.1.1 for additional information.

10.3.3 LCD Timing 1 Register (TIMING1)

The TIMING1 register controls the LCD panel's vertical timing.

TIMING1 controls the number of Lines-Per-Panel (LPP), the Vertical Synchronization pulse Width (VSW), the Vertical Front Porch (VFP) period and the Vertical Back Porch (VBP) period. Table 10-14 lists the bit definitions for the TIMING1 register.

Table 10-13. TIMING1 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	VBP								VFP							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	VSW						LPP									
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.3004															

Table 10-14. TIMING1 Fields

BITS	FIELD	DESCRIPTION
31:24	VBP	**Vertical Back Porch** VBP defines the number of inactive lines at the start of a frame, after the vertical synchronization period (after the framing pulse, LCDFP, is de-asserted). The VBP bit field specifies the number of horizontal line-clocks (LCDLP) inserted at the beginning of each frame. The value in the VBP bit field can generate from 0 to 255 additional line-clock cycles. TFT modes: The VBP delay begins after the vertical synchronization signal for the previous frame (LCDFP) has been deasserted. STN modes: This field can be programmed in STN modes, but the value has no effect on the vertical back porch. The vertical back porch is zero regardless of what is written to this field. Program VBP = 0 on STN displays.
23:16	VFP	**Vertical Front Porch** VFP defines the number of inactive lines at the end of a frame, before the vertical synchronization period (before the framing pulse, LCDFP, is asserted). VFP specifies the number of horizontal line-clocks (LCDLP) inserted at the end of each frame. The value in the VFP bit field can generate from 0 to 255 line-clock cycles. TFT modes: The vertical synchronization signal (LCDFP) is asserted after the VFP delay has expired. STN modes: This field can be programmed in STN modes, but the size of the vertical front porch can affect the display contrast. Typically, the larger the VFP, the worse the display contrast will be. To reduce display contrast issues, keep this value low, or program VFP = 0 on STN displays.
15:10	VSW	**Vertical Synchronization (Pulse) Width** VSW is the width of the LCDFP signal. VSW is specified in terms of the number of horizontal synchronization lines (LCDLP pulses). VSW = (LCDLP Periods) – 1 STN modes: This field can be programmed in STN modes, but the value has no effect upon the vertical sync width. The vertical sync width will always be one line regardless of what is written to this field. Programming any other value than zero causes VFP to be enlarged by whatever is programmed in this field. Therefore program VSW = 0 for STN LCDs.

Table 10-14. TIMING1 Fields (Cont'd)

BITS	FIELD	DESCRIPTION
9:0	LPP	**Lines Per Panel** LPP specifies the number of active lines (rows of pixels) per panel. The LPP bit field is a 10-bit value allowing between 1 and 1,024 lines. LPP = (Active Lines) – 1 Dual-Panel displays: The two panels in dual-panel displays are assumed to be of identical sizes. For dual-panel displays, the LPP bit field should be programmed to describe either the upper or the lower panel, and not be doubled. ALI Active modes: LPP and LCDREV must be considered together. Program LPP to an odd number of lines for AD-TFT and HR-TFT panels. AD-TFT and HR-TFT displays utilize the LCDREV signal as an AC bias signal. The LCDREV signal oscillates, driven HIGH during one frame and driven LOW during the next frame. To avoid long-term LCD damage, the AC bias applied to any line of an LCD panel should average to a net 0 VDC. When correctly programmed, the LCDREV signal will be HIGH for a line during one frame and LOW for the same line during the next frame. If the LPP bit field specifies an even number of Lines Per Panel, this oscillation will be mismatched to the display's lines and the lines will not receive a net 0 VDC bias. See ALITIMING1:REVDEL for additional information.

10.3.4 LCD Timing 2 Register (TIMING2)

The TIMING2 register controls the generation of the CLCDC clocks for the LCD panel. Table 10-16 details this register's bit assignments.

Table 10-15. TIMING2 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///					BCD	CPL									
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///	IOE	IPC	IHS	IVS	ACB					CSEL	PCD				
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RO	RW	RW	RW	RW	RW
ADDR	0x8000.3008															

Table 10-16. TIMING2 Fields

BITS	FIELD	DESCRIPTION
31:27	///	**Reserved** Reading returns 0. Write the reset value.
26	BCD	**Bypass Pixel Clock Divider** 1 = Bypass the pixel clock divider logic 0 = Use the pixel clock divider logic See the description of the PCD bit field, below.
25:16	CPL	**Clocks Per Line** CPL specifies the number of LCDDCLK pulses fed to the LCD panel during each horizontal line. The TIMING2:CPL and TIMING0:PPL fields work together; both must be programmed correctly in order for the CLCDC to function correctly. Actual Pixels Per Line (APPL) = 16 x (TIMING0:PPL – 1) TFT panels: CPL = (APPL – 1) 4-bit mono STN panels: CPL = ((APPL/4) – 1) 8-bit mono STN panels: CPL = ((APPL/8) – 1) Color STN panels: CPL = (((3 x APPL) / 8) – 1)
15	///	**Reserved** Reading returns 0. Write the reset value.
14	IOE	**Invert Output Enable** IOE applies only to TFT modes and should be programmed to 0 for all other modes. In the TFT mode, the LCDENAB pin indicates to the LCD panel that valid display data is available. IOE selects the active polarity of this output enable signal. In the TFT mode, data is driven onto the LCD data lines at the programmed edge of LCDDCLK when LCDENAB is asserted. 1 = The LCDENAB output pin is active LOW 0 = The LCDENAB output pin is active HIGH
13	IPC	**Invert Panel Clock** IPC selects the active edge of the LCDDCLK signal. 1 = Data is driven on the LCD data lines on the falling-edge of LCDDCLK 0 = Data is driven on the LCD data lines on the rising-edge of LCDDCLK
12	IHS	**Invert Horizontal Synchronization** IHS selects the polarity of the LCDLP signal. 1 = The LCDLP pin is active LOW 0 = The LCDLP pin is active HIGH

Table 10-16. TIMING2 Fields (Cont'd)

BITS	FIELD	DESCRIPTION
11	IVS	**Invert the Vertical Synchronization Signal** IVS selects the polarity of the LCDFP signal. 1 = LCDFP is active LOW 0 = LCDFP is active HIGH
10:6	ACB	**AC Bias Signal Frequency** ACB sets the frequency of the LCDENAB signal. STN modes: ACB applies to the CLCDC when it is operating in the STN mode. STN displays require periodic reversal of the pixel voltages in order to prevent damage to the STN panel due to DC charge accumulation. Program this field to select the required number of line clocks (the LCDLP signal) between each toggle of the AC bias signal (LCDENAB). ACB = (line clocks) – 1 TFT modes: This field has no effect if the CLCDC is operating in TFT mode because the LCDENAB pin is instead utilized for a Data Enable signal.
5	CSEL	**Clock Select** Use this bit to select the source for the LCD Clock. 1 = Use 14.7456 MHz for LCD Clock 0 = Use HCLK as the LCD Clock
4:0	PCD	**Panel Clock Divisor** Program this field to select the LCD panel clock frequency (LCDDCLK frequency) from the input CLCDC CLOCK frequency. LCDDCLK = (CLCDC CLOCK)/(PCD+2) Mono STN modes: LCDDCLK for mono STN panels with a four- (or eight-) bit interface should be programmed to be 1/4 (or 1/8) the desired individual pixel clock rate. Color STN modes: Color STN displays receive multiple pixels during each clock cycle. The pixel data for Color STN displays is stored and transferred in packed format, with each pixel represented by three bits (R,G and B). Therefore, one byte contains the pixel data for 2 2/3 pixels (RGB,RGB,RG) and three bytes contain the pixel data for eight complete pixels. For Color STN panels, each LCDDCLK cycle transfers one byte, containing 2 2/3 pixels, to the panel. LCDDCLK should be programmed to be as close as possible to 3/8 the desired individual pixel clock rate. See Table 10-17 for additional STN mode restrictions. TFT mode: For TFT displays, the pixel clock divider can be bypassed by programming TIMING2:BCD = 1.

NOTE: As shown in Figure 10-5, the CLCDC CLOCK signal is fed from the LH7A400 clock-generation circuitry to the CLCDC. The CLCDC CLOCK is an input to the CLCDC. Data path latency restricts the usable minimum values of the Panel Clock Divider (PCD) bit field when operating in STN modes, shown in Table 10-17.

Table 10-17. TIMING2:PCD Restrictions in STN Modes

PANEL	TYPE	INTERFACE	PCD MINIMUM VALUE
Single	Color	(All)	PCD = 1 (LCDDCLK = CLCDC CLOCK/3)
Dual	Color	(All)	PCD = 4 (LCDDCLK = CLCD CLOCK/6)
Single	Mono	4-bit	PCD = 2 (LCDDCLK = CLCDC CLOCK/4)
Dual	Mono	4-bit	PCD = 6 LCDDCLK = CLCDC CLOCK/8)
Single	Mono	8-bit	PCD = 6 (LCDDCLK = CLCDC CLOCK/8)
Dual	Mono	8-bit	PCD = 14 (LCDDCLK = CLCDC CLOCK/16)

10.3.5 LCD Upper Panel Base Address Register (UPBASE)

The UPBASE register must be programmed with the base address of the upper panel's frame buffer. The UPBASE register is used for TFT displays, single-panel STN displays, and the upper panel of dual-panel STN displays. The value in the UPBASE register is used for Color LCD DMA operations (frame buffer-to-panel). Also see the LCD Lower Panel Base address register. Both registers contain frame buffer base addresses.

Software must initialize UPBASE (and LPBASE, for dual panels) prior to enabling the CLCDC. The value in UPBASE can be changed in mid-frame to allow double-buffered video displays to be created.

The value in the UPBASE register is copied to the UPCUR register upon each LCD vertical synchronization. This event sets STATUS:BUI and can optionally generate an interrupt. The interrupt can be used to trigger reprogramming the base address when generating double-buffered video.

Table 11-17 defines the bit fields in the UPBASE register.

Table 10-18. UPBASE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	A31	A30	A29	A28	A27	A26	A25	A24	A23	A22	A21	A20	A19	A18	A17	A16
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.3010															

Table 10-19. UPBASE Fields

BITS	FIELD	DESCRIPTION
31:2	A31:A2	**LCD Upper Panel Base Address** This is the start address of the upper panel frame data stored in memory and is word-aligned.
1:0	A1:A0	**A1 and A0** These two bits read as 0 and must always be written as 0.

10.3.6 LCD Lower Panel Base Address Register (LPBASE)

The LPBASE register is used for the lower panel of dual-panel STN displays and must be programmed with the base address of the lower panel's frame buffer. LPBASE is used for Color LCD DMA operations (frame buffer-to-panel). Also see the LCD Upper Panel Base address register. Both of these registers contain frame buffer base addresses.

When driving dual panels, software must initialize LPBASE prior to enabling the CLCDC. The value in LPBASE can be changed in mid-frame to allow double-buffered video displays to be created.

The value in the LPBASE register is copied to the LPCUR register upon each LCD vertical synchronization. This event sets STATUS:BUI and can optionally generate an interrupt. The interrupt can trigger reprogramming the base address when generating double-buffered video.

Table 11-19 explains the bit fields in the LPBASE register.

Table 10-20. LPBASE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	A31	A30	A29	A28	A27	A26	A25	A24	A23	A22	A21	A20	A19	A18	A17	A16
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.3014															

Table 10-21. LPBASE Register Bit Fields

BITS	FIELD	DESCRIPTION
31:2	A31:A2	**LCD Lower Panel Base Address** This is the start address of the lower panel frame data in memory and is word-aligned.
1:0	A1:A0	**A1 and A0** These two bits read as 0 and must always be written as 0.

10.3.7 LCD Interrupt Enable Register (INTREN)

The INTREN register enables and disables raw CLCDC interrupts.

The bits in the INTREN register are logically ANDed with the corresponding raw interrupt STATUS bit values to be passed to the INTERRUPT register. Thus, the masked interrupt states are reflected in the INTERRUPT register.

Table 10-23 shows the bit assignments for the INTREN register.

Table 10-22. INTREN Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											MBEIEN	VCIEN	BUIEN	FUIEN	///
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RO
ADDR	0x8000.3018															

Table 10-23. INTREN Fields

BITS	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading returns 0. Write the reset value.
4	MBEIEN	**Bus Master ERROR Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
3	VCIEN	**Vertical Compare Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
2	BUIEN	**Next Base Update Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
1	FUIEN	**FIFO Underflow Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
0	///	**Reserved** Reading returns 0. Write the reset value.

10.3.8 LCD Control Register (CONTROL)

The CONTROL register selects the CLCDC's mode of operation. Table 10-25 shows the bit assignments for the CONTROL register. All registers should be set up prior to programming LCDEN to 1.

Note that the operating mode (color/mono, bits-per-pixel, etc.) can only be changed between frames to avoid corruption of the current frame data. To ensure this is done properly, use the Vertical Compare Interrupt to detect that the current frame is complete. To do this, follow these steps when changing operating mode:

1. Program the CONTROL: VCI bit to 0b00 to generate the Vertical Compare Interrupt on entry to the Sync State. Enable this interrupt by programming the INTREN:VCIEN bit to 1.
2. Program the CONTROL:LCDEN bit to 0. The controller will complete the current frame before sampling this bit.
3. Wait for the Vertical Compare Interrupt. Upon assertion of the interrupt, program the new mode (e.g. from color to monochrome using the CONTROL:BW bit).
4. Then program the CONTROL:LCDEN bit to 1 and clear the Vertical Compare Interrupt by writing a 1 to the STATUS:VCI bit. The CLCDC will resume operating, using the newly programmed parameters.

Table 10-24. CONTROL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															WATERMARK
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///		VCI		PWR	BEPO	BEBO	BGR	DUAL	MONO8L	TFT	BW	BPP			LCDEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.301C															

Table 10-25. CONTROL Fields

BITS	FIELD	DESCRIPTION
31:17	///	**Reserved** Reading returns 0. Write the reset value.
16	WATERMARK	**LCD DMA FIFO Watermark Level** 1 = Requests data when either of the two DMA FIFOs have eight or more empty locations. 0 = Requests data when either of the two DMA FIFOs have four or more empty locations.
15:14	///	**Reserved** Reading returns 0. Write the reset value.
13:12	VCI	**LCD Vertical Compare** Program to generate an interrupt at: 00 = Start of vertical synchronization 01 = Start of back porch 10 = Start of active video 11 = Start of front porch
11	PWR	**LCD Power Enable** This bit controls power to the LCD panel. For this bit to be functional, both the CONTROL:LCDEN and ALISETUP:ALIEN bits must be programmed to 1. If either of those bits is programmed to 0, LCD power is off regardless of the setting of the PWR bit. 1 = LCD power on 0 = LCD power off
10	BEPO	**Big-Endian Pixel Ordering** The BEPO bit selects between little and big-endian pixel packing for 1, 2 and 4 bpp display modes. The BEPO bit has no effect on 8 or 16 bpp pixel formats. 1 = Big-endian pixel ordering within a byte 0 = Little-endian ordering within a byte
9	BEBO	**Big-Endian Byte Ordering to the LCD** 1 = Big-endian byte order 0 = Little-endian byte order
8	BGR	**RGB or BGR Format Selection** 1 = Bits 14:10 and 4:0 swapped (blue and red swapped) 0 = Display data normal output
7	DUAL	**Dual Panel STN LCD** 1 = Dual panel LCD is in use 0 = Single panel LCD is in use
6	MONO8L	**Monochrome LCD** LCD is Monochrome with an 8-bit interface. This bit controls whether a monochrome STN LCD uses a 4 or an 8-bit parallel interface. It should be programmed to 0 for all other types of displays. 1 = Mono LCD uses 8-bit interface 0 = Mono LCD uses 4-bit interface
5	TFT	**TFT LCD** 1 = LCD is TFT — do not use grayscaler 0 = LCD is an STN display — use grayscaler

Table 10-25. CONTROL Fields (Cont'd)

BITS	FIELD	DESCRIPTION
4	BW	**Monochrome STN LCD** LCD is Monochrome (Black and White) STN. This bit has no effect in TFT mode. 1 = STN LCD is monochrome 0 = STN LCD is color
3:1	BPP	**LCD Bits-Per-Pixel** 000 = 1 BPP 001 = 2 BPP 010 = 4 BPP 011 = 8 BPP 100 = 16 BPP 101 = Invalid 110 = Invalid 111 = Invalid
0	LCDEN	**Color LCD Controller Enable** LCD displays usually require that their logical signals be operating before the high voltages are applied to the display. Thus, the LCDVDDEN output signal is not asserted unless both the LCDEN and PWR bit fields have been programmed to 1. Most LCD displays require that the controller be enabled (LCDEN = 1) approximately 20 ms before power is applied to the LCD (PWR = 1). Most LCD displays also specify that the power-down sequence be the reverse of the power-up sequence. 1 = Color LCD Controller enabled 0 = Color LCD Controller disabled

10.3.9 Interrupt Status Register (STATUS)

The STATUS register provides the status of the raw LCD interrupts. The STATUS register contains 4 interrupt flags. A bit value of 1 indicates that the corresponding interrupt is asserted, even if not enabled in the INTREN register. STATUS and INTREN are logically ANDed to derive the masked interrupt values in the INTERRUPT register.

Interrupts are cleared by writing a 1 to the corresponding bit. Writing a 0 has no effect.

Table 10-27 shows the bit assignments for the STATUS register.

Table 10-26. STATUS Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											MBEI	VCI	BUI	FUI	///
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW
ADDR	0x8000.3020															

Table 10-27. STATUS Fields

BITS	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading returns 0. Write the reset value.
4	MBEI	**AMBA AHB Master Bus Error Status** Indicates that the CLCDC AHB master has encountered a bus error response from a slave. 1 = Interrupt asserted 0 = Interrupt cleared
3	VCI	**Vertical Compare** Set to 1 when one of the four vertical regions selected in the CONTROL register is reached. 1 = Interrupt asserted 0 = Interrupt cleared
2	BUI	**LCD Next Base Address Update** Mode dependent; set to 1 when the Current Base Address registers have been successfully updated with the data from Next Address registers. Signifies that a new Next Address can be loaded if double buffering is in use. 1 = Interrupt asserted 0 = Interrupt cleared
1	FUI	**FIFO Underflow** Set to 1 when either the upper or lower DMA FIFOs have been accessed when empty, resulting in an underflow condition 1 = Interrupt asserted 0 = Interrupt cleared
0	///	**Reserved** Reading returns 0. Write the reset value.

10.3.10 INTERRUPT Register (INTERRUPT)

The INTERRUPT register provides masked interrupt status indications.

Each of the four bits in the LCD Interrupt register represents a bit-by-bit logical AND of the corresponding bit in the STATUS register with the corresponding bit in the INTREN register. A logical OR of all enabled interrupts is sent to the interrupt controller as a single bit.

Table 10-29 shows the bit field assignments for the INTERRUPT register.

Table 10-28. INTERRUPT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											MBEIM	VCIM	BUIM	FUIM	///
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.3024															

Table 10-29. INTERRUPT Fields

BITS	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading returns 0. Write the reset value.
4	MBEIM	**Masked AHB Master Error Interrupt** 1 = Interrupt asserted and enabled 0 = Interrupt cleared
3	VCIM	**Masked Vertical Compare Interrupt** 1 = Interrupt asserted and enabled 0 = Interrupt cleared
2	BUIM	**Masked LCD Next Base Address Update Interrupt** 1 = Interrupt asserted and enabled 0 = Interrupt cleared
1	FUIM	**Masked FIFO Underflow Interrupt** 1 = Interrupt asserted and enabled 0 = Interrupt cleared
0	///	**Reserved** Reading returns 0. Write the reset value.

10.3.11 LCD Upper Panel Current Address Register (UPCUR)

The UPCUR register contains the present upper-panel LCD DMA address.

This is a read-only register; do not write to this register.

When read, The UPCUR register returns the value of the present upper panel LCD data DMA address. The contents of this register change dynamically, and therefore should be used only as a mechanism to implement a coarse delay.

Table 10-31 shows the bit assignments for the UPCUR register.

Table 10-30. UPCUR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	A31	A30	A29	A28	A27	A26	A25	A24	A23	A22	A21	A20	A19	A18	A17	A16
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.3028															

Table 10-31. UPCUR Register Bit Fields

BITS	FIELD	DESCRIPTION
31:0	A31:A0	A31:A0 of the current lower panel data DMA address. Values change dynamically. Read only.

10.3.12 LCD Lower Panel Current Address Register (LPCUR)

The LPCUR register contains the real-time lower-panel LCD DMA address.

This is a read-only register. Do not write to this register.

When read, The LPCUR register returns the value of the present lower panel LCD data DMA address. The contents of this register change dynamically, and therefore should be used only as a mechanism to implement a coarse delay.

Table 10-33 shows the bit assignments for LPCUR.

Table 10-32. LPCUR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	A31	A30	A29	A28	A27	A26	A25	A24	A23	A22	A21	A20	A19	A18	A17	A16
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.302C															

Table 10-33. LPCUR Fields

BITS	FIELD	DESCRIPTION
31:0	A31:A0	A31:A0 of the current lower panel data DMA address. Values change dynamically. Read-only; do not write.

10.3.13 LCD Overflow Register (OVERFLOW)

The CLCDC has access to an internal frame buffer in embedded SRAM and an extension buffer in SDRAM for dual panel or large displays.

- The LCD frame buffer is normally located within eSRAM.
- A larger frame buffer can be placed in eSRAM and overflow into external SDRAM.
- The frame buffer can be placed exclusively in external SDRAM.

The 80KB eSRAM accommodates the 75KB size of an 8 bpp, 320 x 240 VGA panel. Locating the LCD frame buffer in eSRAM minimizes power consumption and prevents the CLCDC from interfering with SDRAM arbitration by the Synchronous Dynamic Memory Controller (SDMC).

When the LCD frame buffer overflows, any address accessed beyond the embedded SRAM is adjusted by the OVERFLOW register to locate the rest of the Frame Buffer in external SDRAM. The OVERFLOW register points to the start of an overflow frame buffer in SDRAM. The LCD controller automatically uses this register as the base address for data accesses when the requested address is beyond the topmost location of the embedded SRAM (0xB001.3FFF). The overflow region starts at 0xB001.4000. Because the overflow buffer can be located on any 4KB page boundary within SDRAM, software can configure the MMU page tables to make the frame buffer appear as one contiguous memory space. See Figure 10-12 for an example.

Table 10-34. OVERFLOW Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	OVERFLOW															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	OVERFLOW				///											
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.3030															

Table 10-35. OVERFLOW Fields

BITS	NAME	FUNCTION
31:12	OVERFLOW	**Overflow Pointer** Pointer to the start of an overflow frame buffer in SDRAM.
11:0	///	**Reserved** Reading returns 0. Write the reset value.

10.3.14 LCD Palette Registers (PALETTE)

The LH7A400 CLCDC includes 128 PALETTE registers. The LCD Palette registers contain 256 palette entries organized as 128 locations of two entries per register. Each palette entry occupies 16 bits and each register contains two complete palette entries. Values are stored in little-endian format.

Mono STN modes use only the red palette bits [4:1]. Color STN modes use the red palette bits [4:1], the green palette bits [4:1] and the blue palette bits [4:1]. TFT modes with fewer than 16 BPP use all of the palette bits, including the Intensity bit. The 16 BPP TFT mode bypasses the palette and routes data directly to the LCD.

Table 10-37 shows the bit assignments for a PALETTE register, when used with a 5:5:5 + Intensity TFT panel. Table 10-38 shows the arrangement for a 5:6:5 TFT. All PALETTE registers have the same bit fields.

Table 10-36. PALETTE Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	MI	MB4	MB3	MB2	MB1	MB0	MG4	MG3	MG2	MG1	MG0	MR4	MR3	MR2	MR1	MR0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	I	LB4	LB3	LB2	LB1	LB0	LG4	LG3	LG2	LG1	LG0	LR4	LR3	LR2	LR1	LR0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.3200 through 0x8000.33FC															

Table 10-37. PALETTE Register Bit Fields, BGR = 0, 5:5:5 + Intensity TFT

BITS	FIELD	DESCRIPTION
31	MI	**Most Significant Intensity Bit** See the bit 15 description in this table.
30:26	MB4:MB0	**Most Significant Blue Palette Data** See the bit 14:10 description in this table.
25:20	MG4:MG0	**Most Significant Green Palette Data** See the bit 9:5 description in this table.
19:16	MR4:MR0	**Most Significant Red Palette Data** See the bit 4:0 description in this table.
15	LI	**Least Significant Intensity Bit** Unused for STN displays. Can be used as the LSB of the R, G and B inputs to a 6:6:6 TFT display, effectively doubling the number of available colors from 32 K to 64 K, where each color has two different intensities.
14:10	LB4:LB0	**Least Significant Blue Palette Data** For color STN displays, only the four MSBs (bits 4:1) of each color are used.
9:5	LG4:LG0	**Least Significant Green Palette Data** For color STN displays, only the four MSBs (bits 4:1) of each color are used.
4:0	LR4:LR0	**Least Significant Red Palette Data** For color STN displays, only the four MSBs (bits 4:1) of each color are used. For monochrome STN displays, only the four MSBs (bits 4:1) of the red palette data is used.

Table 10-38. PALETTE Register Bit Fields, BGR = 0, 5:6:5 TFT

BITS	FIELD	DESCRIPTION
31:27	MB4:MB0	Most Significant Blue Palette Data
26:20	MG5:MG0	Most Significant Green Palette Data
19:16	MR4:MR0	Most Significant Red Palette Data
15:11	LB4:LB0	Least Significant Blue Palette Data
10:5	LG5:LG0	Least Significant Green Palette Data
4:0	LR4:LR0	Least Significant Red Palette Data

10.4 ALI Register Reference

The Register Base Address for the ALI is:

CLCDC Base: 0x8000.1000.

10.4.1 ALI Memory Map

Programming of the setup and timing registers is done via the APB interface. The ALI must be configured prior to enabling the CLCDC for the first frame. The register memory map is shown in Table 10-39.

Table 10-39. Register Summary

ADDRESS OFFSET	REGISTER NAME	DESCRIPTION
0x000	ALISETUP	ALI Setup Register
0x004	ALICONTROL	ALI Control Register
0x008	ALITIMING1	ALI Timing Register 1
0x00C	ALITIMING2	ALI Timing Register 2

10.4.2 ALI Register Descriptions

This section lists the definitions for each of the programmable registers that control the ALI.

10.4.3 ALI Setup Register (ALISETUP)

The ALISETUP register allows configuration of the ALI pixels-per-line and setting Bypass or Active mode. The CLCDC feeds LCD data and control signals to the ALI, as described in Section 10.2. If the ALI is operating in its Bypass mode, the panel data is transmitted unchanged to the LCD panel. If the ALI is operating in its Active mode, the CLCDC control signals and data are re-timed for the panel's Row and Column driver ASICs prior to transmission.

Change the ALI mode only when the CLCDC is disabled. Software should first disable the CLCDC by writing to CONTROL:LCDEN and CONTROL:PWR. See Section 10.3.8 for more information.

The bit fields for the ALISETUP register are detailed in Table 10-41.

Table 10-40. ALISETUP Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///		ALIEN	PPL									///		CR	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.1000															

Table 10-41. ALISETUP Register Bits

BITS	FIELD	DESCRIPTION
31:12	///	**Reserved** Reading returns 0. Write the reset value.
13	ALIEN	**ALI Enable** This bit enables the ALI interface, configuring the multiplexed pins for ALI, and enabling the ALI internal clock. This bit must be programmed to 1 or the ALI pins will not be active. This bit must also be programmed to 1 for the CONTROL:PWR bit to be functional. 1 = Enable the ALI interface 0 = Disable the ALI interface
12:4	PPL	**Pixels Per Line** PPL = (Actual Pixels per line) – 1.
3:2	///	**Reserved** Reading returns 0. Write the reset value.
1:0	CR	**Conversion Mode Select** This field selects the conversion mode (on/off) for the ALI. Change the ALI mode only when the CLCDC is disabled. 11 = Invalid 10 = Invalid 01 = Active Mode 00 = Bypass Mode (for STN or TFT panels)

10.4.4 ALI Control Register (ALICONTROL)

The ALICONTROL register controls the generation of the LCDCLS and LCDSPS ALI output signals.

This register should be programmed only after the appropriate CLCDC registers and the ALISETUP register have been programmed. These registers should be programmed in specific sequence. See Section 10.2.1.2 for additional information.

Table 10-43 presents the bit definitions for the ALICONTROL register.

Table 10-42. ALICONTROL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														LCDCLSEN	LCDSPSEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW
ADDR	0x8000.1004															

Table 10-43. ALICONTROL Register Bit Fields

BITS	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading returns 0. Write the reset value.
1	LCDCLSEN	**LCDCLS Enable** STN or TFT (Bypass) modes: Reserved Reading returns 0. Values written cannot be read. Active mode: Enables or disables the generation of the LCDCLS (Gate Driver Clock) signal. 1 = LCDCLS signal enabled 0 = LCDCLS signal disabled
0	LCDSPSEN	**LCDSPS Enable** STN or TFT (Bypass) modes: Reserved Reading returns 0. Values written cannot be read. Active mode: Enables or disables the generation of the LCDSPS (Row Reset) signal. 1 = LCDSPS signal is enabled 0 = LCDSPS signal is disabled

10.4.5 ALI Timing 1 Register (ALITIMING1)

The ALITIMING1 register specifies the required delays for Row and Column driver chip control signals LCDLP, LCDREV, LCDPS and LCDCLS. Table 10-45 gives the bit definitions for the ALITIMING1 register.

Table 10-44. ALITIMING1 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				PSCLS				REVDEL				LPDEL			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.1008															

Table 10-45. ALITIMING1 Bits

BIT	FIELD	DESCRIPTION
31:12	///	**Reserved** Reading returns 0. Write Reset Value.
11:8	PSCLS	**LCDPS and LCDCLS Delay** Controls the delay in LCDDCLK periods from the first rising edge of the internal CLCDC clock after the leading edge of the internal LCDLP signal (not the LCDLP pin no. 137), to the leading edge of the LCDREV signal. PSCLS = (LCDDCLK periods) – 1
7:4	REVDEL	**Polarity-Reversal Delay*** Controls the delay in LCDDCLK periods from the first assertion of the LCDLP (horizontal sync) signal, to the falling edge of the LCDREV signal. REVDEL = (LCDDCLK periods) – 1
3:0	LPDEL	**LCDLP Delay** Controls the delay in LCDDCLK periods from the first rising edge of the internal CLCDC clock after the leading edge of the internal LCDLP signal (not the LCDLP pin no. 137), to the leading edge of the LCDLP signal. LPDEL = (LCDDCLK periods) – 1

NOTE: *The LCDREV signal generated by the ALI is intended for input to a grayscaler ASIC associated with an AD-TFT or HR-TFT display. In this application, it acts as a type of AC Bias signal, switching at a horizontal-line rate, synchronized to the LCDDCLK signal. The LCDREV signal is not intended to reverse the panel's direction-of-scan. Panels utilizing the LCDREV signal must be programmed to utilize an 'odd' number of horizontal display lines. If the panel is programmed to display an 'even' number of horizontal lines, then the net AC Bias applied to each line of the panel will not average to 0 VDC and the panel can suffer long-term damage.

10.4.6 ALI Timing 2 Register (ALITIMING2)

The ALITIMING2 register specifies the required delays for the panel's Row and Column driver chip control signal LCDSPL.

Table 10-47 gives the bit definitions for this register.

Table 10-46. ALITIMING2 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SPLDEL							PS2CLS2								
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.100C															

Table 10-47. ALITIMING2 Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Write the reset value.
15:9	SPLDEL	**LCDSPL Delay** Controls the delay in LCDDCLK periods of the LCDSPL signal during vertical front and back porches. This field must be programmed to a value greater than the sum of (TIMING0:HSW + TIMING0:HBP). SPLDEL = (LCDDCLK periods) – 1
8:0	PS2CLS2	**LCDSPL and LCDCLS Delay 2** Controls the delay in LCDDCLK periods from the first rising edge of the LCDSPL signal to the trailing edge of the LCDCLS and LCDPS signals. PS2CLS2 = (LCDDCLK periods) – 1

10.5 Color LCD System Timing Waveforms

This section contains typical output waveform diagrams.

10.5.1 STN Horizontal Timing

Figure 10-8 presents typical horizontal timing waveforms for STN panels.

Figure 10-8 shows that the CLCDC Clock (an input to the CLCDC) is scaled within the CLCDC and utilized to produce the LCDDCLK output.

Figure 10-9 presents typical vertical timing waveforms for STN panels.

10.5.2 TFT Horizontal Timing

Figure 10-10 presents typical horizontal timing waveforms for TFT panels.

10.5.3 TFT Vertical Timing

Figure 10-11 presents typical vertical timing waveforms for TFT panels.

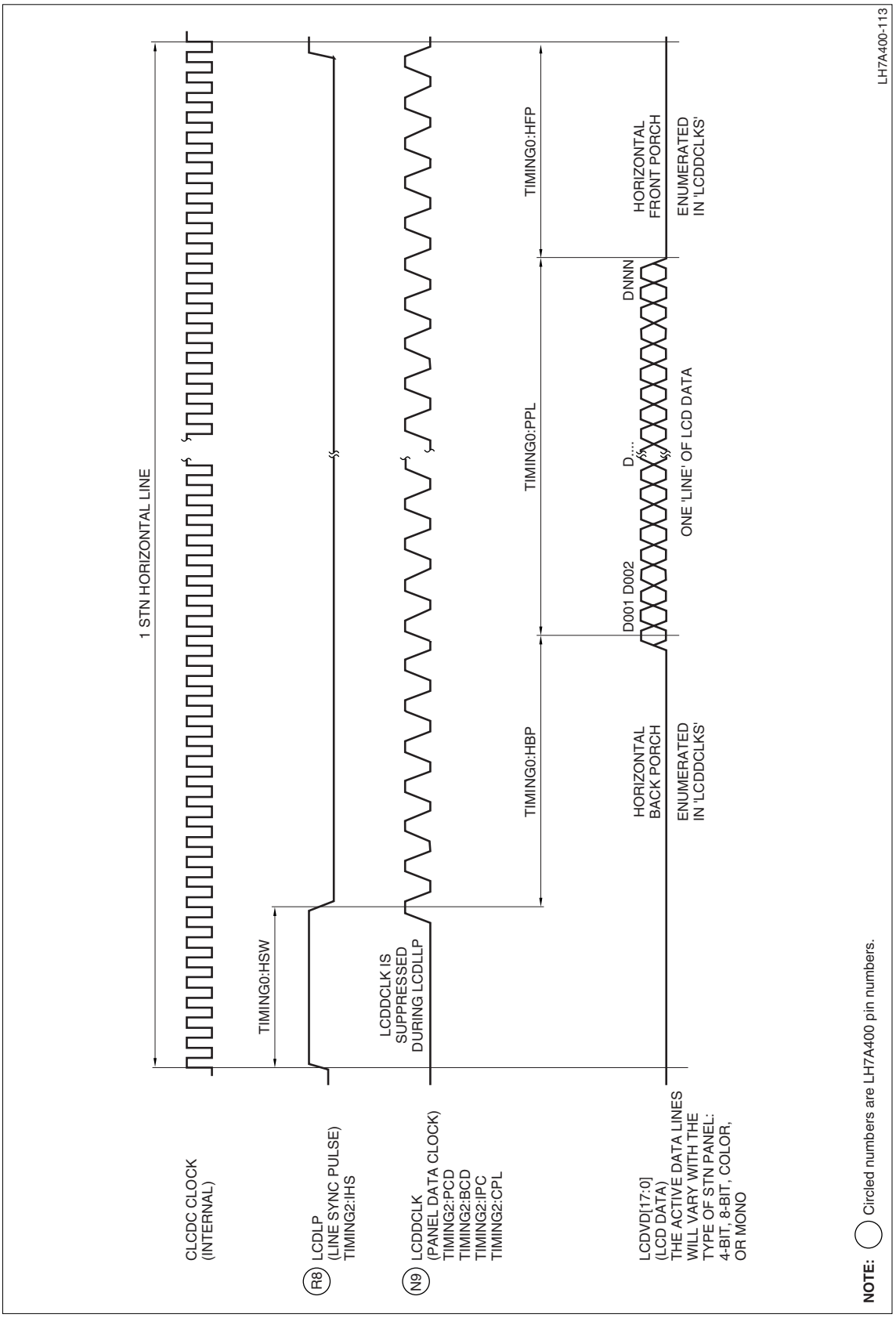


Figure 10-8. STN Horizontal Timing Diagram

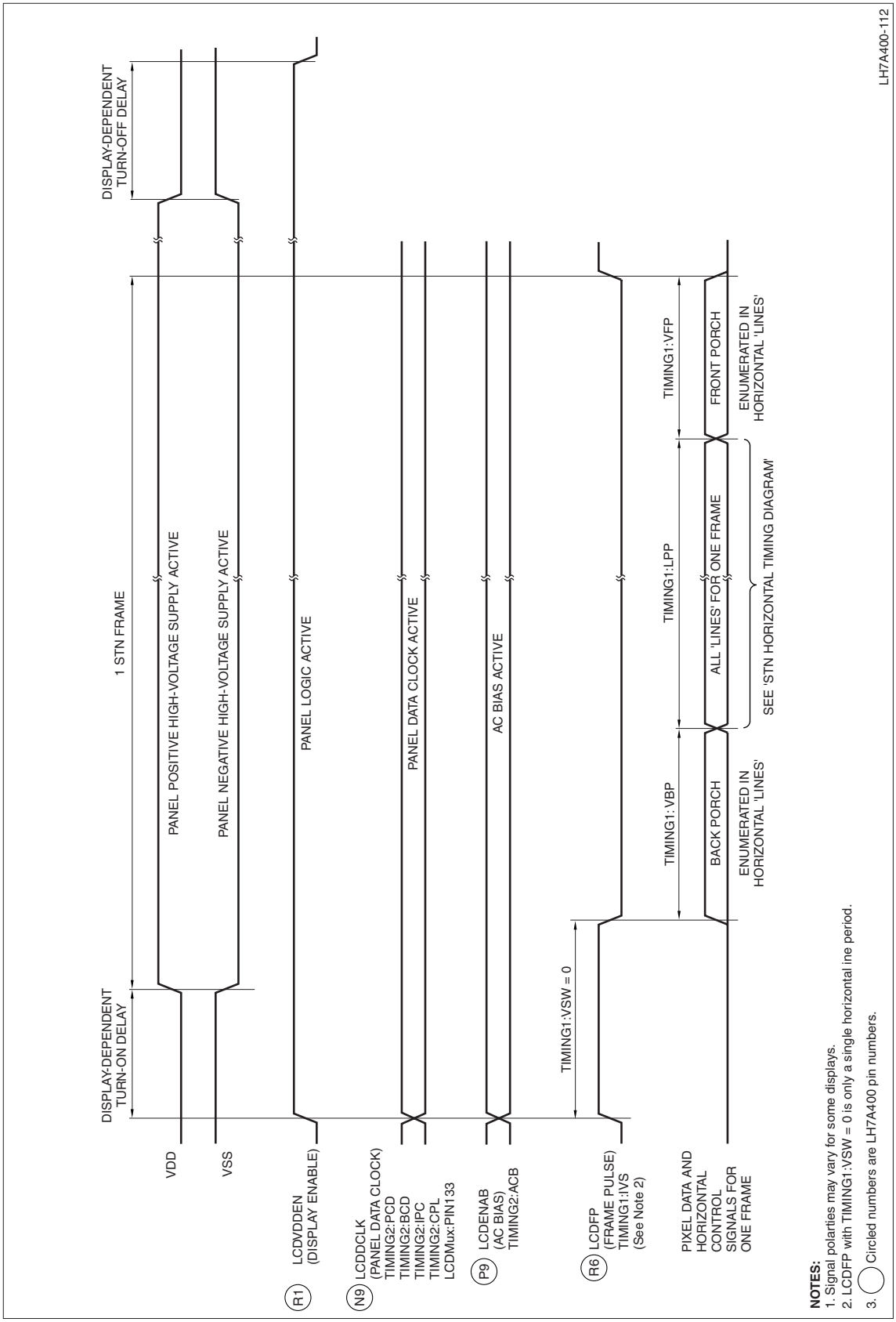


Figure 10-9. STN Vertical Timing Diagram

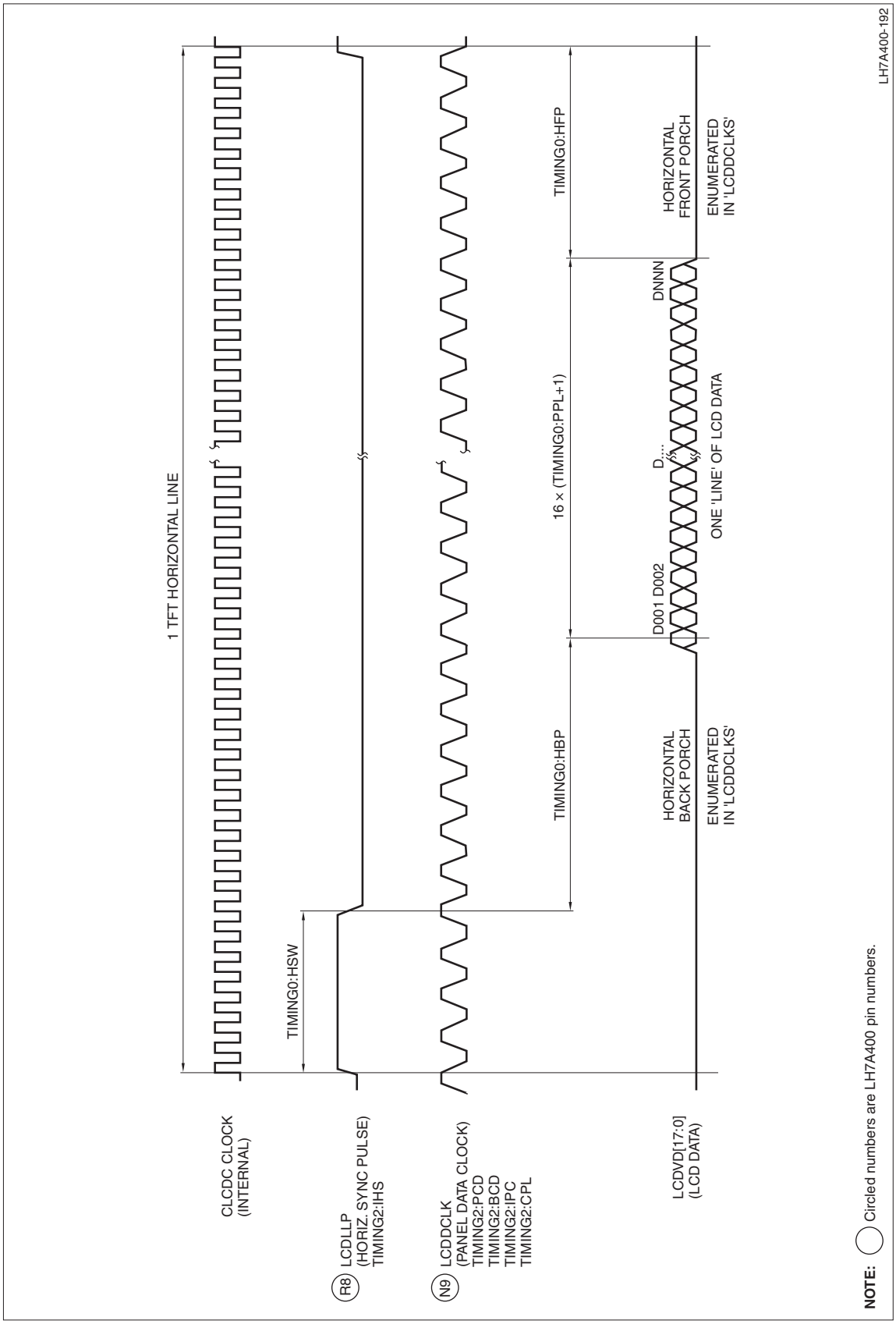


Figure 10-10. TFT Horizontal Timing Diagram

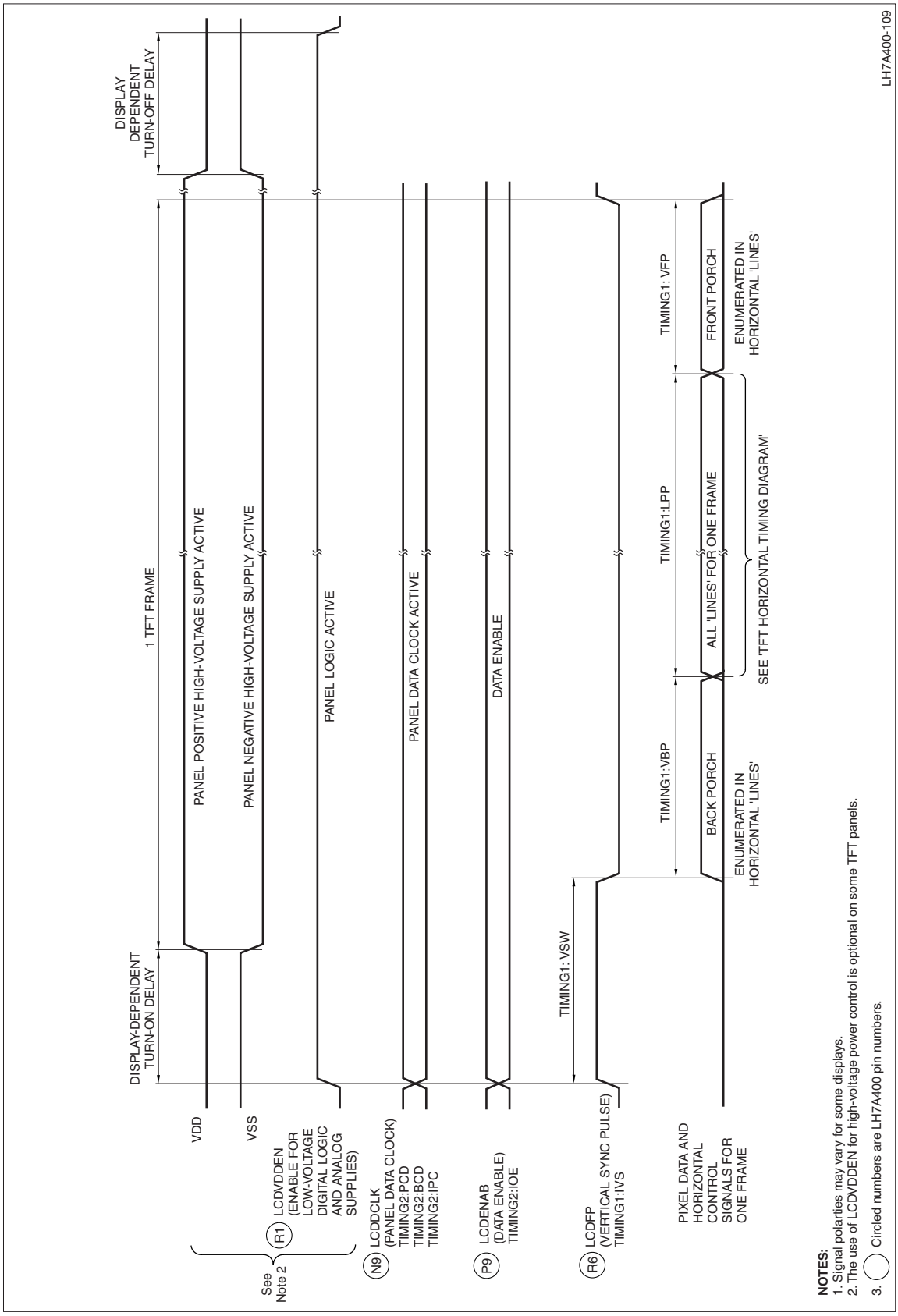


Figure 10-11. TFT Vertical Timing Diagram

10.5.4 AD-TFT and HR-TFT Horizontal Timing Waveforms

Figure 10-12 presents typical horizontal timing waveforms for AD-TFT and HR-TFT panels. The ALI adjusts and delays the normal TFT timing for the Row and Column driver chips integrated into AD-TFT and HR-TFT panels. Other panels requiring the use of the ALI will have similar timing waveforms.

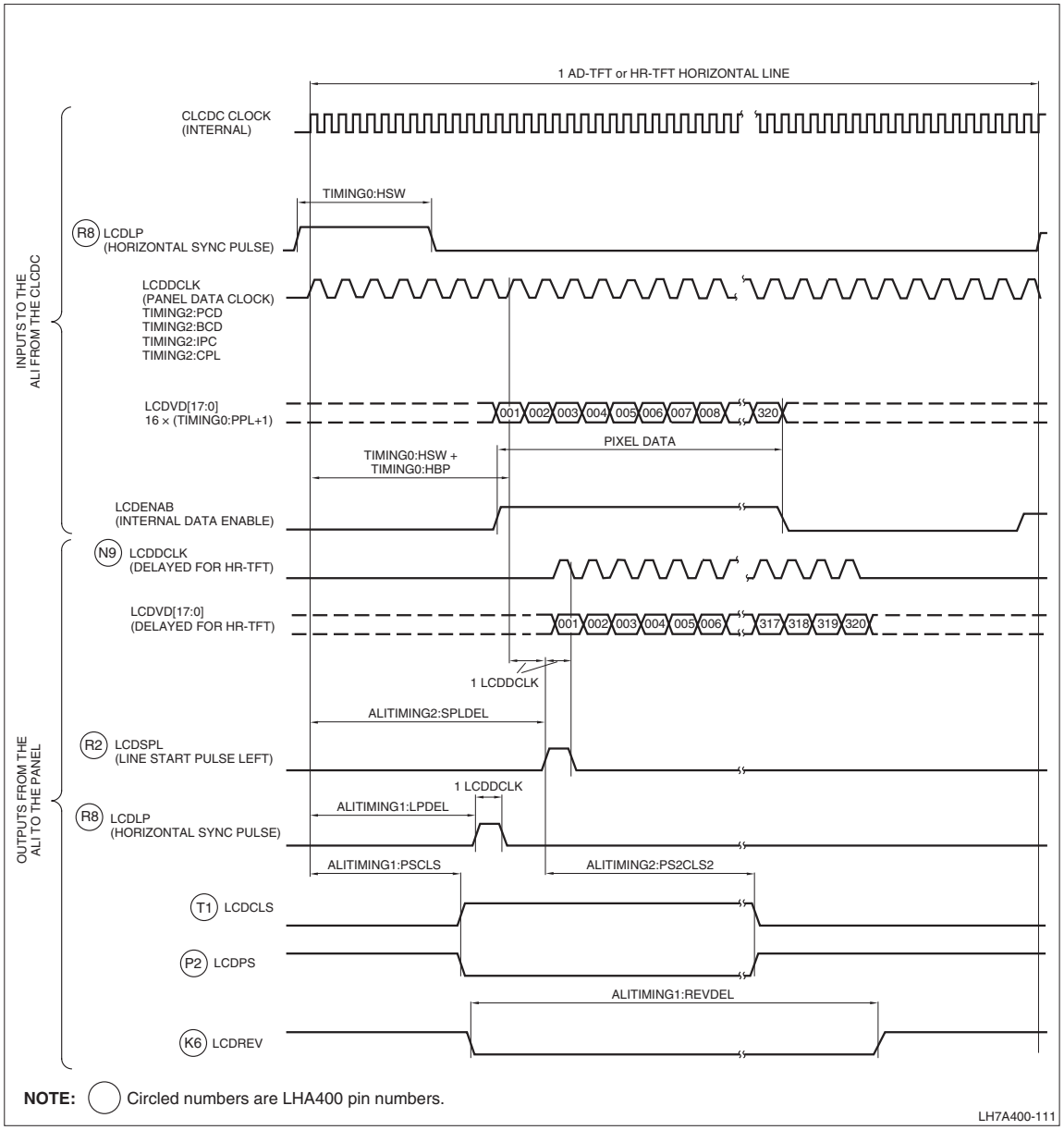


Figure 10-12. AD-TFT and HR-TFT Horizontal Timing Diagram

10.5.5 AD-TFT and HR-TFT Vertical Timing

Figure 10-13 presents typical vertical timing waveforms for AD-TFT and HR-TFT panels. The power sequencing and register information is the same as for TFT vertical timing.

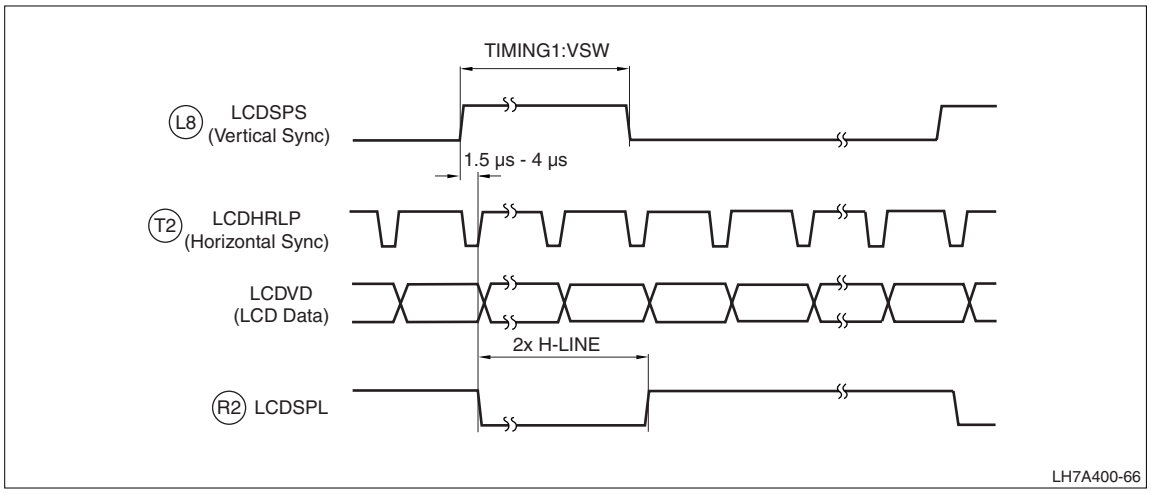


Figure 10-13. AD-TFT and HR-TFT Vertical Timing Diagram

Chapter 11
Watchdog Timer (WDT)

11.1 Theory of Operation

The Watchdog Timer (WDT) is programmed with a timing value and decrements that value on each PCLK cycle. Upon underflow, (timing out) the WDT causes either a WDT Reset.

The WDT allows a ‘sanity check’ to be programmed into software. With the WDT enabled (EN set), software must reset the WDT at regular intervals to avoid an FIQ interrupt or resetting the system. This provides a safeguard mechanism against software malfunctions. When first enabled or when reset, the WDT begins or resumes counting from the programmed timing value.

11.1.1 WDT Configuration

The WDT is enabled and disabled by programming the Control register Enable field (CTL:EN). To reset the WDT, program the Reset register (RST) with the value 0x1984. To prevent the WDT from being inadvertently disabled, the Enable function can be locked by setting the CTL Freeze field (CTL:FRZ).

To configure the initial value, program the CTL Timeout Code field (CTL:TOC). The value in TOC specifies one of 16 time-out periods, ranging from 2^{16} through 2^{31} PCLK cycles. When the WDT is enabled or reset, the value in CTL:TOC is loaded into the Count registers (COUNT[3:0]) and the WDT starts decrementing.

COUNT[3:0] are a set of registers operating as a cascaded counter, reporting the current WDT decrementing value:

- COUNT3 contains bits 31 through 24 of the current value.
- COUNT2 contains bits 23 through 16 of the current value.
- COUNT1 contains bits 15 through 8 of the current value.
- COUNT0 contains bits 7 through 0 of the current value.
- When all of COUNT[3:0] are 0, the WDT has timed out.

CAUTION

Once set, FRZ can only be cleared by a system reset. Ensure that the WDT will always be serviced by software before freezing the enable bit.

When a WDT reset occurs, the chip never leaves RUN mode. CLKEN doesn't go low and a wakeup signal edge isn't needed. The chip is reset and will wakeup without external influence, but it's not a power-on reset. This event can be detected by clearing and monitoring both the cold start and user reset status flags in the PWRSR status register.

NOTE: An FIQ will not be generated during HALT mode.

11.1.1.1 FIQ Generation

Because the reset value of the CTL:TOC is 0x0, immediately after reset the WDT will underflow and generate an FIQ. To prevent this, the following sequence must be executed by software after reset to insure proper operation.

1. Program CTL:EN to 1.
2. Program a 1 to the Interrupt Clear register, bit 2 (ITENC:WDINT; see Chapter 8) to clear the interrupt generated after reset.
3. Program CTL:TOC to the desired count value (do not program the remaining values of CTL at this time; leave them in their reset states of 0).
4. Write 0x1984 to the RST register to reset the WDT and load the new TOC value to the COUNTx registers.
5. Program CTL:EN to 1 (program the remaining CTL bits at this time).
6. Program the Interrupt Enable register, bit 2 (INTENS:WDINT) to enable the WDT FIQ.

The WDT will now begin counting from the value programmed in CTL:TOC and will generate either an FIQ or a reset, depending on the value programmed in CTL:IF.

11.1.1.2 Initialization Following Reset

Prior to use after power up, and following any reset, the CTL:EN bit must be programmed to 0. Then, write 0x1984 to the RST register. Now, the CTL:EN bit may be programmed to 1 to re-enable the WDT. This procedure must be followed exactly for each reset and at power up.

11.2 Register Reference

This section describes the location of the WDT registers and how to program each register.

11.2.1 Memory Map

The watchdog timer base address is 0x8000.1400. The register address offsets shown in Table 11-1 are relative to this base address.

Table 11-1. Watchdog Timer Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	CTL	Watchdog Control Register
0x04	RST	Watchdog Counter Reset
0x08	STATUS	Watchdog Status Register
0x0C	COUNT0	Current Count bits [7:0]
0x10	COUNT1	Current Count bits [15:8]
0x14	COUNT2	Current Count bits [23:16]
0x18	COUNT3	Current Count bits [31:24]

11.2.2 Register Descriptions

11.2.2.1 Control Register (CTL)

The WDT control register, described in Table 11-2 and Table 11-3 enables and disables the WDT, and specifies the timeout period and interrupt response.

Table 11-2. CTL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								TOC				FRZ	IF		EN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.1400															

Table 11-3. CTL Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
7:4	TOC	**Timeout Code** Program this field to select one of 16 possible values to load into the WDT to determine the timeout, in PCLK cycles. The loaded value is $2^{(TOC+16)}$. For example: • TOC = 0x0 results in a timeout period of 2^{16} PCLK cycles. • TOC = 0xF results in a timeout period of 2^{31} PCLK cycles. When a timeout period is programmed, the new value takes effect after a counter reset command or after the count reaches 0.
3	FRZ	**Freeze** Set this bit while the watchdog is enabled, to prevent clearing EN. Only a System Reset can clear FRZ. 1 = When WDT is enabled, the EN bit is frozen and cannot be cleared (set to 0). 0 = WDT function is not frozen. (FRZ *cannot* be cleared by writing a 0 to this bit; a 0 is only valid when this bit is read. FRZ is only cleared with a System Reset)
2:1	IF	**Interrupt First** Program this field to specify whether the first WDT timeout generates an FIQ interrupt or a system reset: 11 = The first timeout generates an FIQ interrupt and restarts the WDT. If this interrupt is not cleared by software or by a reset, the second timeout generates a system reset. A reset clears this interrupt. 00 = Each timeout generates a WDT reset. 01, 10 = Invalid
0	EN	**Enable** Program this bit to enable or disable the WDT: 1 = Enables the WDT. The counter decrements. Timeouts generate interrupts or system resets, depending on the setting of the IF field. To prevent interrupts or system resets, the WDT *must* be periodically reset. 0 = Disables the WDT. The counter does not decrement. Because no timeouts occur, the WDT generates no interrupts or system resets.

11.2.2.2 Counter Reset Register (RST)

Write this register to reset the WDT, preventing a timeout.

Table 11-4. RST Description

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RST															
RESET	undefined															
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.1404															

Table 11-5. RST Field

BIT	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:0	RST	**Reset** Write 0x1984 to this register to reset the WDT. If the first timeout FIQ interrupt is asserted, this write deasserts the interrupt.

11.2.2.3 Status Register (STATUS)

This register, described in Table 11-6 and Table 11-7, provides the status of the WDT counter and response.

Table 11-6. STATUS Description

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								FIQ	RST	IF		///			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.1408															

Table 11-7. STATUS Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
7	FIQ	**FIQ** This bit reports the WDT timeout interrupt status: 1 = An FIQ interrupt has occurred. 0 = No FIQ interrupt has occurred
6	RST	**Reset** This bit reports the system reset status: 1 = A system reset has not occurred. 0 = A system reset has occurred
5:4	IF	**Interrupt First** This field reports whether the WDT is programmed to assert an interrupt or a reset on the first timeout. This field duplicates the value of CTL:IF. 11 = The first timeout generates an FIQ interrupt and restarts the WDT. If this interrupt is not cleared by software or by a reset, the second timeout generates a system reset. A reset clears this interrupt. 00 = Each timeout generates a WDT reset. 01, 10 = Invalid
3:0	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.

11.2.2.4 Current Watchdog Count Registers (COUNT[3:0])

The COUNTx registers, described in Table 11-8 and Table 11-9, are a set of registers operating as a cascaded counter, reporting the current WDT decrementing value:

- COUNT3 contains bits 31 through 24 of the current value
- COUNT2 contains bits 23 through 16 of the current value (note COUNT2 resets to 0x01)
- COUNT1 contains bits 15 through 8 of the current value
- COUNT0 contains bits 7 through 0 of the current value.

When all of COUNT[3:0] are 0, the WDT has timed out.

Table 11-8. COUNTx Description (Except COUNT2)

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								COUNT							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	COUNT0 = 0x8000.140C COUNT1 = 0x8000.1410 COUNT3 = 0x8000.1418															

Table 11-9. COUNTx Fields (Except COUNT2)

BIT	NAME	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written cannot be read.
7:0	COUNT	**Current Count**

Table 11-10. COUNT2 Description

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								COUNT							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	COUNT2 = 0x8000.1414															

Table 11-11. COUNT2 Fields

BIT	NAME	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written cannot be read.
7:0	COUNT	**Current Count**

Chapter 12
Real Time Clock (RTC)

12.1 Theory of Operation

The Real Time Clock (RTC) can be used as a basic alarm, a long time-base counter, a time base for a true real-time clock, or as a wake-up interrupt generator to transfer the LH7A400 from Standby or Halt mode to Run mode. The RTC can be programmed to issue an interrupt when the RTC count matches a programmed value.

The RTC is a free-running 32-bit counter, clocked at a 1 Hz rate. An internal oscillator, using an external 32.768 kHz crystal, generates the 1 Hz reference clock. Further details on the RTC clock generation appear in Chapter 6.

12.1.1 RTC Interrupt

The LH7A400 RTC is clocked by a 1 Hz clock signal (CLK1HZ) which remains active in the LH7A400 reduced-power modes. CLK1HZ is used to increment the RTC free-running counter and the RTC can be programmed to generate an interrupt when the value in the free-running counter matches a value stored in the RTCMR register. After reset, the RTC interrupt (RTCINTR) is disabled and the counter and match values are undefined. Another, internal clock (CLK1kHZ), operates at 1 kHz and clocks the RTC interrupt out to the Interrupt Controller.

12.1.2 Configuring the RTC for Use

To configure the RTC:

1. Set the initial time value by writing the hex value to the RTC Load Register (RTCLR).
2. Set the interrupt trigger value by writing the hex value to the RTC Match Register (RTCMR).
3. Enable the interrupt, by setting the RTC Control Register Interrupt Enable bit (RTCCR:MIE).

The free-running counter is loaded with the RTCLR contents on the next CLK1HZ rising edge, then continues incrementing from that value at 1 second intervals. After each increment, the current counter value appears in, and may be read from, the RTC Data Register (RTCDR). After reaching 0xFFFFFFFF, the counter wraps to 0x0 and resumes incrementing.

When the counter increments on a CLK1HZ rising edge to equal the match value programmed in RTCMR, RTCINTR is asserted on the next CLK1kHZ rising edge, as shown in Figure 12-1. The interrupt appears one-1 kHz cycle (1 ms) following the CLK1HZ edge that caused the counter match. The interrupt status is reported in the RTC Status register Interrupt bit (RTCSTAT:RTCINTR). When enabled, the interrupt is generated and sent to the LH7A400 interrupt controller. To clear the interrupt, write any value to the RTC End-of-Interrupt register (RTCEOI).

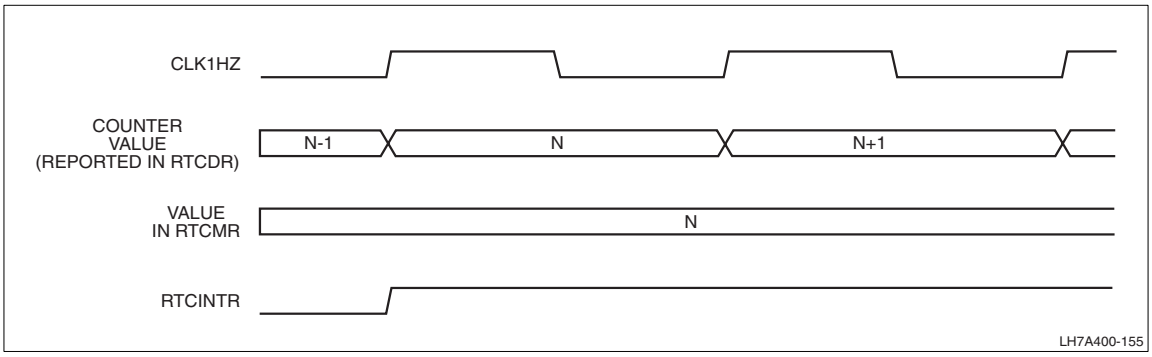


Figure 12-1. RTC Interrupt Timing

12.2 Register Reference

12.2.1 Memory Map

The RTC register offsets shown in Table 12-1 are relative to the RTC base address, 0x8000.0D00.

Table 12-1. RTC Register Summary

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	RTCDR	Reports the current RTC value
0x04	RTCLR	Program with the initial RTC value
0x08	RTCMR	Program with the match value to generate RTCINTR
0x10	RTCSTAT	Reports RTCINTR status
	RTCEOI	Clears the RTCINTR
0x14	RTCCR	Enable or disable RTCINTR
0x18 - 0xFF	///	**Reserved** Reading these locations can return unpredictable values. Do not write to these locations.

12.2.2 Register Descriptions

The following tables define the contents and use of the register bit fields.

12.2.2.1 RTC Data Register (RTCDR)

The RTCDR register, described in Table 12-2 and Table 12-3, contains the present value of the 32-bit free-running RTC counter. Reading this register allows software to get a snapshot of the RTC counter value; the counter continues to increment. Values in this register are only valid after the RTC initial count value is set by writing to the RTCLR register the first time.

Table 12-2. RTCDR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	RTCDR															
RESET	Undefined															
TYPE	RO															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RTCDR															
RESET	Undefined															
TYPE	RO															
ADDR	0x8000.0D00															

Table 12-3. RTCDR Field

BITS	FIELD	DESCRIPTION
31:0	RTCDR	**RTC Data Register Value** Current RTC counter value (hex)

12.2.2.2 RTC Load Register (RTCLR)

The RTCLR register, described in Table 12-4 and Table 12-5, allows software to initialize the free-running RTC counter.

Writing a hex value to this 32-bit register loads the free-running RTC counter with an initial value within 1 RTC clock cycle. The counter is updated with the value written to this register on the next rising edge of the 1 Hz RTC clock signal.

This register is not the free-running RTC counter; this register is a buffer from which the RTC counter is loaded. Reading this register returns the last value written to this register, not the current value of the counter. The current value of the RTC counter can be read from the RTCDR.

Table 12-4. RTCLR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	RTCLR															
RESET	Undefined															
TYPE	RW															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RTCLR															
RESET	Undefined															
TYPE	RW															
ADDR	0x8000.0D04															

Table 12-5. RTCLR Field

BITS	FIELD	DESCRIPTION
31:0	RTCLR	**RTC Load Register Value** Write and read the initial counter value.

12.2.2.3 RTC Match Register (RTCMR)

RTCMR contains the count at which an RTC interrupt is generated (if enabled). To find the current counter value, read the RTC data register.

Writing the RTC match register, as defined in Table 12-6 and Table 12-7, loads a hex value into this register for comparing to the Counter value. Reading this register returns the most recently written value. Valid timings using RTCMR only occur after the RTC has been loaded with the first write to the RTCLR register.

Table 12-6. RTCMR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	RTCMR															
RESET	Undefined															
TYPE	RW															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RTCMR															
RESET	Undefined															
TYPE	RW															
ADDR	0x8000.0D08															

Table 12-7. RTCMR Field

BITS	FIELD	DESCRIPTION
31:0	RTCMR	**RTC Match Register Value** Write and read the match value.

12.2.2.4 RTC Interrupt Status and Interrupt Clear Register (RTCSTAT and RTCEOI)

The RTCSTAT/RTCEOI register has two uses. Reading this register returns the present status of the RTC interrupt bit; writing to this register clears an asserted RTC interrupt. Although this register has two names, depending on whether it is being read or written to, it is actually one register at address offset 0x10.

- Read the RTC Status register RTC Interrupt bit (RTCSTAT:RTCINTR), described in Table 12-8 and Table 12-9, to discover the RTC Match Interrupt (RTCINTR) status.
- Write any 32-bit value to the RTC End-of-Interrupt register (RTCEOI), described in Table 12-10 and Table 12-11, to clear the asserted RTCINTR at the interrupt controller and also clear the RTCSTAT:RTCINTR bit.

Table 12-8. RTCSTAT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	Undefined															
TYPE	RO															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///															RTCINTR
RESET	Undefined															0
TYPE	RO															RO
ADDR	0x8000.0D10															

Table 12-9. RTCSTAT Fields

BITS	FIELD	DESCRIPTION
31:1	///	**Reserved** Reading returns all zeroes. Values written cannot be read.
0	RTCINTR	**RTC Interrupt** Reading this bit returns the RTCINTR status: 1 = RTCINTR is asserted. 0 = RTCINTR is not asserted. Values written to this field clear the assertion of the interrupt, but cannot be read back.

Table 12-10. RTCEOI Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	RTCEOI															
RESET	Undefined															
TYPE	WO															
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RTCEOI															
RESET	Undefined															
TYPE	WO															
ADDR	0x8000.0D10															

Table 12-11. RTCEOI Fields

BITS	FIELD	DESCRIPTION
31:0	RTCEOI	**RTC End of Interrupt** Writing any 32-bit value to this field clears RTCINTR and RTCSTAT:RTCINTR. Reading RTCEOI returns an undefined value. Values written to this field cannot be read back.

12.2.2.5 RTC Control Register (RTCCR)

The RTCCR, defined in Table 12-12 and Table 12-13, enables or disables generating the RTC interrupt. If not enabled, no interrupt is generated when the Counter equals the value set in the RTCMR.

Table 12-12. RTCCR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///															MIE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW
ADDR	0x8000.0D14															

Table 12-13. RTCCR Fields

BITS	FIELD	DESCRIPTION
31:1	///	**Reserved** Reading this field returns all zeroes. Values written must be zeroes.
0	MIE	**Match Interrupt Enable** Program this bit to enable and disable RTCINTR: 1 = Enable RTCINTR 0 = Disable RTCINTR

Chapter 13
Timers

13.1 Theory of Operation

LH7A400 provides three 16-bit Timers usable by software to monitor and control timed events in the system. A Timer marks time by periodically decrementing a value register and asserting an interrupt when the value register contains 0.

Timer1 and Timer2 have identical operation and Timer3 is slightly different. When two or more Timers or registers operate identically, this chapter uses an x to indicate discussion of multiple items. For example, LOADx refers the LOAD1, LOAD2, and LOAD3 registers collectively; Timerx refers to all three timers collectively. Timer[2:1] refers to Timer2 and Timer1 collectively.

All Timers have the following in common:

- Each Timer uses a dedicated set of LOAD, VALUE, CONTROL, and End-of-Interrupt (TCEOI) registers. A LOADx register contains the Initial and Reload Timer values. Reading a VALUEx register returns the corresponding Timerx value. A CONTROLx register enables and disables the corresponding Timerx and configures the corresponding Timerx mode. Writing an TCEOIx register clears the corresponding Timerx interrupt.
- Each Timer can operate in Free Running or Periodic mode. In Free Running mode, a Timer wraps from 0 to 0xFFFF and continues decrementing. In Periodic mode, a Timer reloads the Initial value after reaching 0 and continues decrementing. To select the mode for Timerx, write the corresponding Control register Mode field (CONTROLx:MODE).
- Software can read any Timerx value at any time in the corresponding VALUEx register.
- Writing a value to LOADx loads the value immediately for the corresponding Timerx.
- Each Timerx is started and stopped by writing the appropriate value to the CONTROLx:ENABLE bit. Because the phase of a Timer's clock with respect to the execution pipeline cannot be predicted, there is an uncertainty of up to one Timerx clock period between the setting of the CONTROLx:ENABLE bit and the first decrement of the VALUEx register.
- Each Timer interrupt is enabled and disabled in the LH7A400 Interrupt Controller Interrupt Enable Set and Clear registers (INTENS and INTENC). These registers are mapped with the Interrupt Controller (Chapter 8), not with the Timers.
- Any Timer interrupt is asserted on the first clock cycle after the corresponding Timer value underflows.

Differences between Timer[2:1] and Timer3 are:

- The Timer[2:1] clock sources are 508.469 kHz and 1.994 kHz. To select the clock source for a Timer, write the corresponding Control register Clock Select field (CONTROL[2:1]:CLKSEL). Timer3 uses a single, 3.6864 MHz clock source. The CONTROL2 bits corresponding to CONTROL[2:1]:CLKSEL must be written as 0.
- Timer1 can control the buzzer output signal (TBUZ, pin H3). With the Buzzer Control register Buzzer Drive Mode field set (BZCON:BZMOD), a Timer1 underflow toggles TBUZ. The maximum buzzer output frequency is 254 kHz. To control TBUZ via software instead of via Timer0, do the following:

  1. Clear BZCON:BZMOD.
  2. Set and clear the BZCON Buzzer Toggle field (BZCONT:BZTOG) to toggle TBUZ.

13.2 Register Reference

This section defines the Timer registers.

13.2.1 Memory Map

The Timer register offsets shown in Table 13-1 are relative to the Timer base address, 0x8000.0C00.

Table 13-1. Timers Memory Map

OFFSET ADDRESS	NAME	DESCRIPTION
0x00	LOAD1	Allows setting or reading the initial Timer1 value
0x04	VALUE1	Allows reading the current Timer1 value
0x08	CONTROL1	Allows setting or reading the Timer1 configuration
0x0C	TCEOI1	Clears the Timer1 interrupt
0x10	///	Reserved. Reading this register can return unpredictable values. Avoid writing this register.
0x20	LOAD2	Allows setting or reading the initial Timer2value
0x24	VALUE2	Allows reading the current Timer2 value
0x28	CONTROL2	Allows setting or reading the Timer2 configuration
0x2C	TCEOI2	Clears the Timer2 interrupt
0x40	BZCON	Allows setting or reading the buzzer output configuration
0x80	LOAD3	Allows setting or reading the initial Timer3 value
0x84	VALUE3	Allows reading the current Timer3 value
0x88	CONTROL3	Allows setting or reading the Timer3 configuration
0x8C	TCEOI3	Clears the Timer3 interrupt
0x30 - 0x90	///	Reserved. Reading these locations can return unpredictable values. Avoid writing these locations.

13.2.2 Register Descriptions

The following sections describe the contents and use of the register bit fields.

13.2.2.1 Timer Load Registers (LOADx)

These registers, described in Table 13-2 and Table 13-3, contain the following:

- The corresponding Timerx initial value.
- The corresponding Timerx reload values in Periodic Timer mode.

Table 13-2. LOADx Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	LOAD															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0C00 for LOAD1 0x8000.0C20 for LOAD2 0x8000.0C80 for LOAD3															

Table 13-3. LOADx Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:0	LOAD	**LOADx** Specifies the initial Timer value. The Timer decrements from this value.

13.2.2.2 Timer Value Registers (VALUEx)

The value registers, shown in Table 13-4 and Table 13-5, report the current Timer value.

Table 13-4. VALUEx Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	VALUE															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0C04 for VALUE1 0x8000.0C24 for VALUE2 0x8000.0C84 for VALUE3															

Table 13-5. VALUEx Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Avoid writing this register.
15:0	VALUE	**VALUEx** Read this field to identify the current Timer value.

13.2.2.3 Timer End-of-Interrupt Registers (TCEOIx)

Writing any 32-bit value to an End-of-Interrupt register clears the corresponding interrupt. These registers are shown in Table 13-6 and Table 13-7.

Table 13-6. TCEOIx Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	TCEOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	TCEOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0C0C for TCEOI1 0x8000.0C2C for TCEOI2 0x8000.0C8C for TCEOI3															

Table 13-7. TCEOIx Fields

BITS	FIELD	DESCRIPTION
31:0	TCEOI	**TCEOIx** Reading this field returns 0. Writing any value to this field deasserts the corresponding Timer interrupt.

13.2.2.4 Timer Control Registers (CONTROLx)

The Timer1 and Timer2 control registers, shown in Table 13-8 and Table 13-9, provide enable, disable, and mode configurations for the corresponding Timers. This configuration applies to both Timer1 and Timer2 because these counters share the same input clock sources.

Timer3 uses a 3.6864 MHz clock derived from the oscillator. This frequency remains unchanged when the HCLK frequency changes. The Timer3 control register is shown in Table 13-10 and Table 13-11.

Table 13-8. CONTROL[2:1] Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								ENABLE	MODE	///		CLKSEL	///		
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RO	RO	RW	RO	RO	RO
ADDR	0x8000.0C08 for CONTROL1 0x8000.0C28 for CONTROL2															

Table 13-9. CONTROL[2:1] Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
7	ENABLE	**Enable Timer[2:1]** 1 = Enable the specified Timer 0 = Disable the specified Timer
6	MODE	**Timer[2:1] Mode** Selects the Timer operating mode: 1 = Periodic 0 = Free Running
5:4	///	**Reserved** Reading this field returns 0. When writing this register, ensure this field is 0.
3	CLKSEL	**Timer[2:1] Clock Select** Selects the clock for the specified Timer 1 = 508 kHz 0 = 2 kHz
2:0	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back

Table 13-10. CONTROL3 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								ENABLE	MODE	///					
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0C88															

Table 13-11. CONTROL3 Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
7	ENABLE	**Enable Timer3** 1 = Enable Timer3 2 = Disable Timer3
6	MODE	**Timer3 Mode** Selects the Timer mode: 1 = Periodic 0 = Free Running
5:0	///	**Reserved** Reading this field returns 0. When writing this register, ensure this field is 0. Values written to this field cannot be read back

13.2.2.5 Timer Buzzer Count Register (BZCON)

Timer1 can control the buzzer output signal. The buzzer count register, shown in Table 13-12 and Table 13-13, controls the buzzer drive output. The buzzer operation, as controlled by the interaction between the BZMOD and BZTOG fields, is shown in Table 13-14.

Table 13-12. BZCON Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														BZMOD	BZTOG
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW
ADDR	0x8000.0C40															

Table 13-13. BZCON Fields

BITS	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
1	BZMOD	**Buzzer Mode** Selects the buzzer drive mode. 1 = The Timer1 underflow condition drives the buzzer signal (TBUZ, pin H3). 0 = Software drives the BZTOG bit to drive TBUZ.
0	BZTOG	**Buzzer Toggle** Drives the TBUZ signal directly. Software can periodically set and clear this bit to pulse the output.

Table 13-14. BUZ Operation

BZMOD	BZTOG	TBUZ
0	0	LOW
0	1	HIGH
1	X	Driven by Timer0 underflow

Chapter 14
Synchronous Serial Port (SSP)

14.1 Theory of Operation

The SSP provides the interface between parallel data inside the MCU and Synchronous Serial data on a Slave peripheral device using Motorola SPI, National Semiconductor MICROWIRE, or Texas Instruments Synchronous Serial interfaces. Serial data is transmitted on the SSP Transmit Data signal (SSPTX, pin J2) and received on the SSP Receive Data signal (SSPRX, pin J1).

None of the SSP registers can be programmed until the SSP is enabled by setting the Control Register 0 SSP Enable bit (CR0:SSE) to 1.

14.1.1 Clocking

To generate the bit rate and Serial Clock output (SSPCLK), in the range 113.386 Hz < SSPCLK < 3.6864 MHz, the SSP uses:

- A programmable prescaler in the Clock Prescaler register Divisor field (CPR:DVSR)
- A programmable clock rate divisor in the CR0 Serial Clock Rate (SCR) field (CR0:SCR)
- The source clock from the LH7A400 system clocks (14.7456 MHz ÷ 2 = 7.3728 MHz)

SSPCLK is calculated as follows:

SSPCLK = (7.3728 MHz ÷ (CPR:DVSR)) ÷ (1 + CR0:SCR))

14.1.2 FIFOs

The SSP provides Transmit and Receive FIFOs accessed via the Data Register (DR):

- The FIFOs can be configured to hold up to eight data entries or a single entry. Each entry can be up to 16 bits. Disabling FIFO operation by clearing (0) the Control Register 1 FIFO Enable field (CR1:FEN) configures both FIFOs as single-entry holding registers. Disable FIFO operation for single-word transfers.
- Reading the DR accesses the Receive FIFO or holding register. Writing the DR accesses the Transmit FIFO or holding register.
- Received data is automatically justified into the least significant bits of the DR. For transmission data shorter than 16 bits, software must justify the data into the least significant bits of the DR. To specify the Receive and Transmit data size, program the CR0 Data Size Specification (DSS) field (CR0:DSS). For National Semiconductor MICROWIRE format, Transmit data size is always eight bits and DSS specifies only the Receive data size.
- To flush the Receive FIFO, read the DR until the Receive FIFO is empty. The SSP reports the Receive FIFO empty by clearing (0) the Status Register Receive FIFO Not Empty field (SR:RNE). To flush the Transmit FIFO, disable and re-enable FIFO operation by clearing (0) and then setting (1) CR1:FEN.

Software writing to the DR is timed by PCLK. Transmission from the Transmit FIFO is timed by SSPCLK. Because SSPCLK is slower than PCLK, depending on the timing, software can write either eight or nine entries to the DR before the Transmit FIFO is reported to be full. The SSP reports the Transmit FIFO full by clearing (0) the SR Transmit FIFO Not Full field (SR:TNF).

14.1.3 Interrupts

The SSP generates individual interrupts, described in Table 14-1, to report transmission and reception status. These interrupts are asserted in the Interrupt Identification Register (IIR). Software can configure these interrupts as enabled or disabled by programming CR1. The individual interrupts in the IIR are logically ORed together to generate a single, combined interrupt, SSPINTR, to be handled by the LH7A400 Interrupt Controller.

Table 14-1. SSP Interrupts

NAME	DESCRIPTION
TXII	**Transmit Idle Interrupt** This interrupt indicates the SSP has become idle and either: • FIFO operation is enabled and the Transmit FIFO is empty (transmission complete). • FIFO operation is disabled and the Transmit holding register contains no data. Related flags are as follows: • The Status Register Busy field (SR:BSY) is cleared (0), indicating the SSP is idle. • The SR Transmit FIFO Empty field (SR:TFE) is set to 1. TXII is automatically deasserted and SR:TFE cleared when software writes the DR. SR:BSY is set when transmission resumes.
RXOI	**Receive Overrun Interrupt** This interrupt is generated when a data frame has been received and the SSP attempts to transfer from the receive shift register into the recieve FIFO or receive holding register and either: • FIFO operation is enabled and the Receive FIFO is full. • FIFO operation is disabled and the Receive holding register contains data. Related flags are as follows: • The SR Receive Overrun field (SR:ROR) is set. • The SR Receive FIFO Full field (SR:RFF) is set. When a Receive Overrun occurs, the data already in the FIFO is preserved. Data in the shift register is overwritten until software reads the DR. Some data can be lost. When the FIFO or holding register can accept data, the SSP resumes moving data from the shift register with the next full frame of data. This interrupt is deasserted and SR:ROR cleared when software writes the Receive Overrun End-of-Interrupt register (RXOEOI). The interrupt can also be cleared by writing a 0 to the CR1:RXOIEN bit. SR:RFF is cleared when software reads the DR.
TXSI	**Transmit Service Request Interrupt** This interrupt is generated when: • The SSP has been disabled by software clearing CR0:SSE. • The Transmit FIFO contains four or fewer entries. With FIFO operation disabled, this interrupt is asserted each time the SSP finishes moving a data entry from the holding register to the transmitter. A related flag, the SR Transmit Half Empty field (SR:THE), is set. This interrupt is deasserted and SR:THE cleared automatically when software writes DR enough times to put more than four entries in the FIFO, or when software writes DR once with FIFO operation disabled.
RXSI	**Receive Service Request Interrupt** This interrupt is generated when the Receive FIFO contains four or more entries. With FIFO operation disabled, this interrupt is asserted each time the SSP finishes moving a data entry from the receiver to the holding register. A related flag, the SR Receive Half Full field (SR:RHF), is set. This interrupt is deasserted and SR:RHF cleared automatically when software reads DR enough times to leave no more than three entries in the FIFO, or when software reads DR once with FIFO operation disabled.

14.1.4 SSP Data Formats

The SSP supports three data frame formats:

- Texas Instruments Synchronous Serial
- Motorola SPI
- National Semiconductor MICROWIRE

Specify the frame format to use by programming the CR0 Frame Format field (CR0:FRF). Each frame format is between four and 16 bits in length, depending on the programmed data size. Data frames are transmitted beginning with the most significant bit. For all three formats, the SSPCLK is deasserted LOW while the SSP is idle if SPO is 0. If SPO is 1, the SSPCLK idles HIGH. The SSPCLK transitions only during active data transmission. The SSPFRM signal (pin J3) marks the beginning and end of a frame.

The SSP supports both Single Transfer and Continuous Transfer operation:

- In Single Transfer operation, only one item is written to the Transmit FIFO at a time. No other data items are written to the Transmit FIFO until transmission is complete.
- In Continuous Transfer operation, multiple data items are written to the Transmit FIFO; a continuous transmission ends when the Transmit FIFO is empty.

14.1.4.1 Texas Instruments Synchronous Serial Format

For the Texas Instruments Synchronous Serial format, SSPFRM is active HIGH and is pulsed for one serial clock period beginning at the rising edge, prior to each frame transmission. For this frame format, both the SSP and the external Slave device output data on the rising edge of the clock and latch data from the other device on the falling edge. See Figure 14-1 and Figure 14-2.

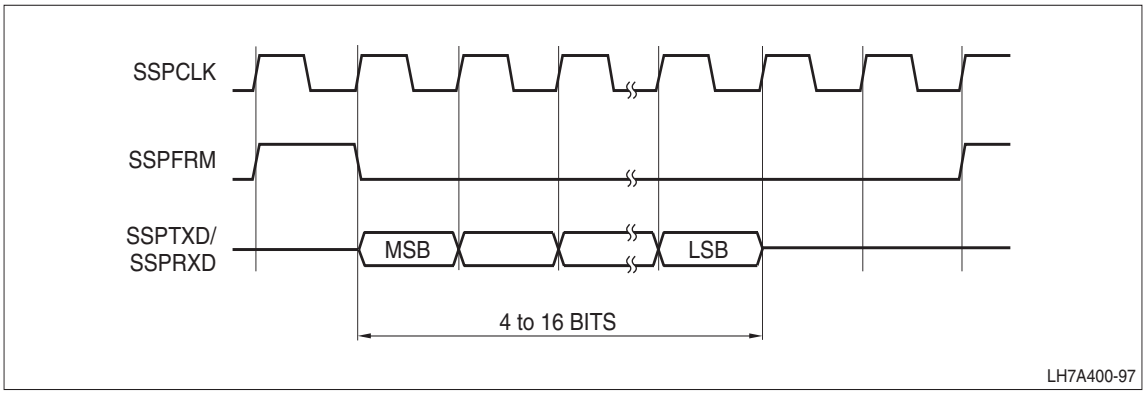


Figure 14-1. Texas Instruments Synchronous Serial Frame Format (Single Transfer)

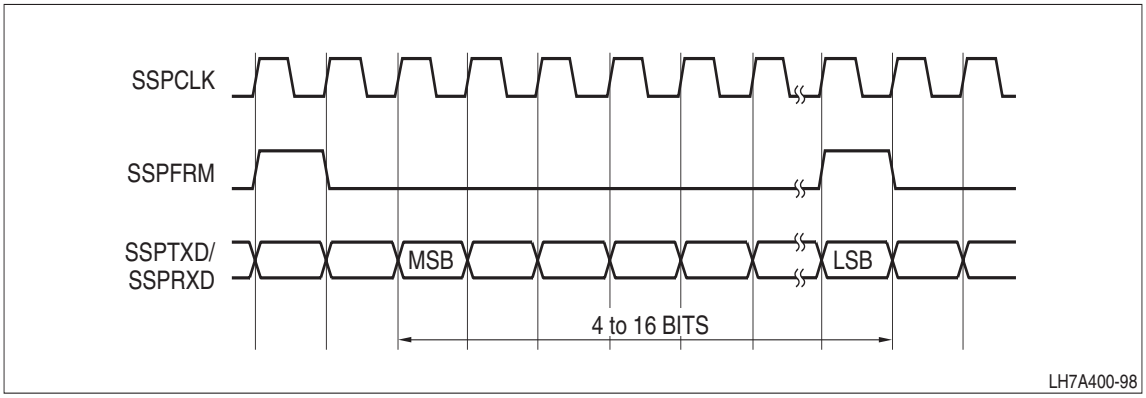


Figure 14-2. Texas Instruments Synchronous Serial Frame Format (Continuous Transfer)

14.1.4.2 Motorola SPI Format

For Motorola SPI format, SSPFRM is active LOW. The CR1 SPI Phase and SPI Polarity fields (CR1:SPH and CR1:SPO, respectively) control SSPCLK and SSPFRM operation in Single and Continuous modes. See Figure 14-3 through Figure 14-10.

When the SSP is in Motorola SPI frame format and the SPO line is toggled between packets, SSPCLK should change polarity. A single SSP device does not require toggling between packets. In a multiple SSP device configuration, external hardware may be required to control the device access during clock polarity change.

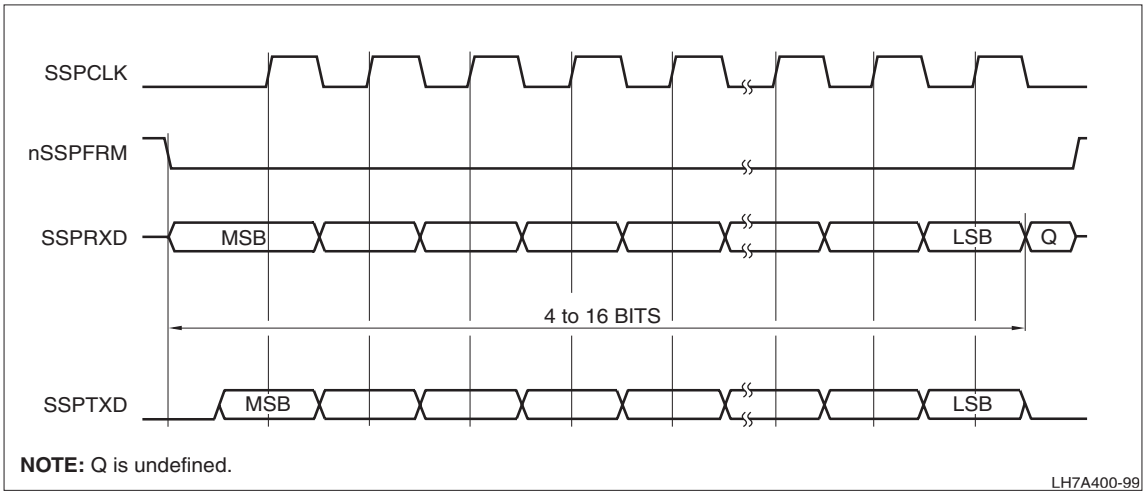


Figure 14-3. Motorola SPI Frame Format (Single Transfer) with SPO = 0 And SPH = 0

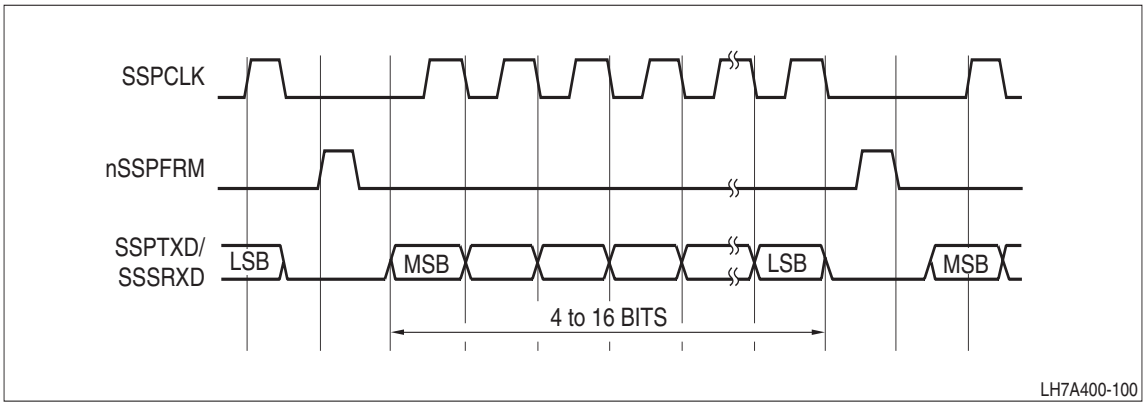


Figure 14-4. Motorola SPI Frame Format (Continuous Transfer) with SPO = 0 And SPH = 0

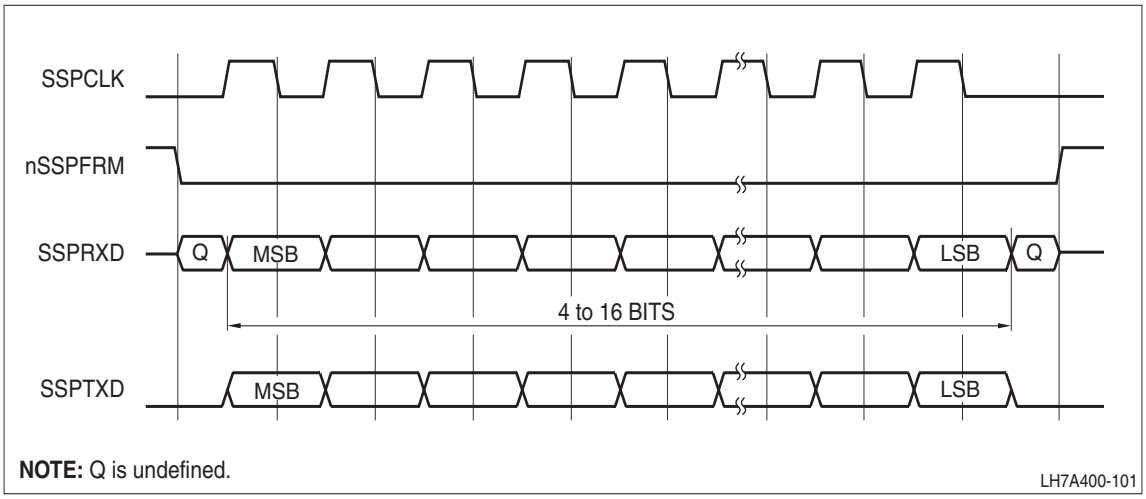


Figure 14-5. Motorola SPI Frame Format (Single Transfer) with SPO = 0 and SPH = 1

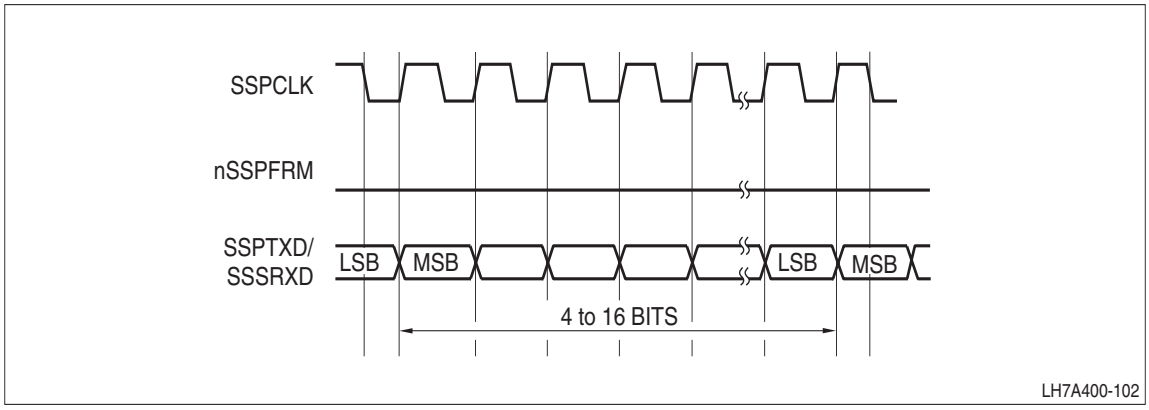


Figure 14-6. Motorola SPI Frame Format (Continuous Transfer) with SPO = 0 and SPH = 1

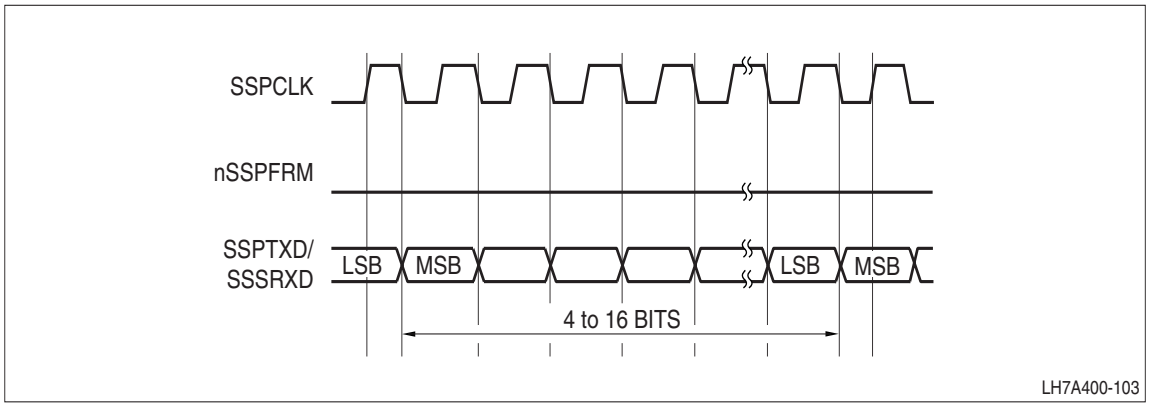


Figure 14-7. Motorola SPI Frame Format (Continuous Transfer) with SPO = 1 and SPH = 1

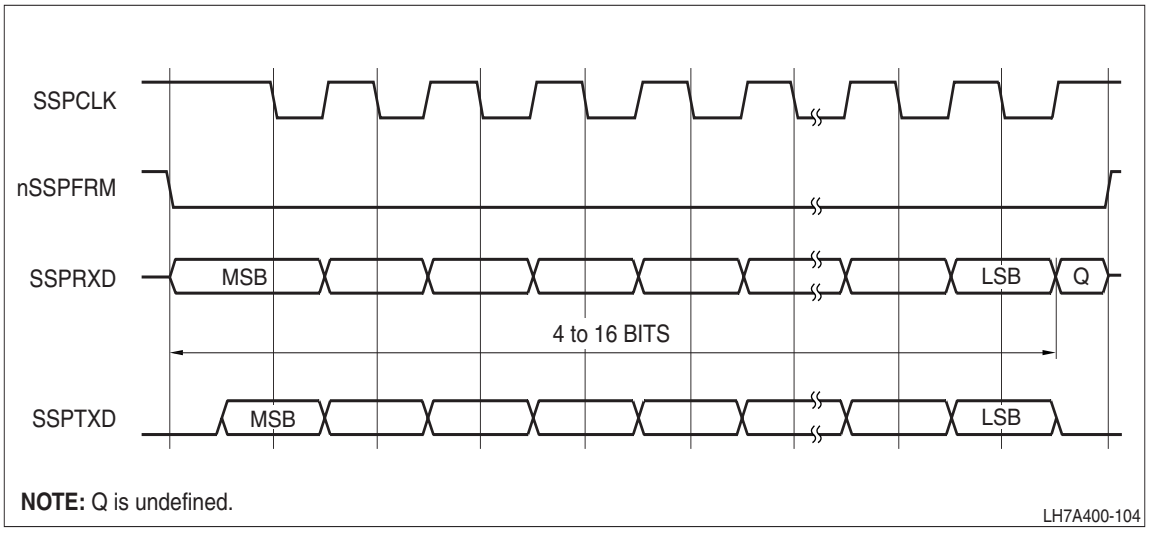


Figure 14-8. Motorola SPI Frame Format (Single Transfer) with SPO = 1 And SPH = 0

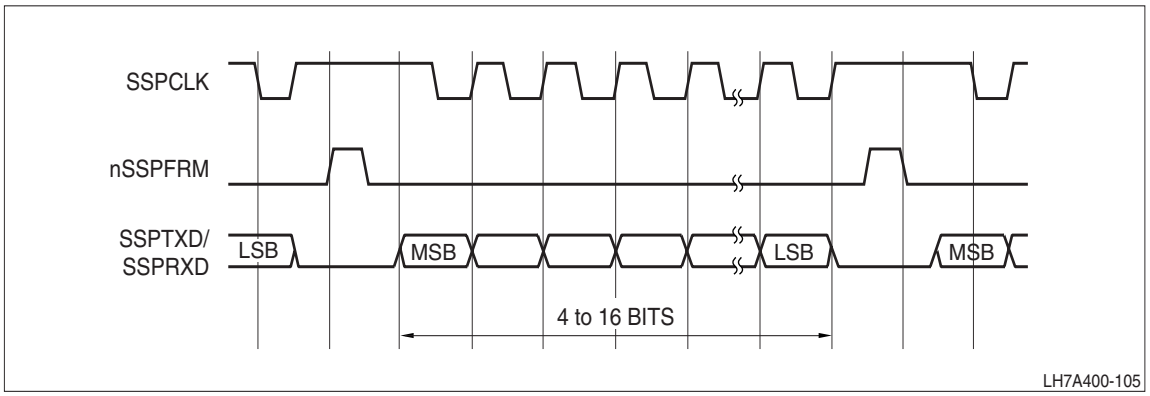


Figure 14-9. Motorola SPI Frame Format (Continuous Transfer) with SPO = 1 And SPH = 0

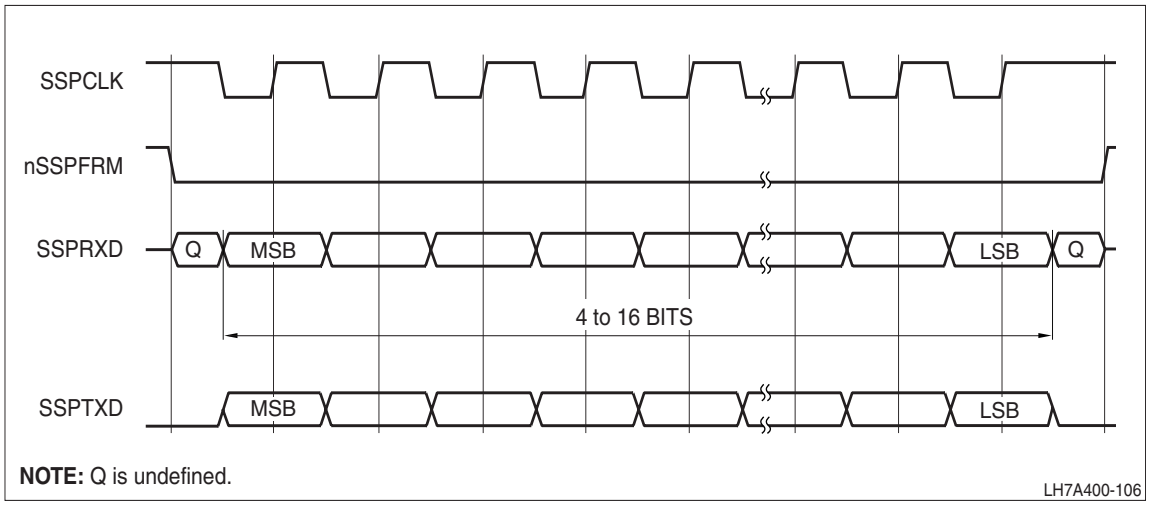


Figure 14-10. Motorola SPI Frame Format (Single Transfer) with SPO = 1 And SPH = 1

14.1.4.3 National Semiconductor MICROWIRE Format

For National Semiconductor MICROWIRE format, SSPFRM is active LOW. Both the SSP and the external Slave device drive their output data on the falling edge of the clock, and latch data from the other device on the rising edge of the clock.

Unlike the full-duplex transmission of the other two frame formats, the National Semiconductor MICROWIRE format uses a half-duplex Master-Slave messaging technique. At the beginning of a frame an eight-bit control message is transmitted to the off-chip Slave. For MICROWIRE mode only, this transmitted message is always eight bits regardless of the programmed data size in CR0:DSS and regardless of the size of data software writes to DR.

During this transmission, no incoming data is received by the SSP. After the message has been sent, the external Slave device decodes the message and after waiting one serial clock period after the last bit of the eight-bit control message was received, responds by returning the requested data. The returned data can be four to 16 bits in length. The total frame length can be 13 to 25 bits in length. See Figure 14-11 and Figure 14-12.

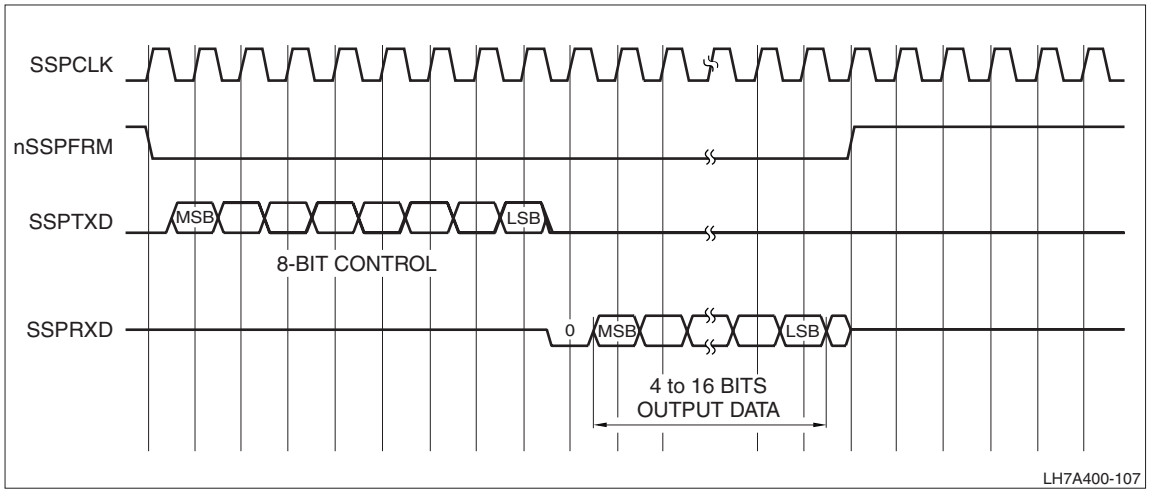


Figure 14-11. National Semiconductor MICROWIRE Format (Single Transfer)

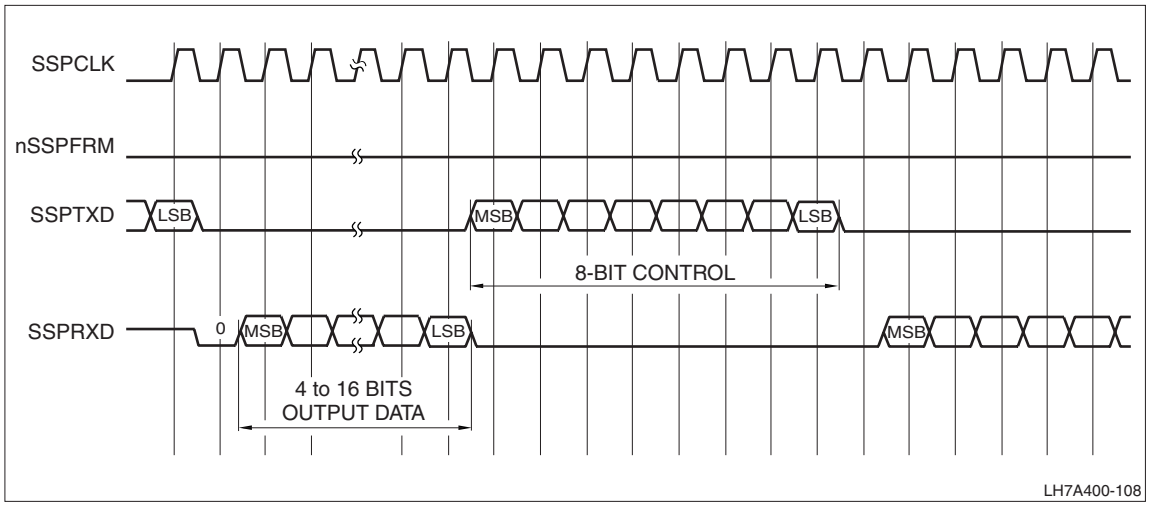


Figure 14-12. National Semiconductor MICROWIRE Format (Continuous Transfer)

14.2 Register Reference

This section describes the registers used in SSP operation.

14.2.1 Memory Map

The SSP registers reside in memory at offsets from the base address, 0x8000.0B00, as shown in Table 14-2.

Table 14-2. SSP Register Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	CR0	Control Register 0
0x04	CR1	Control Register 1
0x08	IIR	Interrupt Identification Register
	ROEOI	Receive Overrun End-of-Interrupt
0x0C	DR	Data Register
0x10	CPR	Clock Prescale Register
0x14	SR	Status Register
0x18 - 0xFF	///	**Reserved** Accessing these locations can cause unpredictable results.

14.2.2 Register Descriptions

14.2.2.1 Control 0 Register (CR0)

This register, defined in Table 14-3 and Table 14-4, enables or disables the SSP and controls the serial clock rate, data size, and frame format.

Table 14-3. CR0 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SCR								SSE	///	FRF		DSS			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0B00															

Table 14-4. CR0 Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written cannot be read.
15:8	SCR	**Serial Clock Rate** To generate the bit rate and Serial Clock output (SSPCLK), the SSP uses two dwivisors on the generated 7.3728 MHz clock: • A programmable prescaler in the Clock Prescaler register Divisor field in the CPR register (CPR:DVSR) • A programmable clock rate divisor in this field (SCR) SSPCLK is calculated as follows: SSPCLK = (7.3728 MHz ÷ DVSR) ÷ (1 + SCR) Program this field to the desired eight-bit SCR value in the above equation. The resulting value of SSPCLK must fall in the range of 113.386 Hz < SSPCLK < 3.6864 MHz.
7	SSE	**SSP Enable** Program this bit as follows to enable or disable the SSP: 1 = SSP operation enabled. 0 = SSP operation disabled. **IMPORTANT:** Enable the SSP before programming any other registers.
6	///	**Reserved** Reading this bit returns 0. When writing this register, ensure this bit is 0.
5:4	FRF	**Frame Format** Program this field to specify the frame format: 11 = Undefined. Do not use this value. 10 = National MICROWIRE frame format. 01 = TI synchronous serial frame format. 00 = Motorola SPI frame format.

Table 14-4. CR0 Fields

BITS	FIELD	DESCRIPTION
3:0	DSS	**Data Size Selection** Program this field to specify the data size: 1111 = 16 bits 1110 = 15 bits 1101 = 14 bits 1100 = 13 bits 1011 = 12 bits 1010 = 11 bits 1001 = 10 bits 1000 = 9 bits 0111 = 8 bits 0110 = 7 bits 0101 = 6 bits 0100 = 5 bits 0011 = 4 bits 0010 = Undefined. Do not use this value. 0001 = Undefined. Do not use this value. 0000 = Undefined. Do not use this value. **IMPORTANT:** Because this field is 0000 after reset, software must initially specify a data size. **IMPORTANT:** When FRF = 10, specifying the MICROWIRE format, the Transmit data width is fixed at eight bits and DSS specifies only the Receive data width.

14.2.2.2 Control 1 Register (CR1)

This register, defined in Table 14-5 and Table 14-6, controls the FIFOs, interrupts, and frame specific settings, and enables or disables Loopback mode.

Table 14-5. CR1 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								TXIIEN	FEN	RXOIEN	SPH	SPO	LBM	TXSIEN	RXSIEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0B04															

Table 14-6. CR1 Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. When writing this register, ensure this field is 0.
7	TXIIEN	**Transmitter Idle Interrupt Enable** Program this bit to enable or disable the Transmitter Idle Interrupt (IIR:TXII): 1 = Enables the interrupt. 0 = Disables the interrupt.
6	FEN	**FIFO Enable** Program this bit to configure FIFO or holding register operation: 1 = Enables FIFO operation. Writing the DR writes an entry to an eight entry Transmit FIFO. Reading the DR reads an entry from an eight-entry Receive FIFO. Frame data is received and transmitted via these FIFOs 0 = Disables FIFO operation. Writing the DR writes a single entry holding register. The Transmit Service Request Interrupt (IIR:TXRI) and Transmit FIFO Empty flag (SR:TFE) are set for each frame transmitted. The Receive Service Request Interrupt (IIR:RXRI) and Receive FIFO Full flag (SR:RFF) are set for each frame received
5	RXOIEN	**Receive Overrun Interrupt Enable** Program this bit to enable or disable the Receive Overrun Interrupt (IIR:RXOIE) as follows: 1 = Enables the interrupt. 0 = Disables the interrupt. If the interrupt is asserted, writing a 0 clears the interrupt.
4	SPH	**SPI Phase** Program this bit to specify the Motorola SPI frame format phase: 1 = SSPFRM remains active until the FIFO is empty. 0 = SSPFRM toggles HIGH for one SSPCLK period between each word. See also Figure 14-3 through Figure 14-10 and Table 14-7.
3	SPO	**SPI Polarity** Program this bit to specify the Motorola SPI frame format SSPCLK polarity, as shown in Figure 14-3 through Figure 14-10 and Table 14-7.

Table 14-6. CR1 Fields (Cont'd)

BITS	FIELD	DESCRIPTION
2	LBM	**Loopback Mode** Program this bit to enable or disable Loopback mode: 1 = Enables Loopback mode, internally connecting the Transmit serial shifter output to the Receive serial shifter input 0 = Enables normal serial port operation, disabling Loopback mode
1	TXSIEN	**Transmit FIFO Service Interrupt Enable** Program this bit to enable or disable the Transmit FIFO Service Interrupt (TXSI): 1 = Enables the interrupt. 0 = Disables the interrupt.
0	RXSIEN	**Receive FIFO Service Interrupt Enable** Program this bit to enable or disable the Receive FIFO Service Interrupt (RXSI): 1 = Enables the interrupt. 0 = Disables the interrupt.

Table 14-7. SPO and SPH Definition

SPO	SPH	VALID DATA
1	1	Data is valid on SPCLK rising edge. See Figure 14-7 and Figure 14-10.
1	0	Data is valid on the first SPCLK falling edge after assertion of SSPFRM. See Figure 14-8 and Figure 14-9.
0	1	Data is valid on SPCLK falling edge. See Figure 14-5 and Figure 14-6.
0	0	Data is valid on the first SPCLK rising edge after assertion of SSPFRM. See Figure 14-3 and Figure 14-4.

14.2.2.3 Interrupt Identification Register (IIR)

This register, defined in Table 14-8 and Table 14-9, reports interrupt sources. Do not write to this register.

Table 14-8. IIR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								TXII	RXOI	///				TXSI	RXSI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0B08															

Table 14-9. IIR Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	TXII	**Transmit Idle Interrupt** 1 = Asserted 0 = Deasserted
6	RXOI	**Receive FIFO Overrun Interrupt** 1 = Asserted 0 = Deasserted
5:2	///	**Reserved** Reading this field returns 0.
1	TXSI	**Transmit FIFO Service Request Interrupt** 1 = Asserted 0 = Deasserted
0	RXSI	**Receive FIFO Service Request Interrupt** 1 = Asserted 0 = Deasserted

14.2.2.4 Receive Overrun End-of-Interrupt Register (RXEOI)

Writing any value to this register, described in Table 14-10 and Table 14-11, clears the Receive Overrun Interrupt (IIR:RXOI). Values written to this register cannot be read back.

Table 14-10. RXEOI Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	RXEOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RXEOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0B08															

Table 14-11. SSPIIR and SSPICR Fields

BITS	FIELD	DESCRIPTION
31:0	RXEOI	**End-of-Interrupt** Write any value to this field to clear IIR:RXOI. Reading this field returns 0.

14.2.2.5 Data Register (DR)

This register, described in Table 14-12 and Table 14-13, is used for reading received data and writing data for transmission.

Table 14-12. DR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW																
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0B0C															

Table 14-13. DR Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:0	DATA	**Data** • Writing this field puts data for transmission into the Transmit FIFO or holding register. For data shorter than 16 bits, software must justify the data into the least significant bits of the field. • Reading this field reads received data from the Receive FIFO or holding register. Data shorter than 16 bits is automatically justified into the least significant bits of the field.

NOTE: When operating in TI mode with SSP word size less than 16 bits, all unused bits through bit 15 must be masked by software as they will contain undefined values.

14.2.2.6 Clock Prescale Register (CPR)

This register, defined in Table 14-14 and Table 14-15, specifies the SSPCLK divisor.

The divisor must be an even number between 2 and 254. The least significant bit of this number is automatically 0. When an odd number is written to this register, the least significant bit of the data read back is 0.

Table 14-14. CPR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								DVSR							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RO
ADDR	0x8000.0B10															

Table 14-15. CPR Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written cannot be read.
7:0	DVSR	**Clock Prescale Divisor** To generate the bit rate and Serial Clock output (SSPCLK), the SSP uses two divisors on the generated 7.3728 MHz clock: • This programmable prescaler in the Clock Prescaler register Divisor field • A programmable clock rate divisor in the CP0 register (CP0:SCR) SSPCLK is calculated as follows: SSPCLK = (7.3728 MHz ÷ (CPR:DVSR)) ÷ (1 + (CP0:SCR)) Program this field to the desired eight-bit value for DVSR in the above equation. The resulting value for SSPCLK must fall in the range of 113.386 Hz < SSPCLK < 3.6864 MHz.

14.2.2.7 SSP Status Register (SR)

This register, defined in Table 14-16 and Table 14-17, shows the FIFO fill status and the SSP busy status. Do not write to this register. Status is not reported unless the SSP is enabled.

Table 14-16. SR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///							RFF	TFE	ROR	RHF	THE	BSY	RNE	TNF	///
RESET	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0B14															

Table 14-17. SR Register description

BITS	FIELD	DESCRIPTION
31:9	///	**Reserved** Reading this field returns 0.
8	RFF	Receive FIFO Full Reports the Receive FIFO or holding register status: 1 = Receive FIFO is full. With FIFOs disabled, this value indicates the Receive holding register contains data. 0 = Receive FIFO is not full. With FIFOs disabled, this value indicates the Receive holding register contains no data.
7	TFE	**Transmit FIFO Empty** Reports the Transmit FIFO or holding register status: 1 = Transmit FIFO is empty. With FIFOs disabled, this value indicates the Transmit holding register contains no data. 0 = Transmit FIFO is not empty. With FIFOs disabled, this value indicates the Transmit holding register contains data.
6	ROR	**Receive Overrun** Reports the Receive FIFO Overrun status: 1 = The Receive FIFO Overrun Interrupt (RXOI) asserted. 0 = The Receive FIFO Overrun Interrupt (RXOI) deasserted.
5	RHF	**Receive FIFO Half Full** Reports the Receive FIFO watermark status: 1 = The Receive FIFO contains 4 or more entries. With FIFOs disabled, this value indicates the Receive holding register contains data. 0 = The Receive FIFO contains 3 or fewer entries. With FIFOs disabled, this value indicates the Receive holding register contains no valid data.
4	THE	**Transmit FIFO Half Empty** Reports the Transmit FIFO watermark status and SSP status: 1 = The Transmit FIFO has 4 or fewer entries, and the SSP is enabled. With FIFOs disabled, this value indicates the Transmit holding register is empty. 0 = The Transmit FIFO has 5 or more entries, or the SSP is disabled.
3	BSY	**Busy** Reports the Receive or Transmit activity status: 1 = SSP is currently transmitting or receiving a frame, or the transmit FIFO is not empty. 0 = SSP is idle.
2	RNE	**Receive FIFO Not Empty** Reports the Receive FIFO or holding register status: 1 = The Receive FIFO or holding register contains data. 0 = The Receive FIFO or holding register is empty.
1	TNF	**Transmit FIFO Not Full** Reports the Transmit FIFO or holding register status: 1 = The Transmit FIFO is not full or the holding register is empty. 0 = The Transmit FIFO is full or the holding register contains data.
0	///	**Reserved** Reading this field returns 0. Values written cannot be read.

Chapter 15
Universal Asynchronous Receiver/Transmitter (UART)

15.1 Theory of Operation

The LH7A400's three UARTs provide the interface between parallel data inside the MCU and asynchronous serial data on a peripheral. The UARTs implement signals to facilitate use as a modem and serial infrared (SIR) transceiver. Features include:

- Selectable data rates between 2,400 and 460,800 bits per second (bit/s)
- Parity checking
- Selectable signal polarity
- Break recognition and generation
- Flow control
- Receive and transmit buffers configurable for single character holding, or as 16-character FIFOs
- High and low watermark interrupts for the FIFOs.

15.1.1 UART Overview

UART1, shown in Figure 15-1, supports wired serial communications and implements infrared communication protocol, supporting a digital encoded output and decoded input with no analog processing. UART2 and UART3, shown in Figure 15-2 and Figure 15-3, support serial transmission and reception and implement modem communication with external support circuitry.

Each UART has dedicated registers for data, control, and status. The register and bit field structure is identical for all UARTs. Because infrared operation is unavailable in UART2 and UART3, the control and status fields corresponding to infrared operation are reserved in the UART2 and UART3 registers.

Each UART FIFO is configurable either as a 16-entry FIFO, or as a holding register with a capacity of a single data entry. For transmission, parallel data is written to the Data register (DATA), then transferred to the transmit FIFO and loaded to the shift register (as it becomes empty) for serial output. For reception, serial data is loaded into the shift register until a complete data frame has been received (see Section 15.1.1.1 for a definition of data frames). Then, the parallel data frame is loaded into the receive FIFO. The FIFO places the frame into DATA along with status information about each received data frame.

UART1 uses a single DATA register, but routes data to the infrared pins or wired serial communication pins, depending on its configuration. Signals are ignored on pins not configured.

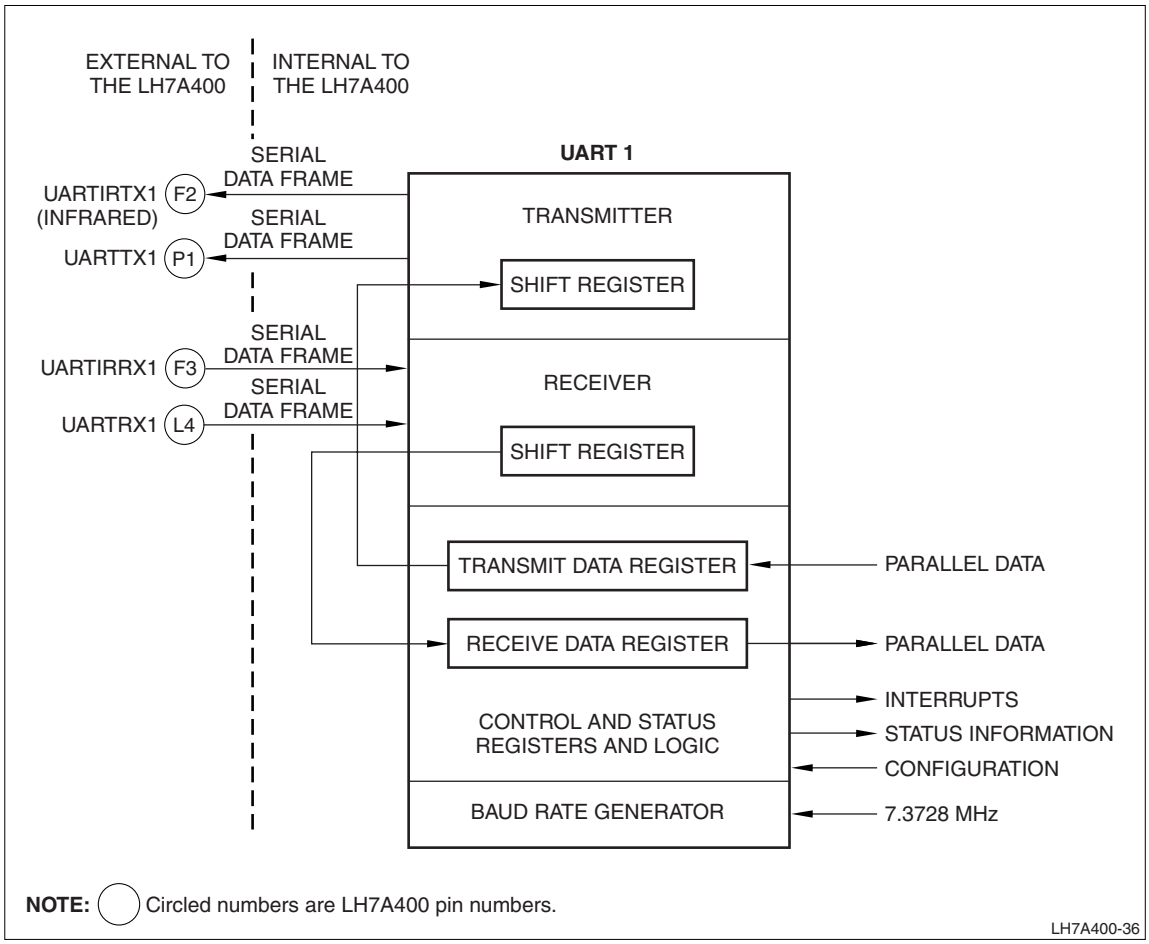


Figure 15-1. UART1 Block Diagram

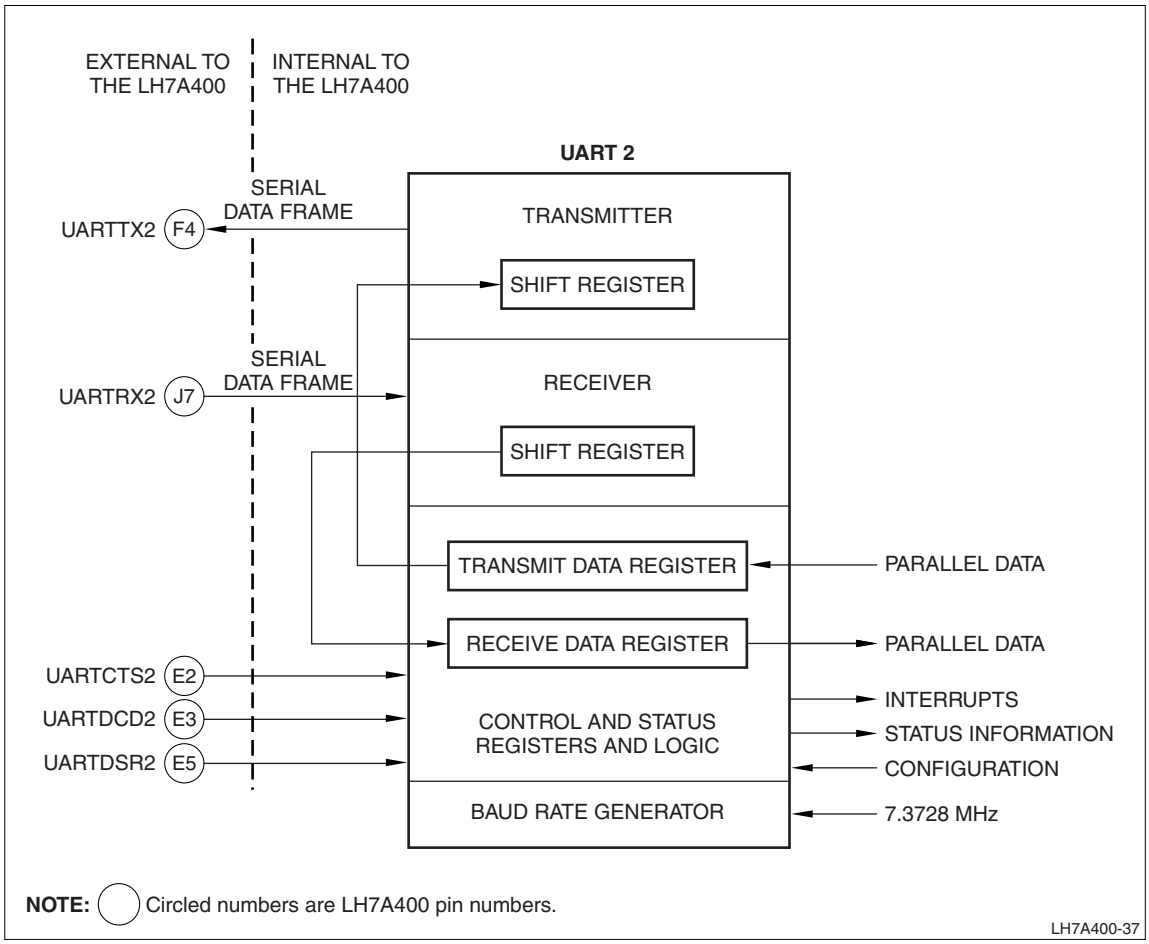


Figure 15-2. UART2 Modem Operation

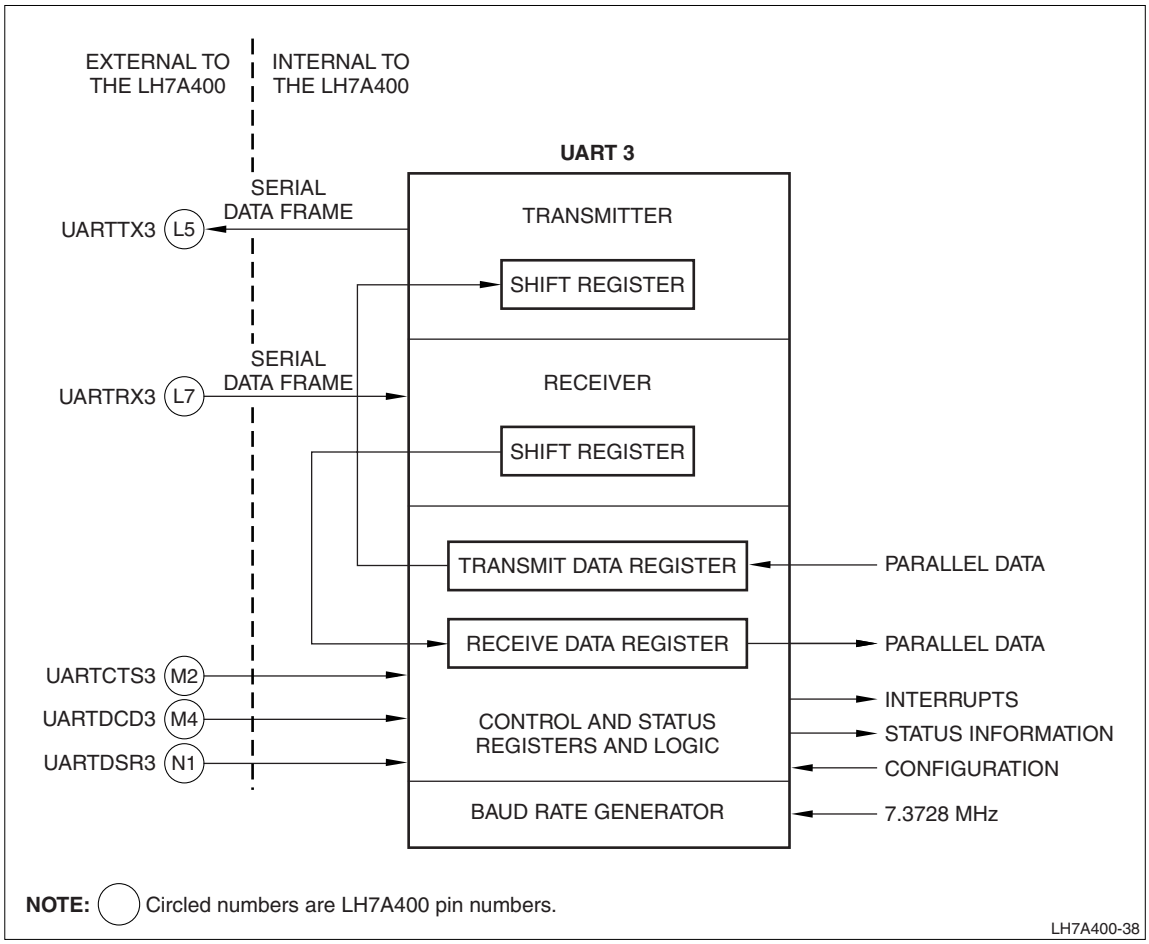


Figure 15-3. UART3 Modem Operation

15.1.1.1 Data Protocol

Serial data is assembled as 'frames' for parallel use. The UART data frames can be programmed to contain five to eight data bits. Each frame begins with a Start bit and ends with one or two Stop bits. During reception, a shift register accumulates the serial data until a complete frame is received, then transfers the frame to the receive FIFO. For transmission, parallel data frames are loaded from the transmit FIFO to the shift register, then serially shifted to the output.

Received data frames arrive on the input pins least-significant bit first. Transmitted data frames leave the output pins least significant bit first. A data frame consists of the following bit sequence, as shown in Figure 15-4:

- One start bit
- Five to eight data bits, as specified in the UART Control register (CON)
- One parity bit, as specified in CON
- One or two stop bits, as specified in CON.

The UART logic removes Start, Stop, and Parity bits and places the data bits into DATA. The UART adds the transmitted framing (start and stop) and parity bits to the output stream, and sets reception status bits in DATA.

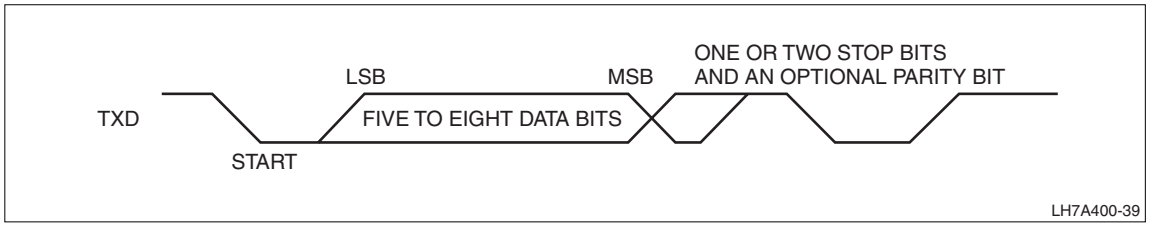


Figure 15-4. UART Data Frame

Each UART has a CON, which software can program to cause the UART to:

- Enable and disable each UART
- Enable and disable FIFO operation for each UART
- Select the signal polarity, data size, parity, and stop bits for each UART
- Specify the baud rate for each UART
- Send a break
- Enable, disable, and configure UART1 infrared operation
- Enable and disable loopback mode for each UART
- Enable and disable individual interrupts for each UART, including UART2 and UART3 status pin inputs.

Status (STATUS) and Interrupt registers (RAWISR and ISR), and some fields in DATA provide information regarding:

- The presence of data in a FIFO or holding register
- Whether the FIFO has exceeded the half-empty (for receive operation) or half-full (for transmit operation) point
- Framing and parity errors in received data
- Signals on UART2 and UART3 modem status inputs
- A received break condition
- Timeout and overflow conditions.

Each UART combines enabled individual interrupts into a single interrupt to be handled by the LH7A400 Interrupt Controller.

15.1.1.2 Operation Summary

All communication between software and the UART blocks takes place through the register set. Use of the register set is described in the detailed operational section of this chapter, and register programming tables appear in the last part of this chapter.

At power up, software must program the configuration parameters for the UARTs that the system will use. Once configured, software can then enable each of the configured UARTs. Once the UARTs are enabled, they can begin receiving and transmitting data.

15.1.1.2.1 Receive Summary

Serial data is received on the UARTRXx or UARTIRRx pins. The data is loaded into the UART's shift register until a complete data frame is received. Once the data frame is complete, it is moved to the FIFO and the shift register can immediately begin shifting in the next data frame. The FIFO can be programmed to receive a single frame at a time (by disabling the FIFO) or to receive multiple frames (by enabling the FIFO). Software can become aware of received data via either polling or interrupts.

To use polling, software reads STATUS at programmed intervals to determine if the FIFO has any data to be read. Two bits, Receive FIFO Empty (RXFE) and Receive FIFO Full (RXFF), report to software whether data is ready to be read. With data present, software reads DATA then polls STATUS repeatedly, until the RXFE is 1, indicating that all valid FIFO data has been read.

For an interrupt driven system, software must first enable interrupts by writing to the Interrupt Enable register (INTEN). The UART begins receiving data and filling the FIFO. When the FIFO exceeds half full (eight entries), the Receive Interrupt (RI) is set. The interrupt service routine can read the Interrupt Status Register (ISR) to determine that RI is set, and then begin reading data from DATA.

Overrun errors (data received when the FIFO is already full), Break errors (break in data stream), Parity errors (invalid received data), Framing errors (no Stop bit detected) are all posted in DATA so that software can immediately deal with an error condition upon reading the erroneous data. Receive timeout errors (at least one unread data character in DATA and no further data has appeared for a 32-clock cycle period) generate an interrupt.

15.1.1.2.2 Transmit Summary

Software writes a complete parallel data frame to DATA. Immediately upon the data frame being written, the UART loads the frame into its transmit FIFO. If the FIFO was empty prior to loading the data frame, the UART immediately moves it to the shift register, appends Start and Stop bits, generates parity, if enabled and sets the BUSY bit to 1. Then, data transmission begins on the UARTTXx or UARTIRTX pin. As with receiving, software can program either polling or interrupt operation for transmit. Also, the FIFO can be set up for single-frame operation (by disabling the FIFO) or FIFO operations (by enabling the FIFO).

For polling operation, software reads STATUS to determine if the FIFO has room. STATUS contains the Transmit FIFO Empty (TXFE) and Transmit FIFO Full (TXFF) bits for software to determine the FIFO condition. As long as TXFF is not 1, software can continue loading data frames into DATA. If the UART is programmed for single frame operation, the Busy bit in STATUS indicates that the character has not finished transmission.

For an interrupt driven system, software must first enable interrupts by writing to INTEN. Software continues to write to DATA until the Transmit Interrupt is asserted, indicating that the FIFO has exceeded half full, or if in single character mode, that the previous character has been sent and the shift register is empty.

15.1.1.2.3 Modem Summary

UART2 and UART3 can, with external circuitry, implement a modem. The state of each of the three modem inputs, DCD, DSR, and CTS, can be read by software from STATUS. Software can then use these signals to implement modem communications.

15.1.1.2.4 Loopback Summary

Each of the UARTs can be set to loopback mode for testing. In loopback mode, the UART routes its transmit signal directly to the receive input, allowing software to send test characters through the UART.

The next sections describe UART operation in detail.

15.1.2 Configuring the UARTs

This section discusses UART configuration affecting both the receive and transmit operations. UARTs must be enabled prior to writing the corresponding Control and Configuration registers to avoid generating spurious interrupts. See Section 15.1.5.

15.1.2.1 Selecting FIFO or Non-FIFO Operation

Each FIFO is configurable as a 16-frame FIFO or as a single character holding register.

To enable 16-character FIFO operation, program the UART FIFO Control register (FCON) FIFO Enable bit (FCON:FEN) to 1. Programming this bit to 0 disables FIFO operation, configuring the FIFO as a single character holding register.

15.1.2.2 Specifying the Data Size

The data character occupies the least significant five, six, seven, or eight bits of each DATA Data field (DATA:D). To specify the character size in bits, write the FIFO and Framing Control Register (FCON) Word Length field (FCON:WLEN) as shown in Table 15-1.

Table 15-1. Data Size and Location

FCON:WLEN VALUE	DATA SIZE	DATA BIT POSITIONS
11	8 bits	DATA[7:0]
10	7 bits	DATA[6:0]
01	6 bits	DATA[5:0]
00	5 bits	DATA[4:0]

15.1.2.3 Enabling and Specifying Parity

Parity type can be selected as either even or odd. When parity is enabled, an additional bit is appended to the data frame. This bit is either a 1 or 0, so that the sum of the individual frame bits will result in an even or odd number, as required by the selected parity type. With parity enabled and specified, the UART checks received data for even or odd parity and transmits data with even or odd parity.

1. To enable parity operations, program the FCON Parity Enable bit (FCON:PEN) to 1.
2. To specify even parity, program the Even Parity Select bit (FCON:EPS) to 1. To specify odd parity, program this bit to 0.

15.1.2.4 Specifying the Baud Rate

The baud rate for each UART applies to both the receive and transmit operations. Baud rate is generated by dividing the UART reference clock by a programmed divisor. To specify a baud rate for a UART, program a divisor to the Baud Rate Control Register (BRCON) Baud Divisor field (BRCON:BAUDDIV). The UART reference clock is the LH7A400 external input clock divided by 2, which is 7.3728 MHz. Calculate BAUDDIV using BAUD in bits per second (bit/s):

$$BAUDDIV = (7372800 \div (16 \times BAUD)) - 1$$

Table 15-2 shows some example baud rates and the corresponding divisors to be programmed into UBRCON:BAUDDIV.

For infrared operation, the transmitted pulse is 3/16 the duration of the baud rate, as shown in Figure 15-5.

Table 15-2. Example Baud Rates and BAUDDIV Values

BAUDDIV	BAUD (BITS PER SECOND)
0xBF	2,400
0x5F	4,800
0x2F	9,600
0x17	19,200
0x0F	28,800
0x0B	38,400
0x07	57,600
0x05	76,800
0x03	115,200
0x02	153,600
0x01	230,400
0x00	460,800

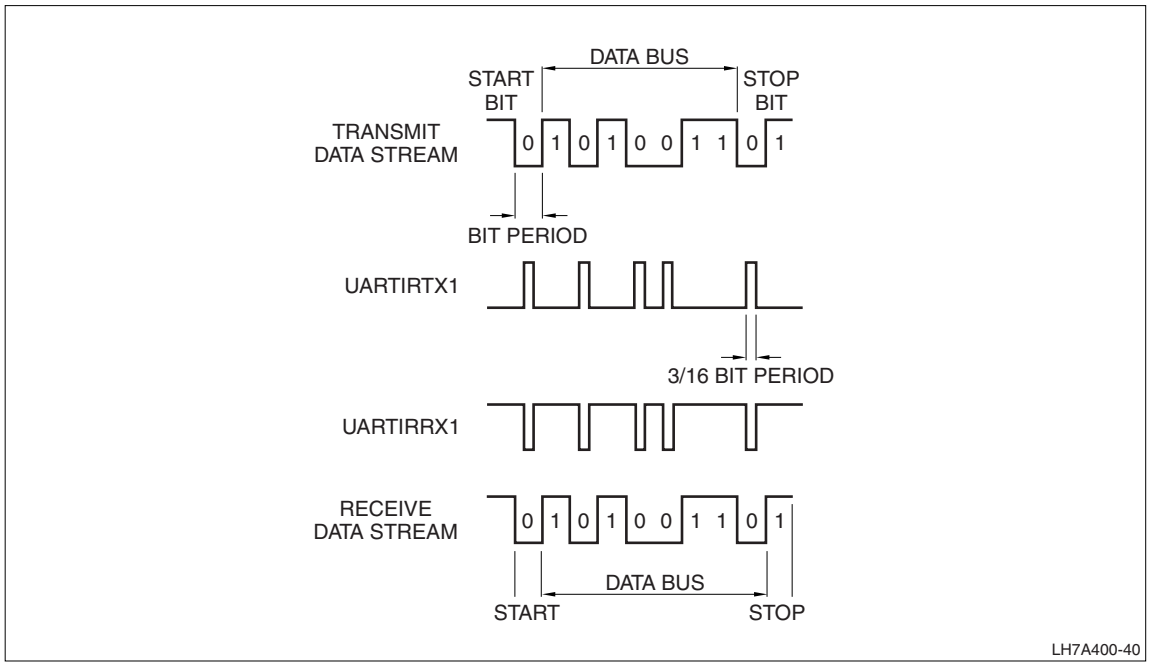


Figure 15-5. Infrared Pulse Timing

15.1.2.5 Setting Low Power Mode for Infrared Operation

For low power operation, program the UART Control Register (CON) Serial Infrared Low Power bit (CON:SIRLP) to 1. Program this bit to 0 for normal power.

15.1.2.6 Selecting Signal Polarity

The UARTs can send and receive data as active HIGH, that is, a 1 data value corresponding to a HIGH level signal; or as active LOW, that is, a 1 data value corresponding to a LOW level signal. The polarity of the modem control signals, DTS, DCD, and DSR, can also be programmed.

To specify polarity, program the CON Modem Transfer Polarity, Transmit Polarity, and Receive Polarity bits (CON:MXP, CON:TXP, and CON:RXP):

- The three modem signals, DTS, DCD, and DSR are configured using the MXP bit in CON. The signals are all active HIGH or active LOW, based on this bit, and cannot be individually configured. These signals are configured active HIGH by programming MXP to 1, and active LOW by programming MXP to 0.
- UART Transmit Polarity is specified with the TXP bit in CON. For active LOW transmission, program TXP to 1. For active HIGH transmission, program this bit to 0.
- UART Receive Polarity is specified with the RXP bit in CON. For active LOW reception, program RXP to 1. For active HIGH reception, program this bit to 0.

15.1.2.7 Configuring the UART3 Multiplexed Pins

The UART3 pins are multiplexed with the General Purpose Input and Output (GPIO) Port B pins. These pins must be configured prior to using UART3 by programming the GPIO Pin Multiplexing (PINMUX) register. To use the pins for UART3, program the PINMUX UART3 Configuration bit (PINMUX:UART3CON) to 1. This register is mapped in GPIO memory, at 0x8000.0E2C. If this bit is not programmed to 1, the pins function as GPIO. See the GPIO chapter for more information on PINMUX.

15.1.2.8 Configuring UART1 for Infrared Operation

To enable infrared operation, program the CON register Serial Infrared Disable bit (CON:SIRD) to 0. To disable infrared operation, program this bit to 1.

15.1.2.9 Managing the Receive Operation

This section discusses configuring the UARTs for the receive operation. Data reception follows this order:

1. Input from the pin is serially loaded into the shift register until a complete frame is received, then the parallel frame is moved to the receive FIFO.
2. The UART checks for correct framing and parity and for a break value. If correct, the UART continues; if an error is detected, the proper error bit or interrupt is set.
3. The UART stores the data in the Receive FIFO and asserts any relevant interrupts.
4. The oldest received frame is moved, along with its status bits, to DATA after software has read the previous value.

15.1.2.10 UART Input Pins

The UART input pins are:

- UARTRX1 (pin L4) is used for wired serial operation. For non-infrared operation, UART1 ignores any UARTIRRX1 input.
- UARTIRRX1 (pin F3) is the infrared reception pin. If enabled, input to UARTRXD1 is ignored.
- UARTRX2 (pin J7) for UART2.
- UARTRX3 (pin L7) for UART 3.

15.1.2.11 Framing

The UART recognizes the beginning of a frame by a Start bit. When the input signal is in Marking state (continuously sending 1 values), a 1 to 0 transition starts a counter based on the programmed baud rate (see Section 15.1.2.4) (Note that the signal polarity for 1 and 0 is programmable to active HIGH or active LOW). The counter alternately drives the baud clock 1 and 0 for half-period lengths defined by the time the counter takes to count down to zero. It is then reloaded and restarts another half cycle. A 0 input during the eighth counter cycle confirms a Start bit. An 1 input on the eighth cycle indicates a False Start and a return to Marking state.

After a confirmed Start bit, the UART samples data on the 8th counter cycle (half way through a bit period). The length of the frame depends on the data size.

At the end of a frame, the UART checks for one Stop bit and ignores any additional Stop bits. A missing Stop bit causes a framing error, setting to 1 the DATA Framing Error bit (DATA:FE) associated with the data containing the framing error. Reading the associated data in DATA clears the framing error bit to 0.

15.1.2.12 Data Handling

The UARTs generate interrupts or post status data indicating:

- The presence or absence of data in the Receive FIFO
- Whether the receive FIFO has exceeded half full
- An overrun (data received with a full FIFO)
- A timeout situation (data not received within one frame-time of a Start bit).

When unread data is available, the UART Receive Interrupt (RI) indicates either:

- The FIFO is half full; that is, the FIFO contains eight of the maximum possible 16 data frames. The interrupt is cleared when the FIFO contains no more than seven unread frames, and re-set whenever the FIFO becomes half-full again.
- The FIFO is disabled and contains an entry. Reading the entry clears the interrupt.

The Receive Interrupt appears in the UART Raw Interrupt register Receive Interrupt bit (RAWISR:RI). When enabled, RI also appears in the Interrupt Status register RI bit (ISR:RI). To enable RI, program the Interrupt Enable register bit (INTEN:RI) to 1. To disable this interrupt, program INTEN:RI to 0.

The UART Status register Receive FIFO Full field (STATUS:RXFF) indicates the FIFO is full. Receiving additional data causes an overrun, and the UART:

- Preserves the DATA contents. Any subsequent data on the input overwrites the shift register. No additional data is moved from the shift register to the FIFO until the overrun error is cleared.
- Reports the overrun error by setting the DATA Overrun Error bit (DATA:OE) corresponding to the most recently received data, to 1.

Reading DATA clears the overrun error. The UART resumes moving data from the shift register into the FIFO as soon as a complete frame has been received in the shift register.

The UART Receive Timeout Interrupt (RTI) indicates at least one unread data frame is in the FIFO and no further data has appeared for a 32-clock cycle period. UARTINTR appears in the RAWISR Receive Timeout Interrupt field (RAWISR:RTI). When enabled, UARTINTR also appears in ISR:RTI. To enable UARTINTR, set INTEN:RTI. To disable this interrupt, clear INTEN:RTI. Reading DATA clears RTI.

The STATUS Receive FIFO Empty bit (STATUS:RXFE) indicates the FIFO is empty.

Disabling the UART stops reception on the subsequent frame boundary. Disabling the UART gates-off the baud clock used for data transmission and reception. The UART need not be enabled for software to read DATA. Programming UART registers with the UART disabled can cause unpredictable operation.

15.1.2.13 Checking Parity

With parity enabled and specified, a mismatch between the parity of the received data and the specified parity selection causes a parity error. The UART reports a parity error by setting the DATA Parity Error field (DATA:PE) associated with the data containing the parity error to 1. Reading the associated data clears the parity error bit to 0. See Section 15.1.2.3.

15.1.2.14 Identifying a Break

A break occurs when the input signal is deasserted for longer than the period required to receive a complete frame. For a break condition, the UART:

- Stores a single data character, with all bits 0
- Sets the DATA Break Error field (DATA:BE) associated with this character to 1
- Stores no more data until the input pin goes to the marking state and a valid start bit is confirmed.

15.1.3 Managing the Transmit Operation

This section discusses configuring the UARTs for the transmit operation.

15.1.3.1 Configuring the Output Pins

The output pins are:

- UARTTX1 (pin P1) for wired serial operation.
- UARTIRTX1 (pin F2) for UART1 infrared operation. For infrared operation, UARTTX1 is held in the 1 state. See Section 15.1.2.4.
- UARTTX2 (pin F4) for UART2 operation
- UARTTX3 (pin L5) for UART3 operation.

Standby and Idle modes force the transmission outputs to inactive states. The inactive state of each UART depends on whether polarity inversion is in effect for the UART. See Section 15.1.2.6.

15.1.3.2 Framing and Generating Parity

The UART inserts a leading Start bit, and appends any required Parity bit, and one or two Stop bits in the output shift register. To send two Stop bits, program the FCON Stop 2 bit (FCON:STP2) to 1. To send one Stop bit, program this bit to 0.

15.1.3.3 Entering a Break State

When this bit is programmed to 1, a LOW is continually output on the UARTTXx pin, following the completion of any character that is currently being sent. FCON:BRK must remain 1 for at least one complete frame transmission period to generate a Break condition.

To stop the Break, program FCON:BRK to 0: the UART resumes transmission from the FIFO. The Break state has no effect on the FIFO contents.

15.1.3.4 Handling the Data

Data to be transmitted is written to the DATA register. DATA contents are loaded into the FIFO, and as soon as a complete frame has been loaded to the FIFO, the UART transfers that frame to the shift register and serial transmission commences. Data continues to be transmitted until there is no data left in the transmit FIFO.

The Busy signal goes HIGH as soon as data is written to the transmit FIFO (that is, the FIFO is non-empty) and remains HIGH while data is being transmitted. Busy is automatically negated when the transmit FIFO becomes empty and the last character has been transmitted from the shift register, including the Stop bit(s). Busy may be HIGH even though the UART may not be enabled, if data remains in the shift register.

Specific interrupt and status values indicate:

- If the UART is transmitting a data frame
- Whether the FIFO is empty
- Whether the transmit FIFO is less than half full.

The Transmit Interrupt (TI) indicates either:

- The FIFOs are enabled and the transmit FIFO is at least half-empty (it has space for eight or more entries), the transmit interrupt is set to 1. The interrupt is cleared when the transmit FIFO is filled to more than half full.
- FIFO operation is disabled and it is empty. Writing to DATA clears the interrupt.

If no more data is to be transmitted, TI should be disabled to avoid erroneous servicing.

The TI bit appears in the Raw Transmit Interrupt Status register (RAWISR:TI). To enable TI, program INTEN:TI to 1. To disable this interrupt, program INTEN:TI to 0. When enabled, TI also appears in ISR:TI.

When the transmit FIFO is empty and the UART remains enabled:

- The UART asserts the output signal HIGH
- The UART sets the STATUS Transmit FIFO Empty bit (STATUS:TXFE) to 1. Writing to DATA clears this bit.

When the FIFO is full, the UART sets the STATUS Transmit FIFO Full bit (STATUS:TXFF) to 1. This bit is cleared to 0 automatically when at least one empty entry exists in the transmit FIFO.

Note that the error flags in UART 1, 2, and 3 (bits [11:8] in Data register0 are not cleared by reading the DATA register, but cleared when a new character is received.

15.1.4 Using the External Modem Control Signals

Any input on a UART2 or UART3 modem status pin appears in a corresponding bit in the STATUS status register, as shown in Table 15-3. For UART1, these STATUS bits are undefined.

State changes on modem status pins assert the UART Modem Status Interrupt (MI). This interrupt appears in the RAWISR Modem Interrupt bit (RAWISR:MI). To enable this interrupt, program INTEN:MI to 1. To disable this interrupt, program INTEN:MI to 0. When enabled, MI also appears in ISR:MI. To clear MI, write the RAWISR Modem Status End-of-Interrupt field (RAWISR:MSEOI). Writing any 28-bit value to RAWISR:MSEOI clears only RAWISR:MI.

No modem status signals are available for UART1 operation. Use GPIO inputs to implement modem control. The following fields are unused in UART1 registers:

- The STATUS Data Carrier Detect, Data Set Ready, and Clear-to-Send fields (STATUS:DCD, STATUS:DSR, and STATUS:CTS)
- RAWISR:MI, INTEN:MI, and ISR:MI

Table 15-3. Modem Status Inputs

SIGNAL NAME	DESCRIPTION	UART2 PIN	UART3 PIN
DCD	Data carrier detect	E3	M4
DSR	Data set ready	E5	N1
CTS	Clear to send	E2	M2

15.1.5 Configuring and Handling Interrupts

Each UART can send a single, combined interrupt to the LH7A400 interrupt controller, representing one or more of the following interrupts:

- Receive Timeout Interrupt (RTI)
- Modem Status Interrupt (MI)
- Transmit Interrupt (TI)
- Receive Interrupt (RI).

When configuring each UART, program INTEN to enable and disable the interrupts used for generating the combined interrupt. Programming a bit in INTEN to 1 enables the corresponding interrupt. Programming a bit to 0 disables the corresponding interrupt.

Note that the error flags in UART 1, 2, and 3 (bits [11:8] in Data register) are not cleared by reading the DATA register, but cleared when a new character is received.

When the combined UARTx Interrupt (UARTxINT) is asserted, software can read ISR to identify all interrupt sources. The ISR is a logical bitwise-AND of RAWISR and INTEN:

ISR:RTI = RAWISR:RTI <AND> INTEN:RTI

ISR:MI = RAWISR:MI <AND> INTEN:MI

ISR:TI = RAWISR:TI <AND> INTEN:TI

ISR:RI = RAWISR:RI AND INTEN:RI

UARTx generates UARTxINT from ISR. (Where the x is 1, 2, or 3, corresponding to UART1, UART2, or UART3):

UARTxINT = ISR:RTI <OR> ISR:MI <OR> ISR:TI <OR> ISR:RI

UART1INT is generated from RTI, RI, and TI, as shown in Figure 15-6, because no Modem Status Interrupts are available. UART2INT and UART3INT are generated from the RTI, RI, TI, and MI, as shown in Figure 15-7.

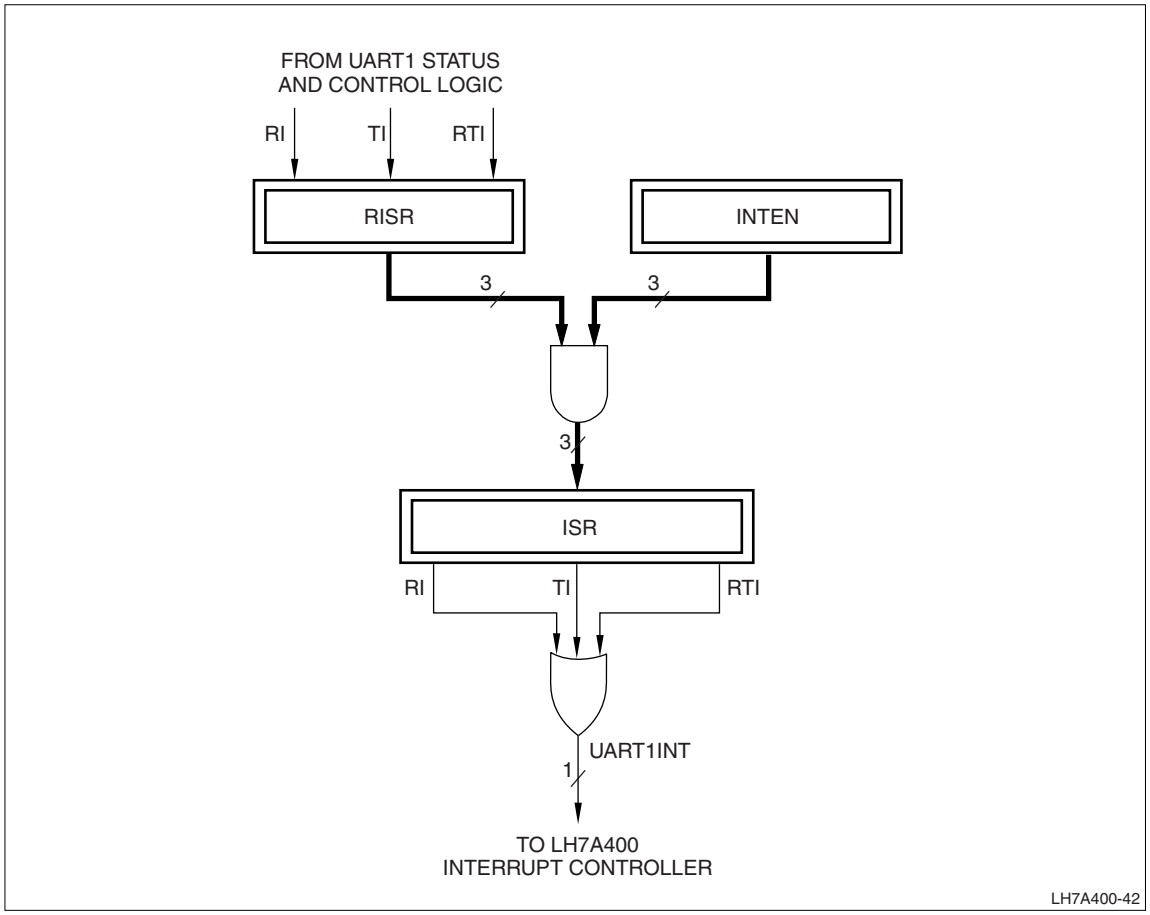


Figure 15-6. UART1 Interrupt Generation

To avoid spurious interrupts when configuring and enabling each UART:

1. Program the Interrupt Controller Interrupt Enable Set register UARTx Interrupt bits (ITENS:UARTxINTR) to disable the combined interrupt.
2. Program all interrupt bits in INTEN to 0 disable the corresponding UART interrupts.
3. Program CON:UARTEN to 1 to enable UARTx.
4. Do NOT enable any UART interrupts until the entire interrupt handler chain has been initialized, including the installation of any UART handlers.
5. Clear all UARTx interrupts:
   a. Read UARTxDATA until the FIFO is empty.
   b. For UART2 or UART3, clear the modem status interrupts.
6. Configure UARTx. Program any bits in INTEN to 1 to enable the corresponding interrupt as the final step in configuration. Enabling TI can cause an immediate, spurious Transmit Interrupt.
7. Program the corresponding Interrupt Controller ITENS:UARTxINTR to enable the UARTx combined interrupt.

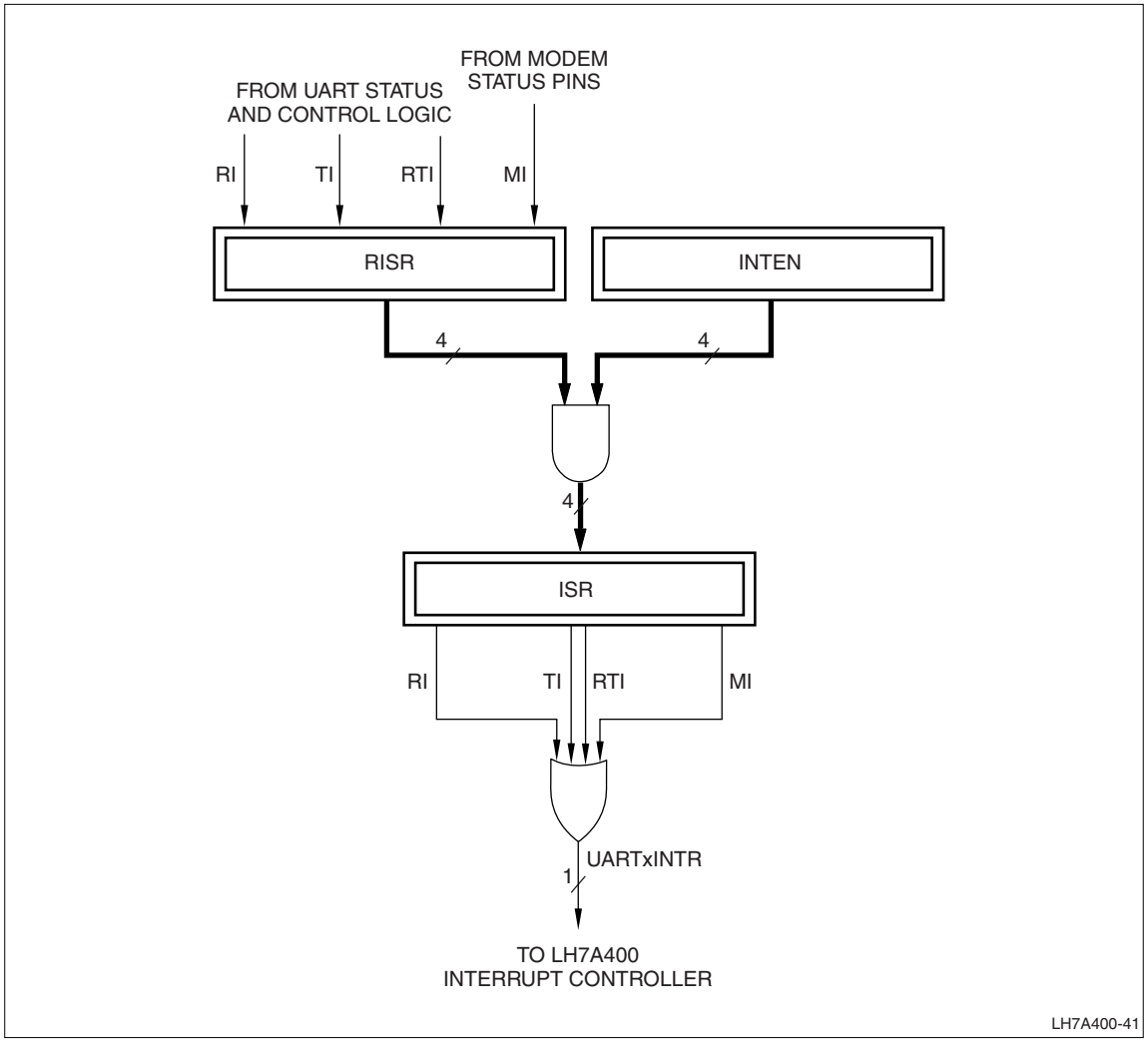


Figure 15-7. UART2 or UART3 Interrupt Generation

15.1.6 Configuring Loopback Mode

To test transmission and reception, use Loopback mode. Configure UARTTX as the input for UARTRX, and UARTIRTX1 as the input for UARTIRRX1, by setting the CON Loopback Enable field (CON:LBE). Clear this field for normal UART operation.

No isolation mechanism in the hardware prevents loopback transmission from interfering with reception. Therefore, isolation is provided by enabling receiver blanking. When using UART1 in Loopback mode with infrared operation enabled, disable the receiver blanking by programming the CON Serial Infrared Blanking Disable bit (CON:SIRBD) to 1. Program this bit to 0 to enable receiver blanking.

15.2 Register Reference

This section describes the registers used in UART operation.

15.2.1 Memory Map

The UART base addresses are:

- UART1 UARTBASE = 0x8000.0600
- UART2 UARTBASE = 0x8000.0700
- UART3 UARTBASE = 0x8000.0800

The offsets for the registers shown in Table 15-4, and in the individual register descriptions in the following sections, are relative to each UARTx base address.

Table 15-4. UART Register Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	DATA	Data Register
0x04	FCON	FIFO Control Register
0x08	BRCON	Baud Rate Control Register
0x0C	CON	Control Register
0x10	STATUS	Status Register
0x14	RAWISR	Raw Interrupt Status Register
0x18	INTEN	Interrupt Mask Register
0x1C	ISR	Interrupt Status Register
0x20 - 0xFF	///	Reserved. Avoid reading or writing these locations.

15.2.2 Register Descriptions

The following sections describe the contents and use of the register bit fields.

15.2.2.1 Data Register (DATA)

This register, defined in Table 15-5 and Table 15-6, contains:

- Received data and corresponding status information.
- Data to be transmitted.

Note that the error flags in UART 1, 2, and 3 (bits [11:8] in Data register) are not cleared by reading DATA register, but cleared when a new character is received. In addition, the error flags do not generate an interrupt, and must be interpreted along with the data when the DATA register is read.

Table 15-5. DATA Register as Used for Receive Operation

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				BE	OE	PE	FE	D7	D6	D5	D4	D3	D2	D1	D0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	UARTBase + 0x00															

Table 15-6. DATA Register as Used for Transmit Operation

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								D7	D6	D5	D4	D3	D2	D1	D0
RESET	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	UARTBase + 0x00															

Table 15-7. DATA Fields

BITS	FIELD	DESCRIPTION
31:12 When Read	///	**Reserved** Reading this field returns 0.
31:8 When Written	///	**Reserved** Values written to this field cannot be read back.
11	BE	**Break Error** A break occurs when the input signal is deasserted for longer than the period required to receive a complete frame. 1 = The UART has detected a break. The data character in D[7:0] is all zeroes. Values written to this field cannot be read back. 0 = No break detected.
10	OE	**Overrun Error** 1 = An overrun error has occurred; that is, a data character has arrived with the receive FIFO already full. Subsequent input overwrites the shift register. Reading DATA moves the next data character from the shift register into the FIFO. 0 = No overrun error. Values written to this field cannot be read back.
9	PE	**Parity Error** 1 = A parity error has occurred; that is, FCON1 is set, enabling parity, and the data character does not match the parity specified in FCON2. 0 = No parity error. Values written to this field cannot be read back.
8	FE	**Framing Error** 1 = A framing error has occurred; that is, the UART did not detect a stop bit at the end of the received data character. 0 = No parity error. Values written to this field cannot be read back.
7:0	D[7:0]	**Data** For receive operations, this field contains the received data character. Once this field is read, the data can be overwritten by subsequent data from the shift register; however, the data remains until overwritten. For transmit operations, write the data to be transmitted to this field.

15.2.2.2 FIFO and Framing Control Register (FCON)

This register, defined in Table 15-8 and Table 15-9, contains the configuration information for the received and transmitted data:

- Specifies the data length.
- Enables or disables FIFO operation.
- Configures framing.
- Sends a break.

Table 15-8. FCON Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET																
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD										WLEN		FEN	STP2	EPS	PEN	BRK
RESET										0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW
ADDR	UARTBase + 0x04															

Table 15-9. FCON Fields

BITS	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading returns 0. Values written cannot be read.
6:5	WLEN	**Word Length** Specifies or reports the number of bits in a data character: 11 = 8-bit data 10 = 7-bit data 01 = 6-bit data 00 = 5 bit data
4	FEN	**FIFO Enable** Enables or disables FIFO operation: 1 = Enable FIFO operation. 0 = Disable FIFO operation.
3	STP2	**Stop 2** Specifies or reports the number of stop bits transmitted at the end of each frame: 1 = Transmit two stop bits. 0 = Transmit one stop bit. This field affects only the transmit operation. The receive operation checks for one stop bit and ignores any additional stop bits.
2	EPS	**Even Parity Set** Specifies even or odd parity: 1 = Specifies even parity. 0 = Specifies odd parity. This field has no effect when FCON[1] = 0.
1	PEN	**Parity Enable** Enables or disables parity checking and generation: 1 = Enables parity checking and generation. 0 = Disables parity checking and generation.
0	BRK	**Break** Assert break: 1 = After completing transmission of the current data character, deassert the UARTTX output. This field must remain set at least one frame transmission time to be detected as a break. 0 = Deassert break.

15.2.2.3 Baud Rate Control Register (BRCON)

Specifies the baud rate. The register is defined in Table 15-10 and Table 15-11. Table 15-12 shows some example baud rates and the corresponding BAUDDIV values.

Table 15-10. BRCON Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET																
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	BAUDDIV															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	UARTBase + 0x08															

Table 15-11. BRCON Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	BAUDDIV	**Baud Divisor** Divisor used by the UART to derive the reception and transmission baud rate from the UART reference clock. This clock is fixed at 7.3728 MHz. Calculate the divisor based on the required baud rate (BAUD), using the formula: BAUDDIV=(7372800 ÷ (16 × BAUD)) – 1 Write this calculated divisor to BAUDDIV to specify the baud rate.

Table 15-12. Example Baud Rates and BAUDDIV Values

BAUDDIV	BAUD RATE
0xBF	2,400
0x5F	4,800
0x2F	9,600
0x17	19,200
0x0F	28,800
0x0B	38,400
0x07	57,600
0x05	76,800
0x03	115,200
0x02	153,600
0x01	230,400
0x00	460,800

15.2.2.4 Control Register (CON)

This register, described in Table 15-13 and Table 15-14, contains configuration data for the UART to:

- Enable or disable the UART.
- Select Loopback mode
- Select Infrared mode for UART1
- Select non-infrared transmit and receive signal polarities and modem signal polarity.

Table 15-13. CON Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								SIRBD	LBE	MXP	TXP	RXP	SIRLP	SIRD	UARTEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	UARTBase + 0x0C															

Table 15-14. CON Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	SIRBD	**Serial Infrared Blanking Disable** For UART1, enables or disables receiver blanking for infrared operation: 1 = Disables receiver blanking. 0 = Enables receiver blanking. This bit is not applicable to UART2 or UART3.
6	LBE	**Loopback Enable** Enables or disables Loopback operation: 1 = Enables loopback mode. 0 = Disables loopback mode. When loopback is enabled, the transmit output signal is internally connected to the receiver input signal. For UART1, UARTIRTX1 output is used as the UARTIRRX1 input.
5	MXP	**Modem Transfer Polarity** Selects the signal polarities for CTS, DCD, and DSR: 1 = Modem signals active HIGH. 0 = Modem signals active LOW.
4	TXP	**Transmit Polarity** Selects the transmit signal polarities: 1 = UARTTXx active LOW and UARTIRTX1 active HIGH. 0 = UARTTXx active HIGH and UARTIRTX1 active LOW.

Table 15-14. CON Fields (Cont'd)

BITS	FIELD	DESCRIPTION
3	RXP	**Receive Polarity** Selects the receive signal polarities: 1 = UARTRXx and UARTIRRX1 active LOW. 0 = UARTRXx and UARTIRRX1 active HIGH.
2	SIRLP	**Serial Infrared Low Power** Enables or disables low power mode for infrared operation (see Section 15.1.2.5): 1 = Enables low power mode. 0 = Disables low power mode.
1	SIRD	**Serial Infrared Disable** For UART1, enables or disables infrared operation: 1 = Disables infrared operation. 0 = Enables infrared operation. **IMPORTANT:** To use multiplexed pins for GPIO, this bit and UARTEN must BOTH be programmed to 0. This bit does not apply to UART2 and UART3.
0	UARTEN	**UART Enable** Enables or disables UART operation: 1 = Enables UART operation. 0 = Disables UART operation. **IMPORTANT:** To use multiplexed pins for GPIO, this bit and SIRD must BOTH be programmed to 0. Writing to UART registers with the UART disabled causes unpredictable results.

15.2.2.5 Status Register (STATUS)

This register, defined in Table 15-15 and Table 15-16, provides:

- The FIFO full or empty status.
- The shift register and output pin status.
- The Modem Status pin values for UART2 and UART3.

Table 15-15. STATUS Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								TXFE	RXFF	TXFF	RXFE	BUSY	DCD	DSR	CTS
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	UARTBase + 0x10															

Table 15-16. STATUS Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	TXFE	**Transmit FIFO Empty** 1 = The transmit FIFO or holding register is empty. 0 = The transmit FIFO or holding register is not empty.
6	RXFF	**Receive FIFO Full** 1 = The receive FIFO or holding register is full. 0 = The receive FIFO or holding register is not full.
5	TXFF	**Transmit FIFO Full** 1 = The transmit FIFO or holding register is full. 0 = The transmit FIFO or holding register is not full.
4	RXFE	**Receive FIFO Empty** 1 = The receive FIFO or holding register is empty. 0 = The receive FIFO or holding register is not empty.
3	BUSY	**Busy** 1 = Either the transmit FIFO or holding register contains at least one entry, regardless of whether the UART is transmitting, or a frame is still transmitting on the UARTTX or UARTIRTX1 pin, regardless of the transmit FIFO or holding register contents. 0 = The transmit FIFO is not busy. This field does not indicate whether the UART is enabled.
2	DCD	**Data Carrier Detect** Contains the current value of the UART2 or UART3 Data Carrier Detect Modem Status input pin.
1	DSR	**Data Set Ready** Contains the current value of the UART2 or UART3 Data Set Ready Modem Status input pin.
0	CTS	**Clear to Send** Contains the current value of the UART2 or UART3 Clear-to-Send Modem Status input pin.

15.2.2.6 Raw Interrupt Register (RAWISR)

This register, described in Table 15-17 and Table 15-18.

- When read, the status of all UART interrupts, whether enabled and disabled is reported.
- When written to, clears the UART2 or UART3 modem status interrupt. Any write to MSEOI clears MI without changing RTI, TI, or RI.
- RI is cleared when the FIFO is emptied to no more than 7 entries.
- TI is cleared when the FIFO is filled to more than 7 entries.
- RTI is cleared when the FIFO is emptied, or when the receive data line becomes active.

Table 15-17. RAWISR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	MSEOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	MSEOI												RTI	MI	TI	RI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	RO	RO	RO	RO
ADDR	UARTBase + 0x14															

Table 15-18. RAWISR Fields

BITS	FIELD	DESCRIPTION
31:4	MSEOI	**Modem Status End-of-Interrupt** Reading this field returns 0. Write this field to clear the modem status interrupt (MI). Writing any value to this field clears MI and affects no other fields in this register.
3	RTI	**Receive Timeout Interrupt** 1 = Interrupt is asserted. 0 = Interrupt is not asserted. Writing has no effect.
2	MI	**Modem Status Interrupt** 1 = Interrupt is asserted. 0 = Interrupt is not asserted. Writing has no effect.
1	TI	**Transmit Interrupt** 1 = Interrupt is asserted. 0 = Interrupt is not asserted. Writing has no effect.
0	RI	**Receive Interrupt** 1 = Interrupt is asserted. 0 = Interrupt is not asserted. Writing has no effect.

15.2.2.7 Interrupt Enable Register (INTEN)

This register, defined in Table 15-19 and Table 15-20, enables or disables the UART interrupts. Writing to the register enables or disables interrupts, as defined in the table. The enabled or disabled state of any interrupt can be ascertained by reading this register.

Table 15-19. INTEN Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												RTI	MSI	TI	RI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	UARTBase + 0x18															

Table 15-20. INTEN Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	RTI	**Receive Timeout Interrupt** Enables the receive timeout interrupt: 1 = Interrupt enabled. 0 = Interrupt disabled.
2	MI	**Modem Status Interrupt** Enables the modem status interrupt: 1 = Interrupt enabled. 0 = Interrupt disabled.
1	TI	**Transmit Interrupt** Enables the transmit interrupt: 1 = Interrupt enabled. 0 = Interrupt disabled.
0	RI	**Receive Interrupt** Enables the receive interrupt: 1 = Interrupt enabled. 0 = Interrupt disabled.

15.2.2.8 Interrupt Status Register (ISR)

This register, described in Table 15-21 and Table 15-22, reports the individual UART interrupts comprising the combined interrupt sent to the LH7A400 interrupt controller. The values in ISR are the logical bitwise-AND of RAWISR and INTEN registers. Writing to this register has no effect.

Table 15-21. ISR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												RTI	MI	TI	RI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	UARTBase + 0x1C															

Table 15-22. ISR Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	RTI	**Receive Timeout Interrupt** Reports the receive timeout interrupt status: 1 = The interrupt is enabled and asserted. 0 = The interrupt is disabled or not asserted.
2	MI	**Modem Status Interrupt** Reports the modem interrupt status: 1 = The interrupt is enabled and asserted. 0 = The interrupt is disabled or not asserted.
1	TI	**Transmit Interrupt** Reports the transmit interrupt status: 1 = The interrupt is enabled and asserted. 0 = The interrupt is disabled or not asserted.
0	RI	**Receive Interrupt** Reports the receive interrupt status: 1 = The interrupt is enabled and asserted. 0 = The interrupt is disabled or not asserted.

Chapter 16
GPIO and External Interrupts

16.1 Theory of Operation

The LH7A400 provides up to 60 General Purpose Input/Output (GPIO) ports. Each GPIO port can be configured as either an input or output. Also included as part of the GPIO interface are the eight dedicated keyboard column drives, COL[7:0].

All GPIO ports are multiplexed with other onboard functions. As such, the number of available GPIO channels depends on what other functions the application design requires. Table 16-1 lists the LH7A400 functions that multiplex with GPIO pins. Designs using a particular function cannot use those pins as GPIO. Further details on multiplexing appear in Chapter 7. For usage of the pin with the particular function, consult the chapter regarding that function.

Table 16-1. GPIO Multiplexing by Function

FUNCTION	GPIO PORTS
AC97	H6
BMI	B[7:6]
External Interrupts	F[7:0]
CLCDC	A[1:0], C[7:1], D[7:0], and E[3:0]
PCMCIA and CompactFlash (CF) PC Cards	F[7:6], G[7:0], H7, and H[5:0]
Smart Card Interface (SCI)	F[5:4]
Universal Asynchronous Receivers and Transmitters (UART1 and UART3)	B[5:0] and C0

16.1.1 GPIO Nomenclature

For discussions applying to all Ports A through H equally, this chapter refers to the Ports collectively or generically as ‘Py’. For discussions referring to all signals in a Port, this chapter refers to the Port number collectively or generically as x; for example, ‘PFx’ refers to any or all of PF[7:0]. ‘Pyx’ refers to any or all GPIO ports.

16.1.2 GPIO Port Usage

Any GPIO pin not configured for use as one of the functions listed in Table 16-1 may be used for GPIO. GPIO pins are individually addressed as separate I/O channels, and a given port may have some pins configured as inputs and others configured as outputs. Since the pins are individually addressed, pins on a port that are not multiplexed with an implemented function (shown in Table 16-1) may be used for GPIO. For example, if the BMI function is implemented, pins [5:0] on Port B may be used for GPIO.

Port E has a maximum of four I/O pins; all other GPIO ports have a maximum of eight I/O pins. Port F implements external interrupts, described in Section 16.1.3.

16.1.2.1 Programming GPIO Pins

Upon Reset, the GPIO ports are configured as shown in Table 16-2.

Each pin must be properly set as an input or output prior to its first use by the application. To reconfigure one or more port pins from the reset configuration software must program the pin as an input or output. This configuration is specified in the particular port's Data Direction register (PyDD), described in Section 16.2.2.3.

Table 16-2. GPIO Port Configuration after Reset

PORT	RESET CONFIGURATION
A[7:0]	Input
B[7:0]	Input
C[7:0]	Output
D[7:0]	Output
E[3:0]	Input
F[7:0]	Input
G[7:0]	Output
H[7:0]	Input

16.1.2.2 Input/Output Data

GPIO port data is read or written using the particular port's Data register (PyD). Input data is acquired by software reading the contents of PyD. Bit values read for pins configured as outputs show the current state of that output pin. Output data is sent by software writing the bits in PyD corresponding to output pins. Writing a value to a bit set up as an input has no effect on that input value.

16.1.3 Port F External Interrupts

In addition to GPIO, Port F pins can also be used for external interrupt signals. To use a Port F pin for an external interrupt, it must be configured as an input by software writing to the Port F Data Direction register (PFDD). Then, software configures each interrupt pin for triggering, and if required, debounce condition.

After Reset, Port F is configured as GPIO.

Table 16-3 shows the correspondence between external interrupts, interrupt name, and the bit positions in the Interrupt Controller register.

Table 16-3. External Interrupt and Interrupt Controller Correspondence

PFx REGISTER BIT POSITION	INTERRUPT CONTROLLER REGISTER BIT POSITION	INTERRUPT SIGNAL NAME
7	26	GPIO7INTR
6	25	GPIO6INTR
5	24	GPIO5INTR
4	23	GPIO4INTR
3	7	GPIO3INTR
2	6	GPIO2INTR
1	5	GPIO1INTR
0	0	GPIO0INTR

16.1.3.1 Configuring the Interrupts

The LH7A400 Interrupt Controller responds to active HIGH levels. However, external interrupts on GPIO Port F can be configured to translate rising- or falling-edge triggers, or active LOW levels for presentation to the Interrupt Controller as active HIGH levels. Figure 16-1 shows a block diagram of external interrupt configuration.

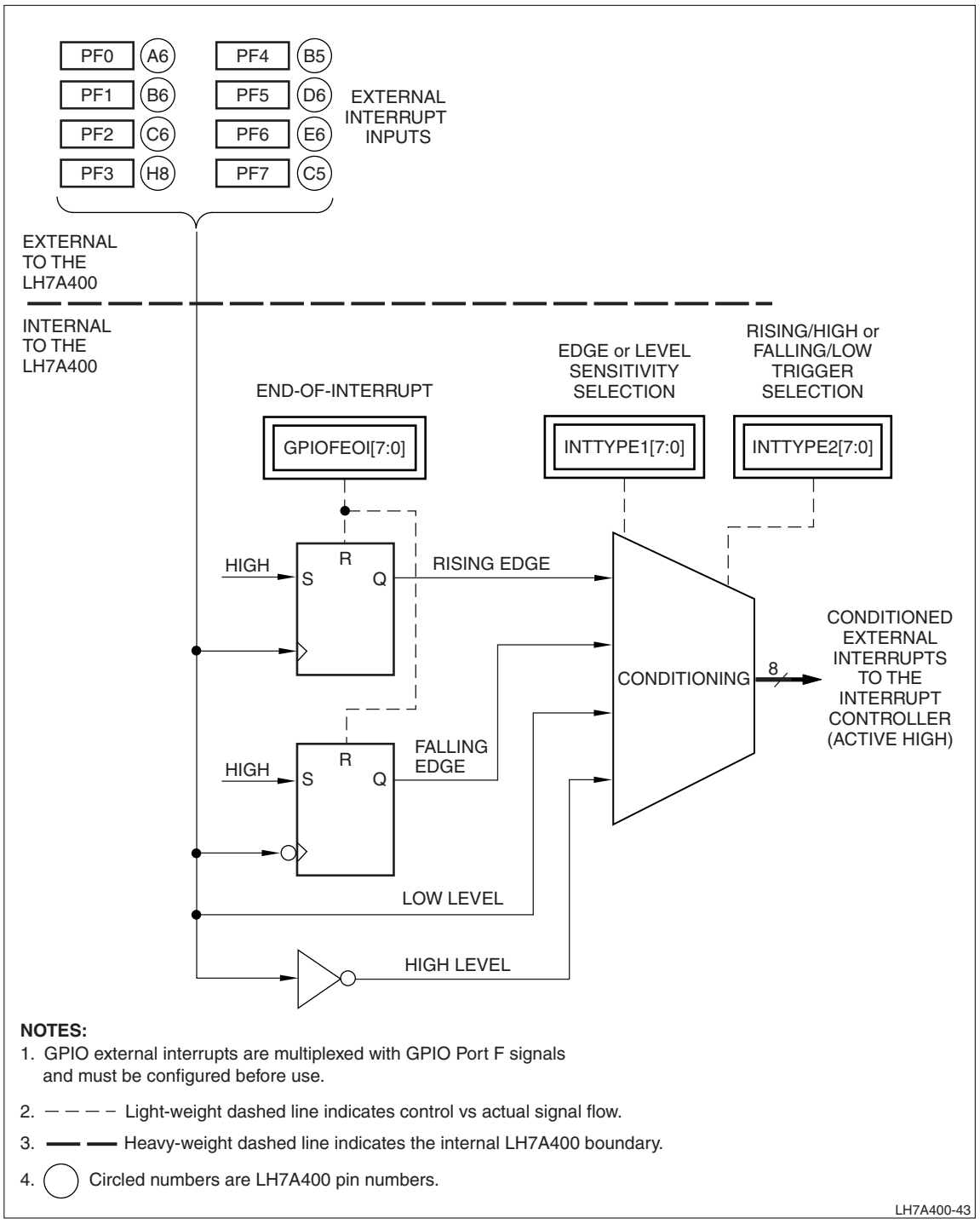


Figure 16-1. External Interrupt Configuration

Software should configure interrupts in the order specified below to avoid generating spurious interrupts and to avoid interrupts being incorrectly enabled in an asserted state:

1. Disable the interrupts to be configured in the GPIO Interrupt Enable register (GPIOINTEN). See Section 16.2.2.9.
2. Select trigger type by programming the Interrupt Edge or Level Type register (INTTYPE1) and the Interrupt HIGH/Rising or LOW/Falling Type register (INTTYPE2). See Section 16.2.2.6 and Section 16.2.2.7.
3. For edge triggering, enable debounce conditioning by programming the GPIO Debounce register (GPIODB). See Section 16.2.2.12.
4. Program the pin as an Input in the Port F Data Direction register (PFDD). See Section 16.2.2.3.
5. Clear the corresponding bits in the GPIO F End of Interrupt register (GPIOFEOI). See Section 16.2.2.8.
6. Enable the conditioned interrupts in GPIOINTEN. Section 16.2.2.9.

To select edge sensitivity for an interrupt, set the corresponding INTTYPE1 bit. To select level sensitivity, clear the bit. To select rising or active-HIGH triggering for an interrupt, set the corresponding INTTYPE2 bit. To select falling or active-LOW triggering, clear the bit.

For example, programming INTTYPE1[0] to 1 configures INT0 on PF0 as edge sensitive (either rising or falling). With INTTYPE1[0] set to 1, programming INTTYPE2[0] to 1 configures INT0 as rising edge sensitive. (See Table 16-29 and Table 16-31 for details).

Edge-triggered interrupts can produce spurious interrupts due to signal 'bounce.' To avoid spurious interrupts, debounce all edge triggered pins. Set the corresponding bit in the GPIODB debounce register. Clearing a bit removes the debounce conditioning from the corresponding pin.

After reset, no PFx pins are debounced. Reset configures the external interrupts as active-LOW and level-sensitive; however external interrupts are disabled after Reset.

16.1.3.2 Enabling and Clearing Interrupts

To enable PFx as an interrupt, set the corresponding bit in the GPIOINTEN. To disable the interrupt, clear that bit. To determine whether an interrupt is enabled, software can read GPIOINTEN.

Asserted interrupts appear in the Raw Interrupt Status register (RAWINTSTATUS), whether or not they are enabled. Enabled and asserted interrupts appear in the Interrupt Status register (INTSTATUS). The INTSTATUS contents are a logical bit-wise AND of RAWINTSTATUS with GPIOINTEN.

The least significant eight bits of each PFx register correspond to the PFx signals and to bits in the LH7A400 interrupt controller registers, as shown in Table 16-4.

To clear a PFx interrupt, clear the corresponding INTSTATUS bit:

- For edge sensitive interrupts, setting a bit in the GPIO End-of-Interrupt register (GPIOFEOI) clears the corresponding bit in INTSTATUS.
- For level sensitive interrupts, deasserting the input signal clears the corresponding INTSTATUS bit.

Table 16-4. GPIO Port F Pin Names, Numbers, and Register Bit Positions

PFx REGISTER BIT POSITION	LH7A400 INTERRUPT CONTROLLER REGISTER BIT POSITION	PFx SIGNAL NAME	INTERRUPT SIGNAL NAME	PIN NUMBER
7	26	PF7	INT7	C5
6	25	PF6	INT6	E6
5	24	PF5	INT5	D6
4	23	PF4	INT4	B5
3	7	PF3	INT3	H8
2	6	PF2	INT2	C6
1	5	PF1	INT1	B6
0	0	PF0	INT0	A6

16.1.3.2.1 Timing Considerations when Clearing Level-Sensitive Interrupts

When external interrupts are configured as level-sensitive, the interrupt service routine must ensure that there is sufficient time delay between clearing the source of the external interrupt and clearing the interrupt at the Interrupt Controller. Specifically, the source of the external interrupt must have pulled the line HIGH (or LOW, depending on whether the external interrupt input pin is configured as active HIGH or active LOW) before the interrupt is cleared at the Interrupt Controller, because the Interrupt Controller will sample the line immediately following the clear and will generate an interrupt again to the ARM core if the line is recognized to be still active.

When an interrupt line is shared by multiple open-collector devices in a wired-OR configuration with a pull-up resistor, the line can be especially susceptible to causing multiple interrupts if there is insufficient delay between clearing the source of the external interrupt and clearing the interrupt at the Interrupt Controller. This is due to the relatively slow rise-time of the interrupt signal when being pulled to its inactive state by the pull-up resistor. The larger the resistor and load capacitance on the interrupt line, the slower the rise-time and hence more is the delay required.

In general, it is good practice to clear the source of the interrupt as early as practical in the interrupt service routine when configuring external interrupts as level-sensitive. This will ensure a maximum delay between clearing the external interrupt and clearing the interrupt at the Interrupt Controller.

16.2 Register Reference

16.2.1 Memory Map

The GPIO register base address is 0x8000.0E00. Addresses in Table 16-5 are offset from this base address.

Each port has three registers; two for data and one for direction (Input/Output):

- For content, a Data register (PyDx) and a Pin Data register (PyPDx) show the individual pin states. The PyDx contents differ from the PyPDx contents according to the configured operations,:
  - PyDx reads the state of the GPIO pin or the programmed value of the pin if not configured as GPIO, and writes values only on the pins configured for GPIO.
  - PyPDx reads values on all Pyx pins, whether configured for GPIO or for another operation, and writes values on no pins.
- For direction, a Data Direction register (PyDDx) configures individual pins for input or output.

Table 16-5. GPIO Register Memory Map

ADDRESS OFFSET	NAME	FUNCTION
0x00	PAD	**Port A Data Register**
0x04	PBD	**Port B Data Register**
0x08	PCD	**Port C Data Register**
0x0C	PDD	**Port D Data Register**
0x10	PADD	**Port A Data Direction Register**
0x14	PBDD	**Port B Data Direction Register**
0x18	PCDD	**Port C Data Direction Register**
0x1C	PDDD	**Port D Data Direction Register**
0x20	PED	**Port E Data Register**
0x24	PEDD	**Port E Data Direction Register**
0x28	KBDCTL	**Keyboard Control Register** Sets the COLx pins LOW, HIGH, or high-impedance.
0x2C	PINMUX	**Pin Multiplexing Register** Port D and E multiplexing for LCD, AC97 Codec, UART3 and Memory Controllers. See Chapter 7.
0x30	PFD	**Port F Data Register**
0x34	PFDD	**Port F Data Direction Register** To use a PFx pin as an External Interrupt, select the data direction as Input. No interrupt can appear on a pin configured as an Output.
0x38	PGD	**Port G Data Register**
0x3C	PGDD	**Port G Data Direction Register**
0x40	PHD	**Port H Data Register**
0x44	PHDD	**Port H Data Direction Register**
0x48	///	**Reserved** Avoid accessing this location.
0x4C	INTTYPE1	**Interrupt Type 1** Selects edge or level sensitivity for GPIO Port F External Interrupts.
0x50	INTTYPE2	**Interrupt Type 2** Selects the following for PFx External Interrupts: • Rising or falling edge when INTTYPE1 specifies edge sensitivity. • HIGH or LOW level when INTTYPE1 specifies level sensitivity.
0x54	GPIOFEOI	**GPIO Port F End-of-Interrupt** Clears PFx External Interrupts configured as edge sensitive by INTTYPE1.
0x58	GPIOINTEN	**GPIO Interrupt Enable** Selects PFx pins for use as External Interrupts or as GPIO.
0x5C	INTSTATUS	**Interrupt Status** Reports asserted External Interrupts on PFx pins enabled as interrupts by GPIOINTEN.
0x60	RAWINTSTATUS	**Raw Interrupt Status** Shows asserted External Interrupts on PFx pins configured as inputs by PFDD.
0x64	GPIODB	**GPIO Debounce** Debounces PFx Interrupt pins.
0x68	PAPD	**Port A Pin Data Register**
0x6C	PBPD	**Port B Pin Data Register**
0x70	PCPD	**Port C Pin Data Register**
0x74	PDPD	**Port D Pin Data Register**
0x78	PEPD	**Port E Pin Data Register**
0x7C	PFPD	**Port F Pin Data Register**
0x80	PGPD	**Port G Pin Data Register**
0x84	PHPD	**Port H Pin Data Register**

16.2.2 Register Descriptions

16.2.2.1 GPIO Data Registers (PyD)

For non-multiplexed GPIO pins and for multiplexed GPIO pins configured for GPIO operation, the data registers, described in Table 16-6 and Table 16-7, contain:

- Bit values read from GPIO input pins. Read these registers to determine the pin states.
- Bit values to be written only to GPIO output pins. Write to these registers to output data signals on the pins.

For multiplexed GPIO pins configured for functions other than GPIO, reading a data register returns a value specified by the configured operation. Writing a data register affects only the pins configured for GPIO operation.

All Ports except Port E are 8-bit ports with 8-bit Data registers. Port E is a 4-bit port with a 4-bit Data register.

Table 16-6. P[A:D]D and P[F:H]D Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								Py7	Py6	Py5	Py4	Py3	Py2	Py1	Py0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E00 for PAx 0x8000.0E04 for PBx 0x8000.0E08 for PCx 0x8000.0E0C for PDx 0x8000.0E30for PFx 0x8000.0E38 for PGx 0x8000.0E40 for PHx															

Table 16-7. PED Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												PE3	PE2	PE1	PE0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	0x8000.0E20															

Table 16-8. P[A:D]D and P[F:H]D Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	Py7	**Py7** Data bit 7 for Port y.
6	Py6	**Py6** Data bit 6 for Port y.
5	Py5	**Py5** Data bit 5 for Port y.
4	Py4	**Py4** Data bit 4 for Port y.
3	Py3	**Py3** Data bit 3 for Port y.
2	Py2	**Py2** Data bit 2 for Port y.
1	Py1	**Py1** Data bit 1 for Port y.
0	Py0	**Py0** Data bit 0 for Port y.

Table 16-9. PED Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	PE3	**PE3** Data bit 3 for Port E.
2	PE2	**PE2** Data bit 2 for Port E.
1	PE1	**PE1** Data bit 1 for Port E.
0	PE0	**PE0** Data bit 0 for Port E.

16.2.2.2 GPIO Pin Data Registers (PyPD)

These registers, described in Table 16-10 and Table 16-11, contain bit values read from the port pins. The difference between the Data registers and these Pin Data registers is that this register is Read Only. The Data registers allow outputs to be written to the GPIO-configured bits.

Read these registers to observe the pin states for all pins. Writing to these registers has no effect.

All Ports except Port E are 8-bit ports with 8-bit Pin Data registers. Port E is a 4-bit port with a 4-bit Pin Data register.

Table 16-10. P[A:D]PD and P[F:H]PD Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								Py7	Py6	Py5	Py4	Py3	Py2	Py1	Py0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0E68 for PAx 0x8000.0E6C for PBx 0x8000.0E70 for PCx 0x8000.0E74 for PDx 0x8000.0E7C for PFx 0x8000.0E80 for PGx 0x8000.0E84 for PHx															

Table 16-11. PEPD Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												PE3	PE2	PE1	PE0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0E78															

Table 16-12. P[A:D]PD and P[F:H]PD Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	Py7	**Py7** Pin Data bit 7 for Port y.
6	Py6	**Py6** Pin Data bit 6 for Port y.
5	Py5	**Py5** Pin Data bit 5 for Port y.
4	Py4	**Py4** Pin Data bit 4 for Port y.
3	Py3	**Py3** Pin Data bit 3 for Port y**.**
2	Py2	**Py2** Pin Data bit 2 for Port y.
1	Py1	**Py1** Pin Data bit 1 for Port y.
0	Py0	**Py0** Pin Data bit 0 for Port y.

Table 16-13. PEPD Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	PE3	**PE3** Pin Data bit 3 for Port E.
2	PE2	**PE2** Pin Data bit 2 for Port E.
1	PE1	**PE1** Pin Data bit 1 for Port E.
0	PE0	**PE0** Pin Data bit 0 for Port E.

16.2.2.3 GPIO Data Direction Registers (PyDD)

These registers, described in Table 16-15 and Table 16-16, select input or output operation for each pin. For ports C, D, and G setting a data direction bit configures the corresponding pin as an input. For ports A, B, E, F, and H setting a bit configures the pin as an output. Table 16-14 shows how setting a data direction bit affects the pins for each port.

Each data direction bit for each port may be independently programmed to be an input or an output.

Reset clears all data direction registers, disabling the output drivers for ports A, B, E, F, and H, and enables the output drivers for ports C, D, and G.

The current direction setting for a pin can be ascertained by reading the corresponding direction register bit.

All Ports except Port E are 8-bit ports with 8-bit Data Direction registers. Port E is a 4-bit port with a 4-bit Data Direction register. Because the port direction with PyxDIR set differs between Ports, Table 16-17 shows the values of the bits in Table 16-15 for Ports A, B, and F, and Table 16-18 shows the values of the bits in Table 16-15 for Ports C, D, and G.

Table 16-14. GPIO Pin Data Directions

PORT	REGISTER	DIRECTION WHEN PyDDx IS SET TO 1
A[7:0]	PADD[7:0]	Output
B[7:0]	PBDD[7:0]	Output
C[7:0]	PCDD[7:0]	Input
D[7:0]	PDDD[7:0]	Input
E[3:0]	PEDD[3:0]	Output
F[7:0]	PFDD[7:0]	Output
G[7:0]	PGDD[7:0]	Input
H[7:0]	PHDD[7:0]	Output

Table 16-15. P[A:D]DD and P[F:H]DD Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								Py7DIR	Py6DIR	Py5DIR	Py4DIR	Py3DIR	Py2DIR	Py1DIR	Py0DIR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E10 for PAx 0x8000.0E14 for PBx 0x8000.0E18 for PCx 0x8000.0E1C for PDx 0x8000.0E34 for PFx 0x8000.0E3C for PGx 0x8000.0E44 for PHx															

Table 16-16. PEDD Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												PE3DIR	PE2DIR	PE1DIR	PE0DIR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	0x8000.0E24															

Table 16-17. PyDD Fields for Ports A, B, F, and H

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	Py7DIR	**Py7DIR** 1 = Output 0 = Input
6	Py6DIR	**Py6DIR** 1 = Output 0 = Input
5	Py5DIR	**Py5DIR** 1 = Output 0 = Input
4	Py4DIR	**Py4DIR** 1 = Output 0 = Input
3	Py3DIR	**Py3DIR** 1 = Output 0 = Input
2	Py2DIR	**Py2DIR** 1 = Output 0 = Input
1	Py1DIR	**Py1DIR** 1 = Output 0 = Input
0	Py0DIR	**Py0DIR** 1 = Output 0 = Input

Table 16-18. PyDD Fields for Ports C, D, and G

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	Py7DIR	**Py7DIR** 1 = Input 0 = Output
6	Py6DIR	**Py6DIR** 1 = Input 0 = Output
5	Py5DIR	**Py5DIR** 1 = Input 0 = Output
4	Py4DIR	**Py4DIR** 1 = Input 0 = Output
3	Py3DIR	**Py3DIR** 1 = Input 0 = Output
2	Py2DIR	**Py2DIR** 1 = Input 0 = Output
1	Py1DIR	**Py1DIR** 1 = Input 0 = Output
0	Py0DIR	**Py0DIR** 1 = Input 0 = Output

Table 16-19. PEDD Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	PE3DIR	**PE3DIR** 1 = Output 0 = Input
2	PE2DIR	**PE2DIR** 1 = Output 0 = Input
1	PE1DIR	**PE1DIR** 1 = Output 0 = Input
0	PE0DIR	**PE0DIR** 1 = Output 0 = Input

16.2.2.4 GPIO Keyboard Control Register (KBDCTL)

This register, described in Table 16-20 through Table 16-22, defines the state of the keyboard column drivers.

Table 16-20. KBDCTL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												CSTATE			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	0x8000.0E28															

Table 16-21. KBDCTL Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
3:0	CSTATE	**Column State** Program this register to specify the COLx output.

Table 16-22. CSTATE VALUES

CSTATE	COLx OUTPUT
0x0	COLx driven HIGH
0x1	COLx driven LOW
0x2 through 0x7	COLx High-Z
0x8	COL0 only driven HIGH; all others High-Z
0x9	COL1 only driven HIGH; all others High-Z
0xA	COL2 only driven HIGH; all others High-Z
0xB	COL3 only driven HIGH; all others High-Z
0xC	COL4 only driven HIGH; all others High-Z
0xD	COL5 only driven HIGH; all others High-Z
0xE	COL6 only driven HIGH; all others High-Z
0xF	COL7 only driven HIGH; all others High-Z

16.2.2.5 GPIO Pin Multiplexing Register (PINMUX)

This register, described in Table 16-26 and Table 16-27, controls multiplexing for GPIO PBx, PDx, PEx, and PHx, and for several pins unrelated to GPIO operations. Table 16-23 shows the Port and function multiplexed pin correspondence that is controlled by PINMUX.

The UART1 and UART3 data signals and the UART3 modem status signals are multiplexed with GPIO Ports B[5:0] and C0, as shown in Table 16-24.

Table 16-23. PINMUX Multiplexing Control

PIN	GPIO	UART3	CLCD	AC97	SMC
N1	Port B5	UARTDSR3			
M4	Port B4	UARTDCD3			
M2	Port B3	UARTCTS3			
L7	Port B2	UARTRX3			
L5	Port B1	UARTTRX3			
R10	Port D7		LCDVD15		
P10	Port D6		LCDVD14		
T9	Port D5		LCDVD13		
R9	Port D4		LCDVD12		
N11	Port D3		LCDVD11		
K8	Port D2		LCDVD10		
L11	Port D1		LCDVD9		
M11	Port D0		LCDVD8		
M10	Port E3		LCDVD7		
M9	Port E2		LCDVD6		
N10	Port E1		LCDVD5		
L10	Port E0		LCDVD4		
R5	Port H6			AC97RESET	
C10					See Table 16-25

Table 16-24. UART Multiplexing

PIN	UART	GPIO
L4	UARTRX1	Port B0
L5	UARTTX3	Port B1
L7	UARTRX3	Port B2
M2	UARTCTS3	Port B3
M4	UARTDCD3	Port B4
N1	UARTDSR3	Port B5
P1	UARTTX1	Port C0

To configure the pins for UART3 data and modem status signals:

- Set the UART3 Control register UART Enable field (CON:UARTEN) to enable UART3 operation.
- Set the PINMUX register UART3 Configuration field (PINMUX:UART3CON).

Configure the pins for UART1 data signals by setting the UART1 Control register UART Enable field (UARTCON1:UARTEN). Enabling UART1 infrared operation does not reconfigure pins L4 and P1 as GPIO Ports. During infrared operation, UART1 continuously asserts UARTTX1 and ignores input on UARTRX1.

Enabling a UART selects the corresponding pins for UART use. Disabling the UART configures the corresponding pins for GPIO use.

The SDMC SCKE1_2 and SCKE0 output signals are multiplexed with the SMC CS6 and CS7 output signals on pins B10 and C10, respectively. The GPIO Pin Multiplexing register Clock 12 Enable and Clock 0 Enable fields (PINMUX:CLK1_2EN and PINMUX:CLK0EN) select the CS and SCKE multiplexing:

- When CLK1_2EN = 0, pin B10 is the SMC CS6 output.
- When CLK0EN = 0, pin C10 is the SMC CS7 output.

After reset, pin B10 is CS6 and pin C10 is CS7.

The SDMC SCKE1_2 and SCKE0, and SCKE3 (pin G9) output signals are multiplexed SDMC clock enable signals. The SDMC signal multiplexing also depends on the PINMUX register, as shown in Table 16-25. In this table, each SCKEx is the corresponding Bank(x) clock enable signal.

Table 16-25. SDRAM Clock Enable Multiplexing

PINMUX		OUTPUT SIGNAL VALUES		
CLK0EN	CLK1_2EN	PIN G9	PIN B10	PIN C10
0	0	SCKE0 or SCKE1 or SCKE2 or SCKE3	CS6	CS7
0	1	SCKE0 or SCKE3	SCKE1_2	CS7
1	0	SCKE1 or SCKE2 or SCKE3	CS6	SCKE0
1	1	SCKE3	SCKE1_2	SCKE0

Table 16-26. PINMUX Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										CLK0EN	CLK1_2EN	UART3CON	CODECON	PDOCON	PEOCON
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E2C															

Table 16-27. PINMUX Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	CLK0EN	**Clock 0 Enable** Selects the pin C10 multiplexing: 1 = SCKE0 0 = CS7 This bit has no effect on GPIO operation.
4	CLK1_2EN	**Clock 1 and 2 Enable** Selects the pin B10 multiplexing: 1 = SCKE1_2 0 = CS6 This bit has no effect on GPIO operation.
3	UART3CON	**UART3 Control** Selects the GPIO Port B multiplexing: 1 = UART3 uses these pins: Data Set Ready (DSR) on N1, Data Carrier Detect (DCD) on M4, Clear-to-Send (CTS) on M2, Receive Data on L7, Transmit Data on L5. 0 = Port B[5:1] use pins N1, M4, M2, L7, and L5, respectively.
2	CODECON	**Codec Control** Selects the AC97 codec multiplexing: 1 = ACI uses pins: Bit Clock (ACBTCLK) on C4, Output Data (ACOUT) on D5, Synchronize (ACSYNC) on B4, Input Data (ACIN) on A4. 0 = AC97 uses pins: Bit Clock (ACBTCLK) on C4, Output Data (ACOUT) on D5, Synchronize (ACSYNC) on B4, Input Data (ACIN) on A4, Reset (AC97RESET) on B5. This selection affects GPIO Port H6 (pin R5): • When AC97 is disabled or CODECON = 1, this pin is GPIO port H6. • When AC97 is enabled and CODECON = 0, this pin is AC97RESET.
1	PDOCON	**PD Output Control** Selects the Port D output multiplexing: 1 = LCDVD[15:8] on pins R10, P10, T9, R9, N11, K8, L11, and M11, respectively. 0 = GPIO port D[7:0] on pins R10, P10, T9, R9, N11, K8, L11, and M11, respectively.
0	PEOCON	**Port E Output Control** Selects the Port E output multiplexing: 1 = LCDVD[7:4] on pins M10, M9, N10, and L10, respectively. 0 = GPIO port E[3:0] on pins M10, M9, N10, and L10, respectively.

16.2.2.6 Interrupt Type 1 Register (INTTYPE1)

This register, described in Table 16-28 and Table 16-29, configures each PFx interrupt as edge or level sensitive. An edge-sensitive interrupt is asserted by a rising or falling edge on the input signal and remains asserted until either:

- The interrupt is deasserted in the PFx Raw Interrupt Status register (RAWINTSTATUS) via the PFx End-of-Interrupt register (GPIOFEOI).
- The interrupt is deasserted in the PFx Interrupt Status register (INTSTATUS) via the PFx Interrupt Enable register (GPIOINTEN). Disabled interrupts remain asserted in RAWINTSTATUS.

A level-sensitive interrupt is asserted by a HIGH or LOW level on the input signal and remains asserted until either:

- The input signal level changes
- The interrupt is deasserted in INTSTATUS via GPIOINTEN. Disabled interrupts remain asserted in RAWINTSTATUS.

The HIGH level or rising edge vs LOW level or falling edge trigger is selected by the PFx Interrupt Type 2 register (INTTYPE2) described in Section 16.2.2.8.

Table 16-28. INTTYPE1

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E4C															

Table 16-29. INTTYPE1 Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	**F7** Port F7 edge or level trigger control 1 = Configures PF7 as edge sensitive. 0 = Configures PF7 as level sensitive.
6	F6	**F6** Port F6 edge or level trigger control 1 = Configures PF6 as edge sensitive. 0 = Configures PF6 as level sensitive.
5	F5	**F5** Port F5 edge or level trigger control 1 = Configures PF5 as edge sensitive. 0 = Configures PF5 as level sensitive.
4	F4	**F4** Port F4 edge or level trigger control 1 = Configures PF4 as edge sensitive. 0 = Configures PF4 as level sensitive.
3	F3	**F3** Port F3 edge or level trigger control 1 = Configures PF3 as edge sensitive. 0 = Configures PF3 as level sensitive.
2	F2	**F2** Port F2 edge or level trigger control 1 = Configures PF2 as edge sensitive. 0 = Configures PF2 as level sensitive.
1	F1	**F1** Port F1 edge or level trigger control 1 = Configures PF1 as edge sensitive. 0 = Configures PF1 as level sensitive.
0	F0	**F0** Port F0 edge or level trigger control 1 = Configures PF0 as edge sensitive. 0 = Configures PF0 as level sensitive.

16.2.2.7 Interrupt Type 2 Register (INTTYPE2)

This register, described in Table 16-30 and Table 16-31, configures each PFx interrupt to be asserted by a HIGH level or rising edge or by a LOW level or falling edge. The edge vs level sensitivity is selected by the PFx Interrupt Type 1 register (INTTYPE1).

Table 16-30. INTTYPE2

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E50															

Table 16-31. INTTYPE2 Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	**F7** Port F7 trigger type control 1 = Configures PF7 as rising-edge or HIGH-level triggered. 0 = Configures PF7 as falling-edge or LOW-level triggered.
6	F6	**F6** Port F6 trigger type control 1 = Configures PF6 as rising-edge or HIGH-level triggered. 0 = Configures PF6 as falling-edge or LOW-level triggered.
5	F5	**F5** Port F5 trigger type control 1 = Configures PF5 as rising-edge or HIGH-level triggered. 0 = Configures PF5 as falling-edge or LOW-level triggered.
4	F4	**F4** Port F4 trigger type control 1 = Configures PF4 as rising-edge or HIGH-level triggered. 0 = Configures PF4 as falling-edge or LOW-level triggered.
3	F3	**F3** Port F3 trigger type control 1 = Configures PF3 as rising-edge or HIGH-level triggered. 0 = Configures PF3 as falling-edge or LOW-level triggered.
2	F2	**F2** Port F2 trigger type control 1 = Configures PF2 as rising-edge or HIGH-level triggered. 0 = Configures PF2 as falling-edge or LOW-level triggered.
1	F1	**F1** Port F1 trigger type control 1 = Configures PF1 as rising-edge or HIGH-level triggered. 0 = Configures PF1 as falling-edge or LOW-level triggered.
0	F0	**F0** Port F0 trigger type control 1 = Configures PF0 as rising-edge or HIGH-level triggered. 0 = Configures PF0 as falling-edge or LOW-level triggered.

16.2.2.8 GPIO Port F End-of-Interrupt Register (GPIOFEOI)

This register, described in Table 16-32 and Table 16-33, deasserts each asserted, edge-sensitive PFx interrupt. Edge sensitivity is configured via the PFx Interrupt Type 1 register (INTTYPE1).

Interrupt assertion status is reported for all External Interrupts in the PFx Raw Interrupt Status register (RAWINTSTATUS) and for enabled External Interrupts in the PFx Interrupt Status register (INTSTATUS). Enable External Interrupts via the PFx Interrupt Enable register (GPIOINTEN).

Reading this register returns 0. Values written to this register cannot be read back. Writing 0b1 to any non-reserved bit in this register affects values in RAWINTSTATUS and INTSTATUS. Writing 0b0 to any bit in this register has no effect on interrupt assertion in RAWINTSTATUS or INTSTATUS.

Table 16-32. GPIOFEOI

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0E54															

Table 16-33. GPIOFEOI Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	1 = Deassert any edge-sensitive interrupt asserted on PF7. 0 = No change to any interrupt asserted on PF7.
6	F6	1 = Deassert any edge-sensitive interrupt asserted on PF6. 0 = No change to any interrupt asserted on PF6.
5	F5	1 = Deassert any edge-sensitive interrupt asserted on PF5. 0 = No change to any interrupt asserted on PF5.
4	F4	1 = Deassert any edge-sensitive interrupt asserted on PF4. 0 = No change to any interrupt asserted on PF4.
3	F3	1 = Deassert any edge-sensitive interrupt asserted on PF3. 0 = No change to any interrupt asserted on PF3.
2	F2	1 = Deassert any edge-sensitive interrupt asserted on PF2. 0 = No change to any interrupt asserted on PF2.
1	F1	1 = Deassert any edge-sensitive interrupt asserted on PF1. 0 = No change to any interrupt asserted on PF1.
0	F0	1 = Deassert any edge-sensitive interrupt asserted on PF0. 0 = No change to any interrupt asserted on PF0.

16.2.2.9 GPIO Port F Interrupt Enable Register (GPIOINTEN)

This register, described in Table 16-34 and Table 16-35, configures each PFx as an External Interrupt or as a GPIO Port. For use as an interrupt, a Port F pin must also be configured as an input in the PFx Data Direction Register (PFDD).

Disabling an interrupt configures the pin as a GPIO port and deasserts the interrupt in the PFx Interrupt Status register (INTSTATUS). Disabled interrupts can remain asserted in the PFx Raw Interrupt Status register (RAWINTSTATUS).

Table 16-34. GPIOINTEN

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E58															

Table 16-35. GPIOINTEN Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	1 = Configures F7 as an External Interrupt. 0 = Disables interrupts on PF7 and clears any existing interrupt.
6	F6	1 = Configures F6 as an External Interrupt. 0 = Disables interrupts on PF6 and clears any existing interrupt.
5	F5	1 = Configures F57 as an External Interrupt. 0 = Disables interrupts on PF5 and clears any existing interrupt.
4	F4	1 = Configures F4 as an External Interrupt. 0 = Disables interrupts on PF4 and clears any existing interrupt.
3	F3	1 = Configures F3 as an External Interrupt. 0 = Disables interrupts on PF3 and clears any existing interrupt.
2	F2	1 = Configures F2 as an External Interrupt. 0 = Disables interrupts on PF2 and clears any existing interrupt.
1	F1	1 = Configures F1 as an External Interrupt. 0 = Disables interrupts on PF1 and clears any existing interrupt.
0	F0	1 = Configures F0 as an External Interrupt. 0 = Disables interrupts on PF0 and clears any existing interrupt.

16.2.2.10 GPIO Port F Interrupt Status Register (INTSTATUS)

This register, described in Table 16-36 and Table 16-37, reports the asserted or deasserted status of each PFx configured:

- The pin is enabled as an interrupt in the PFx Interrupt Enable register (GPIOINTEN).
- The pin is configured as an input in the PFx Data Direction Register (PFDD).

INTSTATUS is a logical bit-wise-AND of GPIOINTEN with the PFx Raw Interrupt Status register (RAWINTSTATUS).

Table 16-36. INTSTATUS

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0E5C															

Table 16-37. INTSTATUS Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	This bit reports the PF7 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
6	F6	This bit reports the PF6 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
5	F5	This bit reports the PF5 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
4	F4	This bit reports the PF4 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
3	F3	This bit reports the PF3 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
2	F2	This bit reports the PF2 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
1	F1	This bit reports the PF1 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
0	F0	This bit reports the PF0 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.

16.2.2.11 GPIO Port F Raw Interrupt Status Register (RAWINSTATUS)

This register, described in Table 16-38 and Table 16-39, reports the asserted or deasserted status of each PFx configured as an input in the PFx Data Direction Register (PFDD), whether or not the interrupt is enabled.

The PFx Interrupt Status register (INTSTATUS) is a logical bit-wise AND of the PFx Interrupt Enable register (GPIOINTEN) with RAWINTSTATUS.

Table 16-38. RAWINTSTATUS

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0E60															

Table 16-39. RAWINTSTATUS Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	This bit reports the PF7 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
6	F6	This bit reports the PF6 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
5	F5	This bit reports the PF5 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
4	F4	This bit reports the PF4 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled
3	F3	This bit reports the PF3 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled
2	F2	This bit reports the PF2 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
1	F1	This bit reports the PF1 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.
0	F0	This bit reports the PF0 interrupt status: 1 = The interrupt is asserted and enabled. 0 = The interrupt is deasserted or disabled.

16.2.2.12 GPIO Port F Debounce Register (GPIODB)

This register, described in Table 16-40 and Table 16-41, debounces each PFx pin.

Table 16-40. GPIODB

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								F7	F6	F5	F4	F3	F2	F1	F0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0E64															

Table 16-41. GPIODB Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	F7	1 = Enable pin debouncing on PF7. 0 = Disable pin debouncing on PF7.
6	F6	1 = Enable pin debouncing on PF6. 0 = Disable pin debouncing on PF6.
5	F5	1 = Enable pin debouncing on PF5. 0 = Disable pin debouncing on PF5.
4	F4	1 = Enable pin debouncing on PF4. 0 = Disable pin debouncing on PF4.
3	F3	1 = Enable pin debouncing on PF3. 0 = Disable pin debouncing on PF3.
2	F2	1 = Enable pin debouncing on PF2. 0 = Disable pin debouncing on PF2.
1	F1	1 = Enable pin debouncing on PF1. 0 = Disable pin debouncing on PF1.
0	F0	1 = Enable pin debouncing on PF0. 0 = Disable pin debouncing on PF0.

Chapter 17
MultiMediaCard (MMC) Controller

17.1 Theory of Operation

The MultiMediaCard (MMC) interface comprises an MMC bus on which MMC cards reside as slaves and a host acts as bus master. The LH7A400 MMC Controller provides the interface between the serial-MMC-bus protocol and the parallel LH7A400 APB, and acts as the host bus master for managing bus transactions. This chapter describes the operation of the onboard MMC Controller and presents an overview of its operation with MMC cards. Operating software for the LH7A400 communicates and programs MMC cards via registers contained in the MMC Controller. The MMC Controller handles communication protocol, handshaking, CRC generation and detection, FIFO control, and error flagging.

Detailed operational and programming information for MMC cards can be found in two sources that should be used as companions to this chapter:

MultiMediaCard Association (MMCA) System Specification, available from the MMCA web site at http://www.nxp.com/redirect/mmca.org.

MMC card manufacturer's data manuals, such as the SanDisk™ MMC Product Manual located on the Internet at: http://www.nxp.com/redirect/sandisk.com.

- The LH7A400 MMC Controller can operate with MultiMediaCards that are compliant with the MMC System Specification up to and including Version 3.2.

The MMC Controller supports the MMC interface and operation:

- Implements MMC specific functions
- Serves as the MMC Bus Master (acts as Host)
- Implements the standard MMC interface, including operations such as card initialization, Cyclic Redundancy Checking (CRC), command and response transactions, and interrupt handling.

17.1.1 Interface

The MMC Controller uses a three-wire serial data bus to interrogate, command, and transfer date to and from MMC cards. The signals on this three-wire bus are:

- Clock (MMCCLK, pin A3). With each cycle of this signal, a one-bit transfer occurs on the command and data lines. The frequency can vary between 0 and 20 MHz.
- Command (MMCCMD, pin B3), a bi-directional line used for card initialization and data transfer commands. This pin operates in push-pull mode for fast command transfer. The Command line carries commands from the MMC Controller to the cards, and responses from the cards to the MMC Controller.
- Data (MMCDATA, pin A2), a bi-directional data channel with a width of one line, operating in push-pull mode with only one card or the MMC Controller driving this line at a time.

In addition, the MMC bus contains the power and ground voltages.

17.1.1.1 MMC Card Registers

The MMC Controller communicates with MMC cards through a set of information registers. Three of these registers are mandatory for every card and three are optional.

17.1.1.1.1 Mandatory MMC Registers

Every MMC card contains a set of three mandatory registers:

- Card Identification Number (CID) is a 128-bit read-only register, containing a unique card identification number, programmed during card manufacture. The MMC Controller can read this register to determine the number and location of currently connected MMC cards.
- Card Specific Data (CSD) is a 128-bit read-only register, describing card operation conditions. The most-significant bytes contain manufacturing-programmed data. The two least-significant bytes contain information about copy and write protection, file storage format, and the error correction code (ECC) register. These two bytes can be programmed by the MMC Controller to define parameters such as the data format, error correction type, maximum data access time, and data transfer speed.
- Relative Card Address (RCA) is a 16-bit write-only register containing the card-relative address assigned to each card by the MMC Controller during card identification. The default RCA is 0x0001. Broadcasting an RCA value 0x0000 to all connected cards sets all cards in Standby State.

17.1.1.1.2 Optional MMC Registers

MMC cards can also have these registers:

- Operation Condition Register (OCR), a 32-bit register containing the VDD voltage range allowed for card access. This is generally implemented only in cards that support the full operational voltage range. The MMC Controller can issue a broadcast command to detect all such cards.
- Driver Stage Register (DSR), a 16-bit register programmable by the MMC Controller to improve the bus performance for extended operating conditions.

17.1.2 MMC Memory Organization

MMC cards contain byte-addressable memory. The MMCA Specification does not define memory/file system organization, but three are suggested: Hard disk-like file system; DOS FAT file system; or Universal file system. Most commercially available MMC cards use the hard disk-like organization. These cards organize memory into blocks of 512 byte blocks, much like the organization of a disk drive. Read operations can address as little as a single byte but write operations operate on full blocks. Performance can be enhanced by using streaming or multiple block transactions, as described in Section 17.1.7.2.

In this organization, blocks are also grouped into *erase groups* of 32 blocks each (or 16 blocks in the case of an 8MB MMC card). Any combination of blocks within a group and any combination of erase groups can be erased by the MMC Controller sending a single erase command. If data is not 'pre-erased', a Write command will perform an implicit erase prior to writing. Group erase produces faster write times, increasing system throughput.

17.1.3 Reset

After reset, the MMC Controller is disabled. To enable the MMC Controller, set the Clock Gating and Clock Predivide register MMC Enable field (CLOCK_PREDIV:MMC_EN). When the MMC Controller is enabled, software can program the MMC registers. Until programmed, the MMC configuration is:

- MMC mode is enabled.
- MMCCMD and MMCDATA are tri-stated.
- MMCCLK is LOW. The MMCCLK frequency is configured as HCLK/8.
- The Response FIFO is cleared. The Data FIFO contents are undefined. The FIFOs are configured to be read via DMA.
- All command and data controls and parameters are cleared, including the 80-bit initialization sequence.
- The BLOCK_COUNT register is initialized to 0x0. Note that this register must be programmed to a non-zero value before attempting to write to an MMC.
- All interrupts and errors are deasserted and cleared, except the FIFO Empty flag is set in the Status register (STATUS:FIFO_EMPTY). The Response Timeout limit defaults to 64 MMCCLK cycles. The Received Data Timeout limit defaults to 65,535 cycles of HCLK/2048.

17.1.4 Clock Generation and Control

The system HCLK is divided by the value contained in the CLOCK_PREDIV register to generate the MMC Master Clock. Then, the MMCCLK signal, which is the clock sent to MMC cards, is set with the Clock Rate Register (CLOCK_RATE). This register allows the MMC Master Clock to be further divided from the frequency determined in the CLOCK_PREDIV register. The Master Clock should be programmed for the fastest speed that will work with all the cards currently plugged in.

Software must stop the clock before reconfiguring the MMC Controller, then restart the clock to send the next command. MMC Controller registers must not be updated with the clock running as it can cause unpredictable operation. When updating the Data FIFOs, software need only restart the clock.

To set the MMCCLK frequency:

- Program the Start Clock bit (START_CLK) to 1 to start the clock.
- Program the Stop Clock bit (STOP_CLK) to 1 to stop the clock. Read the Status register Clock Disabled bit (STATUS:CLK_DIS) to confirm the clock is stopped.
- When both bits are 0, STOP_CLK has priority and the clock is stopped. Both bits are 0 after reset.
- Only one of START_CLK and STOP_CLOCK bits can be set at any time. The value 0b11 is invalid.
- Stop the clock before changing the frequency. Configure the MMCCLK frequency by programming CLOCK_PREDIV and CLOCK_RATE:
  - Program the CLOCK_PREDIV register CLOCK_PREDIV field (CLOCK_PREDIV:CLOCK_PREDIV) to specify a divisor for HCLK, as shown in Table 17-1. This CLOCK_PREDIV rate is called the MMC Master Clock.
  - Program the CLOCK_RATE register Clock Rate field (CLOCK_RATE:CLOCK_RATE) to specify MMCCLK based on the Master Clock (HCLK after a pre-set divisor), as shown in Table 17-2.

Table 17-1. MMCCLK CLOCK_PREDIV

CLOCK_PREDIV FIELD	MASTER CLOCK
0x1	HCLK
0x2	HCLK/2
0x3	HCLK/3
0x4	HCLK/4
0x5	HCLK/5
0x6	HCLK/6
0x7	HCLK/7
0x8	HCLK/8

Table 17-2. MMCCLK Frequency

CLOCK_RATE FIELD	OUTPUT FREQUENCY
0x0	Master Clock
0x1	Master Clock/2
0x2	Master Clock/4
0x3	Master Clock/8
0x4	Master Clock/16
0x5	Master Clock/32
0x6	Master Clock/64

17.1.5 DMA Operation

The MMC interface can use the LH7A400 DMA Controller for data transfers (see also Chapter 9), allowing commands with large data transfers and low processor overhead:

1. The Data FIFOs are set up in SDRAM.
2. The DMA controller is enabled and programmed with base address and byte counts pointing to the buffers.
3. The MMC command is programmed.
4. The data transfers between receive and transmit FIFOs begin and proceed automatically until any of these occur:
   - The transfer is stopped by software
   - The data BLOCK requirements are met
   - A receive overflow or transmit underflow error occurs.

When the MMC Data Block size exceeds the SDRAM FIFO size, the DMA controller can be allocated fresh Data FIFOs as required.

The MMC Controller monitors Data FIFO status, generating receive overflow and transmit underflow errors. Errors end the transfer and generate DMA Controller error interrupts.

17.1.6 MMC Card Communication Overview

Communications between the MMC Controller and MMC cards occur in two modes: Identification Mode and Data Transfer Mode. Software must program the controller to properly perform these two modes. Refer to the MMCA Specification or a manufacturer's User Manual for full descriptions of all commands.

Software sends commands to the MMC cards by writing the command number into the MMC Controller COMMAND register and the command's argument (if any) into the MMC Controller ARGUMENT register (see Section 17.2.2, for MMC Controller register descriptions). Software reads card responses from the MMC Controller RESPONSE_FIFO register. The software places Write data in, or retrieves Read data from the MMC Controller DATA_FIFO register. Other functions are defined in Section 17.2.2.

Application-specific commands (ACMD) require two writes by the software to the COMMAND register. The software first writes CMD55 (application specific command), checks status for response, then writes the command. For example, to send ACMD23, the software first writes CMD55 into the COMMAND register, checks the STATUS register for command completion without error, then writes CMD23 into the COMMAND register. A final check of the STATUS register by the software verifies that the command completed without error.

The speed of the MMC clock can be set by software, as required by particular MMC cards, using the MMC Controller CLOCK_RATE register. Software can also start and stop the MMC clock using the MMC Controller CLOCK_CONTROL register. At the completion of any command, the software should read the MMC Controller STATUS register to ensure completion occurred with no errors.

17.1.6.1 Identification Mode

Upon initial power up, all MMC cards initialize into the Idle State. In this mode, the cards set their RCA registers to default values of 0x00000001. Cards can also be forced into the Idle State by the MMC Controller issuing a CMD0 (GO_IDLE_STATE). To assure all cards on the bus are stable, the MMC Controller must wait 80 MMCCLK states before proceeding with communications over the MMC bus.

The MMC Controller software sends a CMD2 (ALL_SEND_ID), causing all connected cards to begin replying with their CID number. If more than one MMC card is connected, only one will win the bus and transmit its complete CID. The MMC Controller software must assign a relative address to that MMC card using CMD3 (SET_RELATIVE_ADDR). This address programs the RCA register in the MMC card. The identification process is repeated until all connected cards are assigned unique relative addresses. The process ends when no start bit appears on the data line from the MMC cards for more than five clock periods.

At this point, all MMC cards enter the Stand By state and the MMC Controller software enters the Data Transfer Mode. Software should program the MMC Controller to send a CMD7 (SELECT/DESELECT_CARD) with the relative card address of 0x0000 at regular intervals to locate any recently installed cards. This causes all identified cards to return to Stand By state (if they weren't already there) and any non-identified cards to identify themselves. Doing so allows identification of new cards without resetting those cards already identified.

17.1.6.2 Data Transfer Mode

MMC Protocol defines two types of data transfers: sequential and block. Sequential transfers allow specifying a start address and then receiving or sending 'streaming' data from the MMC card. Block transfers specify a single or multiple blocks of data to be read or written. More detailed operational descriptions appear in Section 17.1.7.

17.1.6.2.1 Stream Read

The MMC Controller software selects an MMC card by sending its relative address as the argument to a CMD7 (SELECT/DESELECT_CARD). After receiving a response, the software sends a CMD11 (READ_DAT_UNTIL_STOP) with the starting address as the argument. The MMC card begins sending data over the MMC bus starting with the requested address. Software retrieves the data from the MMC Controller DATA_FIFO register. Data continues to be sent from the card until the MMC Controller software sends a CMD12 (STOP_TRANSMISSION). Because of execution delay, transmission stops after the end bit of the command.

Streaming Reads can begin and end at any address. No CRC is generated for Streaming Reads.

Note that if the MMCCLK stops due to a FIFO overflow (STATUS:FIFO_FULL), the FIFO must be completely emptied before restarting the clock. Failure to do so will result in a half-word being dropped at FIFO boundaries.

17.1.6.2.2 Stream Write

The MMC Controller can initiate a Stream Write in a similar way to reading. The software selects the proper card with CMD7 with the relative address for the MMC card as the argument. For Writes, the starting and ending address must be on block boundaries.

Software places data to be written in the MMC Controller DATA_FIFO register, then sends a CMD20 (WRITE_DAT_UNTIL_STOP) command. When all data has been placed in FIFO, software sends a CMD12 (STOP_TRANSMISSION) to terminate the write.

17.1.6.2.3 Single Block Write

Single Block Write operations also transfer from a single physical block, however the entire block must be written from beginning to end. Any Write operations that do not fill an entire block will be flagged as a misalignment error.

Software selects the MMC card using CMD7 with the card's relative address as the argument. Software fills the DATA_FIFO register then sends CMD24 (WRITE_BLOCK) with the address of the beginning of the block as the argument. The software continues to fill the FIFO until all data is written.

The MMC Controller automatically generates the proper CRC and sends it to the MMC card.

Figure 17-1 illustrates Stream Write and Stream Read transfers.

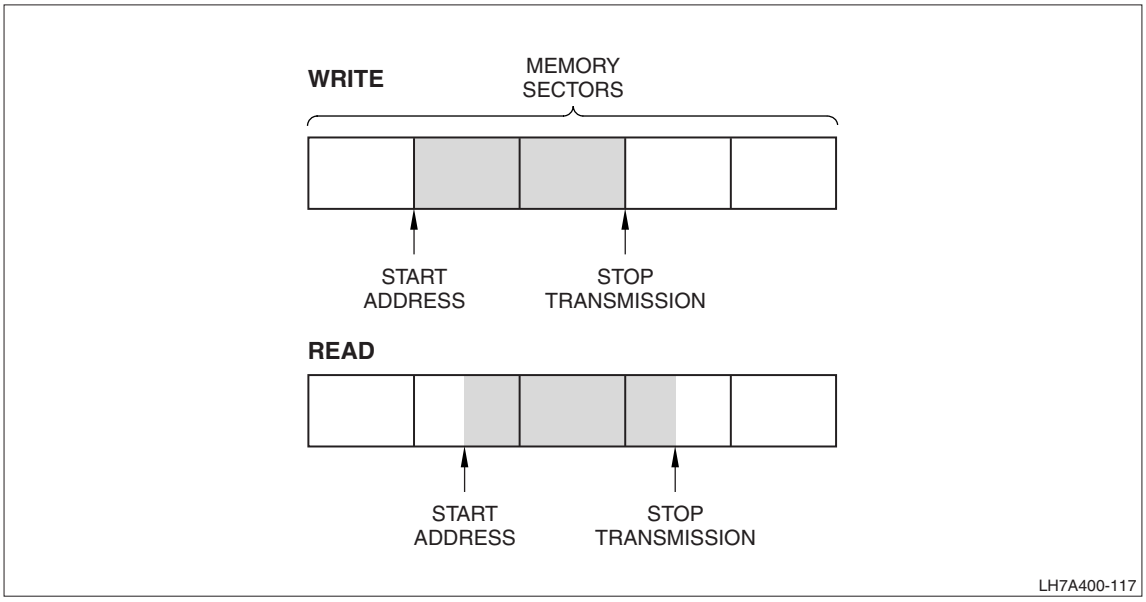


Figure 17-1. Stream Mode Data Transfer

17.1.6.2.4 Single Block Read

Single Block Read transfers read data from a single physical block. The Single Block Read does not have to read the entire block; the Read can be as little as one byte up to the entire block.

MMC Controller software selects the MMC card using a CMD7 with the card's relative address as the argument. The software then sends the block length to be read as the argument to CMD16 (SET_BLOCKLEN) followed by CMD17 (READ_SINGLE_BLOCK) with the starting address as the argument to begin the read. Data is available to the software in the MMC Controller DATA_FIFO register. Block Reads have CRC data bits added to each data block. Figure 17-2 shows the Single Block Write and Read functions.

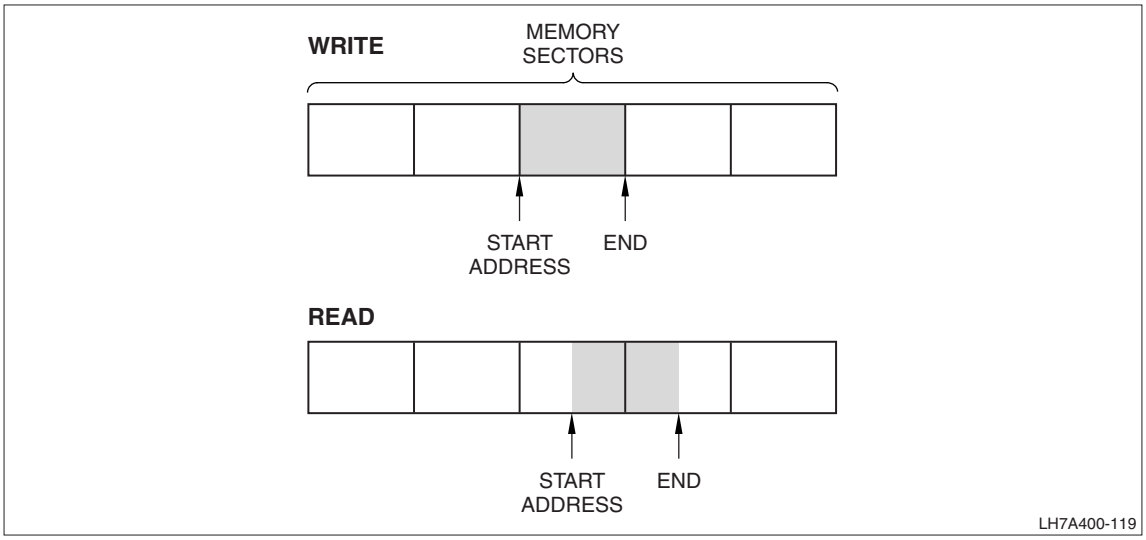


Figure 17-2. Single Block Mode Data Transfers

17.1.6.2.5 Multiple Block Write

Multiple Block Write operations also transfer from two or more physical blocks, however each block must be written from beginning to end. Any Write operations that do not fill all blocks entirely will be flagged as a misalignment error.

Software selects the MMC card using CMD7 with the card's relative address as the argument. The number of blocks to be written is placed in the MMC Controller BLOCK_COUNT register by software. Then, software fills the DATA_FIFO register then sends CMD25 (WRITE_MULTIPLE_BLOCK) with the address of the beginning of the block as the argument. The software continues to fill the FIFO until all data is written.

The MMC Controller automatically generates the proper CRC and sends it to the MMC card.

17.1.6.2.6 Multiple Block Read

Multiple Block Read operations are the same as Single Block Reads except the requested data can span more than one contiguous block. For Reads, the beginning and ending address need not be on block boundaries.

MMC Controller software selects the MMC card using a CMD7 with the card's relative address as the argument. The software then sends the block length to be read as the argument to CMD16 (SET_BLOCKLEN), programs the MMC Controller register BLOCK_COUNT with the number of blocks to be read, then sends a CMD18 (READ_MULTIPLE_BLOCK) with the starting address as the argument to begin the read. Data is available to the software in the MMC Controller DATA_FIFO register.

Block Reads have CRC data bits added to each data block.

Figure 17-3 shows the Multiple Block Write and Read functions.

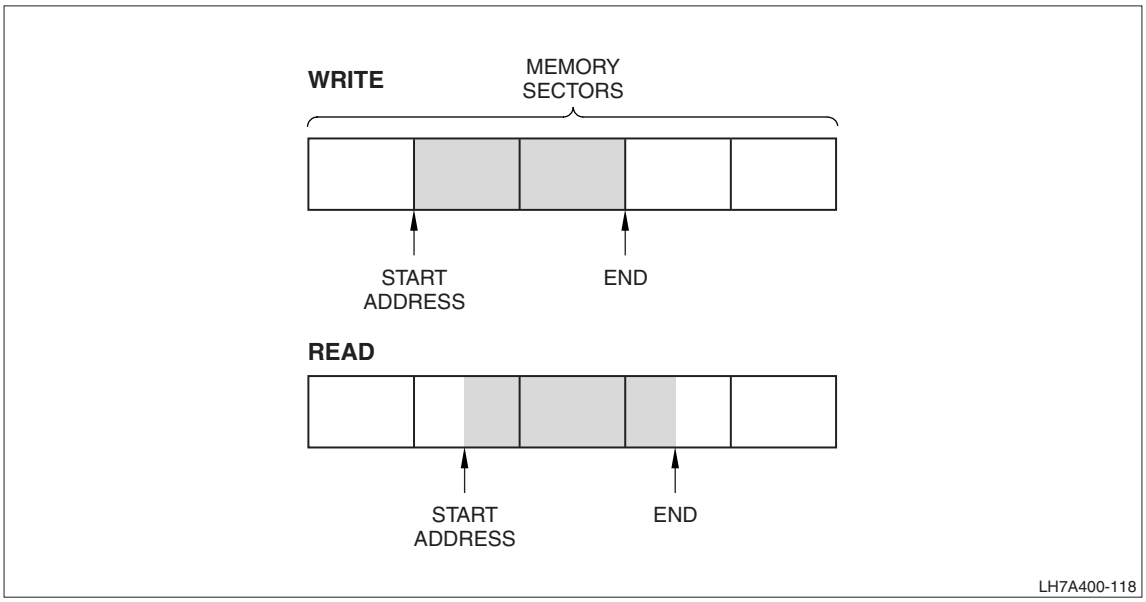


Figure 17-3. Multiple Block Mode Data Transfer

17.1.6.2.7 Block and Group Erase

Software can erase block or groups of block with a single set of commands. This can improve Write performance by pre-erasing multiple blocks prior to Write operations.

Software first selects the proper card with CMD7, then identifies the block start and end with CMD32 (TAG_BLOCK_START) and CMD33 (TAG_BLOCK_END), or the erase group start and end with CMD35 (TAG_ERASE_GROUP_START) and CMD36 (TAG_ERASE_GROUP_END). Blocks or groups can be removed from the list using CMD34 (UNTAG_BLOCK) or CMD37 (UNTAG_ERASE_GROUP) as appropriate. Once set up, software issues a CMD38 (ERASE). The MMC card erases all memory addresses within the boundaries of the tags.

17.1.7 Command Operation and Protocols

This section discusses the software and MMC Controller communication activity, with an overview of required parameters and transfer elements. For specific register programming and flag values, see Section 17.1.10.

17.1.7.1 Basic, No Data, Command-Response Sequence

The Basic, No Data, and Command-Response Sequence commands include:

- CMD0: GO_IDLE_STATE
- CMD1: SEND_OP_COND
- CMD2: ALL_SEND_CID
- CMD3: SET_RELATIVE_ADDR
- CMD7: SELECT/DESELECT_CARD
- CMD9: SEND_CSD
- CMD10: SEND CID
- CMD12: STOP_TRANSMISSION
- CMD13: SEND_STATUS
- CMD15: GO_INACTIVE_STATE

The MMC Controller automatically performs the basic MMC Bus transaction, including these operations:

- Formatting the command
- Generating and appending CRC numbers
- Waiting for the Response Start bit
- Receiving the Response data
- Validating the card CRC
- Adding eight clock cycles.

These transaction parameters can be programmed in the MMC Controller registers:

- Command code and arguments
- The type of the expected response, including no response
- The type, if any, of data transfer associated with the command
- The time-out period for the card response
- Adding the 80-cycle Initialization sequence.

17.1.7.2 Data Transfer

The MMC Controller performs data transactions on the MMC Bus in all basic modes.

Data transfer operations involve two FIFOs controlled by the MMC Controller. Software accesses these FIFOs via the DATA_FIFO register. While software is accessing one FIFO, to read received data or to write data for transmission, the MMC Controller can be receiving or transmitting data in the other FIFO. When both the software access and the transfer are complete, the FIFOs are switched. Software can read or write the FIFO recently filled or emptied by the transfer. Concurrently, the MMC Controller can use the FIFO recently read or written by software for the next reception or transmission.

At the end of any transfer or Busy signal on the MMC Bus, the MMC Controller waits eight MMCCLK cycles before notifying software of the FIFO switch. Depending on the transfer type, a FIFO need not be completely read or written during the software access. Data begins at offset 0x0 in the FIFOF for each transfer.

When a FIFO is ready to be read or written by software, one of these flags is set:

- STATUS:FIFO_FULL indicates one of these conditions:
  - Both buffers have been written to capacity by software (1024 bytes) prior to transmission commencing
  - One buffer is currently transmitting and the other has been written to capacity
  - One buffer is receiving data and the other has been filled by reception and software has not emptied it yet.
- STATUS:FIFO_EMPTY indicates one of these conditions:
  - Both buffers contain no data
  - One buffer is receiving data and the other buffer is empty
  - One buffer is transmitting and the other buffer is empty.

When a transfer completes, the Data Transfer Done interrupt (DATA_TRAN_DONE) is asserted:

- In a read sequence, DATA_TRAN_DONE indicates the end of the data transfer from the MMC Bus.
- In a write sequence, DATA_TRAN_DONE indicates the Data CRC Response Check transmission.

A card cannot be disconnected while the MMC Controller is transmitting or receiving data. At any other time, cards can be connected and disconnected as described in the SanDisk MMC Product Manual.

17.1.7.2.1 Block Data Write

This operation is performed after the command and response sequences, as described in the SanDisk MMC Product Manual. When software has finished writing a FIFO, the MMC Controller performs the Basic Block Data Write transaction:

- Generates the data start bit
- Sends the data
- Generates and appends the CRC number
- Receives the response CRC
- Validates the CRC response
- Waits for a busy signal from the MMC.

In a Multiple Block Write, the controller performs this basic block data transfer on the MMC Bus multiple times.

When software has finished writing a FIFO:

- If the FIFO is not full, software notifies the MMC Controller the FIFO is not full.
- If the FIFO is full, software waits until the controller switches the FIFOs, then writes the next block to the next FIFO. This is signalled with the STATUS:FIFO_EMPTY set to 1.

Software generates the stop transmission command after the last block of data, and is notified when the last FIFO of data has been transmitted. The Stop Transmission command is described in the SanDisk MMC Product Manual.

Upon deasserting the Busy signal after each block of data transfer, the controller waits eight MMCCLK cycles before notifying software the FIFO is ready. Similarly, at the end of each data transfer, the MMC Controller waits eight MMCCLK cycles before notifying software the transfer has finished. The card requires this delay for finishing internal operations. When the MMC Controller completes a transfer before software finishes writing the next FIFO, the MMC Controller stops MMCCLK to avoid losing data on the MMC bus.

CAUTION

A card cannot be disconnected in a Multiple Block Write, including while a Busy signal is active. Doing so may cause data to be corrupted or lost.

In a Block Data Write, these parameters must be defined:

- Identification of the data transfer as a Write
- The block length, for the first block after a reset, or when the block length is different from the previous block length
- The number of blocks
- The block mode.

If an error occurs during Block Write, the Host is reset when:

- An error is detected by the Host or card after receiving a response or timeout
- Software detects this error after starting a Write sequence.

17.1.7.2.2 Block Data Read

After performing the Command Response sequence, the MMC Controller waits two MMCCLK cycles after the end bit of the command before detecting the Data Start bit. The Block Data Read transaction comprises:

- The MMC Controller receives the data and validates the data CRC.
- After receiving data into the FIFO, the MMC Controller notifies software the FIFO is full. Software can then read the FIFO.
- Software generates a Stop Transmission command after the last block of data is received.
- Before each data block, the MMC Controller verifies that data has arrived before the timeout limit programmed in the MMC Controller registers. The Read Timeout is calculated:

$$\text{Read Timeout} = (\text{Master Clock} \times \text{Programmed timeout limit}) \div 256$$

CAUTION

A card cannot be disconnected in a Multiple Block Write, including while a Busy signal is active. Doing so may cause data to be corrupted or lost.

In a Multiple Block Read, the MMC Controller executes a block data transfer on the MMC Bus multiple times. When a CRC error is detected at the end of a Data Block in a Multiple Block Read, the MMC Controller notifies software of the error. Software must then send a Stop command. When the MMC Controller completes a transfer before software finishes reading the previous FIFO, the MMC Controller stops the MMCCLK to avoid losing data on the MMC bus.

After receiving the End bit of the last Data Block, the MMC Controller stops the MMCCLK, allowing software to send the Stop Transmission command. Software reads the last FIFO.

In a Block Data Read, these parameters must be defined:

- Specify that the data transfer is Read
- Block length for the first block after reset, or when the block length is different from the previous block length
- Number of blocks
- Block mode.

If an error occurs during Block Read, the Host is reset when:

- An error is detected by the Host or card after receiving a response or timeout
- Software detects this error after starting a Read sequence.

17.1.7.2.3 Stream Data Write

In Stream Data Write:

- The MMC Controller generates the Data Start bit and sends the data.
- Software must write the last FIFO with only six bytes and the Stop Transmission command parameters.
- Software must inform the MMC Controller of the partially full FIFO.
- The MMC Controller then sends the last six data bytes and the Stop command together.

In Stream Data Transfer mode, the Stop Transmission command must be sent during the data transfer and cannot be sent after the data is finished.

Software can partially fill the FIFOs, but must first send notification of a partially full FIFO. A minimum of one data byte can be specified. When an odd number of bytes is specified, the last byte must be in the high byte of the word written to the FIFO.

In Stream Data Write, these parameters must be defined:

- Identification of the transfer as Stream mode
- Identification of the transfer as a Write.

17.1.7.2.4 Stream Data Read

In Stream Data Read:

- The MMC Controller waits for the Start Data bit
- The MMC Controller receives the data
- Software sends the Data Stop Transmission command.
- Stops the Data Read at the end of the Data Stop Transmission command.

When an odd number of bytes is specified, the last byte is in the low byte of the word read from the FIFO.

In Stream Data Read, these parameters must be defined:

- Identification of the transfer as Stream mode
- Identification of the transfer as a Read
- Timeout for the Data Read, programmed by software.

17.1.7.3 Busy Sequence

The MMC Controller expects a Busy signal:

- After every block of data in a Single or Multiple Block Write operation
- At the end of a command when software specifies a Busy signal is to be expected, for example, after commands such as:
  - Stop Transmission
  - Card Select
  - Erase
  - Program CID.

While a busy signal is on the MMC bus, software can send only these commands:

- Send status command (CMD 13)
- Disconnect command (CMD 7)

A card can be disconnected in Busy state. The Busy signal is deasserted and a different card can be connected.

17.1.8 Error Detection

When an error is detected, an error status flag is set in the STATUS register at the end of the transfer sequence, as shown in Table 17-3. These flags are reset every time the clock is stopped.

Table 17-3. Error Detection

ERROR	DESCRIPTION	STATUS FIELD SET
Response CRC Error	A CRC calculation error has appeared on the command response.	RESPONSE_CRC_ERROR
Response Timeout	No response has appeared for a time exceeding the limit programmed in the Response Timeout register (RESPONSE_TO).	TIME_OUT_RESPONSE
Write CRC Error	The CRC response in the data write sequence has returned a CRC error.	CRC_WRITE_ERROR
Read CRC Error	The CRC calculation on the data read block is incorrect.	CRC_READ_ERROR
Read Data Timeout	The time between sending a read command and receiving the data has exceeded the limit programmed in the Read Timeout register (READ_TO).	TIME_OUT_READ

17.1.9 Interrupts

Besides the error flags discussed in Section 17.1.8, the MMC Controller generates individual active HIGH flags and interrupts to report conditions and events. These flags are asserted in STATUS. Some of these flags correspond to some of the MMC hardware interrupts, generated for these conditions:

- Eight MMCCLK cycles have passed after the end of a command and response sequence in a No Data Transfer operation.
- The Busy signal has ended. This interrupt corresponds to the Program Done flag (STATUS:PRG_DONE).

The flags and corresponding hardware interrupts are represented in the Interrupt Status register (INT_STATUS), as shown in Table 17-4. Software can configure these INT_STATUS interrupts as enabled or masked by programming the Interrupt Mask register (INT_EN). Each INT_STATUS interrupt can be deasserted by writing 0b1 to the appropriate field in the MMC End-of-Interrupt register (INT_CLEAR).

When the MMC interrupt (MMCINTR) is asserted to the LH7A400 Interrupt Controller, software can read INT_STATUS and STATUS for information about the cause.

Table 17-4. MMC Interrupts

INT_STATUS INTERRUPT	INTERRUPT DESCRIPTION	CORRESPONDING STATUS	STATUS DESCRIPTION
END_CMD_RESP	End Command Response. The command and response transfers have finished.	END_CMD_RESP	End Command Response. The command and response transfers have finished.
PRG_DONE	Program Done. The MMC card has completed writing data and the Busy signal has ended.	PRG_DONE	Program Done. The MMC card has completed writing data and the Busy signal has ended.
DATA_TRAN_DONE	Data Transfer Done. The MMC Controller has completed transfer to or from the MMC card.	DATA_TRAN_DONE	Data Transfer Done. The MMC Controller has completed transfer to or from the MMC card.
CLK_DIS*	Bus Clock Stopped. MMCCLK is not running.	CLK_DIS	Clock Disabled. MMCCLK is not running.

NOTE: *This interrupt cannot be cleared using the INT_CLR register. Use care before enabling and using this interrupt.

17.1.10 Transaction Examples

The examples in this section show MMC mode operation.

17.1.10.1 Initialize

To initiate a command, the application must first send 80 MMCCLK cycles on the MMC Bus. Every command on the Bus can be prefixed with this Initialization sequence. This function is useful for acquiring new cards inserted on the Bus.

To prefix a command with the Initialization sequence, set the Command Data Control register Initialize field (CMD_CONTROL:INITIALIZE).

Software can either:

- Wait for the end of Busy by waiting for the Status register Program Done field (STATUS:PRG_DONE) to be set
- Send a Card Select command and address to another card while the card is busy programming.

17.1.10.2 No Data Command and Response Transaction

these registers and content are used in the basic No Data Command an Response transaction:

1. The clock is stopped, by setting the CLOCK_CONTROL register Stop Clock field (CLOCK_CONTROL:STOP_CLK).
2. The command code is programmed in the Command Number register (COMMAND).
3. The most and least significant byte arguments are programmed in ARGUMENT
4. The CMD_CONTROL parameters are programmed:
   - The Response Format field (RESPONSE_FORMAT)
   - The Data Enable field (DATA_EN) is cleared, indicating the transfer includes no data.
   - The Busy field (BUSY) is cleared, indicating no Busy signal is expected after the command.
   - Unless an Initialization sequence is required, INITIALIZE is cleared.
5. The clock is started, by clearing CLOCK_CONTROL:STOP_CLK and setting CLOCK_CONTROL:START_CLK.

After the clock is started, no registers can be reprogrammed until the STATUS register End Command Response field (STATUS:END_CMD_RES) is set, indicating the Command Response has finished and the response is in the Response FIFO register (RESPONSE_FIFO) for software to read.

17.1.10.3 Erase

An erase command is a basic No Data Command and Response sequence, performed as described in Section 17.1.7.1. With the command itself in CMD_RES_CTL, the Busy field (CMD_RES_CTL:BUSY) must be set after the response is read from RESPONSE_FIFO.

17.1.10.4 Single Block Write

For the Single Block Write command, the MMC registers are programmed:

1. The clock is stopped.
2. Set the block size in the BLOCK_LEN register.
3. Set the BLOCK_COUNT register to 0x1.
4. Get card status.
5. Command card into transfer state.
6. Program the command code into the COMMAND register.
7. The most significant byte arguments are programmed in ARGUMENT.
8. The CMD_CONTROL parameters are programmed:
   - RESPONSE_FORMAT programmed to 0x01, specifying Format R1.
   - DATA_EN is set, indicating the command includes a data transfer.
   - The Write field (WRITE) is set, specifying a Write.
   - The Stream field (STREAM) is cleared, specifying a block transfer.
   - BUSY is cleared, indicating no Busy signal is expected after the command.
   - Unless an Initialization sequence is required, INITIALIZE is cleared.
9. The clock is started.
10. Software checks the STATUS register's FIFO Empty field (STATUS:FIFO_EMPTY) to identify whether the FIFO is empty.
11. When the FIFO is empty, software writes the FIFO and starts the clock.
12. Check STATUS:CRC_WRITE_ERROR. The MMC will not accept Write data if received with a CRC error. If a CRC error occurs, software must re-write the data to the MMC.
13. Send STOP_TRANS command.
14. Software polls the STATUS register Data Transfer Done field (STATUS:DATA_TRAN_DONE) until the field is set.
15. After DATA_TRAN_DONE is set, software checks various fields in the STATUS register to identify whether the data transfer finished successfully.
16. To address a different card, software can send a Chip Select command to the card by sending a basic No Data Command and Response transaction. To address the same card, software must wait for the STATUS register Program Done field (STATUS:PRG_DONE) to be set, to ensure the Busy is finished.

17.1.10.5 Single Block Read

For a single block read, software:

1. Sends a Read command modifying:
   a. CMD_CONTROL:
      – RESPONSE_FORMAT is programmed as 0x01, specifying Format R1
      – DATA_EN is set, indicating the command includes a data transfer
      – WRITE is cleared, specifying a Read
      – STREAM is cleared, specifying a block transfer
      – BUSY is cleared, indicating no Busy signal is expected after the command
      – Unless an Initialization sequence is required, INITIALIZE is cleared.
   b. The Block Count register (BLOCK_COUNT) is programmed as 0x0001, specifying a single block.
   c. The Block Length register (BLOCK_LEN) is programmed with the number of bytes in the block.
2. Reads the response from RESPONSE_FIFO.
3. Waits for STATUS:FIFO_FULL to be set.
4. Checks STATUS:CRC_READ_ERROR.
5. Reads the data from DATA_FIFO.
6. When finished, deselects the MMC.

17.1.10.6 Multiple Block Write

For a Multiple Block Write, software:

1. Sends a Write command modifying:
   a. CMD_CONTROL:
      – RESPONSE_FORMAT is programmed as 0x01, specifying Format R1
      – DATA_EN is set, indicating the command includes a data transfer
      – WRITE is set, specifying a Write
      – STREAM is cleared, specifying a block transfer
      – BUSY is cleared, indicating no Busy signal is expected after the command
      – Unless an Initialization sequence is required, INITIALIZE is cleared.
   b. The Block Count register (BLOCK_COUNT) is programmed with the number of blocks in the transfer.
   c. The Block Length register (BLOCK_LEN) is programmed with the number of bytes in the block.
2. After the clock is started, wait until STATUS:END_CMD_RES is set, indicating the command response to the Write is finished.
3. Reads RESPONSE_FIFO.
4. Checks STATUS:CRC_WRITE_ERROR.
5. Repeats the following steps until the final block has been written:
   – Wait for STATUS:FIFO_EMPTY to be set
   – Check for STATUS:CRC_WRITE_ERROR
   – Write DATA_FIFO with 512 bytes
   – Start the clock.

6. Before sending the Stop Transmission command, waits for DATA_TRAN_DONE to be set.
7. Sends the stop transmission command as described in Section 17.1.7.1, with CMD_CONTROL:BUSY set.
8. After receiving the response, waits for the end of the Busy signal by either:
   – Waiting until STATUS:PRG_DONE is set
   – Sending a Send Status command to the card and checking the state of the card in the response.
9. When finished, deselects the MMC.

17.1.10.7 Multiple Block Read

For a Multiple Block Read, software:

1. Sends a Read command, modifying:
   a. CMD_CONTROL:
      – RESPONSE_FORMAT is programmed as 0x01, specifying Format R1
      – DATA_EN is set, indicating the command includes a data transfer
      – WRITE is cleared, specifying a Read
      – STREAM is cleared, specifying a block transfer
      – BUSY is cleared, indicating no Busy signal is expected after the command
      – Unless an Initialization sequence is required, INITIALIZE is cleared.
   b. The Block Count register (BLOCK_COUNT) is programmed with the number of blocks in the transfer.
2. After the clock is started, waits until STATUS:END_CMD_RES is set, indicating the command response is finished.
3. Reads RESPONSE_FIFO.
4. Repeats these steps until the final block has been read:
   – Wait until STATUS:FIFO_EMPTY is set
   – Check for STATUS:CRC_READ_ERROR
   – Read DATA_FIFO.
5. When finished, deselects the MMC.

After receiving the final block, the MMC Controller stops the clock and software sends a Stop Transmission command.

17.1.10.8 Stream Write

For a Stream Write, software:

1. Sends a Write command modifying:
   a. CMD_CONTROL:
      – RESPONSE_FORMAT is programmed as 0x01, specifying Format R1
      – DATA_EN is set, indicating the command includes a data transfer
      – WRITE is set, specifying a Write
      – STREAM is set, specifying a Stream Transfer
      – BUSY is cleared, indicating no Busy signal is expected after the command
      – Unless an Initialization sequence is required, INITIALIZE is cleared.
   b. BLOCK_COUNT is programmed with 0xFFFF.
2. Reads RESPONSE_FIFO.
3. Fills DATA_FIFO.
4. Repeats these steps until all but the final 256 or fewer half words have been written:
   – Wait for STATUS:FIFO_EMPTY to be set.
   – Fill DATA_FIFO.
5. Writes DATA_FIFO with all but the final 6 bytes of data.
6. Starts the clock.
7. Waits for the clock to be stopped by the MMC Controller, as indicated by STATUS:CLK_DIS.
8. Writes DATA_FIFO with the final 6 bytes of data.
9. Programs the MMC registers as described in Section 17.1.7.1.
10. Sets CMD_CONTROL:BUSY.
11. Starts the clock.
12. When finished, deselects the MMC.

No CRCs are used in the streaming mode.

17.1.10.9 Stream Read

For a single block read, software:

1. Sends a Read command modifying:
   a. CMD_CONTROL:
      – RESPONSE_FORMAT is programmed as 0x01, specifying Format R1
      – DATA_EN is set, indicating the command includes a data transfer
      – WRITE is cleared, specifying a Read
      – STREAM is set, specifying a Stream Transfer
      – BUSY is cleared, indicating no Busy signal is expected after the command
      – Unless an Initialization sequence is required, INITIALIZE is cleared.
   b. The Block Length register (BLOCK_LEN) is programmed with the number of bytes in the block.
2. Reads the response from RESPONSE_FIFO.
3. Waits for STATUS:FIFO_FULL to be set.
4. Reads the data from DATA_FIFO.
5. At completion of Read, sends STOP TRANSMISSION.
6. When finished, deselects the MMC.

17.2 Register Reference

17.2.1 Memory Map

The interrupt registers reside in memory at offsets from the MMC Controller base address, 0x8000.0100, as shown in Table 17-5.

Table 17-5. MultiMediaCard Register Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	CLOCK_CONTROL	Clock Control
0x04	STATUS	Controller Status
0x08	CLOCK_RATE	Clock Divider
0x0C	CLOCK_PREDIV	Clock Gating and clock predivider
0x10	///	Reserved. Do not access this location
0x14	CMD_CONTROL	Command Control
0x18	RESPONSE_TO	Response Timeout
0x1C	READ_TO	Read Timeout
0x20	BLOCK_LEN	Block Length
0x24	BLOCK_COUNT	Block Count
0x28	INT_STATUS	Interrupt Sources
0x2C	INT_CLEAR	Clear Interrupts
0x30	///	Reserved. Do not access this location
0x34	INT_EN	Enable Interrupts
0x38	COMMAND	Command Number
0x3C	ARGUMENT	Command Argument
0x40	RESPONSE_FIFO	Response FIFO
0x44	///	Reserved. Do not access this location
0x48	DATA_FIFO	Data FIFO
0x4C	///	Reserved. Do not access this location

17.2.2 Register Descriptions

17.2.2.1 MMC Start and Stop Clock Register (CLOCK_CONTROL)

This register allows starting and stopping the MMC clock. The function is described in Table 17-6 and Table 17-7. Setting both bits to 1 is not allowed. At reset, this register defaults to 0x00000000.

Programming the STOP_CLK bit to 1 causes the STATUS and INT_STATUS registers to assume their reset values.

Table 17-6. CLOCK_CONTROL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														STARTCLK	STOPCLK
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO
ADDR	0x8000.0100															

Table 17-7. CLOCK_CONTROL Fields

BITS	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
1	START_CLK	**Start Clock** This is a write-only bit; reading yields invalid results. 1 = Starts MMCCLK 0 = No effect
0	STOP_CLK	**Stop Clock** This is a write-only bit; reading yields invalid results. 1 = Stops MMCCLK 0 = No effect

NOTE: Bits 1 and 0 must not be simultaneously programmed to 1. Unpredictable results can occur.

17.2.2.2 MMC Status Register (STATUS)

Reading this register, as described in Table 17-8 and Table 17-9, returns the controller status and raw (without masking applied) interrupt status following command execution. Software should read this register following each command to ensure the command has been completed without error. Do not write to this register.

Table 17-8. STATUS Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///		END_CMD_RESP	PRG_DONE	DATA_TRAN_DONE	///		CLK_DIS	FIFO_FULL	FIFO_EMPTY	RESPONSE_CRC_ERROR	///	CRC_READ_ERROR	CRC_WRITE_ERROR	TIME_OUT_RESPONSE	TIME_OUT_READ
RESET	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0104															

Table 17-9. STATUS Fields

BITS	FIELD	DESCRIPTION
31:14	///	**Reserved** Reading this field returns 0.
13	END_CMD_RESP	**End Command Response** When command execution is processing, this bit reports the raw interrupt status. 1 = The command response ended either normally or through a timeout. 0 = The command is still executing; no response has been received.
12	PRG_DONE	**Program Done** This bit is asserted when the MMC card has completed writing the data. This bit reports the raw interrupt status. 1 = Write operation ended . 0 = Write operation has not ended.
11	DATA_TRAN_DONE	**Data Transfer Done** This bit is asserted when the MMC Controller completes transfer of data to the MMC card, or has received all specified data from the MMC card. The MMC Controller adds at least 8 MMC clocks after completion before asserting this bit. This bit reports the raw interrupt status. Following a Read: 1 = The data transfer has completed. 0 = The data transfer has not completed. Following a Block Write: 1 = Transmission of the data CRC response check has completed; waiting for PRG_DONE. 0 = Transmission of the data CRC response check has not completed; waiting for PRG_DONE.

Table 17-9. STATUS Fields (Cont'd)

BITS	FIELD	DESCRIPTION
10:9	///	**Reserved** Reading this field returns 0.
8	CLK_DIS	**Clock Disabled** This bit reports the current MMC Clock state: 1 = The MMC clock is stopped. 0 = The MMC clock is running.
7	FIFO_FULL	**FIFO Full** This bit is set to 1 for any of these conditions: • Both buffers have been written to capacity by software (1,024 bytes) prior to transmission commencing • One buffer is currently transmitting and the other has been written to capacity • One buffer is receiving data and the other has been filled by reception and software has not emptied it yet. 1 = The FIFO meets one of the above conditions. 0 = The FIFO is not full.
6	FIFO_EMPTY	**FIFO Empty** This bit is set to 1 for any of these conditions: • Both buffers contain no data • One buffer is receiving data and the other buffer is empty • One buffer is transmitting and the other buffer is empty. **IMPORTANT:** This flag lags the final read from the FIFO by 2 PRE-DIV clocks and 1 PCLK. If this flag is read immediately after reading the last FIFO entry, it may not yet be set. Therefore, aloways delay at least 1 PCKL between reading the FIFO and checking this flag. 1 = The FIFO meets one of the above conditions. 0 = The FIFO is not empty.
5	RESPONSE_CRC_ERROR	**Response CRC Error** This bit reports: 1 = A response CRC error has occurred. 0 = No response CRC error.
4	///	**Reserved** Reading this field returns 0.
3	CRC_READ_ERROR	**CRC Read Error** This bit reports: 1 = A CRC read error has occurred 0 = No CRC read error
2	CRC_WRITE_ERROR	**CRC Write Error** This bit reports: 1 = A CRC write error has occurred. 0 = No CRC writer error.
1	TIME_OUT_RESPONSE	**Timeout Response** This bit reports: 1 = The number of MMCCLK cycles between the command and the response (N_{CR})* has exceeded the value in RESPONSE_TO. 0 = Response has not timed out.
0	TIME_OUT_READ	**Timeout Read** This bit reports: 1 = The number of (Master Clock/256) cycles between the command and the received error has exceeded the value in READ_TO. 0 = The number of (Master Clock/256) cycles is less than the value in READ_TO.

NOTE: *N_{CR}, per MMCA Specification, is the number of clock cycles from command to response. It should be set to the number of cycles required by the slowest card currently connected.

17.2.2.3 MMC Clock Rate Register (CLOCK_RATE)

This register, described in Table 17-10 and Table 17-11, sets the MMCCLK frequency. Program the MMCCLK to the maximum data transfer rate for the slowest card currently connected. Generally this will be the write rate, which is sometimes slower than the read rate. Per the MMCA Specification, the maximum frequency is 20 MHz. During the Card Identification mode, the clock may need to be run slower.

Before writing this register, the clock MUST be stopped by writing a 1 to the STOP_CLK bit in the CLOCK_CONTROL register. Verify that the clock is stopped by reading the STATUS register CLK_DIS bit. Writing CLOCK_RATE while CLK_DIS = 1 causes unpredictable results.

At reset, this register defaults to 0x006 (slowest Master Clock frequency).

Table 17-10. CLOCK_RATE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													CLOCK_RATE		
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW
ADDR	0x8000.0108															

Table 17-11. CLOCK_RATE Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
2:0	CLOCK_RATE	**Clock Rate Divisor** Program this field to specify the clock rate, based on the Master Clock specified in CLOCK_PREDIV: 000 = 1 × Master Clock 001 = 1/2 × Master Clock 010 = 1/4 × Master Clock 011 = 1/8 × Master Clock 100 = 1/16 × Master Clock 101 = 1/32 × Master Clock 110 = 1/64 × Master Clock

17.2.2.4 MMC Clock Gating and Clock Predivide Register (CLOCK_PREDIV)

This register sets the divisor for the clock predivider. The output of the clock predivider is gated with the CLK_DIS bit to provide the MMC Master Clock. The MMC Master Clock is further divided by the value in the CLOCK_RATE register to provide the operating clock frequency.

The contents of the MMC FIFO are normally transferred via the DMA Controller. Setting the APB_RD_EN to 1 allows direct accesses to the MMC FIFO, ensuring that no half-words are lost. The function of the register is described in Table 17-12 and Table 17-13:

At reset, this register defaults to 0x008 (thus, the default clock CLOCK_PREDIV is HCLK/8).

Table 17-12. CLOCK_PREDIV Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										APB_RD_EN	MMC_EN	CLOCK_PREDIV			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.010C															

Table 17-13. CLOCK_PREDIV Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
5	APB_RD_EN	**APB Read Enable** This bit determines whether the FIFO is read via the ABP or via the DMA Controller. 1 = Read FIFO via APB 0 = Read FIFO via DMA Controller
4	MMC_EN	**Clock Rate Divisor** Set this field to enable the MMC Controller.
3:0	CLOCK_PREDIV	**Clock Predivide** Values in this field specify the Master Clock rate, based on HCLK: 0x1 = HCLK 0x2 = HCLK/2 0x3 = HCLK/3 0x4 = HCLK/4 0x5 = HCLK/5 0x6 = HCLK/6 0x7 = HCLK/7 0x8 = HCLK/8 The value 0x0 is invalid.

17.2.2.5 MMC Command Control Register (CMD_CONTROL)

This register, described in Table 17-14 and Table 17-15, provides control information for each MMC command:

- The response format, as shown in Table 17-16.
- Whether the command includes a Read or Write Data transfer, in Stream or Block mode, or a No Data transfer.
- Whether a busy signal is expected after the command.
- Whether the command includes the 80-bit card Initialization sequence prefix.

At reset, this register defaults to 0x00000000.

Table 17-14. CMD_CONTROL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///							BIG_ENDIAN	///	INITIALIZE	BUSY	STREAM	WRITE	DATA_EN	RESPONSE_FORMAT	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	
ADDR	0x8000.0114															

Table 17-15. CMD_CONTROL Fields

BITS	FIELD	DESCRIPTION
31:9	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
8	BIG_ENDIAN	**Big Endian** This bit allows swapping the order of bytes in the data FIFO. 1 = Swap byte order in data FIFO 0 = Normal byte order in data FIFO
7	///	**Reserved** This bit has no function. Values written can be read.
6	INITIALIZE	**Initialize** This bit enables the 80-bit Initialization sequence. 1 = 80-bit Initialization sequence enabled 0 = 80-bit Initialization sequence disabled
5	BUSY	**Busy** This bit indicates if a Busy signal is expected after the current command. 1 = Busy signal expected 0 = Busy signal not expected

Table 17-15. CMD_CONTROL Fields (Cont'd)

BITS	FIELD	DESCRIPTION
4	STREAM	**Stream** This bit indicates which transfer mode is selected. 1 = Stream transfer mode 0 = Block transfer mode
3	WRITE	**Write** This bit indicates whether the data transfer direction is a Read or a Write. 1 = Write data transfer direction 0 = Read data transfer direction
2	DATA_EN	**Data Enable** This bit indicates whether the current command includes a data transfer. 1 = The current command includes a data transfer 0 = The current command does not include a data transfer
1:0	RESPONSE_FORMAT	**Response Format** Programming this field specifies the response format. Bit programming is defined in Table 17-16.

Table 17-16. Response Formats

RESPONSE FORMAT	CMD_CONTROL:RESPONSE_FORMAT VALUE
No response	00
Format R1	01
Format R2	10
Format R3	11

17.2.2.6 MMC Response Timeout Register (RESPONSE_TO)

This register, described in Table 17-17 and Table 17-18, specifies the number of MMCCLK cycles after the command, before the controller asserts a timeout error for the received response (N_{CR}). Under normal circumstances, RESPONSE_TO should be programmed to the maximum value (0x40) to ensure compatibility with any MMC that may be connected to the system.

At reset, this register defaults to 0x40.

Table 17-17. RESPONSE_TO Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									RESPONSE_TO						
RESET	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0118															

Table 17-18. RESPONSE_TO Fields

BITS	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
6:0	RESPONSE_TO	**Response Timeout** The hexadecimal value of this field specifies the number of MMCCLK cycles before generating a Response Timeout. This value is the N_{CR} value in the MMCA Specification.

17.2.2.7 MMC Read Timeout Register (READ_TO)

This register, described in Table 17-19 and Table 17-20, specifies the number of clocks after the command before the host asserts a timeout error for the received data. The units are (Master Clock ÷ 256). At reset, this register defaults to 0x0000FFFF.

Table 17-19. READ_TO Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	READ_TO															
RESET	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.011C															

Table 17-20. READ_TO Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:0	READ_TO	**Read Timeout** The hexadecimal value of this field specifies the number of clocks before generating a Response Timeout.

17.2.2.8 MMC Block Length Register (BLOCK_LEN)

This register, described in Table 17-21 and Table 17-22, specifies the block length in bytes for Block mode Reads and Writes. At reset, this register defaults to 0x00000000.

Table 17-21. BLOCK_LEN Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///						BLOCK_LEN									
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0120															

Table 17-22. BLOCK_LEN Fields

BITS	FIELD	DESCRIPTION
31:10	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
9:0	BLOCK_LEN	**Block Length** Programming this field specifies the block length, in bytes, for block transfers. Maximum value is 512 bytes.

17.2.2.9 MMC Block Count Register (BLOCK_COUNT)

This register, described in Table 17-23 and Table 17-24, specifies the number of blocks in a Block mode transfer. At reset, this register defaults to 0x00000000.

Table 17-23. BLOCK_COUNT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	BLOCKs															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0124															

Table 17-24. BLOCK_COUNT Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:0	BLOCKS*	**Number of Blocks** Programming this field specifies the number of blocks in a Block Write transfer. This field is not applicable for Block Reads.

NOTE: Do not execute a Block Write with this field set to 0x00.

17.2.2.10 MMC Masked Interrupt Status Register (INT_STATUS)

This register, described in Table 17-25 and Table 17-30, reports the active interrupt sources after having been ANDed with the inverse of the Masked Interrupt bits. This register is read-only; values written to this register cannot be read back. At reset, this register defaults to 0x00000000.

Table 17-25. INT_STATUS Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											CLK_DIS	///	END_CMD	PRG_DONE	DATA_TRAN_DONE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0128															

Table 17-26. INT_STATUS Fields

BITS	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading this field returns 0.
4	CLK_DIS	**Bus Clock Disabled** CLK_DIS interrupt after masking. 1 = The MMC Controller has stopped the MMC clock 0 = No interrupt
3	///	**Reserved** Reading this field returns 0.
2	END_CMD_RES	**End Command** END_CMD_RES interrupt after masking. 1 = The command response has ended 0 = The command response is pending
1	PRG_DONE	**Program Done** PRG_DONE interrupt after masking. 1 = The MMC has completed writing 0 = The MMC is still writing data
0	DATA_TRAN_DONE	**Data Transfer Done** DATA_TRAN_DONE interrupt after masking. 1 = The MMC Controller has finished transferring to or from the MMC. 0 = The MMC Controller is still transferring data.

17.2.2.11 MMC Interrupt Clear Register (INT_CLEAR)

Writing this register, described in Table 17-27 and Table 17-28, clears the corresponding INT_STATUS register bits and the corresponding interrupts. At reset, this register defaults to 0x00000000.

Table 17-27. INT_CLEAR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													END_CMD	PRG_DONE	DATA_TRAN_DONE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO	WO	WO	WO
ADDR	0x8000.012C															

Table 17-28. INT_CLEAR Field

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
2	END_CMD_RES	**End Command Response** Clear the END_CMD_RES interrupt. 1 = END_CMD_RES interrupt cleared 0 = END_CMD_RES interrupt not cleared
1	PRG_DONE	**Program Done** Clear the PRG_DONE interrupt. 1 = PRG_DONE interrupt cleared 0 = PRG_DONE interrupt not cleared
0	DATA_TRAN_DONE	**Data Transfer Done** Clear the DATA_TRAN_DONE interrupt. 1 = DATA_TRAN_DONE interrupt cleared 0 = DATA_TRAN_DONE interrupt not cleared

17.2.2.12 MMC Interrupt Enable Register (INT_EN)

This register, described in Table 17-29 and Table 17-30, allows enabling any or all the specified interrupts. At reset, this register defaults to 0x00000000 (All interrupts disabled).

Table 17-29. INT_EN Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											CLK_DIS	BUF_READY	END_CMD	PRG_DONE	DATA_TRAN_DONE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW
ADDR	0x8000.0134															

Table 17-30. INT_EN Fields

BITS	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
4	CLK_DIS	**Bus Clock Stopped** Enable the CLK_DIS interrupt. 1 = Enable CLK_DIS interrupt 0 = Disable BUS_CLOCK _STOPPED interrupt **IMPORTANT:** This bit cannot be cleared with the INT_CLEAR register. It can only be cleared by setting the STOP_CLK bit in the CLOCK_CONTROL register.
3	///	**Reserved** Reading this bit returns 0. **IMPORTANT:** This bit must ALWAYS be written with 0. Writing a 1 will result in a false interrupt that cannot be cleared with the INT_CLEAR register.
2	END_CMD_RES	**End Command Response** Enable the END_CMD_RES interrupt. 1 = Enable END_CMD_RES interrupt 0 = Disable END_CMD_RES interrupt
1	PRG_DONE	**Program Done** Enable the PRG_DONE interrupt. 1 = Enable PRG_DONE interrupt 0 = Disable PRG_DONE interrupt
0	DATA_TRAN_DONE	**Data Transfer Done** Enable the DATA_TRAN_DONE interrupt. 1 = Enable DATA_TRAN_DONE interrupt 0 = Disable DATA_TRAN_DONE interrupt

17.2.2.13 MMC Command Number Register (COMMAND)

This register, described in Table 17-31 and Table 17-32, specifies the command number. Software writes the command number to be sent by the MMC Controller to the MMC card. The command argument (if any) is programmed into the ARGUMENT register. At reset, this register defaults to 0x40.

Table 17-31. COMMAND Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										CMD_NUM					
RESET	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0138															

Table 17-32. COMMAND Fields

BITS	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
6	///	**Reserved** Reading this field returns 1. Values written to this field cannot be read back.
5:0	CMD_NUM	**Command Number** Program this field with the code for the command to be sent.

17.2.2.14 MMC Command Argument Register (ARGUMENT)

This register, described in Table 17-33 and Table 17-34, is written by software with the argument for the command number in the COMMAND register. At reset, this register defaults to 0x00000000.

Table 17-33. ARGUMENT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	ARGUMENT															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	ARGUMENT															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.013C															

Table 17-34. ARGUMENT Field

BITS	FIELD	DESCRIPTION
31:0	ARGUMENT	**Argument** Programming this field specifies the command argument for the current command number specified in COMMAND.

17.2.2.15 MMC Response FIFO Register (RESPONSE_FIFO)

Software reads this register, described in Table 17-35 and Table 17-36, to obtain the MMC card response following each command sent by the MMC Controller. This register is an eight-word-deep FIFO with the response occupying the least-significant 16-bits of each word. The complete response is obtained by reading this address the exact number of times required to retrieve the expected response.

IMPORTANT: Reading beyond the expected response length will result in erroneous results for subsequent reads of this register.

At reset, this register defaults to 0x00000000.

Data is read as the most significant half-word though the least significant half-word of the response. See Figure 17-4 for details.

Table 17-35. RESPONSE_FIFO Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RESPONSE															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0140															

Table 17-36. RESPONSE_FIFO Field

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0.
15:0	RESPONSE	**Response** Response code for the corresponding command.

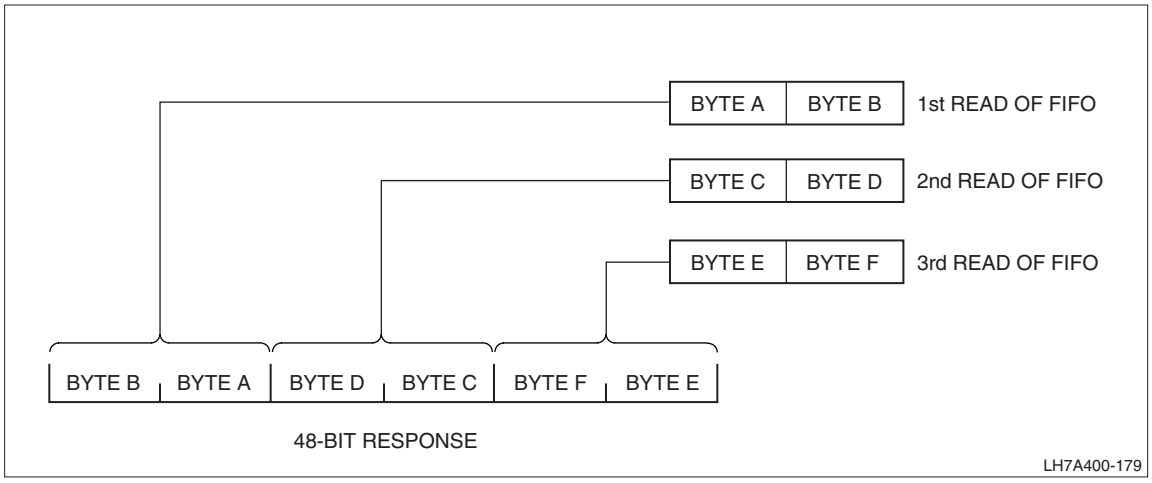


Figure 17-4. Byte Order For the Response FIFO Register

17.2.2.16 MMC Data FIFO Register (DATA_FIFO)

Software reads or writes this register, described in Table 17-37 and Table 17-38, with data for transfer to and from the Data FIFO. After reset, this register is in an undefined state.

The format for reading this register is the same as in Figure 17-4, unless the BIG_ENDIAN bit is programmed to 1 in the CMD_CONTROL register. If that bit is 1, the order of the bytes in the FIFO is reversed.

Table 17-37. DATA_FIFO Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0148															

Table 17-38. DATA_FIFO Field

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:0	DATA	**Data** Data to be transferred to the Data FIFO.

Chapter 18
Universal Serial Bus (USB) Device

18.1 Theory of Operation

The LH7A400 USB client block is compliant to the USB 1.1 specification and compatible with both OpenHCI and Intel UHCI standards. This USB Device supports USB-standard Full-Speed (12 Mbit/s) operation, and SUSPEND and RESUME signalling. Figure 18-1 shows the USB Device block diagram. The individual blocks in the diagram are described in the subsequent sections.

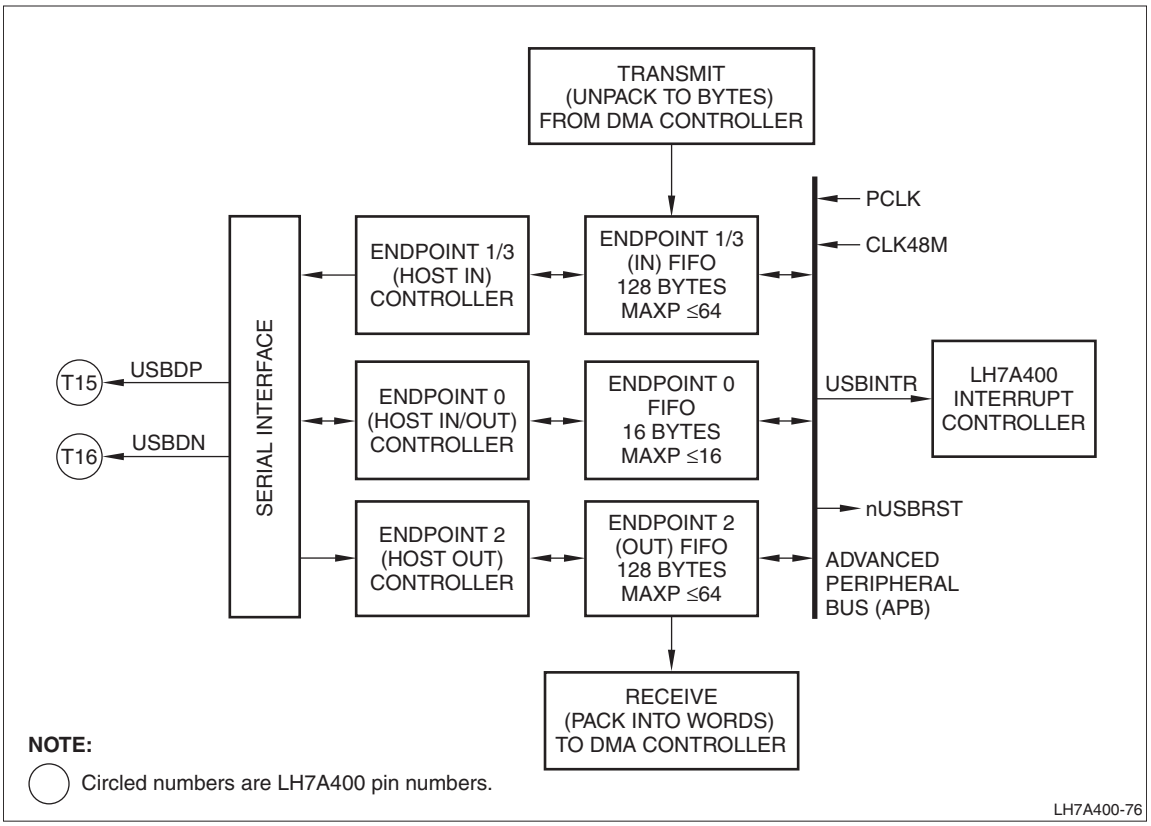


Figure 18-1. USB Device Block Diagram

18.1.1 Architecture

The LH7A400 USB port functions only as a USB Device. All USB communications are managed by one or more external USB Hosts.

18.1.1.1 Endpoints

Communications take place between the Host and the LH7A400 Client via data 'pipes'. Multiple communication pipes can exist between a Host and the Client, with each pipe terminating at the LH7A400 USB Device in an 'endpoint'.

The LH7A400 USB Device has four endpoints, Endpoint 0 (EP0) through Endpoint 3 (EP3). Each endpoint has a FIFO to facilitate communications. Figure 18-2 presents a graphical representation of these endpoints, and Table 18-1 describes the endpoints and their function. Note that the direction type associated with the endpoints is from the perspective of the Host. For example, an IN endpoint terminates a data pipe transferring data from the LH7A400 Client to the Host.

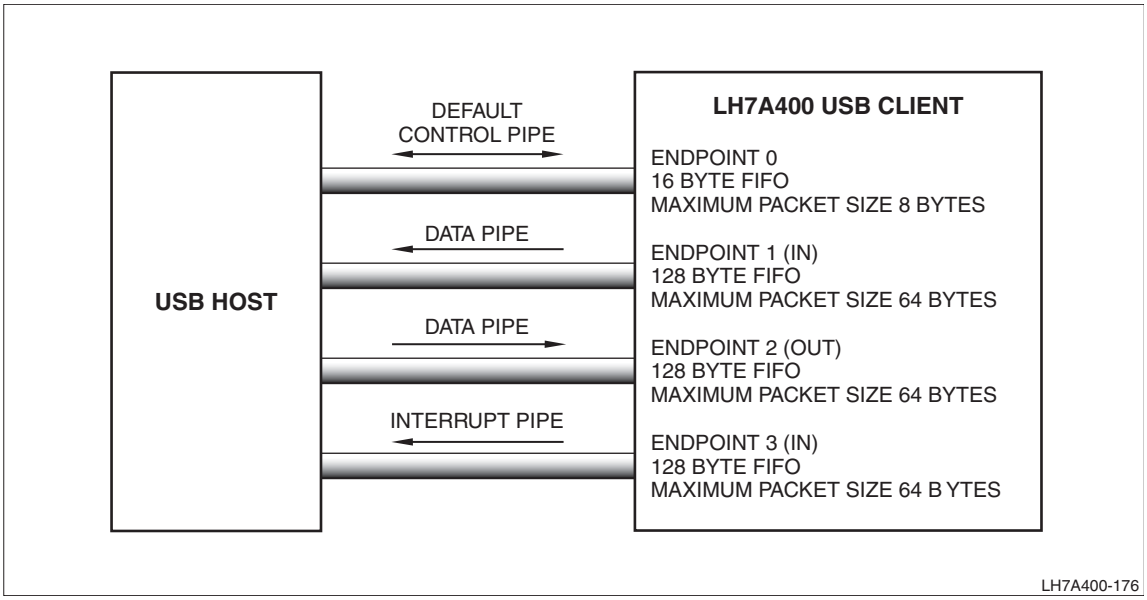


Figure 18-2. USB Communication Endpoints

Table 18-1. Endpoint Function

ENDPOINT	TYPE	FUNCTION
EP0	IN/OUT	Control endpoint. EP0 is always enabled when power is applied. The USB Host uses EP0 for initial configuration and for control.
EP1	IN	EP1 handles Bulk IN transfers. Transfers of large data blocks from the LH7A400 USB Device into the USB Host take place through the pipe terminating in EP1.
EP2	OUT	EP2 handles Bulk OUT transfers. Transfers of large data blocks from the USB Host into the LH7A400 USB Device take place through the pipe terminating in EP2.
EP3	IN	EP3 handles Interrupt IN transfers. The EP3 pipe allows the LH7A400 USB Device to interrupt the USB Host.

18.1.1.2 FIFOs

Each data pipe endpoint has a FIFO to assemble USB serial data into parallel data to be used by the LH7A400 DMA controller. The FIFOs and maximum packet size for each endpoint are described in Table 18-2.

Table 18-2. Endpoint FIFO Characteristics

ENDPOINT	FIFO SIZE	MAXIMUM PACKET SIZE
EP0	8 Bytes	16 Bytes
EP1	128 Bytes	64 Bytes
EP2	128 Bytes	64 Bytes
EP3	128 Bytes	64 Bytes

18.1.1.3 Serial Interface

The LH7A400 USB Device Serial Interface handles the direct USB interface. The Serial Interface functions include:

- Decoding and encoding
- Cyclic redundancy check (CRC) generation and checking
- Bit stuffing
- Endpoint address decoding for USB packets
- Interface signals for an external USB Transceiver.

The Serial Interface incorporates differential USB transceivers implementing a USB-standard Full Speed interface, allowing communication at up to 12 Mb/s.

18.1.1.4 DMA Channels

Two DMA channels are available for bulk data transfers in byte-wide format; one channel for transmit and one for receive. Commands requiring large data quantities can completed with low processor overhead. To use the DMA for data transfers, the data buffers are first configured in SDRAM, then the DMA interface is programmed with base address and byte counts pointing to the buffers. When buffers have been allocated and the DMA interface programmed, the USB endpoint controllers can be configured. The data transfers between receive and transmit FIFOs are made automatically until either:

- The transfer is stopped by software.
- The data block requirements are not met, as indicated by the MAXP, STATUS, and COUNTx registers. When the size of a USB data block is larger than the buffers in the SDRAM, the DMA controller can be allocated fresh data buffers as required.

18.1.2 Programming the USB Device

The USB Device is programmed, and data transfer is conducted via a set of registers. These registers are summarized in the following sections; register details begin in Section 18.2.

18.1.2.1 USB Transactions

Communications over the USB are programmed using a control/status register and a Maximum Packet Size (MAXP) register. The OUT endpoints also have a Write Count Register. These register names are:

- INCSR (IN Status and Control Registers)
- OUTCSR (OUT Status and Control Registers)
- INMAXP (IN Maximum Packet size Register)
- OUTMAXP (OUT Endpoint MAXP Register)
- COUNTx (OUT Write Count Registers).

18.1.2.2 AHB Transactions

Communications between the USB Device and the LH7A400 CPU over the AHB utilize another set of registers to report the CPU interrupt status.

The USB core interrupt registers are:

- IN Interrupt Registers
- OUT Interrupt Registers
- USB Interrupt Registers
- Enable Registers for each of the Interrupt registers

Software writes a 1 to each asserted interrupt field to clear the interrupts. When interrupted, software must perform the these steps:

1. Reads all the interrupt registers.
2. Writes back to all the registers.
3. Performs appropriate action for specified interrupt.
4. Process the USB Interrupt register (must be the last step).

For EP0, a bidirectional endpoint (IN or OUT), the INMAXP, IN Interrupt Registers are used regardless of the direction of the endpoint. The associated Control and Status registers correspond to the direction of the endpoint. EP[3:1] each have a dedicated bank of interrupt status and enable registers.

18.1.2.3 USB Reset

Upon power up, a USB Host Controller must first send a RESET command to the LH7A400 USB Device to automatically reset the USB Device I/O side and create an interrupt to the CPU. The LH7A400 then resets the USB registers. Both resets are asynchronous.

Care must be taken when responding to a reset however.

Figure 18-3 shows a typical USB circuit. A GPIO pin is used to turn on the MOSFET pullup, which makes the USB Host aware of the LH7A400 USB Device. The Host sends a reset and in response, the LH7A400 sets an internal bit to signal that it has been recognized by the host. If at this point the LH7A400 is programmed to issue a reset, the bit will be cleared and the USB Device controller no longer recognizes that it is connected to a Host.

To avoid this situation, follow these steps:

1. Turn off the GPIO pin, disabling the MOSFET pullup.
2. Issue a reset.
3. Turn the GPIO pin back on, connecting the pullup.

The USB Device will now communicate normally with the USB Host.

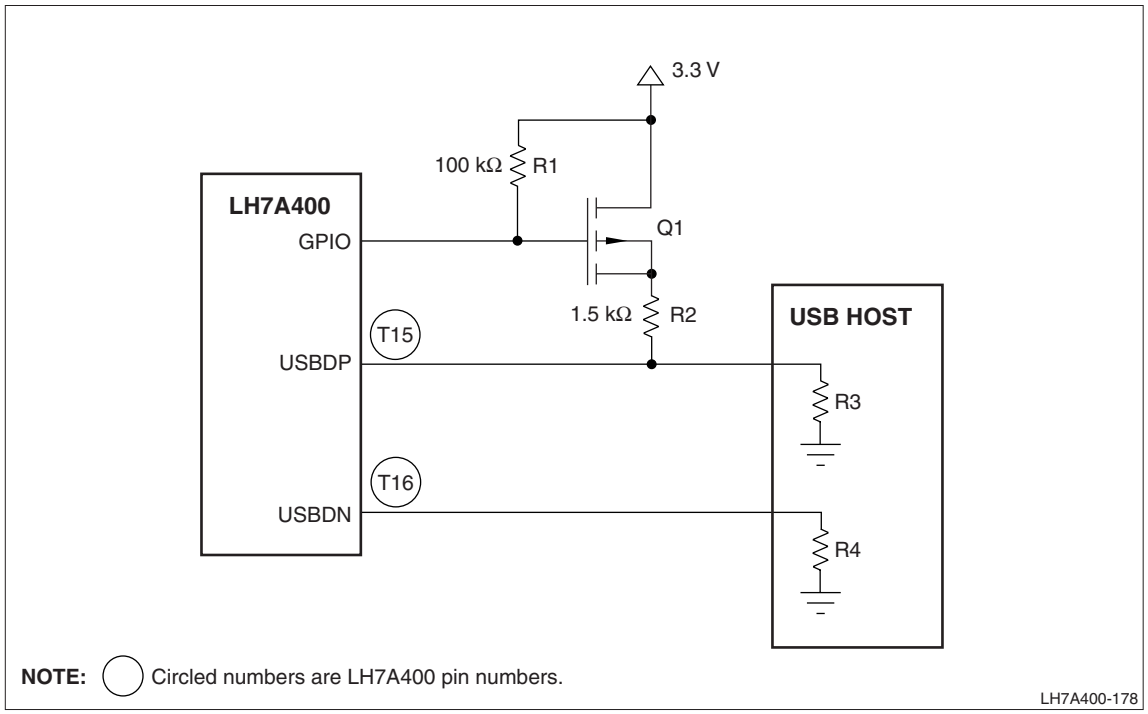


Figure 18-3. Host-Client Application Circuit

18.1.3 Operational Details

This section provides an overview of USB Device programming for normal operation. It is assumed that the usage of the USB (and DMA) is interrupt-driven as opposed to being poll-driven. There are several tasks involved, which are described below. Note that software must keep track of any transfers in progress and correctly load/store data payloads.

18.1.3.1 Initializing the USB

Upon power up, the USB Host sends a RESET to EP0. Upon receipt of that RESET, the LH7A400 must:

- Disable the USB
- Reset the APB and I/O sides of the USB
- Set the INDEX register to 0 (EP0)
  - Set the required MAXP value
- Set the INDEX register to 1 (EP1)
  - Set the required MAXP value
  - If using DMA for transmitting data, set DMA_EN and AUTO_SET
- Set the INDEX register to 2 (EP2)
  - Set the required MAXP value
  - If using DMA for receiving data, set DMA_EN and AUTO_CLR
- Set the INDEX register to 3 (EP3)
  - Set the required MAXP value
- Enable the RESET interrupt
- Enable the SUSPEND interrupt (this also enables the RESUME interrupt)
- Set the ENABLE_SUSPEND bit
- Enable the USB.

The USB Device is now ready to communicate with a USB Host.

18.1.3.2 Interrupt Servicing

The LH7A400 can receive seven different types of interrupts from the USB Device block. Servicing each interrupt is described in the following sections.

18.1.3.2.1 Servicing a RESET Interrupt

- Clear the interrupt.
- Cancel any transfers in progress.
- Purge the USB FIFOs (set the FIFO_FLUSH bit).
- Reset the USB I/O side.

18.1.3.2.2 Servicing a SUSPEND Interrupt

- Clear the interrupt.
- Disable the SUSPEND interrupt.
- If using DMA, disable the channel clock(s) to conserve power.

18.1.3.2.3 Servicing a RESUME Interrupt

- Clear the interrupt.
- Enable the SUSPEND interrupt.
- If using DMA, re-enable the channel clock(s).

18.1.3.2.4 Servicing an EP0 Interrupt

- Program the INDEX register to 0 (EP0).
- If a transfer is in progress and both IN_PKT_RDY and OUT_PKT_RDY are 0:
  - Fill the EP0 FIFO with the next data packet
  - Program the IN_PKT_RDY bit to 1
  - If this is the last packet, DATA_END should also be simultaneously programmed to 1.
- If SETUP_END is 1:
  - Abort the last transfer
  - Program the CLR_SETUP_END bit to 1.
- If SENT_STALL is 1:
  - Program the SEND_STALL bit to 0.
- If OUT_PKT_RDY is 1:
  - Read the data packet from the FIFO
  - Decode the command and perform the appropriate action.
  - Program the CLR_OUT and DATA_END bits to 1
  - If there was an error, the SEND_STALL bit must also be programmed to 1 simultaneously with CLR_OUT and DATA_END

18.1.3.2.5 Servicing an EP1 Interrupt

- Clear the interrupt
- Program the INDEX register to 1
- If there is still data to send:
  - Load the FIFO with the next packet
  - Program IN_PKT_RDY to 1.

18.1.3.2.6 Servicing an EP2 Interrupt

- Set the INDEX register to 2
- If OUT_PKT_RDY is 1 and OUT_WRT_CNT is not 0:
  - Read the data from the FIFO.
- Clear the interrupt.

18.1.3.2.7 Servicing an EP3 Interrupt

Since EP3 is an INTERRUPT IN endpoint and is typically used for data transfers less than 64 bytes, servicing an EP3 interrupt is usually not necessary but to do so is similar to servicing an EP1 interrupt.

- Clear the interrupt
- Program the INDEX register to 3
- If there is still data to send:
  - Load the FIFO with the next packet
  - Program IN_PKT_RDY to 1.

18.1.3.3 Using DMA for BULK Data Transfers

DMA can be used for BULK data transfers on endpoints 1 and 2. When the DMA is enabled for these endpoints, no further EP1 or EP2 interrupts occur. Instead, the relevant DMA channel interrupt is used to handle data transfer. Each channel can be used in either single- or double-buffered mode. For sake of clarity, only single-buffered mode is described with a note at the end about how to extend this procedure to double-buffered mode.

18.1.3.3.1 Initializing the USB DMA Channels

- Enable the DMA channel clock (in the Clock and State Controller (CSC) PWRCNT register)
- Enable the DMA channel (in the DMA CONTROL register)
- Enable the NFB, CHERROR and STALL interrupts
- Enable the DMA interrupt (in the interrupt controller INTENS register).

18.1.3.3.2 Initiating a USB DMA TX Transfer (EP1)

- Set DMA MAXCNT0 to the number of bytes to send
  - If the size of the bulk transfer is greater than 64KB (maximum DMA transfer size), set the DMA MAXCNT0 to 64KB.
- Set the DMA BASE0 to the starting address of the buffer
- If necessary, enable the DMA channel clock.

18.1.3.3.3 Servicing a USB DMA TX Interrupt (EP1)

- Determine the cause of the interrupt:
  - If the cause was CHERROR (channel error), perform the appropriate action — for example abort/restart current transfer. Normally, for single-buffered mode, STALL will be the cause of the interrupt.
- If there is more data to send (e.g. transfer length greater than 64KB):
  - Set the DMA MAXCNT0 to the number of remaining bytes to send, or the maximum 64KB if the transfer is larger than 64KB
  - Set the DMA BASE0 to the starting address of the next block to transfer.
- If there is no more data to send, the DMA channel clock can optionally be disabled.

18.1.3.3.4 Servicing a USB DMA RX Interrupt (EP2)

- Determine the cause of the interrupt:
  - If the cause was CHERROR (channel error), perform the appropriate action — for example abort/restart current transfer. Generally, for single-buffered mode, STALL will be the cause of the interrupt.
  - Set the DMA MAXCNT0 to the desired buffer size.
- Set the DMA BASE0 to the address of this buffer.

18.1.3.4 Using Double-Buffered Mode

Using double-buffered mode is similar to single-buffered mode except that both BASE0/BASE1 and MAXCNT0/MAXCNT1 are used for transfers. The idea is that the DMA channel is provided with two buffers so that when one is full, it can immediately start using the other one. This causes an NFB interrupt which is processed the same as a STALL interrupt except that the correct BASE/MAXCNT pair must be updated. The NEXTBUFFER bit in the DMA STATUS register indicates which is the correct pair to update.

18.1.3.5 Example of Processing a Chapter 9 Command

Assuming that the USB is initialized, connected, has an address assigned to it and there are no interrupts or errors:

- Host sends a SETUP packet.
- Host sends a DATA packet (80 06 00 01 00 001200).
- Device sends an ACK packet.
- An EP0 interrupt is triggered and the USB EP0 handler is called:
  - No transfer is in progress; SETUP_END and SENT_STALL are both 0 while OUT_PKT_RDY is 1.
- Handler reads the EP0 FIFO and decodes command (GET_DESCRIPTOR_DEVICE).
- Handler calls function to handle GET_DESCRIPTOR command.
- Function programs INDEX to 0.
- Function programs CLR_OUT.
- Function loads the first packet into the EP0 FIFO, keeping track of the next packet to be loaded.
- Function sets IN_PKT_RDY and returns.
- Handler exits.

The final step:

- Host sends an IN packet.
- Device sends a DATA packet.
- Host sends an ACK packet.
- An EP0 interrupt is triggered (once the USB programs IN_PKT_RDY to 0) and the EP0 handler is called:
  - A transfer is in progress; SETUP_END, SENT_STALL and OUT_PKT_RDY are all 0.
- Handler sets INDEX to 0.
- Handler loads the next packet into the EP0 FIFO, programs IN_PKT_RDY to 1 and exits. This last cycle continues until the last packet has been loaded in which case DATA_END is programmed to 1 along with IN_PKT_RDY.

18.1.3.6 Important Sent Stall Interrupt Issues

Upon receipt of a bad or unsupported EP0 request the USB Device issues a stall. An EP0 interrupt is sent to the VIC after the USB Device sends the stall on the USB. The USB Device is supposed to remain in the stall state until another setup packet is received. The USB Device then begins sending SOF occurs only once a millisecond, causing a new EP0 interrupt to be sent to the VIC. Once a valid and supported request is received, the interrupt generation ceases. However, it is possible for the bad or unsupported request to be the last request. The host will simply accept the stall as the answer to the request and issue no more setup packets. Traffic will now switch to the other endpoints and the interrupt will continue.

18.2 Register Reference

This section provides a the USB register memory mapping and bit fields.

18.2.1 Memory Map

The USB Device base address is 0x8000.0200. Table 18-3, Table 18-4, and Table 18-5 show the USB registers at offsets from this base address. Some of the USB registers are accessed using the INDEX register. These registers are listed in Table 18-4. The USB Reset register is mapped in the Clock and State Controller address area, at 0x8000.044C.

Table 18-3. USB Non-indexed Control Register Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	FAR	Function Address Register
0X04	PMR	Power Management Register
0X08	IIR	IN Interrupt Register Bank (EP0-EP3)
0X0C	///	**Reserved** Reading this address returns 0x00000000. Writing has no effect on the contents.
0X10	OIR	OUT Interrupt Register Bank (EP2)
0X14	///	**Reserved** Reading this address returns 0x00000000. Writing has no effect on the contents.
0X18	UIR	USB Interrupt Register Bank
0X1C	IIE	IN Interrupt Enable Register Bank (EP0-EP3)
0X20	///	**Reserved** Reading this address returns 0x00000000. Writing has no effect on the contents.
0X24	OIE	OUT Interrupt Enable Register Bank (EP2)
0X28	///	**Reserved** Reading this address returns 0x00000000. Writing has no effect on the contents.
0X2C	UIE	USB Interrupt Enable Register Bank
0X30	FRAME1	Frame Number1 Register
0X34	FRAME2	Frame Number2 Register
0X38	INDEX	Index Register
0X3C	///	**Reserved** Reading this address returns 0x00000000. Writing has no effect on the contents.

Table 18-4. USB Indexed Control Register Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x40	INMAXP	IN Maximum Packet Size Register
0X44	INCSR1	Control and Status Registers for EP0, EP1, and EP3
0X48	INCSR2	IN Control Register for EP1 and EP3
0X4C	OUTMAXP	OUT Maximum Packet Size Register
0X50	OUTCSR1	OUT Control and Status Register for EP2
0X54	OUTCSR2	OUT Control Register for EP2
0X58	COUNT1	OUT FIFO Write Count1 Register
0X5c -0X7C	///	**Reserved** Reading these addresses returns 0x00000000. Writing has no effect on the contents.

Table 18-5. USB FIFO Register Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x80	EP0FIFO	EP0 (Control, 8 Bytes)
0x84	EP1FIFO	EP1 (IN BULK, 64 Bytes)
0x88	EP2FIFO	EP2 (OUT BULK, 64 Bytes)
0x8C	EP3FIFO	EP3 (IN Interrupt, 64 Bytes)
0x90 - 0xFC	///	**Reserved** Reading these addresses returns 0x00000000. Writing has no effect on the contents.

18.2.1.1 Indexed Register Addressing

The registers listed in Table 18-4 are indirectly addressed. These registers are accessed via the INDEX register. For example, to access the EP1 INCSR1 and INCSR2 register2, do these steps:

1. Set the INDEX register to 1 (to address EP1).
2. Write the data at the INCSR1 address (in this example, 0x8000.0244).

More details about using the INDEX register appear in the discussion of the INDEX register and the registers requiring indexing.

18.2.2 Register Descriptions

This section describes the bit fields, reset values, and uses of the registers.

18.2.2.1 USB Reset Register (USBRESET)

The USB Reset register is mapped in the Clock and State Controller address area, at 0x8000.044C. This register allows the CPU to respond to a USB Host RESET command. When a USB RESET command is received, the software must first program the bits in USBRESET to 1, then program them to 0 to execute a USB RESET on either or both the APB and I/O sides.

Table 18-6. USBRESET Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														APBRESET	IORESET
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO
ADDR	0x8000.044C															

Table 18-7. USBRESET Fields

BIT	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	APBRESET	**USB APB Bus RESET** Software programs this bit to 1, followed by 0 to issue a USB RESET to the APB control side. 1 = APB Bus Reset 0 = Normal operation
0	IORESET	**USB I/O RESET** Software programs this bit to 1, followed by 0 to issue a USB RESET to the I/O side. 1 = I/O Reset 0 = Normal operation

18.2.2.2 Function Address Register (FAR)

This register maintains the USB Device Address assigned by the host. The CPU writes the value received through a SET_ADDRESS descriptor to this register. This address is used for the next token. Software must set bit 7 to 1 when updating the Function Address to inform the USB Host that the Function Address has been updated.

Table 18-8. FAR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								ADDR_UPDATE	FUNCTION_ADDR						
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0200															

Table 18-9. FAR Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	ADDR_UPDATE	**Address Update** Software must program this bit to 1 to inform the USB Host that the FUNCTION_ADDR field in this register has been updated. The USB clears this bit. 1 = The FUNCTION_ADDR field has been updated 0 = The FUNCTION_ADDR field has not been updated
6:0	FUNCTION_ADDR	**Function Address** The CPU writes the USB function address to this field.

18.2.2.3 Power Management Register (PMR)

This register is used for SUSPEND, RESUME, and RESET signalling, and for monitoring USB Bus Reset status.

Table 18-10. PMR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											USB_ENABLE	USB_RESET	UC_RESUME	SUSPEND_MODE	ENABLE_SUSPEND
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RW	RW	RW
ADDR	0x8000.0204															

Table 18-11. PMR Bit Fields

BIT	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading returns 0. Values written cannot be read.
4	USB_ENABLE	**USB Enable** 1 = USB functional block enabled 0 = USB functional block disabled
3	USB_RESET	**USB RESET** The USB block programs this bit to 1 when RESET signalling is received from the Host. This bit remains 1 as long as RESET persists on the USB bus. 1 = A RESET signal is asserted on the USB bus 0 = No RESET signal is asserted
2	UC_RESUME	**UC RESUME** Software programs a 1 to this bit for not less than 10 ms, nor more than 15 ms to initiate RESUME signalling. The USB Host generates RESUME signalling in SUSPEND mode when this bit is 1. 1 = Initiate RESUME signalling (must be 10 ms to 15 ms) 0 = Normal operation
1	SUSPEND_MODE	**SUSPEND Mode** The USB block programs this bit to 1 when the Host enters SUSPEND mode. Software must clear the UC_RESUME bit to end RESUME signalling. The CPU reads UIR:RESINT bit. 1 = USB in SUSPEND mode. 0 = USB not in SUSPEND mode.
0	ENABLE_SUSPEND	**SUSPEND Enable** The software programs this bit to 1 to enable the SUSPEND mode. If this bit is zero, the device will not enter SUSPEND mode. 1 = Enable SUSPEND mode 0 = Disable SUSPEND mode (Default)

NOTE: The CPU should use the USB_INTERRUPT register to poll for SUSPEND and RESET conditions.

18.2.2.4 IN Interrupt Register (IIR)

The IN Interrupt register (IIR) acts as an interrupt status register for IN endpoints EP1 and EP3, and Control endpoint EP0. Upon interrupt, software should read each of the three interrupt registers (IIR, OIR, and UIR), then write 1 to each bit that was set, then read the registers once more to clear the interrupt. The UIR must be the last register read and cleared.

Table 18-12. IIR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												EP3IN	///	EP1IN	EP0
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RW	RW
ADDR	0x8000.0208															

Table 18-13. IIR Fields

BIT	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	EP3IN	**End Point 3 IN Interrupt** The EP3 interrupt is generated for Interrupt IN transfers. This bit is programmed to 1 by the USB when: IN_PKT_RDY is cleared to 0 by the USB; The FIFO is flushed by the USB; and USB has issued a STALL response IN token, indicated by SENT_STALL = 1. Software clears this interrupt by programming a 1 to this bit, then reading this register once again. 1 = Interrupt IN transfer pending. 0 = Interrupt cleared or the above conditions are not met.
2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	EP1IN	**End Point 1 IN Interrupt** The EP1 interrupt is generated for BULK IN transfers. The USB block programs this bit to 1 when IN_PKT_RDY bit is cleared to 0 by the USB Host, the FIFO is flushed by the USB Host, and the USB Host has issued a STALL response IN token, as indicated by SENT_STALL = 1. Software clears this interrupt by programming a 1 to this bit, then reading this register once again. 1 = BULK IN transfer pending and the above three conditions are met. 0 = Interrupt cleared or the above conditions are not met.
0	EP0	**End Point 0 Interrupt** The EP0 interrupt is generated for Control transfers. The EP0 interrupt is programmed to 1 by the USB block when: OUT_PKT_RDY is set to 1 by the USB Host; IN_PKT_RDY is cleared to 0 by the USB Host; SENT_STALL is set to 1 by the USB Host; SETUP_END is set to 1 by the USB Host; and DATA_END is cleared to 0 by the USB Host (Indicates end of control transfer). Software clears this interrupt by programming a 1 to this bit, then reading this register once again. 1 = EP0 interrupt set. 0 = EP0 interrupt cleared or the above conditions are not met.

18.2.2.5 OUT Interrupt Register (OIR)

The OUT Interrupt register (OIR) acts as an interrupt status register for the OUT endpoint EP2. Upon interrupt, software should read each of the three interrupt registers (IIR, OIR, and UIR), then write 1 to each bit that was set, then read the registers once more to clear the interrupt. The UIR must be the last register read and cleared.

Table 18-14. OIR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													EP2OUT	///	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RO
ADDR	0x8000.0210															

Table 18-15. OIR Fields

BIT	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	EP2OUT	**EP2 Out Interrupt** This interrupt is generated for BULK OUT transfers. The USB block programs this bit to 1 when: OUT_PKT_RDY and SENT_STALL are set to 1 by the USB Host. Software clears this interrupt by programming a 1 to this bit, then reading this register once again. 1 = BULK OUT transfer is ready. 0 = Interrupt cleared or the above conditions are not met.
1:0	///	**Reserved** Reading returns 0. Values written cannot be read.

18.2.2.6 USB Interrupt Register (UIR)

The USB Interrupt register (UIR) reports interrupt status for the bus signalling conditions SUSPEND, RESUME, and RESET. Upon interrupt, software should read each of the three interrupt registers (IIR, OIR, and UIR), then write 1 to each bit that was set, then read the registers once more to clear the interrupt. The UIR must be the last register read and cleared.

Table 18-16. UIR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													URINT	RESINT	SUSINT
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW
ADDR	0x8000.0218															

Table 18-17. UIR Fields

BIT	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	URINT	**USB RESET Interrupt** The USB block programs this bit to 1 when it receives RESET signalling from the USB Host. Software clears this interrupt by writing a 1 to this bit, then reading this register once again. 1 = USB RESET Interrupt set. 0 = Interrupt cleared.
1	RESINT	**RESUME Interrupt** The USB block programs this bit to 1 when it receives RESUME signalling while in SUSPEND mode from the USB Host. If the RESUME is due to a USB RESET, the CPU is first interrupted with a RESUME interrupt. Once the clocks resume and the SUSPEND condition persists for 3 ms, USB RESET Interrupt will be asserted. Software clears this interrupt by programming a 1 to this bit, then reading this register once again. 1 = RESUME Interrupt set. 0 = Interrupt cleared.
0	SUSINT	**SUSPEND Interrupt** The USB block programs this bit to 1 when it receives SUSPEND signaling from the USB Host. This bit is set whenever there is no activity for 3 ms on the bus. Thus, if the CPU does not stop the clock after the first SUSPEND Interrupt, it will continue to be interrupted every 3 ms as long as there is no activity on the USB bus. This interrupt is disabled by default. Software clears this interrupt by programming a 1 to this bit, then reading this register once again. 1 = SUSPEND Interrupt set. 0 = Interrupt cleared.

18.2.2.7 IN Interrupt Enable Register (IIE)

The IN Interrupt Enable Register (IIE) corresponds to the IN Interrupts, EP3IN, EP1IN, and EP0. All interrupts are initially enabled.

Table 18-18. IIE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												EP3INEN	///	EP1INEN	EP0EN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RW	RW
ADDR	0x8000.021C															

Table 18-19. IIE Fields

BIT	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	EP3INEN	**End Point 3 IN Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	EP1INEN	**End Point 1 IN Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
0	EP0EN	**End Point 0 IN Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled

18.2.2.8 OUT Interrupt Enable Register (OIE)

The OUT Interrupt Enable (OIE) register corresponds to the EP2 OUT Interrupt. All interrupts are initially enabled.

Table 18-20. OIE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													EP2OUTEN	///	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RO
ADDR	0x8000.0224															

Table 18-21. OIE Fields

BIT	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	EP2OUTEN	**End Point 2 OUT Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
1:0	///	**Reserved** Reading returns 0. Values written cannot be read.

18.2.2.9 USB Interrupt Enable Register (UIE)

The USB Interrupt Enable (UIE) corresponds to the USB Interrupt register. By default all interrupts except SUSPEND are enabled. The RESUME interrupt is automatically enabled when the SUSPEND interrupt is enabled.

Table 18-22. UIE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													URINTEN	///	SUSINTEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW
ADDR	0x8000.022C															

Table 18-23. UIE Fields

BIT	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	URINTEN	**USB RESET Interrupt Enable** 1 = Interrupt enabled 0 = Interrupt disabled
1	///	**Reserved** Reading returns 0. Values written cannot be read.
0	SUSINTEN	**SUSPEND Interrupt Enable** Software programs this bit to 1 to enable an Interrupt when it receives SUSPEND signalling. This bit is set whenever there is no activity for 3 ms on the bus. Thus, if the CPU does not stop the clock after the first SUSPEND interrupt, it will be continue to be interrupted every 3 ms as long as there is no activity on the USB bus. By default this interrupt is disabled. This bit also enables and disables the RESUME interrupt. 1 = Interrupt enabled 0 = Interrupt disabled

18.2.2.10 Frame Number Registers (FRAME1 and FRAME2)

The Frame registers store the current USB bus frame number. The frame number comprises 11 bits. FRAME1 holds the lower eight bits and FRAME2 holds the upper three bits.

Table 18-24. FRAME1 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								FRAME1							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0230															

Table 18-25. FRAME2 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													FRAME2		
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0234															

Table 18-26. FRAME1 Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	FRAME1	Least significant 8 bits of USB Frame Number.

Table 18-27. FRAME2 Fields

BIT	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
3:0	FRAME2	Most significant 3 bits of USB Frame Number

18.2.3 Indexed Registers

The next group of registers in the USB block are Indexed. The MAXP, INCSR1, INCSR2, OUTCSR1, OUTCSR2, and COUNT1 are indexed registers used for configuring the four endpoints, EP0, EP1, EP2, and EP3. To access the appropriate register for each endpoint, the endpoint number is first written to the Index register. Then the register of interest is written or read using the address defined in the register tables that follow.

18.2.3.1 Index Register (INDEX)

The INDEX register is used to point to the relative-addressed registers listed in Table 18-4. These registers are accessed by first writing the endpoint number to the INDEX register, then writing or reading the appropriate register at its LH7A400 Address Offset (0x8000.0238). Table 18-28 and Table 18-29 define the usage of INDEX.

Table 18-28. INDEX Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														INDEX	
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW
ADDR	0x8000.0238															

Table 18-29. INDEX Fields

BITS	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1:0	INDEX	**End Point Index** This field specifies, by INDEX offset, which endpoint for the particular register will be accessed by the next software read or write. The Index values are: 11 = EP3 10 = EP2 01 = EP1 00 = EP0 Note that not all index values are valid for every register. Some endpoints are unidirectional, so the opposite direction would be meaningless. For example, EP2 is OUT only.

18.2.3.2 Maximum Packet Size Register (MAXP)

Each endpoint has its own control, Status and MAXP registers. This register set contains the maximum packet size for endpoints. These registers are accessed via the INDEX register and the relevant Control, Status or MAXP register. For example, to access EP1 (Bulk IN) MAXP register, write 1 to the INDEX register and then write the data required to address MAXP (0x40); to access EP2 (Bulk OUT) MAXP register, write 2 to the INDEX register, then write the data required to address MAXP (0x8000.C24C).

The packet size is set in multiples of 8 bytes. If software writes a value greater than the FIFO size, the MAXP register will maintain the FIFO size. Maximum packet size is 64 bytes (except Endpoint 0 has a maximum FIFO size of 8 bytes).

Table 18-30. MAXP Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												MAXP			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	0x8000.0240 (IN) 0x8000.024C (OUT)															

Table 18-31. MAXP Fields

BIT	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3:0	MAXP	0000 = Not Valid 0001 MAXP = 8 0010 MAXP = 16 0011 MAXP = 24 0100 MAXP = 32 0101 MAXP = 40 0110 MAXP = 48 0111 MAXP = 56 1000 MAXP = 64

18.2.3.3 IN Control and Status Register (INCSR1)

The INCSR1 register maintains the control and status bits for IN endpoints. Software should only access this register for an IN endpoint after the endpoint has been configured via INCSR2. The INDEX register must be used to write and read INCSR1.

Table 18-32. INCSR1 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									CLRTOG	SENT_STALL	SEND_STALL	FIFO_FLUSH	///	FIFONE	IN_PKT_RDY
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	RW	RW	RW	RO	RW	RW
ADDR	0x8000.0244															

Table 18-33. INCSR1 Fields

BIT	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading returns 0. Values written cannot be read.
6	CLRTOG	**Clear Data Toggle** The Serial Interface Engine (SIE) toggles the Data PID sequence identifier for USB transactions with multiple data packets. In the case of an error condition that requires the USB transaction to be re-synchronized, this bit must be programmed to 1 by software to reset the data toggle so that the SIE will transmit a DATA0 packet identifier on the succeeding transfer. This is a write-only bit for the LH7A400. The USB block reads this bit, then clears it to 0. 1 = Data Toggle bit cleared. 0 = No effect on Data Toggle.
5	SENT_STALL	**STALL Send Acknowledge** The USB block programs this bit to 1 when a STALL handshake is issued to an IN token by the USB Host, in response to software programming the SEND_STALL bit to 1. When the USB issues a STALL handshake, IN_PKT_RDY is cleared to 0. Clear this bit by writing a 0 to it. 1 = STALL handshake issued by USB to an in IN token in response to the LH7A400 setting the SEND_STALL bit. 0 = Normal operation.
4	SEND_STALL	**Send STALL Handshake to USB** Software must program this bit to 1 to issue a STALL handshake to the next IN token. The USB reads the bit and issues a STALL handshake. Software must program the bit to 0 to end the STALL condition. 1 = Issue a STALL handshake to the USB Host. 0 = End the STALL condition.

Table 18-33. INCSR1 Fields (Cont'd)

BIT	FIELD	DESCRIPTION
3	FIFO_FLUSH	**FIFO Flush Request** Software programs this bit to 1 if it intends to flush the IN FIFO. This bit is programmed to 0 by the USB after the FIFO is flushed (IN_PKT_RDY must be read as a 1 before the USB can program this bit to 0). The CPU is interrupted when this happens. If a token is in progress, the USB waits until the transmission is complete before the FIFO is flushed. If two packets are loaded into the FIFO, only the topmost packet (one that was intended to be sent by the Host) is flushed, and the corresponding IN_PKT_RDY bit for that packet is cleared. 1 = FIFO flush requested. 0 = FIFO flush completed.
2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	FIFO_NE	**FIFO Not Empty** This bit indicates there is at least one packet of data in FIFO. 1 = Either 2 packets are in the IN FIFO and MAXP is equal to, or less than half of the IN FIFO size; or 1 packet is in the IN FIFO and MAXP is less than or equal to the IN FIFO size. 0 = 1 packet in the IN FIFO.
0	IN_PKT_RDY	**IN Packet Ready** After writing a packet of data into the FIFO, software programs this bit to 1. The USB programs this bit to 0 once the packet has been successfully sent to the Host. An interrupt is generated when the USB clears this bit so software can load the next packet. While this bit is 1, software cannot write to the FIFO. If the SEND_STALL bit is programmed by software to a 1, this bit cannot be programmed to 1. 1 = IN FIFO has unsent data. 0 = FIFO available for next IN packet.

18.2.3.4 IN Control and Status Register (INCSR2)

The INCSR2 register allows software to configure USB access and the function of the IN_PKT_RDY bit. Software should configure endpoints via INCSR2 before reading the INCSR1 register.

Table 18-34. INCSR2

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								AUTO_SET	///		USB_DMA_EN	///			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RO	RW	RO	RO	RO	RO
ADDR	0x8000.0248															

Table 18-35. INCSR2 Register Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	AUTO_SET	**Auto Set IN_PKT_RDY Bit** 1 = IN_PKT_RDY is automatically programmed to 1, without any intervention from software, each time MAXP data is written. If software writes less than MAXP data, then IN_PKT_RDY bit must be programmed to 1 by software. 0 = Software must explicitly control IN_PKT_RDY bit.
6:5	///	**Reserved** Reading returns 0. Values written cannot be read.
4	USB_DMA_EN	**USB DMA Enable** 1 = FIFO is accessed via the DMA. 0 = FIFO is accessed via direct Reads. This bit is not applicable to EP3.
3:0	///	**Reserved** Reading returns 0. Values written cannot be read.

18.2.3.5 OUT Control and Status Register 1 (OUTCSR1)

The OUTCSR1 register maintains status information for OUT endpoint 2.

Table 18-36. OUTCSR1

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CLDATATOG	SENT_STALL	SEND_STALL	FIFO_FLUSH	///		FIFO_FULL	OUT_PKT_RDY
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW			R	RW
ADDR	0x8000.0250															

Table 18-37. OUTCSR1 Register Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	CL_DATATOG	**Clear Data Toggle Sequence Bit** The Serial Interface Engine (SIE) tracks the Data PID sequence toggle received for USB transactions with multiple data packets. An error condition that requires the USB transaction to be re-synchronized, this bit should be programmed to 1 to reset the data toggle so that the SIE expects a DATA0 packet identifier on the next transfer. Software writes a 1 to this bit to clear the data toggle bit. The USB block programs this bit to 0 when a read is received from the USB Host. 1 = The data toggle sequence bit is reset to DATA0. 0 = Normal operation.
6	SENT_STALL	**Stall Handshake Sent** The USB block sets this bit to 1 when an OUT token is ended with a STALL handshake from the USB Host. The USB block issues a stall handshake if the Host sends more than MAXP data for the OUT token. Clear this bit by writing a 0 to it 1 = OUT token ended with a STALL handshake. 0 = No STALL handshake received.
5	SEND_STALL	**Send Stall Handshake** Software programs a 1 to this bit to issue a STALL handshake to the USB Host. Software programs this bit to 0 to end the STALL condition. 1 = Issue STALL handshake to USB Host. 0 = End STALL condition.

Table 18-37. OUTCSR1 Register Fields

BIT	FIELD	DESCRIPTION
4	FIFO_FLUSH	**Flush OUT FIFO** Software programs this bit to 1 to flush the FIFO. This bit can be programmed to 1 only when OUT_PKT_RDY(D0) is 1. The packet due to be unloaded by software will be flushed. 1 = Flush OUT FIFO. 0 = Do not flush FIFO.
3:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	FIFO_FULL	**FIFO FULL** This bit indicates no more packets can be accepted. 1 = 2 packets are in the IN FIFO, so the FIFO is full. 0 = FIFO is not full.
0	OUT_PKT_RDY	**OUT Packet Ready** The USB block programs this bit to 1 once the USB Host has loaded a packet of data into the OUT FIFO. After software reads the entire packet from FIFO this bit must be programmed to 0 by software. An interrupt is generated when this bit is set, letting software know that a packet is ready to read. 1 = Data packet ready in OUT FIFO. 0 = No packet is ready in the OUT FIFO.

18.2.3.6 OUT Control and Status Register 2 (OUTCSR2)

The OUTCSR2 is used to configure OUT endpoint 2.

Table 18-38. OUTCSR2

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								AUTO_CLR	///		USB_DMA_EN	///			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RO	RW	RO	RO	RO	RO
ADDR	0x8000.0254															

Table 18-39. OUTCSR2 Register Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	AUTO_CLR	**Auto Clear** 1 = IN_PKT_RDY is automatically programmed to 0, without any intervention from software, each time a complete packet is read from OUT FIFO. 0 = Software must explicitly clear the IN_PKT_RDY bit after reading each packet.
6:5	///	**Reserved** Reading returns 0. Values written cannot be read.
4	USB_DMA_EN	**USB DMA Enable** 1 = The OUT FIFO is accessed via the DMA. 0 = The OUT FIFO is accessed via direct Reads
3:0	///	**Reserved** Reading returns 0. Values written cannot be read.

18.2.3.7 Endpoint 0 Control and Status Register (EP0CSR)

This register has the control and status bits for Endpoint 0.

Table 18-40. EP0CSR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CLR_SETUP_END	CLR_OUT	SEND_STALL	SETUP_END	DATA_END	SENT_STALL	IN_PKT_RDY	OUT_PKT_RDY
RESET	0	0	0	0	0	0	0	0	0	0	0	0			0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	R	RW	RW	RW	R
ADDR	0x8000.0244															

Table 18-41. EP0CSR Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7	CLR_SETUP_END	**Clear SETUP_END Bit** Software programs a 1 to this bit to clear SETUP_END (bit 4).
6	CLR_OUT	**Clear OUT_PKT_RDY Bit** Software programs a 1 to this bit to clear OUT_PKT_RDY (bit 1).
5	SEND_STALL	**Send STALL Handshake** Software writes a 1 to this bit at the same time it programs a 0 to OUT_PKT_RDY(bit 0) when it decodes an invalid token. The USB Host issues a STALL handshake to the current control transfer. Software must write a 0 to end the STALL condition. 1 = Issue STALL Handshake. 0 = End STALL condition.
4	SETUP_END	**Setup Ends** This is a Read Only bit. The USB Host programs this bit to 1 when a control transfer ends, before DATA_END (bit 3) is set. Software programs this bit to 0, by writing a 1 to the CLR_SETUP_END (bit 7) bit. When the USB Host programs this bit to 1, an interrupt is generated to the CPU. When such a condition occurs, the USB Host flushes the FIFO, and invalidates CPU access to the FIFO. When CPU access to the FIFO is invalidated, this bit is programmed to 0. 1 = Control transfer ended. 0 = No control transfer end.

Table 18-41. EP0CSR Fields

BIT	FIELD	DESCRIPTION
3	DATA_END	**Data End** Software programs this bit to 1: • After loading the last packet of data into the FIFO, at the same time IN_PKT_RDY is set • While it clears OUT_PKT_RDY after unloading the last packet of data. For a zero-length data phase, when it clears OUT_PKT_RDY and sets IN_PKT_RDY. 1 = Last packet loaded to FIFO. 0 = Last packet unloaded from FIFO.
2	SENT_STALL	**Sent Stall Handshake** The USB block programs this bit to 1 if the USB Host ends a control transaction due to a protocol violation. An interrupt is generated when this bit is set. 1 = Protocol violation 0 = Normal operation
1	IN_PKT_RDY	**IN Packet Ready** Software programs this bit to 1 after writing a packet of data into ENDPOINT 0 FIFO. The USB block programs this bit to 0 when the USB Host signals that the packet has been successfully received at the Host. An interrupt is generated when the USB Host clears this bit, so software can load the next packet. For a zero-length data phase, software programs IN_PKT_RDY and DATA_END (bit 3) to 1 at the same time. 1 = Data packet written to ENDPOINT 0 FIFO. 0 = Data packet successfully sent to USB host.
0	OUT_PKT_RDY	**OUT Packet Ready** This is a Read Only bit. The USB Host programs this bit to 1 once valid data from the packet is written to the FIFO. An interrupt is generated when the USB Host sets this bit. Software programs this bit to 0 writing a 1 to the CLR_OUT bit (bit 6). 1 = valid data from packet has been written to the OUT FIFO. 0 = No pending data from packet.

18.2.3.8 Out FIFO Write Count Register (COUNT1)

The COUNT1 register maintains the write count. When OUT_PKT_RDY is set for OUT endpoints, this register maintains the number of bytes in the packet due to be unloaded by software.

Table 18-42. COUNT1 Registers

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								COUNT							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	COUNT1 = 0x8000.0258															

Table 18-43. COUNT1 Fields

BIT	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	COUNT	**Count of Packet Bytes** Number of bytes in the packet ready to be unloaded by software.

Chapter 19
AC97 Controller

19.1 Theory of Operation

The LH7A400 AC97 Controller, shown in Figure 19-1, complies with the *Audio Codec '97 Component Specification v2.2*. It is assumed that the reader is familiar with Intel's AC97 Specification. It is highly recommended that the reader understand the AC97 protocol as described in the specification before reading this chapter, as a lot of the discussion pertains to the implementation of this protocol.

This AC97 Controller implements the five-pin serial interface to an external audio codec. This serial interface, called the AC-link, describes the physical and high-level functional aspects of the AC97 Controller to codec interface. Data handling and interface to the LH7A400 core is also handled by the AC97 Controller. The block diagram of the physical AC97 interface appears in Figure 19-1.

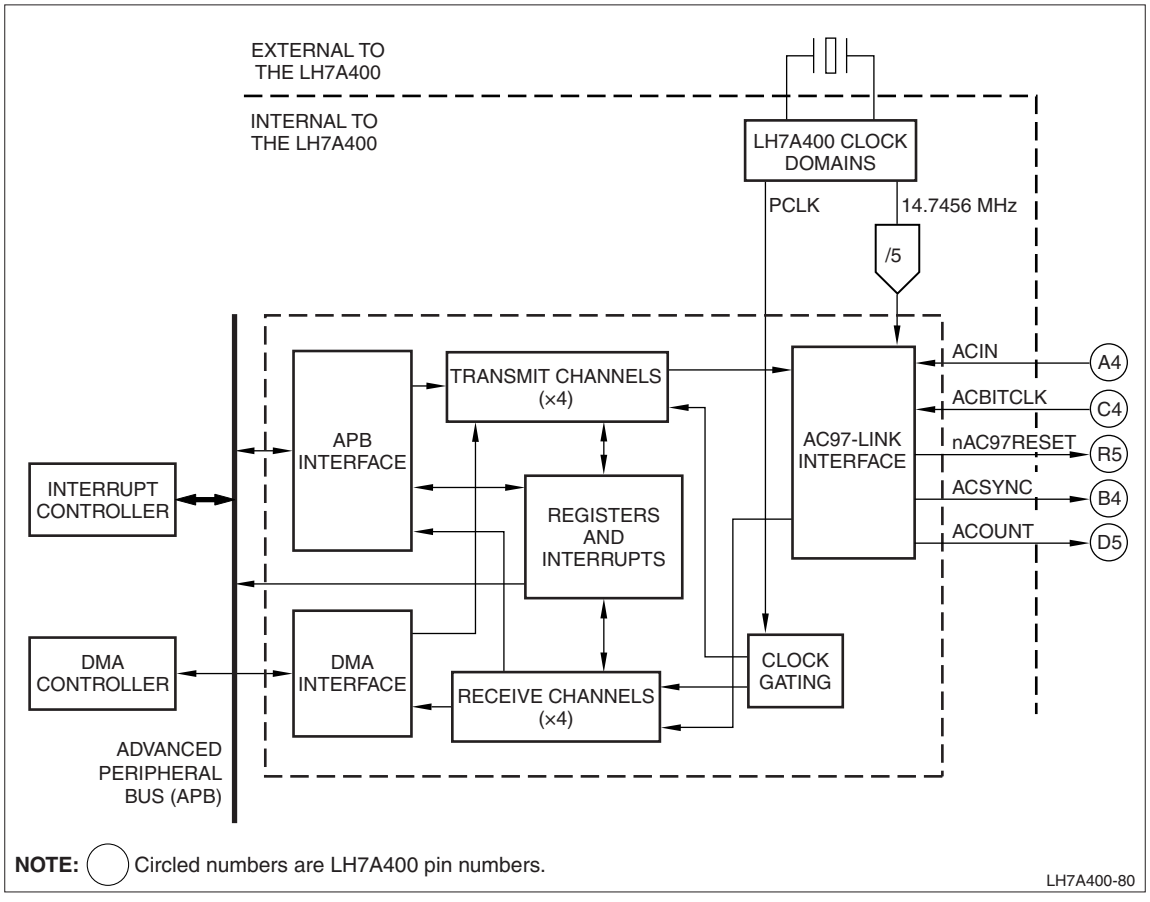


Figure 19-1. AC97 Block Diagram

19.1.1 Data Protocol

Each audio frame is divided into 12 outgoing and 12 incoming data stream time slots, or simply Slots. Each Slot has 20-bit sample resolution. The first three Slots and the 12th Slot contain control and status information and the remaining Slots contain the audio data in Pulse Code Modulation (PCM) format. An active HIGH Sync pulse indicates the beginning of Slot 0 in the data stream. Figure 19-2 illustrates the data stream. Table 19-1 and Table 19-2 define the contents of the outgoing and incoming Slots. More detailed information regarding the serial data streams appears in Section 19.1.4.

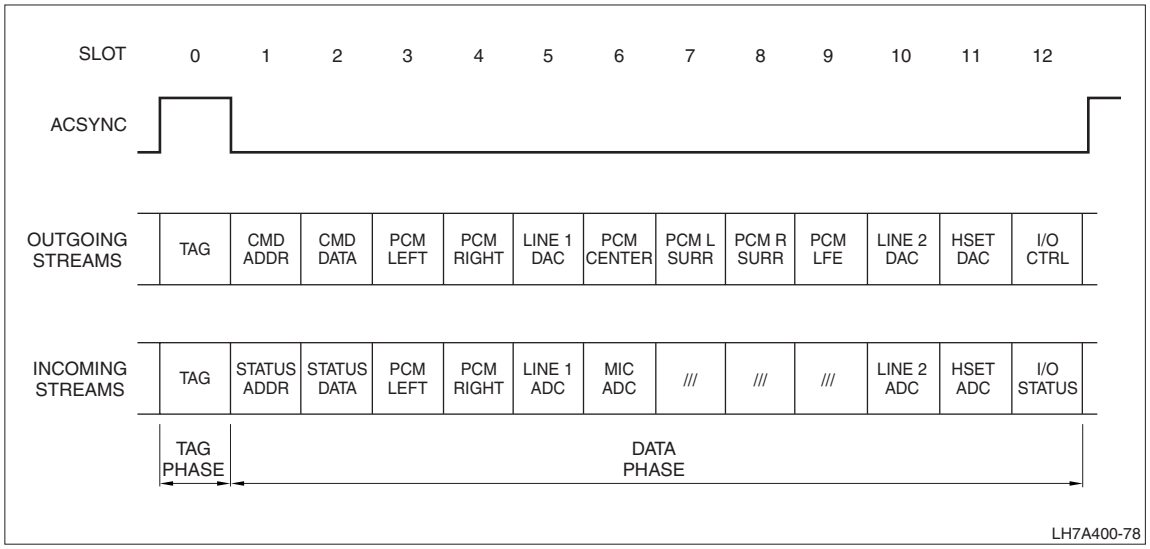


Figure 19-2. AC-Link Data Stream

Table 19-1. Outgoing Slot Definitions

SLOT	NAME	DESCRIPTION
0	TAG	Contains list of Slots with valid data and codec ID.
1	CMD ADDR	Codec register address and Read/Write command bit.
2	CMD DATA	Command register write data.
3	PCM LEFT	Left-channel PCM audio.
4	PCM RIGHT	Right-channel PCM audio.
5	LINE 1 DAC	Modem data for modem line 1 output.
6	PCM CENTER	PCM audio for surround sound center channel.
7	PCM L SURR	PCM audio for surround sound left channel.
8	PCM R SURR	PCM audio for surround sound right channel.
9	PCM LFE	PCM audio for surround sound LFE channel.
10	LINE 2 DAC	Modem data for modem line 2 output.
11	HSET DAC	Modem data for modem handset output.
12	I/O CNTRL	GPIO write port for modem control.

Table 19-2. Incoming Slot Definitions

SLOT	NAME	DESCRIPTION
0	TAG	Contains list of Slots with valid data.
1	STATUS ADDR	Contains list of Slots requesting data and the echo register address.
2	STATUS DATA	Command register read data.
3	PCM LEFT	Left-channel PCM audio.
4	PCM RIGHT	Right-channel PCM audio.
5	LINE 1 ADC	Modem data for modem line 1 input.
6	MIC ADC	Optional third ADC input.
7	///	Reserved
8	///	Reserved
9	///	Reserved
10	LINE 2 ADC	Modem data for modem line 2 input.
11	HSET ADC	Modem data for modem handset input.
12	I/O STATUS	GPIO read port for modem status.

19.1.2 AC97 Architecture

The AC97 Controller:

- Manages the AC-link
- Processes Slot data
- Interfaces to the DMA Controller
- Provides an interface to the AMBA APB.

The AC97 logic incorporates:

- Serial-to-parallel conversion on data received from the external codec
- Parallel-to-serial conversion on data transmitted to the external codec
- Reception and transmission of control and status information
- Up to four different sampling rates concurrently, using four transmit channels and four receive channels.

The transmit and receive paths are buffered with internal FIFO memories, storing data independently in both transmit and receive modes. The data for the FIFOs can be written or read via either the APB interface or the DMA Channels [2:0].

19.1.2.1 Channels and FIFOs

The AC97 Controller has four data channels. Each channel consists of a transmit FIFO, a receive FIFO, and the associated control logic to pack, unpack, and resize the data as necessary. The FIFOs can be configured to handle any data from or to any Slot in a frame. Figure 19-3 shows a block diagram of a single channel.

To support all Slots per frame, the sampling rate for each type of data within the frame must be consistent. For example:

- For an external codec supporting both audio and modem data, all audio data must be at the audio sampling rate and all modem data must be at the modem sampling rate.
- For external codec supporting PCM LEFT, PCM RIGHT, MODEM1, PCM CENTER, PCM L SURROUND, PCM R SURROUND, PCM LFE, MODEM2 and HSET, program the transmit side of the controller to store the PCM LEFT, RIGHT, CENTER, L SURROUND, R SURROUND, and LFE data in channel 1; MODEM1 and MODEM2 data in channel 2; and HSET data in channel 3. To also receive MIC data at a different rate, store the MIC data in channel 4.
- For an external codec supporting more than four sample rates, decide which four sample rates to allow.

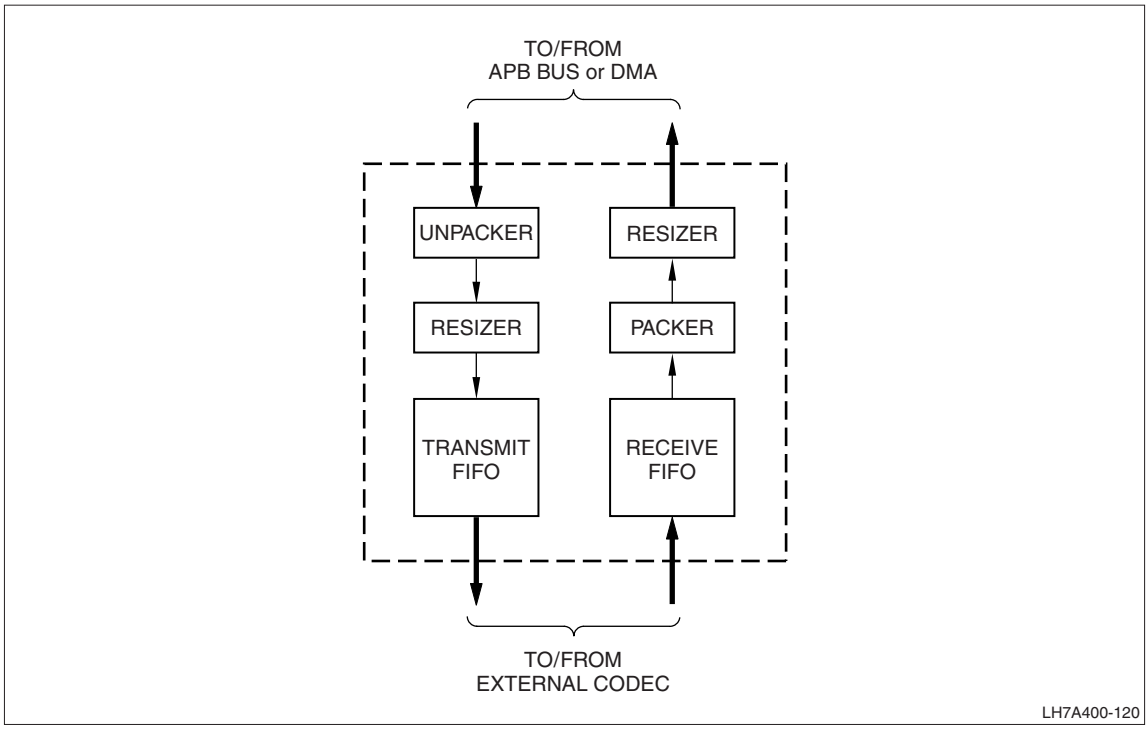


Figure 19-3. Block Diagram of One Channel

19.1.2.1.1 Receive Channel Configuration

The receive section of the channel is controlled via the Receive Control register (RXCR):

- The Slot data from the received frame to be stored in the FIFO. The controller stores only the Slots specified by software. Software must ensure all Slot data stored in a FIFO is at the same sampling rate.
- The length of time before a timeout interrupt is generated.
- Whether the FIFO is enabled or disabled.
- The number of bits required of the Slot.
- Whether the channel can or cannot receive data.

19.1.2.1.2 Transmit Channel Configuration

The transmit section of the channel is controlled via the Transmit Control register (TXCR):

- The Slots to transmit the data in the FIFO. Software must ensure all the data in the FIFO is intended for Slots with the same sampling rate. The data must be supplied lowest Slot number first.
- Whether the FIFO is enabled or disabled.
- The number of bits to be appended to the data for a 20-bit data word length.
- Whether the channel can or cannot transmit data.

The transmit channel also supports variable sample rates via the Data Request Disable Slotbits from the external codec in Slot 1. The data request bits for all audio and modem data must occur within the same frame. Slot 0 for transmission is determined by the controller according to the values in the TXCR register, the data request bits, and the FIFO having valid data to send. When a Slot has no data for transmission, the controller automatically fills the Slot with zeros and invalidates the Tag bits.

For an external codec not supporting the variable sample rate Data Request Disable bits or Variable Rate Extension, these bits are always 0 resulting in a sample rate of 48 kHz. As Slots 1 and 2 are always transmitted at 48 kHz, the external codec has no data request bits for these Slots.

Data for transmission on Slots 1, 2, and 12 can be obtained from either the channel FIFOs or the S1DATA, S2DATA, and S12DATA registers. Software must ensure the Slot data is available from a single source. When the Slot Enable bits are 1, the controller stores the Slots 1, 2, and 12 data in the channel FIFO rather than in the S1DATA, S2DATA, and S12DATA registers. When the Slot Enable bits are 0, the Slot data is stored in their respective registers.

Use the channels to transmit Slot 1 and Slot 2 data when setting the external codec up for operation. Once the setup of the external codec is complete, the data for Slot 1 and 2 should come via the S1DATA and S2DATA registers — this then frees up the channel for audio/modem data.

19.1.2.2 FIFOs

The transmit DMA FIFOs (channels 0-2) are 20 bits wide by eight bits deep. Data is removed from the FIFO buffer one 20-bit word at a time. Data is read from the FIFO into the parallel-to-serial shift converter aligned MSB first.

The APB TX FIFO (channel 3) is 20 bits wide by 16 bits deep. This enables the channel to run at an 8 kHz sample rate with the processor servicing the data in the FIFO approximately every 1.9 ms. One Slot of data comes from the external codec every 124.8 μs (once every 6 frames); 16 × 124.8 μs = 1.9968 ms. When the DMA FIFOs are accessed via the APB, software must account for system bus latencies possibly preventing data from being available quickly enough.

The receive DMA FIFOs (channels 0-2) are 21 bits wide by eight bits deep. The lower 20 bits contain the byte data and the 21st bit contains the receive overrun status flag. The data is read from the serial-to-parallel shift converter into the FIFO MSB first.

The receive overrun bit is used to indicate the status of the data when it was received. Software can read the Status Register RXOE field (SR:RXOE) to determine if the FIFO had a error occur during reception. After checking the SR, software can read the buffer value, which clears RXOE to 0.

As with the TX FIFO, the APB RX FIFO (channel 3) is 21 bits wide by 16 bits deep. This accommodates the channel running at an 48 kHz sample rate and the processor servicing the data in the FIFO approximately every 1.9 ms. When DMA FIFOs are accessed via the APB, software must account for system bus latencies possibly preventing data from being serviced quickly enough.

19.1.2.3 Unpackers and Resizers

For the transmit unpacker, the Compact Mode (CM) bit in TXCR register determines if the data from the CPU is in 32-bit or 16-bit words when TSIZE is specified as 12 or 16 bits. When CM is 1, a 32-bit word sent to the controller consists of two Data Slots. The controller splits the 32-bit word into its two 16-bit constituents. When CM is 0, a 32-bit word sent to the controller consists of a single data Slot.

When CM is 1, software must ensure the FIFO channels are configured to accept an even number of Slots, for example, Slots 3 and 4. Software must interpret the data read from bits 15:0 as belonging to the lower Slot (in this example, Slot 3), and the data read from bits 31:16 as belonging to the higher Slot (in this example, Slot 4).

For the transmit resizer, the TSIZE bits in the TXCR register determine the data size for data from the CPU. The resizer MSB justifies the data received. Once the data is unpacked, the controller left-shifts the data by the specified amount, generating a 20-bit word to store into the FIFO. The LSB is filled with zeros. When TSIZE is specified as 20, no shifting or zero filling is performed. The data in the FIFO is stored in the order of lowest Slot first. For example, when the FIFO is set up to store Slots 3 and 4, Slot 3 is supplied by the first data into the FIFO and Slot 4 is supplied by the second data into the FIFO.

When the RSIZE field specifies 12 or 16 in the receive packer, the CM bit in RXCR determines if the data for the CPU is in 32-bit or 16-bit words. With RSIZE specifying 12 or 16 bits and CM 1, a 32-bit word from the controller consists of data from two Slots. The controller joins two words from the FIFO into a 32-bit word. When CM is 0, a 32-bit word from the controller contains data from a single Slot.

When CM is 1, software must ensure the FIFO channels are configured for an even number of Slots; for example, Slots 3 and 4, not Slots 3, 4, and 5. When RSIZE specifies 12 or 16, CM is 1, and (for example) data is being read from Slots 3 and 4, data from Slot 3 is placed in bits 15:0 and data from Slot 4 is placed in bits 31:16 on the bus.

For the receive resizer, the RSIZE field in the RXCR register determines the data size for Slots from the external codec. The RSIZE field is used to LSB-justify the 20-bit data out of the FIFO. When RSIZE specifies 12, 16, or 18 bits, the controller first right-shifts the 20-bit data from the FIFO to achieve the correct data size. For example, when RSIZE specifies 12, the 20-bit word from the FIFO is shifted right eight bits. The resizer then puts 0 values into the MSB bits of the data word.

The CM bit determines the size of the data word. When CM is set (1), the data word is 16 bits. When CM is cleared (0), the data word is 32 bits. The data from the receive channel is stored in the order of lowest Slot first. For example, when a receive FIFO is configured to store Slots 3 and 4, the first data stored in the FIFO is Slot 3, followed by Slot 4.

19.1.3 DMA Interface Bus Protocol

The primary method of data transfer from memory to the AC97 controller is by DMA, because the data bandwidth for the AC-link is 12 Mb/s. The AC97 Controller has three DMA channels, providing one channel each for the three Data Registers (DR [2:0]). Channel 3 should be used for the slowest sample rate, typically 8 kHz (for example, a touch screen interface).

The DMA controller transfers data in bytes. Data transferred to the controller must be in 16-bit multiples (2 × 8-bit), because the minimum AC97 data width is 12 bits. The CM bit in the RXCR and TXCR registers specifies whether the data is formatted as 16-bit words or 32-bit words.

When DMA is used to transfer data from the receive FIFO, only data is transferred and not the overrun status bit. If an overrun error occurs, the DMA transfer automatically ends. The receive error status in SR is cleared when the corresponding word in the FIFO is read. When the overrun error has been set to generate an interrupt in the Interrupt Enable (IE) register, the interrupt status is cleared by any write to the Interrupt Status register (ISR).

When a timeout error occurs on the receive FIFO, the controller generates an interrupt. The interrupt service routine must read the data in the FIFO. This read can be done via either the DMA or the APB interface. The DMA controller does not directly handle this type of interrupt.

The DMA Controller recognizes the end of the data when the FIFOs are empty and the Transmit Enable bit (TEN) or the Receive Enable bit (REN) has been cleared (0).

Valid receive data is made available to both the APB and the DMA by the AC97 Controller. Software must select either DMA or the APB interface to access the receive data from the FIFOs. The AC97 Controller behaves unpredictably when both DMA and the APB accesses are attempted at the same time. The DMA channels operate only when they are enabled in the DMA controller.

19.1.4 Serial Interface Protocol

The AC-link is the connection between the controller and the external chip. This link, shown in Figure 19-4, consists of a 5-pin interface that is a bi-directional, fixed rate, serial Pulse Code Modulation (PCM) stream. The AC97 Controller interfaces to this link.

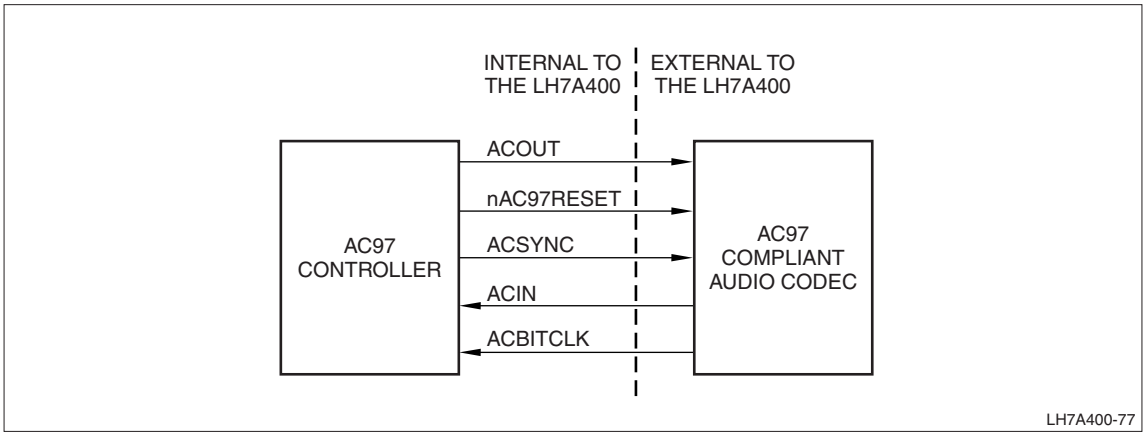


Figure 19-4. AC97 Link Connections

19.1.4.1 ACOUT Slot Data

The audio frame output from the AC97 Controller, contains control and PCM data targeted for the external codec control registers and stereo DAC. Figure 19-5 shows the frame protocol. The Tag Slot, Slot 0, contains 16 bits that tell the AC-link interface circuitry the validity of the subsequent data Slots. A new audio frame is signalled with a LOW to HIGH transition of SYNC. SYNC is synchronous to the rising edge of the ACBITCLK and when the data on ACOUT is the final bit of the previous serial data frame. On the next rising edge of ACBITCLK, the controller drives ACOUT with the first bit of Slot 0. The external codec samples the ACOUT on the falling edge of ACBITCLK. The controller continues outputting the ACOUT stream on each successive rising edge of ACBITCLK.

The beginning of a frame output is shown in Figure 19-6. The SYNC signal remains HIGH for a total of 16 ACBITCLKs at the beginning of each frame, when the ACBITCLK rising edge SYNC = 0.

The ACOUT Slot datastream is described in Table 19-3 through Table 19-15.

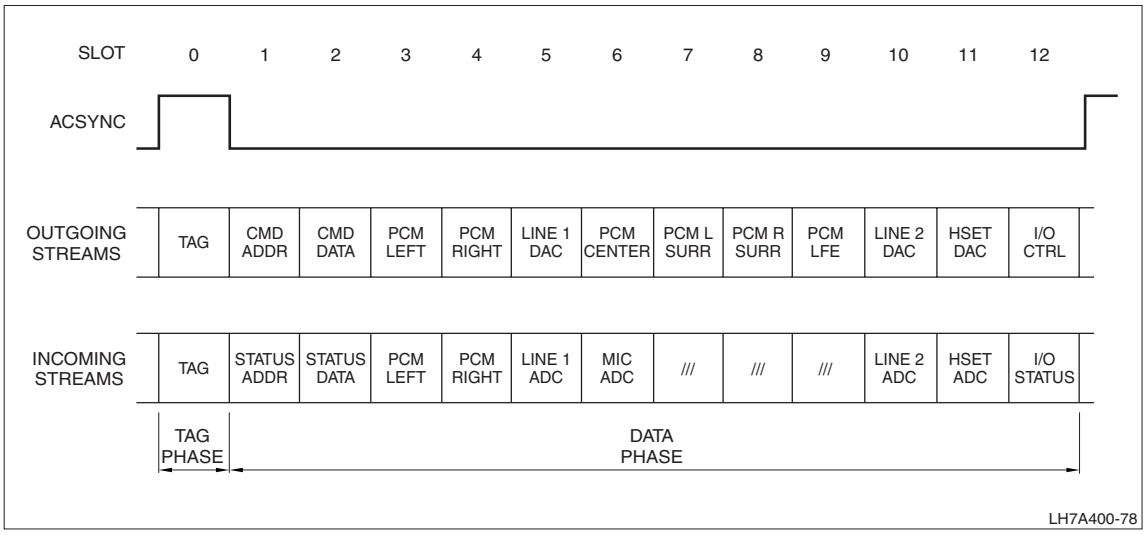


Figure 19-5. AC97 Bidirectional Audio Frame

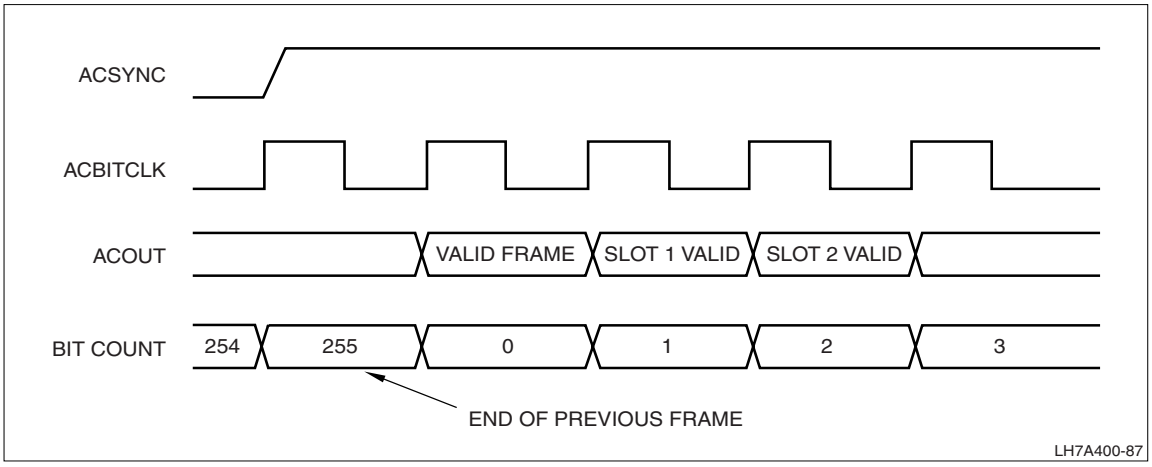


Figure 19-6. Start of Audio Frame Output

19.1.4.1.1 Slot 0: Tag and Codec ID (16 bits)

Slot 0 provides validity status for the remaining Slots in the frame, and the Codec ID, as shown in Table 19-3.

The Frame Valid bit (ACOUT bit 15) flags the validity for the entire frame. If there is valid data in any of the Slots, this bit will be 1. The next 12 bit positions indicate which of the corresponding 12 time Slots contain valid data. Bits 2:0 must always be 0 values as the AC97 Controller only supports Primary codecs (Codec ID 0b00). The AC97 Controller generates the Slot 0 values, determined by the validity of the data in the FIFOs, the values in the TXCR register and the value of the Disable Request Slot from the ACIN Slot 1. The controller fills all non-valid Slot bit positions with zeros.

Table 19-3. Slot 0 Output Bit Definitions

BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FUNCTION	Frame Valid	Slot 1 Primary Codec Valid Command Address Bit	Slot 2 Primary Codec Valid Command Address Bit	Slot 3 Valid PCM Left Channel Data Bist	Slot 4 Valid PCM Right Channel Data Bist	Slot 5 Valid Modem Line 1 Bits	Slot 6 Valid PCM Center Channel Data Bits	Slot 7 Valid PCM Left Surround Data Bits	Slot 8 Valid PCM Right Surround Data Bits	Slot 9 Valid PCM LFE Bits	Slot 10 Valid Modem Line 2 or PCM Left (n+1) Bits	Slot 10 Valid Modem Handset or PCM RIght (n+1) Bits	Slot 12 Valid Modem GPIO or PCM Center (n+1) Bits	Reserved	Codec ID Field	

19.1.4.1.2 Slot 1: Command Address Port (20 bits)

Slot 1 is used to indicate the register address of the current frame's register access, as shown in Table 19-4.

The MSB of Slot 1 (bit 19) signifies whether the current control operation is a read (1) or a write (0). Bits 18:12 specify the register address of the read or write operation. The trailing 12 bits are reserved and must be zeros.

Table 19-4. Slot 1 Output Bit Definitions

BIT	19	18:12	11:0
FUNCTION	R/W Command	Control Register Index	Reserved

19.1.4.1.3 Slot 2: Command Data Port (20 bits)

Slot 2 delivers the 16-bit control register write data, shown in Table 19-5.

Bits 19:4 contain the 16-bit value to be written to the register. The controller zeros bits 3-0. If the access is a register read, the entire Slot is automatically stuffed with zeros by the AC97 Controller.

Table 19-5. Slot 2 Output Bit Definitions

BIT	19:4	3:0
FUNCTION	Control Register Write Data	Reserved

19.1.4.1.4 Slot 3: PCM Playback Left Channel (20 bits)

Slot 3 is used to transmit PCM playback data intended for the left channel DAC on the codec, as shown in Table 19-6.

The AC-link output in Slot 3 is the composite digital audio left-playback stream. If the data stream resolution is less than 20 bits, the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-6. Slot 3 Output Bit Definitions

BIT	19:0
FUNCTION	Left Playback PCM Audio Data

19.1.4.1.5 Slot 4: PCM Playback Right Channel (20 bits)

Slot 4 is used to transmit PCM playback data intended for the right channel DAC on the codec, as shown in Table 19-7.

The AC-link output in Slot 4 is the composite digital audio right-playback stream. If the data stream resolution is less than 20 bits, the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-7. Slot 4 Output Bit Definitions

BIT	19:0
FUNCTION	Right Playback PCM Audio Data

19.1.4.1.6 Slot 5: Modem Line 1 Output Channel (20 bits)

Slot 5 is used to transmit MSB-justified modem line 1 DAC input data, as shown in Table 19-8.

The AC-link output in Slot 5 contains the MSB-justified modem DAC data. The default resolution is 16 bits and the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-8. Slot 5 Output Bit Definitions

BIT	19:0
FUNCTION	Modem Line 1 Data

19.1.4.1.7 Slot 6: PCM Playback Center Channel (20 bits)

Slot 6 is used to transmit PCM playback data intended for the center channel in a six-channel configuration, as shown in Table 19-9.

The AC-link output in Slot 6 is the composite digital audio center-playback stream. If the data stream resolution is less than 20 bits, the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-9. Slot 6 Output Bit Definitions

BIT	19:0
FUNCTION	Center Playback PCM Audio Data

19.1.4.1.8 Slot 7: PCM Playback L Surround Channel (20 bits)

Slot 7 is used to transmit PCM playback data intended for the left-surround channel on the codec in a six-channel configuration, as shown in Table 19-10.

The AC-link output in Slot 7 is the composite digital audio left-surround playback stream. If the data stream resolution is less than 20 bits, the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-10. Slot 7 Output Bit Definitions

BIT	19:0
FUNCTION	Left Surround Playback PCM Audio Data

19.1.4.1.9 Slot 8: PCM Playback R Surround Channel (20 bits)

Slot 8 is used to transmit PCM playback data intended for the right surround channel on the codec in a six-channel configuration, as shown in Table 19-11.

The AC-link output in Slot 8 is the composite digital audio right-surround playback stream. If the data stream resolution is less than 20 bits, the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-11. Slot 8 Output Bit Definitions

BIT	19:0
FUNCTION	Right Surround Playback PCM Audio Data

19.1.4.1.10 Slot 9: PCM Low Frequency Effects DAC (20 bits)

Slot 9 is used to transmit PCM playback data intended for the Low Frequency Effects (LFE) channel on the codec in a six-channel configuration, as shown in Table 19-12.

The AC-link output in Slot 9 is the digital audio LFE playback stream. If the data stream resolution is less than 20 bits, the AC97 Controller stuffs the trailing non-valid bit positions with zeros.

Table 19-12. Slot 9 Output Bit Definitions

BIT	19:0
FUNCTION	PCM LFE Data

19.1.4.1.11 Slot 10: Modem Line 2 Output Channel or PCM L (n+1) (20 bits)

Slot 10 is used to transmit MSB-justified modem line 2 DAC input data or provide extra bandwidth for Double Rate Audio PCM left channel, as shown in Table 19-13.

Slot 10 can be used to either transmit modem line 2 DAC input data or PCM Left channel data when 96 kHz sampling rate is required (e.g. DVD players).

Table 19-13. Slot 10 Output Bit Definitions

BIT	19:0
FUNCTION	Modem Line 2 Data, or PCM Left (n+1) Data

19.1.4.1.12 Slot 11: Modem Handset Output Channel or PCM R (n+1) (20 bits)

Slot 11 is used to transmit the MSB-justified modem handset DAC input data or provide extra bandwidth for Double Rate Audio PCM right channel, as shown in Table 19-14.

Slot 11 can be used to either transmit head set input data or PCM right channel data when 96 kHz sampling rate is required (e.g. DVD players).

Table 19-14. Slot 11 Output Bit Definitions

BIT	19:0
FUNCTION	Modem Handset Data, or PCM Right (n+1) Data

19.1.4.1.13 Slot 12: Modem GPIO Control Channel or PCM C (n+1) (20 bits)

Slot 12 contains the modem GPIO control outputs, or extra bandwidth for Double Rate Audio PCM center channel, as shown in Table 19-15.

Slot 12 can be used to either transmit I/O control input data or PCM Center channel data when 96 kHz sampling rate is required (e.g. DVD players).

Table 19-15. Slot 12 Output Bit Definitions

BIT	19:0
FUNCTION	Modem GPIO Control Channel, or PCM Center (n+1) Data

19.1.4.2 ACIN Slot Data

The audio frame input to the AC97 Controller contains the status and PCM data from the external codec control registers and stereo ADC. The Tag Slot, Slot 0, contains 16 bits indicating to the AC97 Controller whether the external codec is ready and the validity of data from various device subsections. A new audio input frame, as shown in Figure 19-32, is signalled with a LOW to HIGH transition of ACSYNC. ACSYNC is synchronous to the rising edge of ACBITCLK. On the next rising edge of ACBITCLK, the external codec drives ACIN with the first bit of Slot 0. The AC97 Controller samples ACIN on the falling edge of ACBITCLK. The external codec continues outputting the ACIN stream on each successive rising edge of ACBITCLK. The external codec outputs data MSB first, in a MSB justified format. All reserved bits and Slots are filled with 0 values by the external codec.

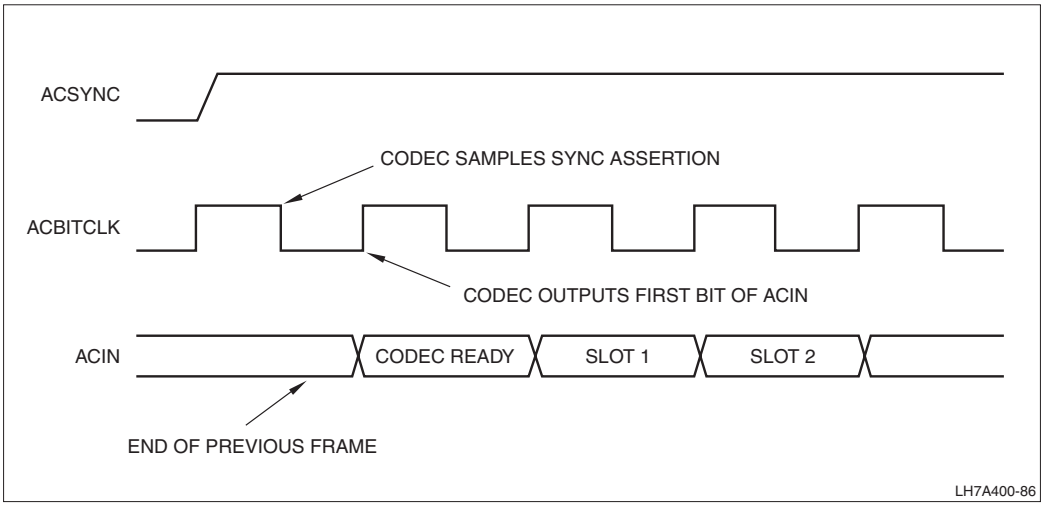


Figure 19-7. Start of Audio Frame Input

19.1.4.2.1 ACIN Operation

Before operating the external codec, the AC97 Controller polls the first bit in the audio frame input (ACIN Slot 0, bit 15) for an indication that the codec is in the Codec Ready state. The first bit received in Slot 0 is a global bit, indicating whether the codec is in Codec Ready state. If the Codec Ready bit is 0, the codec is not ready for normal operation. If the Codec Ready bit is 1, the control and status registers are fully operational. Software must then read the Power down Control and Status registers to determine which subsections, if any, are ready.

Once the AC97 Controller has sampled Codec Ready, the next 12 bit positions sampled indicate which of the corresponding 12 Slots are assigned to input data streams and contain valid data. Data will only be stored if one or more of the FIFOs RXCR registers has its RX bit set (1). Software must ensure that the FIFO control registers are set up to accept all received data. On the rising edge of ACBITCLK, before the last bit of the time slot, SYNC will be deasserted. From this point to the frame end, the Slots will contain 20 data bits.

When any of the FIFOs has no data available for transmission, an underflow occurs and invalid data, all 0 bits, is transmitted from the FIFO until the FIFO becomes non-empty or until transmit is disabled. Software can use the transmit interupt request to write transmit data at a sufficient rate to prevent an underflow error condition.

The ACIN Slot datastream is described in Table 19-16 through Table 19-25.

19.1.4.2.2 Slot 0: Tag (20 bits)

Slot 0 indicates whether the codec is ready, and if so, which subsections are ready, as shown in Table 19-16.

The first bit of ACIN Slot 0 (bit 15) indicates when the codec is ready. The controller checks the subsequent data bits in Slot 0 to see which other subsections are ready. For example, a 1 value in bit 14 indicates Slot 1 data valid; a 1 value in bit 13 indicates Slot 2 data valid. The data obtained from this Slot is stored in the AC97 Controller to indicate which Slots within the frame contain valid data.

Table 19-16. Slot 0 Input Bit Definitions

BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2:0
FUNCTION	Codec Ready	Slot 1 Ready	Slot 2 Ready	Slot 3 Ready	Slot 4 Ready	Slot 5 Ready	Slot 6 Ready	Slot 7 Ready	Slot 8 Ready	Slot 9 Ready	Slot 10 Ready	Slot 11 Ready	Slot 12 Ready	Reserved

19.1.4.2.3 Slot 1: Status Address Port (20 bits)

Slot 1 is used to echo the external codec's register address back to the AC97 Controller when the codec has been issued a read request from the previous frame, as shown in Table 19-17.

The external codec echoes the register index for only a read access. Write accesses return no valid data in Slot 1. For reads, bit 19 is filled with a 0 value. Bits 18:12 contain the 7-bit register index for the codec registers. Bits 11:2 are used for Sample Rate Conversion (SRC), known as Disable Request bits for Slot 3 through Slot 12.

- When the external codec sets these bits to 1, the corresponding Slot must send no data on ACOUT in the following frame.
- When the external codec sets these bits to 0, the corresponding Slot must respond with data on ACOUT in the next frame.

Table 19-17. Slot 1 Input Bit Definitions

BIT	19	18:12	11	10	9	8	7	6	5	4	3	2	1:0
FUNCTION	Reserved	Control Register Index Echo	Slot 3 Request	Slot 4 Request	Slot 5 Request	Slot 6 Request	Slot 7 Request	Slot 8 Request	Slot 9 Request	Slot 10 Request	Slot 11 Request	Slot 12 Request	Reserved

19.1.4.2.4 Slot 2: Status Data Port (20 bits)

Slot 2 delivers the 16-bit control register read data, shown in Table 19-18.

Slot 2 returns the control register data requested by the controller from the previous read request. When Slot 2 is tagged invalid by the Codec Status Bits in Slot 0, the entire Slot is filled with 0 values by the codec. Bits 19:4 contains the 16-bit codec register value returned to the controller. Bits 3:0 are returned as 0 values.

Table 19-18. Slot 2 Input Bit Definitions

BIT	19:4	3:0
FUNCTION	Control Register Read Data	Reserved

19.1.4.2.5 Slot 3: PCM Record Left Channel (20 bits)

Slot 3 contains the left channel ADC data, as shown in Table 19-19.

The digitized signal is selected via register 0x1A. The default value of this register is 0x0000, selecting the MIC input. This is a 20-bit Slot. The 18-bit PCM data returned is MSB first and the two remaining bits are zeros.

Table 19-19. Slot 3 Input Bit Definitions

BIT	19:0
FUNCTION	Left Record PCM Audio Data

19.1.4.2.6 Slot 4: PCM Record Right Channel (20 bits)

Slot 3 contains the right channel ADC data, as shown in Table 19-20.

The digitized signal is selected via register 0x1A. The default value of this register is 0x0000, selecting the MIC input. This is a 20-bit Slot. The 18-bit PCM data returned is MSB first and the two remaining bits are zeros.

Table 19-20. Slot 4 Input Bit Definitions

BIT	19:0
FUNCTION	Right Record PCM Audio Data

19.1.4.2.7 Slot 5: Modem Line 1 ADC(20 bits)

Slot 5 contains the Modem Line 1 ADC data, as shown in Table 19-21.

The AC-link input in Slot 5 contains the MSB-justified modem ADC data. The default resolution is 16 bits and the trailing non-valid bit positions are stuffed with zeros.

Table 19-21. Slot 5 Input Bit Definitions

BIT	19:0
FUNCTION	Modem Line 1 Data

19.1.4.2.8 Slot 6: Microphone Record Data (20 bits)

Slot 6 contains the microphone record data, as shown in Table 19-22.

The AC-link input in Slot 6 is an third PCM system input channel available for dedicated use by a microphone. Data is MSB first, and resolution of fewer than 20 bits has trailing zeros appended to fill out the remaining bit.

Table 19-22. Slot 6 Input Bit Definitions

BIT	19:0
FUNCTION	Microphone Record Data

19.1.4.2.9 Slot 7 - Slot 9: Vendor Reserved (20 bits)

These slots are Vendor Reserved and are otherwise stuffed with zeros by the codec.

19.1.4.2.10 Slot 10: Modem Line 2 ADC Data (20 bits)

Slot 10 contains the Modem Line 2 ADC data, as shown in Table 19-23. Slot 10 contains the modem line 2 ADC input data in MSB-first order.

Table 19-23. Slot 10 Input Bit Definitions

BIT	19:0
FUNCTION	Modem Line 2 Data

19.1.4.2.11 Slot 11: Modem Handset ADC (20 bits)

Slot 11 contains handset ADC data, as shown in Table 19-24. Slot 11 contains the modem handset ADC input data in MSB-first order.

Table 19-24. Slot 11 Input Bit Definitions

BIT	19:0
FUNCTION	Modem Handset Data

19.1.4.2.12 Slot 12: Modem GPIO Status (20 bits)

Slot 12 contains the modem GPIO status inputs, as shown in Table 19-25.

Table 19-25. Slot 12 Input Bit Definitions

BIT	19:0
FUNCTION	Modem GPIO Status Data

19.1.5 External Reset Modes

The three methods to reset the external codecs are Cold Reset, Warm Reset, and Register Reset. When a reset is asserted, the external codec activates ACBITCLK, used to generate the SYNC signal required for normal reception and transmission. SYNC is re-activated for normal operation after a 254-ACBITCLK count. Following a reset, transmission on the ACOUT port will not occur until the software has received a Codec Ready signal.

19.1.5.1 Cold Reset

A Cold Reset is achieved by asserting the AC97RESET output pin for the minimum time specified for the external codec used, then subsequently deasserting AC97RESET. A Cold Reset initializes all AC97 logic and registers to default values. A Cold Reset is required to restart the AC-link when bit PR5 is 1 in register 0x26 in the external codec.

Figure 19-8 shows the Cold Reset timing. tRST_LOW is typically 1 μs (MIN.). tRST2_CLK varies by codec; refer to the codec's data sheet. The AC97RESET pin is controlled via the Reset register. The tRST_LOW time is achieved by counting five pulses of the 2.9491 MHz clock, resulting in a 1.695 μs reset pulse, satisfying the 1 μs minimum requirement.

The 2.9491 MHz clock is generated by the clock divide chains in the Clock and State Controller (CSC). The count of five pulses allows timing the SYNC signal for the Warm Reset from the same counter. When the counter reaches five, the AC97 Controller clears the Reset register.

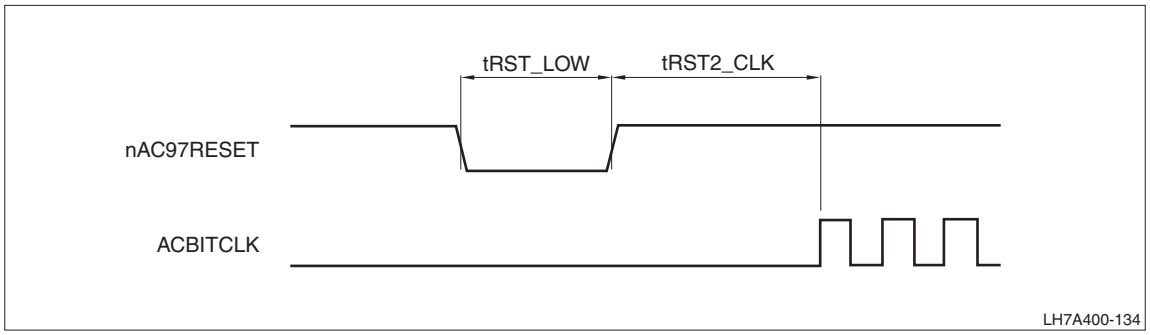


Figure 19-8. Cold Reset Timing

19.1.5.2 Warm Reset

A Warm Reset is required to restart the AC-link when bit PR4 is 1 in register 0x26 in the external codec. A Warm Reset resets the logic to the default state while maintaining the contents of all registers. A Warm Reset allows the AC-link to be reactivated without losing information in the external codec registers.

Figure 19-9 shows the Warm Reset timing. tSYNC_HIGH is typically 1.3 μs (MIN.). TYNC2_CLK varies by codec. The ACSYNC pin is controlled by the Sync register. The tSYNC_HIGH time is achieved by counting five pulses of 2.9491 MHz, resulting in a 1.695 μs reset pulse, satisfying the 1.3 μs minimum requirement.

The 2.9491 MHz clock is generated by the clock divide chains in the CSC. When the counter reaches five, the AC97 Controller clears the SYNC register.

When powered down following a Warm Reset, reactivation of the AC-link via re-assertion of the SYNC signal must not occur for a minimum of four audio frame times (4 × 20.8 μs) following the frame in which the power down was triggered. The SYNC is deactivated for 4 × 20.8 μs before becoming active on the output.

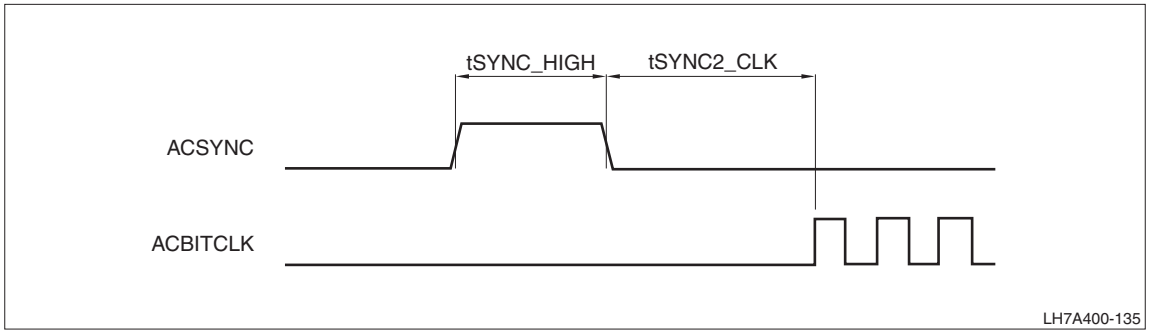


Figure 19-9. Warm Reset Timing

19.1.5.3 Register Reset

The third reset mode provides a Register Reset to the external codec, to reset all codec registers to their default power-up values. A Register Reset occurs when any value is written to the external codec register at address 0x00.

19.1.6 Power Considerations

Removing power from the AC97 external codec chip may result in excess current consumption. When power is removed from the AC97 external codec chip, I/O pins remain in their current state. If driven HIGH, power can be fed back into the chip resulting in high current consumption. In addition, the external codec may not reset properly and may not operate correctly when power is restored. Therefore, the LH7A400 should be programmed to supply power to the AC97 external codec chip at all times. All power management should be done through the power management features available with the AC97 external codec chip.

19.1.6.1 Low Power Mode

The AC-link can be placed in low power (Halt) mode. After the end of Slot 2 transmission, when the codec Power-down Control/Status register (0x26) is programmed with the appropriate value, the external codec drives ACBITCLK and ACIN LOW. So that the AC97 Controller can recognize the fact that the AC-link is to be brought into a low power mode via a command to the external codec, the S1DATA and S2DATA registers are monitored to check if the address is 0x26 and bit 12 in the S2DATA register is set (1).

19.1.7 Clock Gating

Each channel in both the transmit and receive directions has a separately gated clock. A channel clock is running when the corresponding channel enable bit is set (1). The channel clocks are synchronized with the PCLK input to the AC97 Controller. The TEN and REN signals are sampled using the falling edge of PCLK before the gating process to avoid any glitches on the gated output clocks.

19.1.8 Interrupts

The AC97 Controller generates two types of interrupts: local FIFO interrupts and global interrupts.

FIFO interrupts are asserted in the AC97 Raw Interrupt Status Register for each FIFO (RISRx, where x indicates FIFO number 1, 2, 3, or 4). Software can enable or disable these interrupts by programming the AC97 Interrupt Enable register for each FIFO (IEx). The logical bit-wise AND of the asserted and enabled interrupts appears in the AC97 Interrupt Status Register for each FIFO (ISRx). Only interrupts asserted in RISRx and enabled in IEx appear in ISRx, as follows:

ISRx = ((RISRx) bit-wise AND (IEx))

Global interrupts are asserted in the AC97 Raw Global Interrupt Status register (RGIS). Most of these interrupts are not asserted during normal AC97 operation. Software can clear the Wakeup and Codec Ready interrupts by programming the Global End-of-Interrupt register (GEOI). Software can enable or disable the global interrupts by programming the Global Interrupt Enable Register (GIEN). The bit-wise AND of the asserted and enabled global interrupts appears in the Global Interrupt Status register (GIS), as follows:

GIS = ((RGIS) bit-wise AND (GIEN))

The ISR1, ISR2, ISR3, ISR4, and GIS interrupt bits are copied in the Global Control Interrupt Status register (GCIS). Software can read all AC97 interrupts with a single read of GCIS.

The individual interrupts in GCIS are ORed together to generate a single, combined interrupt, AC97INTR, to be handled by the LH7A400 Interrupt Controller. AC97INTR is cleared when all contributing interrupts are cleared in RISRx and RGIS or disabled in IEx and GIEN.

The interrupts are described in the Register Description section, Table 19-39 and Table 19-54.

IMPORTANT: When using the AC97, disable ACI interrupts to avoid false interrupt requests. When using the ACI, disable AC97 interrupts.

19.1.8.1 Important Note on Global Interrupt Timing

Global Interrupts are generated using two internal signals that have their logic in two separate clock domains: the externally generated ACBITCLK and the internal PCLK. There is no synchronization between these clocks, which requires a software delay to ensure the data is ready. To ensure proper data is read, delay one frame (~24 μs) following the interrupt.

19.1.9 System Loopback Testing

A loopback test mode is available for system testing, so data transmitted on ACOUT can also be received on ACIN. To enter loopback mode, set the LOOP bit and the OCR bit to 1 in the Global Control register (GCR). For normal, non-loopback operation, the LOOP bits must be 0, which is the default at reset. This test mode requires an external bit clock.

19.2 Register Reference

19.2.1 Memory Map

The base address for the AC97 Controller Registers is 8000.0000.

Table 19-26. AC97 Controller Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0X00	DR1	Data read from or written to FIFO1
0X04	RXCR1	FIFO1 Receive control register
0X08	TXCR1	FIFO1 Transmit control register
0X0C	SR1	FIFO1 Status register
0X10	RISR1	FIFO1 Raw interrupt status register
0X14	ISR1	FIFO1 Interrupt Status
0X18	IE1	FIFO1 Interrupt Enable
0X1C	///	Reserved. Reading returns 0. Values written cannot be read.
0X20	DR2	Data read or written from or to FIFO2
0X24	RXCR2	FIFO2 Control register for receive
0X28	TXCR2	FIFO2 Control register for transmit
0X2C	SR2	FIFO2 Status register
0X30	RISR2	FIFO2 Raw interrupt status register
0X34	ISR2	FIFO2 Interrupt Status
0X38	IE2	FIFO2 Interrupt Enable
0X3C	///	Reserved
0X40	DR3	Data read from or written to FIFO3.
0X44	RXCR3	FIFO3 Control register for receive
0X48	TXCR3	FIFO3 Control register for transmit
0X4C	SR3	FIFO3 Status register
0X50	RISR3	FIFO3 Raw interrupt status register
0X54	ISR3	FIFO3 Interrupt Status
0X58	IE3	FIFO3 Interrupt Enable
0X5C	///	Reserved. Reading returns 0. Values written cannot be read.
0X60	DR4	Data read from or written to FIFO4.
0X64	RXCR4	FIFO4 Control register for receive
0X68	TXCR4	FIFO4 Control register for transmit
0X6C	SR4	FIFO4 Status register
0X70	RISR4	FIFO4 Raw interrupt status register
0X74	ISR4	FIFO4 Interrupt Status
0X78	IE4	FIFO4 Interrupt Enable
0X7C	///	Reserved. Reading returns 0. Values written cannot be read.
0X80	S1DATA	Data received or transmitted on Slot 1
0X84	S2DATA	Data received or transmitted on Slot 2
0X88	S12DATA	Data received or transmitted on Slot 12
0X8C	RGIS	Raw global interrupt status register
0X90	GIS	Global interrupt status register
0X94	GIEN	Global interrupt enable register
0X98	GEOI	Global interrupt clear register
0X9C	GCR	Global control register
0XA0	RESET	Reset control register
0XA4	SYNC	SYNC control register
0XA8	GCIS	Global control FIFO interrupt status register

19.2.2 Register Descriptions

19.2.2.1 Data Registers (DRx)

These registers, defined in Table 19-27 and Table 19-28, hold the data written to or read from the FIFOs. Reading a data register in receive mode returns the received data. Writing a data register in transmit mode writes the data to be transmitted. Values written to these registers cannot be read back.

To transmit words:

- When FIFOs are enabled, data written to this location is pushed onto the transmit FIFO.
- When FIFOs are disabled, the bottom word of the transmit FIFO stores a single data word.

To receive words:

- When FIFOs are enabled, the data received is pushed onto the receive FIFO.

When FIFOs are disabled, the bottom word of the receive FIFO stores a single data word.

Table 19-27. DRx, Standard Mode

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///												DATA			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO for transmit data RO for receive data			
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO for transmit data RO for receive data															
ADDR	FIFO1: 0x8000.0000 FIFO2: 0x8000.0020 FIFO3: 0x8000.0040 FIFO4: 0x8000.0060															

Table 19-28. DRx Register Fields, Standard Mode

BITS	FIELD	DESCRIPTION
31:20	///	**Reserved** Reading returns 0. Values written cannot be read.
19:0	DATA	**Transmit FIFO** TXCR qualifies the data in the transmit FIFO.
19:0	DATA	**Receive FIFO** RXCR qualifies the data in the receive FIFO.

Table 19-29. DRx, Compact Mode

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	EDATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO for transmit data RO for receive data			
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	ODATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO for transmit data RO for receive data															
ADDR	FIFO1: 0x8000.0000 FIFO2: 0x8000.0020 FIFO3: 0x8000.0040 FIFO4: 0x8000.0060															

Table 19-30. DRx Register Fields, Compact Mode

BITS	FIELD	DESCRIPTION
31:16	EDATA	**Even Number Slot Data** Even-number slot data.
15:0	ODATA	**Odd Number Slot Data** Odd-number Slot data.

19.2.2.2 Receive Control Registers (RXCRx)

These registers, defined in Table 19-31 and Table 19-32, control the receive FIFO data to AC-link Slot mapping. When two channels are enabled for the same Slot number, data from the lower channel number is used for that Slot.

Table 19-31. RXCRx

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///			TOC												FDIS
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	CM	RSIZE		RX12	RX11	RX10	RX9	RX8	RX7	RX6	RX5	RX4	RX3	RX2	RX1	REN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	FIFO1: 0x8000.0004 FIFO2: 0x8000.0024 FIFO3: 0x8000.0044 FIFO4: 0x8000.0064															

Table 19-32. RXCRx Register Fields

BITS	FIELD	DESCRIPTION
31:29	///	**Reserved** Reading returns 0. Values written cannot be read.
28:17	TOC	**Time Out Count** The FIFOs can generate a timeout interrupt when the receive FIFO is non-empty and no further data is received for the number of frames specified by TOC. This period represents a count of the SYNC signal. Clearing TOC disables the counter, so no timeout interrupt is generated. After reset, TOC = 0. The maximum TOC of 4,096 sets the timeout to 85 ms.
16	FDIS	**FIFO Disable** 1 = Disable FIFO (character mode). Disabled FIFOs are single entry holding registers. 0 = Enable FIFO buffers (FIFO mode).
15	CM	**Compact Mode** 1 = Enables compact mode for transmitted data. Setting CM with TSIZE set to either 12 or 16 unpacks the two data words from the CPU into two 20-bit, MSB justified, entries in the transmit FIFO, following the rules shown in Table 19-35. 0 = Justifies the data into one 32-bit word.
14:13	RSIZE	**Receive Size** Specifies receive data size: 00 = 16-bit 01 = 18-bit 10 = 20-bit 11 = 12-bit
12	RX12	FIFO stores Slot 12 data (takes precedence over S12DATA).
11	RX11	FIFO stores Slot 11 data.
10	RX10	FIFO stores Slot 10 data.

Table 19-32. RXCRx Register Fields

BITS	FIELD	DESCRIPTION
9	RX9	FIFO stores Slot 9 data.
8	RX8	FIFO stores Slot 8 data.
7	RX7	FIFO stores Slot 7 data.
6	RX6	FIFO stores Slot 6 data.
5	RX5	FIFO stores Slot 5 data.
4	RX4	FIFO stores Slot 4 data.
3	RX3	FIFO stores Slot 3 data.
2	RX2	FIFO stores Slot 2 data (takes precedence over S2DATA).
1	RX1	FIFO stores Slot 1 data (takes precedence over S1DATA).
0	REN	**Receive Enable** 1 = Enables the FIFO receive and the corresponding channel PCLK. 0 = Disables the FIFO receive and the corresponding channel PCLK.

19.2.2.3 Transmit Control Registers (TXCRx)

These registers, defined in Table 19-33 and Table 19-34, control the transmit FIFO channel data to AC-link Slot mapping. All data in each transmit FIFO channel must be of the same sampling frequency; for example, all audio Slot data is at 44.1 kHz.

Field settings for TXCR are used by the AC97 controller to create the data for Slot 0 transmissions. When TXCR specifies data for Slot 1 and Slot 2 to be stored in a particular FIFO channel, this specification takes precedence over the data in the S1DATA and S2DATA registers. Because Slot 1 and Slot 2 data are always transmitted at 48 kHz, do not enable that FIFO channel to store any Slot data not sampled at 48 kHz.

When two FIFO channels are enabled for the same Slot number, data from the lower channel number is used for that Slot.

Table 19-33. TXCRx

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															FDIS
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	CM	TSIZE		TX12	TX11	TX10	TX9	TX8	TX7	TX6	TX5	TX4	TX3	TX2	TX1	TEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	FIFO1: 0x8000.0008 FIFO2: 0x8000.0028 FIFO3: 0x8000.0048 FIFO4: 0x8000.0068															

Table 19-34. TXCRx Register Fields

BITS	FIELD	DESCRIPTION
31:17	///	**Reserved** Reading returns 0. Values written cannot be read.
16	FDIS	**FIFO Disable** 0 = Enable FIFO buffers (FIFO mode). 1 = Disables FIFO (character mode). Disabled FIFOs are single byte holding registers.
15	CM	**Compact Mode** 1 = Enables compact mode for transmitted data. Setting CM with TSIZE set to either 12 or 16 unpacks the two data words from the CPU into two 20-bit, MSB justified, entries in the transmit FIFO, following the rules shown in Table 19-35. 0 = Justifies the data into one 32-bit word.
14:13	TSIZE	**Transmit Size** Specifies transmit data size: 00 = 16-bit 01 = 18-bit 10 = 20-bit 11 = 12-bit
12	TX12	FIFO transmits Slot 12 data (takes precedence over S12DATA)
11	TX11	FIFO transmits Slot 11 data
10	TX10	FIFO transmits Slot 10 data

Table 19-34. TXCRx Register Fields

BITS	FIELD	DESCRIPTION
9	TX9	FIFO transmits Slot 9 data
8	TX8	FIFO transmits Slot 8 data
7	TX7	FIFO transmits Slot 7 data
6	TX6	FIFO transmits Slot 6 data
5	TX5	FIFO transmits Slot 5 data
4	TX4	FIFO transmits Slot 4 data
3	TX3	FIFO transmits Slot 3 data
2	TX2	1 = FIFO contains Slot 2 data (only use if sampling rate is 48 kHz) — takes precedence over S2DATA register. 0 = S2DATA register data routed to Slot 2.
1	TX1	1 = FIFO contains Slot 1 data (only use if sampling rate is 48 kHz) — takes precedence over S1DATA. 0 = S1DATA register data routed to Slot 1.
0	TEN	**Transmit Enable** 1 = Enable FIFO transmit and corresponding channel PCLK. 0 = Disable FIFO transmit and corresponding channel PCLK.

Table 19-35. Compact Mode Programming

CM	TSIZE		DATA TO CPU
0	0	0	Justified, 1 × 16 bits
0	1	1	Justified, 1 × 12 bits
1	0	0	Compacted, 2 × 16 bits
1	1	1	Compacted, 2 × 12 bits
X	1	0	Justified, 1 × 20 bits
X	0	1	Justified, 1 × 18 bits

19.2.2.4 Controller Status Registers (SRx)

This register, defined in Table 19-36 and Table 19-37, provides information about the transmit and receive status of the AC97 Controller. After reset, the TXFF, RXFF and TXBUSY values are 0, and the TXFE and RXFE values are 1.

Table 19-36. SRx

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									TXUE	RXOE	TXBUSY	TXFF	RXFF	TXFE	RXFE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	FIFO1: 0x8000.000C FIFO2: 0x8000.002C FIFO3: 0x8000.004C FIFO4: 0x8000.006C															

Table 19-37. SRx Register Fields

BITS	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading returns 0. Values written cannot be read.
6	TXUE	**Transmit Underrun Error** This error occurs if data is to be transmitted and two conditions exist: • The FIFO is empty • The FIFO has been written to at least once in the current data transfer. To clear, write to the corresponding channel data register. 1 = Transmit Underrun error. 0 = No error condition.
5	RXOE	**Receive Overrun Error** This error indicates that data was received when the FIFO is already full. To clear, read the corresponding channel data register. 1 = Receive Overrun error. 0 = No error condition
4	TXBUSY	**Transmit Busy** 1 = Either TXCRx:TEN = 1 and the FIFO contains data or data from this FIFO is being sent in the current frame. 0 = The next frame has started and is the one following assertion of the corresponding channel FIFO empty flag. For TXBUSY = 0, TEN is irrelevant.
3	TXFF	**Transmit FIFO Full Flag** This flag indicates if the Transmit FIFO is full or has space remaining. 1 = Transmit FIFO is full. 0 = Transmit FIFO is not full.

Table 19-37. SRx Register Fields

BITS	FIELD	DESCRIPTION
2	RXFF	**Receive FIFO Full Flag** This flag indicates if the Receive FIFO is full or has space remaining. 1 = Receive FIFO is full. 0 = Receive FIFO is not full.
1	TXFE	**Transmit FIFO Empty Flag** This flag indicates if the Transmit FIFO is empty or contains some amount of data. 1 = Transmit FIFO is empty. 0 = Transmit FIFO is not empty.
0	RXFE	**Receive FIFO Empty Flag** This flag indicates if the Receive FIFO is empty or contains some amount of data. 1 = Receive FIFO is empty. 0 = Receive FIFO is not empty.

19.2.2.5 Raw Interrupt Status Registers (RISRx)

These registers, defined in Table 19-38 and Table 19-39, are the controller FIFO raw interrupt status bits. These bits show the interrupt status whether the interrupt is enabled or not. Because the FIFO and shift registers are empty after reset, all RISR fields except TCIS are cleared to 0. Writing to this register clears an overrun error.

Table 19-38. RISRx

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												RIS	TIS	RTIS	TCIS
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	FIFO1: 0x8000.0010 FIFO2: 0x8000.0030 FIFO3: 0x8000.0050 FIFO4: 0x8000.0070															

Table 19-39. RISRx Register Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	RIS	**Receive Interrupt Status** This interrupt is asserted when one of two conditions exist: • When the corresponding receive FIFO is enabled, this interrupt is asserted when the FIFO becomes half full. It is cleared when software has performed enough reads from the corresponding data register to make the receive FIFO less than half full. • When the corresponding receive FIFO is disabled, this interrupt is asserted when data is received into the single entry holding register. It is cleared when software reads the corresponding data register. 1 = FIFO Receive interrupt is asserted. 0 = FIFO Receive interrupt is not asserted.
2	TIS	**Transmit Interrupt Status** This interrupt is asserted when one of two conditions exist: • When the corresponding transmit FIFO is enabled, this interrupt is asserted when the FIFO becomes half empty. It is cleared when software has performed enough writes to the corresponding data register to make the transmit FIFO less than half empty. • When the corresponding transmit FIFO is disabled, this interrupt is asserted when data transmission from the single entry holding register has finished. It is cleared when software writes data to the corresponding data register. 1 = FIFO Transmit interrupt is asserted. 0 = FIFO Transmit interrupt is not asserted.

Table 19-39. RISRx Register Fields

BITS	FIELD	DESCRIPTION
1	RTIS	**Receive Timeout Interrupt Status** This interrupt is asserted when one of two conditions exist: • When the corresponding receive FIFO is enabled, this interrupt is asserted when the FIFO contains at least one entry and no further data has been received for the number of frames specified by the AC97 Receive Control Register Timeout Count field (RXCR:TOC). It is cleared when software has performed enough reads from the corresponding data register to empty the receive FIFO. • When the corresponding receive FIFO is disabled, this interrupt is asserted when the single entry holding register contains data and no further data has been received for the number of frames specified by RXCR:TOC. It is cleared when software reads the corresponding data register. 1 = Timeout FIFO interrupt is asserted. 0 = Timeout FIFO interrupt is not asserted.
0	TCIS	**Transmit Complete Interrupt Status** This interrupt is asserted when one of two conditions exist: • When the corresponding transmit FIFO is enabled, this interrupt is asserted when the transmit FIFO is empty and the parallel to serial shifter is empty. It is cleared when software writes data to the corresponding data register. • When the corresponding transmit FIFO is disabled, this interrupt is asserted when the single-entry transmit holding register is empty and the parallel to serial shifter is empty. It is cleared when software writes data to the corresponding data register. 1 = Transmit FIFO complete interrupt is asserted. 0 = Transmit FIFO has not completed transfer.

19.2.2.6 Interrupt Status Registers (ISRx)

These registers, defined in Table 19-40 and Table 19-41, are the controller FIFO interrupt status registers. Bits in this register reflect the logical bit-wise AND of the enabled interrupts in the Interrupt Enable Register (IEx), and the asserted interrupts from the Raw Interrupt Status Register (RISRx). Because the FIFO and shift registers are empty after reset, all ISR fields except TCIS are cleared to 0.

Table 19-40. ISRx

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												RIS	TIS	RTIS	TCIS
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	FIFO1: 0x8000.0014 FIFO2: 0x8000.0034 FIFO3: 0x8000.0054 FIFO4: 0x8000.0074															

Table 19-41. ISRx Register Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	RIS	**Read Interrupt Status** 1 = Receive FIFO interrupt is asserted and enabled. 0 = Receive FIFO interrupt is not asserted or not enabled.
2	TIS	**Transmit Interrupt Status** 1 = Transmit FIFO interrupt is asserted and enabled. 0 = Transmit FIFO interrupt is not asserted or not enabled.
1	RTIS	**Receive Timeout Interrupt Status** 1 = Timeout FIFO interrupt is asserted and enabled. 0 = Timeout FIFO interrupt is not asserted or not enabled.
0	TCIS	**Transmit Complete Interrupt Status** 1 = Transmit FIFO complete interrupt is asserted and enabled. 0 = Transmit FIFO complete is either not asserted or not enabled.

19.2.2.7 Interrupt Enable Registers (IEx)

These registers, defined in Table 19-42 and Table 19-43, control the interrupt enables for the FIFOs within the controller. All bits are cleared on reset.

Table 19-42. IEx

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												RIE	TIE	RTIE	TCIE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	FIFO1: 0x8000.0018 FIFO2: 0x8000.0038 FIFO3: 0x8000.0058 FIFO4: 0x8000.0078															

Table 19-43. IEx Register Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	RIE	**Receive Interrupt Enable** 1 = Enable the FIFO receive interrupt. 0 = FIFO receive interrupt disabled.
2	TIE	**Transmit Interrupt Enable** 1 = Enable the FIFO transmit interrupt. 0 = FIFO transmit interrupt disabled.
1	RTIE	**Receive Timeout Interrupt Enable** 1 = Enable the FIFO receive timeout interrupt. 0 = FIFO receive timeout interrupt disabled.
0	TCIE	**Transmit Complete Interrupt Enable** 1 = Enable the FIFO transmit complete interrupt. 0 = FIFO transmit complete interrupt disabled.

19.2.2.8 Slot 1 Data Register (S1DATA)

This register is defined in Table 19-44 through Table 19-46. Data written to this register is sent on the next available frame in Slot 1. When read, it yields the last valid data received in Slot 1 from the AC-link interface. For writes to external codec, use this sequence:

1. Write data into S2DATA.
2. Write address into S1DATA.
3. Wait one frame time (24 μs) before writing next data word.

For reads from external codec, use this sequence:

1. Write address into S1DATA.
2. Wait for RGIS:Slot2INTRX to be set (1).

For power-down, the software must write the address 0x26 to S1DATA. Setting bit 12 in S2DATA puts the AC97 Controller into power-down mode.

Table 19-44. S1DATA Receive

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									DATA						
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0080															

Table 19-45. S1DATA Transmit

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///									DATA						
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0080															

Table 19-46. S1DATA Register Fields

BITS	FIELD	DESCRIPTION
31:7	///	**Reserved** Reading returns 0. Values written cannot be read.
6:0	DATA	**Receive** Read data value of the last value written to this register via the AC-link interface. The data is the last valid received Slot 1 (when data in Slot 0 tagged Slot 1 as valid). **Transmit** Write data value to transmit on Slot 1 on the next available frame. After transmission, the data is marked as invalid.

19.2.2.9 Slot 2 Data Register (S2DATA)

This register is defined in Table 19-47 through Table 19-49. Data written to this register is sent on the next available frame in Slot 2. When read, it yields the last valid data received in Slot 2 from the AC-link interface.

For writes to external codec, use this sequence:

1. Write data into S2DATA.
2. Write address into S1DATA.
3. Wait one frame time (24 μs) before writing next data word.

For reads from external codec, use this sequence:

1. Write address into S1DATA.
2. Wait for RGIS:Slot2INTRX to be set (1).

To enter power-down mode, the software must write the address 0x26 to S1DATA. The controller records this address. Setting bit 12 in S2DATA puts the controller into power-down mode.

Table 19-47. S2DATA Receive

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0084															

Table 19-48. S2DATA Transmit

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0084															

Table 19-49. S2DATA Register Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	DATA	**Receive** Read data value of the last value written to this register via the AC-link interface. The data is the last valid received Slot 2 (when data in Slot 0 tagged Slot 2 as valid). **Transmit** Write data value to transmit on Slot 2 on the next available frame. After transmission, the data is marked as invalid.

19.2.2.10 Slot 12 Data Register (S12DATA)

This register is defined in Table 19-50 through Table 19-52. Data written to this register is sent on the next available frame in Slot 12. When read, it yields the last valid data received in Slot 12 from the AC-link interface..

Table 19-50. S12DATA Receive

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///												DATA			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0088															

Table 19-51. S12DATA Transmit

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///												DATA			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DATA															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0088															

Table 19-52. S12DATA Register Fields

BITS	FIELD	DESCRIPTION
31:20	///	**Reserved** Reading returns 0. Values written cannot be read.
19:0	DATA	**Receive** Read data value of the last value written to this register via the AC-link interface. Bit 0 is monitored to determine whether a GPIO interrupt occurs. **Transmit** Write data value to transmit on Slot 12 on the next available frame. After transmission, the data is marked as invalid.

19.2.2.11 Raw Global Interrupt Status Register (RGIS)

This register, shown in Table 19-53 and Table 19-54, indicates the status of the AC97 Controller interrupts other than the FIFO functionality. These bits reflect the status of the interrupt whether it is enabled or not. All bits status bits are read only.

Table 19-53. RGIS

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										CODECREADY	RWIS	GPIOINTRX	GPIOTXCMP	Slot2INTRX	Slot1TXCMP
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.008C															

Table 19-54. RGIS Register Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	CODECREADY	**Codec Ready** This interrupt is automatically set during wakeup when the codec indicates ready by setting Slot 0 bit 15. To clear, write a 1 to GEOI bit 1. 1 = The Codec Ready interrupt is asserted. 0 = The Codec Ready interrupt is not asserted.
4	RWIS	**Raw Wakeup Interrupt Status** This interrupt is asserted when a wakeup event, caused by the external codec device GPIO pins, triggers ACIN assertion while the AC-link is powered-down. An AC-link wakeup interrupt is a 0-to-1 transition on ACIN while the AC-link is powered down. The controller monitors the S1DATA and S2DATA registers for the condition when the external codec has been powered down. When a wakeup event is detected on the ACIN line, an interrupt is generated to allow the processor to reactivate the link with either a Warm or Cold Reset. It is cleared when software writes a 1 to the GEOI bit 0. 1 = The Raw Wakeup interrupt is asserted. 0 = The Raw Wakeup interrupt is not asserted.
3	GPIOINTRX	**GPIO Receive Interrupt** This interrupt is asserted when bit 0 in Slot 12 of ACIN is 1. This bit indicates one or more of the bits in Slot 12 have changed since the last frame. It is cleared when software reads S12DATA. 1 = The GPIO interrupt is asserted. 0 = The GPIO interrupt is not asserted.

Table 19-54. RGIS Register Fields

BITS	FIELD	DESCRIPTION
2	GPIOTXCMP	**GPIO Transmission Complete** This interrupt is asserted when transmission of all values written to S12DATA has finished. It is cleared when software writes S12DATA. 1 = GPIO Transmission Complete interrupt is asserted. 0 = GPIO Transmission Complete interrupt is not asserted.
1	Slot2INTRX	**Slot 2 Receive Valid** This interrupt is asserted when S2DATA contains new, unread data. It is cleared when software reads S2DATA. 1 = Slot 2 Receive Valid interrupt is asserted. 0 = Slot 2 Receive Valid interrupt is not asserted.
0	Slot1TXCMP	**Slot 1 Transmit Complete** This interrupt is asserted when all values written to S1DATA have been transmitted. It is cleared when software writes S1DATA. 1 = Slot 1 Transmit Complete interrupt is asserted. 0 = Slot 1 Transmit Complete interrupt is not asserted.

19.2.2.12 Global Interrupt Status Register (GIS)

This register, shown in Table 19-55 and Table 19-56, indicates the status of the AC97 Controller interrupts other than the FIFO functionality. This register is the logical bit-wise AND of RGIS and GIEN registers, and thus only reflect the status of enabled interrupts. All bits are read only and cleared on reset.

Table 19-55. GIS

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										CODECREADY	WIS	GPIOINTRX	GPIOTXCMP	Slot2INTRX	Slot1TXCMP
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RW	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0090															

Table 19-56. GIS Register Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	CODECREADY	**Codec Ready** 1 = Codec Ready interrupt is enabled and asserted. 0 = The Codec Ready interrupt is not asserted or is not enabled.
4	WIS	**Wakeup Interrupt Status** To clear, write to the GEOI register. 1 = Wakeup interrupt is enabled and asserted. 0 = Wakeup interrupt is not asserted or is not enabled.
3	GPIOINTRX	**GPIO Receive Interrupt** To clear, read the S12DATA register. 1 = GPIO interrupt is enabled and asserted. 0 = GPIO interrupt is not asserted or is not enabled.
2	GPIOTXCMP	**GPIO Transmit Complete Interrupt Status** To clear, write transmit data to the S12DATA register. 1 = GPIO Transmit Complete interrupt is enabled and asserted. 0 = GPIO Transmit Complete interrupt is not asserted or is not enabled.
1	Slot2INTRX	**Slot 2 Receive Valid Interrupt Status** To clear, read the S2DATA register. 1 = Slot2INTRX interrupt is enabled and asserted. 0 = Slot2RXVALIT interrupt is not asserted or is not enabled.
0	Slot1TXCMP	**Slot 1 Transmit Complete** This interrupt is asserted when all values written to S1DATA have been transmitted. It is cleared when software writes S1DATA. To clear, write transmit data to the S1DATA register. 1 = Slot 1 Transmit Complete interrupt is enabled and asserted. 0 = Slot 1 Transmit Complete interrupt is not asserted or not enabled.

19.2.2.13 Global Interrupt Enable Register (GIEN)

This register, shown in Table 19-57 and Table 19-58, controls the interrupt enables for the interrupts other than the FIFO channels. This register is logically bit-wise ANDed with the RGIR to produce the contents of the GIR.

Table 19-57. GIEN

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										CODECREADYEN	WIEN	GPIOINTRXEN	GPIOTXCMPEN	Slot2INTRX	Slot1TXCMPEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0094															

Table 19-58. GIEN Register Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	CODECREADYEN	**Codec Ready** 1 = Enable the codec ready interrupt. 0 = Disable the codec ready interrupt.
4	WIEN	**Wakeup Interrupt Enable** 1 = Enable the wakeup interrupt. 0 = Disable the wakeup interrupt.
3	GPIOINTRXEN	**GPIO Receive Interrupt Enable** 1 = Enable the GPIOINTRX interrupt. 0 = Disable the GPIOINTRX interrupt.
2	GPIOTXCMPEN	**GPIO Transmit Complete Interrupt Enable** 1 = Enable the GPIO Transmit Complete interrupt. 0 = Disable the GPIO Transmit Complete interrupt.
1	Slot2INTRXEN	**Slot 2 Receive Valid Interrupt Enable** 1 = Enable the SLOTRXVALID interrupt. 0 = Disable the SLOTRXVALID interrupt.
0	Slot1TXCMPEN	**Slot 1 Transmit Busy Interrupt Enable** 1 = Enable the Slot1TXCMPEN interrupt. 0 = Disable the Slot1TXCMPEN interrupt.

19.2.2.14 Global End-of-Interrupt Register (GEOI)

This register is shown in Table 19-59 and Table 19-60. Writing to this register clears the codec ready and wakeup interrupts.

Table 19-59. GEOI

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														CODECREADY	WISC
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO
ADDR	0x8000.0098															

Table 19-60. GEOI Register Fields

BITS	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	CODECREADY	**Codec Ready Interrupt Status Clear** 1 = Clear the CODECREADY interrupt. 0 = No effect.
0	WISC	**Wakeup Interrupt Status Clear** 1 = Clear the WIS interrupt. 0 = No effect.

19.2.2.15 Global Control Register (GCR)

This register, shown in Table 19-61 and Table 19-62, is the main control register for the AC97 Controller. All bits are 0 on reset. To enter the loopback test mode, set both the OCR and LOOP bit to 1. They must be 0 for normal operation. OCR and LOOP must be programmed to the same value (either both 1 or 0) for the codec to function properly.

Table 19-61. GCR

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													OCR	LOOP	IFE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW
ADDR	0x8000.009C															

Table 19-62. GCR Register Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	OCR	**Override Codec Ready** 1 = Enable loopback test mode (both OCR and LOOP must be 1). 0 = Normal operation. Defaults to 0 on reset. Ensure this bit is always 0 for normal operation.
1	LOOP	**Loopback Mode** 1 = Enable loopback test mode (both OCR and LOOP must be 1). 0 = Normal operation. Defaults to 0 on reset. Ensure this bit is always 0 for normal operation.
0	IFE	**IF Enable** IFE controls the clock enable signal for the AC97 Controller clock gating block. 1 = Enable the AC97. 0 = Disable the AC97 and clear all AC97 FIFOs. Defaults to 0 on reset.

19.2.2.16 Reset Register (RESET)

This register, shown in Table 19-63 and Table 19-64, controls functions of the AC97RESET pin. All fields are cleared to 0 on reset.

Table 19-63. RESET

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													EFORCER	FORCEDRESET	TIMEDRESET
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	R	R	R	R	R	R	R	R	R	R	R	R	R	RW	RW	RW
ADDR	0x8000.00A0															

Table 19-64. RESET Register Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	EFORCER	**Enable Forced RESET Bit** 1 = Enables value of FORCEDRESET onto the AC97RESET pin. 0 = FORCEDRESET has no effect.
1	FORCEDRESET	**Forced RESET** The value of FORCEDRESET is gated onto the AC97RESET pin. When using this mechanism to control the AC97RESET pin, software must ensure the signal is active long enough to meet the Reset specification for the external codec device. For proper operation, FORCEDRESET and TIMEDRESET (bits 1 and 0) must be set at the same time. 1 = HIGH output on AC97RESET pin. 0 = LOW output on AC97RESET pin.
0	TIMEDRESET	**Timed Reset** For proper operation, FORCEDRESET and TIMEDRESET (bits 1 and 0) must be set at the same time. 1 = Force the AC97RESET pin to 0 for five cycles of the 2.9491 MHz clock. After the reset pulses complete, TIMEDRESET bit is automatically cleared. The maximum reset pulse is 0.339 µs × 5 = 1.695 µs. The minimum reset pulse is 1.356 µs. 0 = No effect.

19.2.2.17 SYNC Port Register (SYNC)

This register, shown in Table 19-65 and Table 19-66, controls functions within the AC97 Controller of the ACSYNC pin. All fields are cleared to 0 on reset.

Table 19-65. SYNC

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													EFORCES	FORCEDSYNC	TIMEDSYNC
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW
ADDR	0x8000.00A4															

Table 19-66. SYNC Register Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	EFORCES	**Forced SYNC Enable** 1 = Enables value of FORCEDSYNC onto the ACSYNC pin. 0 = FORCEDSYNC has no effect.
1	FORCEDSYNC	**Forced SYNC** When EFORCES bit is 1, the value of FORCEDSYNC is gated onto the ACSYNC pin. When using this mechanism to control the ACSYNC pin, software must ensure the signal is active long enough to meet the specification of the external codec device. FORCEDSYNC has priority over TIMEDSYNC. For proper operation, FORCEDSYNC and TIMEDSYNC (bits 1 and 0) must be set at the same time. 1 = HIGH output on ACSYNC pin. 0 = LOW output on ACSYNC pin.
0	TIMEDSYNC	**Timed SYNC** For proper operation, FORCEDSYNC and TIMEDSYNC (bits 1 and 0) must be set at the same time. 1 = Force the ACSYNC pin to 1 for five cycles of the 2.9491MHz clock, controlling the ACSYNC pin via the ACBITCLK counter. After the SYNC pulses complete, TIMEDSYNC is automatically cleared. The maximum SYNC pulse is 0.339 µs × 5 = 1.695 µs; the minimum is 1.356 µs. 0 = No effect.

19.2.2.18 Global Control Interrupt Status Register (GCIS)

This register, shown in Table 19-67 and Table 19-68, echoes all the interrupt status registers in the AC97 Controller, allowing the software to read all the interrupt sources with one read.

Table 19-67. GCIS

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///										GIS					
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	ISR4				ISR3				ISR2				ISR1			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.00A8															

Table 19-68. GCIS Register Fields

BITS	FIELD	DESCRIPTION
31:22	///	**Reserved** Reading returns 0. Values written cannot be read.
21:16	GIS	Copy of the GIS register.
15:12	ISR4	Copy of the FIFO 4 ISR register.
11:8	ISR3	Copy of the FIFO 3 ISR register.
7:4	ISR2	Copy of the FIFO 2 ISR register.
3:0	ISR1	Copy of the FIFO 1 ISR register.

Chapter 20
Audio Codec Interface (ACI)

20.1 Theory of Operation

The ACI provides these features:

- Digital serial interface to an off-chip 8-bit Codec device
- Clocks and timing pulses for serialization and de-serialization of the data stream to or from the Codec device
- Full duplex operation, with Transmit and Receive FIFOs storing up to 16 bytes each of Transmit and Receive data concurrently.

20.1.1 Transmit and Receive Mode Control

To enable ACI operation, program the Clock Divider register (CLKDIV) with a nonzero value and enable the Transmit and Receive modes individually in the Control register (CTL):

- Enable Transmit mode by setting the Transmit Enable field (CTL:TXEN)
- Enable Receive mode by setting the Receive Enable field (CTL:RXEN).

Clearing CLKDIV stops the bit clock and disables both the Transmit and Receive modes. To stop the bit clock in Transmit mode when the Transmit FIFO is empty, without disabling Transmit or Receive mode, set the CTL register Transmit Empty Stop Clock Enable field (CTL:TXEPCLKEN).

20.1.2 Multiplexing

The ACI signals are multiplexed with the AC97 Audio Codec Interface signals on these pins (see Chapter 19 for AC97 information):

- The bit clock output, AC97 or ACI Bit Clock (ACBITCLK), on pin C4
- The transmitted data, AC97 or ACI Output (ACOUT), on pin D5
- The received data, AC97 or ACI Input (ACIN), on pin A4
- The frame synchronizing signal, AC97 or ACI Synchronize (ACSYNC), on pin B4.

To configure these pins for ACI use, set the GPIO Pin Multiplexing register Codec On field (PINMUX:CODECON). To configure these pins for AC97 use, clear PINMUX:CODECON (See also Chapter 7).

20.1.3 Clocking

The ACI programmable frequency divider generates a common Transmit and Receive bit clock output (ACBITCLK). Transmit data bits are synchronously output with the rising edge of ACBITCLK. Receive data bits are sampled on the falling edge of ACBITCLK. The start of a data frame is indicated by ACSYNC, synchronous with the bit clock.

To generate ACBITCLK, the ACI uses the following:

- A programmable divisor in CLKDIV, from 1 to 1,023
- The source clock from the LH7A400 system clocks (ACLK = 14.7456 MHz/115).

ACBITCLK is calculated:

ACBITCLK = ACLK/(CLKDIV + 1)

The ACIBITCLK HIGH:LOW duty cycle is as follows for even or odd CLKDIV values:

- For CLKDIV odd, HIGH:LOW is 1:1
- For CLKDIV even, HIGH:LOW is (CLKDIV/2):((CLKDIV + 2)/2), producing a worst case 1:2 duty cycle for CLKDIV = 2.

20.1.4 Receive FIFO

The Receive FIFO is one byte wide by 16 bytes deep. This FIFO holds data received on ACIN. Reading the Data register (DATA) reads received data from the FIFO. Software can read DATA until the FIFO is empty with Receive mode enabled or disabled.

To flush the Receive FIFO, disable and re-enable Receive mode by clearing and setting CTL:RXEN.

Software can use the following flags and interrupts in the Status register (STATUS) to monitor Receive activity and the FIFO watermark:

- When the Receive FIFO contains no data, the Receive FIFO Empty field (RXFE) is set. RXFE is cleared automatically when data is received.
- When the Receive FIFO contains at least eight bytes of data, the Receive Interrupt field (RXI) is set. Reading DATA until the Receive FIFO contains fewer than eight unread bytes clears RXI.
- When the Receive FIFO is full, the Receive FIFO Full field (RXFF) is set. Reading DATA clears RXFF. When the FIFO is full, any subsequent received data is lost until software reads DATA.
- When all incoming data has been received into the FIFO, or Receive mode is disabled, the Receive Busy field (RXBUSY) is cleared. While data is being received, RXBUSY is set. If software disables Receive mode while a frame is being received, reception continues until the frame ends and the data is put in the Receive FIFO.

20.1.5 Transmit FIFO

The Transmit FIFO is one byte wide by 16 bytes deep. This FIFO holds data to be transmitted. Writing DATA puts data into the Transmit FIFO. From the FIFO, the data is transmitted via a shift register onto ACOUT, most significant bit first. ACIFSYNC is asserted during the first transmitted bit to indicate the start of the data frame.

To flush the Transmit FIFO, disable and re-enable Transmit mode by clearing and setting CTL:TXEN.

Software can use the following flags and interrupts in the Status register (STATUS) to monitor Transmit activity and the FIFO watermark:

- When the Transmit FIFO contains no data, the Transmit FIFO Empty field (TXFE) is set. Writing DATA clears TXFE. ACBITCLK continues and LOW is transmitted on ACOUT until software writes DATA. To configure the ACI to stop ACBITCLK when the Transmit FIFO is empty, without disabling the Transmit or Receive mode, set CTL:TXEPCLKEN.
- When the Transmit FIFO contains eight or fewer bytes of data, the Transmit Interrupt field (TXI) is set. Writing enough bytes to DATA to put more than eight bytes in the FIFO clears TXI.
- When the Transmit FIFO is full, the Transmit FIFO Full field (TXFF) is set. Completing a frame transmission automatically clears TXFF. Software must wait to write DATA until TXFF is cleared.
- When all data has been transmitted from the FIFO, and Transmit mode is disabled, the Transmit Busy field (TXBUSY) is cleared. While data is being transmitted, BUSY is set. If software disables Transmit mode while the FIFO contains data, transmission continues until the FIFO is empty and the last frame has been completely transmitted.

20.1.6 Interrupts

The ACI generates individual active HIGH interrupts, described in Table 20-1, for the FIFO watermarks. Fields corresponding to these interrupts are set in STATUS. Software can configure these interrupts as enabled or disabled by programming CTL. These interrupts are deasserted automatically as the amount of data in the corresponding FIFO changes.

The asserted, enabled interrupts are OR'd together to generate a single, combined interrupt, ACIINTR, to be handled by the LH7A400 Interrupt Controller. Writing any value to the End-of-Interrupt register (EOI) deasserts ACIINTR.

Table 20-1. SWI Interrupts

NAME	DESCRIPTION
RXI	**Receive Interrupt** The Receive FIFO contains eight or more bytes and Receive mode is enabled (CTL:RXEN set). Eight bytes is the half-full watermark. This interrupt is deasserted automatically when the FIFO becomes less than half full. When the CTL register Receive Interrupt Enable field (CTL:RXIE) is set, RXI contrbutes to ACIINTR. STATUS:RXI indicates when RXI is asserted.
TXI	**Transmit Interrupt** The Transmit FIFO contains eight or fewer bytes. Eight bytes is the half-empty watermark. This interrupt is deasserted automatically when the FIFO becomes more than half full. When the CTL register Transmit Interrupt Enable field (CTL:TXIE) is set, TXI contrbutes to ACIINTR. STATUS:TXI indicates when TXI is asserted. Transmit mode need not be enabled (CTL:TXEN can be set or cleared) for this interrupt to be asserted.

20.1.7 Loopback

Loopback mode is available for system testing. In Loopback mode, ACOUT is internally connected to ACIN. To enable Loopback mode, set the CTL register Loopback field (CTL:LB). For normal operation, clear LB.

20.2 Register Reference

20.2.1 Memory Map

The ACI base address is 0x8000.0A00. Table 20-2 shows the ACI registers at offsets from this base address.

Table 20-2. ACI Register Summary

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	DATA	**Data** When read, returns received data. Write data to this register for transmission.
0x04	CTL	**Control** Program this register to enable and disable ACI activity, interrupts, and clocking.
0x08	STATUS	**Status** Reports FIFO and activity status.
0x0C	EOI	**End-of-Interrupt** Write this register to deassert ACIINTR.
0x10	CLKDIV	**Clock Divider** Program this register to specify the ACBITCLK frequency.
0x14 - 0xFF	///	**Reserved** Avoid accessing these locations.

20.2.2 Register Descriptions

This section defines the ACI registers.

20.2.2.1 ACI Data Register (DATA)

This register, described in Table 20-3 and Table 20-4, contains the received and transmitted data:

- Writing DATA puts a byte into the Transmit FIFO.
- Reading DATA returns a byte from the Receive FIFO.

Table 20-3. DATA Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								DATA							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0A00															

Table 20-4. DATA Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
7:0	DATA	**Data** When read, returns a byte from the Receive FIFO. When written, puts a byte into the Transmit FIFO.

20.2.2.2 ACI Control Register (CTL)

This register, described in Table 20-5 and Table 20-6, enables and disables ACI activity, interrupts, and clocking. Note that if only the receiver is enabled (RXEN =1), false RXBUSY flags may be generated. Therefore, always enable the receiver and the transmitter (TXEN = 1) at the same time.

Table 20-5. CTL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										TXEPCLKEN	LB	TXIE	RXIE	RXEN	TXEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0A04															

Table 20-6. CTL Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read back.
5	TXEPCLKEN	**Transmit FIFO Empty Stop Clock Enable** When the Transmit FIFO is empty, program this bit to stop the clock enable bit. 1 = ACBITCLK stops without disabling Transmit or Receive mode 0 = ACBITLCK continues and ACOUT is held LOW
4	LB	**Loopback** To enter loopback, program this bit: 1 = Enables Loopback mode 0 = Normal operation
3	TXIE	**Transmit Interrupt Enable** 1 = Enables the Transmit interrupt 0 = Disables the Transmit interrupt
2	RXIE	**Receive Interrupt Enable** 1 = Enables the Receive interrupt 0 = Disables the Receive interrupt
1	RXEN	**Receive Enable** 1 = Enables Receive mode 0 = Disables Receive mode and flushes the Receive FIFO
0	TXEN	**Transmit Enable** 1 = Enables Transmit mode 0 = Disables Transmit mode and flushes the Transmit FIFO

IMPORTANT: When using the ACI, disable AC97 interrupts to avoid false interrupt requests. When using the AC97, disable ACI interrupts (program bits [3:2] to 0).

20.2.2.3 ACI Status Register (STATUS)

This register, described in Table 20-7 and Table 20-8, reports ACI activity and FIFO status.

Table 20-7. STATUS Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								TXBUSY	RXBUSY	TXI	RXI	TXFE	RXFF	TXFF	RXFE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0A08															

Table 20-8. STATUS Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
7	TXBUSY	**Transmit Busy** 1 = Data transmission is active on ACOUT 0 = Transmit mode is disabled (CTL:TXEN is cleared) and all data from the FIFO has finished transmitting on ACOUT
6	RXBUSY	**Receive Busy** 1 = Data reception is active on ACIN; set when CTL:TXEN = 1, and CTL:RXEN = 0 0 = Receive mode is disabled To clear this bit, program CTL:TXEN = 0, or CTL:TXEPCLKEN = 1, and the transmit FIFO must be empty.
5	TXI	**Transmit Interrupt** 1 = The Transmit FIFO contains eight or fewer bytes of data 0 = The Transmit FIFO contains more than eight bytes of data
4	RXI	**Receive Interrupt** 1 = The Receive FIFO contains eight or more bytes of data 0 = The Receive FIFO contains fewer than eight bytes of data
3	TXFE	**Transmit FIFO Empty** 1 = The Transmit FIFO contains no data. ACOUT is held LOW or ACBITCLK is stopped, depending on CTL:TXFEPCLKEN. 0 = The Transmit FIFO contains data
2	RXFF	**Receive FIFO Full** 1 = The Receive FIFO is full. Subsequent received data is lost until software reads the Receive FIFO. 0 = The Receive FIFO can accept additional data
1	TXFF	**Transmit FIFO Full** 1 = The Transmit FIFO is full. Software cannot write additional data until a byte is transmitted. 0 = The Transmit FIFO can accept additional data
0	RXFE	**Receive FIFO Empty** 1 = The Receive FIFO contains no data 0 = The Receive FIFO contains data

20.2.2.4 ACI End-of-Interrupt Register (EOI)

This register, described in Table 20-9 and Table 20-10, deasserts ACIINTR.

Table 20-9. EOI Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	EOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	EOI															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0A0C															

Table 20-10. EOI Fields

BITS	FIELD	DESCRIPTION
31:0	EOI	**End of Interrupt** Write any value to this field to deassert ACIINTR. Reading this field returns 0.

20.2.2.5 ACI Clock Divisor Register (CLKDIV)

This register, described in Table 20-11 and Table 20-12, contains the divisor for the ACI bit clock (ACBITCLK).

The ACI programmable frequency divider generates a common Transmit and Receive bit clock output (ACBITCLK). Transmit data bits are output synchronous with the rising edge of ACBITCLK. Receive data bits are sampled on the falling edge of ACBITCLK. The start of a data frame is indicated by ACSYNC, synchronous with the bit clock.

To generate ACBITCLK, the ACI uses:

- A programmable divisor in CLKDIV, from 1 to 1,023
- The source clock from the LH7A400 system clocks (ACLK = 14.7456 MHz/115; approximately 128 kHz).

ACBITCLK is calculated:

ACBITCLK = ACLK/(CLKDIV + 1)

The ACIBITCLK HIGH:LOW duty cycle for even or odd CLKDIV values is:

- For CLKDIV odd, HIGH:LOW is 1:1.
- For CLKDIV even, HIGH:LOW is (CLKDIV/2) : ((CLKDIV + 2)/2), producing a worst case 1:2 duty cycle for CLKDIV = 2.

For Codecs requiring a minimum clock rate of 64 kHz, use 1 for CLKDIV (ACLK/(1+1) = 64.1113 kHz).

Table 20-11. CLKDIV Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///						CLKDIV									
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0A10															

Table 20-12. CLKDIV Fields

BITS	FIELD	DESCRIPTION
31:10	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
9:0	CLKDIV	**Clock Divisor** Program this field with a value between 1 and 1023; used to generate ACIBITCLK.

Chapter 21
Battery Monitor Interface (BMI)

21.1 Theory of Operation

The LH7A400 BMI is a serial communication interface for use with two types of battery monitors:

- High speed Single Wire Interface (SWI), compatible with the Texas Instruments HDQ protocol and single-wire devices.
- Smart Battery Interface (SBI), using a System Management Bus (SMB). The BMI complies with SMB version 2.0.

After reset, software must program the SWI and SBI registers for the correct protocols and multiplexing. The SWI and SBI signals are multiplexed as follows:

- Setting the SBI Control Register SBI Enable field (SBICR:SBI_EN) configures the Smart Battery Data signal (SMBD) on pin N2 and the Smart Battery Clock signal (SMBCLK) on pin N3.
- Setting the SWI Control Register SWI Enable field (SWICR:SWIEN) configures the Single Wire Data signal (SWID) on pin N2.
  - Pin N2, when configured for SWI operation, is driven by a tri-state buffer that only drives one direction. The direction it drives is determined by the state of the SP_INVERT bit in the SWI Control register (SWICR:SP_INVERT). On reset, the SP_INVERT bit is deasserted and N2 requires a pull-up resistor to VDD. In applications that invert the Start/Stop bits, SP_INVERT must be programmed to 1 by software and the pin requires a pull-down resistor.
- When both the SBI and the SWI are enabled simultaneously, the SWI has priority.
- When both the SBI and the SWI are disabled, pin N2 is configured as the GPIO Port B6 signal (PB6).
- When the SBI is disabled, pin N3 is configured as the GPIO Port B7 signal (PB7).

21.1.1 Single Wire Interface

The SWI performs:

- Serial-to-parallel conversion on data received from the peripheral device
- Parallel-to-serial conversion on data transmitted to the peripheral device
- Data packet encoding and decoding on data transfers, for Start-Data-Stop (SDS) packets.

21.1.1.1 SWI Overview

The SWI uses a command-based protocol, in which software initiates data transfer by sending a Write Data/Command word to the BMI. Contained within that word is a Command section that informs the SWI the location for the current transaction. The transaction can be either a read or a write.

When writing over the SWI, software loads the data into the Data Register and the bits are shifted out onto the data line by the SWI. The SWI also handles Start and Stop bit insertion on the fly. After completing a word transmission, the SWI generates an interrupt, notifying the software that the transfer has concluded.

A Read begins when a Start bit is detected by the SWI. After a complete word is loaded into the shift register, software is notified with an interrupt and may read the word from the Data Register.

If an error is detected, the software must initiate a Break Sequence. Upon completion of the Break Sequence, an interrupt (if enabled) is generated to notify the software the completion has occurred.

21.1.1.2 Protocol

The SWI uses a command-based asynchronous return-to-one protocol. A Command or Data word consists of a stream of bits, with least significant bit transmitted first. The return-to-one data bit frame consists of three distinct sections, as shown in Figure 21-1:

1. The first section is used to start the transmission by the host or monitor, taking the Data line LOW (Start bit).
2. The second section is the actual data. The data becomes valid after the time period specified in the Timing Register (SWITR), following the falling edge of a Start bit.
3. The third section is used to stop the transmission by returning the Data line to HIGH (Stop bit).

Start, Stop, and Data bits have identical widths. To specify the number of 7.3728 MHz clock cycles for each bit part, program the SWITR Bit Time Generation bit (SWITR:BTG).

Figure 21-2 and Figure 21-3 show the data bit frame for a 0 and a 1 data bit, respectively. The data bit becomes valid after one SWITR:BTG time period from the falling edge of the Start bit, remains valid for one SWITR:BTG time period, and then becomes invalid during the Stop bit, also one SWITR:BTG time period wide. The next data bit frame follows immediately or a Break condition exists.

Figure 21-4 shows an example of a three-bit 010 data stream. Note that the falling edge from the preceding Stop bit is the beginning of the Start bit for the next data bit frame.

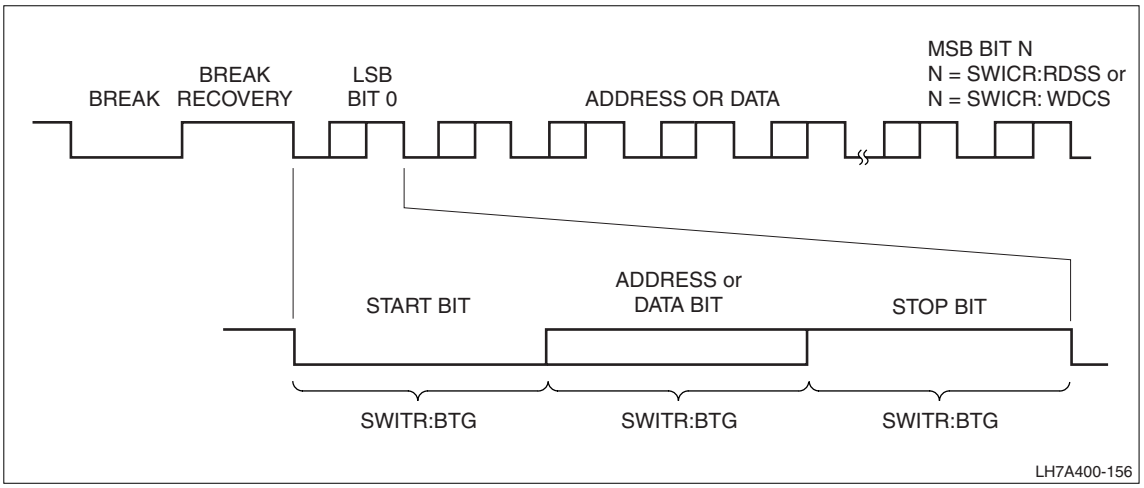


Figure 21-1. SWI data bit frame Protocol

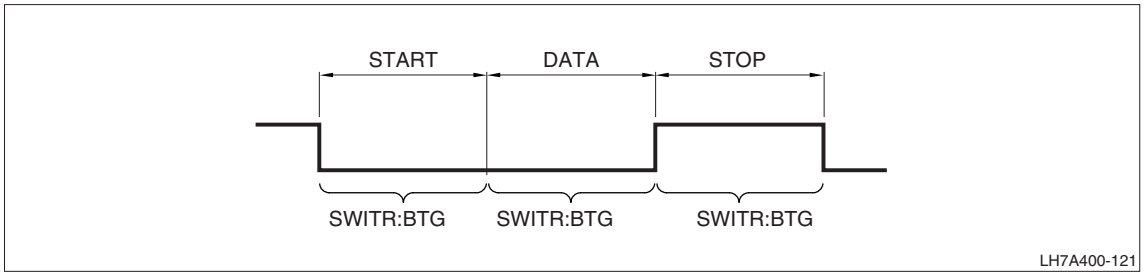


Figure 21-2. SWI data bit frame for a 0 Data Value

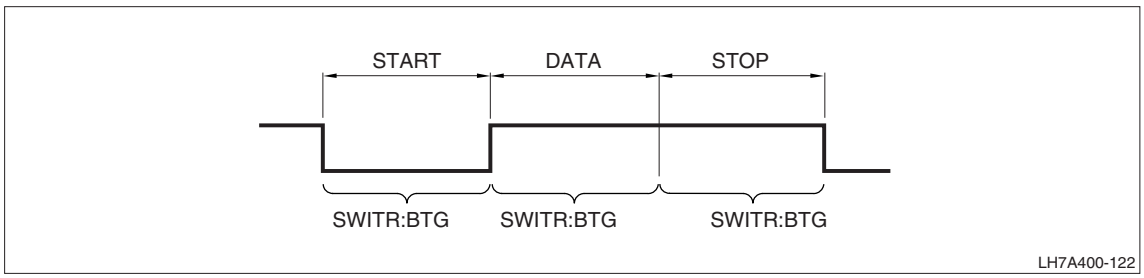


Figure 21-3. SWI data bit frame for a 1 Data Value

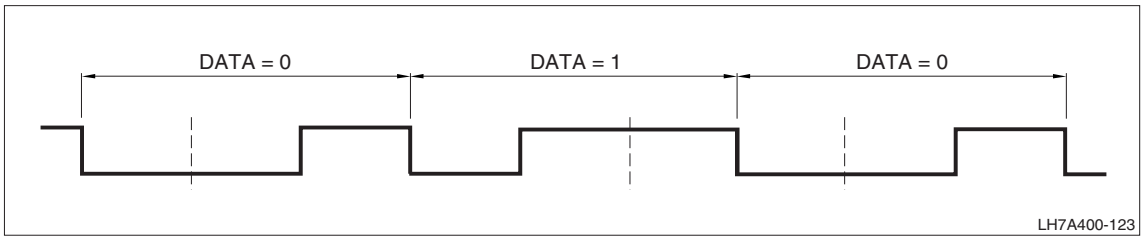


Figure 21-4. SWI Three Bit data bit frame for a 010 Data Stream

Data read from the battery monitor is stored in the Data Register (SWIDR). The polarity of the external Data line can reversed by setting the SP_Invert bit in the Command Register (SWICR). When this is set to 1, the Start bit drives the Data line HIGH and the Stop bit pulls the Data line LOW. Also, with SP_Invert set to 1, data is sampled following the rising edge of a Start bit.

A Command or Data word can be up to 256 bits long. To specify the Read Data size, program the SWICR Read Data Size Select field (SWICR:RDSS). To specify the Write Data or Command size, program the SWICR Write Data Command Size field (SWICR:WDCS).

If a communications time-out occurs, a Break is sent by software. Following a Break, the command can be re-sent. The time-out value is defined in the Break Register (SWIBR). If the Data line is driven LOW for longer than that time, a Break is generated. After a Break is generated, a recovery period is necessary.

The Data line is driven HIGH for the Break Recovery time, also programmed in SWIBR. The start of the first bit of a Command or Data word is valid after the Break and Break Recovery times finish, as shown in Figure 21-1.

21.1.1.3 Configuration

Before using the SWI, software must program the SWI registers to configure the interface in this order:

- Enable the SWI and configure the protocol parameters in the SWI Control Register (SWICR).
- Specify the Start, Data, and Stop bit timing by programming the SWI Timing Register (SWITR).
- Specify the Break and Break Recovery timing by programming the SWI Break Register (SWIBR).
- Configure interrupt handling by programming the SWI Raw Interrupt Status Register (SWIRISR) and the SWI Interrupt Enable Register (SWIIER).

21.1.1.4 Writes and Reads

Writing to the SWI Data Register (SWIDR) starts a Write transfer. Data is loaded into a shift register and serially output to the peripheral device. Completing a Write transfer asserts the Word Transmitted Interrupt (WTI), setting SWIRISR:WTI.

A Read from a peripheral device can occur only when no Write transfer is in progress and no Break mode is in effect. A Read transfer starts when SWICR:SP_Invert is 0 and a falling edge occurs on the SWI bus, or, when SP_Invert is 1 and a rising edge occurs on the SWI bus. The Read transfer sequence is:

1. Data on the SWI bus is sampled after the time period programmed in the SWI Timing Register Bit Time Generation field (SWITR:BTG).
2. When a complete word is in the shift register, the data is loaded into SWIDR.
3. When the data has been justified into SWIDR, the Word Received Interrupt is asserted, setting SWIRISR:WRI. If that interrupt is enabled, the WRI bit is also set in the Interrupt Status Register (SWIISR).
4. No additional Read transfers occur while WRI is asserted. WRI is deasserted when software reads SWIDR.

21.1.1.5 Timeout and Break

Software can detect a communication timeout when the peripheral device fails to respond within a defined time. After a timeout, software must send a Break before re-sending the command. To send a Break sequence:

1. Software sets the SWICR Generate Break Sequence bit (SWICR:GBS) to start the Break.
2. The LH7A400 deasserts the Data line for the time specified in the SWIBR SWI Break field (SWIBR:SWIB).
3. When the Break time expires, the LH7A400 asserts the data line for the Break Recovery time specified in the SWIBR SWI Break Recovery field (SWIBR:SWIBR).
4. When the Break Recovery time expires, the Break Recovery Interrupt (BRI) is asserted, setting SWIRISR:BRI.

A Break is the highest priority operation, overriding other operations:

- When the SWI is transmitting or receiving data, a Break request from the LH7A400 terminates the current transfer and the SWI enters Break mode.
- When the SWI is in Break mode and the LH7A400 initiates a data transfer, the transfer waits to start until the Break completes.

21.1.2 Smart Battery Interface

The Smart Battery Interface (SBI) performs:

- Serial to parallel conversion on data received from the peripheral device
- Parallel to serial conversion of data transmitted to the peripheral device.

21.1.2.1 SBI Overview

The SBI uses a two-wire multi-master bus called the System Management Bus (SMB), meaning that more than one device capable of controlling the bus can be connected to it. A Master device initiates a bus transfer and provides the clock signals. A Slave device can receive data provided by the master or can provide data to the master. Since more than one Master may try to take control of the bus at the same time, SMB provides arbitration, relying on the wired-AND connection of all SMB devices. The SBI can function as either a Master or a Slave, but only becomes a Slave for the Modified Write Word operation.

Both transmit and receive paths are buffered with FIFOs so that data can be independently stored in both transmit and receive modes.

When software has data to write to the SBI, it must first read the FIFO full flag to determine if there is room in the FIFO. If the FIFO is not full, software writes to the Data Register until the FIFO full flag indicates it is full. The SBI arbitrates for the SMB and upon winning, transmits the data. Once the FIFO becomes half empty, software can write additional data. This process continues until all data is written to the Data Register.

When data is sent to the SBI from a Smart Battery device, it is stored in the receive FIFO and software is notified via an interrupt. Software must read the data within a programmed time period to avoid errors or overruns.

If the SBI is requested to enter the Slave mode, it disables the clock generation block, as clocking is always supplied by the Master. The SBI responds to commands from the requesting Master and remains a Slave until the operation is completed. Upon completion, the SBI reenters the Master Mode.

Software must be capable of handling a number of error conditions. Each is represented by a flag or an interrupt that software can identify and execute the proper process.

The following sections provide details about the Smart Battery Interface.

21.1.2.2 FIFOs

Independently configurable FIFOs store transmitted and received data separately. The SBI Control Register (SBICR) enables, disables, and configures the FIFOs. Each FIFO stores up to eight entries of eight-bit (one-byte) data. The Receive FIFO also appends a ninth bit for overrun indication. Disabling a FIFO has the effect of limiting the FIFO to a single entry. The Receive and Transmit FIFOs can be independently enabled and disabled.

The BMI automatically selects the correct FIFO when software reads or writes the SBI Data Register (SBIDR). Writing SBIDR uses the Transmit FIFO. Reading SBIDR uses the Receive FIFO. The SBI Status Register (SBISR) reports FIFO status.

When software writes to the SBIDR, the CPU determines if the Transmit FIFO is full and:

- Waits to write SBIDR until the Transmit Interrupt (TXI) is asserted, indicating the Transmit FIFO is half empty. TXI is deasserted when the Transmit FIFO is less than half empty (contains five or more entries) and remains deasserted until fewer than five bytes of data remain to be transmitted.
- Continues writing SBIDR until the Transmit FIFO is full. The SBISR Transmit FIFO Full field (SBISR:TXFF) is set when the Transmit FIFO is full and is cleared when a byte has been transmitted.

The Transmit Interrupt (TXI) appears in the SBI Raw Interrupt Status Register TXI bit (SBIRISR:TXI). When enabled in the SBI Interrupt Enable Register TXI bit (SBIIER:TXI), TXI causes the BMI Interrupt (BMIINTR) to be asserted to the LH7A400 Interrupt Controller.

To flush the Transmit FIFO, set the SBICR FIFO Flush bit (SBICR:FFLUSH) to 1. This clears the Transmit FIFO and resets all flags and control signals:

1. Any active byte transmission finishes.
2. All remaining bytes in the Transmit FIFO are discarded and not transmitted. The SBISR Transmit FIFO Empty bit (SBISR:TXFE) is set. Writing SBIDR clears TXFE.
3. If untransmitted bytes remained and were flushed from the FIFO, the SBISR Transmit Underrun Error bit (SBISR:TXUE) is set to 1. Writing any value to SBIDR clears TXUE.
4. Once the FIFO has been flushed, software must reset SBICR:FFLUSH to 0.

When data is received, the Receive FIFO provides:

- Each data byte, in the order received, for software to read from SBIDR.
- A status in the SBISR Receive Overrun Error bit (SBISR:RXOE).

When RXOE reads as a 1, the data byte available to be read from SBIDR is the final byte received before a receive overrun error occurred. At least one byte of subsequent data has been lost, because the FIFO was full when this subsequent data was received. Reading SBIDR, to read the data associated with the overrun error, clears RXOE.

Software can configure a time-out value for Receive operations by programming the SBICR Time-out Count field (SBICR:TOC). The Receive Time-out counter is started when data is received in the Receive FIFO and is stopped and reset when software reads SBIDR. When the counter reaches 0, the Receive Time-out Interrupt (RTI) is asserted, setting SBIRISR:RTI to 1. Reading SBIDR deasserts RTI, clearing SBIRISR:RTI.

When the Receive FIFO is half full (contains four bytes of unread data), the Receive Interrupt (RXI) is asserted, setting SBIRISR:RXI to 1. This condition stops the Receive Time-out counter. Reading SBIDR deasserts RXI, clearing SBIRISR:RXI, which stops and resets the Receive Time-out counter.

When enabled in the SBI Interrupt Enable Register RTI and RXI bits (SBIIER:RTI and SBIIER:RXI), either of these interrupts causes the BMI Interrupt (BMIINTR) to be asserted to the LH7A400 Interrupt Controller.

21.1.2.3 System Management Bus

The SBI uses a two-wire System Management Bus (SMB). The full System Management Bus specification is available at: http://www.nxp.com/redirect/smbus.org.

Two types of devices can be connected to the SMB:

- A Slave, which receives or responds to a command.
- A Master, which issues commands, generates the clocks, and terminates the transfer.
- A Host is a specialized Master providing the main interface to the system CPU. A system can have up to one Host in a system. One example of a system with no Host is a simple battery charging station, designed to be plugged into a wall waiting to charge a Smart Battery.

A device can be designed to be any one or more of these types. For example:

- A device can be designed to be a Slave only.
- A device can be designed to act as a Slave most of the time, but become a Master as necessary.
- A Host is usually a Master, but can be designed to become a Slave as necessary.

The SBI can operate in both Master and Slave modes. Each device using the SMB has a unique Slave Address. Master and Host Slave Addresses provide communication between Masters and to the Host.

21.1.2.3.1 Arbitration

Multiple devices capable of controlling (Mastering) the bus can be connected to the SMB. When multiple Masters place information on the SMB, the first Master to send a 1 when any other Master sends 0 loses arbitration and must release the bus. The clock signals during arbitration are the wired-AND combination of all the clocks provided by SMB Masters. Bus clock signals from a Master can be altered only by clock stretching or by other Masters. Such alterations can occur only during bus arbitration. In addition to bus arbitration, the SMB implements clock LOW extending to accommodate devices of different speeds on the same bus.

A Master can start a transfer only when the bus is available; that is, after a Stop Condition or after SMBCLK remains HIGH for longer than the maximum HIGH period. Two or more devices can generate a Start Condition within the minimum hold time, putting a Start Condition on the bus.

Because the devices generating the Start Condition can be unaware of other Masters contending for the bus, arbitration occurs on SMBD while SMBCLK is HIGH. A Master transmitting a HIGH while any other Master is transmitting a LOW on SMBD loses the arbitration, as shown in Figure 21-5.

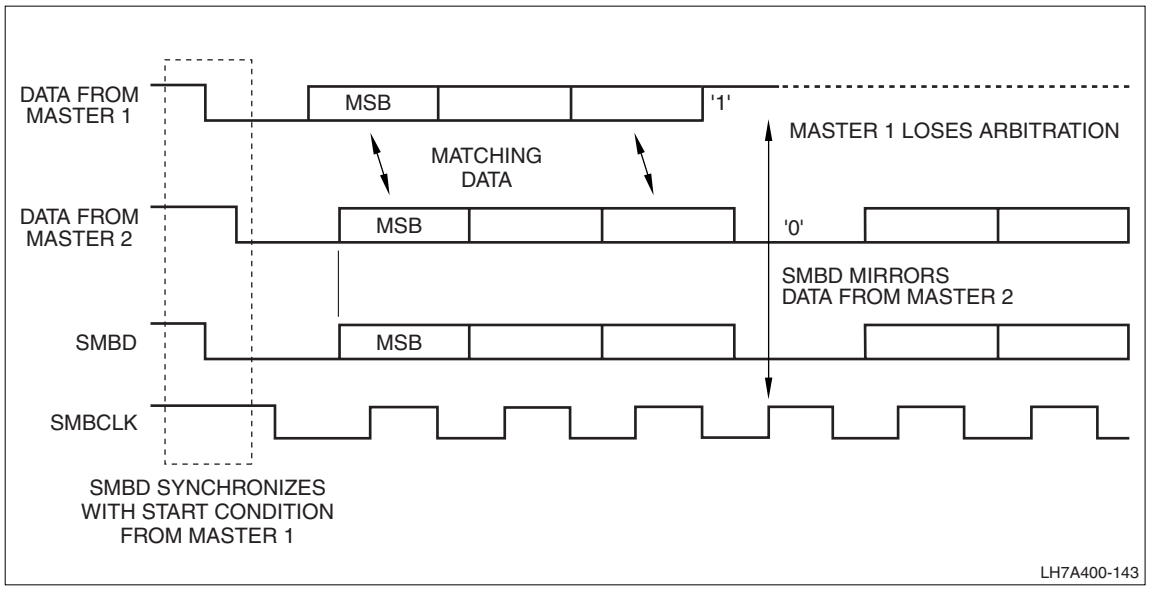


Figure 21-5. SMB Arbitration

The Master that lost arbitration can continue providing clock pulses to complete the current byte. Arbitration between two masters attempting to access the same device can continue past the Address byte, to include the remaining transfer data. All SMB devices must monitor the SMBD during every bus transaction.

When a Master incorporates a Slave function and loses arbitration during the address stage, the Master must check the address placed on the bus to identify whether another Master is attempting access. If so, the Master losing arbitration must switch immediately to Slave receiver mode to receive the rest of the message.

During each bus transaction, any Masters must recognize a repeated Start Condition. A device detecting a repeated Start Condition must quit the transfer. Arbitration is prohibited between the following events:

- A repeated Start Condition and a data bit
- A Stop Condition and a data bit
- A repeated Start Condition and a Stop Condition.

21.1.2.3.2 Protocols and Commands

Specific SMB protocols require the Master to generate a repeated Start Condition followed by the Slave Address with no intervening Stop Condition. The SMB data formats are:

- The Master is the transmitter and the Slave is the receiver. The transfer direction remains unchanged.
- Initially, the Master is the transmitter and the Slave is the receiver. The Master reads from Slave immediately after the first byte. When the first acknowledgment by the Slave occurs, the Master becomes a receiver and the Slave becomes a transmitter.
- A Combined format where the Master becomes a receiver. During the change of direction within a transfer, the Master repeats a Start Condition and the Slave Address with the R/nW bit reversed. The Master receiver terminates the transfer by generating a NACK on the last byte of the transfer, followed by a Stop Condition.

The SMB accommodates several protocols. Each protocol is based on one or more conditions:

- 'PreWrite' is data transmitted after a Start Condition and before either a Stop Condition, a Repeated Start, or a Read.
- 'RepeatWrite' is data transmitted following a Repeated Start but before either a Stop Condition or a Read.
- 'Read' is data read in from the peripheral, before a Stop condition.

A message Start or Stop condition is indicated by:

- A HIGH to LOW transition of the data signal (SMBD) with the clock signal (SMBCLK) HIGH indicates a Start Condition.
- A LOW to HIGH transition of SMBD with SMBCLK HIGH indicates a STOP Condition.

Start and Stop Conditions are generated by the Master. After a Start Condition, the bus is considered to be busy. The bus becomes free again after certain time following a Stop Condition or after both the clock and data lines remain HIGH for more than 50 μs. Figure 21-7 shows Start and Stop Condition timing.

Figure 21-8 shows a data byte. Every data byte consists of 8 bits. Each byte transferred on the bus must be followed by an acknowledge bit. Bytes are transferred with the most significant bit (MSB) first.

Putting the Start Condition, Stop Condition, and Data together, SMB data transfers follow the format shown in Figure 21-6. The Master puts them in this sequence on the bus:

1. The Start Condition
2. The seven-bit Slave Address
3. The data transfer direction (R/nW), 0 indicates a transmission, 1 indicates a request.
4. The Stop Condition.

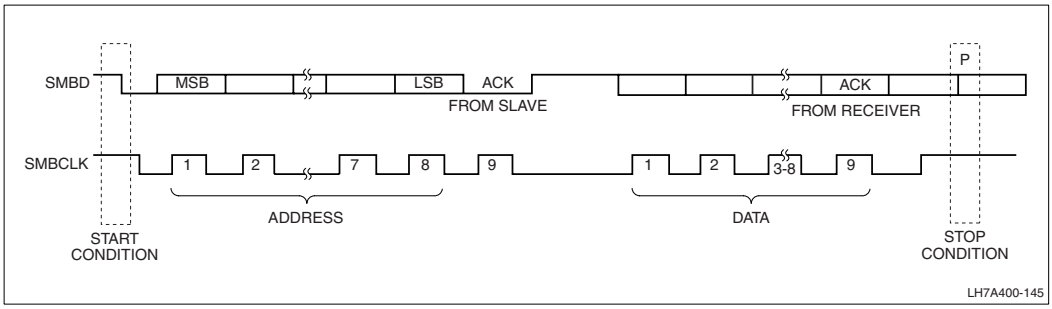


Figure 21-6. Start-Data-Stop Sequence

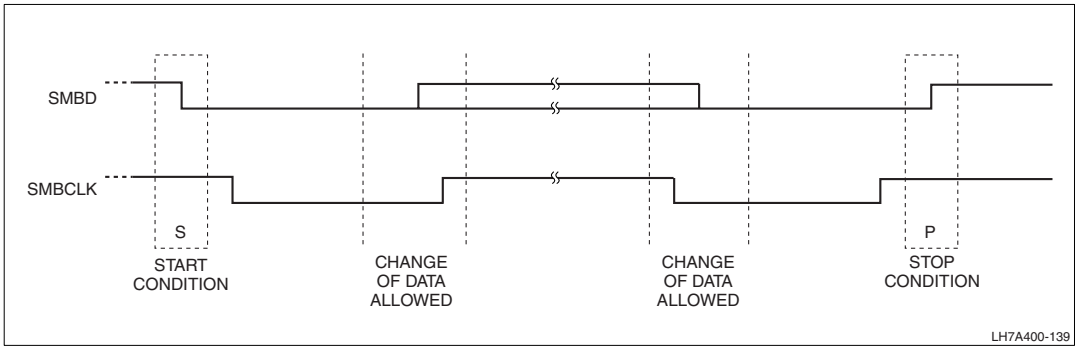


Figure 21-7. SMB Start and Stop Conditions

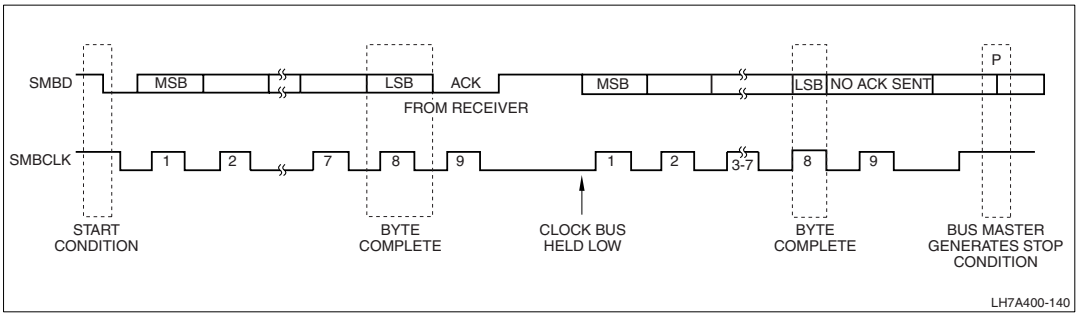


Figure 21-8. SMB Data Transfer

21.1.2.4 Using the SMB

Software must program the SBI Count register (SBICOUNT) to specify the number of bytes of data transferred within each process. Software uses two steps for all SMB protocols except the Block Read Transfer:

1. Program SBICOUNT and SBICR to specify the protocol parameters.
2. Write SBIDR to start the transfer.

A Block Read Transfer is different in that SBICOUNT is unspecified before the transfer begins. The Slave peripheral provides this information in the first data byte (the Length Count) of the transfer. The SBI puts the Length Count into SBICOUNT after receiving the data byte. When the Packet Error Code Enabled Flag is set in the transfer data, the SBI adjusts SBICOUNT to accommodate Packet Error Checking (PEC) following the last data byte.

A Smart SMB interface, such as the SBI, supports a set of commands for reading and writing data. All commands are 8 bits (1 byte) long. Command arguments and return values can vary in length. Accessing a nonexistent or unsupported command causes an error condition. The most significant bit is transferred first. Eight command protocols are possible for each device. A Slave device can use any or all of these protocols. The host device must be able to support all command protocols. These command protocols can be conceptually described as register accesses, although devices need not implement linear register spaces. The commands are:

- Quick Command
- Send Byte
- Receive Byte
- Write Byte/Word
- Read Byte/Word
- Process
- Block Read
- Block Write.

21.1.2.4.1 Addresses and Address Contention

Each device using the SMB has a unique Slave Address. Masters and the host have a Slave Address used when another Master wants to talk with them. Table 21-1 and Table 21-2 list Slave Addresses reserved by the ISMB specifications. These addresses must be avoided by any devices using the LH7A400 SBI.

Table 21-1. Reserved Slave Addresses

SLAVE ADDRESS (BITS 7:1)	RW (BIT 0)	DESCRIPTION
0000 000	0	General Call Address
0000 000	1	START byte
0000 001	X	CBUS address
0000 010	X	Address reserved for different bus format
0000 011	X	Reserved for future use
0000 1XX	X	Reserved for future use
1111 0XX	X	10-bit Slave addressing
1111 1XX	X	Reserved for future use

Table 21-2. Reserved SMB Slave Addresses

SLAVE ADDRESS	DESCRIPTION
0001 000	SMB Host
0001 100	SMB Alert Response Address
1100 001	SMB Device Default Address
0101 000	Reserved for ACCESS.bus host
0110 111	Reserved for ACCESS.bus default address
1001 0XX	Unrestricted addresses

The SMB Alert Response Address (0001100) can be a substitute for device Master capability. The SMB Device Default Address is reserved for future use by SMB devices allowing assignable addresses. All 10-bit Slave addresses are reserved. The host should support access to 10-bit devices. All other addresses are reserved for formal assignment by the SMB Address Coordinating Committee.

Unrestricted addresses (10010XX) are not assigned to any device. These addresses are provided for prototyping and experimenting.

The host has the lowest address, to ensure emergency messages to the host have the highest priority. Emergency messages can carry the General Call address when pertaining to multiple devices.

Several SMB devices can be used simultaneously in an actual system. To resolve device address contention:

- Use programmable features implemented in SMB devices
- Use multiple SMB branches within the same system to spread devices with identical availability to the system designer for configuring specific system implementations.

21.1.2.5 Smart Battery Interface Master and Slave Modes

The LH7A400 SBI can assume the role of either a Master or Slave. By default, the SBI assumes the Master role. Only for the Modified Write Word command does the SBI become a Slave.

21.1.2.5.1 SBI SMB Slave Mode

The SBI enters the Slave mode when requested by another Master on the System Management Bus. When the SBI is in Slave mode, the SBISR Slave bit (SBISR:Slave) is as 1 and the Master bit (SBISR:Master) is 0.

In Slave mode, the SMB uses a clock generated by the Master instead of the LH7A400 clock generation block.

Only for the Modified Write Word protocol can a peripheral become the Master and the SBI become the Slave. In this protocol, the SBI receives the following sequence after a Start Condition generated by the Master:

- The first byte is the SMB Host Address
- The second byte is the Peripheral Device Address
- The third and fourth bytes are data bytes
- The final byte is a Stop Condition.

After receiving the Stop Condition, the SBI generates a Slave Interrupt to inform the host the transfer has completed.

When the SBI Slave receives a data byte while the Receive FIFO is full or disabled, the SBI:

- Disables the SMB
- Pulls the SMB Clock LOW
- Asserts the Receive Interrupt (RXI) by setting the SBI Raw Interrupt Status Register RXI field (SBIRISR:RXI).

When software reads the SBI Data Register (SBIDR), the SBI deasserts RXI, enables the SMB, and releases the SMB Clock.

21.1.2.5.2 SBI SMB Master Mode

When the SBI is in Master mode, the SBISR Master bit (SBISR:Master) is set 1 and the Slave bit (SBISR:Slave) is cleared to 0.

In Master mode, the SMB Clock is generated from the 14.7456 MHz clock. The value programmed into the SBICR Division Factor field (SBICR:DIVFACT) is used to convert the divided-by two BMI clock (7.3728 MHz) into the clock for the SMB:

$$\text{SMB Clock Period} = (\text{DIVFACT} + 1) \times 271 \text{ ns}$$

For example:

- DIVFACT = 255 results in SMB Clock Period = 69.44 μs.
- DIVFACT = 0 results in SMB Clock Period = 271 ns.

The SBI enters Master mode when software initiates a data transfer, by writing the data to SBIDR. This write sets the status fields and interrupts:

- The SBI Status Register Transfer Busy field (SBISR:TXBUSY) is set.
- If the Transmit FIFO is disabled or this write makes the Transmit FIFO at least half full, the Transmit Interrupt (TXI) is deasserted, clearing SBIRISR:TXI.
- If the SBISR Transmit FIFO Empty field (SBISR:TXFE) was cleared, this write sets SBISR:TXFE.

As SMB Master, the SBI transmits a Start Condition, followed by the data, and finally a Stop Condition. The following status fields and interrupts track the transmission operation:

- When the Transmit FIFO becomes less than half full, TXI is asserted. A single transmission with the Transmit FIFO disabled also asserts TXI.
- When the Transmit FIFO becomes empty, TXFE is set.
- After the Stop Condition is transmitted, the Master Transfer Complete Interrupt (MTCI) is asserted, setting SBIRISR:MTCI.
- If data remains in the Transmit FIFO, the SBI deasserts MTCI and continues Start-Data-Stop sequence transmissions as SMB Master.

21.1.2.5.3 Acknowledge (ACK) and Negative Acknowledge (NACK)

The Master generates the clock pulse used for the Acknowledge signal (ACK), as shown in Figure 21-9. The transmitter releases the data line (HIGH, for non-inverted signals) during the ACK clock cycle. To send ACK for a byte, the receiver must pull the data line LOW during the HIGH period of the clock pulse, according to the SMB timing specifications. To send a Negative Acknowledge signal (NACK), the Slave must let the data line remain HIGH during the ACK clock cycle.

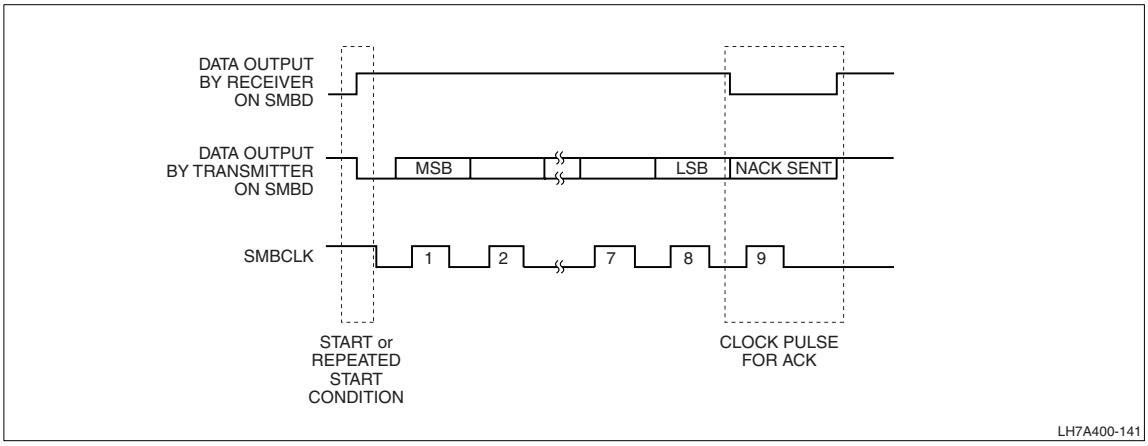


Figure 21-9. SMB ACK and NACK

An SMB device must ACK its own address. The SMB uses this signaling to detect the presence of detachable devices on the bus. An SMB Slave can NACK a byte in the following situations:

- The Slave is busy performing a real-time task, or the requested data is unavailable. After receiving this NACK, the Master must generate a Stop Condition to end the transfer. Alternatively, the Slave can extend the clock LOW period, to complete tasks and continue the transfer.
- The Slave detects an invalid command or invalid data and must NACK the received byte. After receiving this NACK, the Master must generate a Stop Condition before retrying the transaction.
- The Master must signal the end of data to the Slave transmitter by avoiding generating ACK for the final byte clocked out by the Slave. The Slave transmitter must release the data line to allow the Master to generate a Stop Condition.

The SMB withholds ACK to detect whether a Slave transmitter implements Packet Error Checking (PEC). As a Master receiver, the SMB attempts to request more data from the Slave transmitter by acknowledging the last data byte and continuing to provide clocks requesting one more byte. A Slave transmitter implementing PEC provides the Packet Error Code. The Master receiver checks the Code, and, if the Code is valid, registers the device as implementing PEC. A Slave transmitter implementing no PEC provides either invalid data or no data. The Master receiver registers such devices as not implementing PEC.

21.1.2.5.4 Clock LOW Extending (Clock Synchronizing)

The SMB provides a clock synchronization operation to accommodate devices of different speeds on the bus. In addition to the bus arbitration procedure, the clock synchronization mechanism can be used during a bit or a byte transfer to allow slower Slaves to work with faster Masters. Figure 21-10 shows clock LOW extending.

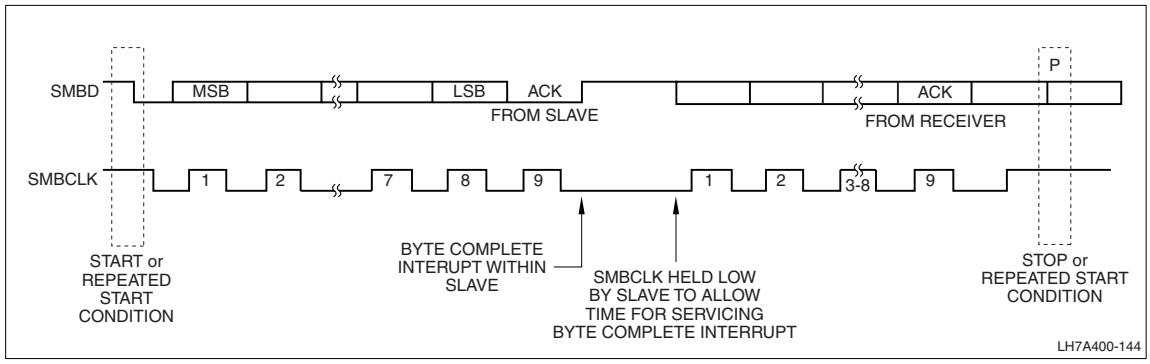


Figure 21-10. SMB Clock LOW Extending

During each bit, a device can slow down the bus by extending the clock LOW period either periodically or as needed. Devices designed to stretch every clock cycle periodically must maintain the minimum SMB frequency of 10 kHz to preserve the SMB bandwidth. Devices can extend the clock up to the maximum limit of the bus during each message transfer. Clock LOW extension must start before the bus minimum LOW period expires.

A Slave can extend the clock LOW period selectively; for example, to allow time for real-time task processing or byte validity checking. Clock LOW extension can occur during any bit transfer, including the clock cycle prior to the ACK clock pulse.

A Slave can extend the clock LOW period between byte transfers on the bus; for example, for received data processing or transmission data preparation. The Slave holds SMBCLK LOW after any byte reception and ACK.

The Master can extend the clock LOW period between bytes or at any time during byte transfer, including during the clock LOW period occurring after the transfer and before the ACK clock. The Master can extend the clock LOW period selectively; for example, to process data or to perform a real-time task.

21.1.2.5.5 Bus Synchronization

Multiple Masters can attempt to put clock signals on the bus simultaneously. The resulting bus signal is the wired-AND of all the clock signals provided by the Masters. The bus integrity requires a clear clock definition, bit-by-bit, for all Masters involved in arbitration.

A HIGH to LOW transition on SMBCLK (pin N3) causes each device involved to start counting off a LOW period. When a device LOW period ends, the device releases SMBCLK. Until all Master LOW periods end, SMBCLK is held LOW by any devices still counting. Meanwhile, the Master that released SMBCLK enters a HIGH wait period. When all device LOW periods end, SMBCLK is released HIGH. All devices involved start counting HIGH periods. The first device that completes a HIGH period pulls SMBCLK LOW, restarting the cycle.

Figure 21-11 shows the clock synchronization timing. This cycle provides a synchronized clock for all devices, with the SMBCLK LOW period determined by the slowest device and the HIGH period by the fastest device.

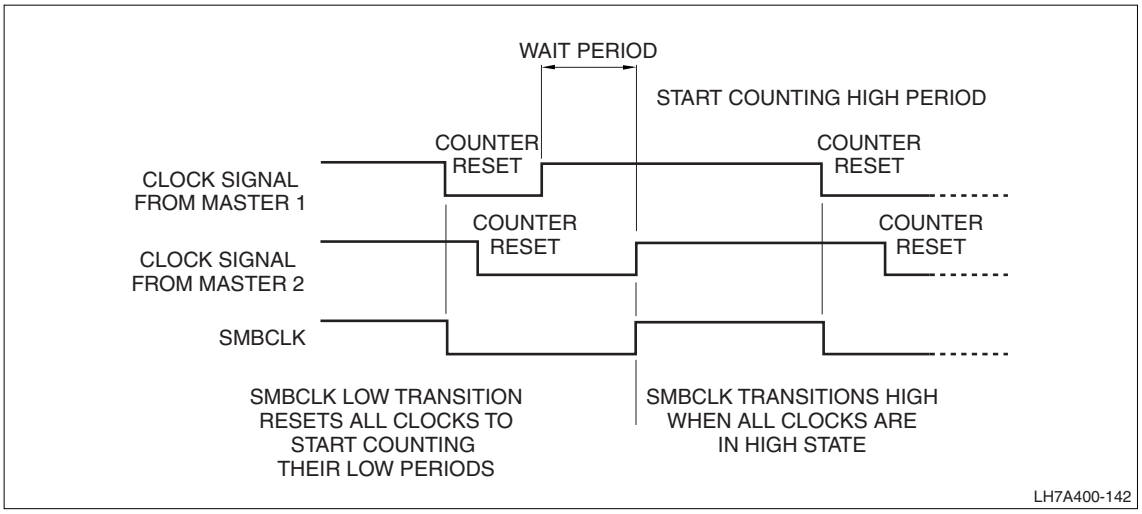


Figure 21-11. SMB Synchronization

21.1.2.5.6 Packet Error Checking

Optional Packet Error Checking is available for reliability and communication robustness. Packet Error Checking is implemented by appending a Packet Error Code (PEC) at the end of each message transfer. Each protocol except the Modified (Slave-to-Host) Write has a Packet Error Checking and a non-Packet Error Checking variant. The PEC is a CRC-8 error checking byte, calculated on all message bytes, including addresses and RW bits. The PEC is appended to the message by the device supplying the final data byte.

The SMB accommodates Packet Error Checking and non-Packet Error Checking devices.

A Slave implementing Packet Error Checking must be prepared to receive and transmit data with or without a PEC. During a Slave receive transfer, after identifying the Protocol and Command, the Slave must accept and check the additional PEC for validity. During a Slave transmit transfer, the Slave transmitter must respond to additional clocks after the last byte transfer and furnish a PEC on request.

A Slave supporting Packet Error Checking must:

- Perform the Slave transfer with or without a PEC
- Validate the PEC if present
- Issue a NACK when an incorrect PEC is present.

A Master receiver supporting PEC must identify the capabilities of any accessed device:

1. The Master performs a Read transfer without PEC to the device version register, as appropriate.
2. If the device version indicates PEC support, the Master repeats the Read with PEC.
3. If the PEC received is correct the Master registers the device as PEC compliant. The SBI sets the SBI Control Register PEC Enabled Flag (SBICR:PEF).

After identifying a Slave-supporting PEC, the Master can use Packet Error Checking for subsequent communications with the device as both Master receiver and Master transmitter.

Each Packet Error Checking transaction requires a PEC calculation by both the transmitter and receiver for each packet. Use an 8-bit cyclic redundancy check (CRC-8) of each Read or Write bus transaction to calculate a Frame Check Sequence (FCS) to be appended to the message. The LH7A400 implements the FCS calculation as appropriate.

The FCS calculation includes the following for each transmission:

- All Address, Command and Data bytes
- No ACK, NACK, START, STOP, and Repeated START bits.

21.1.2.6 Command Protocol Summary

This section describes SBI SMB command protocols. Each command is described and a diagram is provided.

21.1.2.6.1 Quick Command

The Quick Command is useful for very small devices with limited SMB support and to limit data on the bus for simple devices. For example, RW can turn a device function on or off; or enable or disable a low power Standby mode. The RW bit of the Slave address is the command. No data is sent or received. The Quick Command command protocol is illustrated in Figure 21-12.

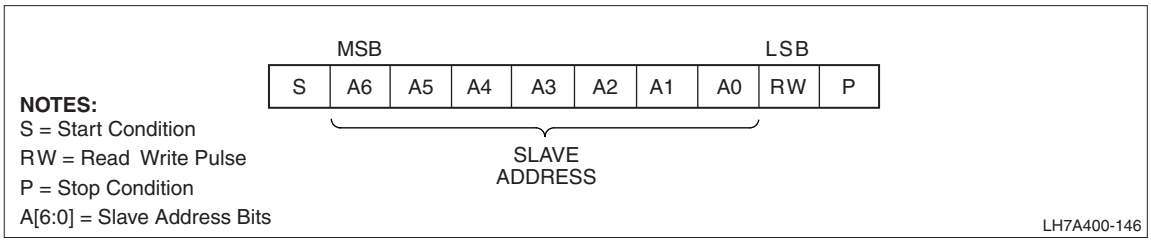


Figure 21-12. Quick Command Protocol

21.1.2.6.2 Send Byte

A device can recognize its own Slave Address and accept any of up to 256 encoded commands as a byte following the Slave Address. All or part of the Send Byte can contribute to the command. For example:

- The highest seven bits of the command code specifies a feature access, and the least significant bit turns the feature on or off.
- The Send Byte value specifies the receiver output volume adjustment.

Figure 21-13 illustrates the Send Byte command protocol.

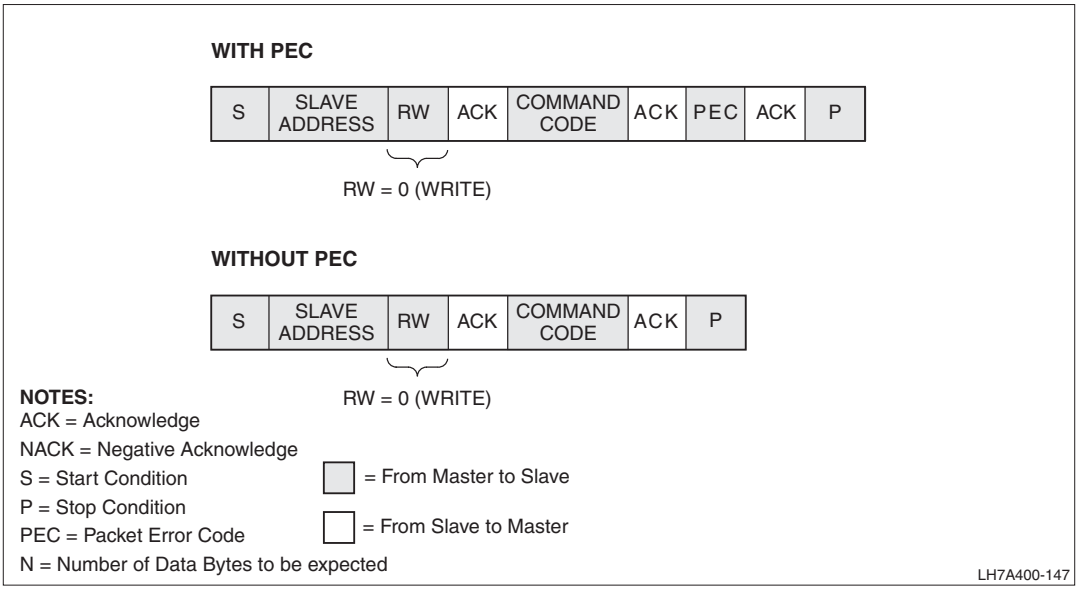


Figure 21-13. Send Byte Protocols

21.1.2.6.3 Receive Byte

Receive Byte is similar to Send Byte, the only difference being the data transfer direction. A device can use Receive Byte to send information needed by the Host. The same device can accept both Send Byte and Receive Byte protocols. NACK indicates the end of a Read transfer. Figure 21-14 illustrates the Receive Byte command protocol.

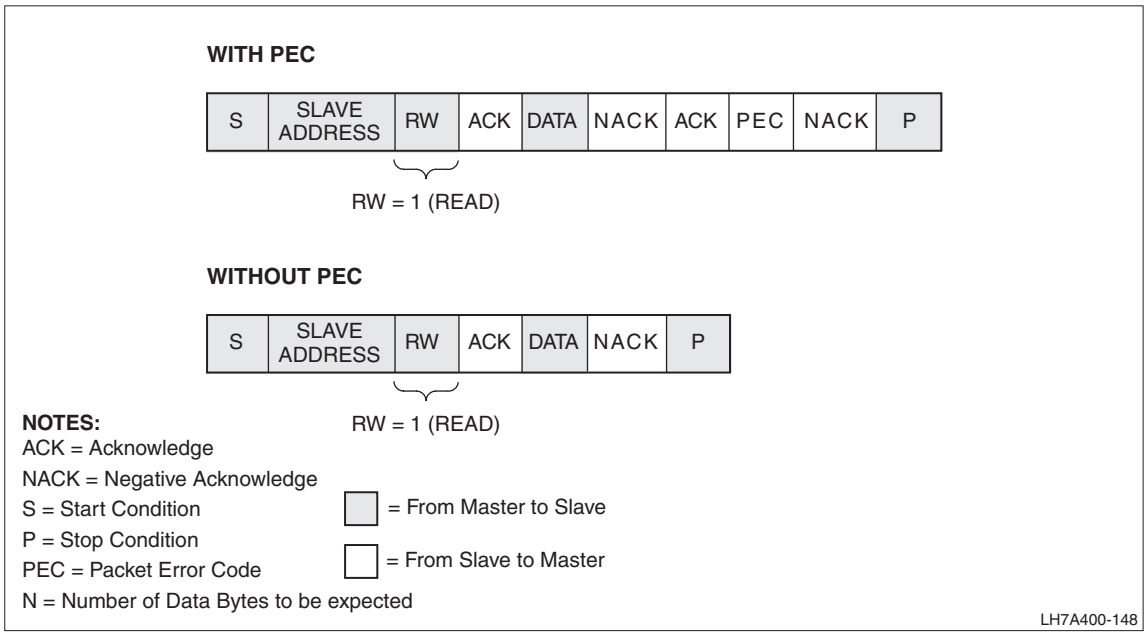


Figure 21-14. Receive Byte Protocols

21.1.2.6.4 Write Byte and Write Word

The first byte of Write Byte or Write Word is the command code. The next one or two bytes are the data to be written, with the low byte first. For example:

- The Master asserts the Slave Address followed by the Write bit.
- The Slave sends ACK.
- The Master delivers the command code.
- The Slave again sends ACK before the Master sends the data byte or word.
- The Slave acknowledges each byte.

The transaction ends with a Stop Condition. Figure 21-15 illustrates the Write Byte and Write Word command protocols.

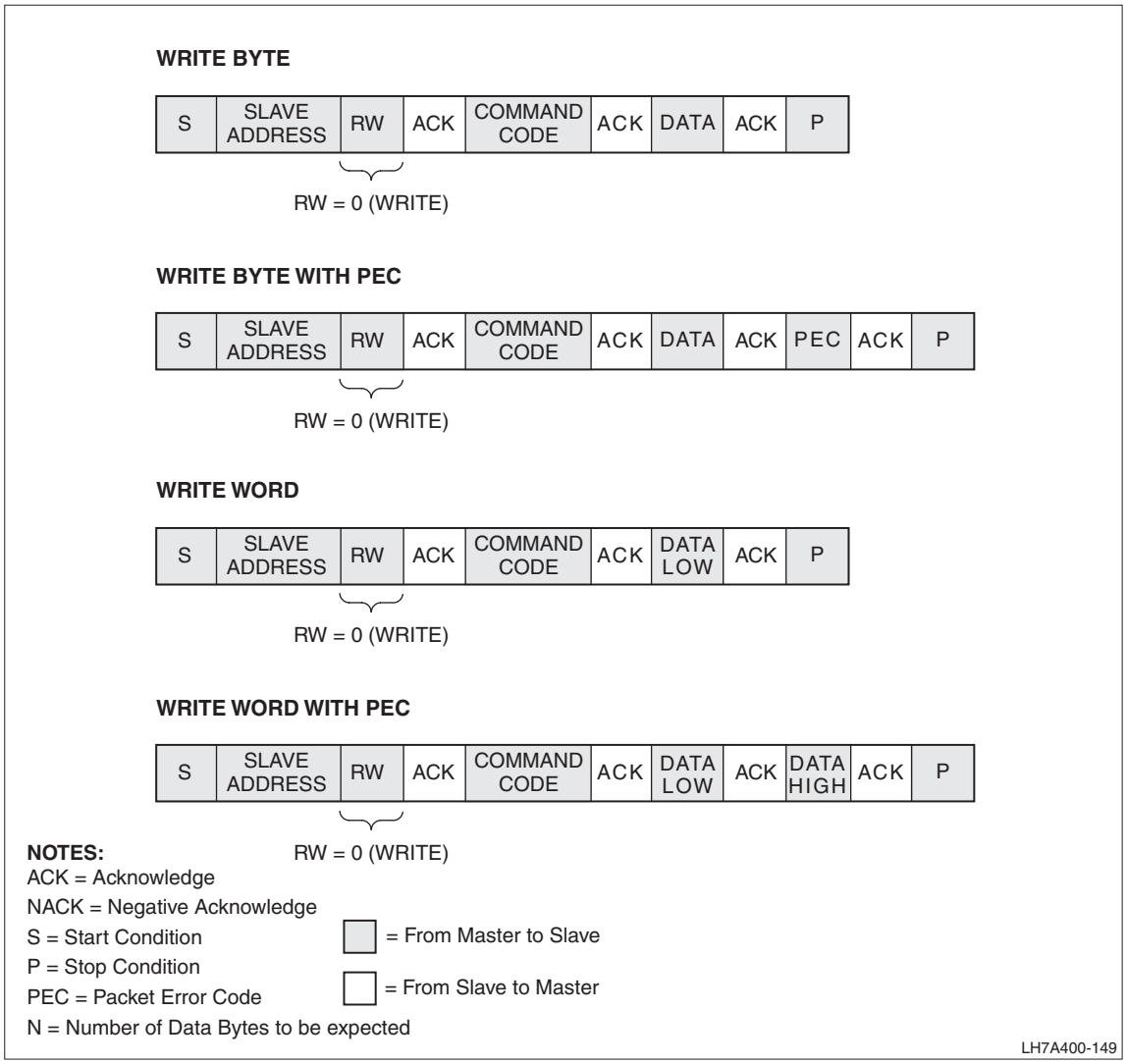


Figure 21-15. Write Byte and Write Word Protocols

21.1.2.6.5 Read Byte and Read Word

To read data:

- The Host writes a command to the Slave.
- With no intervening Stop Condition, the Host sends a Repeated Start, indicating Read from the Slave Address.
- The Slave returns one or two bytes of data.
- A NACK ends the Read transfer.

Figure 21-16 illustrates the Read Byte and Read Word command protocols.

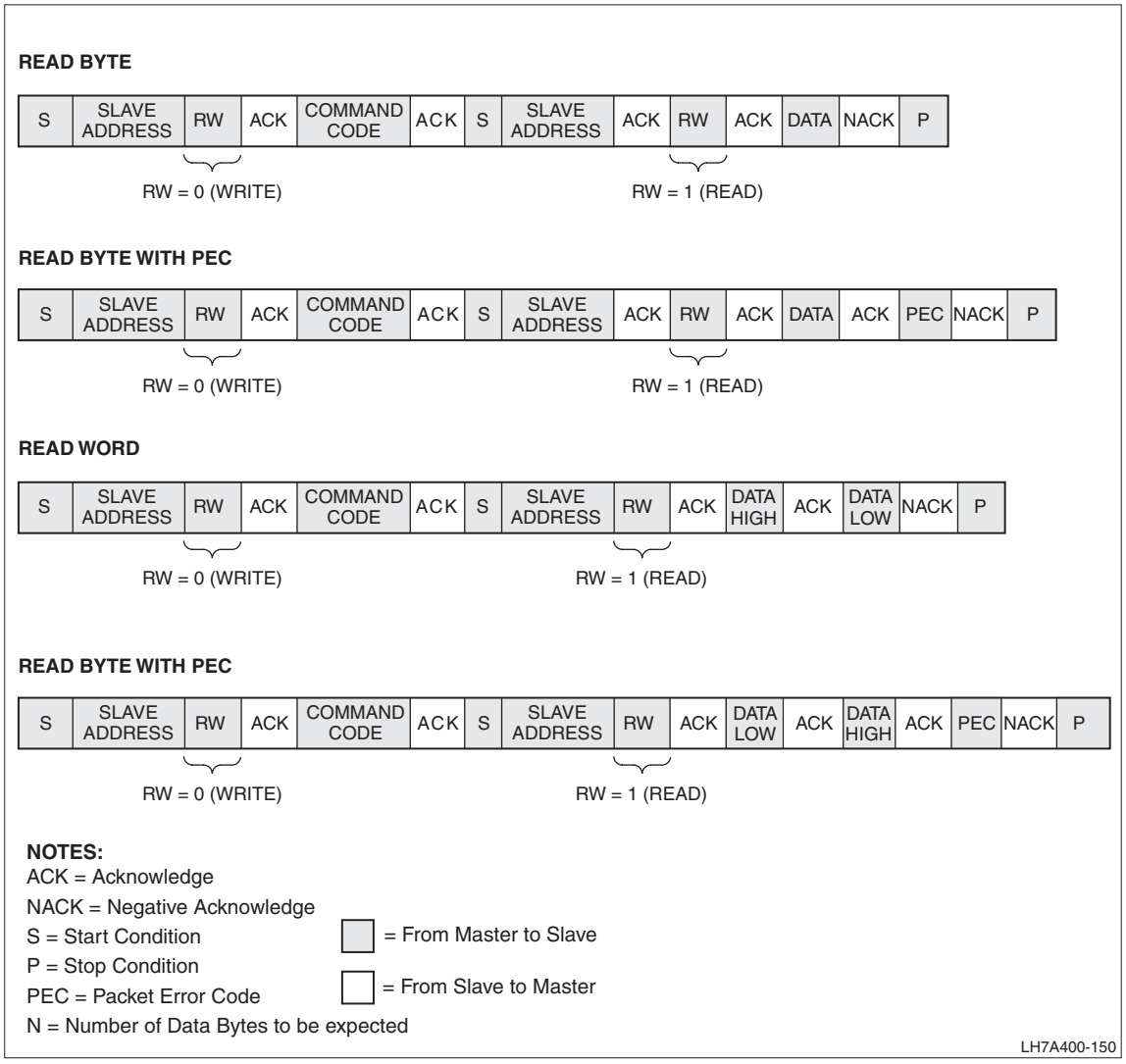


Figure 21-16. Read Byte and Read Word Protocols

21.1.2.6.6 Process Call

This command sends data and waits for the Slave to return a value dependent on the data. The protocol is a Write Word followed by a Read Word, but without a second command or Stop Condition. The slave can perform any calculations or lookups during the time it takes to transmit the Repeated Start and Slave Address. This command protocol is shown in Figure 21-17.

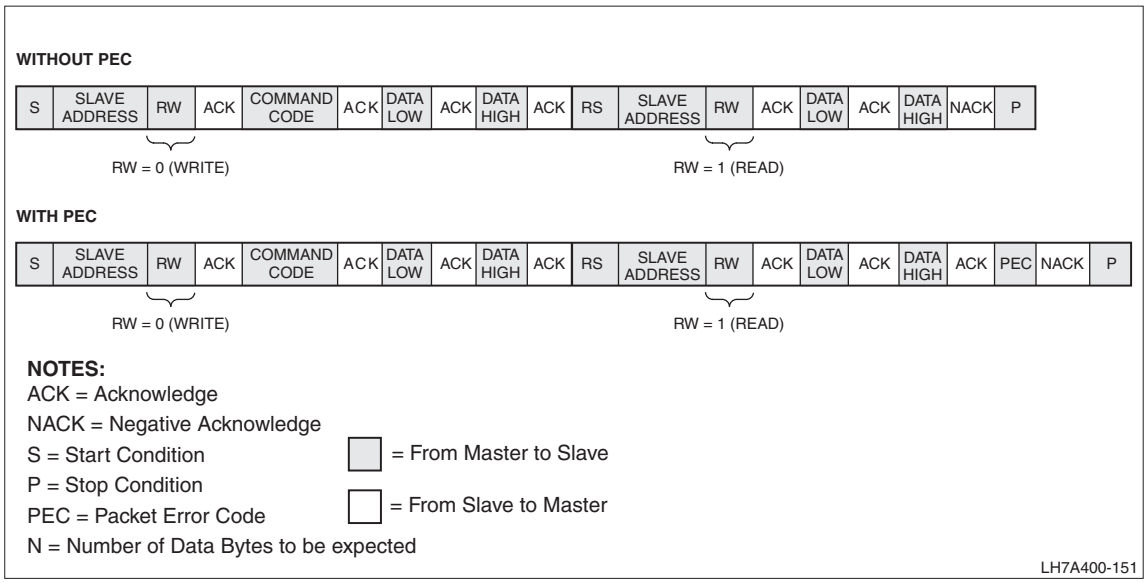


Figure 21-17. Process Call Protocols

21.1.2.6.7 Block Read and Block Write

The Block Write begins with a Slave Address and a Write Condition. After the command code, the Host issues a byte count specifying the number of additional bytes to follow in the message. For example, if a slave has 20 bytes to send, the first byte is the value 0x14, and is followed by the 20 bytes of data. A 0 byte count is invalid. The maximum valid byte count is 32. The Block Read is the same as the Block Write, with the addition of a Repeated Start to satisfy the requirement for a transfer direction change. Figure 21-18 illustrates the Block Read command protocol and Figure 21-19 illustrates the Block Write.

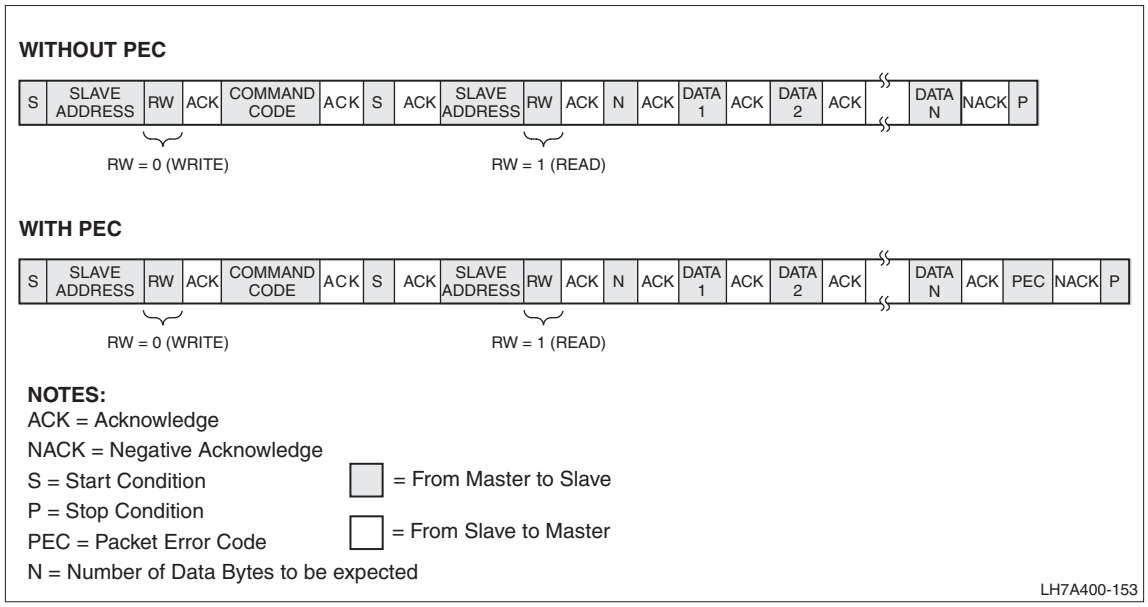


Figure 21-18. Block Read Protocol

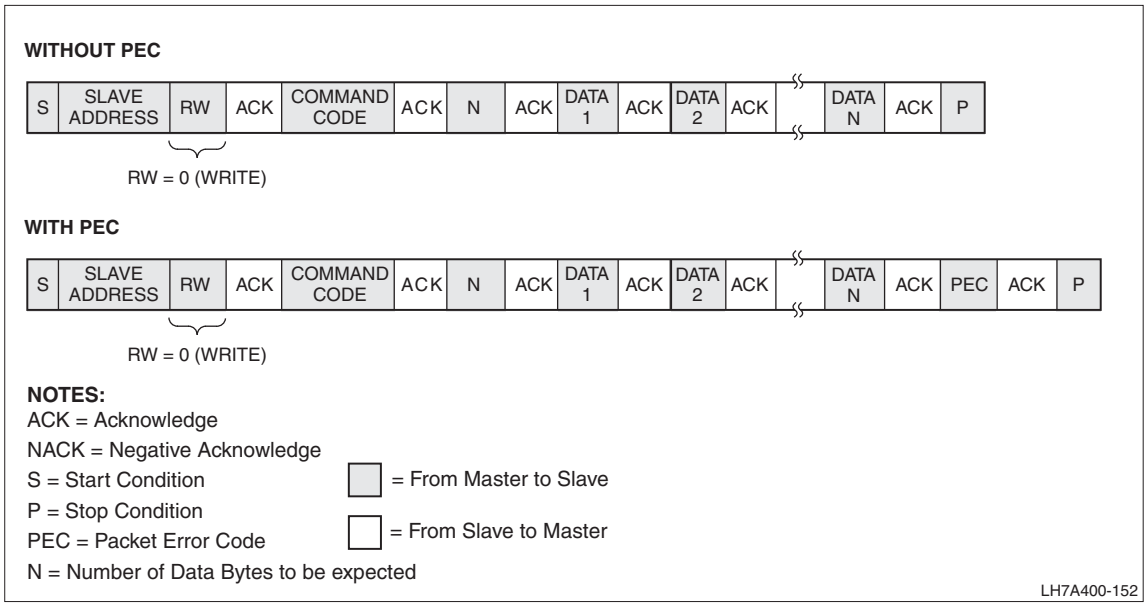


Figure 21-19. Block Write Protocol

21.1.2.6.8 Modified Write Word

The Modified Write Word is required for any message destined for the Host. This protocol is used when a device communicates with the SMB Host acting as a Slave. The standard Write Word protocol is modified by replacing the command code with the address of the device sending the message:

- Device to Host communication begins with the Host address.
- The command code is the address of the device sending the message. The address bits occupy the seven most significant bits of the byte.
- The eighth (least significant) bit can be either 0b0 or 0b1.

The subsequent 16 bits of device status correspond to address in the command code. Figure 21-20 shows this command protocol.

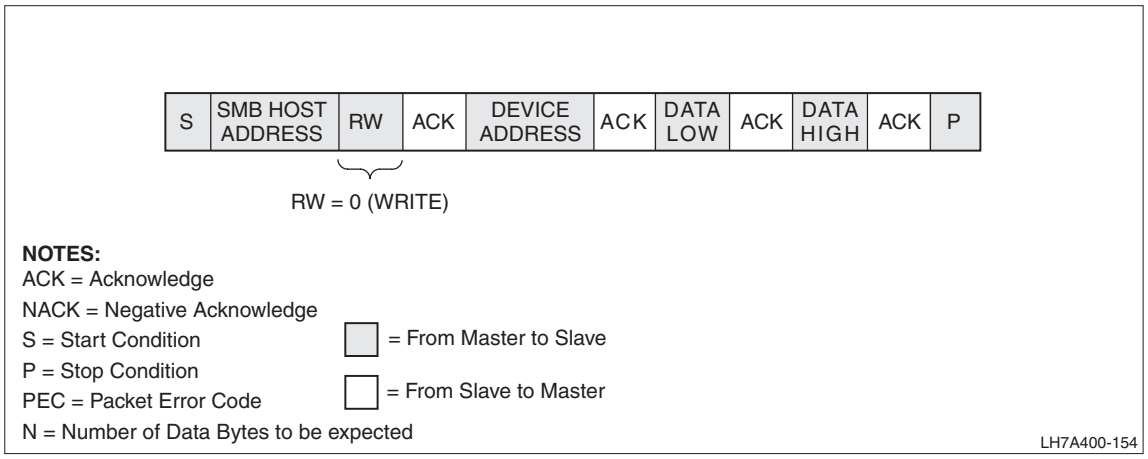


Figure 21-20. Modified Write Word Protocol

21.1.3 BMI Interrupts

The BMI generates interrupts to report the beginning and end of operations and other conditions and events in both the Single Wire Interface (SWI) and Smart Battery Interface (SBI). These interrupts are asserted in the SWI and SBI Raw Interrupt Status Registers (SWIRISR and SBIRISR). Software can enable or disable interrupts by programming the SWI and SBI Interrupt Enable registers (SWIIER and SBIIER). The logical bitwise-AND of the asserted with the interrupts enabled in the SWIIER or SBIIER appears in the SWI and SBI Interrupt Status Registers (SWIISR and SBIISR). Only interrupts asserted in SWIRISR or SBIRISR and enabled in SWIIER or SBIIER appear in SWIISR or SBIISR.

Some interrupts are deasserted during normal BMI operation. Others can be deasserted by writing a 1 to the appropriate field in the SWI or SBI End-of-Interrupt register (SWIEOI or SBIEOI). These interrupts are further explained in the Registers section of this chapter.

The individual interrupts in SBIISR are ORed together to generate a single combined interrupt, BMIINTR, to be handled by the LH7A400 Interrupt Controller. This combined interrupt, BMIINTR is deasserted in two ways:

- Disable all contributing interrupts asserted in SBIISR, by programming SBIIER.
- Deassert all contributing interrupts asserted in SBIRISR, either by writing 1 to the corresponding SBIEOI fields or by performing actions that deassert the interrupts.

Table 21-3 describes the interrupts appearing in SWIRISR, pertaining to SWI operation. Table 21-4 describes the interrupts appearing in SBIRISR, pertaining to SBI operation.

Table 21-3. SWI Interrupts

NAME	DESCRIPTION	HANDLING
BRI	**Break Recovered Interrupt** The Break sequence has ended, using the Break and Break Recovery times programmed in SWITR.	Write a 1 to SWIEOI:BRI to deassert this interrupt.
WRI	**Word Read Interrupt** The data word from the device has been completely received into SWIDR.	Read SWIDR to deassert this interrupt.
WTI	**Word Transmitted Interrupt** The data word written by software to SWIDR has been completely transmitted to the device.	Write a 1 to SWIEOI:WTI to deassert this interrupt.

Table 21-4. SBI Interrupts

NAME	DESCRIPTION	HANDLING
CLTI	**Clock Low Time-out Interrupt** The Slave peripheral transmitting data is reporting an error. When the Slave peripheral holds the SBI bus clock line LOW for more than 25 ms, the interrupt is asserted.	Write 1 to SBIEOI:CLTI to deassert this interrupt.
STCI	**Slave Transfer Complete Interrupt** The SBI has received a complete data transfer while in Slave mode; that is, a data transfer initiated by another Master.	Write 1 to SBIEOI:STCI to deassert this interrupt.
ALI	**Arbitration Lost Interrupt** The SBI lost arbitration while in Master mode.	Write 1 to SBIEOI:ALI to deassert this interrupt.
AFI	**Acknowledge Fail Interrupt** The interface has not received an ACK signal from the peripheral during a data transfer. Asserting this interrupt flushes the FIFOs.	Write 1 to SBIEOI:AFI to deassert this interrupt.
MTCI	**Master Transfer Complete Interrupt** The interface has completed a data transfer in Master mode; that is, a data transfer initiated by the SBI. After the Stop Condition is transmitted, the Master Transfer Complete Interrupt (MTCI) is asserted, setting SBIRISR:MTCI	Write 1 to SBIEOI:MTCI to deassert this interrupt.
RTI	**Receive Time-out Interrupt** The time-out counter has reached the value programmed in SBICON:TOC. The counter is initiated and reset when data is received into the RX FIFO.	When software reads data from the FIFO, the interrupt is cleared and the counter is disabled until the next data byte is received into the RX FIFO.
RXI	**Receive Interrupt** This interrupt indicates either: The FIFO is enabled and at least half full. The FIFO is disabled (has a depth of one location) and data is received.	This interrupt is deasserted when either: The enabled FIFO becomes less than half full. Software reads the FIFO if disabled.
TXI	**Transmit Interrupt** This interrupt indicates either: The FIFO is enabled and no more than half full. The FIFO is disabled (has a depth of one location) and no data is present.	This interrupt is deasserted when either: The enabled FIFO becomes more than half full. Software writes to the FIFO if disabled.

21.2 Register Reference

This section describes the BMI registers.

21.2.1 Memory Map

The BMI register offsets, as shown in Table 21-6 and Table 21-7, are relative to the base address 0x8000.0F00.

Table 21-5. BMI Single Wire Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	SWIDR	Single Wire Interface Data Register
0x04	SWICR	Single Wire Interface Control Register
0x08	SWISR	Single Wire Interface Status Register
0x0C	SWIRISR	Single Wire Interface Raw Interrupt Status Register
	SWIEOI	End of Interrupt
0x10	SWIISR	Single Wire Interface Interrupt Status Register
0x14	SWIIER	Single Wire Interface Interrupt Enable Register
0x18	SWITR	Single Wire Interface Timing Register
0x1C	SWIBR	Single Wire Interface Break Register

Table 21-6. BMI Smart Battery Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x40	SBIDR	Smart Battery Data Register
0x44	SBICR	Smart Battery Control Register
0x48	SBICOUNT	Smart Battery Count Register
0x4C	SBISR	Smart Battery Status Register
0x50	SBIRISR	Smart Battery Raw Interrupt Status Register
	SBIEOI	End of Interrupt
0x54	SBIISR	Smart Battery Interrupt Status Register
0x58	SBIIER	Smart Battery Interrupt Enable Register

21.2.2 Register Descriptions

21.2.2.1 Single Wire Interface Data Register (SWIDR)

This register, defined in Table 21-7 and Table 21-9, contains data read from the BMI, or data to be written to the BMI. Data entries can be up to 32-bits wide. Any data entry with fewer than 32 bits is right-justified. Writing a command or data to this register places the contents in the shift register. From the shift register, data is serially output to the peripheral.

Table 21-7. SWIDR

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	SWID															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SWID															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F00															

Table 21-8. SWIDR Fields

BITS	FIELD	DESCRIPTION
31:0	SWID	**SWI Data** Incoming or outgoing data, up to 32 bits wide.

21.2.2.2 Single Wire Interface Control Register (SWICR)

This register, defined in Table 21-9 and Table 21-10, controls SWI operation.

Table 21-9. SWICR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															SP_INVERT
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	T_RST	RDSS						WDCS						DINV	GBS	SWIEN
RESET	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F04															

Table 21-10. SWICR Fields

BITS	FIELD	DESCRIPTION
31:17	///	**Reserved** Reading returns 0. Write the reset value.
16	SP_INVERT	**Start Stop Invert** This bit reverses the polarity of the Data line. 1 = Polarity reversed: Start bit HIGH, Stop bit LOW, rising-edge triggered. 0 = Normal polarity. Start bit LOW, Stop bit HIGH, falling-edge triggered.
15	T_RST	**Transfer Reset** Resets any active data transmission or reception. 1 = Resets any active transfer. 0 = No reset.
14:9	RDSS	**Read Data Size Select** The value in this field specifies the number of bits to be read for a data word.
8:3	WDCS	**Write Data or Command Size** The value in this field specifies the number of bits to be written for a Data Command or Word.
2	DINV	**Data Invert** Setting this bit inverts the data polarity. 1 = Data in the SWIDR is inverted for transmission and reception. 0 = Data in the SWIDR is sent and received with normal polarity.
1	GBS	**Generate Break Sequence** This bit forces a Break for the time specified in the SWI Break Register SWI Break field (SWIBR:SWIB), followed by a break recovery for the time specified in the SWIBR SWI Break Recovery field (SWIBR:SWIBR). 1 = Generate a Break sequence. 0 = Do not generate a break sequence.
0	SWIEN	**SWI Enable** This bit enables and disables SWI operation. 1 = Enable SWI. 0 = Disable SWI.

21.2.2.3 BMI Single Wire Interface Status Register (SWISR)

This register, defined in Table 21-11 and Table 21-13, reports the SWI operating status.

Table 21-11. SWISR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				COL	TEF	RXB	BRF	BRS	BKS	RXF	TXF	PBS	DBS	SBS	TXB
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0F08															

Table 21-12. SWISR Fields

BITS	FIELD	DESCRIPTION
31:12	///	**Reserved** Reading this field returns 0. Do not write to this register.
11	COL	**Collision** This bit indicates that the SWI has identified a Receive initiation, but cannot start data reception because the current process is busy. 1 = Receive initiation received but the current process is busy. 0 = A new data transfer or a Break generation has occurred.
10	TEF	**Transmit Error Flag** 1 = The SWI cannot start data transmission because the current process is busy. 0 = A Break generation has cleared the flag.
9	RXB	**Receive Busy** 1 = The Receive operation is busy. 0 = The Receive operation is idle.
8	BRF	**Break Recovered Flag** 1 = Break recovery is complete. 0 = Break recovery not complete.
7	BRS	**Break Recovery Status** 1 = The SWI is generating a Break Recovery. 0 = The SWI is not generating a Break Recovery.
6	BKS	**Break Status** 1 = The SWI is generating a Break. 0 = The SWI is not generating a Break.
5	RXF	**Received Flag** 1 = A read word has been transferred from the shift register to the SWIDR. 0 = The data register has been read.
4	TXF	**Transmitted Flag** 1 = A word write has completed to the battery monitor from the shift register. 0 = Clear this bit by writing the corresponding interrupt in the SWIEOI.

Table 21-12. SWISR Fields (Cont'd)

BITS	FIELD	DESCRIPTION
3	PBS	**Stop Bit Status** 1 = The SWI is reading or writing a Stop bit. 0 = The SWI is not reading or writing a Stop bit.
2	DBS	**Data Bit Status** 1 = The SWI is reading or writing a Data bit. 0 = The SWI is not reading or writing a Data bit.
1	SBS	**Start Bit Status** 1 = The SWI is reading or writing a Start bit. 0 = The SWI is not reading or writing a Start bit.
0	TXB	**Transmit Busy** 1 = The Battery Monitor Transmit process is busy. 0 = Transmit process is idle.

21.2.2.4 BMI Single Wire Interface Raw Interrupt Status and Clear Register (SWIRISR and SWIEOI)

This location is both the SWI Raw Interrupt Status Register (SWIRISR) and the SWI End-of-Interrupt register (SWIEOI). Reading accesses the SWIRISR; writing clears the BRI and WTI registers as defined in Table 21-13 and Table 21-14:

- As SWIRISR, this register reports the asserted or deasserted status of SWI interrupts. The values reported in SWIRISR are bit-wise-ANDed with the values programmed in SWIIER, providing the results in SWIISR.
- Writing 1 to a bit in SWIEOI deasserts the corresponding interrupt. Values written to this register cannot be read back.

Table 21-13. SWIRISR and SWIEOI Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													BRI	WRI	WTI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RO	RW
ADDR	0x8000.0F0C															

Table 21-14. SWIRISR and SWIEOI Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Write the reset value. Writing this field has no effect on any interrupt status.
2	BRI	**Break Recovered Interrupt** When this bit is read: 1 = Break sequence is complete. 0 = Break sequence is not complete. Write a 1 to this bit to deassert this interrupt.
1	WRI	**Word Received Interrupt** When this bit is read: 1 = A Data Word has been received from the peripheral. 0 = No complete Data Word has been received. Read the data register to deassert this interrupt. Writing this field has no effect on the register contents.
0	WTI	**Word Transmitted Interrupt** When this bit is read: 1 = A Data Word has been transmitted to a peripheral. 0 = A Data Word has not been transmitted to a peripheral. Write a 1 to this field to deassert this interrupt.

21.2.2.5 BMI Single Wire Interface Interrupt Status Register (SWIISR)

This register, defined in Table 21-16 and Table 21-17, reports the asserted or deasserted status of enabled SWI interrupts. The values reported in SWIRISR are bit-wise-ANDed with the values programmed in SWIIER, providing the results in SWIISR.

Table 21-15. SWIISR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													BRI	WRI	WTI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0F10															

Table 21-16. SWIISR Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Do not write to this register.
2	BRI	**Break Recovered Interrupt** 1 = The Break sequence is complete. 0 = Either the Break sequence is incomplete or this interrupt is disabled in SWIIER.
1	WRI	**Word Received Interrupt** 1 = The Data Word has been completely received from the peripheral. 0 = Either the Data Word has not been completely received from the peripheral or this interrupt is disabled in SWIIER.
0	WTI	**Word Transmitted Interrupt** 1 = The Data Word has been completely transmitted to the peripheral. 0 = Either the Data Word has not been completely transmitted to the peripheral or this interrupt is disabled in SWIIER.

21.2.2.6 BMI Single Wire Interface Interrupt Enable Register (SWIIER)

This register, defined in Table 21-18 and Table 21-19, enables and disables the SWI interrupts:

- Write a 1 to an interrupt bit to enable the corresponding interrupt.
- Write a 0 an interrupt bit to disable the corresponding interrupt.
- Read any field to identify whether the corresponding interrupt is enabled or disabled.

The values reported in SWIRISR are bit-wise-ANDed with the values programmed in SWIIER, providing the results in SWIISR.

Table 21-17. SWIIER

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													BRI	WRI	WTI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW
ADDR	0x8000.0F00 + 0x14															

Table 21-18. Single Wire Interface Interrupt Enable Register Fields

BITS	FIELD	DESCRIPTION
31:3	///	**Reserved** Reading returns 0. Write the reset value.
2	BRI	**Break Recovery Interrupt Enable** 1 = Enables the Break Recovered Interrupt. 0 = Disables the Break Recovered Interrupt.
1	WRI	**Word Received Interrupt Enable** 1 = Enables the Word Received Interrupt. 0 = Disables the Word Received Interrupt.
0	WTI	**Word Transmitted Interrupt Enable** 1 = Enables the Word Transmitted Interrupt. 0 = Disables the Word Transmitted Interrupt.

21.2.2.7 BMI Single Wire Interface Timing Register (SWITR)

This register, defined in Table 21-20 and Table 21-21, specifies the bit frame timing in a Command or Data word. Each bit frame includes a Start bit, Data bit, and Stop bit. Program this register with the number of 7.3728 MHz clock cycles (number of periods) required to generate each bit (Start, Data, and Stop). On Reset, this register defaults to 0, which results in a duration of 135 ns for each bit.

This register value is not the data bit rate. Because the value in this register is the time required for each part of a bit frame and the parts are of equal duration, the bit clock based on this register is three times the clock specified in this register.

Since each 7.3728 MHz clock period is 135 ns, the minimum Bit Cycle Time is:

$3 \times 135 \text{ ns} = 405 \text{ ns}$

To determine the correct value for BTG, divide the Bit Cycle Time (bit rate) by 405 ns:

BTG = Bit Cycle Time ÷ 405 ns

For example, to specify a bit cycle time of 200 μs, program BTG = 0x1EE:

200 μs ÷ 405 ns = 494

= 0x1EE

Table 21-19. SWITR

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	BTG															
RESET	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F18															

Table 21-20. Single Wire Interface Timing Register Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Write the reset value.
15:0	BTG	**Bit Time Generation** Specifies the number of 7.3728 MHz clock cycles for each part of a Command or Data bit frame.

NOTE: The value programmed into the BTG field must be greater than, or equal to the value programmed in the SWIBR register's SWIB and SWIBR fields.

21.2.2.8 BMI Single Wire Interface Break Register (SWIBR)

The SWI break recovery register, defined in Table 21-22 and Table 21-23, contains the time specifications for the Break and Break Recovery values.

Table 21-21. SWIBR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///								SWIB							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	SWIB				SWIBR											
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F1C															

Table 21-22. SWIBR Fields

BITS	FIELD	DESCRIPTION
31:24	///	**Reserved** Reading returns 0. Write the reset value.
23:12	SWIB	**SWI Break Time** Specifies the number of 7.3728 MHz clock cycles for which SWID must be driven LOW to generate a Break. The following examples demonstrate the range: SWIB = 0xFFF generates a 555 μs Break. SWIB = 0x000 generates a 135 ns Break.
11:0	SWIBR	**SWI Break Recovery Time** Specifies the number of 7.3728 MHz clocks in which SWID must be returned HIGH to generate a Break Recovery.The following examples demonstrate the range: SWIB = 0xFFF generates a 555 μs Break Recovery. SWIB = 0x000 generates a 135 ns Break Recovery.

21.2.2.9 BMI Smart Battery Data Register (SBIDR)

This register, defined in Table 21-24 and Table 21-25, provides access to data in the SBI Receive and Transmit FIFOs.

- Writing SBIDR places data into the Transmit FIFO.
- Reading SBIDR reads data from the Receive FIFO.

Table 21-23. SBIDR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								SBID							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F40															

Table 21-24. SBIDR Fields

BITS	FIELD	DESCRIPTION
31:0	SBID	**SBI Data** A single entry, up to 8 bits wide, of received data or data to be transmitted.

21.2.2.10 BMI Smart Battery Control Register (SBICR)

This register, defined in Table 21-26 and Table 21-27, controls SBI operation. Note that the Fifo Flush bit does not automatically reset itself to 0. Software must program this bit to 0 once the FIFO has been flushed.

Table 21-25. SBICR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///						PEF	BRF	TOC							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	TOC				RX_FDIS	TX_FDIS	DIVFACT								FFLUSH	SBI_EN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F44															

Table 21-26. SBICR Fields

BITS	FIELD	DESCRIPTION
31:26	///	**Reserved** Reading returns 0. Write the reset value.
25	PEF	**Packet Error Code Enabled Flag** 1 = The transfer will contain a PEC following the last data byte. 0 = The transfer will not contain a PEC following the last data byte.
24	BRF	**Block Read Flag** 1 = A Block Read transfer has started. 0 = A Block Read transfer has not started. The total number of bytes to be read is unknown. The first data word received from the Slave indicates the number of data words to be transmitted. This number derived from the first data word is reported in SBCR:READ.
23:12	TOC	**Timeout Count Value** The SBI can generate a Receive Timeout Interrupt (RTI) when the receive FIFO contains data and no more data is received for the number of clock periods specified in this field. 0x001 through 0xFFF = Number of clock periods for the timeout. 0x000 = Disables the counter, preventing any timeout interrupt.
11	RX_FDIS	**Receive FIFO Disable** 1 = Disables the FIFO. The FIFO then holds only a single byte. 0 = Enables the FIFO to hold up to eight entries of 8-bit (1-byte) data.
10	TX_FDIS	**Transmit FIFO Disable** 1 = Disables the FIFO. The FIFO then holds only a single byte. 0 = Enables the FIFO to hold up to eight entries of 8-bit (1-byte) data.

Table 21-26. SBICR Fields (Cont'd)

BITS	FIELD	DESCRIPTION
9:2	DIVFACT	**Divisor Factor** Program this field to specify the SBI clock period. The BMI Clock is (XTAL Frequency)/2. For the recommended 14.7456 MHz crystal, the BMI Clock is 7.3728 MHz, with a period of 135.63 ns. Program this value as: (DIVFACT + 1) × 135.63 ns. The following examples demonstrate the range: DIVFACT = 0xFF generates a 34.71 μs clock period (28.81 kHz). DIVFACT = 0x000 generates a 135.63 ns clock period (7.3728 MHz). Note that the minimum frequency the LH7A404 is capable of producing is with DIVFACT = 0xFF (34.71 μs clock period), or 28.81 kHz. This is higher than the minimum frequency allowed by the SMBus specification (10 kHz). Also, the maximum frequency allowed by the SMBus specification is 100 kHz, produced with DIVFACT = 0x49 (100.37 kHz). Any value less than 0x49 produces an invalid SMBus frequency (>100 kHz).
1	FFLUSH	**FIFO Flush** Programming this bit to 1 flushes the FIFO. This bit must be cleared to 0 by software after FIFO is flushed. 1 = Flush the Transmit FIFO. 0 = Do not flush the Transmit FIFO.
0	SBI_EN	**SBI Enable** This bit enables and disables the SBI interface. 1 = Enables SBI operation. 0 = Disables SBI operation.

21.2.2.11 BMI Smart Battery Count Register (SBICOUNT)

This register, defined in Table 21-28 and Table 21-29, specifies the number of bytes to be transferred in each part of any System Management Bus command protocol except Block Read Transfer.

If data is loaded into the FIFO before the SMBus Interface enters IDLE, the state machine can go from GEN-STOP directly to GEN-START, bypassing the IDLE state and not reading the count register again. If the size of the next packet is not the same as the previous packet, for which the old SBICOUNT was read, an error will result.

To avoid these errors, software should sample the TXBUSY bit to ensure the SMBus Interface is in the IDLE state before loading a new byte count in the SBICOUNT resgister.

Table 21-27. SBICOUNT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///	READ						REP				PRE				
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	—	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F48															

Table 21-28. SBICOUNT Fields

BITS	FIELD	DESCRIPTION
31:15	///	**Reserved** Reading returns 0. Write the reset value.
14:10	READ	**Read Byte Count** The value written to this field determines the number of bytes transferred in the Read State.
9:5	REP	**RepeatWrite Count** The value written to this field determines the number of bytes transferred in the RepeatWrite State.
4:0	PRE	**PreWrite Count** The value written to this field determines the number of bytes transferred in the PreWrite State. Note that the reset value of 0x00 is not a valid count. This field must be programmed to a valid count prior to enabling the BMI.

IMPORTANT: In the SMBus Interface, the SBICOUNT register determines how many bytes will be sent or received during the next transaction. SBICOUNT is only read when changing from the IDLE state to GEN-START state. At the completion of a transaction, the SMBus Interface enters the GEN-STOP state. Upon exiting the GEN-STOP state, the TXBUSY status bit is cleared. This is the only indication to software that the interface is idle.

21.2.2.12 BMI Smart Battery Status Register (SBISR)

This register, defined in Table 21-30 and Table 21-31, reports SBI operation status.

Table 21-29. SBISR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///			SBH	CLT	TXUE	RXOE	ACKFAIL	RnW	SLAVE	MASTER	TXBUSY	TXFF	RXFF	TXFE	RXFE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0F4C															

Table 21-30. SBISR Fields

BITS	FIELD	DESCRIPTION
31:13	///	**Reserved** Reading returns 0. Write the reset value.
12	SBH	**Slave Bus Hold** The SBI has received a data byte while the receive FIFO is full. The SMBCLK is held LOW until a location in the receive FIFO becomes available, at which point the Slave will continue to write data into the FIFO then release the SMB. 1 = The SBI Slave block requests to disable the SMB. 0 = Reception has resumed.
11	CLT	**Clock LOW Timeout** This bit indicates that an external peripheral has held the SMBCLK LOW for longer than 25 ms. 1 = An external peripheral has generated a timeout error condition. 0 = No error.
10	TXUE	**Transmit Underrun Error** This bit indicates that data is scheduled to be transmitted but the FIFO is empty. This only occurs if the FIFO has been written to at least once in a current data transfer. TXUE also indicates that the Transmit FIFO has been flushed. Writing to SBIDR clears the error. 1 = Transmit Underrun Error or the Transmit FIFO has been flushed. 0 = The Transmit Underrun Error has been cleared by a Write to SBIDR.
9	RXOE	**Receive Overrun Error** This bit indicates that data has been received but the FIFO is already full. The error is set with the last data byte prior to overrun and the bit is not set until the last byte is read. Reading SMBDR clears this error. 1 = Receive Overrun Error. 0 = Receive Overrun Error cleared by a Read to SBIDR.
8	ACKFAIL	**Acknowledge Fail** This bit is set when the SBI master does not receive an expected ACK signal from a slave following a byte transfer. This bit is not automatically cleared when the interrupt is serviced. Software must clear this bit and clear SBIRISR:AFI, by writing 0b1 to SBIEOI:AFI. 1 = Acknowledge Fail error. 0 = No error.

Table 21-30. SBISR Fields (Cont'd)

BITS	FIELD	DESCRIPTION
7	RnW	**Read/Not Write** This bit reports the data transfer direction. 1 = SBI is receiving data from the peripheral. 0 = SBI is transmitting data to the peripheral.
6	SLAVE	**Slave Mode** This bit indicates that the SBI is in Slave mode. 1 = SBI is in Slave mode. 0 = SBI is not in Slave mode.
5	MASTER	**Master Mode** This bit indicates that the SBI is in Master mode. 1 = The SBI is in Master mode. 0 = The SBI is not in Master mode.
4	TXBUSY	**Transmit Busy** TXBUSY indicates that the Transmit FIFO is not empty or the SBI, as master, is currently transmitting data. 1 = The Transmit FIFO is not empty; or the SBI, as Master, is transmitting data. 0 = The Transmit FIFO is empty and any transmission has finished.
3	TXFF	**Transmit FIFO Full** This bit indicates that the Transmit FIFO is full. 1 = Transmit FIFO is full. 0 = Transmit FIFO is not full.
2	RXFF	**Receive FIFO Full** This bit indicates that the receive FIFO is full. 1 = The receive FIFO is full. 0 = The receive FIFO is not full.
1	TXFE	**Transmit FIFO Empty** This bit indicates that the Transmit FIFO is empty. 1 = The Transmit FIFO is empty. 0 = The Transmit FIFO is not empty.
0	RXFE	**Receive FIFO Empty** This bit indicates that the receive FIFO is empty. 1 = The receive FIFO is empty. 0 = The receive FIFO is not empty.

21.2.2.13 BMI Smart Battery Raw Interrupt Status Register and End-of-Interrupt Register (SBIRISR and SBIEOI)

This location is both the SBI Raw Interrupt Status Register (SBIRISR) and the SBI End-of-Interrupt register (SBIEOI). When reading, this is the SBIRISR; when writing, it is the SBIEOI, as defined in Table 21-31 and Table 21-32:

- As SBIRISR, this register reports the asserted or deasserted status of SBI interrupts. The values reported in SBIRISR are bit-wise-ANDed with the values programmed in SBIIER, providing the results in SBIISR. The results in SBIISR are OR'd together to generate BMIINTR, to be handled by the LH7A400 Interrupt Controller.
- Writing a 1 to a bit in SBIEOI deasserts the corresponding interrupt, except for the FIFO status interrupts. Values written to this register cannot be read back.

The FIFO status interrupts are cleared automatically when the corresponding condition changes.

- The TXI is cleared when the Transmit FIFO becomes more than half full.
- The RXI is cleared when the Receive FIFO becomes more than half empty.
- The RTI is cleared when software reads the data from the Receive FIFO.

Table 21-31. SBIRISR and SBIEOI Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CLTI	STCI	ALI	AFI	RXI	TXI	RTI	MTCI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F50															

Table 21-32. SBIRISR and SBIEOI Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Write the reset value. Written values have no effect on interrupt status.
7	CLTI	**Clock LOW Timeout Interrupt** This interrupt occurs when an external peripheral has held the SBI bus clock LOW for longer than 25 ms, indicating an error. To deassert this interrupt and clear SBIRISR:CLTI, write a 1 to SBIEOI:CLTI. 1 = Clock LOW Timeout Interrupt asserted. 0 = Interrupt cleared.
6	STCI	**Slave Transfer Complete Interrupt** This interrupt is asserted when the SBI, as Slave, has received four bytes of a Modified Write transfer. To deassert this interrupt and clear SBIRISR:STCI, write a 1 to SBIEOI:STCI. 1 = Slave Transfer Complete Interrupt asserted. 0 = Interrupt cleared.

Table 21-32. SBIRISR and SBIEOI Fields (Cont'd)

BITS	FIELD	DESCRIPTION
5	ALI	**Arbitration Lost Interrupt** This interrupt indicates that the SBI, as Master, has lost SMB arbitration. For example, another bus Master is transmitting on the bus, and the LH7A400 SBI is the first to issue a 1. To deassert this interrupt and clear SBIRISR:ALI, write a 1 to SBIEOI:ALI. 1 = Arbitration Lost Interrupt asserted. 0 = Interrupt cleared.
4	AFI	**Acknowledge Fail Interrupt** Assertion of this interrupt indicates that the SBI, as master, has not received an expected ACK signal from the slave after a byte transfer. Writing 0 to this register clears the interrupt and resets the SBISR:ACKFAIL bit. This is not automatically reset; software must clear this bit by writing a 1 to this bit before reception of the next byte. Read 1 = Acknowledge Fail Interrupt asserted. 0 = Interrupt cleared. Write 1 = Reset this bit to 0. 0 = No effect.
3	RXI	**Receive Interrupt** This interrupt occurs when the receive FIFO is half full; that is, contains at least four entries. This interrupt is deasserted, and SBIRISR:RXI cleared, when software has read enough data from SBIDR to leave fewer than four unread entries. 1 = Receive Interrupt asserted. 0 = Interrupt cleared.
2	TXI	**Transmit Interrupt** This interrupt occurs when the Transmit FIFO is half empty; that is, contains no more than four entries. This interrupt is deasserted, and SBIR-ISR:RXI cleared, when software has written enough data to SBIDR to leave fewer than four empty entries. 1 = Transmit Interrupt asserted. 0 = Interrupt cleared. 1 = Transmit Interrupt asserted. 0 = Interrupt cleared. That that his interrupt is asserted whenever the Transmit FIFO contains four or fewer entries, even if transmission is not occuring. To avoid spurrious interrupts, only enable this interrupt during transmission, when the quatity of data to be transferred warrants its use.
1	RTI	**Receive Timeout Interrupt** Assertion of this interrupt occurs when the Receive FIFO contains data available to be read by software, and no more data has been received for the period specified in SBICR:TOC. This interrupt is deasserted, and SBIRISR:RTI cleared, when software reads SBIDR. 1 = Receive Timeout Interrupt asserted. 0 = Interrupt cleared.
0	MTCI	**Master Transfer Complete Interrupt** Interrupt assertion occurs when the SBI, as Master, has completed a data transfer and entered the Stop Condition. To deassert this interrupt and clear SBIRISR:MTCI, write a 1 to SBIEOI:MTCI. 1 = Master Transfer Complete Interrupt asserted. 0 = Interrupt cleared.

21.2.2.14 BMI Smart Battery Interrupt Status Register (SBIISR)

This register, defined in Table 21-34 and Table 21-35, reports the asserted or deasserted status of enabled SBI interrupts. The values reported in SBIRISR are bit-wise-ANDed with the values programmed in SBIIER, providing the results in SBIISR. The results in SBIISR are ORed together to generate the Battery Monitor Interrupt (BMIINTR), to be handled by the LH7A400 Interrupt Controller.

Table 21-33. SBIISR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CLTI	STCI	ALI	AFI	RXI	TXI	RTI	MTCI
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0F54															

Table 21-34. SBIISR Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Write the reset value. Written values have no effect on interrupt status.
7	CLTI	**Clock LOW Timeout Interrupt** This interrupt signals that an external peripheral has held the SBI bus clock LOW for longer than 25 ms, indicating an error. To deassert this interrupt and clear SBIISR:CLTI, write 0b1 to SBIEOI:CLTI. To clear SBIISR:CLTI without deasserting this interrupt, set SBIIER:CLTI. 1 = Clock LOW Timeout Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.
6	STCI	**Slave Transfer Complete Interrupt** This interrupt is asserted when the SBI, as Slave, has received four bytes of a Modified Write transfer. To deassert this interrupt and clear SBIRISR:STCI, write a 1 to SBIEOI:STCI. 1 = Slave Transfer Complete Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.
5	ALI	**Arbitration Lost Interrupt** This interrupt indicates that the SBI, as Master, has lost SMB arbitration. For example, another bus Master is transmitting on the bus, and the LH7A400 SBI is the first to issue a 1. To deassert this interrupt and clear SBIRISR:ALI, write a 1 to SBIEOI:ALI. 1 = Arbitration Lost Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.
4	AFI	**Acknowledge Fail Interrupt** Assertion of this interrupt indicates that the SBI, as Master, has not received an expected ACK signal from the Slave after a byte transfer. To deassert this interrupt and clear SBIRISR:AFI, write a 1 to SBIEOI:AFI. 1 = Acknowledge Fail Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.

Table 21-34. SBIISR Fields (Cont'd)

BITS	FIELD	DESCRIPTION
3	RXI	**Receive Interrupt** This interrupt occurs when the receive FIFO is half full; that is, contains at least four entries. This interrupt is deasserted, and SBIRISR:RXI cleared, when software has read enough data from SBIDR to leave fewer than four unread entries. 1 = Receive Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.
2	TXI	**Transmit Interrupt** This interrupt occurs when the Transmit FIFO is half empty; that is, contains no more than four entries. This interrupt is deasserted, and SBIRISR:RXI cleared, when software has written enough data to SBIDR to leave fewer than four empty entries. 1 = Transmit Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled. Note that his interrupt is asserted *whenever* the Transmit FIFO contains four or fewer entries, even if transmission is not occuring. To avoid spurrious interrupts, only enable this interrupt during transmission, when the quatity of data to be transferred warrants its use.
1	RTI	**Receive Timeout Interrupt** Assertion of this interrupt occurs when the Receive FIFO contains data available to be read by software, and no more data has been received for the period specified in SBICR:TOC. This interrupt is deasserted, and SBIRISR:RTI cleared, when software reads SBIDR. 1 = Receive Timeout Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.
0	MTCI	**Master Transfer Complete Interrupt** Assertion of this interrupt occurs when the SBI, as Master, has completed a data transfer and entered the STOP Condition. To deassert this interrupt and clear SBIRISR:MTCI, write a 1 to SBIEOI:MTCI. 1 = Master Transfer Complete Interrupt is enabled and asserted. 0 = Interrupt cleared or not enabled.

21.2.2.15 BMI Smart Battery Interrupt Enable Register (SBIIER)

This register, defined in Table 21-36 and Table 21-37, enables and disables the SBI interrupts.

- Write a 1 to any field to enable the corresponding interrupt.
- Write a 0 to any field to disable the corresponding interrupt.
- Read any field to identify whether the corresponding interrupt is enabled or disabled.

The values reported in SBIRISR are bit-wise-ANDed with the values programmed in SBIIER, providing the results in SBIISR. The results in SBIISR are ORed together to generate BMIINTR, to be handled by the LH7A400 Interrupt Controller.

Table 21-35. SBIIER Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CLTIE	STCIE	ALE	AFE	RIE	TIE	RTIE	TCIE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0F58															

Table 21-36. SBIIER Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Write the reset value.
7	CLTI	**Clock LOW Timeout Interrupt Enable** 1 = Enables SBIISR:CLTI to be set when CLTI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.
6	STCI	**Slave Transfer Complete Interrupt Enable** 1 = Enables SBIISR:STCI to be set when STCI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.
5	ALI	**Arbitration Lost Interrupt Enable** 1 = Enables SBIISR:ALI to be set when ALI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.
4	AFI	**Acknowledge Failed Interrupt Enable** 1 = Enables SBIISR:AFI to be set when AFI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.

Table 21-36. SBIIER Fields

BITS	FIELD	DESCRIPTION
3	RXI	**Receive Interrupt Enable** 1 = Enables SBIISR:RXI to be set when RXI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.
2	TXI	**Transmit Interrupt Enable** 1 = Enables SBIISR:TXI to be set when TXI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.
1	RTI	**Receive Timeout Interrupt Enable**: 1 = Enables SBIISR:RTI to be set when RTI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.
0	TCI	**Transmit Complete Interrupt Enable** 1 = Enables SBIISR:TCI to be set when TCI is asserted. 0 = Interrupt disabled. This interrupt status appears in SBIRISR but not in SBIISR and does not contribute to BMIINTR.

Chapter 22
Direct Current to Direct Current (DC-DC) Converter Interface

22.1 Theory of Operation

The LH7A400 has two DC-DC Converter interfaces, which, when coupled with a small set of external circuitry, provides two complete DC-DC converters. Each provides pulse-width-modulated (PWM) output with programmable duty cycle, frequency, and polarity. External circuitry completes the conversion, amplification, and filtering process to supply required voltage and current levels. Other applications include audio frequency generation and LCD backlight intensity control.

The DC-DC interface features:

- Dual-drive PWM outputs, with independent closed loop feedback.
- Programmable output frequency selection. Each of eight available frequencies is an integer division of the input clock.
- Programmable duty cycle selection from 0 to 15/16, in intervals of 1/16. Selecting a duty cycle of 0 disables the PWM output.
- Selectable output polarity via hardware input signals during power-on reset. The output polarity specifies positive or negative output signal generation.
- Two selectable frequency and duty cycle configurations using a control input pin.

The DC-DC Converter Interface operation and signals appears in Figure 22-1.

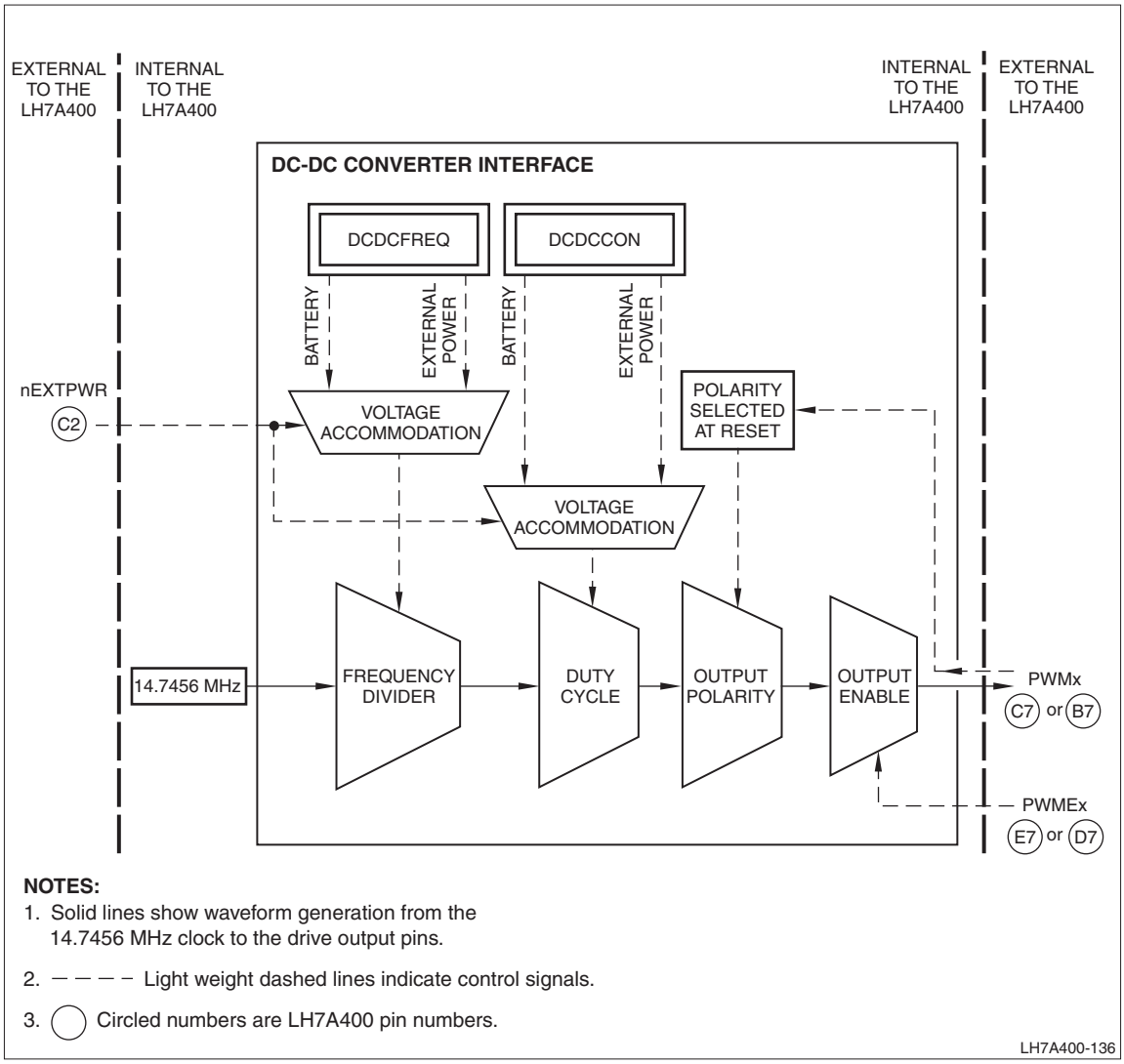


Figure 22-1. DC-DC Converter Interface Functional Diagram

22.1.1 Operation Summary

The two PWMs in the DC-DC interface registers are programmed to provide the required output signals. In addition, external resistors set the polarity, and additional circuitry is necessary to complete a DC-DC converter.

22.1.1.1 Hardware Setup

The polarity (positive or negative) of the output of each PWM is determined at reset by pull-up or pull-down resistors on the output pins (PWM0, pin C7; or PWM1, pin B7), which are kept in a high impedance state during reset. To configure a PWM for positive polarity, a pull-down resistor must be connected to the appropriate PWMx output pin. To configure a PWM for negative polarity, a pull-up resistor must be connected to the PWMx output pin. For proper operation, either a pull-up or pull-down resistor must be connected to output pins. However, if the PWM is not used in the application design, a resistor is not necessary.

The polarity essentially inverts the duty cycle. When positive polarity is selected, the HIGH portion of the output signal is determined by the duty cycle setting (e.g. 20% produces a waveform that is HIGH 20% of the time and LOW 80%). When negative polarity is selected, the LOW portion of the output signal is determined by the duty cycle setting.

The duty cycle control register (DCDCCON) resets to 0x0000, which disables the PWM output signals, leaving the PWMx pins in the high impedance state. As such, static current flow through the external components is minimized until software has programmed the DC-DC converter interface registers.

Each PWM also has an external enable signal, nPWMEx. This signal turns the PWM output on or off, and in the case of a the PWM being used as a DC-DC converter, can be used as a feedback input.

The external power pin (nEXTPWR, pin C2) is internally routed to the PWMs. With this signal, each PWM can be programmed to automatically select different frequency and duty cycle values, depending on whether the application is using battery power or external mains power. Table 22-1 defines the operation. See also the frequency select register (DCDCFREQ) and the duty cycle control register (DCDCCON) for programming details.

Table 22-1. DC-DC Frequency and Duty Cycle Selection

nEXTPWR	POWER	PWMx FREQUENCY	PWMx DUTY CYCLE
LOW	External	DCDCFREQ:PWMxPRELOW	DCDCCON:PWMxDTYLOW
HIGH	Battery	DCDCFREQ:PWMxPREHIGH	DCDCCON:PWMxDTYHIGH

Figure 22-2 shows a simplified schematic for a complete DC-DC converter. Included in the schematic are the polarity setting resistors (RP1 and RP0), the enable signals (nPWMEx) connected as feedback inputs, and the external circuitry to complete the DC-DC converter.

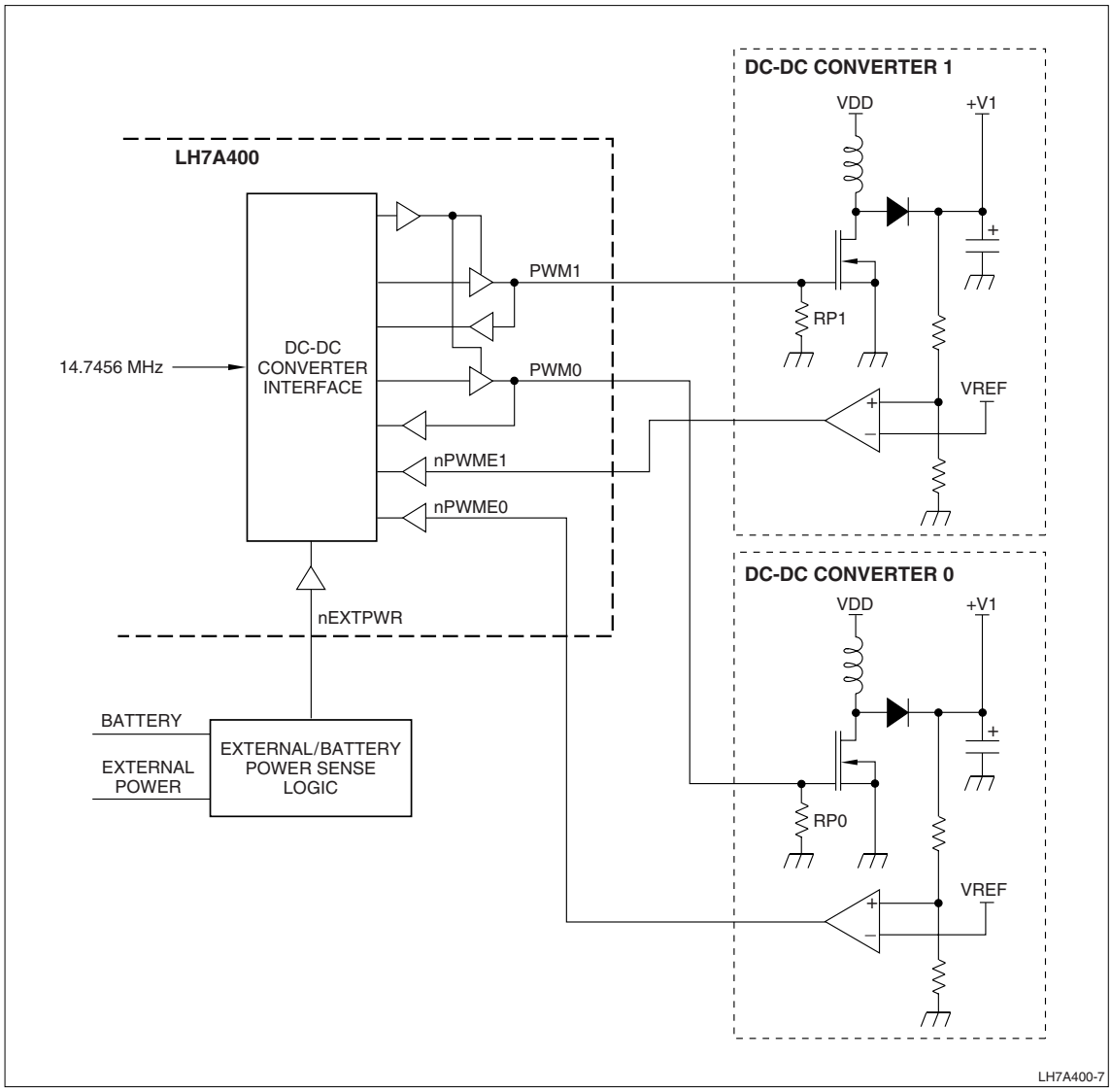


Figure 22-2. Complete DC-DC Converter

22.1.1.2 Programming

The DC-DC converter interface has two registers that control the output signal. The duty cycle is programmed into the duty cycle register (DCDCCON), and the frequency is programmed into the frequency configuration register (DCDCFREQ).

When the reset signal is deasserted, the internal PWMx circuitry becomes active. However, the output at the PWMx pin remains in the high impedance state because DCDCCON resets to 0x0000. This is the case even if the nPWMEx enable signal is asserted.

The DCDCFREQ register resets to 115.2 kHz output frequency for all four fields.

First, program the desired output frequencies into DCDFREQ, then program the duty cycle values into DCDCCON. That way, if the enable pin is already asserted by external hardware, no incorrect frequency signals will appear on the PWMx output pins.

22.2 Register Reference

This section defines the DC-DC Converter Interface registers.

22.2.1 Memory Map

The DC-DC converter interface register offsets shown in Table 22-2 are relative to the DC-DC converter base address, 0x8000.0900.

Table 22-2. DC-DC Converter Interface Memory Map

OFFSET ADDRESS	NAME	DESCRIPTION
0x00	DCDCCON	**DC-DC Converter Configuration** PWM1 and PWM0 duty cycle Configuration register
0x04	///	**Reserved** Reading this address returns 0. Values written to these locations cannot be read back.
0x08	DCDCFREQ	**DC-DC Converter Frequency** PWM1 and PWM0 Frequency configuration register
0x0C - 0xFF	///	**Reserved** Accessing these addresses can cause unpredictable operation.

22.2.2 Register Descriptions

22.2.2.1 DC-DC Duty Cycle Configuration Register (DCDCCON)

This register, shown in Table 22-3 and Table 22-4, specifies the duty cycle for each PWM output for external power or battery powered conditions. Each value in a PWMxDTYy field specifies a duty cycle between 0 to 15/16, as shown in Table 22-5. Clearing a PWMxDTYy field stops the corresponding PWMx waveform generation for the corresponding power source condition.

Table 22-3. DCDCCON Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	PWM1DTYLOW				PWM1DTYHIGH				PWM0DTYLOW				PWM0DTYHIGH			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0900															

Table 22-4. DCDCCON Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading this field returns 0. Values written to this field cannot be read back.
15:12	PWM1DTYLOW	**PWM1 Duty cycle with nEXTPWR LOW** Specifies the duty cycle for PWM1 (pin B7) when the LH7A400 is externally powered. See Table 22-5 for values.
11:8	PWM1DTYHIGH	**PWM1 Duty cycle with nEXTPWR HIGH** Specifies the duty cycle for PWM1 when the LH7A400 is battery powered. See Table 22-5 for values.
7:4	PWM0DTYLOW	**PWM0 Duty cycle with nEXTPWR LOW** Specifies the duty cycle for PWM0 (pin C7) when the LH7A400 is externally powered. See Table 22-5 for values.
3:0	PWM0DTYHIGH	**PWM0 Duty cycle with nEXTPWR HIGH** Specifies the duty cycle for PWM0 when the LH7A400 is battery powered. See Table 22-5 for values.

Table 22-5. Duty Cycle Programming

PWMxDTYy[3:0]	DUTY CYCLE
0x0	Output disabled (high-Z)
0x1	1/16
0x2	2/16
0x3	3/16
0x4	4/16
0x5	5/16
0x6	6/16
0x7	7/16
0x8	8/16
0x9	9/16
0xA	10/16
0xB	11/16
0xC	12/16
0xD	13/16
0xE	14/16
0xF	15/16

22.2.2.2 DC-DC Frequency Configuration Register (DCDCFREQ)

This register, shown in Table 22-6 and Table 22-7, specifies the frequency for each PWM output for external power or battery powered conditions. Each field specifies a value for generating an output frequency from 921.6 kHz down to 7.2 kHz, as shown in Table 22-1.

Table 22-6. DCDCFREQ Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET																
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///	PWM1PRELOW			///	PWM1PREHIGH			///	PWM0PRELOW			///	PWM0PREHIGH		
RESET	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
RW	RO	RW	RW	RW	RO	RW	RW	RW	RO	RW	RW	RW	RO	RW	RW	RW
ADDR	0x8000.0908															

Table 22-7. DCDCFREQ Fields

BITS	FIELD	DESCRIPTION
31:15	///	**Reserved** Reading returns 0. Values written cannot be read.
14:12	PWM1PRELOW	**PWM1 Prescaler with nEXTPWR LOW** Specifies the frequency prescale value for PWM1 (pin B7) when the LH7A400 is externally powered. See Table 22-8 for values.
11	///	**Reserved** Reading returns 0. Values written cannot be read.
10:8	PWM1PREHIGH	PWM1 Prescaler with nEXTPWR HIGH Specifies the frequency prescale value for PWM1 (pin B7) when the LH7A400 is battery powered. See Table 22-8 for values.
7	///	**Reserved** Reading returns 0. Values written cannot be read.
6:4	PWM0PRELOW	**PWM0 Prescaler with nEXTPWR LOW** Specifies the frequency prescale value for PWM0 (pin C7) when the LH7A400 is externally powered. See Table 22-8 for values.
3	///	**Reserved** Reading returns 0. Values written cannot be read.
2:0	PWM0PREHIGH	PWM0 Prescaler with nEXTPWR HIGH Specifies the frequency prescale value for PWM0 (pin C7) when the LH7A400 is battery powered. See Table 22-8 for values.

Table 22-8. Prescale Frequency Selection

DCDCFREQ:PWMxPREy	OUTPUT FREQUENCY
000	921.6 kHz
001	460.8 kHz
010	230.4 kHz
011	115.2 kHz
100	57.6 kHz
101	28.8 kHz
110	14.4 kHz
111	7.2 kHz

Chapter 23
Smart Card Interface (SCI)

23.1 Theory of Operation

The SCI is a block residing on the Advanced Peripheral Bus (APB) providing a communication channel for data transactions between a Smart Card and the LH7A400. This block effectively implements a Smart Card reader. The SCI also meets all criteria contained in the ISO 7816-3 standard. For additional details on the Smart Card Interface, T=0 and T=1 protocols, and other SCI operations, consult the ISO 7816-3 document.

The SCI has these features:

- Converts serial data received from the Smart Card to parallel data used by the LH7A400
- Converts parallel data from LH7A400 to serial data transmitted to the Smart Card
- Provides separate transmit and receive data FIFOs, each buffering up to eight single byte characters
- Implements direct interrupts for transmit and receive FIFO level monitoring
- Supports hardware detection of card insertion and removal
- Supports software or hardware control of activation, deactivation, and reset sequences
- Supports asynchronous T=0 and T=1 protocols, compliant with ISO 7816-3
- Controls Smart Card VCC

Software can control these functions via the SCI registers:

- SCI enable and disable
- Reset, Warm Reset, and Deactivation
- Clock source; clock and I/O multiplexing
- Clock frequency
- The elementary time unit (etu)
- Activation and deactivation durations
- T=0 or T=1 protocol
- Communication baud rate
- Character and block guard times
- Time-outs for debounce, receive data reads, receipt of the first Answer-to-Reset (ATR) character, total ATR duration, and initial waiting time between characters in addition to the guard times.
- Data parity and bit order
- Receive and transmit FIFO watermarks
- Receive and transmit retries.

23.1.1 SCI Operation Summary

After reset, the SCI reverts to its default state for each register. See Section 23.2.2 for definition of the reset state of each register.

Prior to any use of the SCI, it must be initialized, including configuring all multiplexed pins. In particular, the Deactivation Time register (DTIME) must be programmed prior to activating any Smart Card. If this is not done, a Smart Card can be damaged if it is removed prematurely.

After all registers have been initially programmed, the SCI can be enabled (see Section Section 23.1.2). Once enabled, normal communications with Smart Cards via the SCI take place.

23.1.1.1 Card Insertion and Detection

When a Smart Card is inserted, the reader peripheral asserts the SCDETECT signal (pin D6) to notify the LH7A400 that a new card is present. The LH7A400 waits the programmed debounce time (defined in the STABLE register) and if the signal is still valid generates an interrupt. Software services the interrupt and enables the Smart Card in an orderly manner. First, the Smart Card Reset (SCRST, pin A8) is asserted. After a programmed delay, VCC is enabled to the Smart Card by driving SCVCCEN (pin B5) HIGH. After another programmed delay, the clock (SCCLK, pin F8) is enabled. After a delay to allow the clock to stabilize, SCRST is deasserted and the Smart Card is now ready for activation.

23.1.1.2 Activation and Answer-to-Reset (ATR)

Once the initialization sequence completes, software writes a 1 to bit 0 of Control Register 2 (CR2) to begin card activation. This begins the Answer-to-Reset (ATR) sequence from the Smart Card. The ATR sequence contains information about the card requirements for subsequent data transactions. The first character transmitted is the 'TS' character and contains the convention information (direct or inverse format) for all future transactions with this card.

The complete ATR sequence will inform the LH7A400 software about the Smart Card's:

- Clock frequency
- Baud rate
- Guard times
- Protocol type.

This information is retained for all future communications with this particular Smart Card.

23.1.1.3 Transaction Execution

After the ATR sequence, two-way communications between the LH7A400 and the Smart Card can commence. Timing, character length and number, data values, and protocol are all communicated to and from software via SCI registers.

23.1.1.4 Deactivation and Card Removal

After all necessary communications complete, the card can be deactivated and removed. This is an orderly process to avoid damaging the Smart Card. Deactivation takes precedence over all other operations.

Deactivation begins by software writing a 1 to bit 1 of CR2 or by detection of a HIGH on the SCDETECT pin when a card is activated. Upon deactivation initiation the SCRST signal is asserted. After a programmed delay, the SCCKL pin is driven LOW. Following another programmed delay, the SCVCCEN pin (pin B5) is driven LOW, causing power to be removed from the Smart Card. After this sequence, the Card Down Interrupt is asserted, and the Smart Card may be safely removed.

23.1.1.5 Warm Reset

If an error is detected, the software can execute a Warm Reset that resets the Smart Card and re-executes the ATR sequence. Software initiates a warm reset by writing a 1 to CR2, bit 2 (CR2:WRESET).

The following sections describe SCI operation in detail.

23.1.2 Enabling the SCI and Card Signals

Before the SCI can be used, it must be enabled, using this procedure:

1. To gate the reference clock on, program the CONTROL register Enable bit (CONTROL:EN) to 1. When EN = 1, the PCLK clock source is available to the SCI and the registers become programmable. The enable bit must be programmed to 1 prior to septs 2 or 3. GPIO pins are active until the Enable bit is set, which can cause unpredictable results.
2. To detect when a card is present, program the Multiplexing Card Detection bit (CONTROL:MUX_Detect) to 1. Unless this bit is 1, pin D6 operates as GPIO Port F5 and is unavailable to the SCI.
3. To provide the Smart Card supply voltage, program the Multiplexing SCI VCC Enable bit (CONTROL:MUX_VCCEN) to 1. Unless this bit is 1, pin B5 operates as GPIO Port F4 and is unavailable to the SCI.

In addition to power and ground, LH7A400 SCI operation uses the signals defined in Table 23-1. The SCVCCEN Smart Card contact multiplexing is controlled by MUX_VCCEN. The SCDETECT Smart Card Interface pin multiplexing is controlled by MUX_Detect. Reset, clock, and I/O pin multiplexing occurs automatically when the SCI is in operation.

Table 23-1. SCI Pin Multiplexing

PIN	SCI SIGNAL	ISO 7816-3 SMART CARD CONTACT	OTHER LH7A400 SIGNAL
B5	SCVCCEN	Card Supply Voltage Enable(C1: Vcc)	GPIO Port F4
A8	SCRST	Card Reset Input (C2: RST)	Address line A27
F8	SCCLK	Card Clock Input (C3: CLK)	Address line A26
G8	SCIO	Serial Communications (C7: IO)	Address line A25
D6	SCDETECT		GPIO Port F5

23.1.3 Clocking and Timing SCI Operations

The SCI Reference clock, SCIREFCLK, is based on HCLK, the internal system clock. This reference clock is the basis for the elementary time unit (etu) and the free running SCI clock signal (SCCLK, pin F8).

To specify SCIREFCLK, select the divisor for HCLK. To use HCLK/2 as SCIREFCLK, program the CONTROL register pre-divisor bit (CONTROL:PREDIV) to 1. To use HCLK without division, program this bit to 0. In general, SCIREFCLK = HCLK / (PREDIV + 1).

23.1.3.1 Supplying the Smart Card Clock Signal

The SCCLK signal provides the Smart Card Clock (SCCLK, pin F8) and is the timing basis for the activation and deactivation sequences. This signal can be either a free running clock based on SCIREFCLK or a pulse generated via the Synchronous Data register Write clock field (SYNCDATA:WCLK):

- For non ISO 7816-3 compliant Smart Cards, use the Write Clock (WCLK). Program the Asynchronous/Synchronous Clock Multiplexing register Select Clock bit (SYNCCR:SELCLK) to 1. Alternately programming this bit to 1 and 0 generates WCLK pulses on the SCCLK pin. The data must be output on an available GPIO pin, as the SCIO pin (G8) does not function correctly for non-ISO7816-3 compliant cards.
- For ISO 7816-3 compliant Smart Cards, use SCIREFCLK. Program SELCLK to 0 and program SYNCDATA:WCLKEN to 1. Specify the Smart Card Clock Frequency (f) by programming the least significant byte of the Clock Frequency register (CLKDIV) with a value between 0x0 and 0xFF.

  f = SCIREFCLK ÷ ((CLKDIV + 1) × 2).

This CLKDIV programming must be done before programming the Control Register 2 STARTUP bit (CR2:STARTUP) to 1, starting card activation. To drive SCCLK LOW, program WCLKEN to 0.

To monitor the raw SCCLK signal, read the Raw Status register Raw Clock bit (RAWSTAT:RCLK).

The SCCLK must always be operated in the open drain mode by programming CR1:CLKZ1 to 1. SCCLK cannot be used as a buffer output. Maximum SCI clock speed is 5 MHz.

23.1.3.2 Specifying the etu

The etu is the timing basis for the Answer-to-Reset (ATR) duration and data guard times. The pulse width of an etu is one SCIREFCLK. To specify an etu:

- Program the least significant halfword of the SCI Baud Rate register (BAUD) with a number between 0x1 and 0xFFFF
- Program the least-significant halfword of the SCI etu Baud Cycles register (CYCLES) with a number between 0x5 and 0xFFFF
- The relationship between BAUD and CYCLES is such that:
  1 etu = ((BAUD + 1) × CYCLES) ÷ SCIREFCLK.

23.1.4 Detecting, Activating, and Deactivating a Card

Detection of a card is done by hardware. The activation sequence must be managed by software. Deactivation can be done by either hardware or software.

23.1.4.1 Detecting the Card

The SCDETECT signal (pin D6) indicates that a Smart Card is present. This signal is multiplexed with the GPIO Port F5 signal. To use pin D6 for SCI operation, program CONTROL:MUX_Detect to 1. Ensure that CONTROL:EN has been programmed to 1 before programming CONTROL:MUX_Detect.

Card detection involves three steps:

1. A card is inserted, driving the SCDETECT terminal input HIGH.
2. The SCI waits for a programmed debounce time to avoid a false card detection. This debounce time is how long the SCDETECT signal must hold a stable HIGH value before the SCI registers the card insertion.
3. When card detection is confirmed, the Interrupt Identification register Card Inserted Interrupt bit (IIR:CARDININTR) and the Direct Status register Card Present bits (DSTAT:CARDPRESENT) are read as 1.

The debounce time is programmable in terms of SCIREFCLK cycles. To configure the debounce time, program the CR1 Exit Debounce bit (CR1:EXDBNCE) and the LSB of the minimum Stable Time register (STABLE), as follows:

- For no debounce time, program EXDBNCE to 1 and program STABLE 0x00.
- For the minimum nonzero debounce time of 0xFFFF SCIREFCLK cycles, program both EXDBNCE and STABLE to 0.
- For additional multiples of 0xFFFF SCIREFCLK cycles, program EXDBNCE to 0 and program the number of additional multiples into STABLE, up to 0xFF, such that: Debounce time in SCIREFCLK cycles = (STABLE + 1) x 0xFFFF.

23.1.4.2 Activating the Card

When a card has been detected, before the activation sequence ends, configure the SCIO signal (pin G8) as input to the SCI by programming the CR1 register communication direction MODE bit (CR1:MODE) to 0.

If the card is ISO 7816-3 compliant, start activation in this sequence:

1. Configure the SCI for ATR reception.
2. Write the least significant halfword of the SCI Activation Time register (ATIME) to specify the activation event duration. Specify this duration with enough time for the interface power to stabilize, including the minimum required 40,000 SCCLK cycles.
3. Start the activation sequence by programming the CR2:STARTUP bit to 1. Because the activation sequence results appear in DSTAT, do not write DSTAT when activating a card via STARTUP.

The duration programmed into ATIME is one third of the total STARTUP activation time:

1. The first third of the activation sequence enables power to the card and places the data lines at high impedance. The power activation result appears in the DSTAT register POWER field. The data line activation results appear in the DSTAT register off-chip buffer Data Enable (nDATAEN), Data Output Enable (nDATAOUTEN), and Data Enable (DATAEN) bits. If the Card Down Interrupt (IIR: CARDDNINTR) was asserted prior to activation, the activation sequence clears this interrupt.
2. The second third of the sequence enables the card clock. If CR1:CLKZ1 is set, the clock signal appears in the DSTAT register Clock Output bit (DSTAT:CLKOUT); otherwise, the clock signal appears in the Clock Output Buffer Enable bit (DSTAT:nCLKOUTEN).
3. The remainder of the sequence sets the Card Powered-Up Interrupt (IR:CARDUPINTR) and prepares for ATR reception.

For a non-ISO 7816-3 compliant Smart Card, instead of setting STARTUP:

- Perform the full activation sequence by individually writing the DSTAT register Data Enable (DATAEN), Clock Enable (CLKEN), Card Reset (CRESET), and Card VCC Power Supply (POWER) bits. Do not write to these bits when using STARTUP. The results appear in the remaining DSTAT fields.
- If CARDDNINTR was asserted prior to activation, write 1 to the corresponding bit of the Interrupt Clear Register (ICR:CARDDNINTR) to clear the interrupt.

23.1.4.3 Deactivating the Card

Before card deactivation occurs, program the least-significant halfword of the Deactivation Time register (DTIME) to specify the deactivation event duration. This register value is one third of the deactivation sequence time, in SCCLK cycles.

Card deactivation can be started by either:

- Software sets the CR2:FINISH field. A valid card must be detected before FINISH can be written.
- Hardware detects card removal when the SCDETECT signal goes LOW.

The deactivation sequence results appear in the DSTAT and IIR registers:

1. The first third of the sequence, as clocked by DTIME, drives the Smart Card Clock LOW. The DSTAT register nCLKOUTEN, nCLKOUT, and nCLKEN fields are read as 0.
2. The second third of the sequence drives the data lines LOW, clearing the DSTAT register nDATAOUTEN and nDATEAEN fields.
3. The remainder of the sequence deasserts DSTAT:CARDPRESENT. In IIR, the Card Out Interrupt (CARDOUTINTR) and Card Down Interrupt (CARDDNINTR) interrupts are set to 1, and the Card Inserted Interrupt (CARDININTR) is 0.

23.1.5 Handling Answer-to-Reset (ATR)

The card sends an ATR at the following times:

- After activation started via STARTUP is finished.
- In response to a warm reset. Software initiates a warm reset by setting the CR2 Warm RESET bit (CR2:WRESET) after activation is finished.

Before the ATR sequence begins:

- Specify the appropriate time-out limits.
- Clear the protocol register, Control Register 0 (CR0).
- Program the Watermark register Receive Watermark bit (WMARK:RXWMARK) and the Receive Read Time-Out register (RXTIME) with appropriate values.
  RXTIME must be programmed with a value greater than 1 before reception begins. (For more information on RXTIME and WMARK, see Section 23.1.6.)

The time-out limits operate in this manner:

- Assertion of the Card powered-Up Interrupt (IIR:CARDUPINTR) signals the start of the ATR receive countdown. If this countdown reaches 0 before a valid ATR start bit is received, the ATR Start Time-Out Interrupt (IIR:STOUTINTR) is asserted. Program the starting value, in SCCLK cycles, of this countdown in the least significant halfword of the ATR Start Time register (ATRSTIME). A valid start bit is a LOW on the data line for at least 1/2 etu.
- Reception of a valid start bit starts the ATR duration countdown. If this countdown reaches 0 before the end of the ATR block is received, the ATR Duration Time-Out Interrupt (IIR:ATRDTOUTINTR) is asserted. Program the duration value, in etus, of this countdown in the least significant halfword of the ATR Duration Time register (ATRDTIME). After ATR reception ends, disable this duration countdown by clearing the Control Register 1 ATR Duration Enable bit (CR1:ATRDEN).

Clear CR0 with this procedure:

- Specify even transmit parity by programming the Transmit Parity bit (CR0:TXPARITY) to 0.
- Specify even receive parity by programming the Receive Parity bit (CR0:RXPARITY) to 0.
- Enable receive parity checking by programming the Receive Negative Error Acknowledge bit (RXNAK) to 0.
- Disable checking for a receive parity error by programming the Transmit Negative Error Acknowledge field (RXNAK) to 0.
- Specify the direct convention for data bit order by programming the Order bit to 0. In this convention, the Least Significant Bit (LSb) is the first bit following the start bit.
- Specify the direct convention for data and parity bit logic levels by programming the Sense bit to 0. In this convention, a LOW signal is interpreted as a logical 0.

The SCI performs no automatic interpretation of the ATR characters. After the TS byte is received, and before the card sends the T=0 byte, program the Order and Sense bits based on the TS character.

When the ATR protocol information is available, program the CR0 parity and handshaking fields (RXNAK, RXPARITY, TXNAK, and TXPARITY) and the least significant halfword of the Character Time-Out register (SCHCHTIME). These registers specify the protocol parameters used for the remainder of the ATR and subsequent data. During ATR reception:

- Parity errors are recorded in the Data register (DATA) with the erroneous data, but no character retry is performed.
- Excessive time between characters causes a Character Time-Out Interrupt (IIR:CHTOUTINTER). The time allowed between the leading edge of two consecutive characters is SCHCHTIME + 12 for T=0 protocol and SCHCHTIME + 11 for T=1 protocol.

After ATR reception ends:

- For the data character extra guard time, program the Character Guard Time register (CHGUARD), in etus, from the TC1 character received in the ATR. This extra guard time is added to the minimum duration between leading edges of the start bits of two consecutive characters.
- For the block guard time, program the Block Guard Time register (BLKGUARD), in etus, based on the protocol specified in TS. Because the SCI uses a minimum block guard time of 12 etus for T=0 and 11 etus for T=1, adjust the BLKGUARD values accordingly. For the minimum T=0 block guard time of 16 etus, program BLKGUARD with 4 etus. For the minimum T=1 block guard time of 22 etus, program BLKGUARD with 11 etus.

23.1.6 Receiving and Transmitting Data

The SCIO signal (pin G8) carries the receive and transmit data. This signal can be driven by either the SCI FIFOs or the Synchronous Data register Write Data bit (SYNCDATA:WDATA).

- For non-ISO 7816-3 compliant cards, use the Write Data bit (SYNCDATA:WDATA) to transmit data. Program the Synchronous Card Register Select Data source bit (SYNCCR:SELDATA) to 1. Alternately programming WDATA to 1 and 0 drives SCIO HIGH and LOW, respectively.
- For ISO 7816-3 compliant cards, program the Select Data source bit (SYNCCR:SELDATA) to 0 and program the Write Data Enable bit (SYNCDATA:WDATAEN) to 1. Programming the SELDATA bit to 0 uses the SCI FIFO for transmit data. To drive the data line LOW, program WDATAEN to 0.

The Least Significant Byte (LSB) of the DATA register (DATA:DATA) provides software access to the transmit and receive FIFOs. The CR1:MODE field selects the data direction in DATA as transmit or receive. To receive data, program MODE to 0 and read DATA. To transmit data, program MODE to 1 and write DATA. Each FIFO holds eight bytes of single-byte character data.

The transmit FIFO holds data to be sent to the card. To monitor the transmit FIFO contents:

- When the amount of data in the transmit FIFO falls below a specified number of characters, the Transmit Watermark Interrupt (IIR:TXWMARKINTR) is asserted. To specify this mark, program the Watermark register Transmit Watermark Mark field (WMARK:TXWMARK). To prevent generation of TXWMARKINTR, program TXWMARK to 0. The TXWMARKINTR can occur during reception or transmission; that is, regardless of the MODE value.
- When the transmit FIFO is full, the FIFO Register Transmit FIFO Full bit (FR:TXFF) is read as 1. When the transmit FIFO is empty, the FIFO Register Transmit FIFO Empty bit (FR:TXFE) is read as 1.
- To identify the amount of data in the transmit FIFO, read the Transmit Count register Transmit Count field (TXCOUNT:TXCOUNT).
- A character remains in the transmit FIFO until successfully transmitted or flushed. Writing any value to TXCOUNT flushes the transmit FIFO.

The receive FIFO holds data received from the card. To monitor the receive FIFO contents:

- When the amount of data in the receive FIFO rises above a specified number of characters, the Receive Watermark Interrupt (IR:RXWMARKINTR) is asserted. To specify this mark, program the WMARK register RXWMARK field. To prevent generation of RXWMARKINTR, program RXWMARK with a value equal to or greater than 0x8. To generate RXWMARKINTR for each character received, program RXWMARK to 0. The RXWMARKINTR interrupt can occur only during reception; that is, when MODE is programmed to 0.
- When the receive FIFO is full, the FIFO Register Receive FIFO Full bit (FR:RXFF) is read as 1. When the receive FIFO is empty, the FIFO Register Receive FIFO Empty bit (FR:RXFE) is read as 1.
- To identify the amount of data in the receive FIFO, read the Receive Count register Receive COUNT field (RXCOUNT:RXCOUNT).
- Writing any value to RXCOUNT flushes the transmit FIFO.

Programming TXWMARK or RXWMARK with a value to prevent interrupt generation is different from disabling TXWMARKINTR or RXWMARKINTR:

- When an interrupt is disabled in the Interrupt Enable Register (IER), the corresponding interrupt appears in the Interrupt Identification Register (IIR) but generates no IRQ interrupt for the LH7A400 interrupt controller.
- When TXWMARK or RXWMARK is programmed to prevent interrupt generation, no corresponding interrupt appears in IIR.

When the receive FIFO contains at least one character, and no characters have been read for a specified time, the Receive Time-Out Interrupt (IIR:RTOUTINTR) is asserted. To specify this time in SCCLK cycles, program the least significant halfword of the Receive Time-Out register (RXTIME). A Receive Watermark (RXWMARK) between 0x1 and 0x7 generates an RXWMARKINTR interrupt for every RXWMARK number of characters received. For any message block containing other than an exact multiple of RXWMARK characters, the trailing characters generate no interrupt. To ensure all characters are read from the receive FIFO, program RXTIME to accommodate the number of etus needed to receive RXWMARK characters, plus additional time to allow for interrupt latency. When the characters received are too few to assert RXWMARKINTR, and are not read, RTOUTINTR is asserted.

The receive FIFO also provides a Parity Error bit with each character (DATA:PARITY). Handshaking based on parity checking is enabled and disabled by the CR0:RXNAK and TXNAK bits. Program these bits based on the protocol selected in CR0 (T=0 or T=1). When parity check handshaking is in effect:

- Setting TXNAK specifies the T=0 protocol. When a character is incorrectly received by the card, the SCI retransmits the character up to the number of times specified in the RETRY register Transmit Retry field (RETRY:TXRETRY). If the card never receives the character correctly within the specified number of retries, the Transmission Error Interrupt (IIR:TXERRINTR) is asserted. Before the next character can be transmitted, the error condition must be cleared by flushing the transmit FIFO.
- With RXNAK set, when a character is incorrectly received, the SCI requests retransmission from the card up to the number of times specified in the Receive Retry field (RETRY:RXRETRY). If the SCI never receives the character correctly within the specified number of retries, the parity flag is set for the character (DATA:PARITY).

The character-to-character time-out, programmed into SCHCHTIME during the ATR, also applies to data reception. Excessive time between the leading edge of two consecutive characters causes CHTOUTINTER.

For transmission, the Character Guard Time register (CHGUARD) specifies the time, in etus, to be inserted between the leading edges of two consecutive characters sent from the SCI to the card. This value depends on the protocol and is derived from the ATR TC1 character.

When switching from transmission to reception, the SCI sends a character to the card giving the card permission to send. After sending this character, the SCI starts a time-out counter using the value in the least significant halfword of the Block Time-Out register (BLKTIME). If none of the following occurs before the time-out, the BLKTOUTINTR is asserted, indicating the expected reception has timed-out:

- The SCI receives the start bit of the expected character from the card.
- The CR1:MODE bit reads as 1, indicating the SCI is transmitting.
- The CR1:BLKEN bit reads as 1, disabling the time-out.

When switching from reception to transmission, the SCI observes two protocol-dependent timing requirements:

- A minimum time, in etus, between the leading edge of the last start bit received from the card and the leading edge of the first start bit transmitted by the SCI. For T = 0, this time is 12 etus. For T = 1, this time is 11 etus.
- An additional time, in etus, specified in the Block Guard time register (BLKGUARD). For T = 0, BLKGUARD must be greater than or equal to 4. For T = 1, BLKGUARD must be greater than or equal to 11. For no additional time, program the CR1 register Block Guard Time Enable bit (CR1:BGTEN) to 0.

The transmitted data appears in the DSTAT register Data Output Enable bit (DSTAT:nDATAOUTEN), after any inversion specified by CR0:SENSE. When a character has been fully transmitted, including the parity bit, the DSTAT register Data Enable bit (DSTAT:nDATAEN) is read as 1 until a retry request is received or the next start bit is to be sent.

23.1.7 SCI In Standby Mode

The SCI must be disabled prior to the LH7A404 entering Standby mode. Failure to do so may result in spurious interrupts or unpredictable operation. Therefore, the SCI must be disabled prior to entering Standby, and the re-enabled upon exiting Standby.

23.1.8 Boundary Scan Mode

The Smart Card I/O pin is always tri-stated when the LH7A400 is in JTAG mode. Therefore, the pin cannot be tested in boundary scan mode, and cannot be used for connectivity testing on a board.

23.2 Register Reference

This section describes the SCI registers.

23.2.1 Memory Map

The SCI registers are shown in Table 23-2 offset from the base address, 0x8000.0300.

Table 23-2. Smart Card Interface Memory Map

ADDRESS OFFSET	NAME	DESCRIPTION
0x00	DATA	**Transmit and Receive Data** Read data from the receive FIFO; write data to the transmit FIFO.
0x04	CR0	**Control Register 0** Protocol control
0x08	CR1	**Control Register 1** Interface control
0x0C	CR2	**Control Register 2** Activation, Deactivation, and Warm Reset control
0x10	IER	**Interrupt Enable Register** Enable IRQ interrupt generation
0x14	RETRY	**Retry** Transmit and receive retry limits
0x18	WMARK	**Watermark** Transmit and receive FIFO watermarks
0x1C	TXCOUNT	**Transmit Count** Read amount of data in transmit FIFO; write to flush transmit FIFO
0x20	RXCOUNT	**Receive Count** Read amount of data in receive FIFO; write to flush receive FIFO
0x24	FR	**FIFO Register** FIFO status
0x28	RXTIME	**Receive Time-Out Register** Receive FIFO read time-out limit
0x2C	DSTAT	**Direct Status Register** Smart Card status, providing direct access to Smart Card signals for non-compliant configurations.
0x30	STABLE	**Stable Time Register** Debounce time
0x34	ATIME	**Activation Time Register** Minimum duration for activation
0x38	DTIME	**Deactivation Time Register** Minimum duration for deactivation
0x3C	ATRSTIME	**Answer-to-Reset Start Time-Out Register** Reset-to-start of ATR time-out limit
0x40	ATRDTIME	**Answer-to-Reset Duration Time-Out Register** ATR duration time-out limit
0x44	BLKTIME	**Block Time-Out Register** Receive time-out limit between blocks
0x48	CHTIME	**Character Time-Out Register** Character-to-character time-out limit
0x4C	CLKDIV	**Clock Frequency Register** Smart Card Clock frequency
0x50	BAUD	**Baud Register** Baud rate
0x54	CYCLES	**Baud Cycles Register** Baud cycle
0x58	CHGUARD	**Character Guard Register** Character-to-character extra guard time
0x5C	BLKGUARD	**Block Guard Register** Block guard time
0x60	SYNCCR	**Synchronous Control Register** Software vs. hardware control for the Smart Card clock and I/O lines
0x64	SYNCDATA	**Synchronous Data Register** Values for software control of the Smart Card clock and I/O lines
0x68	RAWSTAT	**Raw Status Register** Raw I/O and clock status
0x6C	IIR	**Interrupt Identification Register** Read this register to identify interrupt sources.
	ICR	**Interrupt Clear Register** Write to this register to clear interrupts.
0x70	CONTROL	**Control Register** Pin multiplexing, reference clock scaling, and power
0x74 - 0xFC	///	**Reserved**

23.2.2 Register Descriptions

23.2.2.1 Data Register (DATA)

This register, defined in Table 23-3 and Table 23-4, provides access to the transmit and receive FIFOs.

Table 23-3. DATA Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///							PARITY	DATA							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0300															

Table 23-4. DATA Fields

BITS	FIELD	DESCRIPTION
31:9	///	**Reserved** Reading returns 0. Values written cannot be read.
8	PARITY	**Parity Error** 1 = Parity error in DATA field 0 = Valid data
7:0	DATA	**Transmit or receive DATA** To write a character to the transmit FIFO, program CR1:MODE to 1 and write the character to this field. To read a character from the receive FIFO, program CR1:MODE to 0 and read the character from this filed.

23.2.2.2 Control 0 Register (CR0)

This register, defined in Table 23-5 and Table 23-6, configures the protocol parameters.

Table 23-5. CR0 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										RXNAK	RXPARITY	TXNAK	TXPARITY	ORDER	SENSE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0304															

Table 23-6. CR0 Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	RXNAK	**Receive Negative Error Acknowledge** 1 = T=0 protocol 0 = T=1 protocol. The SCI pulls the I/O line LOW after detecting a parity error.
4	RXPARITY	**Receive Parity** Selects the receive parity. 1 = Odd parity 0 = Even parity
3	TXNAK	**Transmit Negative Error Acknowledge** 1 = T=0 protocol. The SCI checks the I/O line level for a parity error after each character transmission. 0 = T=1 protocol
2	TXPARITY	**Transmit Parity** Selects the transmit parity. 1 = Odd parity 0 = Even parity
1	ORDER	**Data Bit Order** Selects the transmit and receive data endianness: 1 = Specifies the inverse convention. The MSB is the first bit after the start bit. 0 = Specifies the direct convention. The LSB is the first bit after the start bit.
0	SENSE	**Data and Parity HIGH and LOW Sense** Specifies the active level for data and parity bits: 1 = Specifies inverse convention. A 0 data or parity value appears as HIGH on SCIO. 0 = Specifies direct convention.

23.2.2.3 Control 1 Register (CR1)

This register, defined in Table 23-7 and Table 23-8, configures the interface.

Table 23-7. CR1 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										EXDBNCE	BGTEN	CLKZ1	MODE	BLKEN	ATRDEN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0308															

Table 23-8. CR1 Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	EXDBNCE	**Enable Bypass for Debounce** Specifies whether to use the non-programmable part of the internal debounce timer. 1 = Bypass the non-programmable section of the internal debounce timer. For a zero debounce time, program EXDBNCE to 1 and STABLE to 0. 0 = Use both the non programmable and programmable parts of the debounce timer. The debounce time = (STABLE + 1) × 0xFFFF.
4	BGTEN	**Block Guard Timer Enable** 1 = Starts the block guard timer. 0 = Stops the block guard timer.
3	CLKZ1	**Clock Z1 Configuration** Configures the SCCLK output pad: 1 = This bit must be programmed to 1 to configure the SCCLK as open drain. Use this configuration with an external pull-up resistor. 0 = Do not program this bit to 0.
2	MODE	**Receive or Transmit Mode** Selects the SCIO signal directions: 1 = Transmit (from SCI to Smart Card) 0 = Receive (from Smart Card to SCI)
1	BLKEN	**Block Time-Out Enable** 1 = Starts the block timer. 0 = Stops the block timer.
0	ATRDEN	**Answer-to-Reset Duration Enable** 1 = Starts the ATR duration timer. 0 = Stops the ATR duration timer.

23.2.2.4 Control 2 Register (CR2)

This register, defined in Table 23-9 and Table 23-10, initiates activation, deactivation, and warm reset events. Avoid writing this register during deactivation.

Table 23-9. CR2 Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///													WRESET	FINISH	STARTUP
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	WO	WO	WO
ADDR	0x8000.030C															

Table 23-10. CR2 Fields

BITS	FIELD	FUNCTION
31:3	///	**Reserved** Reading returns 0. Values written cannot be read.
2	WRESET	**Warm Reset** 1 = Initiate a warm reset. 0 = Normal operation. This bit can only be written after activation ends.
1	FINISH	**Finish Card Session** 1 = Deactivate Smart Card. 0 = Normal operation. This bit can only be written if a valid card is present (DSTAT:CARDPRESENT is 1).
0	STARTUP	**Start-up Card Session** 1 = Activate Smart Card. 0 = Normal Operation. This bit can only be written if a valid card is present (DSTAT:CARDPRESENT is 1).

23.2.2.5 Interrupt Enable Register (IER)

This register, defined in Table 23-11 and Table 23-12, controls the inclusion of individual interrupts in the composite SCI Interrupt (SCIINTR).

Interrupts are enabled and disabled using this register:

- To enable an interrupt, program the corresponding IER bit to 1.
- To disable an interrupt, program the corresponding IER bit to 0.

Both enabled and disabled interrupts can be asserted in Interrupt Identification Register (IIR). Enabled asserted interrupts are ORed together to generate SCIINTR, sent as an IRQ interrupt to the LH7A400 interrupt controller.

Table 23-11. IER Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				TXWMARKIE	RXWMARKIE	RTOUTIE	CHTOUTIE	BLKTOUTIE	ATRDTOUTIE	ATRSTOUTIE	TXERRIE	CARDDNIE	CARDUPIE	CARDOUTIE	CARDINIE
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0310															

Table 23-12. IER Fields

BITS	FIELD	DESCRIPTION
31:12	///	**Reserved** Reading returns 0. Values written cannot be read.
11	TXWMARKIE	**Transmit Watermark Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
10	RXWMARKIE	**Receive Watermark Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
9	RTOUTIE	**Receive Time-Out Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
8	CHTOUTIE	**Character Time-Out Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
7	BLKTOUTIE	**Block Time-Out Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.

Table 23-12. IER Fields

BITS	FIELD	DESCRIPTION
6	ATRDTOUTIE	**Answer-to-Reset Duration Time-Out Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
5	ATRSTOUTIE	**Answer-to-Reset Start Time-OUT Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
4	TXERRIE	**Transmit Error Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
3	CARDDNIE	**Card Power-Down Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
2	CARDUPIE	**Card Power-Up Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
1	CARDOUTIE	**Card Taken-Out Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.
0	CARDINIE	**Card Inserted Interrupt Enable** 1 = Interrupt enabled. 0 = Interrupt disabled.

23.2.2.6 Retry Limit Register (RETRY)

This register, defined in Table 23-13 and Table 23-14, configures the number of transmit and receive retries allowed for a character.

For T = 0 protocol, with CR0:TXNAK set, TXRETRY specifies the maximum number of retransmission attempts for a character incorrectly received by the card, before the SCI stops transmission and generates a TXERR interrupt. For normal T=0 operation, TXRETRY = 0b011, specifying three retries. Programming TXRETRY to 0 specifies no retries, causing a TXERR interrupt to occur as soon as an error is detected.

Using T = 1 protocol, with TXNAK 0, disable character-based handshaking by programming CR0:TXNAK to 0. TXRETRY is unused.

For T=0 protocol, with CR0:RXNAK programmed to 1, RXRETRY specifies the maximum number of retransmission requests of a character after a parity error is detected before setting the DATA register Parity Error bit (DATA:PARITY). For normal T = 0 operation, RXRETRY = 0b011, specifying three retries. Programming RXRETRY to 0b000 specifies no retries, writing the received character to the receive FIFO with no request for retransmission in the event of a parity error.

For T = 1 operation, disable character based handshaking by programming CR0:RXNAK to 0. RXRETRY is unused.

Table 23-13. RETRY Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										RXRETRY			TXRETRY		
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0314															

Table 23-14. RETRY Fields

BITS	FIELD	FUNCTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5:3	RXRETRY	**Receive Retry** Specifies the maximum number of retries to receive when a parity error has occurred.
2:0	TXRETRY	**Transmit Retry** Specifies the maximum number of times to retransmit a character after detecting a parity error.

23.2.2.7 Watermark Register (WMARK)

This register, defined in Table 23-15 and Table 23-16, specifies the trigger points for the TXWMARK and RXWMARK interrupts:

The RXWMARK interrupt indicates the number of characters in the receive FIFO is greater than the value in WMARK:RXWMARK. The RXWMARK interrupt can occur only when CR1:MODE is cleared, specifying receive mode. WMARK:RXWMARK specifies the receive FIFO trigger point:

- Programming WMARK:RXWMARK to 0b0000 causes an interrupt as soon as the receive FIFO is non-empty.
- Any WMARK:RXWMARK value greater than 0b0111 prevents the RXWMARK interrupt.

The TXWMARK interrupt indicates the number of characters in the transmit FIFO is less than the value in WMARK:TXWMARK. WMARK:TXWMARK specifies the transmit FIFO trigger point:

- Programming WMARK:TXWMARK to 0b0000 prevents the TXWMARK interrupt.
- Only values from 0x0 through 0x8 are valid.

TXFIFO can be written only when CR1:MODE is 1 (transmit mode). The TXWMARK interrupt, however, does not depend on MODE. The interrupt can be generated even after the data direction has changed from transmit to receive.

Table 23-15. WMARK Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								RXWMARK				TXWMARK			
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0318															

Table 23-16. WMARK Fields

BITS	FIELD	FUNCTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:4	RXWMARK	**Receive Watermark** Trigger point for RXWMARKINTR
3:0	TXWMARK	**Transmit Watermark** Trigger point for TXWMARKINTR

23.2.2.8 Transmit FIFO Count and Clear Register (TXCOUNT)

These registers show the amount of data in the transmit FIFO when read, and flush the transmit FIFO when written.

Reading this register as the Transmit FIFO Count register (TXCOUNT), defined in Table 23-17 and Table 23-18, returns the number of characters in the transmit FIFO. Writing any value to this register as the Transmit FIFO Clear register (TXFCLEAR), defined in Table 23-23 and Table 23-24, flushes the transmit FIFO.

When an unsuccessful transmission occurs in the T = 0 protocol, the SCI generates a TXERR interrupt and stops transmitting. Before any further characters can be transmitted or received, the error condition must be cleared by flushing the transmit FIFO.

Table 23-17. TXCOUNT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											TXCOUNT				
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.031C															

Table 23-18. TXCOUNT Fields

BITS	FIELD	FUNCTION
31:5	///	**Reserved** Reading returns 0. Values written cannot be read.
4:0	TXCOUNT	**Transmit Count** Reading this field returns the number of characters, including any character currently being transmitted, in the transmit FIFO. Values written to this field cannot be read back.

Table 23-19. TXCLEAR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	TXCOUNTCLR															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	TXCOUNTCLR															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.031C															

Table 23-20. TXCOUNT Fields

BITS	FIELD	FUNCTION
31:0	TXCOUNTCLR	**Transmit FIFO Clear** Writing any value to this register flushes the transmit FIFO. Values written to this register cannot be read back.

23.2.2.9 Receive FIFO Count and Clear Register (RXCOUNT)

These registers show the amount of data in the receive FIFO when read, and flush the receive FIFO when written to.

Reading this register as the Receive FIFO Count register (RXCOUNT), defined in Table 23-21 and Table 23-22, returns the number of characters in the receive FIFO. Writing any value to this register as the Receive FIFO Clear register (RXFCLEAR), defined in Table 23-23 and Table 23-24, flushes the receive FIFO.

Table 23-21. RXCOUNT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///											RXCOUNT				
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW
ADDR	0x8000.0320															

Table 23-22. RXCOUNT Fields

BITS	FIELD	DESCRIPTION
31:5	///	**Reserved** Reading returns 0. Values written cannot be read.
4:0	RXCOUNT	**Receive Count** Reading this field returns the number of characters in the receive FIFO. Values written to this field cannot be read back.

Table 23-23. RXCLEAR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	RXCOUNTCLEAR															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RXCOUNTCLEAR															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO	WO
ADDR	0x8000.0320															

Table 23-24. RXCLEAR Fields

BITS	FIELD	DESCRIPTION
31:0	RXCOUNTCLR	**Receive FIFO Clear** Writing any value to this register flushes the receive FIFO. Values written to this register cannot be read back.

23.2.2.10 FIFO Status Register (FR)

This register, defined in Table 23-25 and Table 23-26, reports the transmit and receive FIFO status.

Table 23-25. FR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												RXFE	RXFF	TXFE	TXFF
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0324															

Table 23-26. FR Field

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	RXFE	**Receive FIFO Empty** 1 = The receive FIFO is empty. 0 = The receive FIFO is not empty.
2	RXFF	**Receive FIFO Full** 1 = The receive FIFO is full. 0 = The receive FIFO is not full.
1	TXFE	**Transmit FIFO Empty** 1 = The transmit FIFO is empty. 0 = The transmit FIFO is not empty.
0	TXFF	**Transmit FIFO Full** 1 = The transmit FIFO is full. 0 = The transmit FIFO is not full.

23.2.2.11 Receive Read Time-Out Register (RXTIME)

This register, defined in Table 23-27 and Table 23-28, specifies the time-out limit in SCCLK cycles for data to remain unread in the receive FIFO.

This register must be programmed with a nonzero value before FIFO reception begins. Avoid clearing this register.

A Read Time-Out Interrupt (IR:RTOUTINTR) occurs when the receive FIFO contains at least one character, and no characters have been read for the time in Smart Card Clock cycles specified in this register.

Table 23-27. RXTIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	RXTIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0328															

Table 23-28. RXTIME Fields

BITS	FIELD	FUNCTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	RXTIME	**Receive Read Time-Out** Specify the time-out limit in SCCLK cycles for data to remain unread in the receive FIFO.

23.2.2.12 Direct Status Register (DSTAT)

This register, defined in Table 23-29 and Table 23-30, provides direct access to Smart Card signals, required only for ISO 7816-3 noncompliant configurations. This register is updated automatically during activation, deactivation and warm reset events.

The SCI has no separate bit to distinguish between ISO 7816-3 compliant and noncompliant cards. Software must follow the appropriate sequences to ensure correct and consistent behavior, as follows:

- For noncompliant cards, do not write STARTUP; perform the activation sequence via explicit writes to DSTAT.
- For compliant cards, set STARTUP, and avoid writing DSTAT.
- Avoid writing DSTAT during card validation via the hardware debounce mechanism.
- Writing DSTAT has no effect during deactivation.

For ISO 7816-3 noncompliant cards, the clock and data lines are driven by software after activation:

- When the Synchronous Control Register Select Clock bit (SYNCCR:SELCLK) is 1, the nCLKEN output and the Smart Card clock are controlled by the Synchronous Data register (SYNCDATA) Write Clock Enable (WCLKEN) and Write Clock (WCLK) bits, respectively.
- When the Select Data bit (SYNCCR:SELDATA) is 1, the nDATAEN output and the nDATAOUTEN output are controlled by the SYNCDATA Write Data Enable bit (WDATAEN) and Write Data bit (WDATA) respectively.

Table 23-29. DSTAT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///						CARDPRESENT	nDATAEN	nDATAOUTEN	CLKOUT	nCLKEN	nCLKOUTEN	DATAEN	CLKEN	CRESET	POWER
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	0x8000.032C															

Table 23-30. DSTAT Fields

BITS	FIELD	DESCRIPTION
31:10	///	**Reserved** Reading returns 0. Values written cannot be read.
9	CARDPRESENT	**Card Present** 1 = A Smart Card is present. 0 = No Smart Card present.
8	nDATAEN	**Data Enable** This bit is the control signal for external tristate data input buffers. 1 = Input data enabled. 0 = Input data not enabled.
7	nDATAOUTEN	**Data Output Enable** This bit is the control signal for external tristate data output buffers. 1 = Data output enabled. 0 = Data output not enabled.
6	CLKOUT	**Clock Output** Smart Card clock output.
5	nCLKEN	**Clock Enable** 1 = SCCLK enabled. 0 = SCCLK not enabled.
4	nCLKOUTEN	**Clock Output Enable** This bit is the control signal for external tristate clock output buffers. 1 = Clock output enabled. 0 = Clock output not enabled.
3	DATAEN	**Data Enable** Smart Card data enable. 1 = Smart Card data enabled. 0 = Smart Card data forced LOW.
2	CLKEN	**Clock Enable** Smart Card clock enable. 1 = Smart Card clock enabled. 0 = Smart Card clock forced LOW.
1	CRESET	**Card Reset** 1 = Reset Smart Card. 0 = Normal operation.
0	POWER	**Power** 1 = Smart Card VCC enabled. 0 = Smart Card VCC not enabled.

23.2.2.13 Debounce Timer Register (STABLE)

This register, defined in Table 23-31 and Table 23-32, specifies how long the SCDETECT signal must hold a stable HIGH value, before the interface registers the card insertion. This debounce time is measured in SCIREFCLK cycles.

The Card Inserted Interrupt (CARDININTR) indicates when the card insertion is registered. Either of the following resets CARDININTR:

- Completing card deactivation
- Card removal.

Clear CR1:EXDBNCE and write the Least Significant Byte (LSB) of STABLE to specify the debounce time as (STABLE + 1) × (0xFFFF). Program EXDBNCE to 1 and STABLE to 0 to specify a zero debounce time.

Table 23-31. STABLE Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								STABLE							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0330															

Table 23-32. STABLE Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	STABLE	**Stable Debounce Time** Specifies the debounce time, measured in SCIREFCLK cycles.

23.2.2.14 Activation Time Register (ATIME)

This register, defined in Table 23-33 and Table 23-34, specifies one-third of the minimum duration, in SCCLK cycles, for card activation. The SCI uses ATIME as the duration for each of the three stages of activation. Program ATIME to satisfy the minimum SCRST signal LOW time of 40,000 cycles (0xC40), plus any additional time required for the interface power to stabilize.

Table 23-33. ATIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	ATIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0334															

Table 23-34. ATIME Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	ATIME	**Activation Time** Specifies the minimum duration for each stage of card activation, in SCCLK cycles.

23.2.2.15 Deactivation Event Time Register (DTIME)

This register, defined in Table 23-35 and Table 23-36, specifies one third of the minimum duration, in SCIREFCLK cycles, for card activation. The SCI uses ATIME as the duration for each of the three stages of activation.

Table 23-35. DTIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	DTIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0338															

Table 23-36. DTIME Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	DTIME	**Deactivation Time** Specifies the minimum duration for each stage of card deactivation, measured in SCIREFCLK cycles.

23.2.2.16 ATR Reception Start Time Register (ATRSTIME)

This register, defined in Table 23-37 and Table 23-38, specifies the receive time-out limit, in SCCLK cycles, from the deassertion of SCRST to the start of the first ATR character. This time-out asserts the Answer-to-Reset Start Time-Out Interrupt (IIR:ATRSTOUTINTR). Program ATRSTIME with a minimum of 40,000 cycles (0xC40).

Table 23-37. ATRSTIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	ATRSTIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.033C															

Table 23-38. ATRSTIME Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	ATRSTIME	**Answer-to-Reset Start Time** Specifies the time-out limit from the deassertion of SCRST to the start of the first ATR character.

23.2.2.17 ATR Duration Register (ATRDTIME)

This register, defined in Table 23-39 and Table 23-40, specifies the time-out limit of the ATR message block, from the start bit of the first ATR character until the end of the final character. This value is specified in elementary time units (etus).

This time-out asserts the Answer-to-Reset Duration Time-Out Interrupt (IIR:ATRDTOUTINTR). This timer runs when CR1:ATRDEN is set. After receiving the ATR block, stop the timer by clearing CR1:ATRDEN.

Table 23-39. ATRDTIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	ATRDTIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0340															

Table 23-40. ATRDTIME Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	ATRDTIME	**Answer-to-Reset Duration Time** Specifies the ATR message reception time-out limit, measured in etus.

23.2.2.18 Receive Block Time-Out Register (BLKTIME)

This register, defined in Table 23-41 and Table 23-42, specifies the receive time-out limit between blocks. This limit is the maximum time between:

1. The leading edge of the most recent character giving permission to send to the card.
2. The first character sent by the card.

This time-out asserts the Block Time-Out Interrupt (IIR:BLKTOUTINTR).

BLKTIME applies to both T=0 and T=1 protocols:

- For T=0, the SCI adds 12 etus to the value in BLKTIME. Write BLKTIME as the time-out limit in etus, minus 12.
- For T=1, the SCI adds 11 etus to the value in BLKTIME. Write BLKTIME as the required time-out limit in etus, minus 11.

The protocol is specified in CR0:TXNAK.

BLKTIME does not apply to ATR reception. ATRSTIME is used for the time-out limit for receiving the first ATR character.

Table 23-41. BLKTIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	BLKTIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0344															

Table 23-42. BLKTIME Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	BLKTIME	**Block Time** Specifies the block receive time-out limit.

23.2.2.19 Character-to-Character Time-Out Register (CHTIME)

This register, defined in Table 23-43 and Table 23-44, specifies the maximum time in etus between the leading edge of two consecutive characters. The time-out asserts the Character Time-Out Interrupt (IIR:CHTOUTINTR).

This time-out applies to ATR reception and to both T = 0 and T = 1 protocols:

- For T = 0, the time between characters is the Work Waiting Time (WWT). The SCI adds 12 etus to the value in CHTIME. Write CHTIME as the required time-out limit in etus, minus 12.
- For T = 1, the time between characters is the Character Waiting Time (CWT), and the respective characters must reside in the same block. The SCI adds 11 etus to the value in CHTIME. Write CHTIME as the required time-out limit in etus, minus 11.

The protocol is specified in CR0:TXNAK.

Table 23-43. CHTIME Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	CHTIME															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0348															

Table 23-44. CHTIME Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	CHTIME	**Character Time** Specifies the character-to-character time-out limit.

23.2.2.20 Clock Frequency Register (CLKDIV)

This register, defined in Table 23-45 and Table 23-46, specifies the Smart Card Clock (SCCLK) frequency (f) based on the Reference Clock (SCIREFCLK). The SCIREFCLK clock is specified in the CONTROL register Pre-Divide field (CONTROL:PREDIV). The Least Significant Byte (LSB) of CLKDIV is used to specify f as follows:

$$fF = (\text{SCIREFCLK}) \div (\text{CLKDIV} + 1) \times 2$$

Program CLKDIV before using CR2:STARTUP or DSTAT to enable SCCLK.

Table 23-45. CLKDIV Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CLKDIV							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.034C															

Table 23-46. CLKDIV Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	CLKDIV	**Clock Frequency Divisor** Specifies SCCLK based on SCIREFCLK, as defined in the formula above.

23.2.2.21 Baud Rate Register (BAUD)

This register, defined in Table 23-47 and Table 23-48, specifies the divisor used with the Least Significant Byte (LSB) of CYCLES to generate a baud rate clock based on SCIREFCLK. The SCIREFCLK value is specified in the CONTROL register PRE-DIVide field (CONTROL:PREDIV). The least significant halfword of BAUD is used to specify the baud rate as follows:

$$1\ etu = ((BAUD + 1) \times CYCLES) \div SCIREFCLK$$

This register must be programmed with a nonzero value before communication begins. Avoid clearing this register.

Table 23-47. BAUD Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	BAUD															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0350															

Table 23-48. BAUD Fields

BITS	FIELD	DESCRIPTION
31:16	///	**Reserved** Reading returns 0. Values written cannot be read.
15:0	BAUD	**Baud Rate Divisor** Specifies divisor used to generate the baud rate clock, based on the formula above.

23.2.2.22 Baud Cycles Register (CYCLES)

This register, defined in Table 23-49 and Table 23-50, specifies the number of BAUD cycles per etu, as follows:

1 etu = ((BAUD + 1) × CYCLES) ÷ SCIREFCLK

Write this register with any value between 0x05 and 0xFF.

Table 23-49. CYCLES Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								VALUE							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0354															

Table 23-50. CYCLES Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	VALUE	**Baud Value** Specifies the number of BAUD cycles per etu, based on the formula above.

23.2.2.23 Character-to-Character Guard Time Register (GUARD)

This register, defined in Table 23-52 and Table 23-53, specifies the extra guard time added to the minimum duration between leading edges of the start bits of two consecutive characters, for subsequent communication from the interface to the Smart Card.

CHGUARD is derived from the TC1 value extracted from the ATR character stream, as shown in Table 23-51. The protocol is specified in CR0:TXNAK.

Table 23-51. Character-to-Character Guard Times for TC0 and TC1

TC1 VALUE	CHGUARD		GUARD TIME (etu)	
	T = 0	T = 1	T = 0	T = 1
0 ≤ TC1 < 255	TC1	TC1 + 1	TC1 + 12	TC1 + 11
TC1 = 255	0	0	12	11

Table 23-52. GUARD Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								CHGUARD							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.0358															

Table 23-53. GUARD Fields

BITS	FIELD	DESCRIPTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	CHGUARD	**Character Guard** Specifies the minimum duration between the leading edges of the start bits of two consecutive characters for subsequent communication from the SCI to the Smart Card.

23.2.2.24 Block Guard Time Register (BLKGUARD)

This register, defined in Table 23-54 and Table 23-55, specifies the minimum time in etus between the leading edges of two consecutive characters sent in opposite directions. This guard time depends on the protocol:

- For T=0, the SCI adds 12 etus to the value in BLKGUARD. Write BLKGUARD as the required time-out limit in etus, minus 12. Because the BLKGUARD minimum time is 16 etus, the minimum programmable BLKGUARD value is 4.
- For T=1, the SCI adds 11 etus to the value in BLKGUARD. Write BLKGUARD as the required time-out limit in etus, minus 11. Because the BLKGUARD minimum time is 22 etus. the minimum programmable BLKGUARD value is 11.

The protocol is specified in CR0:TXNAK.

Table 23-54. BLKGUARD Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///								BLKGUARD							
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.035C															

Table 23-55. BLKGUARD Fields

BITS	FIELD	FUNCTION
31:8	///	**Reserved** Reading returns 0. Values written cannot be read.
7:0	BLKGUARD	**Block Guard** Specifies the minimum time, in etus, between the leading edges of two consecutive characters sent in opposite directions

23.2.2.25 Asynchronous and Synchronous Multiplexing Register (SYNCCR)

This register, defined in Table 23-56 and Table 23-57, selects the Smart Card clock and I/O line sources.

The Smart Card can operate in two modes:

- In asynchronous mode the clock is derived from SCIREFCLK and data is driven directly by the interface or the card.
- In synchronous mode, the system processor provides the clock and data by writing appropriate values to the SYNCDATA register.

Table 23-56. SYNCCR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														SELCLK	SELDATA
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW
ADDR	0x8000.0360															

Table 23-57. SYNCCR Fields

BITS	FIELD	DESCRIPTION
31:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	SELCLK	**Select Clock** Selects the source of the Smart Card clock: 1 = SYNCDATA register bit 1 (WCLK) drives SCCLK. 0 = SCCLK is derived from SCIREFCLK.
0	SELDATA	**Select Data** Selects the signal used to drive SCIO: 1 = SYNCDATA:WDATA drives SCIO. 0 = The DATA transmit FIFO drives SCIO.

23.2.2.26 Synchronous Data Register (SYNCDATA)

This register, defined in Table 23-58 and Table 23-59, in conjunction with the Synchronous Control Register Select Clock bit (SYNCCR:SELCLK), specifies the alternate sources for driving the Smart Card data (SCIO) and clock (SCCLK) signals.

Table 23-58. SYNCDATA Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///												WCLKEN	WDATAEN	WCLK	WDATA
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RW	RW
ADDR	0x8000.0364															

Table 23-59. SYNCDATA Fields

BITS	FIELD	DESCRIPTION
31:4	///	**Reserved** Reading returns 0. Values written cannot be read.
3	WCLKEN	**Write Clock Enable** Clearing SELCLK and WCLKEN drives SCCLK LOW.
2	WDATAEN	**Write Data Enable** Clearing SELDATA and WDATAEN drives SCIO LOW.
1	WCLK	**Write Clock** When SELCLK is set, WCLK drives SCCLK.
0	WDATA	**Write Data** When SELDATA is set, WDATA drives SCIO.

23.2.2.27 Raw I/O and Clock Status Register (RAWSTAT)

This register, defined in Table 23-60 and Table 23-61, reports the raw status of the SCIO and SCCLK signals.

For ISO 7816-3 noncompliant operation, because received data is unavailable in the receive FIFO, use RAWSTAT to read the data from card.

Table 23-60. RAWSTAT Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///														RCLK	RDATA
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
ADDR	0x8000.0368															

Table 23-61. RAWSTAT Fields

BITS	FIELD	FUNCTION
31:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	RCLK	**Raw Clock** Returns the SCCLK signal value.
0	RDATA	**Raw Data** Returns the SCIO signal value.

23.2.2.28 Interrupt Identification and Clear Register (IIR) (ICR)

This register, defined in Table 23-62 and Table 23-63, when read shows the asserted interrupts, and when written to clears asserted interrupts.

Interrupts are asserted in the Interrupt Identification Register (IIR) and enabled in the Interrupt Enable Register (IER). Both enabled and disabled interrupts can be asserted in IIR. Enabled asserted interrupts are ORed together to generate SCIINTR, then sent as an IRQ interrupt to the LH7A400 interrupt controller.

An asserted interrupt in IIR reads as 1. When SCIINTR is asserted, to determine the specific interrupt sources, bitwise-AND IIR with IER. The resulting bit pattern lists the enabled asserted interrupts contributing to SCIINTR.

Writing a 1 to an interrupt field in IIR clears the interrupt. The interrupt field reads back as a 0 when cleared. Writing a 0 to any location in IIR has no effect on the register contents.

For ISO 7816-3 compliant systems, some interrupts are automatically cleared:

- TXWMARKINTR and RXWMARKINTR are cleared by operations on the transmit and receive FIFOs, respectively.
- RTOUTINTR is cleared by reading DATA.
- CRARDDNINTR is cleared by activating the card.
- CARDININTR is cleared by deactivating the card.

Table 23-62. IIR/ICR Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///				TXWMARKINTR	RXWMARKINTR	RTOUTINTR	CHTOUTINTR	BLKTOUTINTR	ATRDTOUTINTR	ATRSTOUTINTR	TXERRINTR	CARDDNINTR	CARDUPINTR	CARDOUTINTR	CARDININTR
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW	RW
ADDR	0x8000.036C															

Table 23-63. IIR/ICR Read/Write Register Bits

BITS	FIELD	FUNCTION
31:12	///	**Reserved** Reading returns 0. Values written cannot be read.
11	TXWMARKINTR	**Transmit Watermark Interrupt** 1 = The amount of data in the transmit FIFO is less than the minimum programmed in WMARK:TXWMARK. 0 = Interrupt cleared.
10	RXWMARKINTR	**Receive Watermark Interrupt** 1 = The amount of data in the receive FIFO has exceeded the limit programmed in WMARK:RXWMARK. 0 = Interrupt cleared.
9	RTOUTINTR	**Read Time-Out Interrupt** 1 = Data has remained unread in the receive FIFO for longer than the time limit programmed in RXTIME. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
8	CHTOUTINTR	**Character Time-Out Interrupt** 1 = The time between the leading edge of two consecutive received characters has exceeded the limit programmed in SCHCHTIME. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
7	BLKTOUTINTR	**Block Time-Out Interrupt** 1 = The SCI has timed-out waiting for an expected character from the card. This time limit is programmed in BLKTIME. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
6	ATRDTOUTINTR	**Answer-to-Reset Duration Time-Out Interrupt** 1 = ATR message reception has exceeded the time limit programmed in ATRDTIME. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
5	ATRSTOUTINTR	**Answer-to-Reset Start Time-Out Interrupt** 1 = The SCI has timed-out waiting for the start of an ATR message. This time limit is programmed in ATRSTIME 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
4	TXERRINTR	**Transmit Error Interrupt** 1 = A transmit parity error has occurred. For T=0, the error remains after the maximum number of retries have been done. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.

Table 23-63. IIR/ICR Read/Write Register Bits

BITS	FIELD	FUNCTION
3	CARDDNINTR	**Card Down Interrupt** 1 = The card is deactivated. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
2	CARDUPINTR	**Card Up Interrupt** 1 = The card is activated. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
1	CARDOUTINTR	**Card Out Interrupt** 1 = No card is present. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.
0	CARDININTR	**Card Inserted Interrupt** 1 = A card is present. 0 = Interrupt cleared. When asserted, writing a 1 to this bit clears the interrupt.

23.2.2.29 Control Register (CONTROL)

This register, defined in Table 23-64 and Table 23-65, specifies the pin multiplexing and SCI Reference Clock (SCIREFCLK) divisor, and enables the SCI. The Enable bit must be programmed to 1 prior to ussing MUX_Detect or MUX_VCCEN. GPIO pins are active until the Enable bit is set, which can cause unpredictable results.

Table 23-64. CONTROL Register

BIT	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FIELD	///															
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FIELD	///										MUX_Detect	MUX_VCCEN	///		PREDIV	EN
RESET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPE	RO	RO	RO	RO	RO	RO	RO	RO	RO	RO	RW	RW	RO	RO	RW	RW
ADDR	0x8000.0370															

Table 23-65. CONTROL Fields

BITS	FIELD	DESCRIPTION
31:6	///	**Reserved** Reading returns 0. Values written cannot be read.
5	MUX_Detect	**Multiplex Detect Enable** The SCDETECT signal (pin D6) is multiplexed with the GPIO Port F5 signal. 1 = Pin D6 configured for SCI operation. 0 = Pin D6 configured for GPIO operation.
4	MUX_VCCEN	**Multiplex SCI_VCC Enable** The SCI_VCC signal (pin B5) is multiplexed with the GPIO Port F4 signal. 1 = Pin B5 configured for SCI operation. 0 = Pin B5 configured for GPIO operation.
3:2	///	**Reserved** Reading returns 0. Values written cannot be read.
1	PREDIV	**Pre-Divisor** Specifies the pre-divisor for the Reference Clock (SCIREFCLK): 1 = SCIREFCLK = HCLK/2 0 = SCIREFCLK = HCLK
0	EN	**Enable** 1 = Enables the Smart Card Interface. 0 = Disables the Smart Card Interface.

Chapter 24
Glossary

AC
Audio Codec

AC97
AC97 Codec following Intel's AC97 specification.

AHB
Advanced High-Performance Bus. Defined in the AMBA specification, the AHB connects the high-performance blocks. In the LH7A400, the AHB connects the ARM922T core, the SMC, the SDMC, the embedded SRAM, the CLCDC, the HRTFTLCDTC, and the DMA controller. The AHB connects to the APB via the APB Bridge. The AHB supports burst mode data transfers and split transactions, and all timing is referenced to a single clock edge.

AMBA
Advanced Microprocessor Bus Architecture. This architecture is an open standard for an on-chip bus connecting the blocks of an MCU.

APB
Advanced Peripheral Bus. Defined in the AMBA specification, the APB connects the lower-performance peripheral blocks. In the LH7A400, the APB connects the RTC, the WDT, the Timers, the GPIO, the SSP, the BMI, the UARTS, the USB Interface, the MMC, the Audio Codec, the AC97, the SCI, the DC-DC Interface, and the Interrupt Controller. The APB connects to the AHB via the APB Bridge.

APB Bridge
Connection between the AHB and APB.

ARM922T Core
A microprocessor based on the ARM9TDMI 32-bit RISC CPU, with an 8KB instruction cache and 8KB data cache, MMU support, and AMBA compliant interfaces. For more information, see the ARM Ltd. website: http://www.nxp.com/redirect/arm.com.

Big-endian
The most significant part of the data is stored at the lowest storage address or transmitted or received first. See Endianness.

Block
In an MCU, a Block is the on-chip circuitry to implement a peripheral, memory circuit, or processor.

BMI

Battery Monitor Interface. In the LH7A400, a serial communication interface specified for battery interfaces, including high speed, single wire compatibility and smart battery system specification with an I^2C interface.

I^2C

Bidirectional, two wire serial bus providing a communication link between integrated circuits.

Byte

An 8-bit data element. Bytes in this User's Guide are shown with the most significant bit on the left (or top) and the least significant bit on the right (or bottom). Also see Half Word, Nibble, and Word.

Byte Lane

A data path that is one byte wide.

CF

Compact Flash. Very small removable mass storage device, providing complete PCMCIA-ATA functionality and compatibility and TrueIDE functionality compatible with ATA/ATAPI-4. For more information, see the CompactFlash Association website, http://www.nxp.com/redirect/compactflash.org.

Chip

A packaged integrated circuit device.

CLCDC

The on-chip Color Liquid Crystal Display Controller.

Core

See ARM922T Core.

CPSR

Current Program Status Register. In ARM architecture, the CPSR stores the condition code bits.

DC-DC Converter

Direct Current-to-Direct Current Converter

DMA

Direct Memory Access. The LH7A400 includes an on-chip DMA Controller.

Embedded SRAM

In the LH7A400, 80KB of on-chip SRAM. The LCD controller has access to an internal frame buffer in embedded SRAM and an extension buffer in SDRAM for dual panel or large displays. The core and DMA controller share the main system bus, providing access to all external memory devices and the embedded SRAM frame buffer.

ENDEC

ENcoder and DECoder

Endianness

Describes the bit, byte, or word sequence of data communication or storage, associating the most significant or least significant end of a data sequence with the lowest address or with the beginning of reception or transmission. See Big-endian and Little-endian.

GPIO

General Purpose Input and Output

Half Word

In the 32-bit LH7A400, a 16-bit data element structured as an ordered pair of bytes. Half words in this User's Guide are shown with the most significant byte on the left (or top) and the least significant byte on the right (or bottom). Also see Byte, Nibble, and Word.

HRTFLCDTC

HR-TFT LCD Timing Controller

Interrupt Controller

In the LH7A400, a block that provides a uniform way of enabling, disabling, and examining the status of up to 28 IRQ sources and 4 FIQ sources.

IRQ

Interrupt Request. The LH7A400 supports up to 28 IRQ sources. The hardware responds to an IRQ by saving some registers and moving execution to the address 0x00000018 for an additional branch to the interrupt handling software. For an IRQ, the LH7A400 saves more registers than for an FIQ. IRQ interrupts are lower priority than FIQ. See FIQ.

FIQ

Fast Interrupt request. The LH7A400 supports up to four FIQ sources. The hardware responds to an IRQ by saving some registers and moving execution to the address 0x0000001C for software interrupt handling. Interrupt handling software can be located at 0x0000001C without requiring another branch instruction. For an FIQ, the LH7A400 saves fewer registers than for an IRQ. FIQ interrupts are higher priority than an IRQ. See IRQ.

IrDA

A serial, half-duplex optical communications protocol sponsored by the InfraRed Data Association.

Little-endian

The least significant part of the data is stored at the lowest storage address or transmitted or received first. The LH7A400 uses little-endian byte ordering for storage. See Endianness.

LSB; LSb
Least significant byte (LSB) or least significant bit (LSb) of an ordered sequence.

LSW
Least significant word of an ordered sequence.

Maskable
Can be enabled or disabled. See Non-maskable.

MCU
Microcontroller. A single-chip microprocessor system directly supporting peripherals used by an embedded-design product.

Merging Write Buffer
A merging write buffer compacts writes of all widths (byte, half-word, and word) into quad-word bursts which can be efficiently transferred to SDRAM.

MMC
MultiMediaCard. The complete specification is available at the MultiMediaCard Association website: http://www.nxp.com/redirect/mmca.org

MSB; MSb
Most significant byte (MSB) or most significant bit (MSb) of an ordered sequence.

MSW
Most significant word of an ordered sequence.

Nibble
In the LH7A400, a 4-bit data element. Nibbles in this User's Guide are shown with the most significant bit on the left (or top) and the least significant bit on the right (or bottom). Also see Byte, Half Word, and Word.

Non-maskable
Cannot be disabled. See Maskable.

Non-Volatile Memory
A memory technology that retains its contents when power is removed. Examples are ROM and Flash. Also see Volatile Memory.

PCMCIA
Personal Computer Memory Card International Association. For more information, see the PC Card Standard, available from: http://www.nxp.com/redirect/pcmcia.com.

Pixel
Picture Element. The smallest controllable unit of a matrix LCD display.

RO
Read Only. Values written to RO fields cannot be read back. Writing RO fields can cause unpredictable LH7A400 operation.

RTC
Real Time Clock

RW
Read or Write. RW bits or fields can be read from or written to.

SCI
Smart Card Interface

SDMC
Synchronous Dynamic Memory Controller

SIR
Serial InfraRed

SMC
Static Memory Controller. In the LH7A400, the SMC is an AHB slave block, providing an interface between the AHB and external asynchronous memory mapped devices. The SMC supports eight independently configurable memory banks, including two banks dedicated to PCMCIA and Compact Flash (CF) PC card interfaces.

SSP
Synchronous Serial Port

SWI
Software Interrupt; also Single Wire Interface (Battery Monitor)

UART
Universal Asynchronous Receiver and Transmitter

USB
Universal Serial Bus

VBP
Vertical Back Porch. The quantity of inactive lines at the start of a frame, after the vertical synchronization period.

VFP
Vertical Front Porch. The quantity of inactive lines at the end of a frame, before the vertical synchronization period.

Volatile Memory
A general term for any memory technology that loses its contents when power is removed.

Examples are RAM, SRAM, and SDRAM. See Non-Volatile Memory.

VSW

Vertical Synchronization (Pulse) Width. The quantity of horizontal synchronization lines fed to an LCD panel.

WDT

Watchdog Timer

WO

Write Only. Write Only fields should not be read as the data is invalid.

Word

In the 32-bit LH7A400, a 32-bit data element structured as an ordered sequence. Words in this User's Guide are shown with the most significant byte on the left (or top) and the least significant byte on the right (or bottom). Also see Byte, Half Word, and Nibble.

Index

Symbols

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

ANNEX A: Disclaimers (11)

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