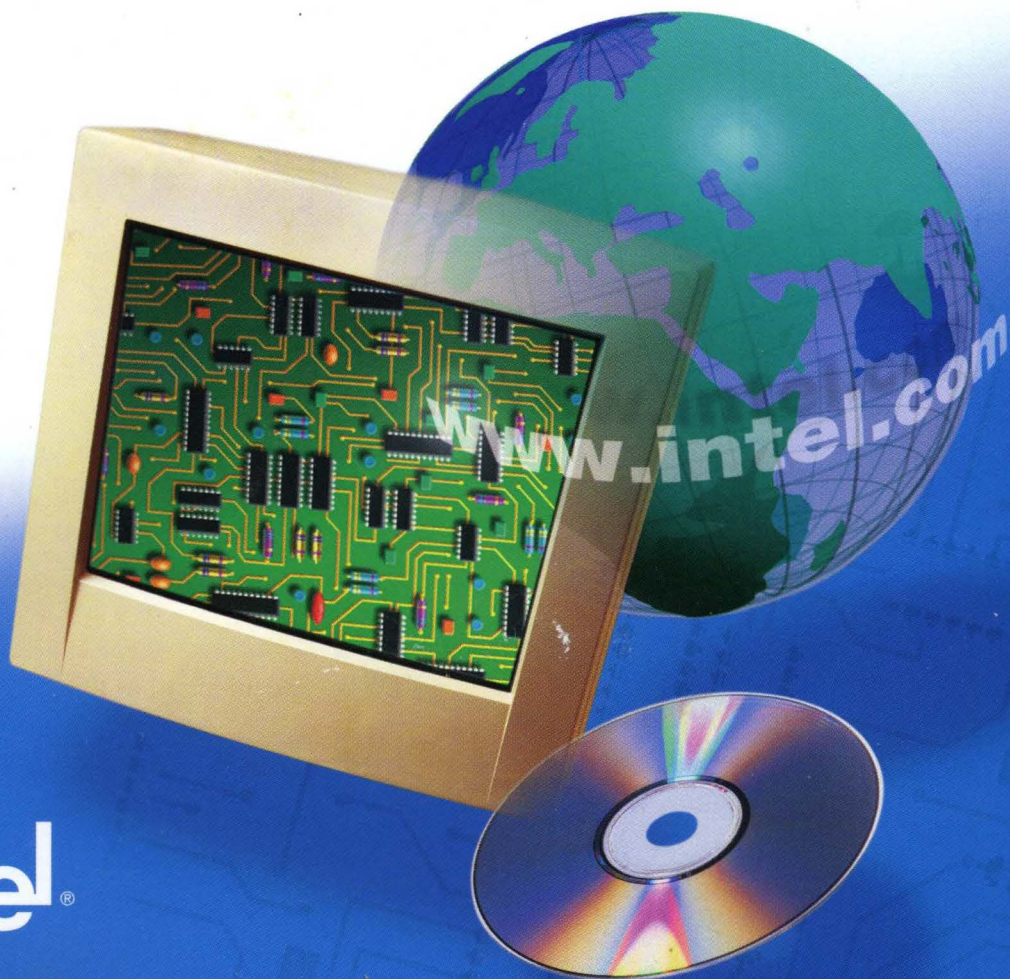


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8x930Ax, 8x930Hx Universal Serial Bus Microcontroller User's Manual

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September 1996

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1

Guide to this Manual





CHAPTER 1 GUIDE TO THIS MANUAL

This manual describes the 8x930Ax and 8x930Hx[†] microcontrollers; the initial members of a new family of products for universal serial bus (USB) applications. This manual is intended for use by both firmware and hardware designers familiar with the principles of microcontroller architecture.

1.1 MANUAL CONTENTS

This chapter provides an overview of the manual with brief summaries of the chapters and appendices. It also explains the terminology and notational conventions used throughout the manual, provides references to related documentation, and tells how to contact Intel for additional information.

Chapter 2 — “Architectural Overview” — provides an overview of device hardware. It covers core functions (pipelined CPU, clock and reset unit, and interrupts), I/O ports, on-chip memory, the USB module, and on-chip peripherals (timer/counters, watchdog timer, programmable counter array, and serial I/O port).

Chapter 3 — “Address Spaces” — describes the three address spaces of the 8x930: memory address space, special function register (SFR) space, and the register file. It also provides a map of the SFR space showing the location of the SFRs and their reset values and explains the mapping of the address spaces relative to the MCS[®] 51 and MCS[®] 251 architectures into the address spaces of the 8x930.

Chapter 4 — “Device Configuration” — describes microcontroller features that are configured at device reset, including the external memory interface (the number of external address bits, the number of wait states, page mode, memory regions for asserting RD#, WR#, and PSEN#), binary/source opcodes, interrupt mode, and the mapping of a portion of on-chip code memory to data memory. It describes the configuration bytes and how to program them for the desired configuration. It also describes how internal memory maps into external memory.

Chapter 5 — “Programming Considerations” — provides an overview of the instruction set. It describes each instruction type (control, arithmetic, logical, etc.) and lists the instructions in tabular form. This chapter also discusses the addressing modes, bit instructions, and the program status words. Appendix A, “Instruction Set Reference” provides a detailed description of each instruction.

Chapter 6 — “Interrupt System” — describes the 8x930 interrupt circuitry which provides a TRAP instruction interrupt and ten maskable interrupts: two external interrupts, three timer interrupts, a PCA interrupt, a serial port interrupt, and three USB interrupts. This chapter also discusses the interrupt priority scheme, interrupt enable, interrupt processing, and interrupt response time.

[†] In this manual, the 8x930Ax and 8x930Hx are referred to collectively as the 8x930.

Chapter 7 — “USB Function”— describes the FIFOs and special function registers (SFRs) associated with the USB function interface. This chapter describes the operation of function interface on the 8x930 USB microcontrollers.

Chapter 8 — “USB Hub”— describes the operation of the Intel Universal Serial Bus (USB) on-chip hub. This chapter introduces on-chip hub operation and includes information on bus enumeration, hub endpoint status and configuration, hub port control, hub suspend and resume, and hub power control.

Chapter 9 — “USB Programming Models”— describes the programming models of the 8x930 USB function interface. This chapter provides flow charts of suggested firmware routines for using the transmit and receive FIFOs to perform data transfers between the host PC and the embedded function and describes how the firmware interacts with the USB module hardware.

Chapter 10 — “Input/Output Ports”— describes the four 8-bit I/O ports (ports 0–3) and discusses their configuration for general-purpose I/O. This chapter also discusses external memory accesses (ports 0, 2) and alternative special functions.

Chapter 11 — “Timer/Counters and Watchdog Timer”— describes the three on-chip timer/counters and discusses their application. This chapter also provides instructions for using the hardware watchdog timer (WDT) and describes the operation of the WDT during the idle and powerdown modes.

Chapter 12 — “Programmable Counter Array”— describes the PCA on-chip peripheral and explains how to configure it for general-purpose applications (timers and counters) and special applications (programmable WDT and pulse-width modulator).

Chapter 13 — “Serial I/O Port”— describes the full-duplex serial I/O port and explains how to program it to communicate with external peripherals. This chapter also discusses baud rate generation, framing error detection, multiprocessor communications, and automatic address recognition.

Chapter 14 — “Minimum Hardware Setup”— describes the basic requirements for operating the 8x930 in a system. It also discusses on-chip and external clock sources and describes device resets, including power-on reset.

Chapter 15 — “Special Operating Modes”— provides an overview of the idle, powerdown, and on-circuit emulation (ONCE) modes and describes how to enter and exit each mode. This chapter also describes the power control (PCON) special function register and lists the status of the device pins during the special modes and reset.

Chapter 16 — “External Memory Interface”— describes the external memory signals and bus cycles and provides examples of external memory design. It provides waveform diagrams for the bus cycles, bus cycles with wait states, and the configuration byte bus cycles. It also provides bus cycle diagrams with AC timing symbols and definitions of the symbols.

Chapter 17 — “Verifying Nonvolatile Memory”— provides instructions for verifying on-chip program memory, configuration bytes, signature bytes, and lock bits.

Appendix A — “Instruction Set Reference”— provides reference information for the instruction set. It describes each instruction; defines the bits in the program status word registers (PSW,

PSW1); shows the relationships between instructions and PSW flags; and lists hexadecimal opcodes, instruction lengths, and execution times.

Appendix B — “Signal Descriptions”— describes the function(s) of each device pin. Descriptions are listed alphabetically by signal name. This appendix also provides a list of the signals grouped by functional category.

Appendix C — “Registers”— accumulates, for convenient reference, copies of the register definition figures that appear throughout the manual.

Appendix D — “Data Flow Model”— describes the data flow model for the 8x930 USB transactions.

Glossary — a glossary of terms has been provided for reference of technical terms.

Index — an index has been included for your convenience.

1.2 NOTATIONAL CONVENTIONS AND TERMINOLOGY

The following notations and terminology are used in this manual. The Glossary defines other terms with special meanings.

The pound symbol (#) has either of two meanings, depending on the context. When used with a signal name, the symbol means that the signal is active low. When used with an instruction mnemonic, the symbol prefixes an immediate value in immediate addressing mode.

italics Italics identify variables and introduce new terminology. The context in which italics are used distinguishes between the two possible meanings.

Variables in registers and signal names are commonly represented by x and y , where x represents the first variable and y represents the second variable. For example, in register $Px.y$, x represents the variable [1–4] that identifies the specific port, and y represents the register bit variable [7:0]. Variables must be replaced with the correct values when configuring or programming registers or identifying signals.

XXXX, xxxx Uppercase X (no italics) and lowercase x (no italics) represent unknown values or a “don’t care” states or conditions. The value may be either binary or hexadecimal, depending on the context. For example, $2xAFH$ (hex) indicates that bits 11:8 are unknown; $10xx$ in binary context indicates that the two LSBs are unknown.

Assert and Deassert	The terms <i>assert</i> and <i>deassert</i> refer to the act of making a signal active (enabled) and inactive (disabled), respectively. The active polarity (high/low) is defined by the signal name. Active-low signals are designated by a pound symbol (#) suffix; active-high signals have no suffix. To assert RD# is to drive it low; to assert ALE is to drive it high; to deassert RD# is to drive it high; to deassert ALE is to drive it low.
Instructions	Instruction mnemonics are shown in upper case to avoid confusion. When writing code, either upper case or lower case may be used.
Logic 0 (Low)	An input voltage level equal to or less than the maximum value of V_{IL} or an output voltage level equal to or less than the maximum value of V_{OL} . See data sheet for values.
Logic 1 (High)	An input voltage level equal to or greater than the minimum value of V_{IH} or an output voltage level equal to or greater than the minimum value of V_{OH} . See data sheet for values.
Numbers	Hexadecimal numbers are represented by a string of hexadecimal digits followed by the character <i>H</i> . Decimal and binary numbers are represented by their customary notations. That is, 255 is a decimal number and 1111 1111 is a binary number. In some cases, the letter <i>B</i> is added for clarity.
Register Access	All register bits support read/write access unless noted otherwise in the bit description. Other types of access include read-only, write-only, read/conditional-write, etc.
Register Bits	Bit locations are indexed by 7:0 for byte registers, 15:0 for word registers, and 31:0 for double-word (dword) registers, where bit 0 is the least-significant bit and 7, 15, or 31 is the most-significant bit. An individual bit is represented by the register name, followed by a period and the bit number. For example, PCON.4 is bit 4 of the power control register. In some discussions, bit names are used. For example, the name of PCON.4 is POF, the power-off flag.
Register Names	Register names are shown in upper case. For example, PCON is the power control register. If a register name contains a lowercase character, it represents more than one register. For example, CCAPMx represents the five registers: CCAPM0 through CCAPM4.
Reserved Bits	Some registers contain reserved bits. These bits are not used in this device, but they may be used in future implementations. Do not write a "1" to a reserved bit. The value read from a reserved bit is indeterminate.

Set and Clear

The terms *set* and *clear* refer to the value of a bit or the act of giving it a value. If a bit is *set*, its value is “1”; *setting* a bit gives it a “1” value. If a bit is *clear*, its value is “0”; *clearing* a bit gives it a “0” value.

Signal Names

Signal names are shown in upper case. When several signals share a common name, an individual signal is represented by the signal name followed by a number. Port pins are represented by the port abbreviation, a period, and the pin number (e.g., P0.0, P0.1). A pound symbol (#) appended to a signal name identifies an active-low signal.

Units of Measure

The following abbreviations are used to represent units of measure:

A	amps, amperes
DCV	direct current volts
Kbyte	kilobytes
K Ω	kilo-ohms
mA	milliamps, milliamperes
Mbyte	megabytes
MHz	megahertz
ms	milliseconds
mW	milliwatts
ns	nanoseconds
pF	picofarads
W	watts
V	volts
μ A	microamps, microamperes
μ F	microfarads
μ s	microseconds
μ W	microwatts

1.3 RELATED DOCUMENTS

The following documents contain additional information that is useful in designing systems that incorporate the 8x930. To order documents, please call Intel Literature Fulfillment (1-800-548-4725 in the U.S. and Canada; +44(0) 793-431155 in Europe).

<i>Embedded Microcontrollers</i>	Order Number 270646
<i>Embedded Processors</i>	Order Number 272396
<i>Embedded Applications</i>	Order Number 270648
<i>Packaging</i>	Order Number 240800
<i>Universal Serial Bus Specification</i>	Order Number 272904

1.3.1 Data Sheet

The data sheet is included in *Embedded Microcontrollers* and is also available individually.

<i>8x930Ax Universal Serial Bus Microcontroller</i>	Order Number 272917
<i>8x930Hx Universal Serial Bus Microcontroller</i>	Order Number 272928

1.3.2 Application Notes

The following MCS 251 application notes apply to the 8x930.

<i>AP-125, Designing Microcontroller Systems for Electrically Noisy Environments</i>	Order Number 210313
<i>AP-155, Oscillators for Microcontrollers</i>	Order Number 230659
<i>AP-708, Introducing the MCS® 251 Microcontroller—the 8XC251SB</i>	Order Number 272670
<i>AP-709, Maximizing Performance Using MCS® 251 Microcontroller—Programming the 8XC251SB</i>	Order Number 272671
<i>AP-710, Migrating from the MCS® 51 Microcontroller to the MCS 251 Microcontroller (8XC251SB)—Firmware and Hardware Considerations</i>	Order Number 272672

The following MCS 51 microcontroller application notes also apply to the 8x930.

<i>AP70, Using the Intel MCS® 51 Boolean Processing Capabilities</i>	Order Number 203830
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<i>AP-223, 8051 Based CRT Terminal Controller</i>	Order Number 270032
<i>AP-252, Designing With the 80C51BH</i>	Order Number 270068
<i>AP-425, Small DC Motor Control</i>	Order Number 270622
<i>AP-410, Enhanced Serial Port on the 83C51FA</i>	Order Number 270490
<i>AP-415, 83C51FA/FB PCA Cookbook</i>	Order Number 270609
<i>AP-476, How to Implement I²C Serial Communication Using Intel MCS[®] 51 Microcontrollers</i>	Order Number 272319

1.4 APPLICATION SUPPORT SERVICES

You can get up-to-date technical information from a variety of electronic support systems: the World Wide Web, the FaxBack* service, and Intel's Brand Products and Applications Support bulletin board service (BBS). These systems are available 24 hours a day, 7 days a week, providing technical information whenever you need it.

In the U.S. and Canada, technical support representatives are available to answer your questions between 5 a.m. and 5 p.m. Pacific Standard Time (PST). Outside the U.S. and Canada, please contact your local distributor. You can order product literature from Intel literature centers and sales offices.

Table 1-1 lists the information you need to access these services.

Table 1-1. Intel Application Support Services

Service	U.S. and Canada	Asia-Pacific and Japan	Europe
World Wide Web	URL: http://www.intel.com/	URL: http://www.intel.com/	URL: http://www.intel.com/
World Wide Web	URL: http://www.intel.com/design/usb/	URL: http://www.intel.com/design/usb/	URL: http://www.intel.com/design/usb/
FaxBack*	800-525-3019	503-264-6835 916-356-3105	+44(0)1793-496646
BBS	503-264-7999 916-356-3600	503-264-7999 916-356-3600	+44(0)1793-432955
Help Desk	800-628-8686 916-356-7999	Please contact your local distributor.	Please contact your local distributor.
Literature	800-548-4725	708-296-9333 +81(0)120 47 88 32	+44(0)1793-431155 England +44(0)1793-421777 France +44(0)1793-421333 Germany

1.4.1 World Wide Web

We offer a variety of technical and product information through the World Wide Web (URL: <http://www.intel.com/design/mcs96>). Also visit Intel's Web site for financials, history, news and USB information at: www.intel.com/design/usb/.

1.4.2 FaxBack Service

The FaxBack service is an on-demand publishing system that sends documents to your fax machine. You can get product announcements, change notifications, product literature, device characteristics, design recommendations, and quality and reliability information from FaxBack 24 hours a day, 7 days a week.

Think of the FaxBack service as a library of technical documents that you can access with your phone. Just dial the telephone number and respond to the system prompts. After you select a document, the system sends a copy to your fax machine.

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The following catalogs and information are available at the time of publication:

1. *Solutions OEM* subscription form
2. Microcontroller and flash catalog
3. Development tools catalog
4. Systems catalog
5. Multimedia catalog
6. Multibus and iRMX[®] firmware catalog and BBS file listings
7. Microprocessor, PCI, and peripheral catalog
8. Quality and reliability and change notification catalog
9. iAL (Intel Architecture Labs) technology catalog

1.4.3 Bulletin Board System (BBS)

Intel's Brand Products and Applications Support bulletin board system (BBS) lets you download files to your PC. The BBS has the latest ApBUILDER firmware, hypertext manuals and datasheets, firmware drivers, firmware upgrades, application notes and utilities, and quality and reliability data.

Any customer with a PC and modem can access the BBS. The system provides automatic configuration support for 1200- through 19200-baud modems. Use these modem settings: no parity, 8 data bits, and 1 stop bit (N, 8, 1).

To access the BBS, just dial the telephone number (see Table 1-1 on page 1-7) and respond to the system prompts. During your first session, the system asks you to register with the system operator by entering your name and location. The system operator will set up your access account within 24 hours. At that time, you can access the files on the BBS.

NOTE

In the U.S. and Canada, you can get a BBS user's guide, a master list of BBS files, and lists of FaxBack documents by calling 1-800-525-3019. Use these modem settings: no parity, 8 data bits, and 1 stop bit (N, 8, 1).

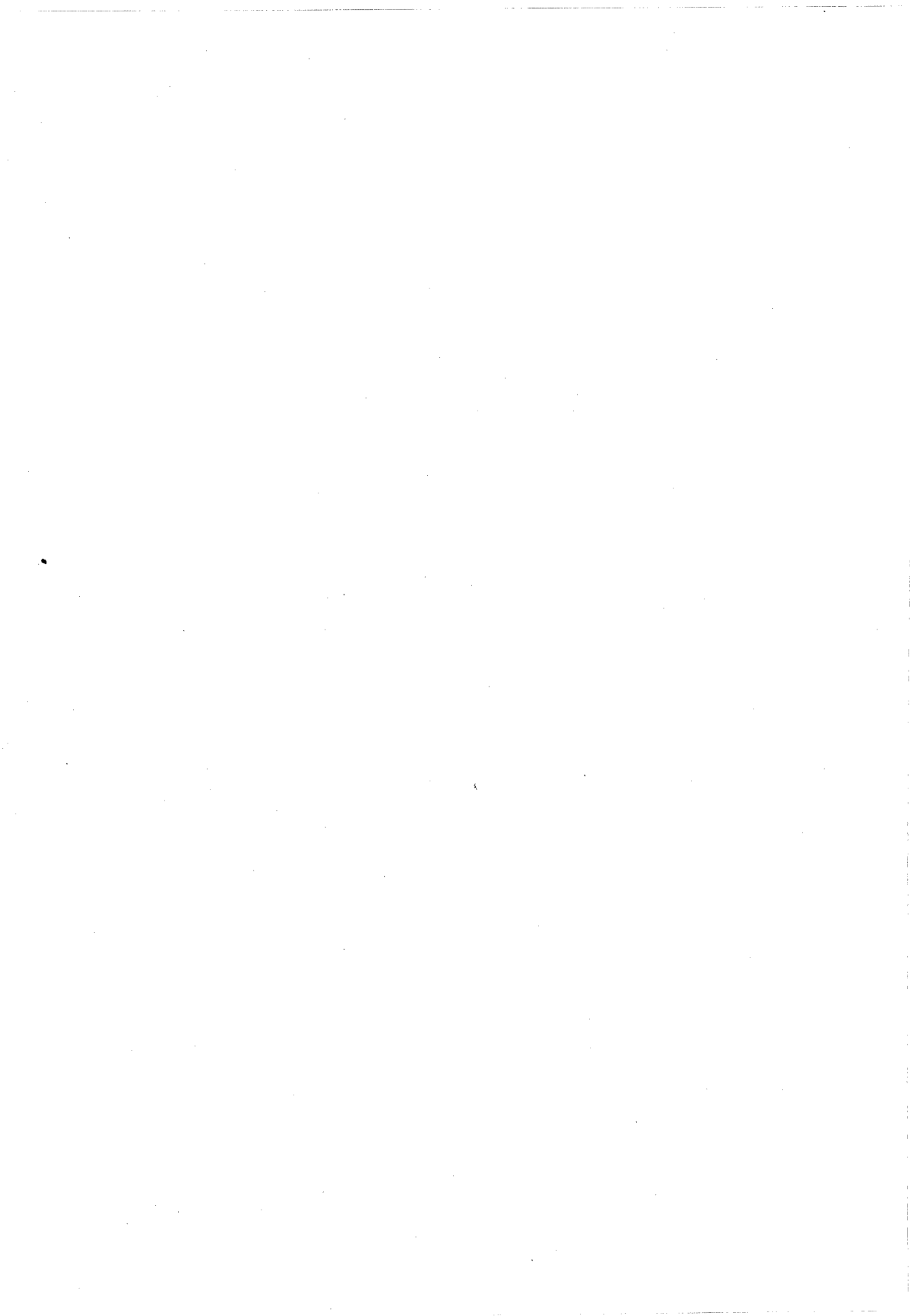




2

Architectural Overview





CHAPTER 2 ARCHITECTURAL OVERVIEW

The 8x930Ax and 8x930Hx are PC peripheral microcontrollers for Universal Serial Bus (USB) applications. These microcontrollers provide the means for connecting PC peripherals such as monitors, keyboards, joysticks, telephones, and modems to USB-equipped personal computers. The USB material in this document relies heavily on the *Universal Serial Bus Specification* which provides a detailed description of the USB system.

In the language of the USB specification, the 8x930Ax and 8x930Hx are *USB devices*. A USB device can serve as a *function* by providing an interface for a PC peripheral, and it can serve as a *hub* by providing USB ports for additional PC peripherals.

The 8x930Ax described in this manual serves as a USB function. The 8x930Hx serves as both a USB function and as a hub; it supports one embedded function and provides three external downstream ports. Figure 2-1 depicts the 8x930Ax and 8x930Hx in an example USB system.

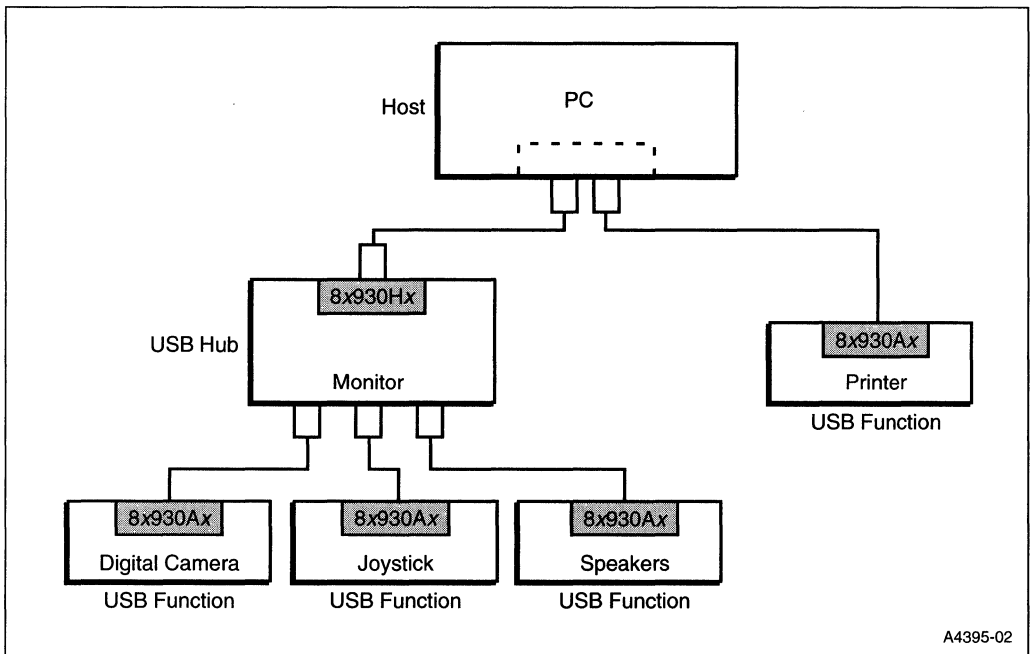


Figure 2-1. 8x930Ax and 8x930Hx in a USB System

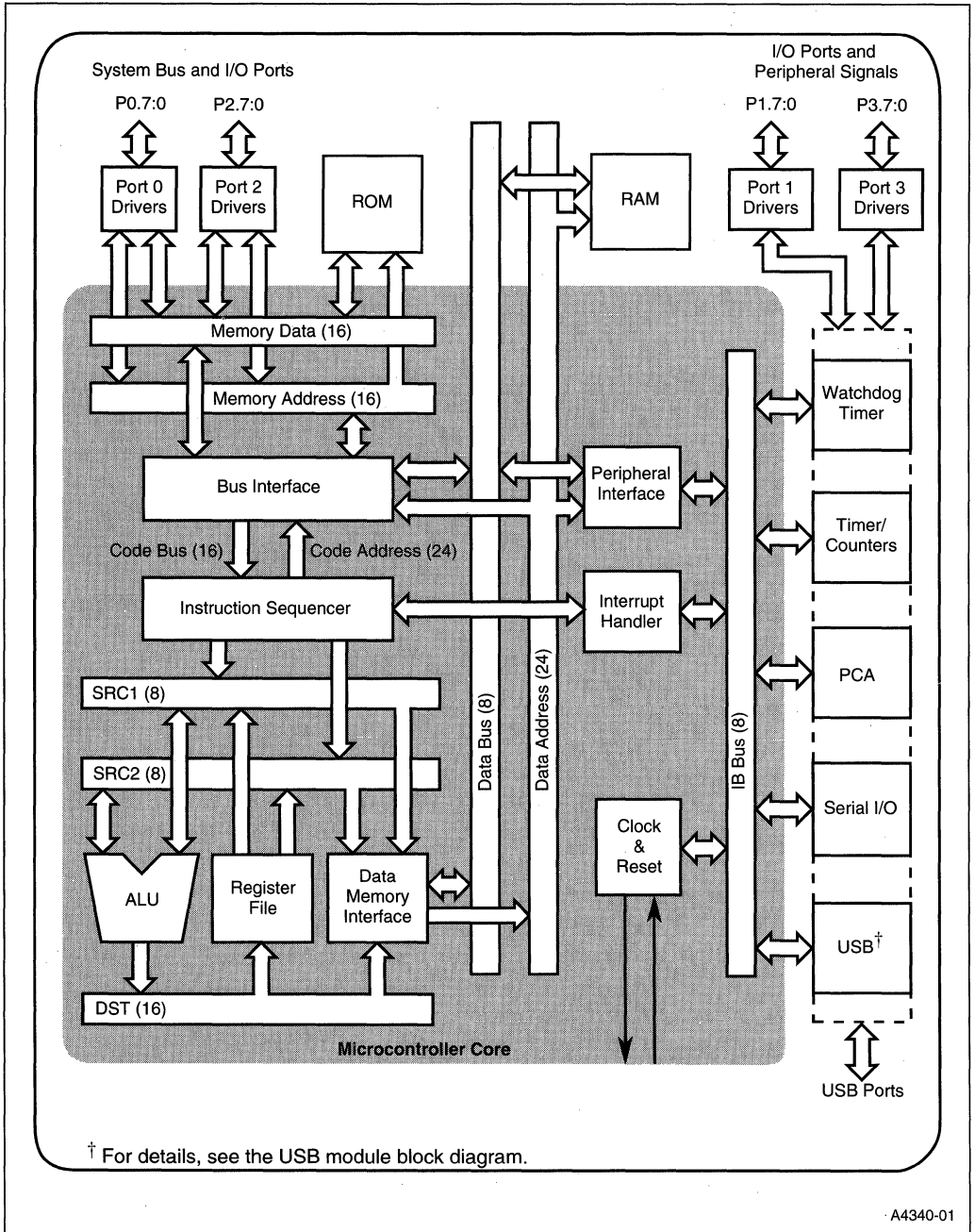


Figure 2-2. Functional Block Diagram of the 8x930

2.1 PRODUCT OVERVIEW

The 8x930 can be briefly described as an MCS[®] 251 microcontroller with an on-chip USB module, and additional pinouts for USB signals. As shown in the functional block diagram (Figure 2-2), the 8x930 consists of a microcontroller core, on-chip ROM (optional) and RAM, I/O ports, the on-chip USB module, and on-chip peripherals. The USB module operates in conjunction with the CPU to provide the capabilities of a USB device.

Table 2-1 lists the on-chip memory options. The on-chip peripherals provide hardware timers, counters, and a serial I/O port. The 8x930 uses the standard instruction set of the MCS 251 architecture.

2.1.1 8x930Ax Features

The 8x930Ax USB microcontroller contains all the features of the MCS[®] 251 architecture, plus it provides a USB interface for a PC peripheral. The 8x930Ax supports all four types of USB data transfers: control, isochronous, interrupt, and bulk. The user can select the number of function endpoint pairs (4 or 6) and whether USB reset is separate from chip reset. Each endpoint pair has a transmit FIFO and a receive FIFO data buffer. Table 2-2 on page 2-4 provides a summary of USB features including FIFO sizes and operating rates. Table 2-3 on page 2-5 provides a summary of MCS[®] 251 architecture features. The block diagram in Figure 2-3 shows the main components of the 8x930Ax USB module and how they interface with the CPU.

2.1.2 8x930Hx Features

The 8x930Hx USB microcontroller is similar to the 8x930Ax in that it contains all the features of the MCS[®] 251 architecture and provides a USB interface for a PC peripheral. The 8x930Hx also provides a USB hub capability, permitting the connection of additional PC peripherals or hubs. It provides three external downstream ports and one internal downstream port. The 8x930Hx supports two hub endpoint pairs and four function endpoint pairs. Each endpoint pair (except hub endpoint 1) has a transmit FIFO and a receive FIFO. Table 2-2 on page 2-4 provides a summary of USB features including FIFO sizes and operating rates. Table 2-3 on page 2-5 provides a summary of MCS[®] 251 architecture features. The block diagram in Figure 2-4 shows the main components of the 8x930Hx USB module and how they interface with the CPU. (The 8x930Hx does not provide the separate USB reset or the six-endpoint pair options.)

Table 2-1. 8x930 Memory Options

8x930Ax (Hubless)	8x930Hx (Hub)	On-chip Memory	
		ROM (Kbytes)	RAM (Bytes)
80930AD	80930HD	0	1024
83930AD	83930HD	8	1024
83930AE	83930HE	16	1024

Table 2-2. 8x930 USB Features Summary

	8x930Ax	8x930Hx
General USB Features		
Complete <i>Universal Serial Bus Specification</i> rev. 1.0 compatibility	Yes	Yes
On-chip USB transceivers	Yes	Yes
Automatic transmit/receive FIFO management	Yes	Yes
Timebase (crystal/PLL)	6 or 12 MHz	12 MHz
USB rate (full speed)	12 Mbps	12 Mbps (1)
USB rate (low speed)	1.5 Mbps	—
Low-clock mode	Yes	Yes
USB interrupt vectors	3	3
Suspend/resume	Yes	Yes
Separate USB and chip resets (2)	Yes	No
USB Function Features		
Function endpoint pairs	4 or 6 (3)	4
Transmit/receive FIFO/ sizes:		
Endpoint 0	16 bytes	16 bytes
Endpoints 2, 3	16 or 32 bytes	16 bytes
Endpoint 4 (8x930Ax only) (2)	16 or 32 bytes	—
Endpoint 5 (8x930Ax only) (2)	16 bytes	—
Endpoint 1 (4)	0-1024 bytes	0-1024 bytes
USB Hub Features		
External downstream ports	—	3
Internal downstream ports	—	1
Hub Endpoint 0: Transmit and receive FIFOs	—	16 bytes
Hub Endpoint 1: One transmit data buffer register	—	1 byte

NOTES:

1. The 8x930Hx operates at full speed only. Root port (D_{PO}, D_{MO}) data transfers are always full speed. Data transfer rates on the external downstream ports are matched to the type of USB device attached (full speed or low speed).
2. Early sample devices did not have this feature.
3. The 8x930Ax can be programmed to have either four or six function endpoint pairs. Endpoint 2, 3, and 4 FIFOs sizes are 16 bytes for the four endpoint pair (4EPP) option and 32 bytes for the 6EPP option. Early sample devices did not have this feature.
4. Programmable size. The 4EPP option provides transmit/receive FIFO size options of 256/256, 512/512, 1024/0, or 0/1024 bytes for function endpoint 1. The 6EPP option supports only 256/256-byte FIFOs for function endpoint 1.

2.1.3 MCS® 251 Architecture Features

The 8x930 retain all the features of the MCS 251 architecture including the configurable external memory bus, four 8-bit I/O ports, on-chip peripherals, and code-compatibility with the MCS® 251 microcontroller. The features of the MCS 251 architecture are discussed in the following paragraphs and summarized in Table 2-2.

The 8x930 stores code and data in a single, linear 16-Mbyte memory space. The usable memory space of the 8x930 consists of four 64-Kbyte regions (256 Kbytes). The external bus provides up to 256 Kbytes of external memory addressability. The special function registers (SFRs) and the

register file have separate address spaces. Refer to Chapter 3, “Address Spaces” for a description of the address modes.

Certain instructions in the MCS 251 instruction set operate on 8-bit, 16-bit, or 32-bit operands, providing easier and more efficient programming in high-level languages such as C. Additional features include the TRAP instruction, a displacement addressing mode, and several conditional jump instructions. Chapter 5, “Programming Considerations,” describes the instruction set and compares it with the instruction set for MCS 51 microcontrollers.

You can configure the 8x930 for the *binary mode* or *source mode* opcode arrangement. Both modes execute all of the MCS 51 architecture instructions and all of the MCS 251 architecture instructions. However, source mode is more efficient for MCS 251 architecture instructions, and binary mode is more efficient for MCS 51 architecture instructions. In binary mode, object code for an MCS 51 microcontroller runs on the 8x930 without recompiling. For details see “Opcode Configurations (SRC)” on page 4-12.

Each pin of the four 8-bit I/O ports can be individually programmed as a general I/O signal or as a special-function signal that supports the external bus or one of the on-chip peripherals. Ports P0 and P2 comprise a 16-line external bus, which transmits a 16-bit address multiplexed with 8 data bits. (You can also configure the 8x930 to have a 17-bit or an 18-bit external address bus. Refer to “Configuring the External Memory Interface” on page 4-7. Ports P1 and P3 carry bus-control and peripheral signals.

The 8x930 has two power-saving modes. In idle mode, the CPU clock is stopped, while clocks to the peripherals continue to run. In global suspend mode (powerdown), the on-chip oscillator is stopped, and the chip enters a static state. An enabled interrupt or a hardware reset can bring the chip back to its normal operating mode from idle or powerdown. Refer to Chapter 15, “Special Operating Modes,” for details on the power-saving modes.

Table 2-3. MCS[®] 251 Architecture Features

Address space	256 Kbytes
External bus (multiplexed)	
Address	16, 17, or 18 bits
Data	8 bits
On-chip ROM	0, 8 or 16 Kbytes
On-chip RAM	1024 bytes
Register file	40 bytes
Eight interrupt vectors	
I/O ports	Four 8-bit I/O ports
On-chip Peripherals:	
Serial I/O port (industry-standard MCS [®] 51 UART)	
Programmable counter array with 5 compare/capture modules	
Three general-purpose timer/counters	
Hardware watchdog timer	
User-selectable configurations: external address range, wait states, page mode	
Real-time wait states	
Powerdown and idle power-saving modes	
Register-based MCS [®] 251 architecture	
Code-compatible with MCS 51 and MCS 251 microcontrollers	

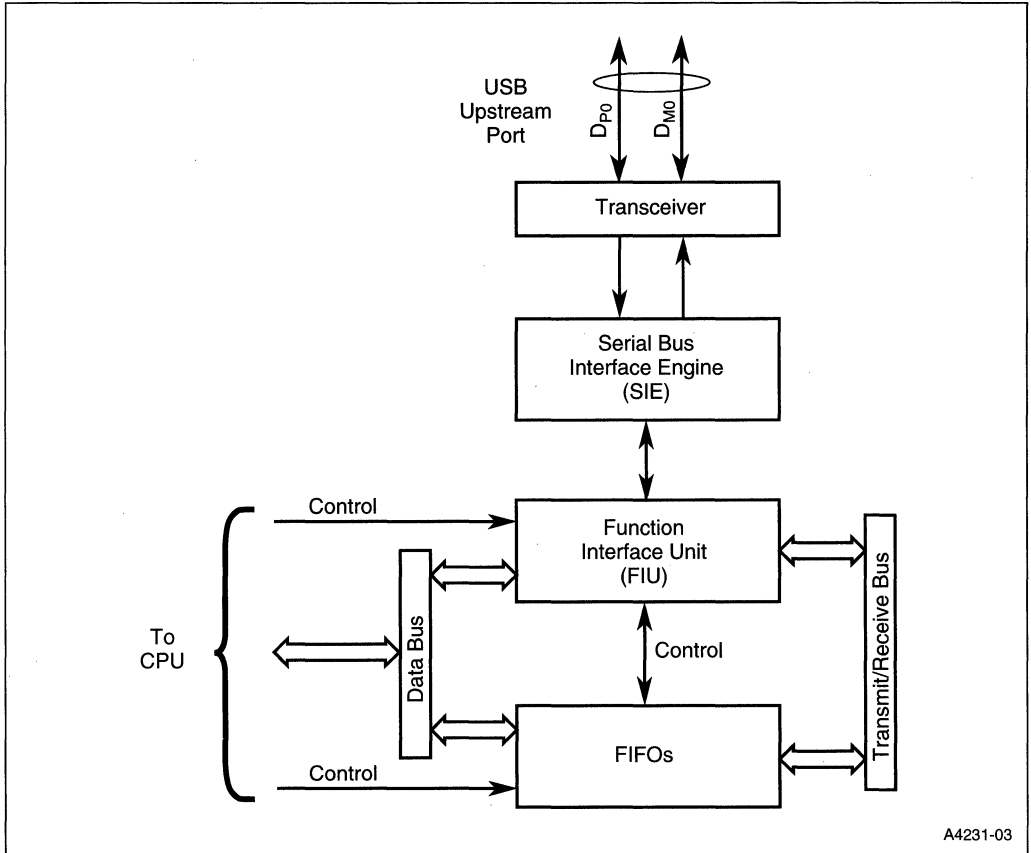


Figure 2-3. 8x930Ax USB Module Block Diagram

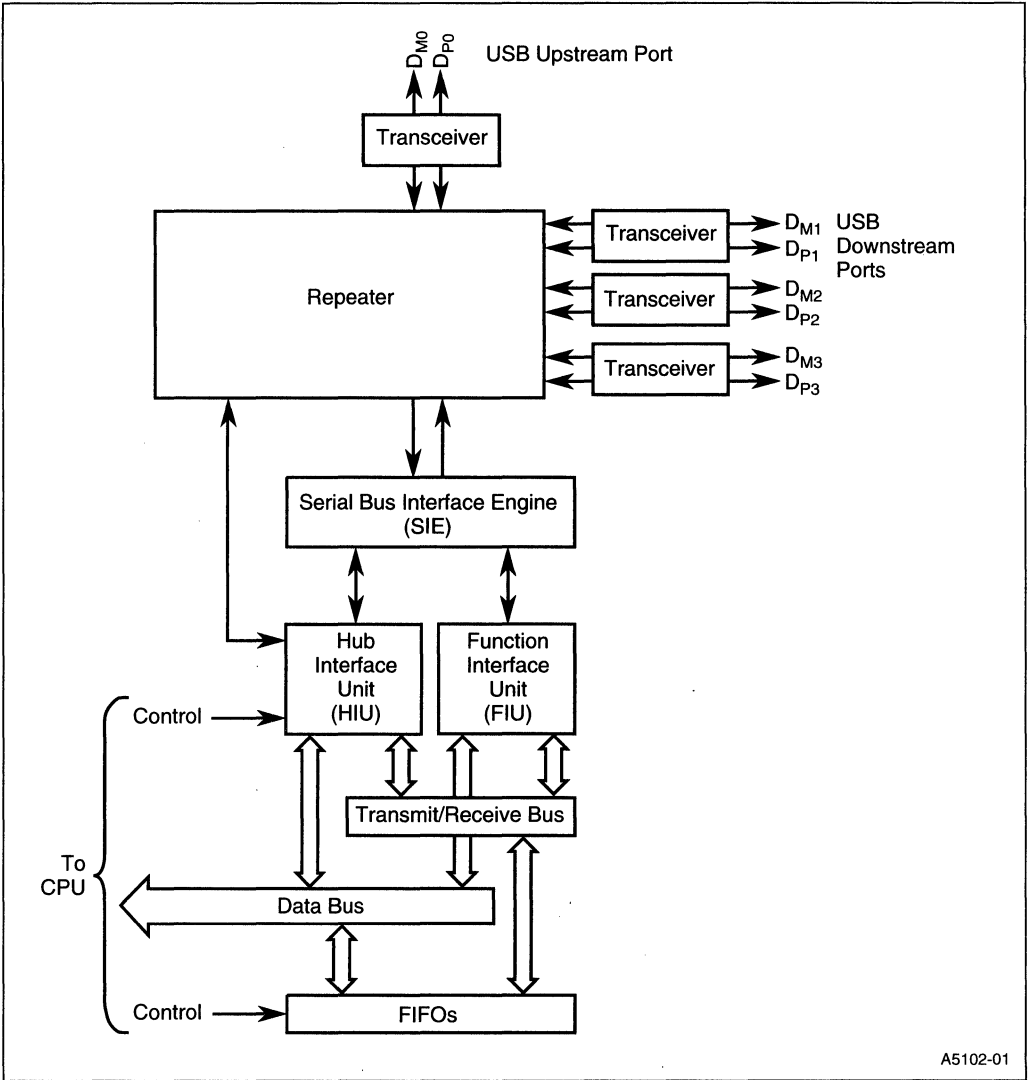


Figure 2-4. 8x930Hx USB Module Block Diagram

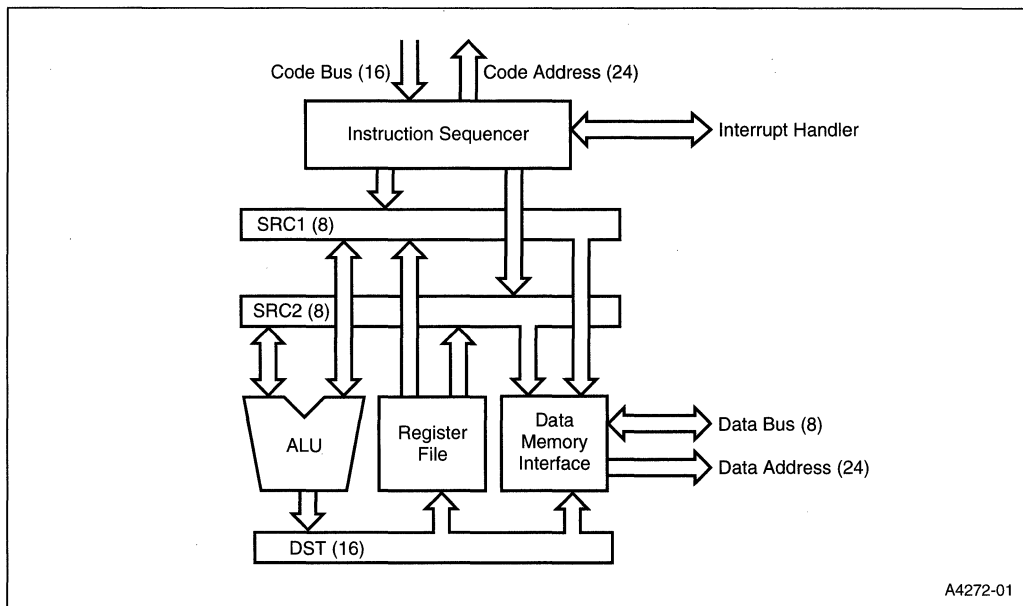


Figure 2-5. The CPU

2.2 MICROCONTROLLER CORE

The microcontroller core contains the CPU, the clock and reset unit, the interrupt handler, the bus interface, and the peripheral interface. The CPU contains the instruction sequencer, ALU, register file, and data memory interface.

2.2.1 CPU

Figure 2-5 is a functional block diagram of the CPU (central processor unit). The 8x930 fetches instructions from on-chip code memory two bytes at a time, or from external memory in single bytes. The instructions are sent over the 16-bit code bus to the execution unit. You can configure the 8x930 to operate in *page mode* for accelerated instruction fetches from external memory. In page mode, if an instruction fetch is to the same 256-byte “page” as the previous fetch, the fetch requires one state time rather than two state times. See “State Time and Peripheral Cycles” on page 2-9.

The 8x930 register file has forty registers, which can be accessed as bytes, words, and double words. As in the MCS[®]51 architecture, registers 0–7 consist of four banks of eight registers each, where the active bank is selected by the program status word (PSW) for fast context switches. Refer to Chapter 3, “8x930 Register File” or see Figure 5-2 on page 5-17.

The 8x930 is a single-pipeline machine. When the pipeline is full and code is executing from on-chip code memory, an instruction is completed every state time. When the pipeline is full and

code is executing from external memory (with no wait states and no extension of the ALE signal), an instruction is completed every two state times.

2.2.2 Clock and Reset Unit

Figure 2-6 on page 2-9 shows the internal clock circuitry of the 8x930. The timing waveform at XTAL1 can be provided by:

- an on-chip oscillator employing an external crystal/resonator connected across XTAL1 and XTAL2
- an external frequency source connected to XTAL1

“Clock Sources” on page 14-2 discusses the requirements for external-clock signals and on-chip oscillators. Power management options – idle, powerdown, and low-clock mode – are discussed in Chapter 15, “Special Operating Modes.”

Device pins PLLSEL2:0 determine the USB operating rate (full speed or low speed) and the internal frequency (F_{CLK}) distributed to the CPU and on-chip peripherals. See Table 2-4. Because of its hub capability, the 8x930Hx (including the embedded function) always operates as a full-speed USB device. Root port data transfers are always full speed. Data transfer rates on the external downstream ports are matched to the type of USB device attached (i.e., full speed or low speed). For full speed operation, the PLL provides the 4X USB sampling rate.

2.2.2.1 State Time and Peripheral Cycles

The basic unit of time for 8x930 microcontrollers is the *state time* (or *state*). States are divided into two phases identified as *phase 1* and *phase 2*. See Figures 2-7 and 2-8. The 8x930 on-chip peripherals operate on a *peripheral cycle*, which is six state times. A specific time within a peripheral cycle is denoted by its state and phase. For example, the PCA timer is incremented once each peripheral cycle in phase 2 of state 5 (denoted as S5P2).

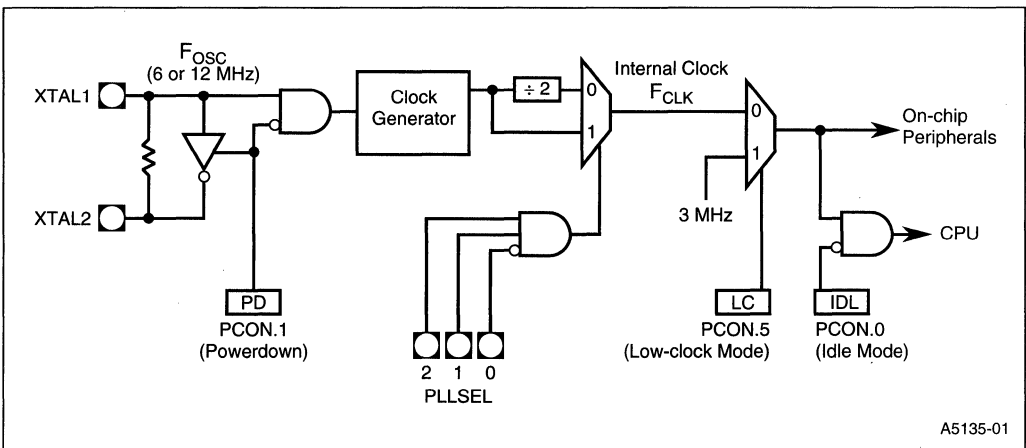


Figure 2-6. Clock Circuit

As shown in Table 2-4 and Figure 2-7, when PLLSEL2:0 = 001 or 100 (low speed), there are two T_{OSC} periods per state. As shown in Table 2-4 and Figure 2-8, when PLLSEL2:0 = 110 (full speed), there is one T_{OSC} period per state. See “Low-clock Mode” below.

As shown in Table 2-4 the internal clock frequency (F_{CLK}) distributed to the CPU and peripherals (3, 6, or 12 MHz) is a function of PLLSEL2:0 and F_{OSC} . Note that in Figure 2-6, for PLLSEL2:0 = 110 (full speed), the two-to-one divider stage is bypassed and $F_{CLK} = F_{OSC} = 12$ MHz.

2.2.2.2 Low-clock Mode

A special power-reduction mode (low-clock mode) overrides the timing definitions given in “State Time and Peripheral Cycles” above and Figures 2-7 and Figures 2-8. Following device reset, the CPU and on-chip peripherals operate in low-clock mode ($F_{CLK} = 3$ MHz) until the LC bit in PCON is cleared. During low-clock mode, there are four T_{OSC} periods per state for PLLSEL2:0 = 001 or 100. Low-clock mode does not affect the USB rate. Also see Chapter 15, “Special Operating Modes.”

2.2.2.3 Reset Unit

The reset unit resets the 8x930 to a known state. A chip reset is initiated by asserting the RST pin, by a USB-initiated reset, or by allowing the watchdog timer to time out. The 8x930Ax can be programmed so a USB-initiated reset does not cause a chip reset. For information on resets refer to Chapter 14, “Minimum Hardware Setup”.

Table 2-4. 8x930 Operating Frequency

Device	PLLSEL2:0 (Pins 43, 42, 44) (1)	XTAL1 Frequency (F_{OSC})	USB Rate (2)	Internal Frequency (F_{CLK}) (3)	XTAL1 Clocks per State ($T_{OSC}/state$) (5)	Comments
8x930Ax	001	6 Mhz	1.5 Mbps (Low Speed)	3 Mhz	2 (4)	PLL Off
8x930Ax	100	12 Mhz	1.5 Mbps (Low Speed)	6 Mhz (4)	2 (4)	PLL Off
8x930Ax 8x930Hx	110	12 Mhz	12 Mbps (Full Speed)	12 Mhz (4)	1	PLL On

NOTES:

- Other PLLSEL2:0 combinations are not valid.
- The sampling rate is 4X the USB rate.
- The internal frequency, $F_{CLK} = 1/T_{CLK}$, is the clock signal distributed to the CPU and the on-chip peripherals,
- Following device reset, the CPU and on-chip peripherals operate in low-clock mode ($F_{CLK} = 3$ Mhz) until the LC bit in the PCON register is cleared. In low clock mode, there are four T_{OSC} periods per state for PLLSEL2:0 = 100 or 110. Low-clock mode does not affect the USB rate.
- The number of XTAL1 clock periods per state ($T_{OSC}/state$) depends on PLLSEL2:0 and the LC bit.

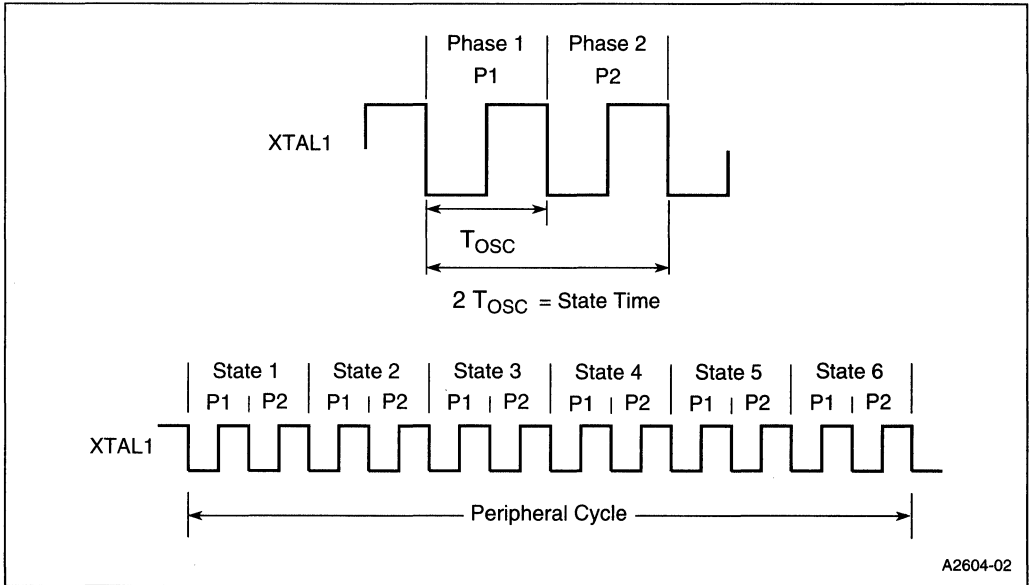


Figure 2-7. Clocking Definitions (Low Speed)

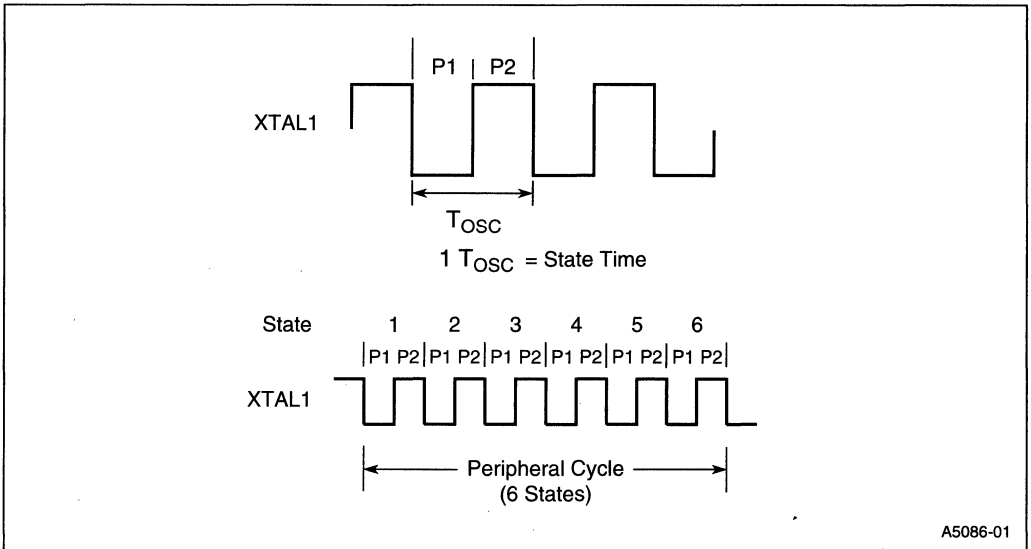


Figure 2-8. Clocking Definitions (Full Speed)

2.2.3 Interrupt Handler

The interrupt handler can receive interrupt requests from eleven maskable sources and the TRAP instruction. When the interrupt handler grants an interrupt request, the CPU discontinues the normal flow of instructions and branches to a routine that services the source that requested the interrupt. You can enable or disable the interrupts individually (except for TRAP) and you can assign one of four priority levels to each interrupt. Refer to Chapter 6, "Interrupt System," for a detailed description.

2.3 ON-CHIP MEMORY

For ROM devices, the 8x930 provides on-chip program memory beginning at location FF:0000H. See Table 2-1 for memory options. Following chip reset, the first instruction is fetched from location FF:0000H. (For devices without ROM, instruction fetches are always from external memory. Following chip reset, the first instruction is fetched from the external memory location that corresponds to internal address FF:0000H. Figure 4-5 on page 4-8 and Figure 4-6 on page 4-9 show how addresses in region FF: map into external memory for various memory configurations.)

The 8x930 provides on-chip data RAM beginning at location 00:0020H (just above the four banks of registers R0–R7 which occupy the first 32 bytes of the memory space). See Table 2-1 for memory options. Data RAM locations can be accessed with direct, indirect, and displacement addressing. Ninety-six of these locations (20H–7FH) are bit addressable.

2.4 UNIVERSAL SERIAL BUS MODULE

The USB module operates in conjunction with the CPU to provide the capabilities of a USB device. The 8x930Ax USB module provides a function interface for one USB function. The 8x930Hx USB module supports one USB function and in addition provides a USB hub capability.

The 8x930 USB module communicates with the host PC by means of upstream data port 0 (pins D_{P0} , D_{M0}). In addition to the upstream port, the 8x930Hx has three external downstream ports for bus expansion (pins D_{P1} , D_{M1} , D_{P2} , D_{M2} , D_{P3} , D_{M3}) and an internal downstream port for communicating with the embedded function. The 8x930 provides on-chip transceivers for each external USB port.

Operation of the USB module is controlled through the use of special function registers (SFRs). SFRs associated with the function interface are described in Chapter 7, "USB Function." SFRs associated with USB hub operations are described in Chapter 8, "USB Hub." Interrupt SFRs are described in Chapter 6, "Interrupt System." Register definition tables in these chapters describe register usage and define the register bits. The register definition tables also appear in Appendix C in alphabetical order. Memory maps of the 8x930Ax and 8x930Hx SFRs are presented in Chapter 3, "Address Spaces" and Appendix C.

Data transfers with the host are made to/from endpoint pairs (EPPs) on the USB module. The 8x930Hx provides four function endpoint pairs and two hub endpoint pairs. The 8x930Ax can be programmed to support either four or six function endpoint pairs. Table 2-5 lists the hub and function endpoint pairs available on the 8x930Hx along with the associated transmit and receive FIFO data buffers. Except for hub endpoints 0 and 1, Table 2-5 also applies to the 8x930Ax when the 4EPP option is selected. Table 2-6 lists the endpoint pairs available on the 8x930Ax when the

6EPP option is selected. The value in the EPINDEX register determines the endpoint pair involved in any given data transfer operation (Tables 2-5 and Table 2-6).

A complete description of the USB can be found in *Universal Serial Bus Specification*. For a description of the transceiver see the “Driver Characteristics” and “Receiver Characteristics” sections of the “Electrical” chapter of the *Universal Serial Bus Specification*. For electrical characteristics and data signal timing, see the “Bus Timing/Electrical Characteristics” and “Timing Diagram” sections of the same chapter.

Table 2-5. Endpoint Pairs for 8x930Hx and 8x930Ax (4EPP Option)

EPINDEX	Endpoint Pair	Transmit FIFOs	Receive FIFOs	FIFO Size Select (1)
0000 0000	Function Endpoint 0 (Control)	16 bytes	16 bytes	XX
0000 0001	Function Endpoint 1	256 bytes	256 bytes	0 0
		512 bytes	512 bytes	0 1
		1024 bytes	0 bytes	1 0
		0 bytes	1024 bytes	1 1
0000 0010	Function Endpoint 2	16 bytes	16 bytes	XX
0000 0011	Function Endpoint 3	16 bytes	16 bytes	XX
1000 0000	Hub Endpoint 0 (Control) (2)	16 bytes	16 bytes	XX
1000 0001	Hub Endpoint 1 (2), (3)	N/A	N/A	XX

NOTE:

1. Bits FFSZ1:0 (TXCON.6:5) specify the size of the transmit and receive FIFOs for function endpoint 1.
2. Hub endpoints are not applicable to the 8X930Ax.
3. Hub endpoint 1 assembles status-change information in a buffer register (TXDAT) and transmits it to the host PC. Hub endpoint 1 does not require FIFOs.

Table 2-6. Endpoint Pairs for 8x930Ax (6EPP Option)

EPINDEX	Endpoint Pair	Transmit FIFOs	Receive FIFOs	FIFO Size Select (1)
0000 0000	Function Endpoint 0 (Control)	16 bytes	16 bytes	XX
0000 0001	Function Endpoint 1	256 bytes	256 bytes	0 0
0000 0010	Function Endpoint 2	32 bytes	32 bytes	XX
0000 0011	Function Endpoint 3	32 bytes	32 bytes	XX
0000 0100	Function Endpoint 4 (2)	32 bytes	32 bytes	XX
0000 0101	Function Endpoint 5 (2)	16 bytes	16 bytes	XX

NOTE:

1. Bits FFSZ1:0 (TXCON.6:5) specify the size of the transmit and receive FIFOs for function endpoint 1. For the 6EPP option, use FFSZ1:0 = 00.
2. On the 8x930Ax, setting the SIXEPPEN bit in the EPCONFIG register selects the six-endpoint option (6EPP). Function endpoints 4 and 5 are available only when the 6EPP option is selected. Early sample devices did not have this feature.

2.4.1 The 8x930Ax USB Module

Figure 2-3 on page 2-6 shows the main functional blocks of the 8x930Ax USB module and how they interface with the CPU. The USB function interface manages communications between the host PC and the USB function. This interface consists of the serial bus interface engine (SIE), the function interface unit (FIU), and the transmit and receive FIFOs. The SIE handles the communication protocol of the universal serial bus, and the FIU handles data transfers and provides the interface between the SIE and the 8x930Ax CPU.

The 8x930Ax function interface, which can be programmed to have either four or six endpoint pairs, supports all four types of USB data transfer: control, isochronous, interrupt, and bulk. Function endpoint 1 handles only control data transfers, whereas function endpoints 1 through 5 handle all four data transfer types.

2.4.1.1 Serial Bus Interface Engine (SIE)

The SIE is the USB protocol interpreter for communications between the 8x930Hx and the host PC over the USB lines. It provides serial-to-parallel conversion for data transfers from the host and parallel-to-serial conversion for data transfers to the host. For additional information on the SIE, see "SIE Details" on page 7-33.

2.4.1.2 Function Interface Unit (FIU)

The FIU manages data movement within the USB module. It controls the operation of the FIFOs, monitors the status of the data transactions, and at the appropriate moment transfers event control to the CPU through an interrupt request. The exact nature of a data transaction depends on the type of data transfer and the initial conditions of the transmit and receive FIFOs.

2.4.1.3 Function FIFOs

Each endpoint pair contains a transmit FIFO and a receive FIFO. See Table 2-5 for FIFO configurations. Transmit FIFOs are written by the CPU, then read by the FIU for transmission. Receive FIFOs are written by the FIU following reception, then read by the CPU. All transmit FIFOs have the same architecture, and all receive FIFOs have the same architecture.

2.4.2 The 8x930Hx USB Module

Figure 2-4 on page 2-7 shows the main functional blocks of the 8x930Hx USB module and how they interface with CPU. As on the 8x930Ax USB module described above, the SIE, FIU, and function FIFOs comprise the function interface. The 8x930Hx function interface is similar to that of the 8x930Ax. See "The 8x930Ax USB Module" on page 2-14. There are three main differences: the 8x930Hx function interface is accessed via the internal downstream port, and it does not have the six-endpoint pair option nor the separate USB reset feature.

The 8x930Hx function interface has four endpoint pairs. It supports all four types of USB data transfer: control, isochronous, interrupt, and bulk. Function endpoint 0 handles only control data transfers, whereas function endpoints 1, 2, and 3 handle all four data transfer types.

The repeater, the SIE, the hub interface unit (HIU), and the hub FIFOs provide the hub capability. The hub interface has two endpoint pairs. Hub endpoint 0 supports only control data transfers. Hub endpoint 1 is used to transmit hub status change information to the host PC.

8x930Hx USB hub operations are divided into two categories: hub repeater operations and hub controller operations. The hub controller is split among four modules: the serial bus interface engine, the hub interface unit, the hub endpoint 0 transmit and receive FIFOs, and the 8x930Hx CPU. (See Chapter 8.) The following subsections discuss the role of each module.

2.4.2.1 Hub Repeater

The repeater is the connectivity manager for the 8X930Hx. It detects the connection or disconnection of devices on the external downstream ports and manages the upstream/downstream connectivity for data packets. It keeps track of hub port status, manages connectivity, and performs power management for external down stream ports. The repeater supports both full-speed (12 Mbps) and low-speed (1.5 Mbps) data traffic. The repeater also controls bus fault detection and recovery. Downstream port control is managed primarily by the HIU.

2.4.2.2 Serial Bus Interface Engine (SIE)

The SIE is the USB communication protocol interpreter. It places data on and accepts data from the bus. On the 8x930Hx, the hub interface and the function interface share the SIE. This is possible because the host communicates with only a single device during any one transaction. The SIE is permanently attached to the internal downstream port. The SIE provides serial-to-parallel conversion for data transfers from the host and parallel-to-serial conversion for data transfers to the host. For additional information on the SIE, see “SIE Details” on page 7-33. For complete functional, signal, and timing information, refer to the *USB Function SIE Interface Specification*.

2.4.2.3 Hub Interface Unit (HIU)

The HIU uses special function registers (SFRs) to control the operation of the hub and to maintain the status of the hub and its downstream ports. Control SFRs are set by firmware in response to USB requests. Status SFRs are set by the repeater hardware. Refer to Chapter 8, “USB Hub”, and Chapter 9, “USB Programming Models,” for a discussion on the use of the HIU SFRs.

2.4.2.4 Hub FIFOs

Hub FIFOs operate in the same manner as the function interface FIFOs. See Chapter 7, “USB Function.” Hub endpoint 0 handles only control data transfers. It is implemented with 16-byte transmit and receive FIFO data buffers. The maximum packet size for hub control data transfers is eight bytes. Data received from the USB for endpoint 0 is stored in the receive FIFO for reading by firmware. Data to be sent to the host from hub endpoint 0 is loaded into the transmit FIFO.

Hub endpoint 1 transmits single-byte interrupt tokens to the host and does not have FIFO data buffers.

2.4.2.5 8x930Hx CPU

The CPU runs the firmware associated with the operation of the hub and the function interface. The CPU reads the receive FIFOs, loads the transmit FIFOs, and decodes and executes USB requests for the hub. Control transaction stages are also tracked by firmware. Hub operation is implemented by reading and writing SFRs in the HIU. Operation of the function interface is implemented by reading and writing SFRs in the FIU.

2.5 ON-CHIP PERIPHERALS

The on-chip peripherals reside outside the microcontroller core. They perform specialized functions in hardware. Firmware controls the peripherals via their special function registers (SFRs). The 8x930 has four peripherals: the watchdog timer, the timer/counter unit, the programmable counter array (PCA), and the serial I/O port.

2.5.1 Timer/Counters and Watchdog Timer

The timer/counter unit has three timer/counters, which can be clocked by the oscillator (for timer operation) or by an external input (for counter operation). You can set up an 8-bit, 13-bit, or 16-bit timer/counter. You can program them for special applications, such as capturing the time of an event on an external pin, outputting a programmable clock signal on an external pin, or generating a baud rate for the serial I/O port. Timer/counter events can generate interrupt requests.

The watchdog timer is a circuit that automatically resets the 8x930 in the event that a hardware or firmware operation fails to complete. When enabled by firmware, the watchdog timer begins running, and unless firmware intervenes, the timer overflows and initiates a chip reset. In normal operation, firmware periodically clears the timer register to prevent the reset. If a malfunction occurs and firmware fails to clear the timer, the resulting chip reset disables the timer and returns the system to a known state. The watchdog timer and the timer/counters are described in Chapter 11, "Timer/Counters and Watchdog Timer."

2.5.2 Programmable Counter Array (PCA)

The programmable counter array (PCA) has its own timer and five capture/compare modules that perform several functions: capturing (storing) the timer value in response to a transition on an input pin; generating an interrupt request when the timer matches a stored value; toggling an output pin when the timer matches a stored value; generating a programmable PWM (pulse width modulator) signal on an output pin; and serving as a firmware watchdog timer. Chapter 12, "Programmable Counter Array," describes this peripheral in detail.

2.5.3 Serial I/O Port

The serial I/O port provides one synchronous and three asynchronous communication modes. The synchronous mode (mode 0) is half-duplex: the serial port outputs a clock signal on one pin and transmits or receives data on another pin.

The asynchronous modes (modes 1–3) are full-duplex (i.e., the port can send and receive simultaneously). Mode 1 uses a serial frame of 10 bits: a start bit, 8 data bits, and a stop bit. The baud rate is generated by the overflow of timer 1 or timer 2. Modes 2 and 3 use a serial frame of 11 bits: a start bit, eight data bits, a programmable ninth data bit, and a stop bit. The ninth bit can be used for parity checking or to specify that the frame contains an address and data. In mode 2, you can use a baud rate of 1/32 or 1/64 of the oscillator frequency. In mode 3, you can use the overflow from timer 1 or timer 2 to determine the baud rate.

In its asynchronous modes (modes 1–3) the serial port can operate as a slave in an environment where multiple slaves share a single serial line. It can accept a message intended for itself or a message that is being broadcast to all of the slaves, and it can ignore a message sent to another slave.

2.6 OPERATING CONDITIONS

The 8x930 is designed for a commercial operating environment and to accommodate the operating rates of the USB interface. For detailed specifications, refer to the current 8x930 Universal Serial Bus Microcontroller datasheet. For USB module operating rates, see “Clock and Reset Unit” on page 2-9.





3

Address Spaces





CHAPTER 3 ADDRESS SPACES

The 8x930 has three address spaces: a memory space, a special function register (SFR) space, and a register file. This chapter describes these address spaces as they apply to the 8x930. It also discusses the compatibility of the MCS[®] 251 architecture and the MCS[®] 51 architecture in terms of their address spaces.

3.1 MCS[®] 251 ARCHITECTURE ADDRESS SPACES

Figure 3-1 shows the memory space, the SFR space, and the register file for MCS 251 architecture. (The address spaces are depicted as being eight bytes wide with addresses increasing from left to right and from bottom to top.)

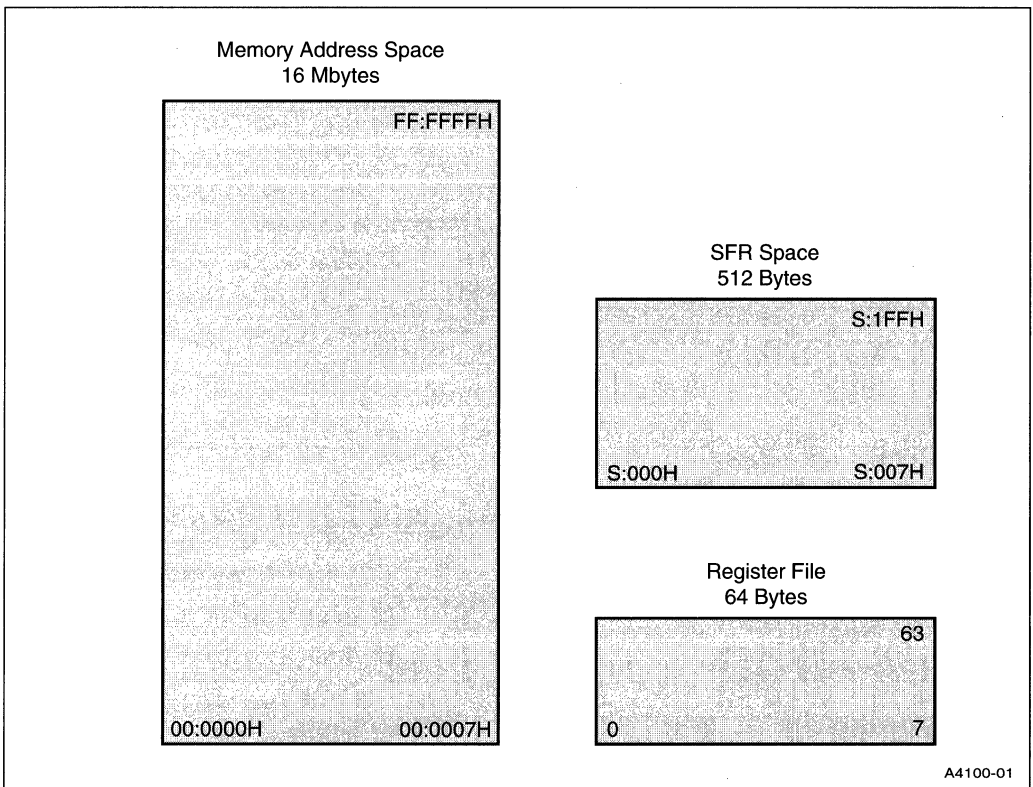


Figure 3-1. MCS[®] 251 Architecture Address Spaces

It is convenient to view the unsegmented, 16-Mbyte memory space as consisting of 256 64-Kbyte regions, numbered 00: to FF:.

NOTE

The memory space in the 8x930 is unsegmented. The 64-Kbyte “regions” 00:, 01:, ..., FF: are introduced only as a convenience for discussions. Addressing in the 8x930 is linear; there are *no* segment registers.

On-chip RAM is located at the bottom of the memory space, beginning at location 00:0000H. The first 32 bytes (00:0000H–00:001FH) provide storage for a part of the register file. The on-chip, general-purpose data RAM resides just above this, beginning at location 00:0020H.

On-chip ROM (code memory) is located in the top region of the memory space, beginning at location FF:0000H. Following device reset, execution begins at this address. The top eight bytes of region FF: are reserved for the configuration array.

The register file has its own address space (Figure 3-1). The 64 locations in the register file are numbered decimally from 0 to 63. Locations 0–7 represent one of four switchable register banks, each having eight registers. The 32 bytes required for these banks occupy locations 00:0000H–00:001FH in the memory space. Register file locations 8–63 do not appear in the memory space. See “8x930 Register File” on page 3-9 for a further description of the register file.

The SFR space accommodates up to 512 eight-bit special function registers with addresses S:000H–S:1FFH. SFRs implemented in the 8x930 are shown in Table 3-6 on page 3-10. In the MCS 251 architecture, use the prefix “S:” with SFR addresses to distinguish them from the memory space addresses 00:0000H–00:01FFH. See “Special Function Registers (SFRs)” on page 3-15 for details on the SFR space.

3.1.1 Compatibility with the MCS[®] 51 Architecture

The address spaces in the MCS 51 architecture[†] are mapped into the address spaces in the MCS 251 architecture. This mapping allows code written for MCS 51 microcontrollers to run on MCS 251 microcontrollers. (Chapter 5, “Programming Considerations” discusses the compatibility of the two instruction sets.)

Figure 3-2 shows the address spaces for the MCS 51 architecture. Internal data memory locations 00H–7FH can be addressed directly and indirectly. Internal data locations 80H–FFH can only be addressed indirectly. Directly addressing these locations accesses the SFRs. The 64-Kbyte code memory has a separate memory space. Data in the code memory can be accessed only with the MOV_C instruction. Similarly, the 64-Kbyte external data memory can be accessed only with the MOV_X instruction.

The register file (registers R0–R7) comprises four switchable register banks, each having eight registers. The 32 bytes required for the four banks occupy locations 00H–1FH in the on-chip data memory.

Figure 3-3 shows how the address spaces in the MCS 51 architecture map into the address spaces in the MCS 251 architecture; details are listed in Table 3-1.

[†] MCS[®]51 Microcontroller Family User's Manual (Order Number: 272383)

The 64-Kbyte code memory for MCS 51 microcontrollers maps into region FF: of the memory space for MCS 251 microcontrollers. Assemblers for MCS 251 microcontrollers assemble code for MCS 51 microcontrollers into region FF:, and data accesses to code memory are directed to this region. The assembler also maps the interrupt vectors to region FF:. This mapping is transparent to the user; code executes just as before, without modification.

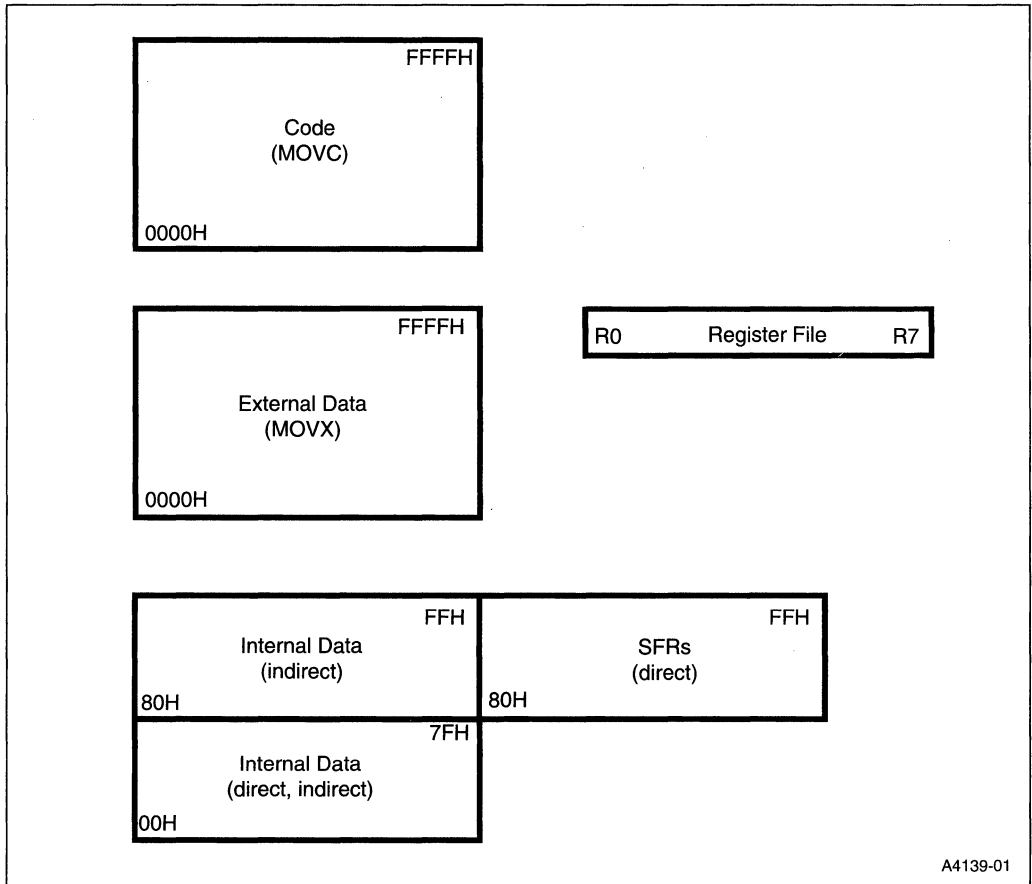


Figure 3-2. Address Spaces for the MCS® 51 Architecture

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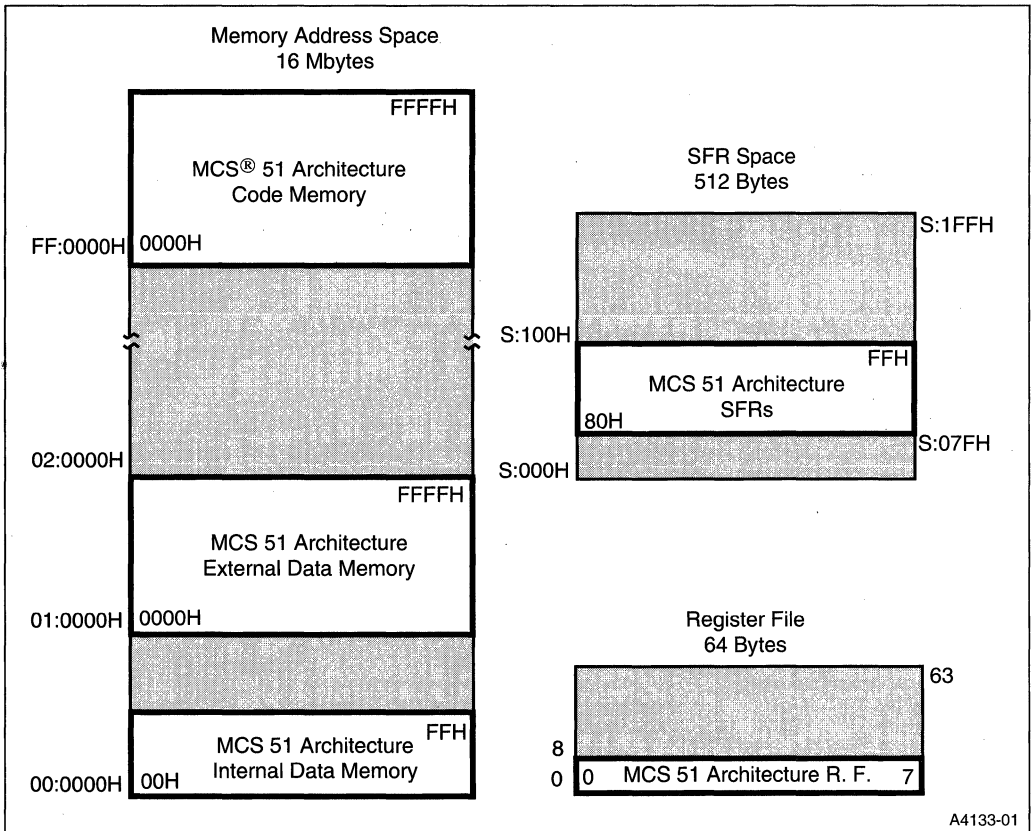


Figure 3-3. Address Space Mappings MCS® 51 Architecture to MCS® 251 Architecture

Table 3-1. Address Mappings

Memory Type	MCS® 51 Architecture			MCS® 251 Architecture
	Size	Location	Data Addressing	Location
Code	64 Kbytes	0000H–FFFFH	Indirect using MOVC instr.	FF:0000H–FF:FFFFH
External Data	64 Kbytes	0000H–FFFFH	Indirect using MOVX instr.	01:0000H–01:FFFFH
Internal Data	128 bytes	00H–7FH	Direct, Indirect	00:0000H–00:007FH
	128 bytes	80H–FFH	Indirect	00:0080H–00:00FFH
SFRs	128 bytes	S:80H–S:FFH	Direct	S:080H–S:0FFH
Register File	8 bytes	R0–R7	Register	R0–R7

The 64-Kbyte external data memory for MCS 51 microcontrollers is mapped into the memory region specified by bits 16–23 of the data pointer DPX, i.e., DPXL. DPXL is accessible as register file location 57 and also as the SFR at S:084H (see “Dedicated Registers” on page 3-12). The reset value of DPXL is 01H, which maps the external memory to region 01: as shown in Figure 3-3. You can change this mapping by writing a different value to DPXL. A mapping of the MCS 51 microcontroller external data memory into any 64-Kbyte memory region in the MCS 251 architecture provides complete run-time compatibility because the lower 16 address bits are identical in the two address spaces.

The 256 bytes of on-chip data memory for MCS 51 microcontrollers (00H-FFH) are mapped to addresses 00:0000H-00:00FFH to ensure complete run-time compatibility. In the MCS 51 architecture, the lower 128 bytes (00H-7FH) are directly and indirectly addressable; however the upper 128 bytes are accessible by indirect addressing only. In the MCS 251 architecture, all locations in region 00: are accessible by direct, indirect, and displacement addressing (see “8x930 Memory Space” on page 3-5).

The 128-byte SFR space for MCS 51 microcontrollers is mapped into the 512-byte SFR space of the MCS 251 architecture starting at address S:080H, as shown in Figure 3-3. This provides complete compatibility with direct addressing of MCS 51 microcontroller SFRs (including bit addressing). The SFR addresses are unchanged in the new architecture. In the MCS 251 architecture, SFRs A, B, DPL, DPH, and SP (as well as the new SFRs DPXL and SPH) reside in the register file for high performance. However, to maintain compatibility, they are also mapped into the SFR space at the same addresses as in the MCS 51 architecture.

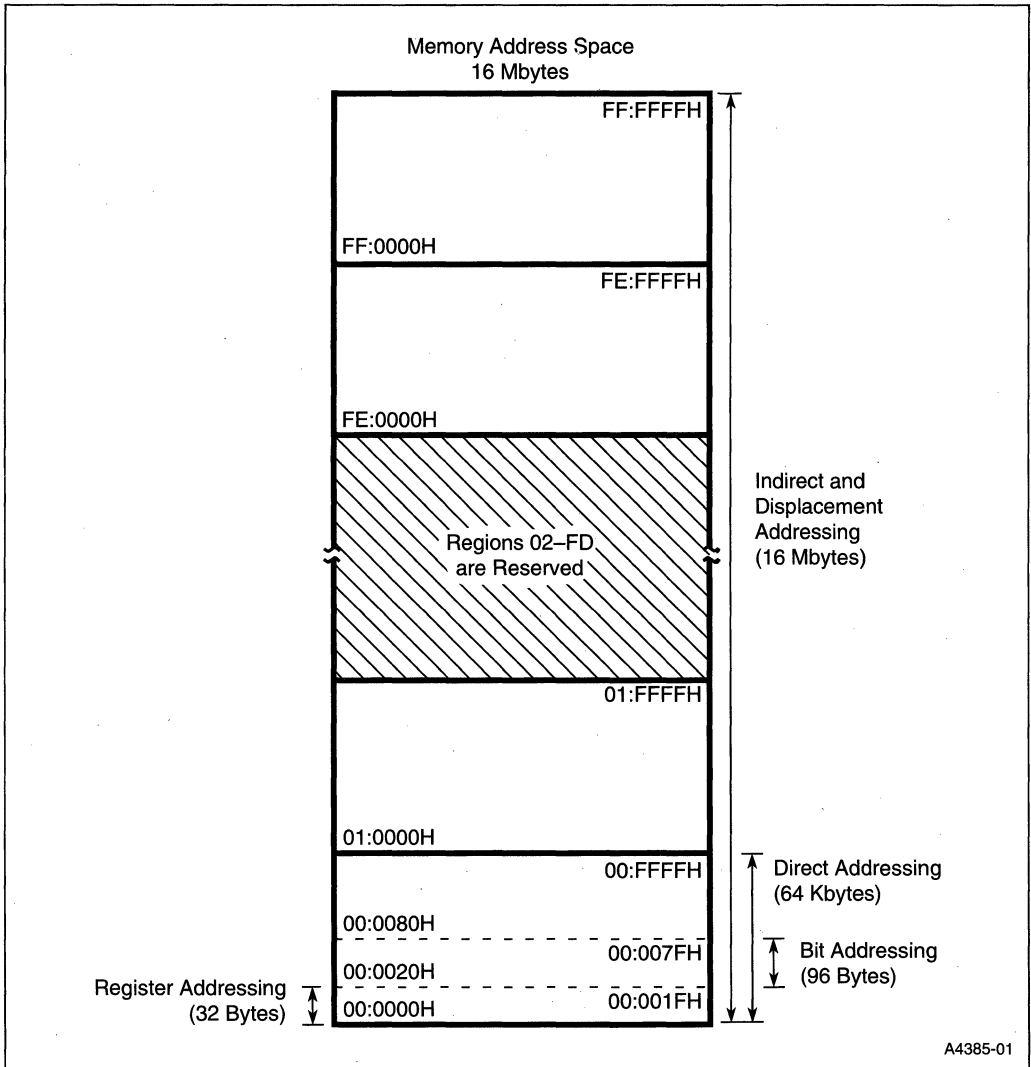
3.2 8x930 MEMORY SPACE

Figure 3-4 shows the logical memory space for the 8x930 microcontroller. The usable memory space of the 8x930 consists of four 64-Kbyte regions: 00:, 01:, FE:, and FF:. Code can execute from all four regions; code execution begins at FF:0000H. Regions 02:-FD are reserved. Reading a location in the reserved area returns an unspecified value. Firmware can execute a write to the reserved area, but nothing is actually written.

All four regions of the memory space are available at the same time. The maximum number of external address lines is 18, which limits external memory to a maximum of four regions (256 Kbytes). See “Configuring the External Memory Interface” on page 4-7, and “External Memory Design Examples” on page 16-17.

Locations FF:FFF8H–FF:FFFFH are reserved for the configuration array (see Chapter 4, “Device Configuration”). The two configuration bytes for the 8x930 are accessed at locations FF:FFF8H and FF:FFF9H; locations FF:FFFAH–FF:FFFFH are reserved for configuration bytes in future products. Do not attempt to execute code from locations FF:FFF8H–FF:FFFFH. Also, see the caution on page 4-3 regarding execution of code from locations immediately below the configuration array.

Figure 3-4 also indicates the addressing modes that can be used to access different areas of memory. The first 64 Kbytes can be directly addressed. The first 96 bytes of general-purpose RAM (00:0020H–00:007FH) are bit addressable. Chapter 5, “Programming Considerations,” discusses addressing modes.



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Figure 3-4. 8x930 Address Space

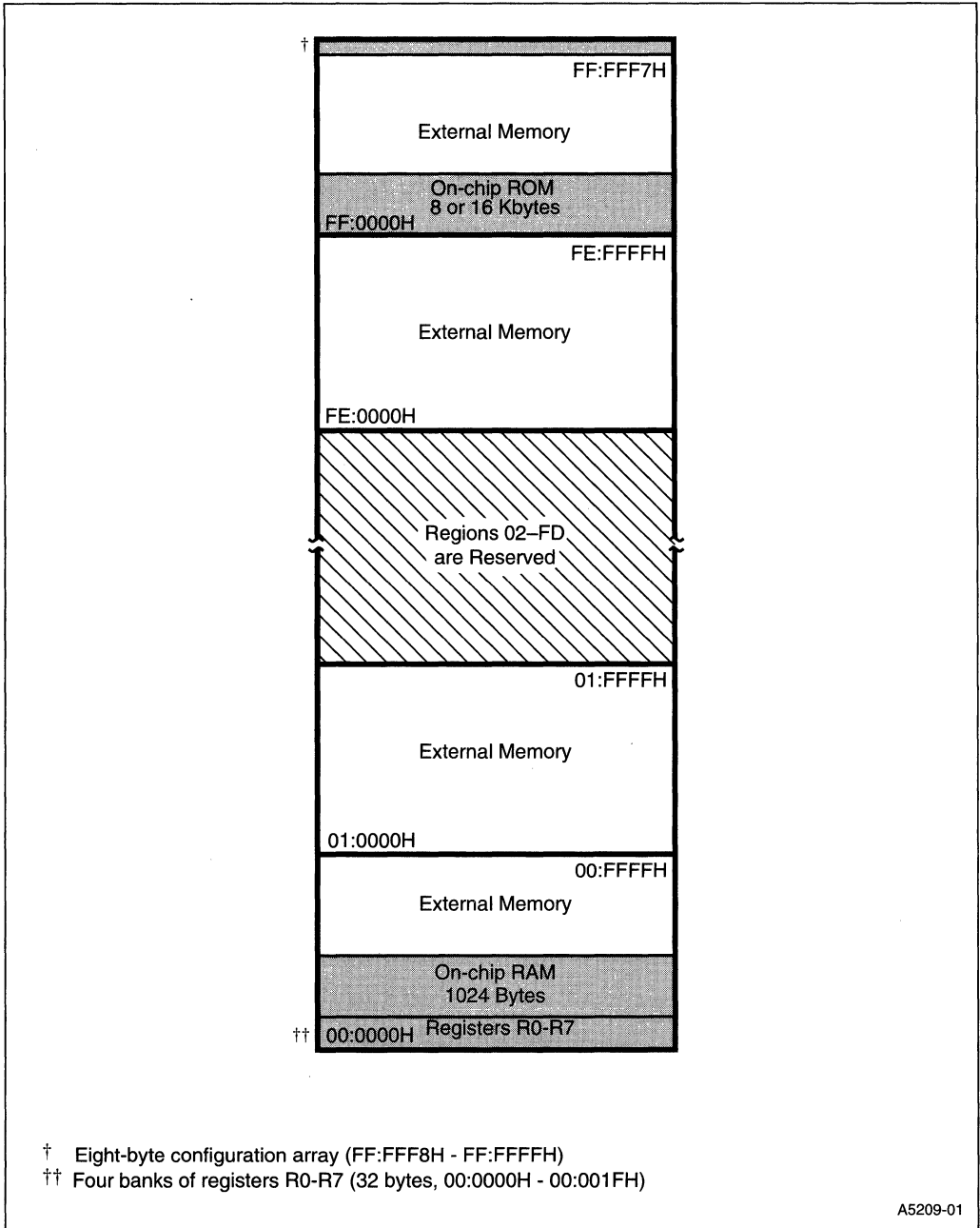


Figure 3-5. Hardware Implementation of the 8x930 Address Space

Figure 3-5 shows how areas of the memory space are implemented by on-chip RAM and external memory. The first 32 bytes of on-chip RAM store banks 0–3 of the register file (see “8x930 Register File” on page 3-9).

3.2.1 On-chip General-purpose Data RAM

On-chip RAM provides general data storage (Figure 3-5). Instructions cannot execute from on-chip data RAM. The data is accessible by direct, indirect, and displacement addressing. Locations 00:0020H–00:007FH are also bit addressable.

3.2.2 On-chip Code Memory

The 8x930 is available with 0, 8 or 16 Kbytes of on-chip ROM located in memory region FF: (Figure 3-5). Table 2-1 on page 2-3 lists the amount of on-chip code memory for each device. On-chip ROM is intended primarily for code storage, although its contents can also be read as data with the indirect and displacement addressing modes. Following a chip reset, program execution begins at FF:0000H. Chapter 17, “Verifying Nonvolatile Memory,” describes the procedure for verifying the contents of on-chip ROM.

A code fetch within the address range of the on-chip ROM accesses the on-chip ROM only if EA# = 1. For EA# = 0, a code fetch in this address range accesses external memory. The value of EA# is latched when the chip leaves the reset state. Code is fetched faster from on-chip code memory than from external memory. Table 3-2 lists the minimum times to fetch two bytes of code from on-chip memory and external memory.

NOTE

If your program executes exclusively from on-chip ROM (not from external memory), beware of executing code from the upper eight bytes of the on-chip ROM (FF:1FF8H–FF:1FFFH for 8 Kbytes, FF:3FF8H–FF:3FFFH for 16 Kbytes). Because of its pipeline capability, the 8x930 may attempt to prefetch code from external memory (at an address above FF:1FFFH/ FF:3FFFH) and thereby disrupt I/O ports 0 and 2. Fetching code constants from these eight bytes does not affect ports 0 and 2.

If your program executes from both on-chip ROM and external memory, code can be placed in the upper eight bytes of on-chip ROM. As the 8x930 fetches bytes above the top address in the on-chip ROM, code fetches automatically become external bus cycles. In other words, the rollover from on-chip ROM to external code memory is transparent to the user.

Table 3-2. Minimum Times to Fetch Two Bytes of Code

Type of Code Memory	State Times
On-chip Code Memory	1
External Memory (page mode)	2
External Memory (nonpage mode)	4

3.2.2.1 Accessing On-chip Code Memory in Region 00:

Devices with 16 Kbytes of on-chip code memory can be configured so that the upper half of the on-chip code memory can also be read as data at locations at the top of region 00: (see “Mapping On-chip Code Memory to Data Memory (EMAP#)” on page 4-14). That is, locations FF:2000H–FF:3FFFH can also be accessed at locations 00:E000H–00:FFFFH. This is useful for accessing code constants stored in ROM. Note, however, that all of the following three conditions must hold for this mapping to be effective:

- The device is configured with EMAP# = 0 in the UCONFIG1 register (See Figure 4-3 on page 4-5).
- EA# = 1.
- The access to this area of region 00: is a data read, not a code fetch.

If one or more of these conditions do not hold, accesses to the locations in region 00: are referred to external memory.

3.2.3 External Memory

Regions 01:, FE:, and portions of regions 00: and FF: of the memory space are implemented as external memory (Figure 3-5). For discussions of external memory, see “Configuring the External Memory Interface” on page 4-7, and Chapter 16, “External Memory Interface.”

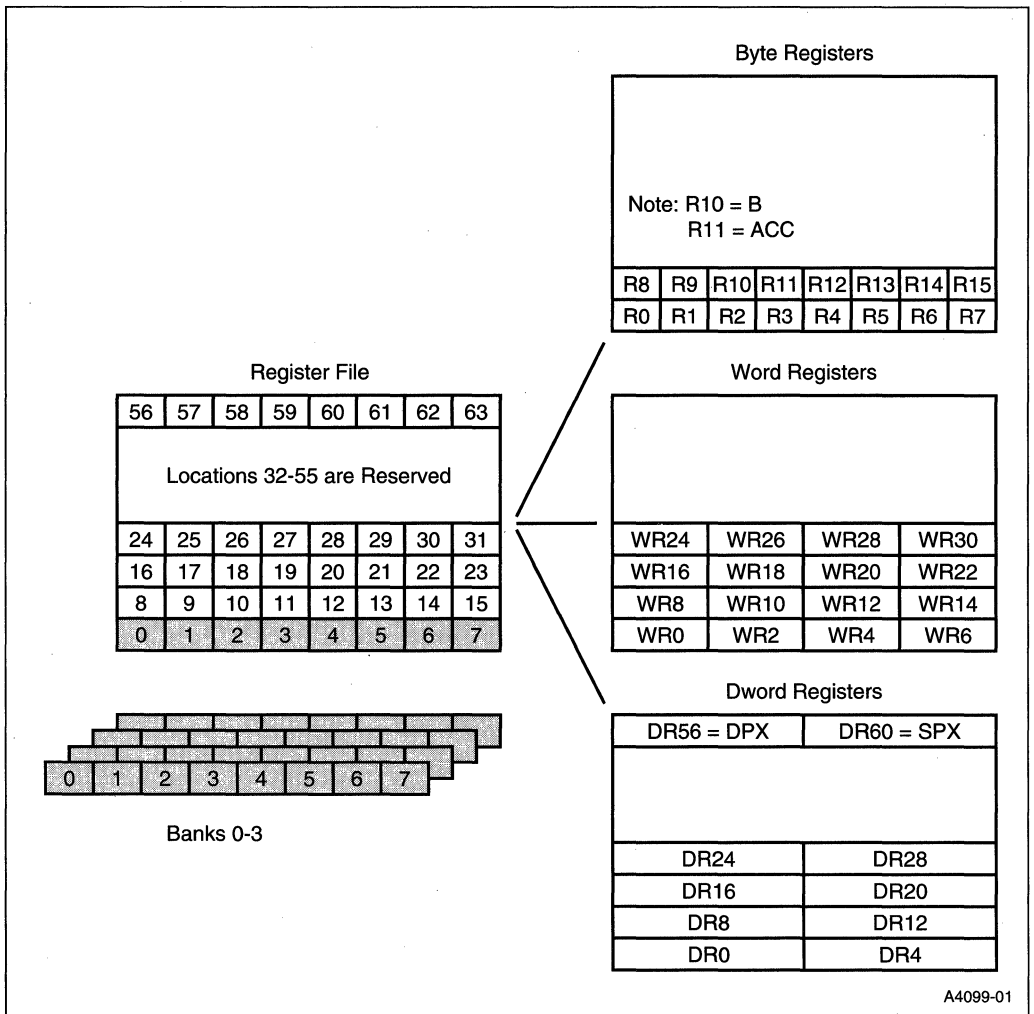
3.3 8x930 REGISTER FILE

The 8x930 register file consists of 40 locations: 0–31 and 56–63, as shown in Figure 3-6. These locations are accessible as bytes, words, and dwords, as described in “Byte, Word, and Dword Registers” on page 3-12.” Several locations are dedicated to special registers (see “Dedicated Registers” on page 3-12); the remainder are general-purpose registers.

Register file locations 0–7 actually consist of four switchable banks of eight registers each, as illustrated in Figure 3-7 on page 3-11. The four banks are implemented as the first 32 bytes of on-chip RAM and are always accessible as locations 00:0000H–00:001FH in the memory address space.† Only one of the four banks is accessible via the register file at a given time. The accessible, or “active,” bank is selected by bits RS1 and RS0 in the PSW register, as shown in Table 3-3. (The PSW is described in “Program Status Words” on page 5-15.”) This bank selection can be used for fast context switches.

Register file locations 8–31 and 56–63 are always accessible. These locations are implemented as registers in the CPU. Register file locations 32–55 are reserved and cannot be accessed.

† Because these locations are dedicated to the register file, they are not considered a part of the general-purpose, 1-Kbyte, on-chip RAM (locations 00:0020H–00:041FH).



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Figure 3-6. The Register File

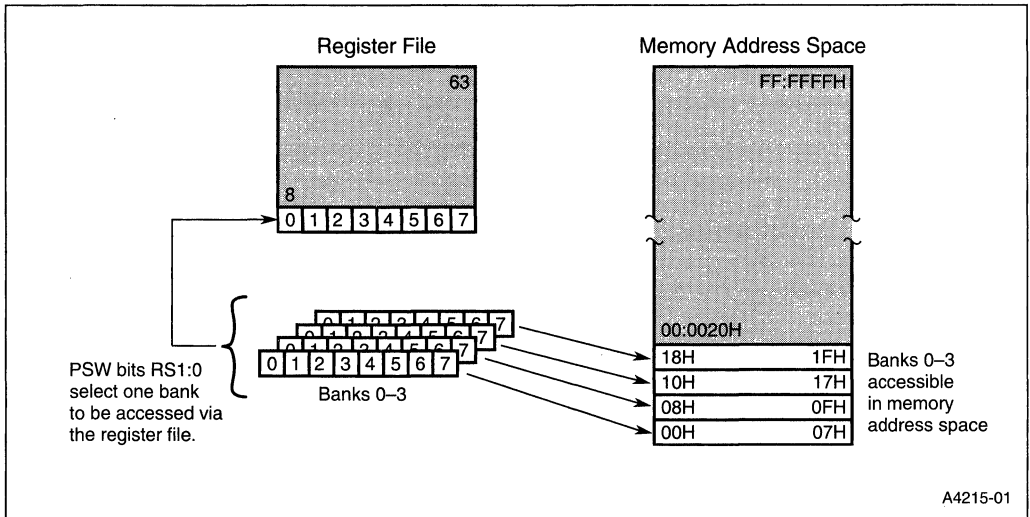


Figure 3-7. Register File Locations 0-7

Table 3-3. Register Bank Selection

Bank	Address Range	PSW Selection Bits	
		RS1	RS0
Bank 0	00H-07H	0	0
Bank 1	08H-0FH	0	1
Bank 2	10H-17H	1	0
Bank 3	18H-1FH	1	1

3.4 BYTE, WORD, AND DWORD REGISTERS

Depending on its location in the register file, a register is addressable as a byte, a word, and/or a dword, as shown on the right side of Figure 3-6. A register is named for its lowest numbered byte location. For example:

R4 is the byte register consisting of location 4.

WR4 is the word register consisting of registers 4 and 5.

DR4 is the dword register consisting of registers 4–7.

Locations R0–R15 are addressable as bytes, words, or dwords. Locations 16–31 are addressable only as words or dwords. Locations 56–63 are addressable only as dwords. Registers are addressed only by the names shown in Figure 3-6 — except for the 32 registers that comprise the four banks of registers R0–R7, which can also be accessed as locations 00:0000H–00:001FH in the memory space.

3.4.1 Dedicated Registers

The register file has four dedicated registers:

- R10 is the B-register
- R11 is the accumulator (ACC)
- DR56 is the extended data pointer, DPX
- DR60 is the extended stack pointer, SPX

These registers are located in the register file; however, R10; R11; the DPXL, DPH, and DPL bytes in DR56; and the SPH and SP bytes in DR60 are also accessible as SFRs. The bytes of DPX and SPX can be accessed in the register file only by addressing the dword registers. The dedicated registers in the register file and their corresponding SFRs are illustrated in Figure 3-8 and listed in Table 3-4.

3.4.1.1 Accumulator and B Register

The 8-bit *accumulator* (ACC) is byte register R11, which is also accessible in the SFR space as ACC at S:E0H (Figure 3-8). The *B register*, used in multiplies and divides, is register R10, which is also accessible in the SFR space as B at S:F0H. Accessing ACC or B as a register is one state faster than accessing them as SFRs.

Instructions in the MCS 51 architecture use the accumulator as the primary register for data moves and calculations. However, in the MCS 251 architecture, any of registers R1–R15 can serve for these tasks[†]. As a result, the accumulator does not play the central role that it has in MCS 51 microcontrollers.

[†] Bits in the PSW and PSW1 registers reflect the status of the accumulator. There are no equivalent status indicators for the other registers.

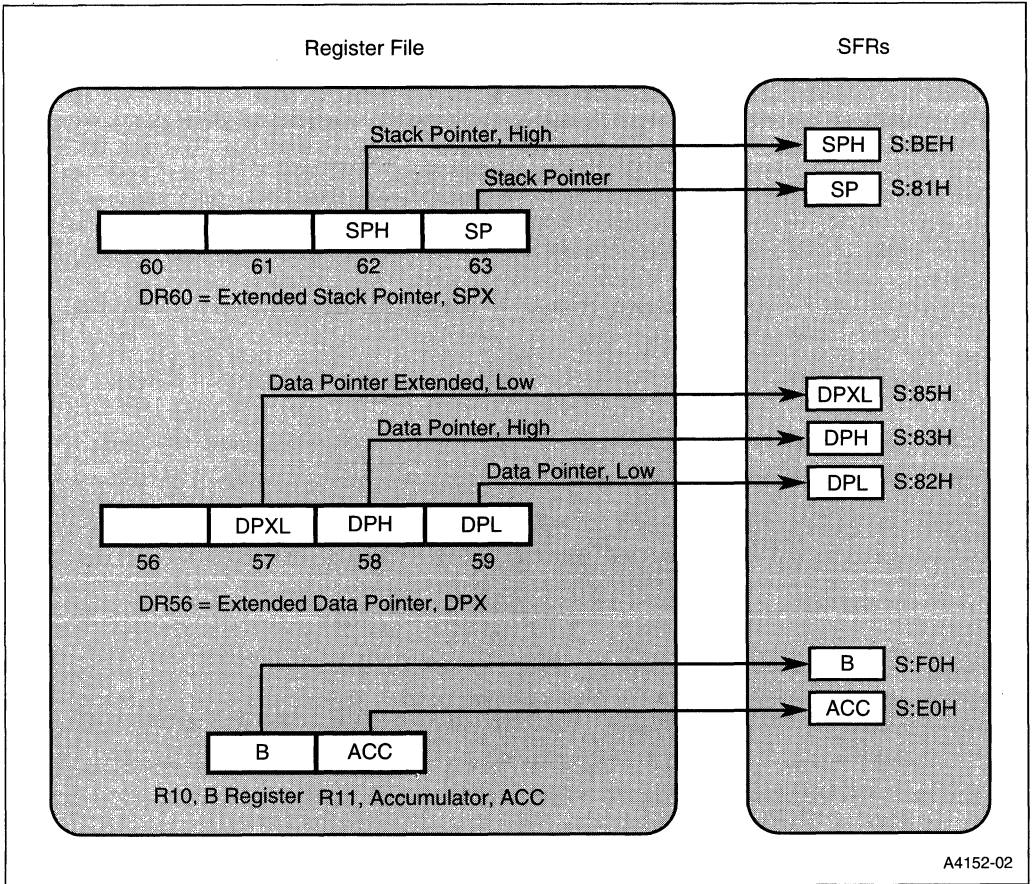


Figure 3-8. Dedicated Registers in the Register File and their Corresponding SFRs

3.4.1.2 Extended Data Pointer, DPX

Dword register DR56 is the *extended data pointer*, DPX (Figure 3-8). The lower three bytes of DPX (DPL, DPH, DPXL) are accessible as SFRs. DPL and DPH comprise the 16-bit *data pointer* DPTR. While instructions in the MCS 51 architecture always use DPTR as the data pointer, instructions in the MCS 251 architecture can use any word or dword register as a data pointer.

DPXL, the byte in location 57, specifies the region of memory (00:–FF:) that maps into the 64-Kbyte external data memory space in the MCS 51 architecture. In other words, the MOVX instruction addresses the region specified by DPXL when it moves data to and from external memory. The reset value of DPXL is 01H.

3.4.1.3 Extended Stack Pointer, SPX

Dword register DR60 is the *stack pointer*, SPX (Figure 3-8). The byte at location 63 is the 8-bit stack pointer, SP, in the MCS 51 architecture. The byte at location 62 is the *stack pointer high*, SPH. The two bytes allow the stack to extend to the top of memory region 00:.. SP and SPH can be accessed as SFRs.

Two instructions, PUSH and POP directly address the stack pointer. Subroutine calls (ACALL, ECALL, LCALL) and returns (ERET, RET, RETI) also use the stack pointer. To preserve the stack, do not use DR60 as a general-purpose register.

Table 3-4. Dedicated Registers in the Register File and their Corresponding SFRs

Register File					SFRs		
Name		Mnemonic	Reg.	Location	Mnemonic	Address	
Stack Pointer (SPX)	—	—	DR60	60	—	—	
	—	—		61	—	—	
	Stack Pointer, High	SPH		62	SPH	S:BEH	
	Stack Pointer, Low	SP		63	SP	S:81H	
Data Pointer (DPX)	—	—	DR56	56	—	—	
	Data Pointer Extended, Low	DPXL		57	DPXL	S:85H	
	DPTR	Data Pointer, High		DPH	58	DPH	S:83H
		Data Pointer, Low		DPL	59	DPL	S:82H
Accumulator (A Register)		A	R11	11	ACC	S:E0H	
B Register		B	R10	10	B	S:F0H	

3.5 SPECIAL FUNCTION REGISTERS (SFRS)

The special function registers (SFRs) reside in the microcontroller core, the USB module, and the on-chip peripherals. Memory maps showing the location of all the 8x930Ax and 8x930Hx SFRs are presented in Tables 3-5 and Tables 3-6. The contents of each register following device reset is given. An “x” indicates the bit value following reset is indeterminate.

Blank locations in Tables 3-5 and 3-6 and locations below S:80H and above S:FFH are unimplemented, i.e., no register exists. If an instruction attempts to write to an unimplemented SFR location, the instruction executes, but nothing is actually written. If an unimplemented SFR location is read, it returns an unspecified value.

Endpoint-indexed SFRs are implemented as banks of registers similar to register file locations R0-R7. There is a set or bank of registers for each endpoint pair. Endpoint-indexed SFRs are accessed by means of the SFR address and an index value. The EPINDEX register specifies hub/function and the endpoint number (which serves as the index value). See “Endpoint-indexed SFRs” on page 7-3 and “Hub Endpoint Indexing Using EPINDEX” on page 8-11.

Port-indexed SFRs (HPCON, HPSC, and HPSTST) are implemented in a similar manner. There is a set or bank of these registers for each USB downstream port. Port-indexed SFRs are accessed by means of the SFR address and an index value. The HPINDEX register contains the port number which serves as the index value. See “Hub Port Indexing Using HPINDEX” on page 8-23.

SFR addresses are preceded by “S:” to differentiate them from addresses in the memory space.

Tables describing the SFRs are presented in alphabetical order in Appendix C.

Table 3-7 through Table 3-14 list the SFRs by functional category.

Table 3-7 — Core SFRs

Table 3-8 — Interrupt System SFRs

Table 3-9 — I/O Port SFRs

Table 3-10 — Serial I/O SFRs

Table 3-11 — USB Function SFRs

Table 3-12 — USB Hub SFRs

Table 3-13 — Timer/Counter and Watchdog Timer SFRs

Table 3-14 — Programmable Counter Array (PCA) SFRs

NOTE

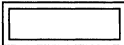
SFRs may be accessed only as bytes; they may not be accessed as words or dwords.

Table 3-5. 8x930Ax SFR Map

	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	
F8		CH 00000000	CCAP0H xxxxxxx	CCAP1H xxxxxxx	CCAP2H xxxxxxx	CCAP3H xxxxxxx	CCAP4H xxxxxxx		FF
F0	B 00000000	EPINDEX 1xxxx000	TXSTAT 00000000	TXDAT xxxxxxx	TXCON 000x0100†	TXFLG 00xx1000	TXCNTL 00000000†	TXCNTH xxxxxx00	F7
E8		CL 00000000	CCAP0L xxxxxxx	CCAP1L xxxxxxx	CCAP2L xxxxxxx	CCAP3L xxxxxxx	CCAP4L xxxxxxx		EF
E0	ACC 00x000000	EPCON 00x10000†	RXSTAT 00000000	RXDAT xxxxxxx	RXCON 0x000100	RXFLG 00xx1000	RXCNTL 00000000†	RXCNTH xxxxxx00	E7
D8	CCON 00x000000	CMOD 00xx0000	CCAPM0 x0000000	CCAPM1 x0000000	CCAPM2 x0000000	CCAPM3 x0000000	CCAPM4 x0000000	PCON1 xx000000	DF
D0	PSW 00000000	PSW1 00000000	SOFL 00000000	SOFH 00000000					D7
C8	T2CON 00000000	T2MOD xxxxxx00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000			CF
C0	FIFLG 00000000	FIFLG1 00000000						EPCONFIG xxxxxxx0	C7
B8	IPL0 x00000000	SADEN 00000000					SPH 00000000		BF
B0	P3 11111111	IEN1 xxx00000	IPL1 x0000000	IPH1 x0000000				IPH0 x00000000	B7
A8	IEN0 00000000	SADDR 00000000							AF
A0	P2 11111111		FIE 00000000	FIE1 00000000			WDTRST xxxxxxx	WCN xxxxxx00	A7
98	SCON 00000000	SBUF xxxxxxx							9F
90	P1 11111111								97
88	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000		FADDR 00000000	8F
80	P0 11111111	SP 00000111	DPL 00000000	DPH 00000000		DPXL 00000001		PCON 00XX0000	87



MCS 251 microcontroller SFRs



Endpoint-indexed SFRs

† For EPCON, TXCON, TXCNTL, and RXCNTL, the reset value depends on the endpoint pair selected. Refer to the register definition tables in Appendix C or Chapter 7, "USB Function."

Table 3-6. 8X930Hx SFR Map

	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	
F8		CH 00000000	CCAP0H xxxxxxx	CCAP1H xxxxxxx	CCAP2H xxxxxxx	CCAP3H xxxxxxx	CCAP4H xxxxxxx		FF
F0	B 00000000	EPINDEX 1xxxx00	TXSTAT 00000000	TXDAT†† xxxxxxx†	TXCON 000x0100†	TXFLG 00xx1000	TXCNTL 00000000†	TXCNTH xxxxxx00	F7
E8	HIFLG 0xxxxx00	CL 00000000	CCAP0L xxxxxxx	CCAP1L xxxxxxx	CCAP2L xxxxxxx	CCAP3L xxxxxxx	CCAP4L xxxxxxx		EF
E0	ACC 00000000	EPCON 00x10000†	RXSTAT 00000000	RXDAT xxxxxxx	RXCON 0x000100	RXFLG 00xx1000	RXCNTL 00000000†	RXCNTH xxxxxx00	E7
D8	CCON 00x00000	CMOD 00xxx000	CCAPM0 x0000000	CCAPM1 x0000000	CCAPM2 x0000000	CCAPM3 x0000000	CCAPM4 x0000000	PCON1 xxx00000	DF
D0	PSW 00000000	PSW1 00000000	SOFL 00000000	SOFH 00000000	HPINDEX xxxxx000	HPSC xx000000		HPSTAT 0x000100	D7
C8	T2CON 00000000	T2MOD xxxxxx00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000		HPCON xxxxx000	CF
C0	FIFLG 00000000								C7
B8	IPL0 x0000000	SADEN 00000000					SPH 00000000		BF
B0	P3 11111111	IEN1 xxxxx000	IPL1 x0000000	IPH1 x0000000				IPH0 x0000000	B7
A8	IEN0 00000000	SADDR 00000000					HSTAT x0000000		AF
A0	P2 11111111	HIE 0xxxxx00	FIE 00000000				WDTRST xxxxxxx	WCN xxxxxx00	A7
98	SCON 00000000	SBUF xxxxxxx	HPPWR xxx1000x						9F
90	P1 11111111							HADDR 00000000	97
88	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000		FADDR 00000000	8F
80	P0 11111111	SP 00000111	DPL 00000000	DPH 00000000		DPXL 00000001		PCON 00XX0000	87

0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F
MCS 251 microcontroller SFRs			Port-indexed SFRs				
Endpoint-indexed SFRs							

† For EPCON, TXCON, TXDAT, TXCNTL, and RXCNTL the reset value depends on the endpoint pair selected. Refer to the register definition tables in Appendix C or Chapter 7, "USB Function."

†† For hub endpoint 1 (EPINDEX = 1000 0001), the only endpoint SFR implemented is TXDAT. A separate TXDAT register definition table is provided for this endpoint (see Chapter 8, "USB Hub.")

Table 3-7. Core SFRs

Mnemonic	Name	Address
ACC†	Accumulator	S:E0H
B†	B Register	S:F0H
PSW	Program Status Word	S:D0H
PSW1	Program Status Word 1	S:D1H
SP†	Stack Pointer – LSB of SPX	S:81H
SPH†	Stack Pointer High – MSB of SPX	S:BEH
DPTR†	Data Pointer (2 bytes)	—
DPL†	Low Byte of DPTR	S:82H
DPH†	High Byte of DPTR	S:83H
DPXL†	Data Pointer Extended, Low	S:85H
PCON	Power Control	S:87H
PCON1	USB Power Control.	S:DFH
WCON	Wait State Control Register	S:A7H

† These SFRs can also be accessed by their corresponding registers in the register file (see Table 3-4).

Table 3-8. Interrupt System SFRs

Mnemonic	Description	Address
FIE	USB Function Interrupt Enable Register.	S:A2H
FIE1	USB Function Interrupt Enable Register.	S:A3H
FIFLG	USB Function Interrupt Flag Register.	S:C0H
FIFLG1	USB Function Interrupt Flag Register.	S:C1H
HIE	Hub Interrupt Enable Register.	S:A1H
HIFLG	Hub Interrupt Flag Register.	S:E8H
IEN0	Interrupt Enable Register 0.	S:A8H
IEN1	Interrupt Enable Register1.	S:B1H
IPL0	Interrupt Priority Low Register 0.	S:B8H
IPH0	Interrupt Priority High Register 0.	S:B7H
IPL1	Interrupt Priority Low Register 1.	S:B2H
IPH1	Interrupt Priority High Register 1.	S:B3H
SOFH	Start of Frame High Register.	S:D3H
SOFL	Start of Frame Low Register.	S:D2H

Table 3-9. I/O Port SFRs

Mnemonic	Name	Address
P0	Port 0	S:80H
P1	Port 1	S:90H
P2	Port 2	S:A0H
P3	Port 3	S:B0H

Table 3-10. Serial I/O SFRs

Mnemonic	Name	Address
SCON	Serial Control	S:98H
SBUF	Serial Data Buffer	S:99H
SADEN	Slave Address Mask	S:B9H
SADDR	Slave Address	S:A9H

Table 3-11. USB Function SFRs

Mnemonic	Name	Address
EPCON	Endpoint Control Register.	S:E1H
EPCONFIG	Endpoint Configuration Register	S:C7H
EPINDEX	Endpoint Index Register.	S:F1H
FADDR	Function Address Register.	S:8FH
RXCNTH	Receive FIFO Byte-Count High Register.	S:E7H
RXCNTL	Receive FIFO Byte-Count Low Register.	S:E6H
RXCON	Receive FIFO Control Register.	S:E4H
RXDAT	Receive FIFO Data Register.	S:E3H
RXFLG	Receive FIFO Flag Register.	S:E5H
RXSTAT	Endpoint Receive Status Register.	S:E2H
TXCNTH	Transmit Count High Register.	S:F7H
TXCNTL	Transmit Count Low Register.	S:F6H
TXCON	Transmit FIFO Control Register.	S:F4H
TXDAT	Transmit FIFO Data Register.	S:F3H
TXFLG	Transmit Flag Register.	S:F5H
TXSTAT	Endpoint Transmit Status Register.	S:FAH

Table 3-12. USB Hub SFRs

Mnemonic	Name	Address
HADDR	Hub Address Register.	S:97H
HPCON	Hub Port Control.	S:CFH
HPINDEX	Hub Port Index Register.	S:D4H
HPPWR	Hub Port Power Control.	S:9AH
HPSC	Hub Port Status Change.	S:D5H
HPSTAT	Hub Port Status.	S:D7H
HSTAT	Hub Status and Configuration.	S:AEH

Table 3-13. Timer/Counter and Watchdog Timer SFRs

Mnemonic	Name	Address
TL0	Timer/Counter 0 Low Byte	S:8AH
TH0	Timer/Counter 0 High Byte	S:8CH
TL1	Timer/Counter 1 Low Byte	S:8BH
TH1	Timer/Counter 1 High Byte	S:8DH
TL2	Timer/Counter 2 Low Byte	S:CCH
TH2	Timer/Counter 2 High Byte	S:CDH
TCON	Timer/Counter 0 and 1 Control	S:88H
TMOD	Timer/Counter 0 and 1 Mode Control	S:89H
T2CON	Timer/Counter 2 Control	S:C8H
T2MOD	Timer/Counter 2 Mode Control	S:C9H
RCAP2L	Timer 2 Reload/Capture Low Byte	S:CAH
RCAP2H	Timer 2 Reload/Capture High Byte	S:CBH
WDTRST	Watchdog Timer Reset	S:A6H

Table 3-14. Programmable Counter Array (PCA) SFRs

Mnemonic	Name	Address
CCON	PCA Timer/Counter Control	S:D8H
CMOD	PCA Timer/Counter Mode	S:D9H
CCAPM0	PCA Timer/Counter Mode 0	S:DAH
CCAPM1	PCA Timer/Counter Mode 1	S:DBH
CCAPM2	PCA Timer/Counter Mode 2	S:DCH
CCAPM3	PCA Timer/Counter Mode 3	S:DDH
CCAPM4	PCA Timer/Counter Mode 4	S:DEH
CL	PCA Timer/Counter Low Byte	S:E9H
CH	PCA Timer/Counter High Byte	S:F9H
CCAP0L	PCA Compare/Capture Module 0 Low Byte	S:EAH
CCAP1L	PCA Compare/Capture Module 1 Low Byte	S:EBH
CCAP2L	PCA Compare/Capture Module 2 Low Byte	S:ECH
CCAP3L	PCA Compare/Capture Module 3 Low Byte	S:EDH
CCAP4L	PCA Compare/Capture Module 4 Low Byte	S:EEH
CCAP0H	PCA Compare/Capture Module 0 High Byte	S:FAH
CCAP1H	PCA Compare/Capture Module 1 High Byte	S:FBH
CCAP2H	PCA Compare/Capture Module 2 High Byte	S:FCH
CCAP3H	PCA Compare/Capture Module 3 High Byte	S:FDH
CCAP4H	PCA Compare/Capture Module 4 High Byte	S:FEH



4

Device Configuration



CHAPTER 4 DEVICE CONFIGURATION

The 8x930 provides design flexibility by configuring certain operating features during device reset. These features fall into the following categories:

- external memory interface (page mode, address bits, wait states, range for RD#, WR#, and PSEN#)
- source mode/binary mode opcodes
- selection of bytes stored on the stack by an interrupt
- mapping of the upper portion of on-chip code memory to region 00:

You can specify a 16-bit, 17-bit, or 18-bit external addresses bus (256 Kbyte external address space). Wait state selection provides 0, 1, 2, or 3 wait states.

This chapter provides a detailed discussion of device configuration. It describes the configuration bytes and provides information to aid you in selecting a suitable configuration for your application. It discusses the choices involved in configuring the external memory interface and shows how the internal memory space maps into external memory. See “Configuring the External Memory Interface” on page 4-7. “Opcode Configurations (SRC)” on page 4-12 discusses the choice of source mode or binary mode opcode arrangements.

4.1 CONFIGURATION OVERVIEW

The configuration of the 8x930 is established by the reset routine based on information stored in configuration bytes. The 8x930 stores configuration information in two user configuration bytes (UCONFIG0 and UCONFIG1) located in code memory. Devices with no on-chip code memory fetch configuration data from external memory. Factory programmed ROM devices use customer-provided configuration data supplied on floppy disk.

4.2 DEVICE CONFIGURATION

The 8x930 reserves the top eight bytes of the memory address space (FF:FFF8H–FF:FFFFH) for an eight-byte configuration array (Figure 4-1). The two lowest bytes of the configuration array are assigned to the two configuration bytes UCONFIG0 (FF:FFF8H) and UCONFIG1 (FF:FFF9H). Bit definitions of UCONFIG0 and UCONFIG1 are provided in Figures 4-3 and 4-4. The upper six bytes of the configuration array are reserved for future use.

When EA# = 1, the 8x930 obtains configuration information at reset from on-chip nonvolatile memory at addresses FF:FFF8H and FF:FFF9H. For ROM devices, configuration information is entered at these addresses during fabrication. The user can verify configuration information stored on-chip using the procedures presented in Chapter 17, “Verifying Nonvolatile Memory.”

For devices without on-chip program memory, configuration information is accessed from external memory using these same addresses. The designer must store configuration information in an eight-byte configuration array located at the highest addresses implemented in external code memory. See Table 4-1 and Figure 4-2. When EA# = 0, the microcontroller obtains configuration information at reset from external memory using internal addresses FF:FFF8H and FF:FFF9H.

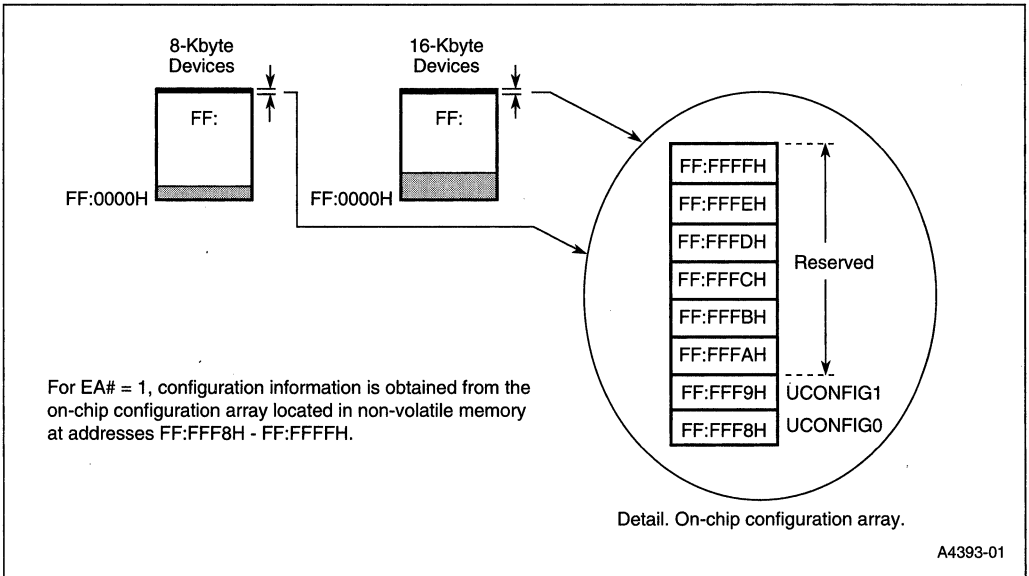


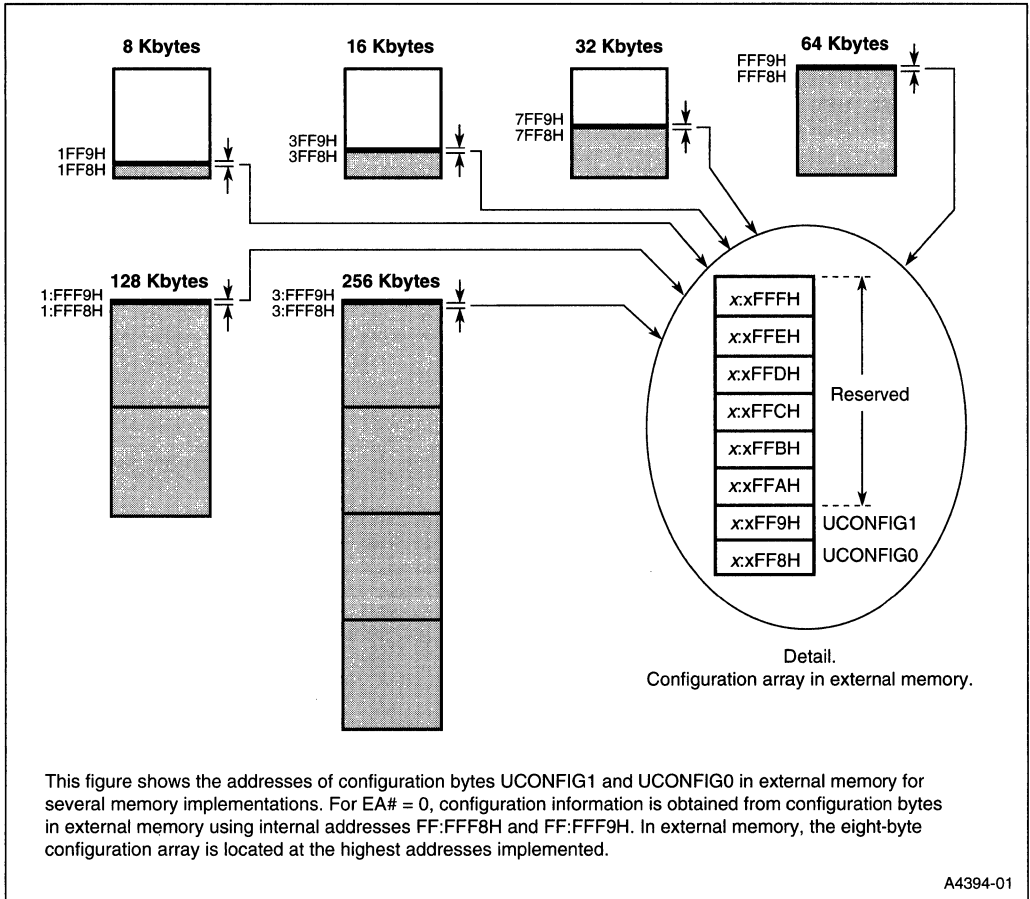
Figure 4-1. Configuration Array (On-chip)

Table 4-1. External Addresses for Configuration Array

Size of External Address Bus (Bits)	Address of Configuration Array on External Bus (2)	Address of Configuration Bytes on External Bus (1)
16	FFF8H–FFFFH	UCONFIG1: FFF9H UCONFIG0: FFF8H
17	1FFF8H–1FFFFH	UCONFIG1: 1FFF9H UCONFIG0: 1FFF8H
18	3FFF8H–3FFFFH	UCONFIG1: 3FFF9H UCONFIG0: 3FFF8H

NOTES:

- When EA# = 0, the reset routine retrieves UCONFIG0 and UCONFIG1 from external memory using the internal addresses FF:FFF8H and FF:FFF9H which appear on the external address bus (A17, A16, A15:0) as shown in this table. See Figure 4-2.
- The upper six bytes of the configuration array are reserved for future use.



This figure shows the addresses of configuration bytes UCONFIG1 and UCONFIG0 in external memory for several memory implementations. For EA# = 0, configuration information is obtained from configuration bytes in external memory using internal addresses FF:FFF8H and FF:FFF9H. In external memory, the eight-byte configuration array is located at the highest addresses implemented.

A4394-01

Figure 4-2. Configuration Array (External)

CAUTION

The eight highest addresses in the memory address space (FF:FFF8H–FF:FFFFH) are reserved for the configuration array. Do not read or write application code at these locations. These address are also used to access the configuration array in external memory, so the same restrictions apply to the eight highest addresses implemented in external memory. Instructions that might inadvertently cause these addresses to be accessed due to call returns or prefetches should not be located at addresses immediately below the configuration array. Use an EJP instruction, five or more addresses below the configuration array, to continue execution in other areas of memory.

4.3 THE CONFIGURATION BITS

This following list briefly describes the configuration bits contained in configuration bytes UCONFIG0 and UCONFIG1 (Figures 4-3 and 4-4):

- SRC. Selects source mode or binary mode opcode configuration.
- INTR. Selects the bytes pushed onto the stack by interrupts.
- EMAP#. Maps on-chip code memory (16 Kbyte devices only) to memory region 00:.

The following bits configure the external memory interface:

- PAGE#. Selects page/nonpage mode and specifies the data port.
- RD1:0. Selects the number of external address bus pins and the address range for RD#, WR, and PSEN#.
- XALE#. Extends the ALE pulse.
- WSA1:0#. Selects 0, 1, 2, or 3 wait states for all memory regions except 01:.
- WSB1:0#. Selects 0, 1, 2, or 3 wait states for memory region 01:.
- EMAP#. Affects the external memory interface in that, when asserted, addresses in the range 00:E000H-00:FFFFH access on-chip memory.

UCONFIG0 (1), (3)				Address: FF:FFF8H (2)			
7				0			
—	WSA1#	WSA0#	XALE#	RD1	RD0	PAGE#	SRC
Bit Number	Bit Mnemonic	Function					
7	—	Reserved: Reserved for internal or future use. Set this bit when programming UCONFIG0.					
6:5	WSA1:0#	Wait State A (all regions except 01:): For external memory accesses, selects the number of wait states for RD#, WR#, and PSEN#. WSA1# WSA0# 0 0 Inserts 3 wait states for all regions except 01: 0 1 Inserts 2 wait states for all regions except 01: 1 0 Inserts 1 wait state for all regions except 01: 1 1 Zero wait states for all regions except 01:					
4	XALE#	Extend ALE: Set this bit for ALE = T _{OSC} . Clear this bit for ALE = 3T _{OSC} (adds one external wait state).					
3:2	RD1:0	Memory Signal Selection: RD1:0 bit codes specify an 18-bit, 17-bit, or 16-bit external address bus and address ranges for RD#, WR#, and PSEN#. See Table 4-2 on page 4-7.					
1	PAGE#	Page Mode Select: Clear this bit for page mode enabled with A15:8/D7:0 on P2 and A7:0 on P0. Set this bit for page mode disabled with A15:8 on P2 and A7:0/D7:0 on P0.					
0	SRC	Source Mode/Binary Mode Select: Set this bit for source mode. Clear this bit for binary mode (opcodes compatible with MCS 51 microcontrollers).					

NOTES:

1. User configuration bytes UCONFIG0 and UCONFIG1 define the configuration of the 8x930.
2. Address. UCONFIG0 is the lowest byte of the 8-byte configuration array. When EA# = 1, the 8x930 fetches configuration information from an on-chip configuration array located in nonvolatile memory at the top of region FF:. When EA# = 0, the 8x930 fetches configuration information from a configuration array located at the highest addresses implemented in external memory using addresses FF:FFF8H and FF:FFF9H. The physical location of the configuration array in external memory depends on the size and decode arrangement of the external memory (Table 4-1 and Figure 4-2).
3. Instructions for verifying on-chip configuration bytes are given in Chapter 17.

Figure 4-3. User Configuration Byte 0 (UCONFIG0)

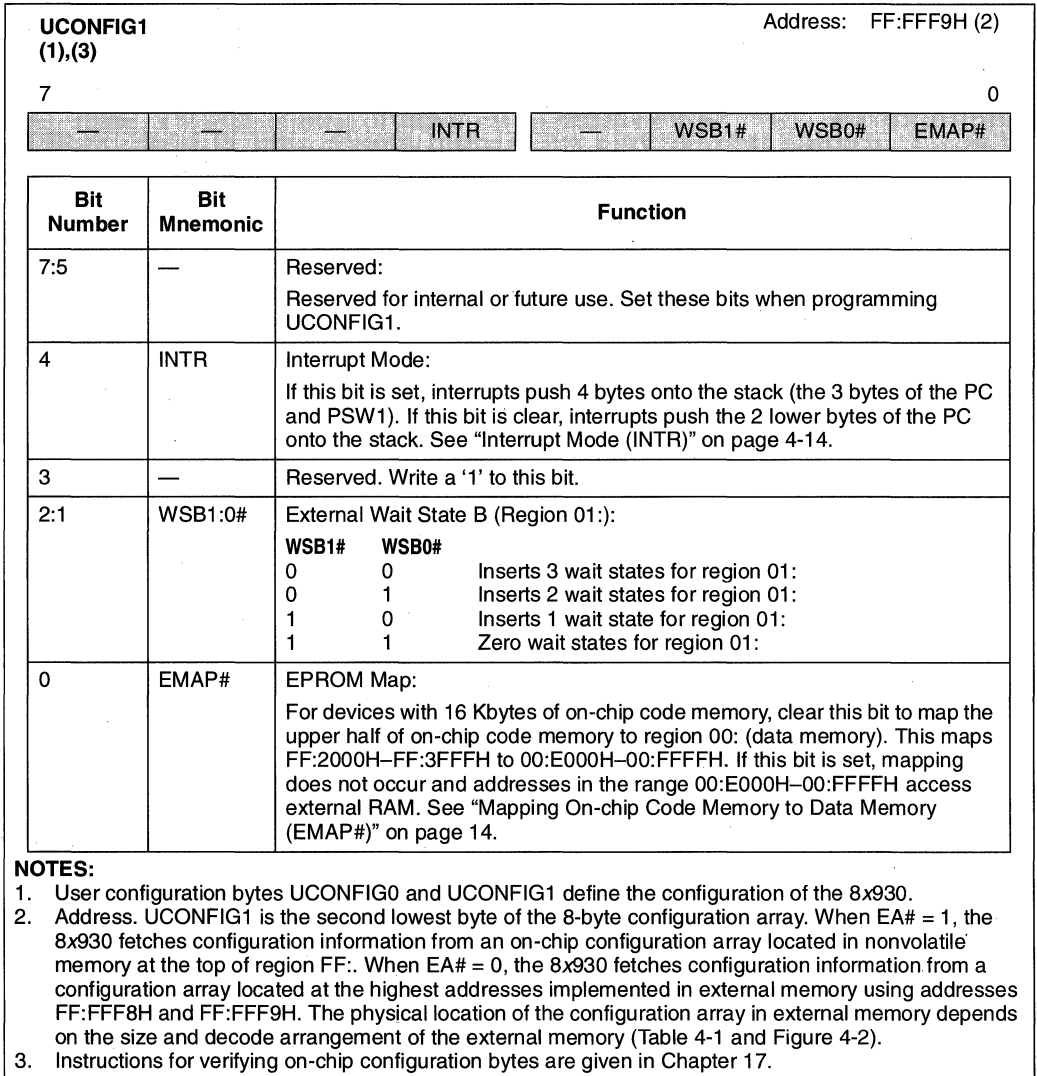


Figure 4-4. User Configuration Byte 1 (UCONFIG1)

Table 4-2. Memory Signal Selections (RD1:0)

RD1:0	A17/P1.7/ CEX4/WCLK	A16/P3.7/RD#	PSEN#	P3.6/WR#	Features
0 0	A17	A16	Asserted for all addresses	Asserted for writes to all memory locations	256 Kbyte external memory
0 1	P1.7/CEX4/ WCLK	A16	Asserted for all addresses	Asserted for writes to all memory locations	128 Kbyte external memory
1 0	P1.7/CEX4/ WCLK	P3.7 only	Asserted for all addresses	Asserted for writes to all memory locations	64 Kbyte external memory. One additional port pin.
1 1	P1.7/CEX4/ WCLK	RD# asserted for addresses $\leq 7F:FFFFH$	Asserted for $\geq 80:0000H$	Asserted only for writes to MCS [®] 51 microcontroller data memory locations.	Compatible with MCS 51 microcontrollers. Separate 64-Kbyte external program and data memories.

NOTE: RD1:0 are bits 3:2 of configuration byte UCONFIG0 (Figure 4-3).

4.4 CONFIGURING THE EXTERNAL MEMORY INTERFACE

This section describes the configuration options that affect the external memory interface. The configuration bits described here determine the following interface features:

- page mode or nonpage mode (PAGE#)
- the number of external address pins — 16, 17, or 18 (RD1:0)
- the memory regions assigned to the read signals RD# and PSEN# (RD1:0)
- the external wait states (WSA1:0#, WSB1:0#, XALE#)
- mapping a portion of on-chip code memory to data memory (EMAP#)

4.4.1 Page Mode and Nonpage Mode (PAGE#)

The PAGE# bit (UCONFIG0.1) selects page-mode or nonpage-mode code fetches and determines whether data is transmitted on P2 or P0. See Figure 16-1 on page 16-1 and “Page Mode Bus Cycles” on page 16-6 for a description of the bus structure and page mode operation.

- Nonpage mode: PAGE# = 1. The bus structure is the same as for the MCS 51 architecture with data D7:0 multiplexed with A7:0 on P0. External code fetches require two state times ($4T_{OSC}$).
- Page mode: PAGE# = 0. The bus structure differs from the bus structure in MCS 51 controllers. Data D7:0 is multiplexed with A15:8 on P2. Under certain conditions, external code fetches require only one state time ($2T_{OSC}$).

4.4.2 Configuration Bits RD1:0

The RD1:0 configuration bits (UCONFIG0.3:2) determine the number of external address lines and the address ranges for asserting the read signals PSEN#/RD# and the write signal WR#. These selections offer different ways of addressing external memory. Figures 4-5 and 4-6 show how internal memory space maps into external memory space for the four values of RD1:0. Chapter 16, "External Memory Interface," provides examples of external memory designs for each choice of RD1:0.

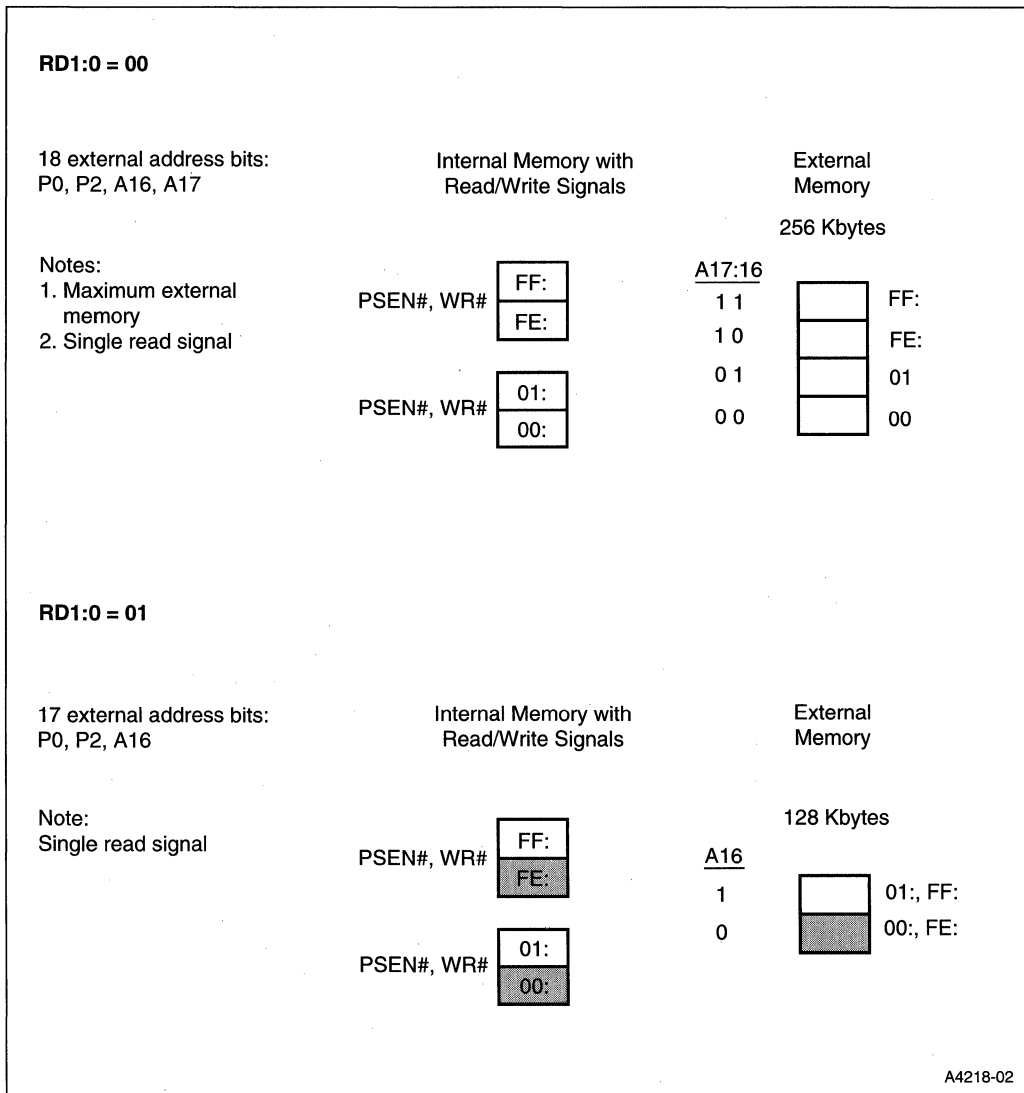


Figure 4-5. Internal/External Address Mapping (RD1:0 = 00 and 01)

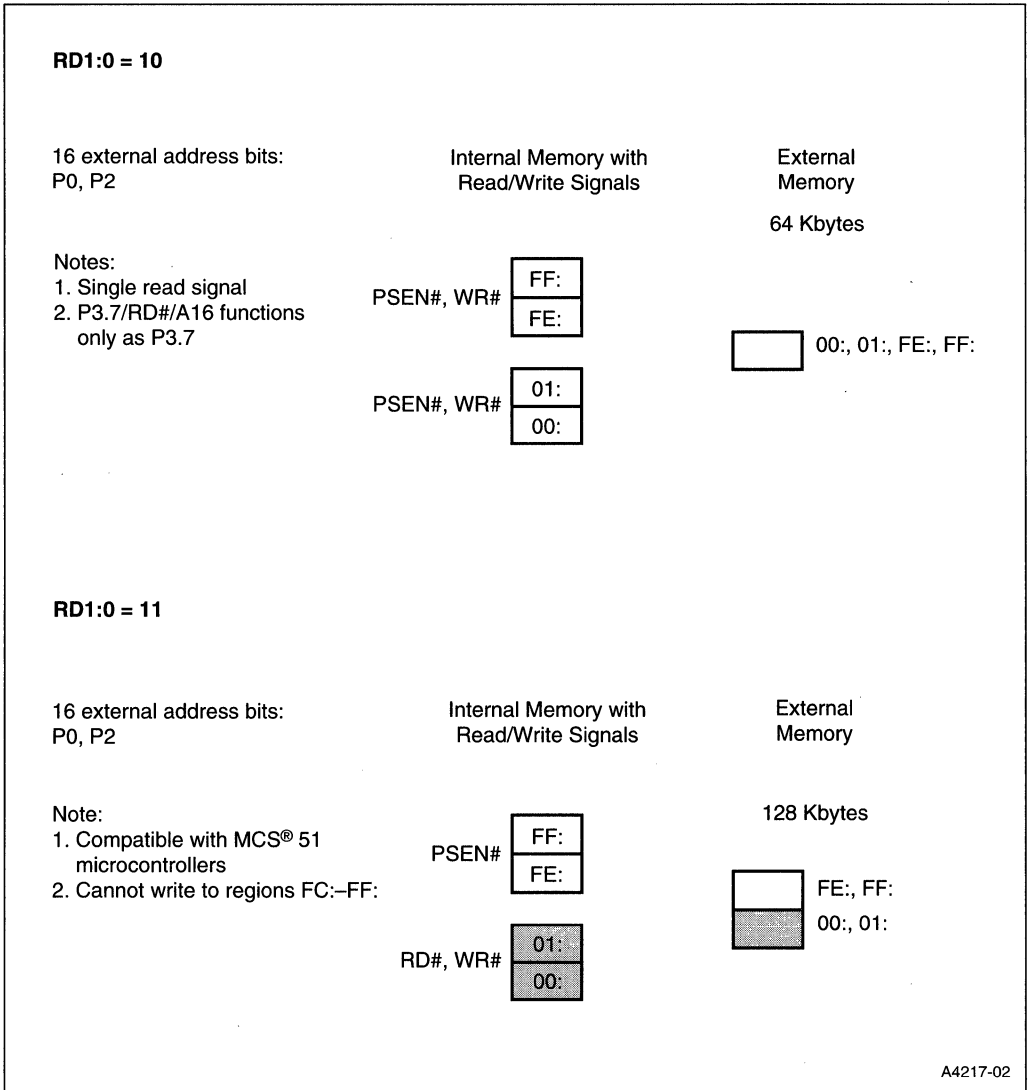


Figure 4-6. Internal/External Address Mapping (RD1:0 = 10 and 11)

A key to the memory interface is the relationship between internal memory addresses and external memory addresses. While the 8x930 has 24 internal address bits, the number of external address lines is less than 24 (i.e., 16, 17, or 18, depending on the values of RD1:0). This means that reads/writes to different internal memory addresses can access the same location in external memory.

For example, if the 8x930 is configured for 18 external address lines, a write to location 01:6000H and a write to location FF:6000H accesses the same 18-bit external address (1:6000H) because A16 = 1 and A17 = 1 for both internal addresses. In other words, regions 00: and FE: map into the same 64 Kbyte region in external memory.

In some situations, however, a multiple mapping from internal memory to external memory does not preclude using more than one region. For example, for a device with on-chip ROM configured for 17 address bits and with EA# = 1, an access to FF:0000H–FF:3FFFH (16 Kbytes) accesses the on-chip ROM, while an access to 01:0000H–01:3FFFH is to external memory. In this case, you could execute code from these locations in region FF: and store data in the corresponding locations in region 01: without conflict. See Figure 4-5 and “Example 1: RD1:0 = 00, 18-bit Bus, External Flash and RAM” on page 16-17.”

4.4.2.1 RD1:0 = 00 (18 External Address Bits)

The selection RD1:0 = 00 provides 18 external address bits: A15:0 (ports P0 and P2), A16 (from P3.7/RD#/A16), and A17 (from P1.7/CEX4/A17/WCLK). Bits A16 and A17 can select four 64 Kbyte regions of external memory for a total of 256 Kbytes (top half of Figure 4-5). This is the largest possible external memory space. See “Example 1: RD1:0 = 00, 18-bit Bus, External Flash and RAM” on page 16-17.

4.4.2.2 RD1:0 = 01 (17 External Address Bits)

The selection RD1:0 = 01 provides 17 external address bits: A15:0 (ports P0 and P2) and A16 (from P3.7/RD#/A16). Bit A16 can select two 64 Kbyte regions of external memory for a total of 128 Kbytes (bottom half of Figure 4-5). Regions 00: and FE: (each having A16 = 0) map into the same 64 Kbyte region in external memory. This duplication also occurs for regions 01: and FF:.

This selection provides a 128 Kbyte external address space. The advantage of this selection, in comparison with the 256 Kbyte external memory space with RD1:0 = 00, is the availability of pin P1.7/CEX4/A17/WCLK for general I/O, PCA I/O or real-time wait clock output. I/O P3.7 is unavailable. All four 64 Kbyte regions are stored by PSEN# and WR#. Chapter 16, “External Memory Interface,” shows examples of memory designs with this option.

4.4.2.3 RD1:0 = 10 (16 External Address Bits)

For RD1:0 = 10, the 16 external address bits (A15:0 on ports P0 and P2) provide a single 64 Kbyte region in external memory (top of Figure 4-6). This selection provides the smallest external memory space; however, pin P3.7/RD#/A16 is available for general I/O and pin P1.7/CEX4/A17 is available for general I/O or PCA I/O. This selection is useful when the availability of these pins is required and/or a small amount of external memory is sufficient.

4.4.2.4 RD1:0 = 11 (Compatible with MCS 51 Microcontrollers)

The selection RD1:0 = 11 provides only 16 external address bits (A15:0 on ports P0 and P2). However, PSEN# is the read signal for regions FE:–FF:, while RD# is the read signal for regions 00:–01: (bottom of Figure 4-6). The two read signals effectively expand the external memory space to two 64 Kbyte regions. WR# is asserted only for writes to regions 00:–01:. This selection provides compatibility with MCS 51 microcontrollers, which have separate external memory spaces for code and data.

4.4.3 Wait State Configuration Bits

You can add wait states to external bus cycles by extending the RD#/WR#/PSEN# pulse and/or extending the ALE pulse. Each additional wait state extends the pulse by $2T_{OSC}$. A separate wait state specification for external accesses via region 01: permits a slow external device to be addressed in region 01: without slowing accesses to other external devices. Table 4-3 summarizes the wait state selections for RD#,WR#,PSEN#. For waveform diagrams showing wait states, see “External Bus Cycles With Configurable Wait States” on page 16-8.

4.4.3.1 Configuration Bits WSA1:0#, WSB1:0#

The WSA1:0# wait state bits (UCONFIG0.6:5) permit RD#, WR#, and PSEN# to be extended by 1, 2, or 3 wait states for accesses to external memory via all regions except region 01:. The WSB1:0# wait state bits (UCONFIG1.2:1) permit RD#, WR#, and PSEN# to be extended by 1, 2, or 3 wait states for accesses to external memory via region 01:.

4.4.3.2 Configuration Bit XALE#

Clearing XALE# (UCONFIG0.4) extends the time ALE is asserted from T_{OSC} to $3T_{OSC}$. This accommodates an address latch that is too slow for the normal ALE signal. Figure 16-10 on page 16-10 shows an external bus cycle with ALE extended.

Table 4-3. RD#, WR#, PSEN# External Wait States

8x930		
Regions 00: FE: FF:	WSA1# WSA0#	
	0 0	3 Wait States
	0 1	2 Wait States
	1 0	1 Wait State
	1 1	0 Wait States
Region 01:	WSB1# WSB0#	
	0 0	3 Wait States
	0 1	2 Wait States
	1 0	1 Wait State
	1 1	0 Wait States

4.5 OPCODE CONFIGURATIONS (SRC)

The SRC configuration bit (UCONFIG0.0) selects the source mode or binary mode opcode arrangement. Opcodes for the 8x930 architecture are listed in Table A-6 on page A-4 and Table A-7 on page A-5. Note that in Table A-6 every opcode (00H–FFH), is used for an instruction except A5H (ESC), which provides an alternative set of opcodes for columns 6H through FH. The SRC bit selects which set of opcodes is assigned to columns 6H through FH and which set is the alternative.

Binary mode and *source mode* refer to two ways of assigning opcodes to the instruction set for the 8x930 architecture. One of these modes must be selected when the chip is configured. Depending on the application, binary mode or source mode may produce more efficient code. This section describes the binary and source modes and provides some guidelines for selecting the mode for your application.

The 8x930 architecture has two types of instructions:

- instructions that originate in the MCS® 51 architecture
- instructions that are common with the MCS® 251 architecture

Figure 4-7 shows the opcode map for binary mode. Area I (columns 1 through 5 in Table A-7) and area II (columns 6 through F) make up the opcode map for the instructions that originate in the MCS 51 architecture. Area III in Figure 4-7 represents the opcode map for the instructions that are common with the MCS 251 architecture (Table A-7). Some of these opcodes are reserved for future instructions. Note that the opcode values for areas II and III are identical (06H–FFH). To distinguish between the two areas in binary mode, the opcodes in area III are given the prefix A5H. The area III opcodes are thus A506H–A5FFH.

Figure 4-8 shows the opcode map for source mode. Areas II and III have switched places (compare with Figure 4-7). In source mode, opcodes for instructions in area II require the A5F escape prefix while opcodes for instructions in area III do not.

To illustrate the difference between the binary-mode and source-mode opcodes, Table 4-4 shows the opcode assignments for three sample instructions.

4.5.1 Selecting Binary Mode or Source Mode

If a system was originally developed using an MCS 51 microcontroller, and if the new 8x930-based system will run code written for the MCS 51 microcontroller, performance will be better with the 8x930 running in binary mode. Object code written for the MCS 51 microcontroller runs faster on the 8x930.

However, if most of the code is rewritten using the MCS 251 instruction set, performance will be better with the 8x930 running in source mode. In this case, the 8x930 can run significantly faster than the MCS 51 microcontroller.

If you have code that was written for an MCS 51 microcontroller and you want to run it unmodified on an 8x930, choose binary mode. You can use the object code without reassembling the source code. You can also assemble the source code with an assembler for the MCS 251 architecture and have it produce object code that is binary-compatible with MCS 51 microcontrollers.

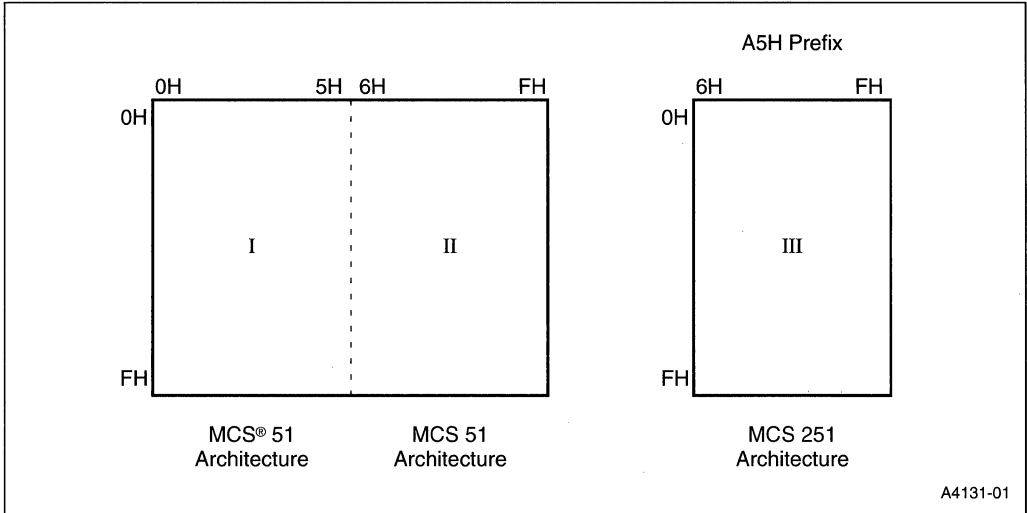


Figure 4-7. Binary Mode Opcode Map

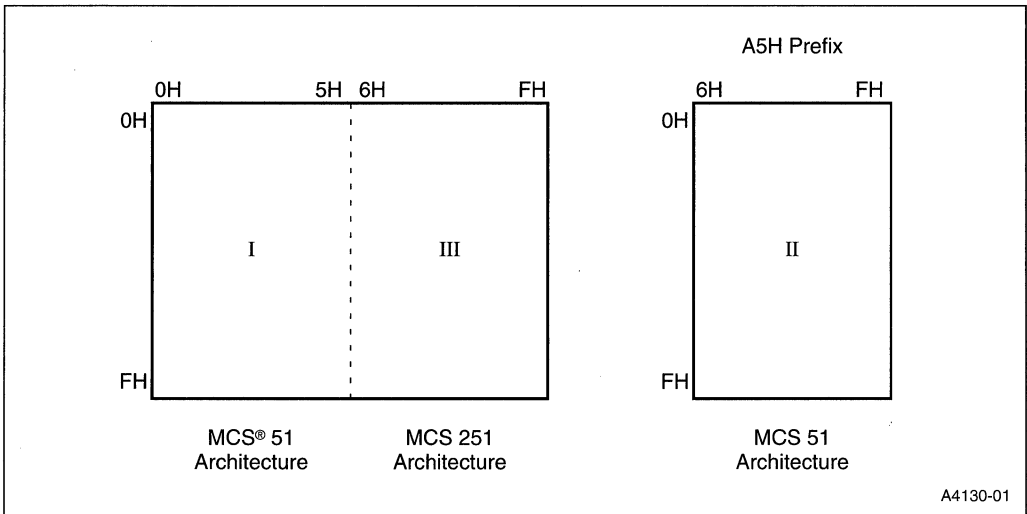


Figure 4-8. Source Mode Opcode Map

Table 4-4. Examples of Opcodes in Binary and Source Modes

Instruction	Opcode	
	Binary Mode	Source Mode
DEC A	14H	14H
SUBB A,R4	9CH	A59CH
SUB R4,R4	A59CH	9CH

If a program uses only instructions from the MCS 51 architecture, the binary-mode code is more efficient because it uses no prefixes. On the other hand, if a program uses many more new instructions than instructions from the MCS 51 architecture, source mode is likely to produce more efficient code. For a program where the choice is not clear, the better mode can be found by experimenting with a simulator.

For both architectures, an instruction with a prefixed opcode requires one more byte for code storage, and if an additional fetch is required for the extra byte, the execution time is increased by one state. This means that using fewer prefixed opcodes produces more efficient code.

4.6 MAPPING ON-CHIP CODE MEMORY TO DATA MEMORY (EMAP#)

For devices with 16 Kbytes of on-chip code memory, the EMAP# bit (UCONFIG1.0) provides the option of accessing the upper half of on-chip code memory as data memory. This allows code constants to be accessed as data in region 00: using direct addressing. See "Accessing On-chip Code Memory in Region 00:" on page 3-9 for the exact conditions required for this mapping to be effective.

EMAP# = 0. For the 83930AE and 83930HE, the upper eight Kbytes of on-chip code memory (FF:2000–FF:3FFFH) are mapped to locations 00:E000H–00:FFFFH.

EMAP# = 1. Mapping of on-chip code memory to region 00: does not occur. Addresses in the range 00:E000H–00:FFFFH access external RAM.

4.7 INTERRUPT MODE (INTR)

The INTR bit (UCONFIG1.4) determines what bytes are stored on the stack when an interrupt occurs and how the RETI (Return from Interrupt) instruction restores operation.

For INTR = 0, an interrupt pushes the two lower bytes of the PC onto the stack in the following order: PC.7:0, PC.15:8. The RETI instruction pops these two bytes in the reverse order and uses them as the 16-bit return address in region FF:.

For INTR = 1, an interrupt pushes the three PC bytes and the PSW1 register onto the stack in the following order: PSW1, PC.23:16, PC.7:0, PC.15:8. The RETI instruction pops these four bytes and then returns to the specified 24-bit address, which can be anywhere in the 16 Mbyte address space.

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Programming Considerations



CHAPTER 5

PROGRAMMING CONSIDERATIONS

The instruction set for the architecture supports the instruction set for the MCS® 51 architecture and MCS® 251 architecture. This chapter describes the addressing modes and summarizes the instruction set, which is divided into data instructions, bit instructions, and control instructions. The program status word registers PSW and PSW1 are also described. Appendix A, “Instruction Set Reference,” contains an opcode map and a detailed description of each instruction.

NOTE

The instruction execution times given in Appendix A are for code executing from external memory and for data that is read from and written to on-chip RAM. Execution times are increased by accessing peripheral SFRs, accessing data in external memory, using a wait state, or extending the ALE pulse.

For some instructions, accessing the port SFRs ($P_x, x = 3:0$) increases the execution time. These cases are noted in the tables in Appendix A.

5.1 SOURCE MODE OR BINARY MODE OPCODES

Source mode and *Binary mode* refer to the two ways of assigning opcodes to the instruction set of the 8x930. Depending on the application, one mode or the other may produce more efficient code. The mode is established during device reset based on the value of the SRC bit in configuration byte UCONFIG0. For information regarding the selection of the opcode mode, see “Opcode Configurations (SRC)” on page 4-12.

5.2 PROGRAMMING FEATURES OF THE 8x930 ARCHITECTURE

The instruction set for 8x930 microcontrollers provides the user with instructions that exploit the features of the MCS 251 architecture while maintaining compatibility with the instruction set for MCS 51 microcontrollers. Many of the MCS 251 architecture instructions operate on 8-bit, 16-bit, or 32-bit operands. (In comparison with 8-bit and 16-bit operands, 32-bit operands are accessed with fewer addressing modes.) This capability increases the ease and efficiency of programming the 8x930 microcontroller in a high-level language such as C.

The instruction set is divided into data instructions, bit instructions, and control instructions. These are described in this chapter. Data instructions process 8-bit, 16-bit, and 32-bit data; bit instructions manipulate bits; and control instructions manage program flow.

5.2.1 Data Types

Table 5-1 lists the data types that are addressed by the instruction set. Words or dwords (double words) can be in stored memory starting at any byte address; alignment on two-byte or four-byte boundaries is not required. Words and dwords are stored in memory and the register file in *big endian* form.

Table 5-1. Data Types

Data Type	Number of Bits
Bit	1
Byte	8
Word	16
Dword (Double Word)	32

5.2.1.1 Order of Byte Storage for Words and Double Words

The 8x930 microcontroller stores words (2 bytes) and double words (4 bytes) in memory and in the register file in big endien form. In memory storage, the most significant byte (MSB) of the word or double word is stored in the memory byte specified in the instruction; the remaining bytes are stored at higher addresses, with the least significant byte (LSB) at the highest address. Words and double words can be stored in memory starting at any byte address. In the register file, the MSB is stored in the lowest byte of the register specified in the instruction. For a description of the register file, see "8x930 Register File" on page 3-9. The code fragment in Figure 5-1 illustrates the storage of words and double words in big endien form.

5.2.2 Register Notation

In register-addressing instructions, specific indices denote the registers that can be used in that instruction. For example, the instruction ADD A,Rn uses "Rn" to denote any one of R0, R1, ..., R7; i.e., the range of n is 0–7. The instruction ADD Rm,#data uses "Rm" to denote R0, R1, ..., R15; i.e., the range of m is 0–15. Table 5-2 summarizes the notation used for the register indices. When an instruction contains two registers of the same type (e.g., MOV Rmd,Rms) the first index "d" denotes "destination" and the second index "s" denotes "source."

5.2.3 Address Notation

In the 8x930 architecture, memory addresses include a region number (00:, 01:, ..., FF:) (Figure 3-5 on page 3-7). SFR addresses have a prefix "S:" (S:000H–S:1FFH). The distinction between memory addresses and SFR addresses is necessary because memory locations 00:0000H–00:01FFH and SFR locations S:000H–S:1FFH can both be directly addressed in an instruction.

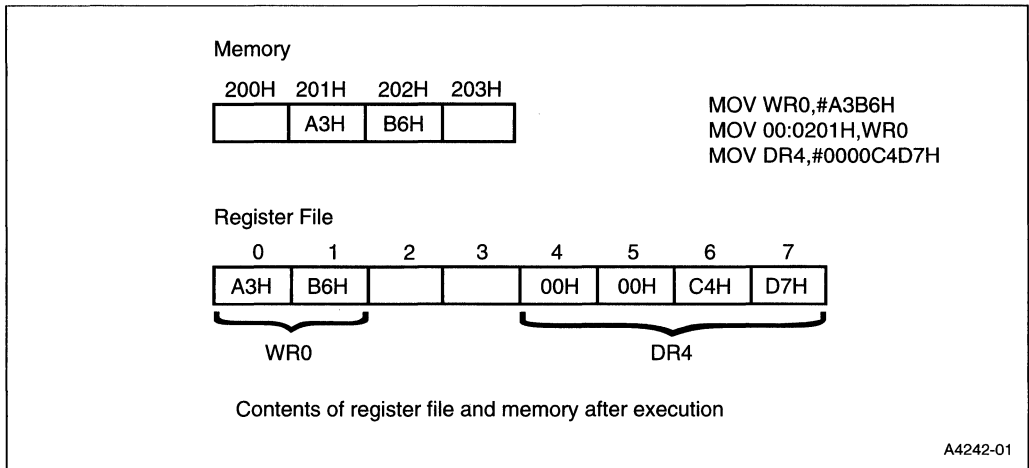


Figure 5-1. Word and Double-word Storage in Big Endien Form

Table 5-2. Notation for Byte Registers, Word Registers, and Dword Registers

Register Type	Register Symbol	Destination Register	Source Register	Register Range
Byte	Ri	—	—	R0, R1
	Rn	—	—	R0–R7
	Rm	Rmd	Rms	R0–R15
Word	WRj	WRjd	WRjs	WR0, WR2, WR4, ..., WR30
Dword	DRk	DRkd	DRks	DR0, DR4, DR8, ..., DR28, DR56, DR60

Instructions in the MCS 51 architecture use 80H–FFH as addresses for both memory locations and SFRs, because memory locations are addressed only indirectly and SFR locations are addressed only directly. For compatibility, firmware tools for 8x930 microcontrollers recognize this notation for instructions in the 8x930 architecture. No change is necessary in any code written for MCS 51 controllers.

For the MCS 251 architecture instructions, the memory region prefixes (00:, 01, ..., FF:) and the SFR prefix (S:) are required. Also, firmware tools for the 8x930 architecture permit 00: to be used for memory addresses 00H–FFH and permit the prefix S: to be used for SFR addresses in instructions in the 8x930 architecture.

5.2.4 Addressing Modes

The 8x930 architecture supports the following addressing modes:

- **register addressing:** The instruction specifies the register that contains the operand.
- **immediate addressing:** The instruction contains the operand.
- **direct addressing:** The instruction contains the operand address.
- **indirect addressing:** The instruction specifies the register that contains the operand address.
- **displacement addressing:** The instruction specifies a register and an offset. The operand address is the sum of the register contents (the base address) and the offset.
- **relative addressing:** The instruction contains the signed offset from the next instruction to the target address (the address for transfer of control, e.g., the jump address).
- **bit addressing:** The instruction contains the bit address.

More detailed descriptions of the addressing modes are given in “Data Addressing Modes” on page 5-4, “Bit Addressing” on page 5-10, and “Addressing Modes for Control Instructions” on page 5-12.

5.3 DATA INSTRUCTIONS

Data instructions consist of arithmetic, logical, and data-transfer instructions for 8-bit, 16-bit, and 32-bit data. This section describes the data addressing modes and the set of data instructions.

5.3.1 Data Addressing Modes

This section describes the data-addressing modes, which are summarized in two tables: Table 5-4 for the instructions that are native to the MCS 51 architecture, and Table 5-4 for the data instructions in the MCS 251 architecture.

NOTE

References to registers R0–R7, WR0–WR6, DR0, and DR2 always refer to the register bank that is currently selected by the PSW and PSW1 registers (see “Program Status Words” on page 5-15). Registers in all banks (active and inactive) can be accessed as memory locations in the range 00H–1FH.

Instructions from the MCS 51 architecture access external memory through the region of memory specified by byte DPXL in the extended data pointer register, DPX (DR56). Following reset, DPXL contains 01H, which maps the external memory to region 01:. You can specify a different region by writing to DR56 or the DPXL SFR (see “Dedicated Registers” on page 3-12).

5.3.1.1 Register Addressing

Both architectures address registers directly:

- MCS 251 architecture. In the register addressing mode, the operand(s) in a data instruction are in byte registers (R0–R15), word registers (WR0, WR2, ..., WR30), or dword registers (DR0, DR4, ..., DR28, DR56, DR60).
- MCS 51 architecture. Instructions address registers R0–R7 only.

5.3.1.2 Immediate

Both architectures use immediate addressing.

- MCS 251 architecture. In the immediate addressing mode, the instruction contains the data operand itself. Byte operations use 8-bit immediate data (#data); word operations use 16-bit immediate data (#data16). Dword operations use 16-bit immediate data in the lower word, and either zeros in the upper word (denoted by #0data16), or ones in the upper word (denoted by #1data16). MOV instructions that place 16-bit immediate data into a dword register (DRk), place the data either into the upper word while leaving the lower word unchanged, or into the lower word with a sign extension or a zero extension. The increment and decrement instructions contain immediate data (#short = 1, 2, or 4) that specifies the amount of the increment/decrement.
- MCS 51 architecture. Instructions use only 8-bit immediate data (#data).

5.3.1.3 Direct

- MCS 251 architecture. In the direct addressing mode, the instruction contains the address of the data operand. The 8-bit direct mode addresses on-chip RAM (dir8 = 00:0000H–00:007FH) as both bytes and words, and addresses the SFRs (dir8 = S:080H–S:1FFH) as bytes only. (See the second note in “Data Addressing Modes” on page 5-4 regarding SFRs in the MCS 251 architecture.) The 16-bit direct mode addresses both bytes and words in memory (dir16 = 00:0000H–00:FFFFH).
- MCS 51 architecture. The 8-bit direct mode addresses 256 bytes of on-chip RAM (dir8 = 00H–7FH) as bytes only and the SFRs (dir8 = 80H–FFH) as bytes only.

Table 5-3. Addressing Modes for Data Instructions in the MCS[®] 51 Architecture

Mode	Address Range of Operand	Assembly Language Reference	Comments
Register	00H–1FH	R0–R7 (Bank selected by PSW)	
Immediate	Operand in Instruction	#data = #00H–#FFH	
Direct	00H–7FH	dir8 = 00H–7FH	On-chip RAM
	SFRs	dir8 = 80H–FFH or SFR mnemonic.	SFR address

Table 5-3. Addressing Modes for Data Instructions in the MCS® 51 Architecture (Continued)

Mode	Address Range of Operand	Assembly Language Reference	Comments
Indirect	00H–FFH	@R0, @R1	Accesses on-chip RAM or the lowest 256 bytes of external data memory (MOVX).
	0000H–FFFFH	@DPTR, @A+DPTR	Accesses external data memory (MOVX).
	0000H–FFFFH	@A+DPTR, @A+PC	Accesses region FF: of code memory (MOVC).

5.3.1.4 Indirect

In arithmetic and logical instructions that use indirect addressing, the source operand is always a byte, and the destination is either the accumulator or a byte register (R0–R15). The source address is a byte, word, or dword. The two architectures do indirect addressing via different registers:

- MCS 251 architecture. Memory is indirectly addressed via word and dword registers:
 - Word register (@WRj, j = 0, 2, 4, ..., 30). The 16-bit address in WRj can access locations 00:0000H–00:FFFFH.
 - Dword register (@DRk, k = 0, 4, 8, ..., 28, 56, and 60). The 24 least significant bits can access the entire 16-Mbyte address space. The upper eight bits of DRk must be 0. (If you use DR60 as a general data pointer, be aware that DR60 is the extended stack pointer register SPX.)
- MCS 51 architecture. Instructions use indirect addressing to access on-chip RAM, code memory, and external data RAM. (See the second note in “Data Addressing Modes” on page 5-4 regarding the region of external data RAM that is addressed by instructions in the MCS 51 architecture.)
 - Byte register (@Ri, i = 1, 2). Registers R0 and R1 indirectly address on-chip memory locations 00H–FFH and the lowest 256 bytes of external data RAM.
 - 16-bit data pointer (@DPTR or @A+DPTR). The MOVC and MOVX instructions use these indirect modes to access code memory and external data RAM.
 - 16-bit program counter (@A+PC). The MOVC instruction uses this indirect mode to access code memory.

Table 5-4. Addressing Modes for Data Instructions in the MCS[®] 251 Architecture

Mode	Address Range of Operand	Assembly Language Notation	Comments
Register	00:0000H–00:001FH (R0–R7, WR0–WR3, DR0, DR2) (1)	R0–R15, WR0–WR30, DR0–DR28, DR56, DR60	R0–R7, WR0–WR6, DR0, and DR2 are in the register bank currently selected by the PSW and PSW1.
Immediate, 2 bits	N.A. (Operand is in the instruction)	#short = 1, 2, or 4	Used only in increment and decrement instructions.
Immediate, 8 bits	N.A. (Operand is in the instruction)	#data8 = #00H–#FFH	
Immediate, 16 bits	N.A. (Operand is in the instruction)	#data16 = #0000H–#FFFFH	
Direct, 8 address bits	00:0000H–00:007FH	dir8 = 00:0000H–00:007FH	On-chip RAM
	SFRs	dir8 = S:080H–S:1FFH (2) or SFR mnemonic	SFR address
Direct, 16 address bits	00:0000H–00:FFFFH	dir16 = 00:0000H–00:FFFFH	
Indirect, 16 address bits	00:0000H–00:FFFFH	@WR0–@WR30	
Indirect, 24 address bits	00:0000H–FF:FFFFH	@DR0–@DR30, @DR56, @DR60	Upper 8 bits of DRk must be 00H.
Displacement, 16 address bits	00:0000H–00:FFFFH	@WRj + dis16 = @WR0 + 0H through @WR30 + FFFFH	Offset is signed; address wraps around in region 00:.
Displacement, 24 address bits	00:0000H–FF:FFFFH	@DRk + dis24 = @DR0 + 0H through @DR28 + FFFFH, @DR56 + (0H–FFFFH), @DR60 + (0H–FFFFH)	Offset is signed, upper 8 bits of DRk must be 00H.

NOTES:

1. These registers are accessible in the memory space as well as in the register file (see “8x930 Register File” on page 3-9).
2. The MCS 251 architecture supports SFRs in locations S:000H–S:1FFH; however, in the 8x930 all SFRs are in the range S:080H–S:0FFH.

5.3.1.5 Displacement

Several move instructions use displacement addressing to move bytes or words from a source to a destination. Sixteen-bit displacement addressing (@WRj+dis16) accesses indirectly the lowest 64 Kbytes in memory. The base address can be in any word register WRj. The instruction contains a 16-bit signed offset which is added to the base address. Only the lowest 16 bits of the sum are used to compute the operand address. If the sum of the base address and a positive offset exceeds FFFFH, the computed address wraps around within region 00: (e.g. F000H + 2005H becomes 1005H). Similarly, if the sum of the base address and a negative offset is less than zero, the computed address wraps around the top of region 00: (e.g., 2005H + F000H becomes 1005H).

Twenty-four-bit displacement addressing (@DRk+dis24) accesses indirectly the entire 16-Mbyte address space. The base address must be in DR0, DR4, ..., DR24, DR28, DR56, or DR60. The upper byte in the dword register must be zero. The instruction contains a 16-bit signed offset which is added to the base address.

5.3.2 Arithmetic Instructions

The set of arithmetic instructions is greatly expanded in the MCS 251 architecture. The ADD and SUB instructions (Table A-19 on page A-13) operate on byte and word data that is accessed in several ways:

- as the contents of the accumulator, a byte register (Rn), or a word register (WRj)
- in the instruction itself (immediate data)
- in memory via direct or indirect addressing

The ADDC and SUBB instructions (Table A-19) are the same as those for MCS 51 microcontrollers.

The CMP (compare) instruction (Table A-20 on page A-14) calculates the difference of two bytes or words and then writes to flags CY, OV, AC, N, and Z in the PSW and PSW1 registers. The difference is not stored. The operands can be addressed in a variety of modes. The most frequent use of CMP is to compare data or addresses preceding a conditional jump instruction.

Table A-21 on page A-14 lists the INC (increment) and DEC (decrement) instructions. The instructions for MCS 51 microcontrollers are supplemented by instructions that can address byte, word, and dword registers and increment or decrement them by 1, 2, or 4 (denoted by #short). These instructions are supplied primarily for register-based address pointers and loop counters.

The 8x930 architecture provides the MUL (multiply) and DIV (divide) instructions for unsigned 8-bit and 16-bit data (Table A-22 on page A-15). Signed multiply and divide are left for the user to manage through a conversion process. The following operations are implemented:

- eight-bit multiplication: 8 bits \times 8 bits \rightarrow 16 bits
- sixteen-bit multiplication: 16 bits \times 16 bits \rightarrow 32 bits
- eight-bit division: 8 bits \div 8 bits \rightarrow 16 bits (8-bit quotient, 8-bit remainder)
- sixteen-bit division: 16 bits \div 16 bits \rightarrow 32 bits (16-bit quotient, 16-bit remainder)

These instructions operate on pairs of byte registers (Rmd,Rms), word registers (WRjd,WRjs), or the accumulator and B register (A,B). For 8-bit register multiplies, the result is stored in the word register that contains the first operand register. For example, the product from an instruction MUL R3,R8 is stored in WR2. Similarly, for 16-bit multiplies, the result is stored in the dword register that contains the first operand register. For example, the product from the instruction MUL WR6,WR18 is stored in DR4.

For 8-bit divides, the operands are byte registers. The result is stored in the word register that contains the first operand register. The quotient is stored in the lower byte, and the remainder is stored in the higher byte. A 16-bit divide is similar. The first operand is a word register, and the result is stored in the double word register that contains that word register. If the second operand (the divisor) is zero, the overflow flag (OV) is set and the other bits in PSW and PSW1 are meaningless.

5.3.3 Logical Instructions

The 8x930 architecture provides a set of instructions that perform logical operations. The ANL, ORL, and XRL (logical AND, logical OR, and logical exclusive OR) instructions operate on bytes and words that are accessed via several addressing modes (Table A-23 on page A-16). A byte register, word register, or the accumulator can be logically combined with a register, immediate data, or data that is addressed directly or indirectly. These instructions affect the Z and N flags.

In addition to the CLR (clear), CPL (complement), SWAP (swap), and four rotate instructions that operate on the accumulator, 8x930 microcontroller has three shift commands for byte and word registers:

- SLL (Shift Left Logical) shifts the register one bit left and replaces the LSB with 0
- SRL (Shift Right Logical) shifts the register one bit right and replaces the MSB with 0
- SRA (Shift Right Arithmetic) shifts the register one bit right; the MSB is unchanged

5.3.4 Data Transfer Instructions

Data transfer instructions copy data from one register or memory location to another. These instructions include the move instructions (Table A-24 on page A-18) and the exchange, push, and pop instructions (Table A-25 on page A-21). Instructions that move only a single bit are listed with the other bit instructions in Table A-26 on page A-22.

MOV (Move) is the most versatile instruction, and its addressing modes are expanded in the 8x930 architecture. MOV can transfer a byte, word, or dword between any two registers or between a register and any location in the address space.

The MOVX (Move External) instruction moves a byte from external memory to the accumulator or from the accumulator to memory. The external memory is in the region specified by DPXL, whose reset value is 01H (see “Dedicated Registers” on page 3-12).

The MOVC (Move Code) instruction moves a byte from code memory (region FF:) to the accumulator.

MOVS (Move with Sign Extension) and MOVZ (Move with Zero Extension) move the contents of an 8-bit register to the lower byte of a 16-bit register. The upper byte is filled with the sign bit

(MOVS) or zeros (MOVZ). The MOVH (Move to High Word) instruction places 16-bit immediate data into the high word of a dword register.

The XCH (Exchange) instruction interchanges the contents of the accumulator with a register or memory location. The XCHD (Exchange Digit) instruction interchanges the lower nibble of the accumulator with the lower nibble of a byte in on-chip RAM. XCHD is useful for BCD (binary coded decimal) operations.

The PUSH and POP instructions facilitate storing information (PUSH) and then retrieving it (POP) in reverse order. Push can push a byte, a word, or a dword onto the stack, using the immediate, direct, or register addressing modes. POP can pop a byte or a word from the stack to a register or to memory.

5.4 BIT INSTRUCTIONS

A bit instruction addresses a specific bit in a memory location or SFR. There are four categories of bit instructions:

- **SETB (Set Bit), CLR (Clear Bit), CPL (Complement Bit).** These instructions can set, clear or complement any addressable bit.
- **ANL (And Logical), ANL/ (And Logical Complement), ORL (OR Logical), ORL/ (Or Logical Complement).** These instructions allow ANDing and ORing of any addressable bit or its complement with the CY flag.
- **MOV (Move)** instructions transfer any addressable bit to the carry (CY) bit or vice versa.
- Bit-conditional jump instructions execute a jump if the bit has a specified state. The bit-conditional jump instructions are classified with the control instructions and are described in “Conditional Jumps” on page 5-13.

5.4.1 Bit Addressing

The bits that can be individually addressed are in the on-chip RAM and the SFRs (Table 5-5). The bit instructions that are unique to the MCS 251 architecture can address a wider range of bits than the instructions from the MCS 51 architecture.

There are some differences in the way the instructions from the two architectures address bits. In the MCS 51 architecture, a bit (denoted by bit51) can be specified in terms of its location within a certain register, or it can be specified by a bit address in the range 00H–7FH. The 8x930 architecture does not have bit addresses as such. A bit can be addressed by name or by its location within a certain register, but not by a bit address.

Table 5-6 illustrates bit addressing in the two architectures by using two sample bits:

- RAMBIT is bit 5 in RAMREG, which is location 23H. “RAMBIT” and “RAMREG” are assumed to be defined in user code.
- IT1 is bit 2 in TCON, which is an SFR at location 88H.

Table 5-5. Bit-addressable Locations

Architecture	Bit-addressable Locations	
	On-chip RAM	SFRs
MCS® 251 Architecture	20H–7FH	All defined SFRs
MCS 51 Architecture	20H–2FH	SFRs with addresses ending in 0H or 8H: 80H, 88H, 90H, 98H, ..., F8H

Table 5-7 lists the addressing modes for bit instructions and Table A-26 on page A-22 summarizes the bit instructions. “Bit” denotes a bit that is addressed by an instruction in the MCS 251 architecture and “bit51” denotes a bit that is addressed by an instruction in the MCS 51 architecture.

Table 5-6. Addressing Two Sample Bits

Location	Addressing Mode	MCS® 51 Architecture	MCS 251 Architecture
On-chip RAM	Register Name	RAMREG.5	RAMREG.5
	Register Address	23H.5	23H.5
	Bit Name	RAMBIT	RAMBIT
	Bit Address	1DH	NA
SFR	Register Name	TCON.2	TCON.2
	Register Address	88.2H	S:88.2H
	Bit Name	IT1	IT1
	Bit Address	8A	NA

Table 5-7. Addressing Modes for Bit Instructions

Architecture	Variants	Bit Address	Memory/SFR Address	Comments
MCS® 251 Architecture (bit)	Memory	NA	20H.0–7FH.7	
	SFR	NA	All defined SFRs	
MCS 51 Architecture (bit51)	Memory	00H–7FH	20H.0–7FH.7	
	SFR	80H–F8H	XXH.0–XXH.7, where XX = 80, 88, 90, 98, ..., F0, F8.	SFRs are not defined at all bit-addressable locations.

5.5 CONTROL INSTRUCTIONS

Control instructions—instructions that change program flow—include calls, returns, and conditional and unconditional jumps (see Table A-27 on page A-23). Instead of executing the next instruction in the queue, the processor executes a target instruction. The control instruction provides

the address of a target instruction either implicitly, as in a return from a subroutine, or explicitly, in the form of a relative, direct, or indirect address.

The 8x930 has a 24-bit program counter (PC), which allows a target instruction to be anywhere in the 16-Mbyte address space. However, as discussed in this section, some control instructions restrict the target address to the current 2-Kbyte or 64-Kbyte address range by allowing only the lowest 11 or lowest 16 bits of the program counter to change.

5.5.1 Addressing Modes for Control Instructions

Table 5-8 lists the addressing modes for the control instructions.

- **Relative addressing:** The control instruction provides the target address as an 8-bit signed offset (rel) from the address of the next instruction.
- **Direct addressing:** The control instruction provides a target address, which can have 11 bits (addr11), 16 bits (addr16), or 24 bits (addr24). The target address is written to the PC.
 - **addr11:** Only the lower 11 bits of the PC are changed; i.e., the target address must be in the current 2-Kbyte block (the 2-Kbyte block that includes the first byte of the next instruction).
 - **addr16:** Only the lower 16 bits of the PC are changed; i.e., the target address must be in the current 64-Kbyte region (the 64-Kbyte region that includes the first byte of the next instruction).
 - **addr24:** The target address can be anywhere in the 16-Mbyte address space.
- **Indirect addressing:** There are two types of indirect addressing for control instructions:
 - For the instructions LCALL @WRj and LJMP @WRj, the target address is in the current 64-Kbyte region. The 16-bit address in WRj is placed in the lower 16 bits of the PC. The upper eight bits of the PC remain unchanged from the address of the next instruction.
 - For the instruction JMP @A+DPTR, the sum of the accumulator and DPTR is placed in the lower 16 bits of the PC, and the upper eight bits of the PC are FF:, which restricts the target address to the code memory space of the MCS 51 architecture.

Table 5-8. Addressing Modes for Control Instructions

Description	Address Bits Provided	Address Range
Relative, 8-bit relative address (rel)	8	-128 to +127 from first byte of next instruction
Direct, 11-bit target address (addr11)	11	Current 2 Kbytes
Direct, 16-bit target address (addr16)	16	Current 64 Kbytes
Direct, 24-bit target address (addr24)†	24	00:0000H–FF:FFFFH
Indirect (@WRj)†	16	Current 64 Kbytes
Indirect (@A+DPTR)	16	64-Kbyte region specified by DPXL (reset value = 01H)

†These modes are not used by instructions in the MCS[®] 51 architecture.

5.5.2 Conditional Jumps

The 8x930 architecture supports bit-conditional jumps, compare-conditional jumps, and jumps based on the value of the accumulator. A bit-conditional jump is based on the state of a bit. In a compare-conditional jump, the jump is based on a comparison of two operands. All conditional jumps are relative, and the target address (rel) must be in the current 256-byte block of code. The instruction set includes three kinds of bit-conditional jumps:

- JB (Jump on Bit): Jump if the bit is set.
- JNB (Jump on Not Bit): Jump if the bit is clear.
- JBC (Jump on Bit then Clear it): Jump if the bit is set; then clear it.

“Bit Addressing” on page 5-10 describes the bit addressing used in these instructions.

Compare-conditional jumps test a condition resulting from a compare (CMP) instruction that is assumed to precede the jump instruction. The jump instruction examines the PSW and PSW1 registers and interprets their flags as though they were set or cleared by a compare (CMP) instruction. Actually, the state of each flag is determined by the last instruction that could have affected that flag.

The condition flags are used to test one of the following six relations between the operands:

- equal (=), not equal (≠)
- greater than (>), less than (<)
- greater than or equal (≥), less than or equal (≤)

For each relation there are two instructions, one for signed operands and one for unsigned operands (Table 5-9).

Table 5-9. Compare-conditional Jump Instructions

Operand Type	Relation					
	=	¼	>	<	§	£
Unsigned	JE	JNE	JG	JL	JGE	JLE
Signed			JSG	JSL	JSGE	JSLE

5.5.3 Unconditional Jumps

There are five unconditional jumps. NOP and SJMP jump to addresses relative to the program counter. AJMP, LJMP, and EJMP jump to direct or indirect addresses.

- NOP (No Operation) is an unconditional jump to the next instruction.
- SJMP (Short Jump) jumps to any instruction within -128 to 127 of the next instruction.
- AJMP (Absolute Jump) changes the lowest 11 bits of the PC to jump anywhere within the current 2-Kbyte block of memory. The address can be direct or indirect.
- LJMP (Long Jump) changes the lowest 16 bits of the PC to jump anywhere within the current 64-Kbyte region.
- EJMP (Extended Jump) changes all 24 bits of the PC to jump anywhere in the 16-Mbyte address space. The address can be direct or indirect.

5.5.4 Calls and Returns

The 8x930 architecture provides relative, direct, and indirect calls and returns.

ACALL (Absolute Call) pushes the lower 16 bits of the next instruction address onto the stack and then changes the lower 11 bits of the PC to the 11-bit address specified by the instruction. The call is to an address that is in the same 2-Kbyte block of memory as the address of the next instruction.

LCALL (Long Call) pushes the lower 16 bits of the next-instruction address onto the stack and then changes the lower 16 bits of the PC to the 16-bit address specified by the instruction. The call is to an address in the same 64-Kbyte block of memory as the address of the next instruction.

ECALL (Extended Call) pushes the 24 bits of the next instruction address onto the stack and then changes the 24 bits of the PC to the 24-bit address specified by the instruction. The call is to an address anywhere in the 16-Mbyte memory space.

RET (Return) pops the top two bytes from the stack to return to the instruction following a subroutine call. The return address must be in the same 64-Kbyte region.

ERET (Extended Return) pops the top three bytes from the stack to return to the address following a subroutine call. The return address can be anywhere in the 16-Mbyte address space.

RETI (Return from Interrupt) provides a return from an interrupt service routine. The operation of RETI depends on the INTR bit in the UCONFIG1 or CONFIG1 configuration byte:

- For INTR = 0, an interrupt pushes the two lower bytes of the PC onto the stack in the following order: PC.7:0, PC.15:8. The RETI instruction pops these two bytes and uses them as the 16-bit return address in region FF:. RETI also restores the interrupt logic to accept additional interrupts at the same priority level as the one just processed.
- For INTR = 1, an interrupt pushes the three PC bytes and PSW1 onto the stack in the following order: PSW1, PC.23:16, PC.7:0, PC.15:8. The RETI instruction pops these four bytes and then returns to the specified 24-bit address, which can be anywhere in the 16-Mbyte address space. RETI also clears the interrupt request line. (See the note in Table 5-8 regarding compatibility with code written for MCS 51 microcontrollers.)

The TRAP instruction is useful for the development of emulations of an 8x930 microcontroller.

5.6 PROGRAM STATUS WORDS

The Program Status Word (PSW) register (Figure 5-2) and the Program Status Word 1 (PSW1) register (Figure 5-3) contain four types of bits:

- CY, AC, OV, N, and Z are flags set by hardware to indicate the result of an operation.
- The P bit indicates the parity of the accumulator.
- Bits RS0 and RS1 are programmed by firmware to select the active register bank for registers R0–R7.
- F0 and UD are available to the user as general-purpose flags.

The PSW and PSW1 registers are read/write registers; however, the parity bit in the PSW is not affected by a write. Individual bits can be addressed with the bit instructions (see “Bit Addressing” on page 5-10). The PSW and PSW1 bits are used implicitly in the conditional jump instructions (see “Conditional Jumps” on page 5-13).

The PSW register is identical to the PSW register in MCS 51 microcontrollers. The PSW1 register exists only in MCS 251 microcontrollers. Bits CY, AC, RS0, RS1, and OV in PSW1 are identical to the corresponding bits in PSW; i.e., the same bit can be accessed in either register. Table 5-10 lists the instructions that affect the CY, AC, OV, N, and Z bits.

Table 5-10. The Effects of Instructions on the PSW and PSW1 Flags

Instruction Type	Instruction	Flags Affected (1), (5)				
		CY	OV	AC (2)	N	Z
Arithmetic	ADD, ADDC, SUB, SUBB, CMP	X	X	X	X	X
	INC, DEC				X	X
	MUL, DIV (3)	0	X		X	X
	DA	X			X	X
Logical	ANL, ORL, XRL, CLR A, CPL A, RL, RR, SWAP				X	X
	RLC, RRC, SRL, SLL, SRA (4)	X			X	X
Program Control	CJNE	X			X	X
	DJNE				X	X

NOTES:

1. X = the flag can be affected by the instruction.
0 = the flag is cleared by the instruction.
2. The AC flag is affected only by operations on 8-bit operands.
3. If the divisor is zero, the OV flag is set, and the other bits are meaningless.
4. For SRL, SLL, and SRA instructions, the last bit shifted out is stored in the CY bit.
5. The parity bit (PSW.0) is set or cleared by instructions that change the contents of the accumulator (ACC, Register R11).

PSW		Address: S:D0H					
		Reset State: 0000 0000B					
7							0
CY	AC	F0	RS1	RS0	OV	UD	P

Bit Number	Bit Mnemonic	Function																				
7	CY	<p>Carry Flag:</p> <p>The carry flag is set by an addition instruction (ADD, ADDC) if there is a carry out of the MSB. It is set by a subtraction (SUB, SUBB) or compare (CMP) if a borrow is needed for the MSB. The carry flag is also affected by logical bit, bit move, multiply, decimal adjust, and some rotate and shift instructions (see Table 5-10).</p>																				
6	AC	<p>Auxiliary Carry Flag:</p> <p>The auxiliary carry flag is affected only by instructions that address 8-bit operands. The AC flag is set if an arithmetic instruction with an 8-bit operand produces a carry out of bit 3 (from addition) or a borrow into bit 3 (from subtraction). Otherwise, it is cleared. This flag is useful for BCD arithmetic (see Table 5-10).</p>																				
5	F0	<p>Flag 0:</p> <p>This general-purpose flag is available to the user.</p>																				
4:3	RS1:0	<p>Register Bank Select Bits 1 and 0:</p> <p>These bits select the memory locations that comprise the active bank of the register file (registers R0–R7).</p> <table style="margin-left: 20px; border-collapse: collapse;"> <tr> <td style="padding-right: 10px;">RS1</td> <td style="padding-right: 10px;">RS0</td> <td style="padding-right: 10px;">Bank</td> <td>Address</td> </tr> <tr> <td>0</td> <td>0</td> <td>0</td> <td>00H–07H</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>08H–0FH</td> </tr> <tr> <td>1</td> <td>0</td> <td>2</td> <td>10H–17H</td> </tr> <tr> <td>1</td> <td>1</td> <td>3</td> <td>18H–1FH</td> </tr> </table>	RS1	RS0	Bank	Address	0	0	0	00H–07H	0	1	1	08H–0FH	1	0	2	10H–17H	1	1	3	18H–1FH
RS1	RS0	Bank	Address																			
0	0	0	00H–07H																			
0	1	1	08H–0FH																			
1	0	2	10H–17H																			
1	1	3	18H–1FH																			
2	OV	<p>Overflow Flag:</p> <p>This bit is set if an addition or subtraction of signed variables results in an overflow error (i.e., if the magnitude of the sum or difference is too great for the seven LSBs in 2's-complement representation). The overflow flag is also set if a multiplication product overflows one byte or if a division by zero is attempted.</p>																				
1	UD	<p>User-definable Flag:</p> <p>This general-purpose flag is available to the user.</p>																				
0	P	<p>Parity Bit:</p> <p>This bit indicates the parity of the accumulator. It is set if an odd number of bits in the accumulator are set. Otherwise, it is cleared. Not all instructions update the parity bit. The parity bit is set or cleared by instructions that change the contents of the accumulator (ACC, Register R11).</p>																				

Figure 5-2. Program Status Word Register

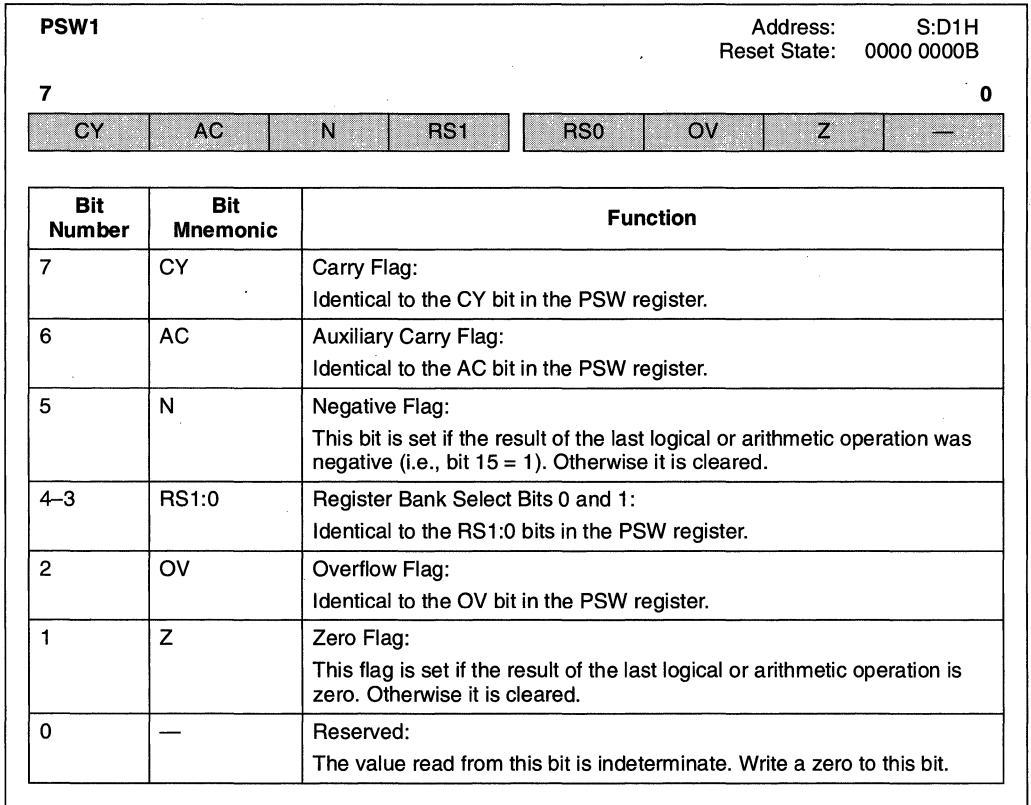


Figure 5-3. Program Status Word 1 Register

intel[®]

6

Interrupt System



CHAPTER 6 INTERRUPT SYSTEM

6.1 OVERVIEW

The 8x930, like other control-oriented microcontroller architectures[†], employs a program interrupt method. This operation branches to a subroutine and performs some service in response to the interrupt. When the subroutine completes, execution resumes at the point where the interrupt occurred. Interrupts may occur as a result of internal 8x930 activity (e.g., timer overflow) or at the initiation of electrical signals external to the microcontroller (e.g., serial port communication). In all cases, interrupt operation is programmed by the system designer, who determines priority of interrupt service relative to normal code execution and other interrupt service routines. Ten of the eleven interrupts are enabled or disabled by the system designer and may be manipulated dynamically.

A typical interrupt event chain occurs as follows. An internal or external device initiates an interrupt-request signal. This signal, connected to an input pin (see Table 6-1) and periodically sampled by the 8x930, latches the event into a flag buffer. The priority of the flag (see Table 6-2) is compared to the priority of other interrupts by the interrupt handler. A high priority causes the handler to set an interrupt flag. This signals the instruction execution unit to execute a context switch. This context switch breaks the current flow of instruction sequences. The execution unit completes the current instruction prior to a save of the program counter (PC) and reloads the PC with the start address of a firmware service routine. The firmware service routine executes assigned tasks and as a final activity performs a RETI (return from interrupt instruction). This instruction signals completion of the interrupt, resets the interrupt-in-progress priority, and reloads the program counter. Program operation then continues from the original point of interruption.

Table 6-1. Interrupt System Input Signals

Signal Name	Type	Description	Multiplexed With
INT1:0#	I	External Interrupts 0 and 1. These inputs set bits IE1:0 in the TCON register. If bits IT1:0 in the TCON register are set, bits IE1:0 are controlled by a negative-edge trigger on INT1#/INT0#. If bits IT1:0 are clear, bits IE1:0 are controlled by a low level trigger on INT1:0#.	P3.3:2

NOTE: Other signals are defined in their respective chapters and in Appendix B, "Signal Descriptions."

[†] A non-maskable interrupt (NMI#) is not included on the 8x930.

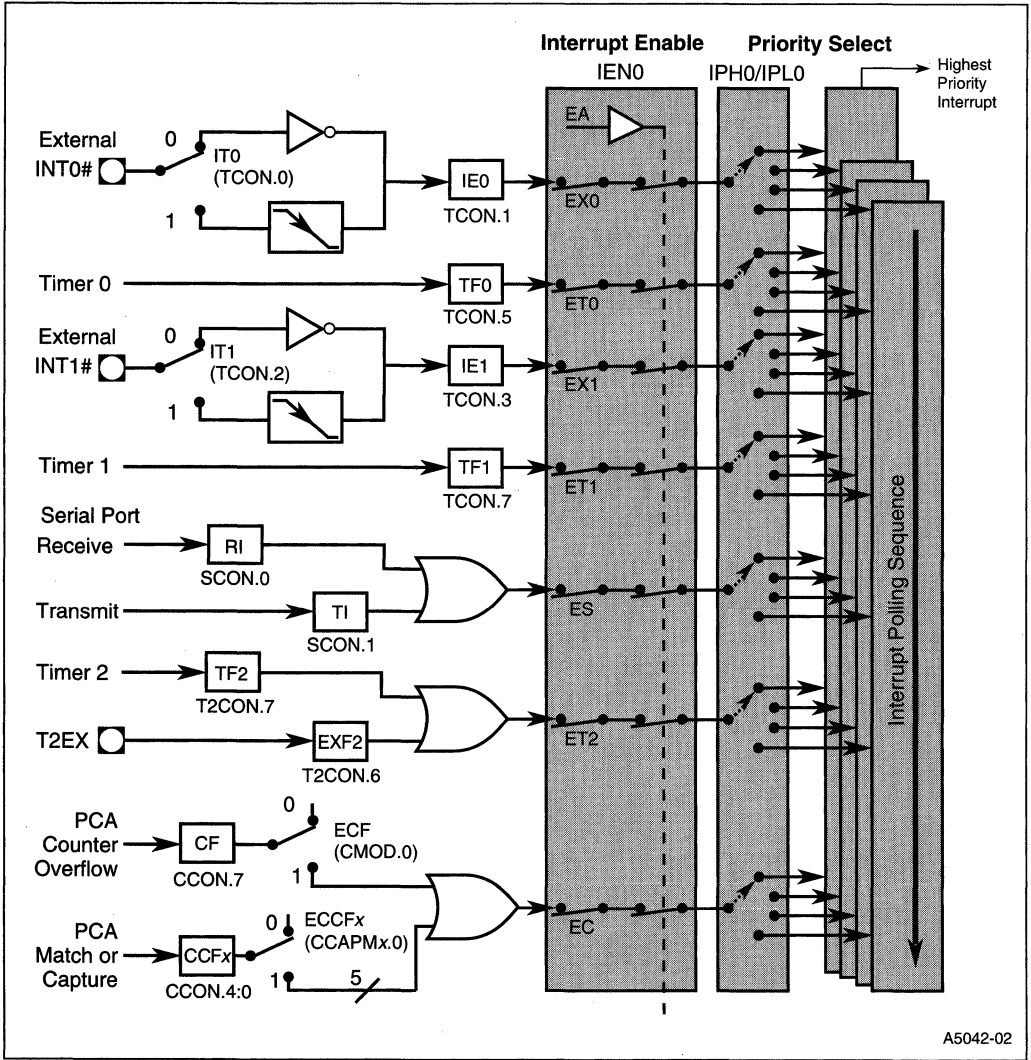


Figure 6-1. Interrupt Control System

6.2 8x930 INTERRUPT SOURCES

Figures 6-1 and 6-2 illustrate the interrupt control system. The 8x930 has eleven interrupt sources; ten maskable sources and the TRAP instruction (always enabled). The maskable sources include two external interrupts (INT0# and INT1#), three timer interrupts (timers 0, 1, and 2), one programmable counter array (PCA) interrupt, one serial port interrupt, and three USB interrupts (one of which doubles as a hub interrupt). Each interrupt (except TRAP) has an interrupt request flag, which can be set by firmware as well as by hardware (see Table 6-3). For some interrupts, hardware clears the request flag when it grants an interrupt. Firmware can clear any request flag to cancel an impending interrupt.

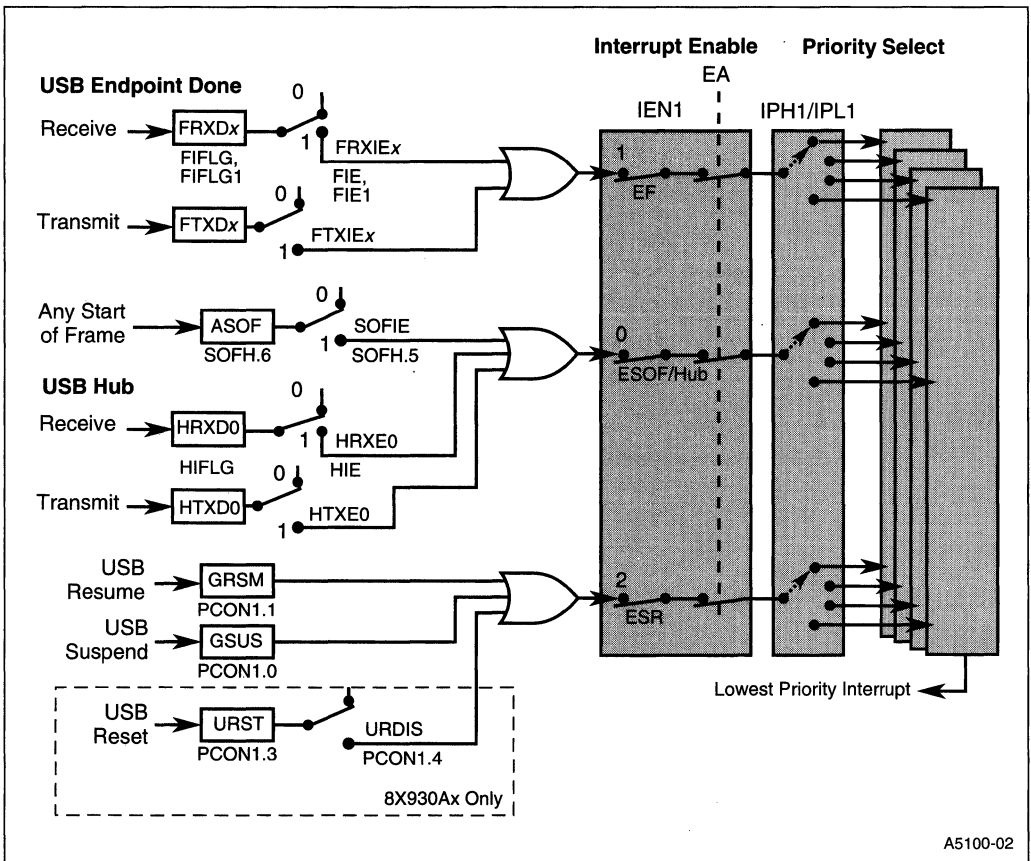


Figure 6-2. USB/Hub Interrupt Control System

Table 6-2. Interrupt System Special Function Registers

Mnemonic	Description	Address
FIE	USB Function Interrupt Enable Register. Enables and disables the receive and transmit done interrupts for the four function endpoints.	S:A2H
FIE1	USB Function Interrupt Enable Register. Available on the 8x930Ax only, this register enables and disables the receive and transmit done interrupts for the function endpoints 4 and 5.	S:A3H
FIFLG	USB Function Interrupt Flag Register. Contains the USB function's transmit and receive done interrupt flags for non-isochronous endpoints.	S:C0H
FIFLG1	USB Function Interrupt Flag Register. Contains the USB function's transmit and receive done interrupt flags for non-isochronous endpoints. This register, available in the 8x930Ax only, contains the function interrupt flags for endpoints 4 and 5.	S:C1H
HIE	Hub Interrupt Enable Register. Contains the hub interrupt enable bits.	S:A1H
HIFLG	Hub Interrupt Flag Register. Contains the hub interrupt status flags.	S:E8H
IEN0	Interrupt Enable Register 0. Enables individual programmable interrupts. Also provides a global enable for the programmable interrupts. The reset value for this register is zero (interrupts disabled).	S:A8H
IEN1	Interrupt Enable Register 1. Enables individual programmable interrupts for the USB interrupts. The reset value of this register is zero (interrupts disabled).	S:B1H
IPL0	Interrupt Priority Low Register 0. Establishes relative priority for programmable interrupts. Used in conjunction with IPH0.	S:B8H
IPH0	Interrupt Priority High Register 0. Establishes relative priority for programmable interrupts. Used in conjunction with IPL0.	S:B7H
IPL1	Interrupt Priority Low Register 1. Establishes relative priority for programmable interrupts. Used in conjunction with IPH1.	S:B2H
IPH1	Interrupt Priority High Register 1. Establishes relative priority for programmable interrupts. Used in conjunction with IPL1.	S:B3H
PCON1	USB Power Control. Contains USB global suspend and resume interrupt bits. Also contains the USB reset separation enable and interrupt bits for the 8x930Ax. See Figure 15-2 on page 15-4.	S:DFH
SOFH	Start of Frame High Register. Contains isochronous data transfer enable and interrupt bits and the upper three bits of the 11-bit time stamp received from the host.	S:D3H
SOFL	Start of Frame Low Register. Contains the lower eight bits of the 11-bit time stamp received from the host.	S:D2H

NOTE: Other SFRs are described in their respective chapters and in Appendix C, "Registers."

6.2.1 External Interrupts

External interrupts INT0# and INT1# (INTx#) pins may each be programmed to be level-triggered or edge-triggered, dependent upon bits IT0 and IT1 in the TCON register (see Figure 11-6 on page 11-8). If ITx = 0, INTx# is triggered by a detected low at the pin. If ITx = 1, INTx# is negative-edge triggered. External interrupts are enabled with bits EX0 and EX1 (EXx) in the IEN0 register (see Figure 6-12). Events on the external interrupt pins set the interrupt request flags IEx in TCON. These request bits are cleared by hardware vectors to service routines only if the interrupt is negative-edge triggered. If the interrupt is level-triggered, the interrupt service routine must clear the request bit. External hardware must deassert INTx# before the service routine completes, or an additional interrupt is requested. External interrupt pins must be deasserted for at least four state times prior to a request.

External interrupt pins are sampled once every four state times (a frame length of 666.4 ns at 12 MHz). A level-triggered interrupt pin held low or high for any five-state time period guarantees detection. Edge-triggered external interrupts must hold the request pin low for at least five state times. This ensures edge recognition and sets interrupt request bit EXx. The CPU clears EXx automatically during service routine fetch cycles for edge-triggered interrupts.

Table 6-3. Interrupt Control Matrix

Interrupt Name [†]	Global Enable	PCA	Timer 2	Serial Port	Timer 1	INT1#	Timer 0	INT0#
Bit Name in IEN0 Register	EA	EC	ET2	ES	ET1	EX1	ET0	EX0
Interrupt Priority-Within-Level (10 = Low Priority, 1 = High Priority)	NA	7	6	5	4	3	2	1
Bit Names in: IPH0 IPL0	Reserved Reserved	IPH0.6 IPL0.6	IPH0.5 IPL0.5	IPH0.4 IPL0.4	IPH0.3 IPL0.3	IPH0.2 IPL0.2	IPH0.1 IPL0.1	IPH0.0 IPL0.0
Programmable for Negative-edge Triggered or Level-triggered Detect?	NA	Edge	No	No	No	Yes	No	Yes
Interrupt Request Flag in CCON, T2CON, SCON, or TCON Register	NA	CCON: CF, CCFx	T2CON: TF2, EXF2	SCON: RI, TI	TCON: TF1	TCON: IE1	TCON: TF0	TCON: IE0
Interrupt Request Flag Cleared by Hardware?	No	No	No	No	Yes	Edge Yes, Level No	Yes	Edge Yes, Level No
ISR Vector Address	NA	FF: 0033H	FF: 002BH	FF: 0023H	FF: 001BH	FF: 0013H	FF: 000BH	FF: 0003H

[†] The 8x930 also contains a TRAP interrupt, not cleared by hardware, with a vector address of FF007BH. For a discussion of TRAP and other interrupt sources, see "8x930 Interrupt Sources" on page 6-3.

Additional interrupts specific to USB and USB hub operation appear in Table 6-4.

Table 6-4. USB/Hub Interrupt Control Matrix

Interrupt Name	USB Global Suspend/Resume and USB Reset†	USB Function [Non-Isochronous Endpoint]	USB Hub/SOF [Isochronous Endpoint]
Bit Name in IEN1 Register	ESR	EF	ESOF
Interrupt Priority-Within-Level (10 = Low Priority, 1 = High Priority)	10	9	8
Bit Names in: IPH1 IPL1	IPH1.2 IPL1.2	IPH1.1 IPL1.1	IPH1.0 IPL1.0
Programmable for Negative-edge Triggered or Level-triggered Detect?	N/A	N/A	N/A
Interrupt Request Flag in PCON1, FIFLG, HIFLG, or SOFH Register	PCON1: GSUS GRSM URST†	FIFLG: FTXD _x , FRXD _x x=0,1,2,3	SOFH:ASOF, HIFLG: HTXD0, HRXD0
Interrupt Request Flag Cleared by Hardware?	No	No	No
ISR Vector Address	FF:0053H	FF:004BH	FF:0043H

† USB Reset interrupt applies to the 8x930Ax only.

6.2.2 Timer Interrupts

Two timer-interrupt request bits TF0 and TF1 (see TCON register, Figure 11-6 on page 11-8) are set by timer overflow (the exception is Timer 0 in Mode 3, see Figure 11-4 on page 11-6). When a timer interrupt is generated, the bit is cleared by an on-chip hardware vector to an interrupt service routine. Timer interrupts are enabled by bits ET0, ET1, and ET2 in the IEN0 register (see Figure 6-12).

Timer 2 interrupts are generated by a logical OR of bits TF2 and EXF2 in register T2CON (see Figure 11-12 on page 11-17). Neither flag is cleared by a hardware vector to a service routine. In fact, the interrupt service routine must determine if TF2 or EXF2 generated the interrupt, and then clear the bit. Timer 2 interrupt is enabled by ET2 in register IEN0.

6.3 PROGRAMMABLE COUNTER ARRAY (PCA) INTERRUPT

The programmable counter array (PCA) interrupt is generated by the logical OR of five event flags (CCF_x) and the PCA timer overflow flag (CF) in the CCON register (see Figure 12-8 on page 12-14). All PCA interrupts share a common interrupt vector. Bits are not cleared by hardware vectors to service routines. Normally, interrupt service routines resolve interrupt requests and clear flag bits. This allows the user to define the relative priorities of the five PCA interrupts.

The PCA interrupt is enabled by bit EC in the IEN0 register (see Figure 6-1). In addition, the CF flag and each of the CCF_x flags must also be individually enabled by bits ECF and ECCF_x in registers CMOD and CCAPM_x, respectively, for the flag to generate an interrupt (see Figure 12-7 on page 12-13 and Figure 12-9 on page 12-16).

NOTE

CCF_x refers to five separate bits, one for each PCA module (CCF0, CCF1, CCF2, CCF3, CCF4). CCAPM_x refers to 5 separate registers, one for each PCA module (CCAPM0, CCAPM1, CCAPM2, CCAPM3, CCAPM4).

6.4 SERIAL PORT INTERRUPT

Serial port interrupts are generated by the logical OR of bits RI and TI in the SCON register (see Figure 13-2 on page 13-4). Neither flag is cleared by a hardware vector to the service routine. The service routine resolves RI or TI interrupt generation and clears the serial port request flag. The serial port interrupt is enabled by bit ES in the IEN0 register (see Figure 6-12).

6.5 USB INTERRUPTS

There are three types of USB interrupts, as shown in Figure 6-2 on page 6-3: The USB function interrupt, used to control the flow of non-isochronous data; the hub/any start-of-frame interrupt (SOF), used to signal a hub interrupt or to monitor the transfer of isochronous data; and the global suspend/resume interrupt, used to allow USB power control and, for the 8x930Ax only, to provide a separate USB interrupt. These interrupts are enabled using the IEN1 register. See Table 6-4 and Figure 6-13.

6.5.1 USB Function Interrupt

The USB function generates two types of interrupts to control the transfer of non-isochronous data: the receive done interrupt and the transmit done interrupt. Individual USB function interrupts in the 8x930 are enabled by setting the corresponding bits in the FIE register (Figure 6-3). The 8x930Ax, with its six function endpoints, also uses the FIE1 register (Figure 6-4) to enable interrupts for endpoints 4 and 5.

NOTE

In order to use any of the USB function interrupts, the EF bit in the IEN1 register must be enabled.

The USB Function Interrupt Flag register (FIFLG, as shown in Figure 6-5) is used to indicate pending function interrupts for a given endpoint. The 8x930Ax, with its six function endpoints, also uses the FIFLG1 register (Figure 6-6) to indicate interrupts for endpoints 4 and 5. For all bits in FIFLG or FIFLG1, a '1' indicates that an interrupt is actively pending for that endpoint; a '0' indicates that the interrupt is not active. The interrupt status is shown in the FIFLG or FIFLG1 register regardless of the state of the corresponding interrupt enable bit in the FIE or FIE1 register (Figures 6-3 and 6-4).

FIE	Address: S:A2H	
	Reset State: 0000 0000B	
Function Interrupt Enable Register. Enables and disables the receive and transmit done interrupts for the four function endpoints.		
7		0
FRXIE3	FTXIE3	FRXIE2
FRXIE2	FTXIE2	FRXIE1
FRXIE1	FTXIE1	FRXIE0
FRXIE0	FTXIE0	FTXIE0

Bit Number	Bit Mnemonic	Function
7	FRXIE3	Function Receive Interrupt Enable 3: Enables receive done interrupt for endpoint 3 (FRXD3).
6	FTXIE3	Function Transmit Interrupt Enable 3: Enables transmit done interrupt for endpoint 3 (FTXD3).
5	FRXIE2	Function Receive Interrupt Enable 2: Enables the receive done interrupt for endpoint 2 (FRXD2).
4	FTXIE2	Function Transmit Interrupt Enable 2: Enables the transmit done interrupt for endpoint 2 (FTXD2).
3	FRXIE1	Function Receive Interrupt Enable 1: Enables the receive done interrupt for endpoint 1 (FRXD1).
2	FTXIE1	Function Transmit Interrupt Enable 1: Enables the transmit done interrupt for endpoint 1 (FTXD1).
1	FRXIE0	Function Receive Interrupt Enable 0: Enables the receive done interrupt for endpoint 0 (FRXD0).
0	FTXIE0	Function Transmit Interrupt Enable 0: Enables the transmit done interrupt for endpoint 0 (FTXD0).

NOTE: For all bits, a '1' means the interrupt is enabled and will cause an interrupt to be signaled to the microcontroller. A '0' means the associated interrupt source is disabled and cannot cause an interrupt, even though the interrupt bit's value is still reflected in the FIFLG register.

Figure 6-3. FIE: USB Function Interrupt Enable Register

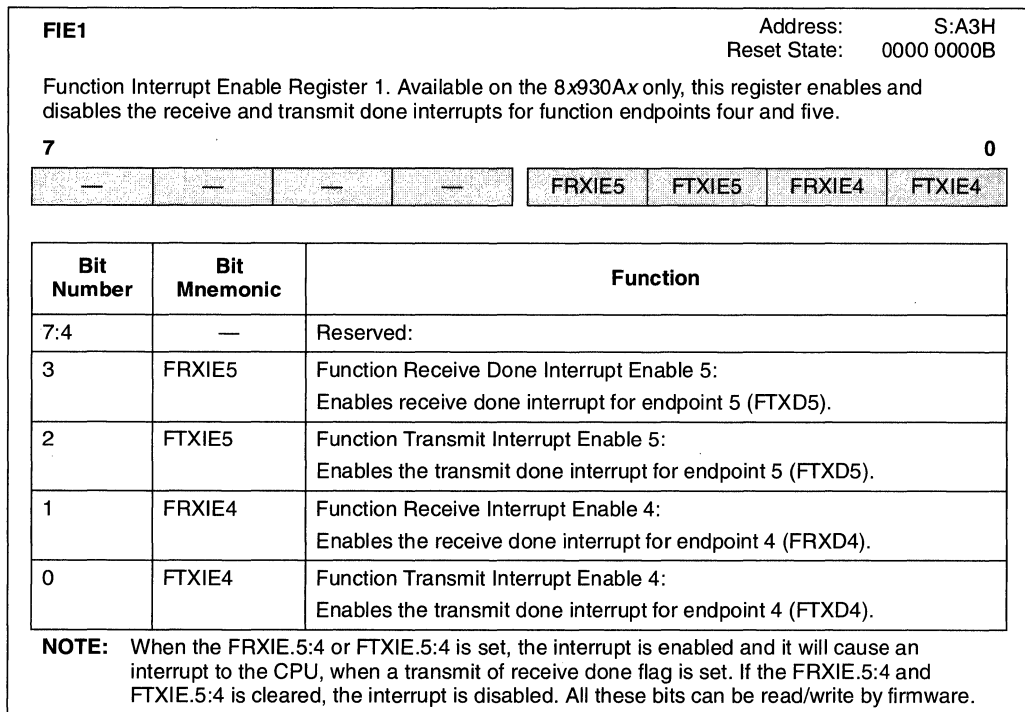


Figure 6-4. FIE1: USB Function Interrupt Enable Register

The USB function generates a receive done interrupt for an endpoint x ($x = 0-3$) by setting the FRXD x bit in the FIFLG or FIFLG1 register (Figures 6-5 and 6-6). Only non-isochronous transfer can cause a receive done interrupt. Receive done interrupts are generated only when *all* of the following are true:

1. A valid SETUP or OUT token is received to function endpoint x , *and*
2. Endpoint x is enabled for reception (RXEPEN in EPCON = '1'), *and*
3. Receive is enabled (RXIE = '1') and STALL is disabled (RXSTL = '0') for OUT tokens (or the token received is a SETUP token), *and*
4. A data packet is received with no time-out — *regardless* of transmission errors (CRC, bit-stuffing) or FIFO errors (overrun, underrun), *and*
5. There is no data sequence PID error.

Because the FRXD x bit is set and a receive done interrupt is generated regardless of transmission errors, this condition means either:

1. Valid data is waiting to be serviced in the receive FIFO for function endpoint x and that the data was received without error and has been acknowledged; or
2. Data was received with a receive data error and requires firmware intervention to be cleared. This could be either a transmission error or a FIFO-related error. You must check for these conditions and respond accordingly in the interrupt service routine (ISR).

The USB function generates a transmit done interrupt for an endpoint x ($x = 0-3^\dagger$) by setting the FTXD x bit in the FIFLG or FIFLG1 register (Figures 6-5 and 6-6). Only non-isochronous transfer can cause a transmit done interrupt. Transmit done interrupts are generated only when *all* of the following are true:

1. A valid IN token is received to function endpoint x , *and*
2. Endpoint x is enabled for transmission (TXEPEN = '1'), *and*
3. Transmit is enabled (TXIE = '1') and STALL is disabled (TXSTL = '0'), *and*
4. A data packet/byte count has been loaded in the transmit FIFO and was transmitted in response to the IN token — *regardless* of whether or not a FIFO error occurs, *and*
5. An ACK is received from the host or there was a time-out in the SIE.

Because the FTXD x bit is set and a transmit done interrupt is generated regardless of transmission errors, this condition means either:

1. The transmit data has been transmitted and the host has sent an acknowledgment to indicate that it was successfully received; or
2. A transmit data error occurred during transmission of the data packet, which requires servicing by firmware to be cleared. You must check for these conditions and respond accordingly in the ISR.

NOTE

Setting an endpoint interrupt's bit in the Function Interrupt Enable register (FIE or FIE1, as shown in Figures 6-3 and 6-4) means that the interrupt is enabled and will cause an interrupt to be signaled to the microcontroller. Clearing a bit in the FIE register disables the associated interrupt source, which can no longer cause an interrupt even though its value will still be reflected in the FIFLG or FIFLG1 register (Figures 6-5 and 6-6).

[†] The 8x930Ax can be configured for up to six endpoints, 0-5.

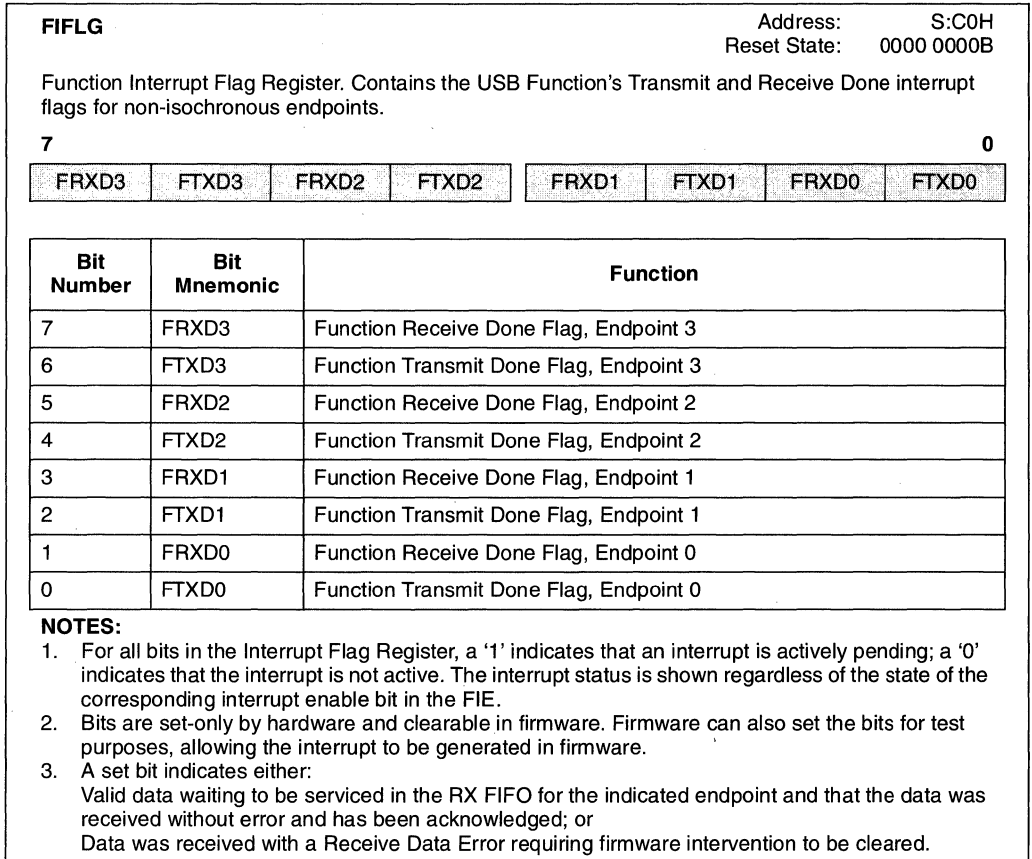


Figure 6-5. FIFLG: USB Function Interrupt Flag Register

FIFLG1		Address: S:C1H
		Reset State: 0000 0000B
Function Interrupt Flag Register 1. Available on the 8x930Ax only, this register contains the USB Function's Transmit and Receive Done interrupt flags for non-isochronous endpoints.		
7	0	
—	—	FRXD5
—	—	FTXD5
—	—	FRXD4
—	—	FTXD4
Bit Number	Bit Mnemonic	Function
7:4	—	Reserved: Write zeros to these bits.
3	FTXD5	Function Receive Done Flag, Endpoint 5:
2	FTXD5	Function Transmit Done Flag, Endpoint 5:
1	FRXD4	Function Receive Done Flag, Endpoint 4:
0	FTXD4	Function Transmit Done Flag, Endpoint 4:
NOTES:		
1. For all bits in the Interrupt Flag Register, a '1' indicates that an interrupt is actively pending; a '0' indicates that the interrupt is not active. The interrupt status is shown regardless of the state of the corresponding interrupt enable bit in the FIE.		
2. Bits are set-only by hardware and clearable in firmware. Firmware can also set the bits for test purposes, allowing the interrupt to be generated in firmware.		
3. A set bit indicates either: Valid data waiting to be serviced in the RX FIFO for the indicated endpoint and that the data was received without error and has been acknowledged; or Data was received with a Receive Data Error requiring firmware intervention to be cleared.		

Figure 6-6. FIFLG1: USB Function Interrupt Flag Register

6.5.2 USB Start-of-frame Interrupt

The USB start-of-frame interrupt (SOF) is used to control the transfer of isochronous data. The 8x930 frame timer attempts to synchronize to the frame time automatically. When the frame timer is locked to the USB frame time, hardware sets the FTLOCK bit in SOFH (Figure 6-7). To enable the start-of-frame interrupt, set the SOFIE bit in SOFH.

The 8x930 generates a start-of-frame interrupt whenever a start-of-frame packet is received from the USB lines, or whenever a start-of-frame packet should have been received (i.e., an artificial SOF). The 8x930 generates an SOF interrupt by setting the ASOF bit in the SOFH SFR. When a start-of-frame interrupt occurs, the 8x930 loads the current value of the frame timer into the SOFH/SOFL registers (Figures 6-7 and 6-8).

NOTE

The start-of-frame interrupt shares an interrupt vector with the hub interrupt. When this interrupt is triggered, firmware must examine the ASOF bit in the SOFH SFR to determine that it was the start-of-frame interrupt that was triggered, and not the hub interrupt.

SOFH		Address: S:D3H Reset State: 0000 0000B
Start of Frame High Register. Contains isochronous data transfer enable and interrupt bits and the upper three bits of the 11-bit time stamp received from the host.		
7	0	
SOFACK	ASOF	SOFIE
FTLOCK	SOFODIS	TS10
	TS9	TS8

Bit Number	Bit Mnemonic	Function
7	SOFACK	<p>SOF Token Received without Error (read-only):</p> <p>When set, this bit indicates that the 11-bit time stamp stored in SOFL and SOFH is valid. This bit is updated every time a SOF token is received from the USB bus, and it is cleared when an artificial SOF is generated by the frame timer. This bit is set and cleared by hardware.</p>
6	ASOF	<p>Any Start of Frame:</p> <p>This bit is set by hardware to indicate that a new frame has started. The interrupt can result either from reception of an actual SOF packet or from an artificially-generated SOF from the frame timer. This interrupt is asserted in hardware even if the frame timer is not locked to the USB bus frame timing. When set, this bit is an indication that either an actual SOF packet was received or an artificial SOF was generated by the frame timer. This bit must be cleared by firmware or inverted and driven to the SOF# pin. The effect of setting this bit by firmware is the same as hardware: the external pin will be driven with an inverted ASOF value for eight T_{CLKS}.</p> <p>This bit also serves as the SOF interrupt flag. This interrupt is only asserted in hardware if the SOF interrupt is enabled (SOFIE set) and the interrupt channel is enabled.</p>
5	SOFIE	<p>SOF Interrupt Enable:</p> <p>When this bit is set, setting the ASOF bit causes an interrupt request to be generated if the interrupt channel is enabled. Hardware reads but does not write this bit.</p>
4	FTLOCK	<p>Frame Timer Locked (read-only):</p> <p>When set, this bit indicates that the frame timer is presently locked to the USB bus' frame time. When cleared, this bit indicates that the frame timer is attempting to synchronize to the frame time.</p>

Figure 6-7. SOFH: Start of Frame High Register



SOFH (Continued)		Address: S:D3H Reset State: 0000 0000B
Start of Frame High Register. Contains isochronous data transfer enable and interrupt bits and the upper three bits of the 11-bit time stamp received from the host.		
7	0	
SOFACK	ASOF	SOFIE
FTLOCK	SOFODIS	TS10
	TS9	TS8

Bit Number	Bit Mnemonic	Function
3	SOFODIS	SOF# Pin Output Disable: When set, no low pulse will be driven to the SOF# pin in response to setting the ASOF bit. The SOF# pin will be driven to '1' when SOFODIS is set. When this bit is clear, setting the ASOF bit causes the SOF# pin to be toggled with a low pulse for eight T_{CLK} s.
2:0	TS10:8	Time stamp received from host: TS10:8 are the upper three bits of the 11-bit frame number issued with an SOF token. This time stamp is valid only if the SOFACK bit is set.

Figure 6-7. SOFH: Start of Frame High Register (Continued)

SOFL		Address: S:D2H Reset State: 0000 0000B
Start-of-Frame Low Register. Contains the lower eight bits of the 11-bit time stamp received from the host.		
7	0	
TS7:0		

Bit Number	Bit Mnemonic	Function
7:0	TS7:0	Time stamp received from host: This time stamp is valid only if the SOFACK bit in the SOFH register is set. TS7:0 are the lower eight bits of the 11-bit frame number issued with a SOF token. If an artificial SOF is generated, the time stamp remains at its previous value and it is up to firmware to update it. These bits are set and cleared by hardware.

Figure 6-8. SOFL: Start of Frame Low Register

The 8x930 uses the start-of-frame interrupt to signal either of two complementary events:

1. When transmitting: The next isochronous data packet needs to be retrieved from memory and loaded into the transmit FIFO in preparation for transmission in the next frame; or
2. When receiving: An isochronous packet has been received in the previous frame and needs to be retrieved from the receive FIFO.

Since the start-of-frame packet could be corrupted, there is a chance that a new frame could be started without successful reception of the SOF packet. For this reason, an artificial SOF is provided. The frame timer signals a time-out when an SOF packet has not been received within the allotted amount of time. In this fashion, the 8x930 generates an SOF interrupt reliably once each frame within 1 μ s of accuracy, except when this interrupt is suspended or when the frame timer gets out-of-sync with the USB bus frame time.

In summary, in order to utilize the USB start-of-frame functionality for isochronous data transfer, the following must all be true:

1. The global enable bit must be set. That is, the EA bit must be set in the IEN0 register (Figure 6-12).
2. The isochronous endpoint any SOF interrupt must be enabled. That is, the ESOF bit must be set in the IEN1 register (Figure 6-13).
3. The start-of-frame interrupt must be enabled. That is, the SOFIE bit must be set in the SOFH Register (Figure 6-7).

NOTE

The SOF interrupt is brought out to an external pin (SOF#) in order to provide a 1 ms pulse, subject to the accuracy of the USB start-of-frame. This pin is enabled by clearing the SOFODIS bit in the SOFH register.

6.5.3 USB Hub Interrupt

The USB hub interrupt is used to signal a receive done or transmit done for hub endpoint 0.

To enable the hub interrupt:

1. Set the global enable bit (EA) in the IEN0 register (Figure 6-12)
2. Enable the hub endpoint 0 transmit done and receive done interrupts individually:
 - a. To enable the receive done interrupt, set the HRXE0 bit in the Hub Interrupt Enable SFR (HIE, as shown in Figure 6-9)
 - b. To enable the transmit done interrupt, set the HTXE0 bit in HIE

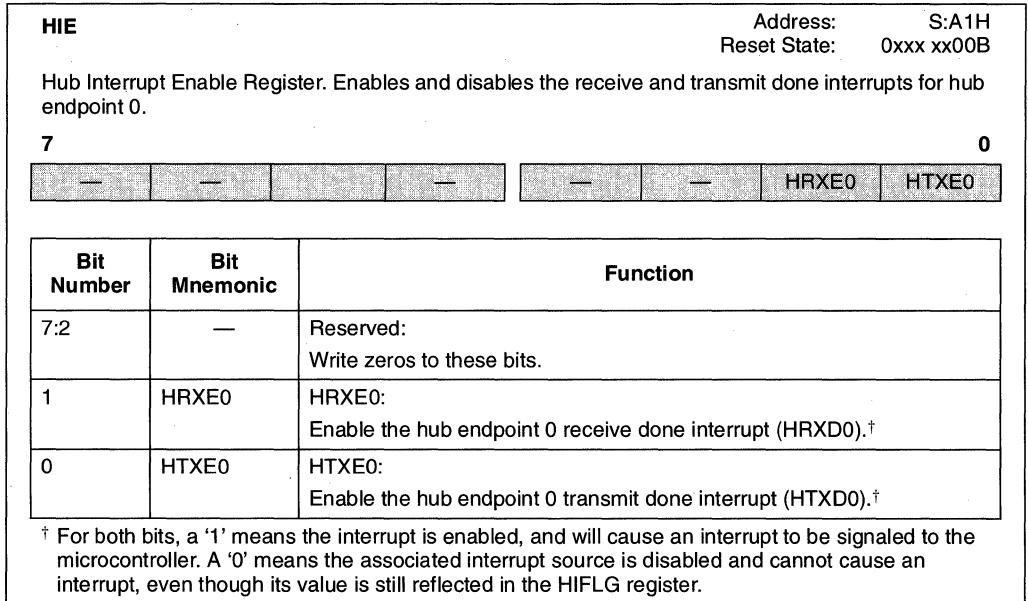


Figure 6-9. HIE: Hub Interrupt Enable Register

The USB Hub Interrupt Flag Register (HIFLG, as shown in Figure 6-10) is used to indicate pending hub interrupts. For all bits in HIFLG, a '1' indicates that an interrupt is actively pending; a '0' indicates that the interrupt is not active. The interrupt status is shown in the HIFLG register regardless of the state of the corresponding interrupt enable bit in the HIE Register (Figure 6-9).

NOTE

The hub interrupt shares an interrupt vector with the start-of-frame interrupt. When this interrupt is triggered, firmware must examine the HIFLG SFR to determine that it was the hub interrupt that was triggered and not the start-of-frame interrupt.

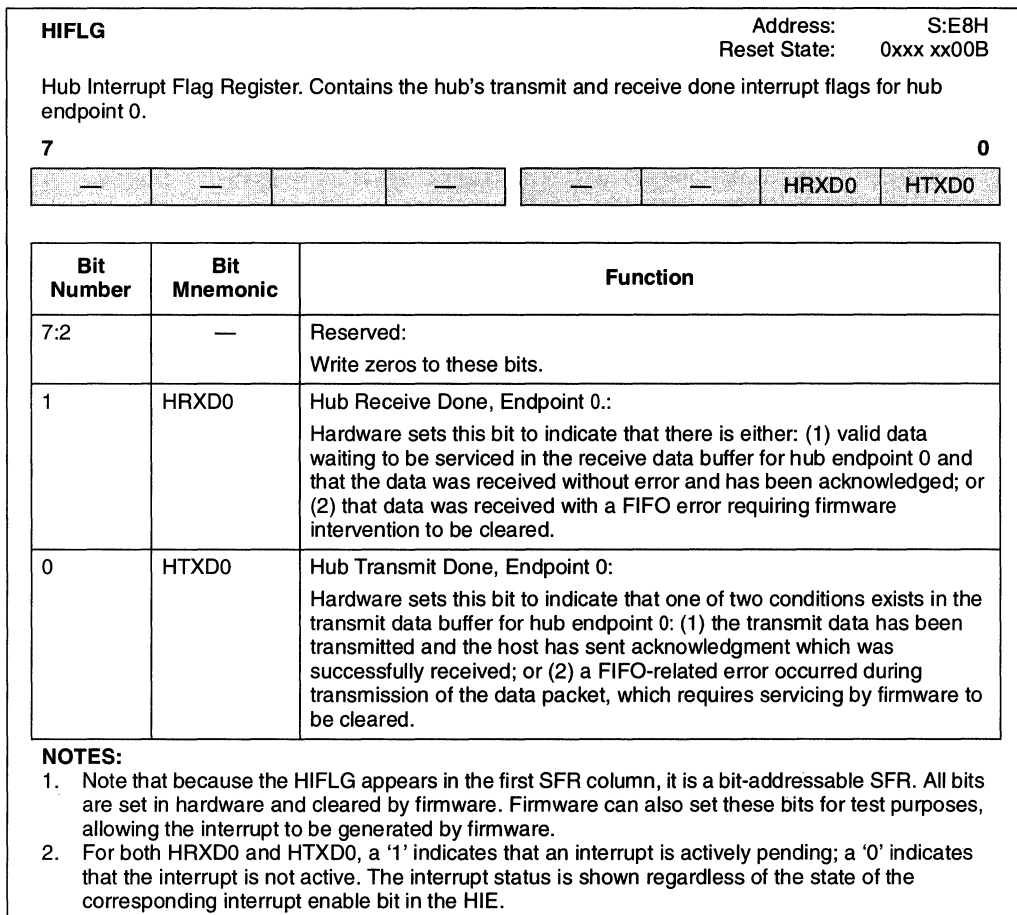


Figure 6-10. HIFLG: Hub Interrupt Status Register

6.5.4 USB Global Suspend/Resume Interrupt

The 8x930 supports USB power control through firmware. The USB power control register (PCON1, as shown in Figure 15-2 on page 15-4) facilitates USB power control of the 8x930, including global suspend/resume and USB function resume.

NOTE

On the 8x930Ax only, the global suspend/resume interrupt shares an interrupt vector with the USB reset interrupt. When this interrupt is triggered, firmware must examine the GSUS and GRSM bits in the PCON1 SFR (Figure 15-2 on page 15-4) to determine that it was the global suspend/resume interrupt that was triggered, and not the USB reset interrupt.

6.5.4.1 Global Suspend

When a global suspend is detected by the 8x930, the global suspend bit (GSUS of PCON1) is set and the global suspend/resume interrupt is generated. Global suspend is defined as bus inactivity for more than 3 ms on the USB lines. For additional information, see “Global Suspend Mode” on page 15-8.

6.5.4.2 Global Resume

When a global resume is detected by the 8x930, the global resume bit (GRSM of PCON1) is set and the global suspend/resume interrupt is generated. As soon as resume signaling is detected on the USB lines, the oscillator is restarted. After executing the resume interrupt service routine, the 8x930 resumes operation from where it was when it was interrupted by the suspend interrupt. For additional information, see “Global Resume Mode” on page 15-10.

6.5.4.3 USB Remote Wake-up

The 8x930 can also initiate resume signaling to the USB lines through remote wake-up of the USB function while it is in powerdown/idle mode. While in powerdown mode, remote wake-up has to be initiated through assertion of an enabled external interrupt. The external interrupt has to be enabled and it must be configured with level trigger and with higher priority than a suspend/resume interrupt. An external interrupt restarts the clocks to the 8x930 and program execution branches to the external interrupt service routine.

Within this external interrupt service routine, you must set the remote wakeup bit (RWU in PCON1) to drive resume signaling on the USB lines to the host or upstream hub. After executing the external ISR, the program continues execution from where it was put into powerdown mode and the 8x930 resumes normal operation. For additional information, see “USB Remote Wake-up” on page 15-10.

6.5.5 8x930Ax USB Reset Separation

The 8x930Ax features an optional USB reset that functions independently from the chip reset. When the PCON1 SFR's URDIS bit is set, the MCS 251 core and peripherals will not reset when a USB reset signal is detected. After an 8x930Ax with URDIS set detects a USB reset signal, it resets all the USB blocks (including the USB SFRs), sets the URST bit in PCON1, and generates a USB reset interrupt. USB reset signals can originate only from the host PC or upstream hub.

NOTE

The use of a separate USB reset is recommended only for applications where the device is required to be operated continually, even when the PC is powered-off. All other applications are advised against using the separate USB reset. Leaving the URDIS bit clear will ensure a robust, chip-level reset.

The USB reset must be implemented partially in firmware, including an initialization routine as part of chip start-up. To ensure compliance with USB-specified timing constraints and minimize the potential for data corruption, you must implement flag checking as part of your main routine, subroutines, and ISRs. These requirements increase the complexity of your firmware code.

If the 8x930Ax is in powerdown or suspend mode when the separate USB reset interrupt is generated, the device will wake up from powerdown or suspend mode upon receiving the USB reset signal. The ISR of a bus-powered device must set the LC bit of PCON (Figure 15-1 on page 15-3) in order to operate at 3 MHz. This ensures that the device meets the 100 mA current limit during enumeration, as required by the *Universal Serial Bus Specification*. Self-powered devices (i.e., devices drawing less than 100mA from the USB wires) may choose not to switch to Low Clock mode after detecting the USB reset.

NOTE

If desired, your firmware can handle the separate USB reset without using an ISR. To do this, you must clear the ESR bit in the IEN1 SFR. The USB reset hardware operations will still take place, but the ISR will not be called. That is, step 1 and step 2 under “USB Reset Hardware Operations” on page 6-22 will still occur, but step 3 will not. Your firmware must poll the URST flag periodically to detect the USB reset and take the appropriate action.

Since the global suspend and global resume interrupts share the same interrupt vector as USB reset, your firmware must also poll the GRSM and GSUS bits in PCON1 to detect global suspend or resume.

If, instead, you choose to implement a separate USB reset using an ISR, follow the procedure outlined in the following subsections and shown in Figure 6-11.

6.5.5.1 Initialization Required for USB Reset

Because USB reset implementation depends heavily on firmware, your code must perform the following initialization prior to execution of the main routine (See Figure 6-11):

1. To enable the USB reset interrupt on the 8x930Ax, your initialization routine must set the following bits to ‘1’:
 - a. the EA bit of IEN0 (Figure 6-12)
 - b. the ESR bit of IEN1 (Figure 6-13)
 - c. the URDIS bit of PCON1 (Figure 15-2 on page 15-4)

2. Use bit 2 of IPH1/IPL1 to set the priority of the USB reset interrupt (See “Interrupt Priorities” on page 6-27).

NOTE

It is recommended that you set the USB reset interrupt to the highest priority.

3. After enabling the USB reset interrupt and assigning it a priority, your initialization routine should clear the USB_RST_FLG flag. This flag is a global variable declared in your firmware, not a bit in an SFR.

This flag, an indicator that a USB reset has occurred, will be examined at various points in your main routine, subroutines, and ISRs.

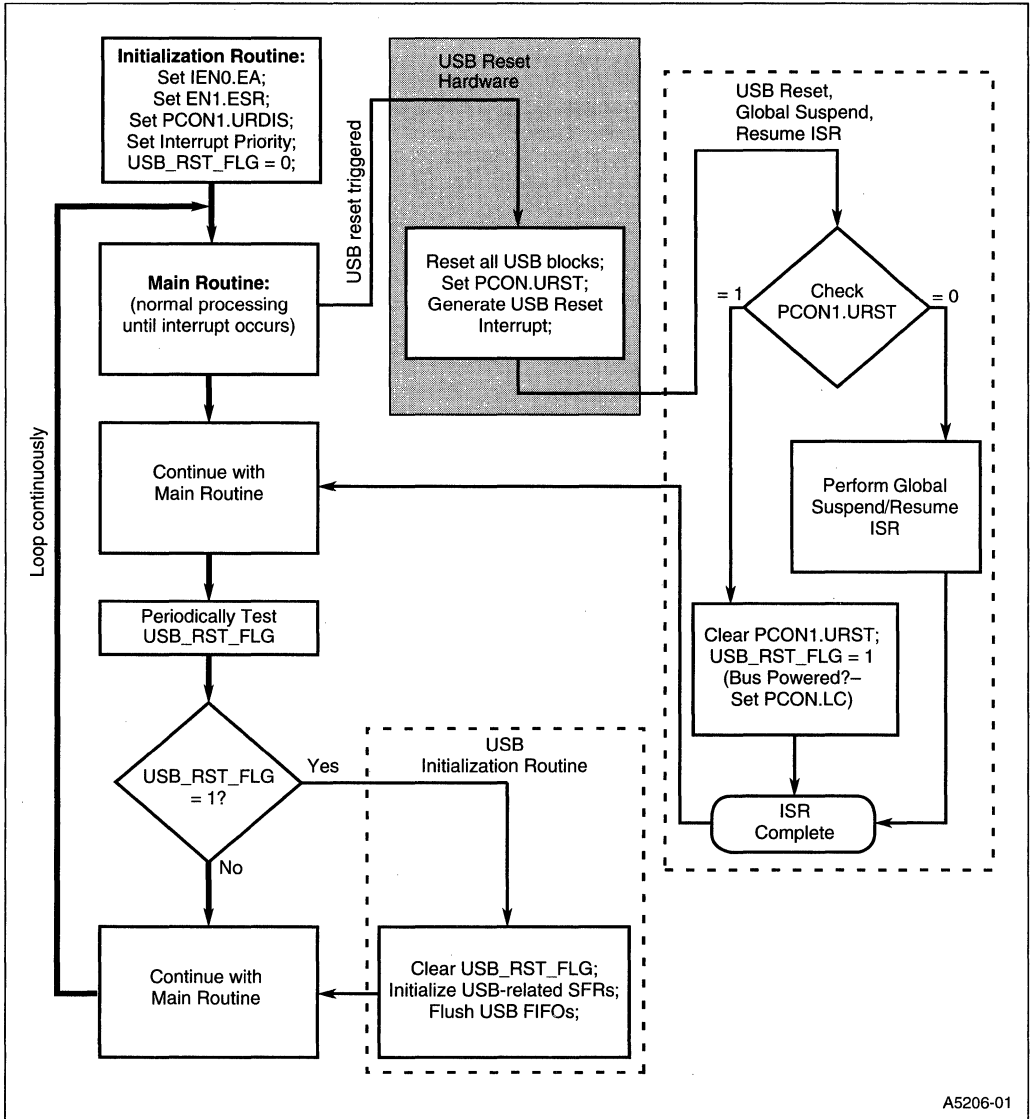


Figure 6-11. USB Reset Separation Operating Model

6.5.5.2 USB Reset Hardware Operations

When the host initiates a USB reset signal, the following series of events is performed by the 8x930Ax hardware (See Figure 6-11):

1. Upon detecting a USB reset signal, the 8x930Ax hardware resets all the USB blocks (i.e., the FIFOs, the SIU, the SIE, and the USB transceiver).

As a result of this process, all USB-related SFRs are reset to their default reset states. This includes EPINDEX, EPCON, SOFL, SOFH, FIE, FIFLG, FADDR, TXSTAT, TXDAT, TXCON, TXFLG, TXCNTL, TXCNTH, RXSTAT, RXDAT, RXCON, RXFLG, RXCNTL, RXCNTH, and PCON1. Note that PCON1 is only partially reset — the URDIS and URST bits retain their original values.

Because of this hardware reset, any USB-related operations (e.g., MOV TXDAT,A) will not provide valid data.

2. The 8x930Ax sets the PCON1.URST bit to indicate a USB reset to the ISR.
3. If the ESR bit in IEN1 is set, the 8x930Ax generates a USB reset interrupt, which causes a branch to the interrupt service routine whose vector is located at FF:0053H. This ISR services both the USB reset interrupt and the global suspend/resume interrupt.

6.5.5.3 USB Reset ISR

Because the USB reset interrupt shares an interrupt vector with the USB global suspend/resume interrupt, the interrupt service routine must play a dual role. The ISR must first check PCON1's URST bit to ensure that this interrupt is indeed a USB reset interrupt.

If URST = '0', then this interrupt must be a global suspend/resume interrupt and the ISR must branch to service that type of interrupt. See "USB Global Suspend/Resume Interrupt" on page 6-18 for a description of this portion of the ISR.

If the URST bit is set to '1', then this interrupt is a USB reset interrupt. The ISR must perform the following procedure (See Figure 6-11):

1. Clear PCON1's URST bit — to indicate that the USB reset interrupt has been serviced.
2. Set the user flag USB_RST_FLG that was cleared as part of your initialization routine.
This flag is discussed in "Initialization Required for USB Reset" on page 6-19. Setting this flag is necessary to inform your firmware routines that a USB reset has occurred and that USB initialization must be performed.
3. Bus-powered devices must set the LC bit of PCON (Figure 15-1 on page 15-3) in order to operate at 3 MHz. This ensures that the device meets the *Universal Serial Bus Specification's* 100 mA current limit during enumeration.
4. Restore any register values and return from interrupt.

The rest of the USB reset procedure will be initiated by a USB initialization routine that can be called from the main routine, subroutines, or other ISRs.

6.5.5.4 Main Routine Considerations

Although the USB-related SFRs were reset by the USB reset ISR, they must also be initialized by a special USB initialization routine called by the main routine. Since the USB reset interrupt can occur at any time, the only way the main routine will know that a USB reset occurred is to periodically check the USB reset flag (USB_RST_FLG). This is the firmware flag that was set in Step 2 of the “USB Reset ISR” on page 6-22.

When a set reset flag is detected, the main routine branches to a USB initialization routine, which performs the following tasks (See Figure 6-11):

1. Clear the user flag USB_RST_FLG.

Clearing this flag indicates that USB initialization is not required. Clear this flag first in case a second USB reset occurs during this initialization routine, rendering this initialization invalid.

2. Initialize the USB-related SFRs to the values required by your program.

If your application requires any other SFRs to be initialized upon USB reset (e.g., SCON), now is the time to do so.

3. Restore any USB-related user flags specific to your application.
4. Flush all USB FIFOs. This is done by setting RXCLR in RXCON and TXCLR in TXCON. This must be done for each function endpoint.
5. Return to the calling routine.

At this point, the main routine can resume normal processing. Eventually, the host PC will transmit a SETUP token. This will trigger an interrupt that will perform USB enumeration.

NOTE

USB specifications require that all devices must be able to accept a device address via a SET_ADDRESS command no later than 10 ms after the reset is removed.

It is recommended that you ensure that the total time required for the following is less than 10ms:

1. The time to complete and exit from the USB reset ISR (accounting for latency — see “Interrupt Processing” on page 6-32)
2. The time for the maximum number of instructions that could execute before your code recognizes that a USB reset has occurred (by checking USB_RST_FLG) and calls your USB initialization routine
3. The time to execute your USB initialization routine

This time constraint may require you to check USB_RST_FLG at multiple points in your code (and within any ISRs that may take longer than 10ms to perform). By inserting this checkpoint, your program can branch from a routine (or ISR) after the USB reset without having to complete the routine (or ISR). Your program can continue the interrupted routine after ensuring that the device is ready for USB enumeration.

CAUTION

If a USB reset interrupt occurs during execution of a USB receive ISR (e.g., receive done or start-of-frame), the 8x930Ax will reset the USB hardware. This will render invalid any data received during the USB transfer. If this is not detected by your firmware, misprocessing can occur.

The risk of USB reset-related misprocessing can be reduced if your USB receive/transmit ISRs check `USB_RST_FLG` before returning. If this flag is set, your code should branch to the USB initialization routine to initialize the USB-related SFRs and flush the FIFOs. If this is done, the only potential opportunity for misprocessing would be if the USB reset interrupt occurs between the test of `USB_RST_FLG` and the branch to the USB initialization routine.

NOTE

Because of the risk of misprocessing, however slight, it is recommended that applications that will not substantially benefit from a separate USB reset disable this option (by leaving the `URDIS` bit in `PCON1` cleared) to simplify firmware coding and ensure a robust, chip-level reset.

6.6 INTERRUPT ENABLE

Each interrupt source (with the exception of `TRAP`) may be individually enabled or disabled by the appropriate interrupt enable bit in the `IEN0` register at `S:A8H` (see Figure 6-12) or the `IEN1` register at `S:B1H` (see Figure 6-13). Note `IEN0` also contains a global disable bit (`EA`). If `EA` is set, interrupts are individually enabled or disabled by bits in `IEN0` and `IEN1`. If `EA` is clear, all interrupts are disabled.

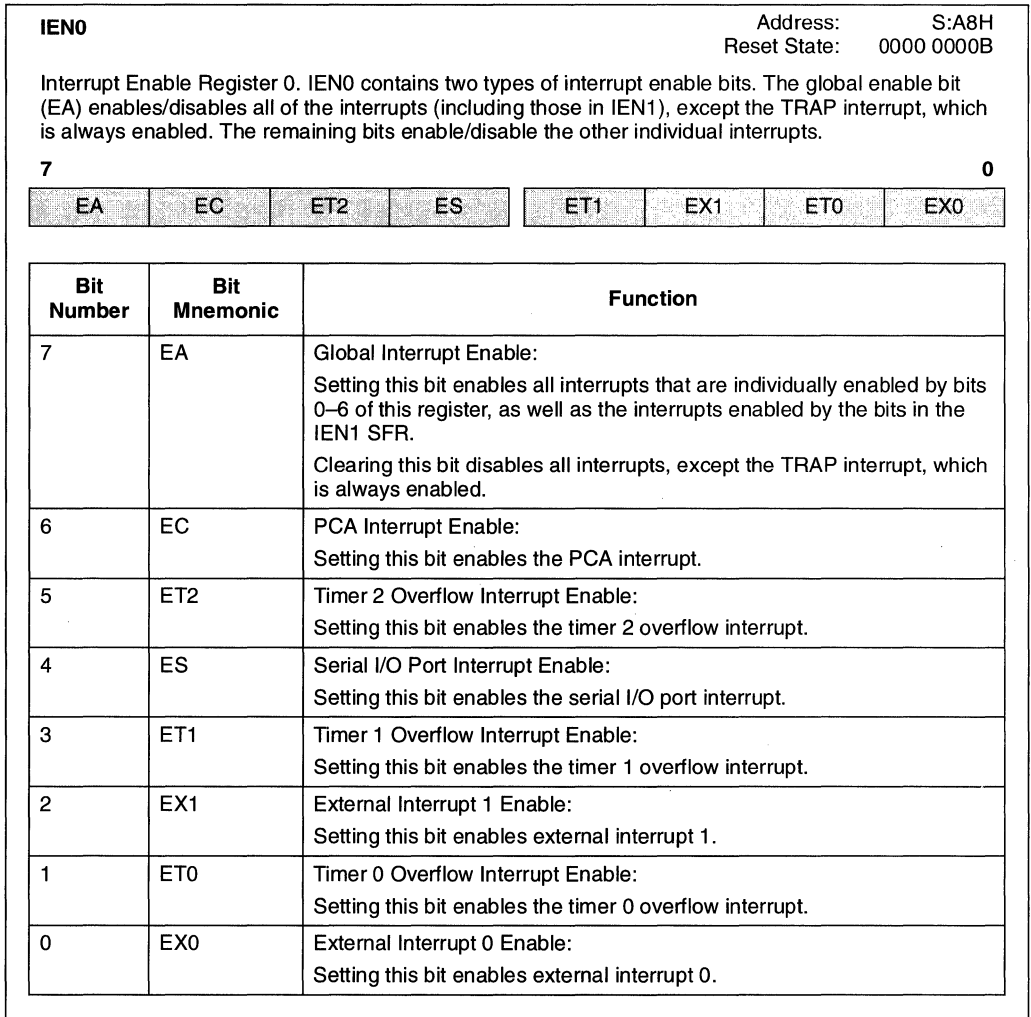


Figure 6-12. IEN0: Interrupt Enable Register 0

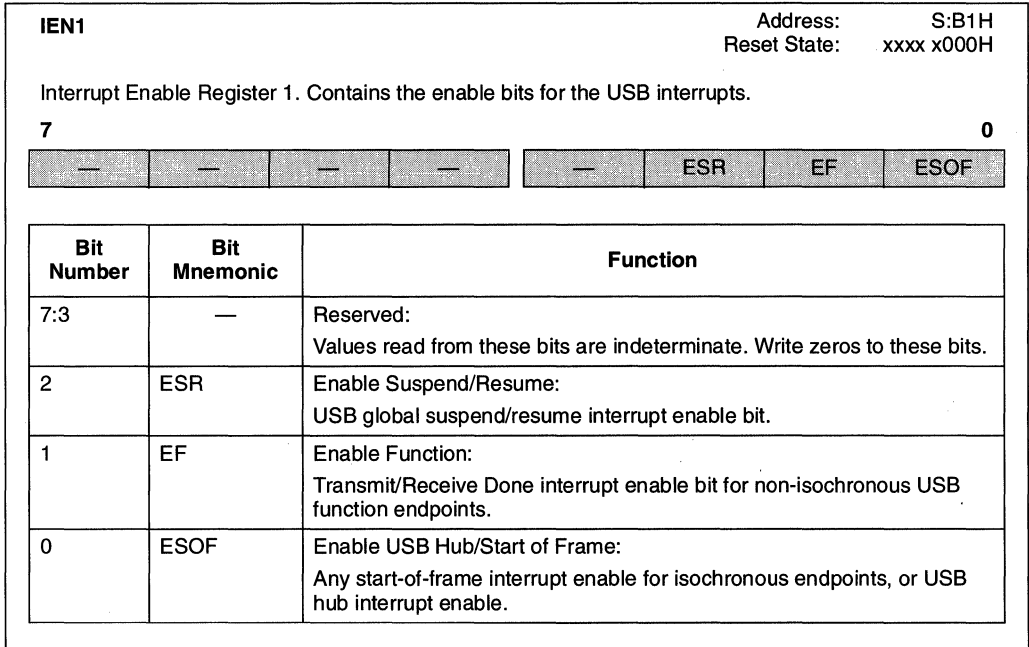


Figure 6-13. IEN1: USB Interrupt Enable Register

6.7 INTERRUPT PRIORITIES

Ten of the eleven 8x930 interrupt sources (TRAP excluded) may be individually programmed to one of four priority levels. This is accomplished with the IPHX.x/IPLX.x bit pairs in the interrupt priority high (IPH1/IPH0 in Figure 6-14 and 6-16) and interrupt priority low (IPL1/IPL0) registers (Figures 6-15 and 6-17). Specify the priority level as shown in Table 6-5 using IPH0.x (or IPH1.x) as the MSB and IPL0.x (or IPL1.x) as the LSB.

Table 6-5. Level of Priority

Priority Level	IPH1.x, IPL1.x	IPH0.x, IPL0.x
0 Lowest Priority	00	00
1	01	01
2	10	10
3 Highest Priority	11	11

A low-priority interrupt is always interrupted by a higher priority interrupt but not by another interrupt of equal or lower priority. The highest priority interrupt is not interrupted by any other interrupt source. Higher priority interrupts are serviced before lower priority interrupts. The response to simultaneous occurrence of equal priority interrupts (i.e., sampled within the same four-state interrupt cycle) is determined by a hardware priority-within-level resolver (see Table 6-6).

Table 6-6. Interrupt Priority Within Level

Priority Number	Interrupt Name
1 (Highest Priority)	INT0#
2	Timer 0
3	INT1#
4	Timer 1
5	Serial Port
6	Timer 2
7	PCA
8	USB Hub / SOF
9	USB Function
10	USB Global Suspend/Resume

IPH0		Address:	S:B7H					
		Reset State:	x000 0000B					
Interrupt Priority High Control Register 0. IPH0, together with IPL0, assigns each interrupt in IEN0 a priority level from 0 (lowest) to 3 (highest):								
	IPH0.x	IPL0.x	Priority Level					
	0	0	0 (lowest priority)					
	0	1	1					
	1	0	2					
	1	1	3 (highest priority)					
7						0		
	—	IPH0.6	IPH0.5	IPH0.4	IPH0.3	IPH0.2	IPH0.1	IPH0.0
Bit Number	Bit Mnemonic	Function						
7	—	Reserved. The value read from this bit is indeterminate. Write a zero to this bit.						
6	IPH0.6	PCA Interrupt Priority Bit High						
5	IPH0.5	Timer 2 Overflow Interrupt Priority Bit High						
4	IPH0.4	Serial I/O Port Interrupt Priority Bit High						
3	IPH0.3	Timer 1 Overflow Interrupt Priority Bit High						
2	IPH0.2	External Interrupt 1 Priority Bit High						
1	IPH0.1	Timer 0 Overflow Interrupt Priority Bit High						
0	IPH0.0	External Interrupt 0 Priority Bit High						

Figure 6-14. IPH0: Interrupt Priority High Register 0

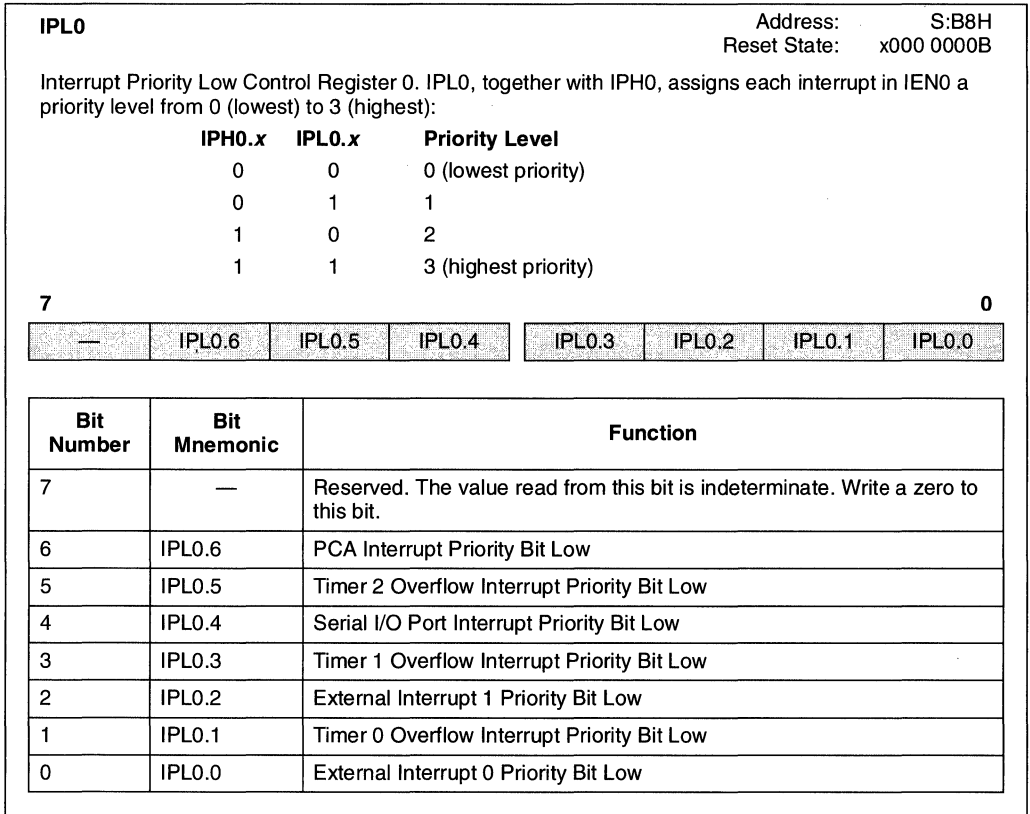


Figure 6-15. IPL0: Interrupt Priority Low Register 0

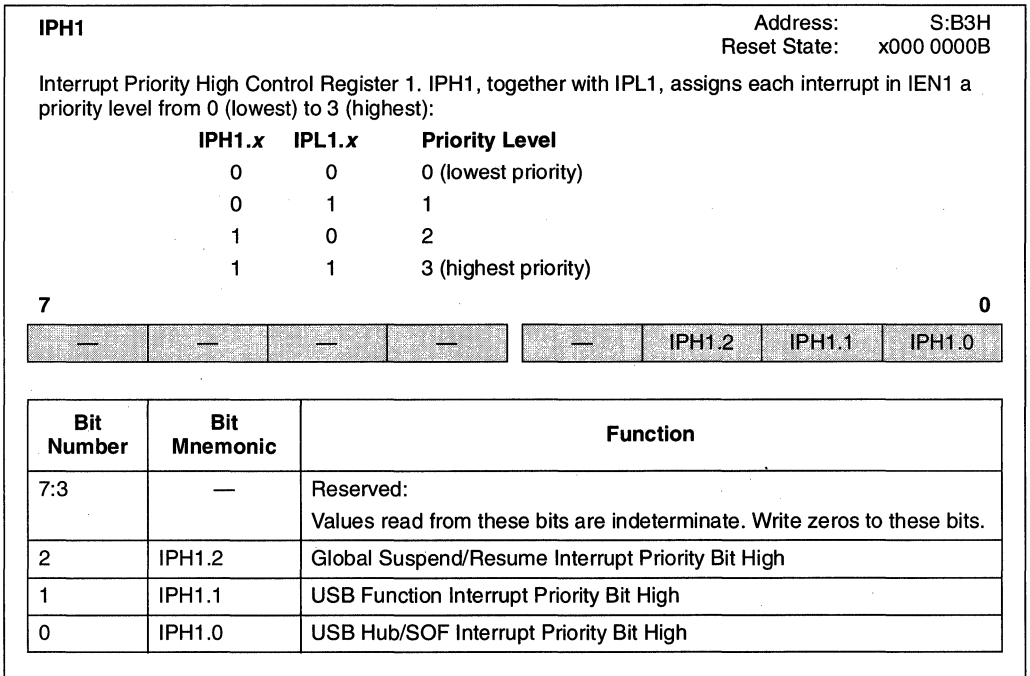


Figure 6-16. IPH1: Interrupt Priority High Register 1

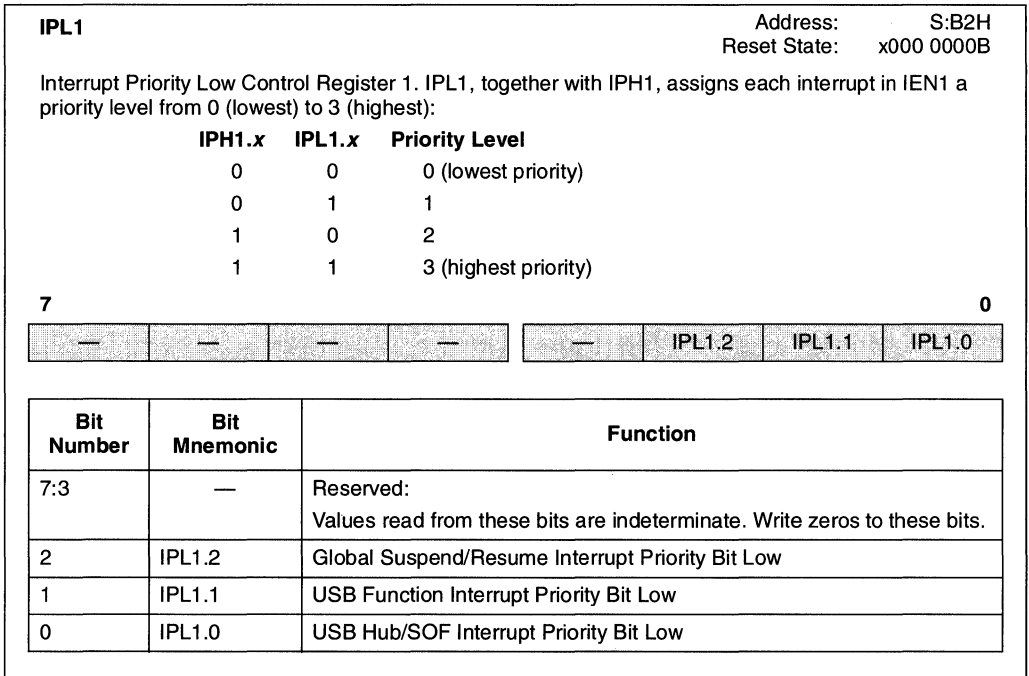


Figure 6-17. IPL1: Interrupt Priority Low Register 1

6.8 INTERRUPT PROCESSING

Interrupt processing is a dynamic operation that begins when a source requests an interrupt and lasts until the execution of the first instruction in the interrupt service routine (see Figure 6-18). *Response time* is the amount of time between the interrupt request and the resulting break in the current instruction stream. *Latency* is the amount of time between the interrupt request and the execution of the first instruction in the interrupt service routine. These periods are dynamic due to the presence of both fixed-time sequences and several variable conditions. These conditions contribute to total elapsed time.

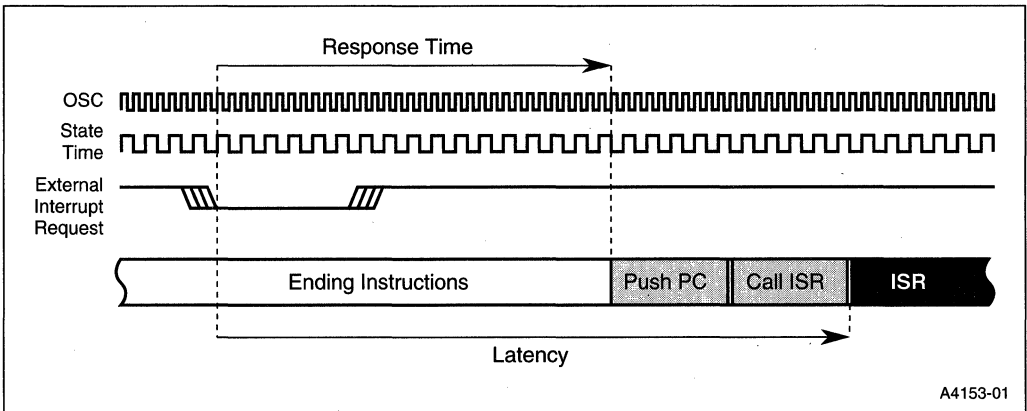


Figure 6-18. The Interrupt Process

Both response time and latency begin with the request. The subsequent minimum fixed sequence comprises the interrupt sample, poll, and request operations. The variables consist of (but are not limited to): specific instructions in use at request time, internal versus external interrupt source requests, internal versus external program operation, stack location, presence of wait states, page-mode operation, and branch pointer length.

NOTE

In the following discussion, external interrupt request pins are assumed to be inactive for at least four state times prior to assertion. In this chapter all external hardware signals maintain some setup period (i.e., less than one state time). Signals must meet V_{IH} and V_{IL} specifications prior to any state time under discussion. This setup state time is not included in examples or calculations for either response or latency.

6.8.1 Minimum Fixed Interrupt Time

All interrupts are sampled or polled every four state-times (see Figure 6-18). Two of eight interrupts are latched and polled per state time within any given window of four state-times. One additional state time is required for a context switch request. For code branches to jump locations in the current 64-Kbyte memory region (compatible with MCS 51 microcontrollers), the context switch time is 11 states. Therefore, the minimum fixed poll and request time is 16 states (4 poll states + 1 request state + 11 states for the context switch = 16 state times).

Therefore, this minimum fixed period rests upon four assumptions:

- The source request is an internal interrupt with high enough priority to take precedence over other potential interrupts,
- The request is coincident with internal execution and needs no instruction completion time,
- The program uses an internal stack location, and
- The ISR is in on-chip ROM.

6.8.2 Variable Interrupt Parameters

Both response time and latency calculations contain fixed and variable components. By definition, it is often difficult to predict exact timing calculations for real-time requests. One large variable is the completion time of an instruction cycle coincident with the occurrence of an interrupt request. Worst-case predictions typically use the longest-executing instruction in an architecture's code set. In the case of the 8x930, the longest-executing instruction is a 16-bit divide (DIV). However, even this 21- state instruction may have only 1 or 2 remaining states to complete before the interrupt system injects a context switch. This uncertainty affects both response time and latency.

6.8.2.1 Response Time Variables

Response time is defined as the start of a dynamic time period when a source requests an interrupt and lasts until a break in the current instruction execution stream occurs (see Figure 6-18). Response time (and therefore latency) is affected by two primary factors: the incidence of the request relative to the four-state-time sample window and the completion time of instructions in the response period (i.e., shorter instructions complete earlier than longer instructions).

NOTE

External interrupt signals require one additional state time in comparison to internal interrupts. This is necessary to sample and latch the pin value prior to a poll of interrupts. The sample occurs in the first half of the state time and the poll/request occurs in the second half of the next state time. Therefore, this sample and poll/request portion of the minimum fixed response and latency time is five states for internal interrupts and six states for external interrupts. External interrupts must remain active for at least five state times to guarantee interrupt recognition when the request occurs immediately after a sample has been taken (i.e., requested in the second half of a sample state time).

If the external interrupt goes active one state after the sample state, the pin is not resampled for another three states. After the second sample is taken and the interrupt request is recognized, the interrupt controller requests the context switch. The programmer must also consider the time to complete the instruction at the moment the context switch request is sent to the execution unit. If 9 states of a 10-state instruction have completed when the context switch is requested, the total response time is 6 states, with a context switch immediately after the final state of the 10-state instruction (see Figure 6-19).

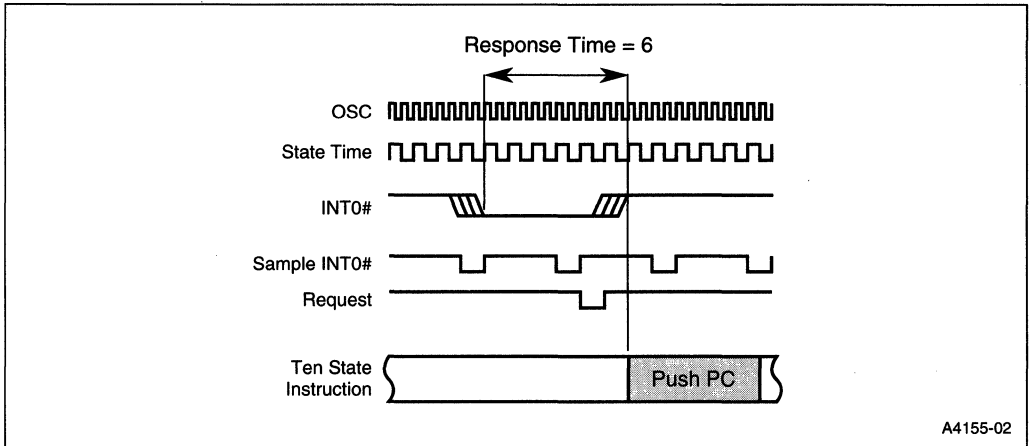
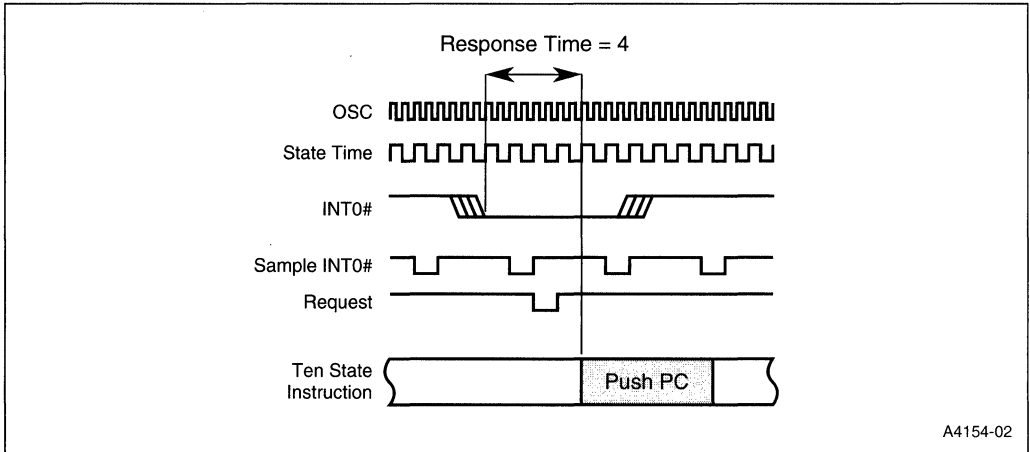


Figure 6-19. Response Time Example #1

Conversely, if the external interrupt requests service in the state just prior to the next sample, response is much quicker. One state asserts the request, one state samples, and one state requests the context switch. If at that point the same instruction conditions exist, one additional state time is needed to complete the 10-state instruction prior to the context switch (see Figure 6-20). The total response time in this case is four state times. The programmer must evaluate all pertinent conditions for accurate predictability.



A4154-02

Figure 6-20. Response Time Example #2

6.8.2.2 Computation of Worst-case Latency With Variables

Worst-case latency calculations assume that the longest 8x930 instruction used in the program must fully execute prior to a context switch. The instruction execution time is reduced by one state with the assumption the instruction state overlaps the request state (therefore, 16-bit DIV is 21 state times - 1 = 20 states for latency calculations). The calculations add fixed and variable interrupt times (see Table 6-7) to this instruction time to predict latency. The worst-case latency (both fixed and variable times included) is expressed by a pseudo-formula:

$$\text{FIXED_TIME} + \text{VARIABLES} + \text{LONGEST_INSTRUCTION} = \text{MAXIMUM LATENCY PREDICTION}$$

Table 6-7. Interrupt Latency Variables

Variable	INT0#, INT1#, T2EX	External Execution	Page Mode	>64K Jump to ISR (1)	External Memory Wait State	External Stack <64K (1)	External Stack >64K (1)	External Stack Wait State
Number of States Added	1	2	1	8	1 per bus cycle	4	8	1 per bus cycle

NOTES:

1. <64K/>64K means inside/outside the 64-Kbyte memory region where code is executing.
2. Base-case fixed time is 16 states and assumes:
 - A 2-byte instruction is the first ISR byte. — Internal execution
 - <64K jump to ISR — Internal stack
 - Internal peripheral interrupt

6.8.2.3 Latency Calculations

Assume the use of a zero-wait-state external memory where current instructions, the ISR, and the stack are located within the same 64-Kbyte memory region (compatible with memory maps for MCS 51 microcontrollers.) Further, assume there are 3 states yet to complete in the current 21-state DIV instruction when INTO# requests service. Also assume INTO# has made the request one state prior to the sample state (as in Figure 6-20). Unlike Figure 6-20, the response time for this assumption is three state times as the current instruction completes in time for the branch to occur. Latency calculations begin with the minimum fixed latency of 16 states. From Table 6-7, one state is added for an INTO# request from external hardware; two states are added for external execution; and four states for an external stack in the current 64-Kbyte region. Finally, three states are added for the current instruction to complete. The actual latency is 26 states. Worst-case latency calculations predict 43 states for this example due to inclusion of total DIV instruction time (less one state).

Table 6-8. Actual vs. Predicted Latency Calculations

Latency Factors	Actual	Predicted
Base Case Minimum Fixed Time	16	16
INTO# External Request	1	1
External Execution	2	2
<64K Byte Stack Location	4	4
Execution Time for Current DIV Instruction	3	20
TOTAL	26	43

6.8.2.4 Blocking Conditions

If all enable and priority requirements have been met, a single prioritized interrupt request at a time generates a vector cycle to an interrupt service routine (see CALL instructions in Appendix A, "Instruction Set Reference"). There are three causes of blocking conditions with hardware-generated vectors:

1. An interrupt of equal or higher priority level is already in progress (defined as any point after the flag has been set and the RETI of the ISR has not executed).
2. The current polling cycle is not the final cycle of the instruction in progress.
3. The instruction in progress is RETI or any write to the IEN0, IEN1, IPH0, IPH1, IPL0 or IPL1 registers.

Any of these conditions blocks calls to interrupt service routines. Condition two ensures the instruction in progress completes before the system vectors to the ISR. Condition three ensures at least one more instruction executes before the system vectors to additional interrupts if the instruction in progress is a RETI or any write to IEN0, IEN1, IPH0, IPH1, IPL0 or IPL1. The complete polling cycle is repeated every four state-times.

6.8.2.5 Interrupt Vector Cycle

When an interrupt vector cycle is initiated, the CPU breaks the instruction stream sequence, resolves all instruction pipeline decisions, and pushes multiple program counter (PC) bytes onto the stack. The CPU then reloads the PC with a start address for the appropriate ISR. The number of bytes pushed to the stack depends upon the INTR bit in the UCONFIG1 (Figure 4-4 on page 4-6) configuration byte. The complete sample, poll, request and context switch vector sequence is illustrated in the interrupt latency timing diagram (Figure 6-18).

NOTE

If the interrupt flag for a level-triggered external interrupt is set but denied for one of the above conditions and is clear when the blocking condition is removed, then the denied interrupt is ignored. In other words, blocked interrupt requests are not buffered for retention.

6.8.3 ISRs in Process

ISR execution proceeds until the RETI instruction is encountered. The RETI instruction informs the processor that the interrupt routine is completed. The RETI instruction in the ISR pops PC address bytes off the stack (as well as PSW1 for INTR = 1) and execution resumes at the suspended instruction stream.

NOTE

Some programs written for MCS 51 microcontrollers use RETI instead of RET to return from a subroutine that is called by ACALL or LCALL (i.e., not an interrupt service routine (ISR)). In the 8x930, this causes a compatibility problem if INTR = 1 in configuration byte CONFIG1. In this case, the CPU pushes four bytes (the three-byte PC and PSW1) onto the stack when the routine is called and pops the same four bytes when the RETI is executed. In contrast, RET pushes and pops only the lower two bytes of the PC. To maintain compatibility, configure the 8x930 with INTR = 0.

With the exception of TRAP, the start addresses of consecutive interrupt service routines are eight bytes apart. If consecutive interrupts are used (IE0 and TF0, for example, or TF0 and IE1), the first interrupt routine (if more than seven bytes long) must execute a jump to some other memory location. This prevents overlap of the start address of the following interrupt routine.

CAUTION

It is recommended that programmers set the contents of EPINDEX and/or HPINDEX once, at the start of each routine, instead of writing to the EPINDEX register prior to each access of an endpoint-indexed SFR and to HPINDEX prior to each access of a port-indexed SFR.

This means that interrupt service routines must save the contents of the EPINDEX and HPINDEX registers at the start of the routine and restore the contents at the end of the routine to prevent the EPINDEX and HPINDEX registers from being corrupted.

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7

USB Function



CHAPTER 7

USB FUNCTION

This chapter describes the FIFOs and special function registers (SFRs) associated with the USB function interface. This chapter, along with Chapter 2, “Architectural Overview” and Chapter 9, “USB Programming Models,” describes the operation of function interface on the 8x930Ax and 8x930Hx USB microcontrollers.

A data flow model for USB transactions, intended to bridge the hardware and firmware layers of the 8x930, is presented in truth table form in Appendix D, “Data Flow Model.” The model describes 8x930 behavior in response to a particular USB event, given a known state/configuration.

The USB signals discussed in this chapter are described in Table 7-1. Pinout diagrams for the 8x930Ax and 8x930Hx appear in Appendix B, “Signal Descriptions.”

The SFRs described in this chapter are listed in Table 7-2. The SFR definition tables that appear in this chapter also appear in alphabetical order in Appendix C, “Registers.”

7.1 FUNCTION INTERFACE

The function interface provides a USB interface capability for one USB function. The main components of the function interface are the serial bus interface engine (SIE) and the function interface unit (FIU). Refer to the block diagrams in Figure 2-3 on page 2-6 (8x930Ax) and Figure 2-4 on page 2-7 (8x930Hx). The operation of the function interface is discussed in “Universal Serial Bus Module” on page 2-12. On the 8x930Hx, the hub accesses the function interface by means of the internal downstream port.

7.1.1 Function Endpoint Pairs

The endpoint pairs implemented on the 8x930Ax and 8x930Hx are listed in Tables 2-5. The EPINDEX register selects the endpoint pair for any given data transaction.

The 8x930Ax can be programmed to support either four function endpoint pairs (4EPP, 0-3) or six function endpoint pairs (6EPP, 0-5). See the EPCONFIG register (Figure 7-1 on page 7-5). The selection is made during initialization and should not be changed during program execution. Endpoint 0 handles only control data transfers. Endpoints 1 through 4 handle all four data transfer types: control, isochronous (ISO), interrupt, and bulk. Endpoint 5 handles three data transfer types: control, interrupt, and bulk.

The 8x930Hx supports four function endpoint pairs (identical to the four-endpoint pair option on the 8x930Ax) and two hub endpoint pairs. See “USB Hub Endpoints” on page 8-10.

7.1.2 Function FIFOs

The 8x930 provides a transmit/receive FIFO pair in support of each endpoint pair. Figure 7-1 on page 7-5 shows the byte capacities of the 8x930 FIFOs. For the 8x930Ax (with the four-endpoint pair option selected) and the 8x930Hx, the function endpoint 1 transmit/receive FIFO pair can be

programmed for capacities of 256/256, 512/512, 1024/0, or 0/1024 bytes respectively. This is done with the FFSZ1:0 bits in the TXCON register associated with function endpoint1.

For the 8x930Ax with the six-endpoint option selected, program the endpoint 1 transmit/receive FIFOs for 256/256 bytes (FFSZ1:0 = 00).

Transmit FIFOs are written by the CPU and then read by the FIU for transmission on the USB. Receive FIFOs are written by the FIU following reception from the host PC, then read by the CPU. All transmit FIFOs have the same architecture, and all receive FIFOs have the same architecture.

7.1.3 Special Function Registers (SFRs)

The FIU controls operations through the use of four sets of special functions registers (SFRs): the FIU SFRs, the transmit FIFO SFRs, the receive FIFO SFRs, and the USB interrupt SFRs. Table 7-2 lists the special function registers (SFRs) described in this chapter. USB interrupt SFRs are described in Chapter 6, "Interrupt System." Table 3-5 on page 3-16 and Table 3-6 on page 3-17 are SFR memory maps for the 8x930Ax and 8x930Hx.

The registers in the FIU SFR set are: EPINDEX, EPCON, TXSTAT, RXSTAT, SOFL, SOFH, and FADDR. The SOFH and SOFL SFRs are defined in Figure 6-7 on page 6-13 and Figure 6-8 on page 6-14. The remaining registers are defined in Figures 7-1 through 7-6.

Table 7-1. Non-hub USB Signal Descriptions

Signal Name	Type	Description	Alternate Function
PLLSEL2:0	I	Phase-locked Loop Select. Three-bit code selects the USB data rate (see Table 2-4 on page 2-10).	—
SOF#	O	Start of Frame. The SOF# pin is asserted for eight states when an SOF token is received.	—
D _{P0} , D _{M0}	I/O	USB Port 0. D _{P0} and D _{M0} are the data plus and data minus lines of differential USB upstream port 0. These lines do not have internal pullup resistors. For low-speed devices, provide an external 1.5 K Ω pullup resistor at D _{M0} . For full-speed devices, provide an external 1.5 K Ω pullup resistor at D _{P0} . NOTE: For the 8x930Ax, either D _{P0} or D _{M0} must be pulled high. Otherwise a continuous SE0 (USB reset) will be applied to these inputs causing the 8x930Ax to stay in reset. For the 8x930Hx, provide an external 1.5 K Ω pullup resistor at D _{P0} so the device indicates to the host that it is a full-speed device.	—
ECAP	I	External Capacitor. Must be connected to a 1 μ F capacitor (or larger) to ensure proper operation of the differential line driver. The other lead of the capacitor must be connected to V _{SS} .	—

The registers in the transmit FIFO SFR set are TXDAT, TXCON, TXFLG, TXCNTL, and TXCNTH. These registers are defined in Figures 7-8 through 7-11 beginning on page 7-18.

The registers in the receive FIFO SFR set are RXDAT, RXCON, RXFLG, RXCNTL, and RXCNTH. These registers are defined in Figures 7-13 through 7-16 beginning on page 7-27.

The transmit SFR set, the receive SFR set, EPCON, TXSTAT, and RXSTAT are endpoint-indexed

CAUTION

Unless otherwise noted in the bit definition, SFRs can be read and written by firmware. All SFRs should be written using *read-modify-write instructions only*, due to the possibility of simultaneous writes by hardware and firmware. These instructions are listed in “Read-Modify-Write Instructions” on page 10-5.

7.1.3.1 Endpoint-indexed SFRs

As indicated in the SFR memory maps in Table 3-5 on page 3-16 (8x930Ax) and Table 3-6 on page 3-17 (8x930Hx), certain USB SFRs are endpoint-indexed. These SFRs are implemented as banks of registers similar to register file locations R0-R7 (Figure 3-7 on page 3-11). Endpoint-indexed SFRs are accessed by means of the SFR address and the current contents of the EPINDEX register (which selects the appropriate bank).

With the exception of hub endpoint 1, there is a bank of SFRs (TXDAT, TXCON, TXFLG, etc.) for each hub and function endpoint pair. Thus the 8x930Ax, with four-endpoint pair option selected, has four TXCON registers. When EPINDEX = 0000 0001, the function endpoint 1 TXCON is accessed. When EPINDEX = 0000 0010, the function endpoint 2 TXCON is accessed. The contents of a given SFR are retained when other endpoints are selected.

Only SFRs necessary for device operation are implemented. For example, since hub endpoint 1 is transmit only, RXDAT for that endpoint is not implemented. The high-order byte count registers (TXCNTH and RXCNTH) are implemented only for function endpoint 1, since only that endpoint pair has FIFOs larger than 32 bytes.

7.1.3.2 Endpoint Selection

The most significant bit of the endpoint index register (EPINDEX) selects hub or function. The low-order bits (EPINX2:0 for the six-endpoint pair option and EPINX1:0 for the four-endpoint pair option) indicate the endpoint and serve as an index value for selecting the SFR bank. To specify the endpoint pair, write a value of the form Zxxx xYYYB or Zxxx xxYYB to EPINDEX, where Z specifies hub or function and YYY and YY specify the endpoint number. See Figure 7-2.

It is recommended that programmers set the contents of EPINDEX once, at the start of each routine, instead of writing the EPINDEX register prior to each access of an endpoint-indexed SFR. This means that interrupt service routines must save the contents of the EPINDEX register at the start of the routine and restore the contents at the end of the routine to prevent the EPINDEX register from being corrupted.

Table 7-2. USB Function SFRs

Mnemonic	Description	Address
EPCON	Endpoint Control Register. Configures the operation of the endpoint specified by EPIINDEX.	S:E1H
EPCONFIG	Endpoint Configuration Register. Selects the four-endpoint pair or six-endpoint pair configuration for function endpoint 1 (8X930Ax only).	S:C7H
EPIINDEX	Endpoint Index Register. Selects the appropriate endpoint pair.	S:F1H
FADDR	Function Address Register. Stores the USB function address for the device. The host PC assigns the address and informs the device via endpoint 0.	S:8FH
RXCNTH	Receive FIFO Byte-Count High Register. High register in a two-register ring buffer used to store the byte count for the data packets received in the receive FIFO specified by EPIINDEX.	S:E7H
RXCNTL	Receive FIFO Byte-Count Low Register. Low register in a two-register ring buffer used to store the byte count for the data packets received in the receive FIFO specified by EPIINDEX.	S:E6H
RXCON	Receive FIFO Control Register. Controls the receive FIFO specified by EPIINDEX.	S:E4H
RXDAT	Receive FIFO Data Register. Receive FIFO data is read from this register (specified by EPIINDEX).	S:E3H
RXFLG	Receive FIFO Flag Register. These flags indicate the status of data packets in the receive FIFO specified by EPIINDEX.	S:E5H
RXSTAT	Endpoint Receive Status Register. Contains the endpoint status of the receive FIFO specified by EPIINDEX.	S:E2H
TXCNTH	Transmit Count High Register. High register in a two-register ring buffer used to store the byte count for the data packets in the transmit FIFO specified by EPIINDEX.	S:F7H
TXCNTL	Transmit Count Low Register. Low register in a two-register ring buffer used to store the byte count for the data packets in the transmit FIFO specified by EPIINDEX.	S:F6H
TXCON	Transmit FIFO Control Register. Controls the transmit FIFO specified by EPIINDEX.	S:F4H
TXDAT	Transmit FIFO Data Register. Transmit FIFO data is written to this register (specified by EPIINDEX).	S:F3H
TXFLG	Transmit Flag Register. These flags indicate the status of data packets in the transmit FIFO specified by EPIINDEX.	S:F5H
TXSTAT	Endpoint Transmit Status Register. Contains the endpoint status of the transmit FIFO specified by EPIINDEX.	S:FAH

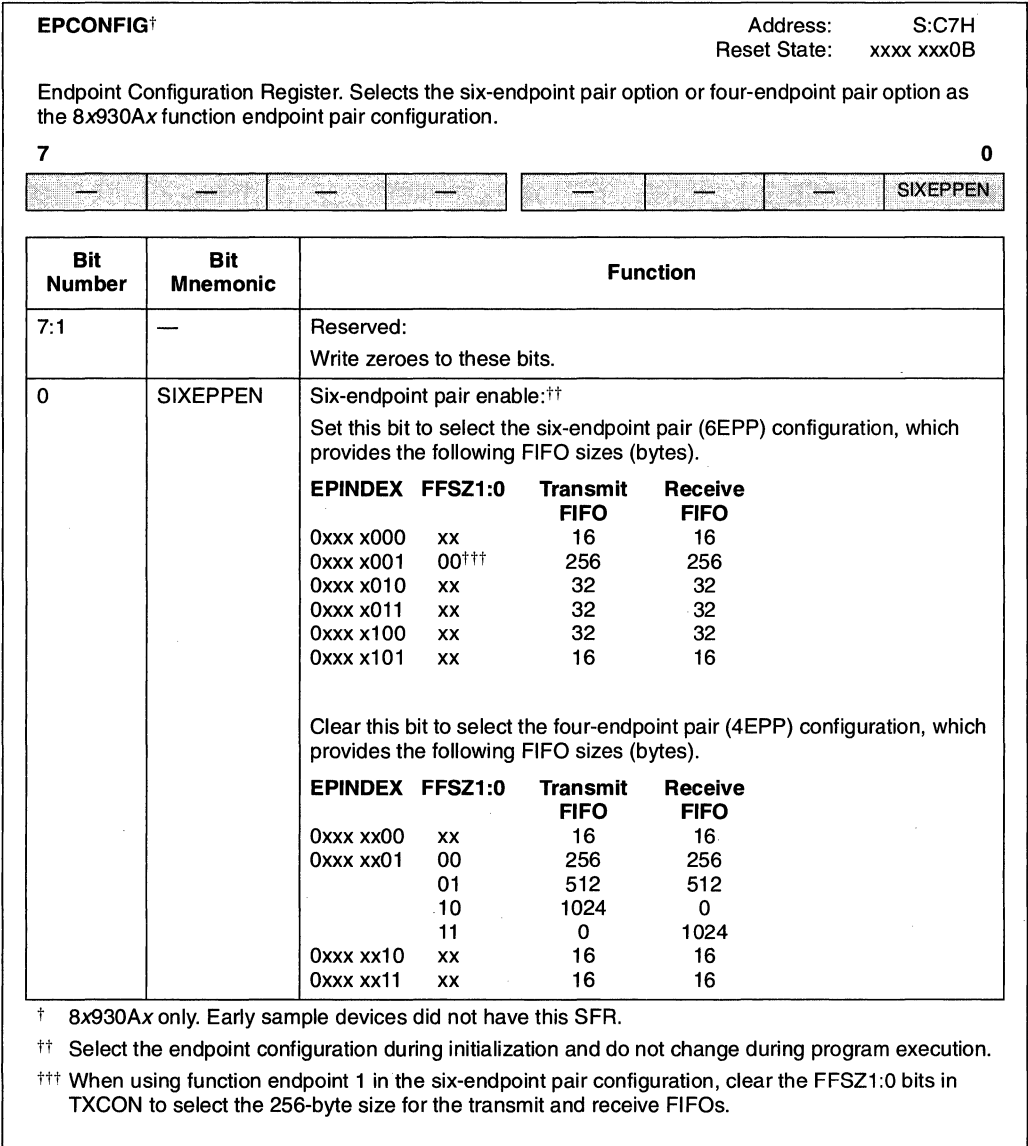
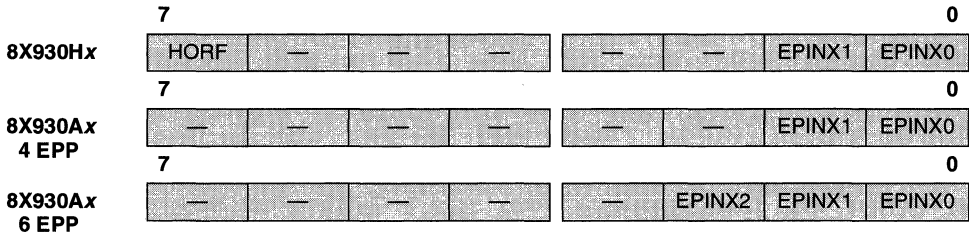


Figure 7-1. EPCONFIG: Endpoint Configuration Register

EPINDEX

Address: S:F1H
Reset State: 1xxx x000B

Endpoint Index Register. This register identifies the endpoint pair. Its contents select the transmit and receive FIFO pair and serve as an index to endpoint-specific SFRs.



Bit Number	Bit Mnemonic	Function
7	HORF (8X930Hx)	Hub/function Bit: 1 = Hub. Selects USB hub FIFOs and SFRs. 0 = Function. Selects USB function FIFOs and SFRs.
	— (8X930Ax)	Reserved: Although the reset state for this bit is "1", always write a zero to this bit for 8X930Ax applications.
6:3	—	Reserved: Write zeros to these bits.
2	— 8X930Hx or 8X930Ax (4 EPP)	Reserved: Write a zero to this bit. 8x930Hx
1:0	EPINX1:0 8X930Hx or 8X930Ax (4 EPP)	Endpoint Index: EPINDEX † 0xxx xx00 Function Endpoint 0 0xxx xx01 Function Endpoint 1 0xxx xx10 Function Endpoint 2 0xxx xx11 Function Endpoint 3 EPINDEX † (8x930Hx only) 1xxx xx00 Hub Endpoint 0 1xxx xx01 Hub Endpoint 1
2:0	EPINX2:0 8X930Ax (6 EPP)	Endpoint Index: EPINDEX † 0xxx x000 Function Endpoint 0 0xxx x001 Function Endpoint 1 0xxx x010 Function Endpoint 2 0xxx x011 Function Endpoint 3 0xxx x100 Function Endpoint 4 0xxx x101 Function Endpoint 5

† The EPINDEX register identifies the endpoint pair and selects the associated transmit and receive FIFO pair. The value in this register plus SFR addresses select the associated bank of endpoint-indexed SFRs (TXDAT, TXCON, TXFLG, TXCNTH/L, RXDAT, RXCON, RXFLG, RXCNTH/L, EPCON, TXSTAT, and RXSTAT).

Figure 7-2. EPINDEX: Endpoint Index Register

EPCON Address: S:E1H
 (Endpoint-indexed) Reset State: Endpoint 0 0011 0101B
 Function Endpoints 1, 2, 3 0001 0000B

Endpoint Control Register. This SFR configures the operation of the endpoint specified by EPINDEX.

7

0

RXSTL	TXSTL	CTLEP	RXSPM	RXIE	RXEPEN	TXOE	TXEPEN
-------	-------	-------	-------	------	--------	------	--------

Bit Number	Bit Mnemonic	Function
7	RXSTL	Stall Receive Endpoint: Set this bit to stall the receive endpoint. Clear this bit only when the host has intervened through commands sent down endpoint 0. When this bit is set and RXSETUP is clear, the receive endpoint will respond with a STALL handshake to a valid OUT token. When this bit is set and RXSETUP is set, the receive endpoint will NAK. This bit does not affect the reception of SETUP tokens by a control endpoint.
6	TXSTL	Stall Transmit Endpoint: Set this bit to stall the transmit endpoint. This bit should be cleared only when the host has intervened through commands sent down endpoint 0. When this bit is set and RXSETUP is clear, the receive endpoint will respond with a STALL handshake to a valid IN token. When this bit is set and RXSETUP is set, the receive endpoint will NAK.
5	CTLEP	Control Endpoint:† Set this bit to configure the endpoint as a control endpoint. Only control endpoints are capable of receiving SETUP tokens.
4	RXSPM	Receive Single Packet Mode:† Set this bit to configure the receive endpoint for single data packet operation. When enabled, only a single data packet is allowed to reside in the receive FIFO. NOTE: For control endpoints (CTLEP=1), this bit should be set for single packet mode operation as the recommended firmware model. However, it is possible to have a control endpoint configured in dual packet mode as long as the firmware handles the endpoint correctly.
3	RXIE	Receive Input Enable: Set this bit to enable data from the USB to be written into the receive FIFO. If cleared, the endpoint will not write the received data into the receive FIFO and at the end of reception, but will return a NAK handshake on a valid OUT token if the RXSTL bit is not set. This bit does not affect a valid SETUP token. A valid SETUP token and packet overrides this bit if it is cleared, and place the receive data in the FIFO.

† For hub endpoint 0 (EPINDEX = 1000 0000, 8x930Hx only), bits 5 and 4 are hard-wired to '1' since hub endpoint 0 is always a control endpoint.

Figure 7-3. EPCON: Endpoint Control Register

EPCON (Continued) (Endpoint-indexed)	Address: Reset State:	S:E1H Endpoint 0 Function Endpoints 1, 2, 3	0011 0101B 0001 0000B
Endpoint Control Register. This SFR configures the operation of the endpoint specified by EPINDEX.			
7			0
RXSTL	TXSTL	CTLEP	RXSPM
RXIE	RXEPEN	TXOE	TXEPEN

Bit Number	Bit Mnemonic	Function
2	RXEPEN	Receive Endpoint Enable: Set this bit to enable the receive endpoint. When disabled, the endpoint does not respond to a valid OUT or SETUP token. This bit is hardware read-only and has the highest priority among RXIE and RXSTL. Note that endpoint 0 is enabled for reception upon reset.
1	TXOE	Transmit Output Enable: This bit is used to enable the data in TXDAT to be transmitted. If cleared, the endpoint returns a NAK handshake to a valid IN token if the TXSTL bit is not set.
0	TXEPEN	Transmit Endpoint Enable: This bit is used to enable the transmit endpoint. When disabled, the endpoint does not respond to a valid IN token. This bit is hardware read only. Note that endpoint 0 is enabled for transmission upon reset.

† For hub endpoint 0 (EPINDEX = 1000 0000, 8x930Hx only), bits 5 and 4 are hard-wired to '1' since hub endpoint 0 is always a control endpoint.

Figure 7-3. EPCON: Endpoint Control Register (Continued)

TXSTAT
(Endpoint-indexed)

Address: S:F2H
Reset State: 0000 0000B

Endpoint Transmit Status Register. Contains the current endpoint status of the transmit FIFO specified by EPINDEX.

7

0

TXSEQ	—	—	TXFLUSH	TXSOVW	TXVOID	TXERR	TXACK
-------	---	---	---------	--------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
7	TXSEQ	Transmitter's Current Sequence Bit (read, conditional write): † This bit will be transmitted in the next PID and toggled on a valid ACK handshake. This bit is toggled by hardware on a valid SETUP token. This bit can be written by firmware if the TXSOVW bit is set when written together with the new TXSEQ value.
6:5	—	Reserved: Write zeros to these bits.
4	TXFLUSH	Transmit FIFO Packet Flushed (read-only): When set, this bit indicates that hardware flushed a stale ISO data packet from the transmit FIFO due to a TXFIF1:0 = 11 at SOF. To guard against a missed IN token in ISO mode, if, with TXFIF1:0 = 11, no IN token is received for the current endpoint, hardware automatically flushes the oldest packet and decrements the TXFIF1:0 value.
3	TXSOVW	Transmit Data Sequence Overwrite Bit: † Write a '1' to this bit to allow the value of the TXSEQ bit to be overwritten. Writing a '0' to this bit has no effect on TXSEQ. This bit always returns '0' when read. ††
2	TXVOID	Transmit Void (read-only): ††† A void condition has occurred in response to a valid IN token. Transmit void is closely associated with the NAK/STALL handshake returned by the function after a valid IN token, due to the conditions that cause the transmit FIFO to be unenabled or not ready to transmit. Use this bit to check any NAK/STALL handshake returned by the function. This bit does not affect the FTxDx, TXERR or TXACK bits. This bit is updated by hardware at the end of a non-isochronous transaction in response to a valid IN token. For isochronous transactions, this bit is not updated until the next SOF.

† Under normal operation, this bit should not be modified by the user.

†† The SIE will handle all sequence bit tracking. This bit should only be used when initializing a new configuration or interface.

††† For additional information on the operation of these bits see Appendix D, "Data Flow Model."

Figure 7-4. TXSTAT: Transmit FIFO Status Register

TXSTAT (Continued)
(Endpoint-indexed)

Address: S:F2H
Reset State: 0000 0000B

Endpoint Transmit Status Register. Contains the current endpoint status of the transmit FIFO specified by EPINDEX.

7

0

TXSEQ	—	—	TXFLUSH	TXSOVW	TXVOID	TXERR	TXACK
-------	---	---	---------	--------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
1	TXERR	<p>Transmit Error (read-only):^{††}</p> <p>An error condition has occurred with the transmission. Complete or partial data has been transmitted. The error can be one of the following:</p> <ol style="list-style-type: none"> 1. Data transmitted successfully but no handshake received 2. Transmit FIFO goes into underrun condition while transmitting <p>The corresponding transmit done bit, FTXD_x in FIFLG or FIFLG1 (8x930Ax with 6EPP), is set when active. For non-isochronous transactions, this bit is updated by hardware along with the TXACK bit at the end of the data transmission (this bit is mutually exclusive with TXACK). For isochronous transactions, this bit is not updated until the next SOF.</p>
0	TXACK	<p>Transmit Acknowledge (read-only):^{††}</p> <p>Data transmission completed and acknowledged successfully. The corresponding transmit done bit, FTXD_x in FIFLG or FIFLG1 (8x930Ax with 6EPP), is set when active. For non-isochronous transactions, this bit is updated by hardware along with the TXERR bit at the end of data transmission (this bit is mutually exclusive with TXERR). For isochronous transactions, this bit is not updated until the next SOF.</p>

[†] Under normal operation, this bit should not be modified by the user.

^{††} The SIE will handle all sequence bit tracking. This bit should only be used when initializing a new configuration or interface.

^{†††} For additional information on the operation of these bits see Appendix D, "Data Flow Model."

Figure 7-4. TXSTAT: Transmit FIFO Status Register (Continued)

RXSTAT

(Endpoint-indexed)

 Address: S:E2H
 Reset State: 0000 0000B

Endpoint Receive Status Register. Contains the current endpoint status of the receive FIFO specified by EPINDEX. (Endpoint-indexed SFR)

7

0

RXSEQ	RXSETUP	STOVW	EDO VW	RXSO VW	RXVOID	RXERR	RXACK
-------	---------	-------	--------	---------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
7	RXSEQ	Receiver Endpoint Sequence Bit (read, conditional write): † This bit will be toggled on completion of an ACK handshake in response to an OUT token. This bit will be set (or cleared) by hardware after reception of a SETUP token. This bit can be written by firmware if the RXSO VW bit is set when written along with the new RXSEQ value. NOTE: Always verify this bit after writing to ensure that there is no conflict with hardware, which could occur if a new SETUP token is received.
6	RXSETUP	Received Setup Token: This bit is set by hardware when a valid SETUP token has been received. When set, this bit causes received IN or OUT tokens to be NAKed until the bit is cleared to allow proper data management for the transmit and receive FIFOs from the previous transaction. IN or OUT tokens are NAKed even if the endpoint is stalled (RXSTL or TXSTL) to allow a control transaction to clear a stalled endpoint. Clear this bit upon detection of a SETUP token after the firmware is ready to complete the status stage of a control transaction.
5	STOVW	Start Overwrite Flag (read-only): Set by hardware upon receipt of a SETUP token for any control endpoint to indicate that the receive FIFO is being overwritten with new SETUP data. When set, the FIFO state (FIF and read pointer) resets and is locked for this endpoint until EDO VW is set. This prevents a prior, ongoing firmware read from corrupting the read pointer as the receive FIFO is being cleared and new data is being written into it. This bit is cleared by hardware at the end of handshake phase transmission of the setup stage. This bit is used only for control endpoints.

† Under normal operation, this bit should not be modified by the user.

†† For additional information on the operation of these bits see Appendix D, "Data Flow Model."

††† The SIE will handle all sequence bit tracking. This bit should be used only when initializing a new configuration or interface.

Figure 7-5. RXSTAT: Receive FIFO Status Register

RXSTAT (Continued) (Endpoint-indexed)		Address: S:E2H Reset State: 0000 0000B
Endpoint Receive Status Register. Contains the current endpoint status of the receive FIFO specified by EPINDEX. (Endpoint-indexed SFR)		
7	0	
RXSEQ	RXSETUP	STOVW
EDOVW	RXSOVW	RXVOID
RXERR	RXACK	

Bit Number	Bit Mnemonic	Function
4	EDOVW	End Overwrite Flag: [†] This flag is set by hardware during the handshake phase of a SETUP stage. It is set after every SETUP packet is received and must be cleared prior to reading the contents of the FIFO. When set, the FIFO state (FIF and read pointer) remains locked for this endpoint until this bit is cleared. This prevents a prior, ongoing firmware read from corrupting the read pointer after the new data has been written into the receive FIFO. This bit is only used for control endpoints. NOTE: Make sure the EDOVW bit is cleared prior to reading the contents of the FIFO.
3	RXSOVW	Receive Data Sequence Overwrite Bit: [†] Write a '1' to this bit to allow the value of the RXSEQ bit to be overwritten. Writing a '0' to this bit has no effect on RXSEQ. This bit always returns '0' when read. ^{†††}
2	RXVOID	Receive Void Condition (read-only): ^{††} This bit is set when no valid data is received in response to a SETUP or OUT token due to one of the following conditions: 1. The receive FIFO is still locked 2. The EPCON register's RXSTL bit is set This bit is set and cleared by hardware. For non-isochronous transactions, this bit is updated by hardware at the end of the transaction in response to a valid OUT token. For isochronous transactions, it is not updated until the next SOF.

[†] Under normal operation, this bit should not be modified by the user.

^{††} For additional information on the operation of these bits see Appendix D, "Data Flow Model."

^{†††} The SIE will handle all sequence bit tracking. This bit should be used only when initializing a new configuration or interface.

Figure 7-5. RXSTAT: Receive FIFO Status Register (Continued)

<p>RXSTAT (Continued) (Endpoint-indexed)</p> <p>Endpoint Receive Status Register. Contains the current endpoint status of the receive FIFO specified by EPINDEX. (Endpoint-indexed SFR)</p>	<p>Address: S:E2H Reset State: 0000 0000B</p>									
7	0									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 12.5%; text-align: center;">RXSEQ</td> <td style="width: 12.5%; text-align: center;">RXSETUP</td> <td style="width: 12.5%; text-align: center;">STOVW</td> <td style="width: 12.5%; text-align: center;">EDOVW</td> <td style="width: 12.5%; text-align: center;">RXSOVW</td> <td style="width: 12.5%; text-align: center;">RXVOID</td> <td style="width: 12.5%; text-align: center;">RXERR</td> <td style="width: 12.5%; text-align: center;">RXACK</td> </tr> </table>	RXSEQ	RXSETUP	STOVW	EDOVW	RXSOVW	RXVOID	RXERR	RXACK		
RXSEQ	RXSETUP	STOVW	EDOVW	RXSOVW	RXVOID	RXERR	RXACK			
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Bit Number</th> <th style="width: 15%;">Bit Mnemonic</th> <th style="width: 75%;">Function</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">RXERR</td> <td> <p>Receive Error (read-only):^{††}</p> <p>Set when an error condition has occurred with the reception. Complete or partial data has been written into the receive FIFO. No handshake is returned. The error can be one of the following conditions:</p> <ol style="list-style-type: none"> 1. Data failed CRC check. 2. Bit stuffing error. 3. A receive FIFO goes into overrun or underrun condition while receiving. <p>This bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXD_x bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXACK bit at the end of data reception and is mutually exclusive with RXACK.</p> </td> </tr> <tr> <td style="text-align: center;">0</td> <td style="text-align: center;">RXACK</td> <td> <p>Receive Acknowledged (read-only):^{††}</p> <p>This bit is set when data is received completely into a receive FIFO and an ACK handshake is sent. This read-only bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXD_x bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXERR bit at the end of data reception and is mutually exclusive with RXERR.</p> </td> </tr> </tbody> </table>	Bit Number	Bit Mnemonic	Function	1	RXERR	<p>Receive Error (read-only):^{††}</p> <p>Set when an error condition has occurred with the reception. Complete or partial data has been written into the receive FIFO. No handshake is returned. The error can be one of the following conditions:</p> <ol style="list-style-type: none"> 1. Data failed CRC check. 2. Bit stuffing error. 3. A receive FIFO goes into overrun or underrun condition while receiving. <p>This bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXD_x bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXACK bit at the end of data reception and is mutually exclusive with RXACK.</p>	0	RXACK	<p>Receive Acknowledged (read-only):^{††}</p> <p>This bit is set when data is received completely into a receive FIFO and an ACK handshake is sent. This read-only bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXD_x bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXERR bit at the end of data reception and is mutually exclusive with RXERR.</p>	
Bit Number	Bit Mnemonic	Function								
1	RXERR	<p>Receive Error (read-only):^{††}</p> <p>Set when an error condition has occurred with the reception. Complete or partial data has been written into the receive FIFO. No handshake is returned. The error can be one of the following conditions:</p> <ol style="list-style-type: none"> 1. Data failed CRC check. 2. Bit stuffing error. 3. A receive FIFO goes into overrun or underrun condition while receiving. <p>This bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXD_x bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXACK bit at the end of data reception and is mutually exclusive with RXACK.</p>								
0	RXACK	<p>Receive Acknowledged (read-only):^{††}</p> <p>This bit is set when data is received completely into a receive FIFO and an ACK handshake is sent. This read-only bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXD_x bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXERR bit at the end of data reception and is mutually exclusive with RXERR.</p>								
<p>[†] Under normal operation, this bit should not be modified by the user.</p> <p>^{††} For additional information on the operation of these bits see Appendix D, "Data Flow Model."</p> <p>^{†††} The SIE will handle all sequence bit tracking. This bit should be used only when initializing a new configuration or interface.</p>										

Figure 7-5. RXSTAT: Receive FIFO Status Register (Continued)

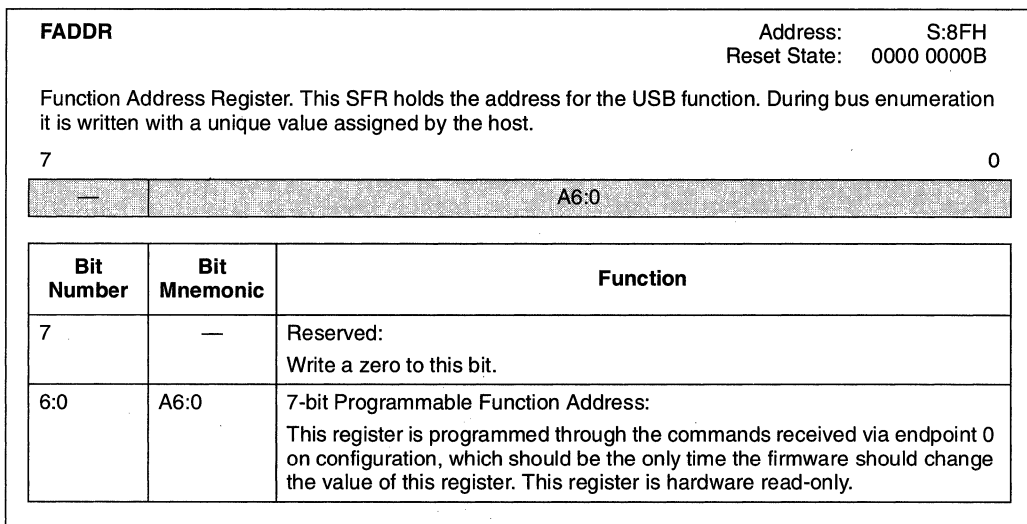


Figure 7-6. FADDR: Function Address Register

7.2 TRANSMIT FIFOS

The 8x930 has a transmit FIFO for each function endpoint pair. In this manual, the term “transmit FIFO” refers to the transmit FIFO associated with the current endpoint pair specified by the EPINDEX register. 8x930 FIFOs are listed in Table 2-5 and Table 2-6 on page 2-13.

7.2.1 Transmit FIFO Overview

The transmit FIFOs are circulating data buffers with the following features:

- support for up to two separate data sets of variable sizes[†]
- a byte count register to store the number of bytes in the data sets
- protection against overwriting data in a full FIFO
- capability to retransmit the current data set

All transmit FIFOs have the same architecture (Figure 7-7). The transmit FIFO and its associated logic can manage up to two data sets, data set 0 (ds0) and data set 1 (ds1). The ability to have two data sets in the FIFO supports back-to-back transmissions.

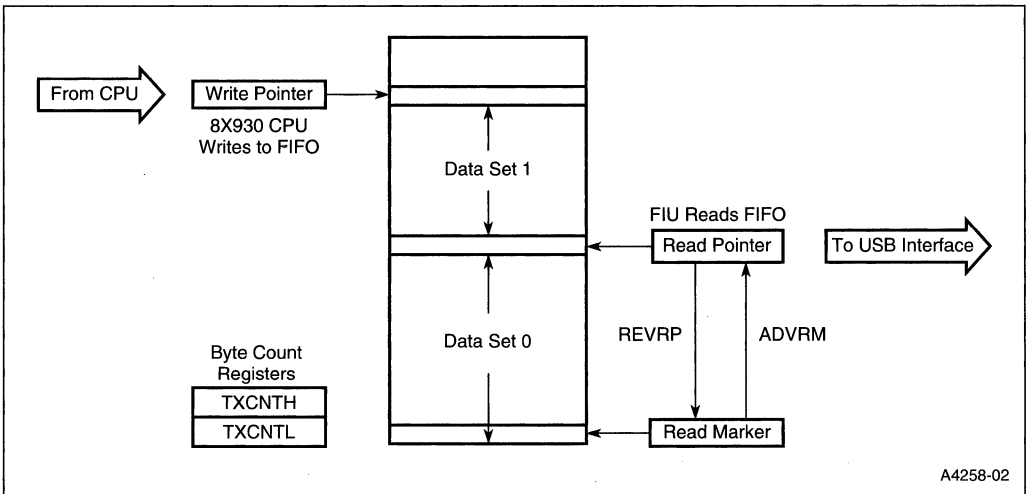


Figure 7-7. Transmit FIFO Outline

The CPU writes to the FIFO location specified by the *write pointer*, which automatically increments by one after a write. The *read marker* points to the first byte of data written to a data set, and the *read pointer* points to the next FIFO location to be read by the function interface. The read pointer automatically increments by one after a read.

[†] When operating in dual packet mode, the maximum packet size should be at most half the FIFO size to ensure that both packets will simultaneously fit in the FIFO (see the Endpoint description in the *Universal Serial Bus Specification*).

When a good transmission is completed, the read marker can be advanced to the position of the read pointer to set up for reading the next data set. When a bad transmission is completed, the read pointer can be reversed to the position of the read marker to enable the function interface to re-read the last data set for retransmission. The read marker advance and read pointer reversal can be accomplished two ways: explicitly by firmware or automatically by hardware, as specified by bits in the transmit FIFO control register (TXCON).

7.2.2 Transmit FIFO Registers

There are five registers directly involved in the operation of the transmit FIFOs:

- TXDAT, the transmit FIFO data register
- TXCNTH and TXCNTL, the transmit FIFO byte count registers referred to jointly as TXCNT
- TXCON, the transmit FIFO control register
- TXFLG, the transmit FIFO flag register

These registers are endpoint indexed, i.e., they are used as a set to control the operation of the transmit FIFO associated with the current endpoint specified by the EPINDEX register. Figures 7-8 through 7-11 beginning on page 7-18 describe the transmit FIFO registers and provide bit definitions.

7.2.3 Transmit Data Register (TXDAT)

Bytes are written to the transmit FIFO via TXDAT, the transmit FIFO data register (Figure 7-8 on page 7-18).

7.2.4 Transmit Byte Count Registers (TXCNTL/TXCNTH)

The format of the transmit byte count register depends on the endpoint. For endpoint 1, registers TXCNTH and TXCNTL form a two-register, ten-bit ring buffer. For endpoints 0, 2, and 3 (and for the 8x930Ax, endpoints 4 and 5), TXCNTL is used alone as a five-bit ring buffer. These formats are shown in Figure 7-9 on page 7-19. The term TXCNT refers to either of these arrangements.

The transmit FIFO byte count register (TXCNT) stores the number of bytes in either of the two data sets, data set 0 (ds0) and data set 1 (ds1). The FIFO logic for maintaining the data sets assumes that data is written to the FIFO in the following sequence:

1. The CPU first writes data bytes to TXDAT.
2. The CPU writes the number of bytes that were written to TXDAT to the byte count register TXCNT. TXCNT must be written after the write to TXDAT to guarantee data integrity. For function endpoint 1, TXCNTL should be written after TXCNTH. Writing to TXCNTH does not affect the TXFIF bits, however writing to TXCNTHL does set the associated TXFIF bits.

NOTE

TXCNTH does not need to be written if it is always 00H, as the reset value is 00H. However, if TXCNTH is not 00H, it should always be written even though the value does not change from the previous cycle; this is because the byte count registers are 2-byte circular buffers and not “static” registers.

For all endpoints except function endpoint 1, TXCNTH is not available and TXCNTL only contains BC4:0. Bits 7:5 are reserved in this case and should always be written with ‘0’.

The function interface reads the byte count register to determine the number of bytes in the set.

7.2.5 Transmit Data Set Management

Two read-only data set index bits, FIF1:0 in the TXFLG register, indicate which data sets (ds0 and/or ds1) have been written into the FIFO and are armed (ready for transmission). See the left side of Table 7-3. $FIF_x = 1$ indicates that data set x has been written and is armed. Following reset, FIF1:0 = 00, signifying an empty FIFO. FIF1:0 also determine which data set is written next. Note that FIFO specifies the next data set to be written, except for the case of FIF1:0 = 11. In this case further writes to TXDAT or TXCNT are ignored.

NOTE

To simplify firmware development, it is recommended that you utilize control endpoints in single-packet mode only.

Two events cause the data set index bits to be updated:

- A new data set is written to the FIFO: the 8x930 writes bytes to the FIFO via TXDAT and writes the number of bytes to TXCNT. The data set index bits are updated after the write to TXCNT. This process is illustrated in Table 7-3.
- A data set in the FIFO is successfully transmitted: the function interface reads a data set from the FIFO, and when a good transmission is acknowledged, the read marker is advanced to the read pointer. The data set index bits are updated after the read marker is advanced. Note that in ISO mode, this happens at the next SOF.

Table 7-3. Writing to the Byte Count Register

FIF1:0	Data Sets Written			Set for Next Write to TXCNT	Write bytes to TXDAT. → Write byte count to TXCNT →	FIF1:0	
	ds1	ds0					
0 0	No	No	(Empty)	ds0			0 1
0 1	No	Yes	(1 set)	ds1			1 1
1 0	Yes	No	(1 set)	ds0			1 1
1 1	Yes	Yes	(2 sets)	Write ignored			1 1

Table 7-4 summarizes how the actions following a transmission depend on the TXISO bit, the ATM bit, the TXACK bit, and the TXERR bit.

Table 7-4. Truth Table for Transmit FIFO Management

TXISO (TXCON.3)	ATM (TXCON.2)	TXERR (TXSTAT.1)	TXACK (TXSTAT.0)	Action at End of Transfer Cycle
X	X	0	0	No operation.
X	0	0	1	Read marker, read pointer, and TXFIF bits remain unchanged. Managed by firmware.
X	0	1	0	Read marker, read pointer, and TXFIF bits remain unchanged. Managed by firmware.
0	1	0	1	Read marker advanced automatically. The TXFIF bit for the corresponding data set is cleared.
0	1	1	0	Read pointer reversed automatically. The TXFIF bit for the corresponding data set remains unchanged.
1	1	X	X	Read marker advanced automatically. The TXFIF bit for the corresponding data set is cleared at the SOF.

NOTE

For normal operation, set the ATM bit in TXCON. Hardware will automatically control the read pointer and read marker, and track the TXFIF bits.

TXDAT (Endpoint-indexed) [†]	Address: S:F3H	0
	Reset State: xxxx xxxxB	
USB Transmit FIFO Data Register. Data to be transmitted by the FIFO specified by EPINDEX is first written to this register.		
7		0
Transmit Data Byte		
Bit Number	Bit Mnemonic	Function
7:0	TXDAT.7:0	Transmit Data Byte (write-only): To write data to the transmit FIFO, write to this register. The write pointer is incremented automatically after a write.
[†] For hub endpoint 1, TXDAT is used in a different manner. See Figure 8-6 on page 8-12.		

Figure 7-8. TXDAT: Transmit FIFO Data Register

TXCNTH, TXCNTL (Endpoint-indexed)	Address: S:F7H S:F6H Reset States: Endpoint 1 TXCNTH xxxx xx00B TXCNTL 0000 0000B Other Endpoints† TXCNTL xxx0 0000B									
Transmit FIFO Byte-count High and Low Registers. High and low register in a two-register ring buffer used to store the byte count for the data packets in the transmit FIFO specified by EPINDEX. Note that TXCNTH exists only for function endpoint 1 and is unavailable for all other endpoints.										
15 (TXCNTH)	Endpoint 1	8								
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">BC9</td> <td style="width: 25%; text-align: center;">BC8</td> </tr> </table>	—	—	—	—	—	—	BC9	BC8		
—	—	—	—	—	—	BC9	BC8			
7 (TXCNTL)		0								
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%; text-align: center;">BC7</td> <td style="width: 25%; text-align: center;">BC6</td> <td style="width: 25%; text-align: center;">BC5</td> <td style="width: 25%; text-align: center;">BC4</td> <td style="width: 25%; text-align: center;">BC3</td> <td style="width: 25%; text-align: center;">BC2</td> <td style="width: 25%; text-align: center;">BC1</td> <td style="width: 25%; text-align: center;">BC0</td> </tr> </table>	BC7	BC6	BC5	BC4	BC3	BC2	BC1	BC0		
BC7	BC6	BC5	BC4	BC3	BC2	BC1	BC0			
7 (TXCNTL)	Other Endpoints	0								
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">—</td> <td style="width: 25%; text-align: center;">BC4</td> <td style="width: 25%; text-align: center;">BC3</td> <td style="width: 25%; text-align: center;">BC2</td> <td style="width: 25%; text-align: center;">BC1</td> <td style="width: 25%; text-align: center;">BC0</td> </tr> </table>	—	—	—	BC4	BC3	BC2	BC1	BC0		
—	—	—	BC4	BC3	BC2	BC1	BC0			
Bit Number	Bit Mnemonic	Function								
Function Endpoint 1										
15:10	—	Reserved. Write zeros to these bits.								
9:0	BC9:0	Transmit Byte Count. (write, conditional read ^{††}) Ten-bit, ring buffer. Stores transmit byte count (TXCNT). Implemented for function endpoint 1 only.								
Other Endpoints [†]										
7:0	—	Reserved. Write zeros to these bits.								
4:0	BC4:0	Transmit Byte Count. (write, conditional read ^{††}) Five-bit, ring buffer. Stores transmit byte count (TXCNT) for endpoints 0, 2, and 3.								
[†] Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (6EPP option, 8x930Ax only). Byte count registers are not implemented for hub endpoint 1.										
^{††} Read these bits only if TXFIF1:0 = 0; otherwise underrun errors may occur.										

Figure 7-9. TXCNTH/TXCNTL Transmit FIFO Byte Count Registers
NOTE

To send a status stage after a control write or no data control command or a null packet, write 0 to TXCNT.

TXCON (Endpoint-indexed)	Address: Reset State:	Function Endpoint 1 Other Endpoints†	S:F4H 000x 0100B 0xxx 0100B								
USB Transmit FIFO Control Register. Controls the transmit FIFO specified by EPINDEX.											
7	7	0									
Function Endpoint 1	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 12.5%;">TXCLR</td> <td style="width: 12.5%;">FFSZ1</td> <td style="width: 12.5%;">FFSZ0</td> <td style="width: 12.5%;">—</td> <td style="width: 12.5%;">TXISO</td> <td style="width: 12.5%;">ATM</td> <td style="width: 12.5%;">ADVRM</td> <td style="width: 12.5%;">REVRP</td> </tr> </table>	TXCLR	FFSZ1	FFSZ0	—	TXISO	ATM	ADVRM	REVRP	0	
TXCLR	FFSZ1	FFSZ0	—	TXISO	ATM	ADVRM	REVRP				
7	7	0									
Other Endpoints †	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 12.5%;">TXCLR</td> <td style="width: 12.5%;">—</td> <td style="width: 12.5%;">—</td> <td style="width: 12.5%;">—</td> <td style="width: 12.5%;">TXISO</td> <td style="width: 12.5%;">ATM</td> <td style="width: 12.5%;">ADVRM</td> <td style="width: 12.5%;">REVRP</td> </tr> </table>	TXCLR	—	—	—	TXISO	ATM	ADVRM	REVRP	0	
TXCLR	—	—	—	TXISO	ATM	ADVRM	REVRP				

Bit Number	Bit Mnemonic	Function										
7	TXCLR	Transmit Clear: Setting this bit flushes the transmit FIFO, resets all the read/write pointers and markers, sets the EMPTY bit in TXFLG, and clears all other bits in TXFLG. After the flush, hardware clears this bit. Setting this bit does not affect the ATM, TXISO, and FFSZ bits, or the TXSEQ bit in the TXSTAT register.										
6:5	FFSZ1:0 Function Endpoint 1 only	FIFO Size: For function endpoint 1 only (EPINDEX = 0000 0001B), these bits select the sizes of both the transmit and receive FIFOs. (There are no FFSZ bits in the corresponding RXCON.) These bits are not reset when the TXCLR bit is set in the TXCON register.										
	FFSZ1:0	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%;">Transmit Size</th> <th style="width: 20%;">Receive Size</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">00</td> <td style="text-align: center;">256</td> </tr> <tr> <td style="text-align: center;">01</td> <td style="text-align: center;">512</td> </tr> <tr> <td style="text-align: center;">10</td> <td style="text-align: center;">1024</td> </tr> <tr> <td style="text-align: center;">11</td> <td style="text-align: center;">0</td> </tr> </tbody> </table>	Transmit Size	Receive Size	00	256	01	512	10	1024	11	0
Transmit Size	Receive Size											
00	256											
01	512											
10	1024											
11	0											
	— Other Endpoints †	Reserved: Values read from this bit are indeterminate. Write zero to this bit.										
4	—	Reserved: Values read from this bit are indeterminate. Write zero to this bit.										
3	TXISO	Transmit Isochronous Data: Firmware sets this bit to indicate that the transmit FIFO contains isochronous data. The FIU uses this bit to set up the handshake protocol at the end of a transmission. This bit is not reset when TXCLR is set and must be cleared by firmware.										

† Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (for 6EPP option, 8x930Ax only).

†† ATM mode is recommended. ADVRM and REVRP, which control the read marker and read pointer when ATM = 0, are used for test purposes.

Figure 7-10. TXCON: Transmit FIFO Control Register

TXCON (Continued) (Endpoint-indexed)	Address: Reset State:	Function Endpoint 1 Other Endpoints†	S:F4H 000x 0100B 0xxx 0100B							
USB Transmit FIFO Control Register. Controls the transmit FIFO specified by EPINDEX.										
Function Endpoint 1	7	TXCLR	FFSZ1	FFSZ0	—	TXISO	ATM	ADVRM	REVRP	0
Other Endpoints †	7	TXCLR	—	—	—	TXISO	ATM	ADVRM	REVRP	0

Bit Number	Bit Mnemonic	Function												
2	ATM	<p>Automatic Transmit Management:</p> <p>Setting this bit (the default value) causes the read pointer and read marker to be adjusted automatically as indicated:</p> <table border="1"> <thead> <tr> <th>TXISOTX Status</th> <th>Read Pointer</th> <th>Read Marker</th> </tr> </thead> <tbody> <tr> <td>X ACK</td> <td>Unchanged</td> <td>Advanced (1)</td> </tr> <tr> <td>0 NAK</td> <td>Reversed (2)</td> <td>Unchanged</td> </tr> <tr> <td>1 NAK</td> <td>Unchanged</td> <td>Advanced (1)</td> </tr> </tbody> </table> <p>1. to origin of next data set 2. to origin of the data set last read</p> <p>This bit should always be set, except for test purposes. Setting this bit disables ADVRM and REVRP. This is a sticky bit that is not reset when TXCLR is set, but can be set and cleared by firmware. Hardware neither clears nor sets this bit.</p>	TXISOTX Status	Read Pointer	Read Marker	X ACK	Unchanged	Advanced (1)	0 NAK	Reversed (2)	Unchanged	1 NAK	Unchanged	Advanced (1)
TXISOTX Status	Read Pointer	Read Marker												
X ACK	Unchanged	Advanced (1)												
0 NAK	Reversed (2)	Unchanged												
1 NAK	Unchanged	Advanced (1)												
1	ADVRM	<p>Advance Read Marker Control (non-ATM mode only)^{††}:</p> <p>Setting this bit prepares for the next packet transmission by advancing the read marker to the origin of the next data packet (the position of the read pointer). Hardware clears this bit after the read marker is advanced. This bit is effective only when the REVRP, ATM, and TXCLR bits are all clear.</p>												
0	REVRP	<p>Reverse Read Pointer Control (non-ATM mode only)^{††}:</p> <p>In the case of a bad transmission, the same data stack may need to be available for retransmit. Setting this bit reverses the read pointer to point to the origin of the last data set (the position of the read marker) so that the FIU can reread the last set for retransmission. Hardware clears this bit after the read pointer is reversed. This bit is effective only when the ADVRM, ATM, and TXCLR bits are all clear.</p>												

† Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (for 6EPP option, 8x930Ax only).

†† ATM mode is recommended. ADVRM and REVRP, which control the read marker and read pointer when ATM = 0, are used for test purposes,

Figure 7-10. TXCON: Transmit FIFO Control Register (Continued)

TXFLG

(Endpoint-indexed)

Address: S:F5H
Reset State: 00xx 1000B

Transmit FIFO Flag Register. These flags indicate the status of data packets in the transmit FIFO specified by EPINDEX.

7

0

TXFIF1	TXFIF0	—	—	TXEMP	TXFULL	TXURF	TXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function																																																		
7:6	TXFIF1:0	<p>FIFO Index Flags (read-only):</p> <p>These flags indicate which data sets are present in the transmit FIFO. The FIF bits are set in sequence after each write to TXCNT to reflect the addition of a data set. Likewise, TXFIF1 and TXFIF0 are cleared in sequence after each advance of the read marker to indicate that the set is effectively discarded. The bit is cleared whether the read marker is advanced by firmware (setting ADVRM) or automatically by hardware (ATM = 1). The next-state table for the TXFIF bits is shown below:</p> <table border="1"> <thead> <tr> <th>TXFIF1:0</th> <th>Operation</th> <th>Flag</th> <th>Next TXFIF1:0</th> <th>Next Flag</th> </tr> </thead> <tbody> <tr> <td>00</td> <td>Wr TXCNT</td> <td>X</td> <td>01</td> <td>Unchanged</td> </tr> <tr> <td>01</td> <td>Wr TXCNT</td> <td>X</td> <td>11</td> <td>Unchanged</td> </tr> <tr> <td>10</td> <td>Wr TXCNT</td> <td>X</td> <td>11</td> <td>Unchanged</td> </tr> <tr> <td>11</td> <td>Wr TXCNT</td> <td>X</td> <td>11</td> <td>TXOVF = 1</td> </tr> <tr> <td>00</td> <td>Adv RM</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>01</td> <td>Adv RM</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>11</td> <td>Adv RM</td> <td>X</td> <td>10/01</td> <td>Unchanged</td> </tr> <tr> <td>10</td> <td>Adv RM</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>XX</td> <td>Rev RP</td> <td>X</td> <td>Unchanged</td> <td>Unchanged</td> </tr> </tbody> </table> <p>In ISO mode, TXOVF, TXURF, and TXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. TXFIF is "incremented" by firmware and "decremented" by the USB. Therefore, writes to TXCNT "increment" TXFIF immediately. However, a successful USB transaction any time within a frame "decrements" TXFIF only at SOF. You must check the TXFIF flags before and after writes to the transmit FIFO and TXCNT for traceability. See the TXFLUSH bit in TXSTST.</p> <p>NOTE: To simplify firmware development, configure control endpoints in single-packet mode.</p>	TXFIF1:0	Operation	Flag	Next TXFIF1:0	Next Flag	00	Wr TXCNT	X	01	Unchanged	01	Wr TXCNT	X	11	Unchanged	10	Wr TXCNT	X	11	Unchanged	11	Wr TXCNT	X	11	TXOVF = 1	00	Adv RM	X	00	Unchanged	01	Adv RM	X	00	Unchanged	11	Adv RM	X	10/01	Unchanged	10	Adv RM	X	00	Unchanged	XX	Rev RP	X	Unchanged	Unchanged
TXFIF1:0	Operation	Flag	Next TXFIF1:0	Next Flag																																																
00	Wr TXCNT	X	01	Unchanged																																																
01	Wr TXCNT	X	11	Unchanged																																																
10	Wr TXCNT	X	11	Unchanged																																																
11	Wr TXCNT	X	11	TXOVF = 1																																																
00	Adv RM	X	00	Unchanged																																																
01	Adv RM	X	00	Unchanged																																																
11	Adv RM	X	10/01	Unchanged																																																
10	Adv RM	X	00	Unchanged																																																
XX	Rev RP	X	Unchanged	Unchanged																																																
5:4	—	<p>Reserved:</p> <p>Values read from these bits are indeterminate. Write zeros to these bits.</p>																																																		
3	TXEMP	<p>Transmit FIFO Empty Flag (read-only):</p> <p>Hardware sets this bit when the write pointer has not rolled over and is at the same location as the read pointer. Hardware clears this bit when the pointers are at different locations.</p> <p>Regardless of ISO or non-ISO mode, this bit always tracks the current transmit FIFO status.</p>																																																		

† When set, all transmissions are NAKed.

Figure 7-11. TXFLG: Transmit FIFO Flag Register

TXFLG (Continued)
(Endpoint-indexed)

Address: S:F5H
Reset State: 00xx 1000B

Transmit FIFO Flag Register. These flags indicate the status of data packets in the transmit FIFO specified by EPINDEX.

7

0

TXFIF1	TXFIF0	—	—	TXEMP	TXFULL	TXURF	TXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
2	TXFULL	<p>Transmit FIFO Full Flag (read-only):</p> <p>Hardware sets this bit when the write pointer has rolled over and equals the read marker. Hardware clears this bit when the full condition no longer exists.</p> <p>Regardless of ISO or non-ISO mode, this bit always tracks the current transmit FIFO status. Check this bit to avoid causing a TXOVF condition.</p>
1	TXURF	<p>Transmit FIFO Underrun Flag (read, clear only)[†]:</p> <p>Hardware sets this flag when an additional byte is read from an empty transmit FIFO or TXCNT [This is caused when the value written to TXCNT is greater than the number of bytes written to TXDAT.]. This is a sticky bit that must be cleared through firmware. When this flag is set, the FIFO is in an unknown state, thus it is recommended that you reset the FIFO in your error management routine using the TXCLR bit in TXCON.</p> <p>When the transmit FIFO underruns, the read pointer will not advance — it remains locked in the empty position.</p> <p>If the TXCNT doesn't agree with the data, hardware sets TXURF. This indicates that the transmitted data was corrupted by a bit-stuffing or CRC error.</p> <p>In ISO mode, TXOVF, TXURF, and TXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since underrun can only be caused by USB, TXURF is updated at the next SOF regardless of where the underrun occurs in the frame.</p>
0	TXOVF	<p>Transmit FIFO Overrun Flag[†]:</p> <p>This bit is set when an additional byte is written to a full FIFO or full TXCNT with TXFIF1:0 = 11. This is a sticky bit that must be cleared through firmware. When this bit is set, the FIFO is in an unknown state, thus it is recommended that you reset the FIFO in your error management routine using the TXCLR bit in TXCON.</p> <p>When the receive FIFO overruns, the write pointer will not advance — it remains locked in the full position. Check this bit after loading the FIFO prior to writing the byte count register.</p> <p>In ISO mode, TXOVF, TXURF, and TXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since overrun can only be caused by firmware, TXOVF is updated immediately. Check the TXOVF flag after writing to the transmit FIFO before writing to TXCNT.</p>

[†] When set, all transmissions are NAKed.

Figure 7-11. TXFLG: Transmit FIFO Flag Register (Continued)

7.3 RECEIVE FIFOs

The 8x930 has a receive FIFO for each function endpoint pair. In this manual, the term “receive FIFO” refers to the receive FIFO associated with the current endpoint pair specified by the EPIN-DEX register. 8x930 FIFOs are listed in Table 2-5 and Table 2-6 on page 2-13.

7.3.1 Receive FIFO Overview

The receive FIFOs are circulating data buffers with the following features:

- support for up to two separate data sets of variable sizes[†]
- a byte count register that accesses the number of bytes in the data sets
- flags to signal a full FIFO and an empty FIFO
- capability to re-receive the last data set

Figure 7-12 illustrates a receive FIFO. A receive FIFO and its associated logic can manage up to two data sets, data set 0 (ds0) and data set 1 (ds1). The ability to have two data sets in the FIFO supports back-to-back receptions.

In many ways the receive FIFO is symmetrical to the transmit FIFO. The FIU writes to the FIFO location specified by the *write pointer*, which increments by one automatically following a write. The *write marker* points to the first byte of data written to a data set, and the *read pointer* points to the next FIFO location to be read by the 8x930. The read pointer increments by one automatically following a read.

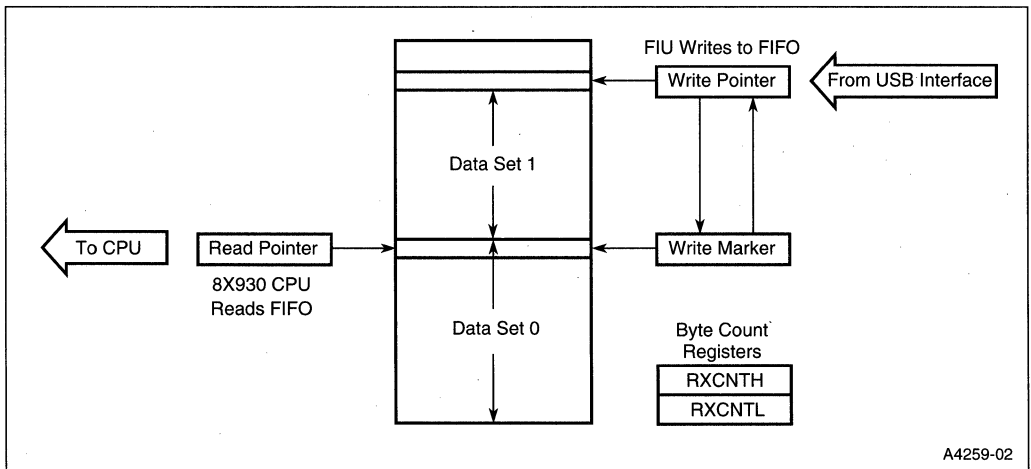


Figure 7-12. Receive FIFO

[†] When operating in dual packet mode, the maximum packet size should not exceed one half the FIFO size to ensure that both packets will simultaneously fit in the FIFO (see the endpoint descriptor in the *Universal Serial Bus Specification*).

When a good reception is completed, the write marker can be advanced to the position of the write pointer to set up for writing the next data set. When a bad reception is completed, the write pointer can be reversed to the position of the write marker to enable the FIU to rewrite the last data set after receiving the data again. The write marker advance and write pointer reversal can be accomplished two ways: explicitly by firmware or automatically by hardware, as specified by bits in the receive FIFO control register.

The 8x930 should not read data from the receive FIFO before all bytes are received and successfully acknowledged because the reception may be bad.

The FIU can monitor the FIFO full flag (RXFULL bit in RXFLG) to avoid overwriting data in the receive FIFO. In the single packet mode, 8x930 can monitor the FIFO empty flag (RXEMP bit in RXFLG) to avoid reading a byte when the FIFO is empty.

7.3.2 Receive FIFO Registers

There are five registers directly involved in the operation of the receive FIFOs:

- RXDAT, the receive FIFO data register
- RXCNTH and RXCNTL, the receive FIFO byte count registers referred to jointly as RXCNT
- RXCON, the receive FIFO control register
- RXFLG, the receive FIFO flag register

These registers are endpoint indexed, i.e., they are used as set to control the operation of the receive FIFO associated with the current endpoint specified by the EPINDEX register. Figures 7-13 through 7-11 beginning on page 7-27 describe the receive FIFO registers and provide bit definitions.

7.3.2.1 Receive Data Register (RXDAT)

Received data bytes are written to the receive FIFO via the receive FIFO data register (RXDAT).

7.3.2.2 Receive Byte Count Registers (RXCNTL/RXCNTH)

The format of the receive byte count register depends on the endpoint. For endpoint 1, registers RXCNTH and RXCNTL form a ten-bit ring buffer which accommodates packet sizes of 0 to 1023 bytes. For endpoints 0, 2, and 3, RXCNTL is used alone as five-bit ring buffer to accommodate packet sizes of 0 to 16 bytes. These formats are shown in Table 7-14 on page 7-28. The term RXCNT refers to either of these arrangements.

The receive FIFO byte count register (RXCNT) stores the number of bytes in either of the two data sets, data set 0 (ds0) and data set 1 (ds1). The FIFO logic for maintaining the data sets assumes that data is written to the FIFO in the following sequence:

1. The USB interface first writes the received data packet into the receive FIFO.
2. The USB interface then writes the number of bytes that were written into the receive FIFO to the byte count register RXCNT.

NOTE

For all endpoints except function endpoint 1, RXCNTH is not available and RXCNTL only contains BC4:0. Bits 7:5 are reserved in this case and will always be read as '0'.

The CPU reads the byte count register to determine the number of bytes in the set.

The receive byte count register has a *read/write index* to allow it to access the byte count for either of the two data sets. This is similar to the methodology used for the transmit byte count register. After reset, the read/write index points to data set 0. Thereafter, the following logic determines the position of the read/write index:

- After a read of RXCNT, the read/write index (RXFIF) is unchanged
- After a write of RXCNT, the read/write index (RXFIF) is toggled

The position of the read/write index can also be determined from the data set index bits, FIF1:0 (see "Receive FIFO Data Set Management" on page 7-26).

CAUTION

Do not read RXCNT to determine if data is present in the receive FIFO. A read attempt to RXCNT during the time the receive FIFO is empty causes the RXURF flag in RXFLG to be set. Always read the RXFIF bits in RXFLG to determine if data is present in the receive FIFO. The RXFIF bits are updated after RXCNT is written (at the end of the receive operation, and at the SOF for ISO data).

7.3.3 Receive FIFO Data Set Management

As in the transmit FIFO, the receive FIFO uses a pair of bits (FIF1:0 in the RXFLG register) to indicate which data sets are present in the receive FIFO (see Table 7-5).

Table 7-5. Status of the Receive FIFO Data Sets

FIF1:0		Data Sets Written		
		ds1	ds0	
0	0	No	No	(Empty)
0	1	No	Yes	(1 set)
1	0	Yes	No	(1 set)
1	1	Yes	Yes	(2 sets)

Table 7-6 summarizes how the actions following a reception depend on the RXISO bit, the ARM bit, and the handshake issued by the 8x930.

Table 7-6. Truth Table for Receive FIFO Management

RXISO (RXCON.3)	ARM (RXCON.2)	RXERR (RXSTAT.1)	RXACK (RXSTAT.0)	Action at End of Transfer Cycle
X	X	0	0	No operation.
X	0	0	1	Write marker, write pointer, and RXFIF bits remain unchanged. Managed by firmware.
X	0	1	0	Write marker, write pointer, and RXFIF bits remain unchanged. Managed by firmware.
0	1	0	1	Write marker advanced automatically. The RXFIF bit for the corresponding data set is set.
0	1	1	0	Write pointer reversed automatically. The RXFIF bit for the corresponding data set is cleared.
1	1	X	X	Write marker advanced automatically. If data was written to the receive FIFO, the RXFIF bit for the corresponding data set is set.

NOTE

For normal operation, set the ARM bit in RXCON: hardware will automatically control the write pointer and write marker and track the RXFIF bits.

<p>RXDAT (Endpoint-indexed)</p> <p>Receive FIFO Data Register. Receive FIFO data specified by EPINDEX is stored and read from this register.</p>	<p>Address: S:E3H Reset: xxxx xxxxB</p>						
<div style="border: 1px solid black; background-color: #e0e0e0; padding: 5px; width: fit-content; margin: 0 auto;">RXDAT.7:0</div>							
<div style="display: flex; justify-content: space-between; width: 100%;"> 7 0 </div>							
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Bit Number</th> <th style="text-align: center;">Bit Mnemonic</th> <th style="text-align: left;">Function</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">7:0</td> <td style="text-align: center;">RXDAT.7:0</td> <td>To write data to the receive FIFO, the FIU writes to this register. To read data from the receive FIFO, the 8x930 reads from this register. The write pointer and read pointer are incremented automatically after a write and read, respectively.</td> </tr> </tbody> </table>	Bit Number	Bit Mnemonic	Function	7:0	RXDAT.7:0	To write data to the receive FIFO, the FIU writes to this register. To read data from the receive FIFO, the 8x930 reads from this register. The write pointer and read pointer are incremented automatically after a write and read, respectively.	
Bit Number	Bit Mnemonic	Function					
7:0	RXDAT.7:0	To write data to the receive FIFO, the FIU writes to this register. To read data from the receive FIFO, the 8x930 reads from this register. The write pointer and read pointer are incremented automatically after a write and read, respectively.					

Figure 7-13. RXDAT: Receive FIFO Data Register

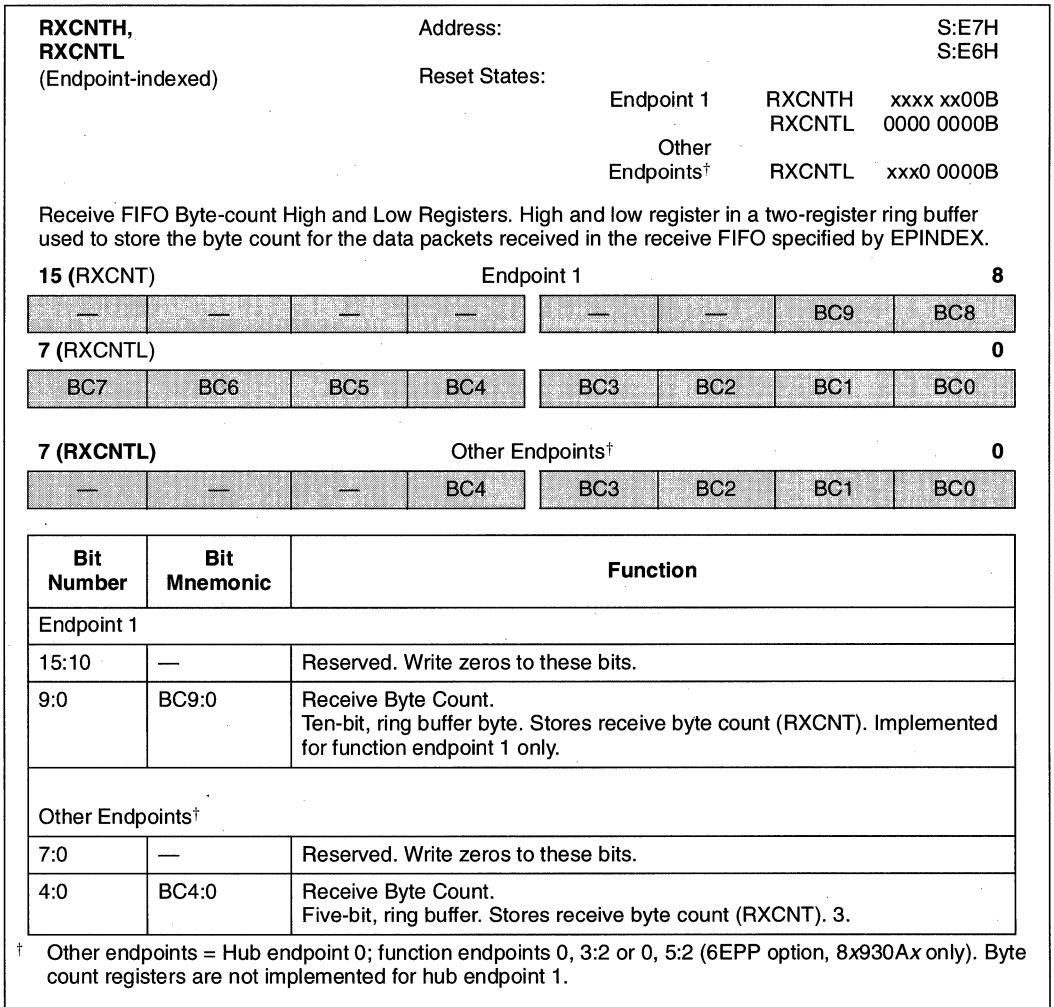


Figure 7-14. RXCNTH/RXCNTL: Receive FIFO Byte Count Registers

CAUTION

Do not read RXCNT to determine if data is present in the receive FIFO. Always read the FIF bits in the RXFLG register. RXCNT contains random data during a receive operation. A read attempt to RXCNT during the time the receive FIFO is empty causes the RXURF flag in RXFLG to be set. Always read the FIF bits to determine if data is present in the receive FIFO. The RXFLG FIF bits are updated after RXCNT is written (at the end of the receive operation).

<p>RXCON (Endpoint-indexed)</p> <p>Receive FIFO Control Register. Controls the receive FIFO specified by EPINDEX.</p>	<p>Address: S:E4H Reset State: 0x00 0100B</p>								
7	0								
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 12.5%; text-align: center;">RXCLR</td> <td style="width: 12.5%; text-align: center;">—</td> <td style="width: 12.5%; text-align: center;">RXWS</td> <td style="width: 12.5%; text-align: center;">RXFFRC</td> <td style="width: 12.5%; text-align: center;">RXISO</td> <td style="width: 12.5%; text-align: center;">ARM</td> <td style="width: 12.5%; text-align: center;">ADVWM</td> <td style="width: 12.5%; text-align: center;">REVWP</td> </tr> </table>	RXCLR	—	RXWS	RXFFRC	RXISO	ARM	ADVWM	REVWP	
RXCLR	—	RXWS	RXFFRC	RXISO	ARM	ADVWM	REVWP		
Bit Number	Bit Mnemonic	Function							
7	RXCLR	<p>Clear the Receive FIFO:</p> <p>Set this bit to flush the entire receive FIFO. All flags in RXFLG revert to their reset states (RXEMP is set; all other flags clear). The ARM, RXISO and RXWS bits in this register and the RXSEQ bit in the RXSTAT register are not affected by this operation. Hardware clears this bit when the flush operation is completed.</p>							
6	—	<p>Reserved:</p> <p>Values read from this bit are indeterminate. Write zero to this bit.</p>							
5	RXWS	<p>Receive FIFO Wait-state Read:</p> <p>At the 8x930 core frequency of 12 MHz, not all instructions that access the receive FIFO are guaranteed to work due to critical paths inherent in the 8x930 architecture. While all MOV instructions from the receive FIFO are guaranteed to work at 12 MHz, arithmetic instructions (e.g., ADD, SUB, etc.) where the receive FIFO is the source and the register file the destination may not work at this speed. For applications using arithmetic instructions, set the RXWS bit to read the receive FIFO with one wait state — this will eliminate the critical path. This bit is not reset when the RXCLR bit is set.</p>							
4	RXFFRC	<p>FIFO Read Complete:†</p> <p>Set this bit to release the receive FIFO when a data set read is complete. Setting this bit “clears” the RXFIF “bit” (in the RXFLG register) corresponding to the data set that was just read. Hardware clears this bit after the RXFIF bit is cleared. All data from this data set must have been read. Note that FIFO Read Complete only works if STOVW and EDOVW are cleared.</p>							
3	RXISO	<p>Isochronous Data Type:†</p> <p>Set this bit to indicate that the receive FIFO is programmed to receive isochronous data and to set up the USB interface to handle an isochronous data transfer. This bit is not reset when the RXCLR bit is set; it must be cleared by firmware.</p>							

† ARM mode is recommended. ADVWM and REVWP, which control the write marker and write pointer when ARM = 0, are used for test purposes,

Figure 7-15. RXCON: Receive FIFO Control Register

RXCON (Continued)
(Endpoint-indexed)

Address: S:E4H
Reset State: 0x00 0100B

Receive FIFO Control Register. Controls the receive FIFO specified by EPINDEX.

7

0

RXCLR	—	RXWS	RXFFRC	RXISO	ARM	ADVWM	REVWP
-------	---	------	--------	-------	-----	-------	-------

Bit Number	Bit Mnemonic	Function																
2	ARM	<p>Auto Receive Management:</p> <p>When set, the write pointer and write marker are adjusted automatically based on the following conditions:</p> <table border="1"> <thead> <tr> <th>RXISO</th> <th>RX Status</th> <th>Write Pointer</th> <th>Write Marker</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>ACK</td> <td>Unchanged</td> <td>Advanced</td> </tr> <tr> <td>0</td> <td>NAK</td> <td>Reversed</td> <td>Unchanged</td> </tr> <tr> <td>1</td> <td>NAK</td> <td>Unchanged</td> <td>Advanced</td> </tr> </tbody> </table> <p>When this bit is set, setting REVWP or ADVWM has no effect. Hardware neither clears nor sets this bit. This is a sticky bit that is not reset when RXCLR is set.</p> <p>NOTE: This bit should always be set, except for testing.</p>	RXISO	RX Status	Write Pointer	Write Marker	X	ACK	Unchanged	Advanced	0	NAK	Reversed	Unchanged	1	NAK	Unchanged	Advanced
RXISO	RX Status	Write Pointer	Write Marker															
X	ACK	Unchanged	Advanced															
0	NAK	Reversed	Unchanged															
1	NAK	Unchanged	Advanced															
1	ADVWM	<p>Advance Write Marker: †</p> <p>(For non-ARM mode only) Set this bit to advance the write marker to the origin of the next data set. Advancing the write marker is used for back-to-back receptions. Hardware clears this bit after the write marker is advanced. Setting this bit is effective only when the REVWP, ARM and RXCLR bits are clear.</p>																
0	REVWP	<p>Reverse Write Pointer: †</p> <p>(For non-ARM mode only) Set this bit to return the write pointer to the origin of the last data set received, as identified by the write marker. The FIU can then re-receive the last data packet and write to the receive FIFO starting from the same origin when the host re-sends the same data packet. Hardware clears this bit after the write pointer is reversed. Setting this bit is effective only when the ADVWM, ARM, and RXCLR bits are all clear.</p> <p>REVWP is used when a data packet is bad. When the function interface receives the data packet again, the write starts at the origin of the previous (bad) data set.</p>																

† ARM mode is recommended. ADVWM and REVWP, which control the write marker and write pointer when ARM = 0, are used for test purposes,

Figure 7-15. RXCON: Receive FIFO Control Register (Continued)

<p>RXFLG (Endpoint-indexed)</p> <p>Receive FIFO Flag Register. These flags indicate the status of data packets in the receive FIFO specified by EPINDEX.</p>	<p>Address: S:E5H Reset State: 00xx 1000B</p>																																																									
7	0																																																									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 12.5%; text-align: center;">RXFIF1</td> <td style="width: 12.5%; text-align: center;">RXFIF0</td> <td style="width: 12.5%; text-align: center;">—</td> <td style="width: 12.5%; text-align: center;">—</td> <td style="width: 12.5%; text-align: center;">RXEMP</td> <td style="width: 12.5%; text-align: center;">RXFULL</td> <td style="width: 12.5%; text-align: center;">RXURF</td> <td style="width: 12.5%; text-align: center;">RXOVF</td> </tr> </table>	RXFIF1	RXFIF0	—	—	RXEMP	RXFULL	RXURF	RXOVF																																																		
RXFIF1	RXFIF0	—	—	RXEMP	RXFULL	RXURF	RXOVF																																																			
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">Bit Number</th> <th style="width: 15%;">Bit Mnemonic</th> <th style="width: 70%;">Function</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">7:6</td> <td style="text-align: center;">RXFIF1:0</td> <td> <p>Receive FIFO Index Flags: (read-only)</p> <p>These read-only flags indicate which data packets are present in the receive FIFO (see Table 7-5 on page 7-26). The RXFIF bits are updated after each write to RXCNT to reflect the addition of a data packet. Likewise, the RXFIF bits are cleared in sequence after each setting of the RXFFRC bit. The next-state table for RXFIF bits is shown below for operation in dual packet mode.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">RXFIF1:0</th> <th style="width: 15%;">Operation</th> <th style="width: 10%;">Flag</th> <th style="width: 15%;">Next RXFIF1:0</th> <th style="width: 45%;">Next Flag</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">00</td> <td>Adv WM</td> <td style="text-align: center;">X</td> <td style="text-align: center;">01</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">01</td> <td>Adv WM</td> <td style="text-align: center;">X</td> <td style="text-align: center;">01</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">10</td> <td>Adv WM</td> <td style="text-align: center;">X</td> <td style="text-align: center;">11</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">00</td> <td>Set RXFFRC</td> <td style="text-align: center;">X</td> <td style="text-align: center;">00</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">01</td> <td>Set RXFFRC</td> <td style="text-align: center;">X</td> <td style="text-align: center;">00</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">11</td> <td>Set RXFFRC</td> <td style="text-align: center;">X</td> <td style="text-align: center;">10/01</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">10</td> <td>Set RXFFRC</td> <td style="text-align: center;">X</td> <td style="text-align: center;">00</td> <td>Unchanged</td> </tr> <tr> <td style="text-align: center;">XX</td> <td>Rev WP</td> <td style="text-align: center;">X</td> <td style="text-align: center;">Unchanged</td> <td>Unchanged</td> </tr> </tbody> </table> <p>When the receive FIFO is programmed to operate in single packet mode (RXSPM set in EPCON), valid RXFIF states are 00 and 01 only.</p> <p>In ISO mode, RXOVF, RXURF, and RXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. RXFIF is “incremented” by the USB and “decremented” by firmware. Therefore, setting RXFFRC “decrements” RXFIF immediately. However, a successful USB transaction within a frame “increments” RXFIF only at SOF. For traceability, you must check the RXFIF flags before and after reads from the receive FIFO and the setting of RXFFRC in RXCON.</p> <p>NOTE: To simplify firmware development, it is recommended that you utilize control endpoints in single-packet mode only.</p> </td> </tr> <tr> <td style="text-align: center;">5:4</td> <td style="text-align: center;">—</td> <td> <p>Reserved: Values read from these bits are indeterminate. Write zeros to these bits.</p> </td> </tr> <tr> <td style="text-align: center;">3</td> <td style="text-align: center;">RXEMP</td> <td> <p>Receive FIFO Empty Flag (read-only):</p> <p>Hardware sets this flag when the write pointer is at the same location as the read pointer and the write pointer equals the write marker and neither pointer has rolled over. Hardware clears the bit when the empty condition no longer exists. This is not a sticky bit and always tracks the current status of the receive FIFO, regardless of ISO or non-ISO mode.</p> </td> </tr> </tbody> </table>	Bit Number	Bit Mnemonic	Function	7:6	RXFIF1:0	<p>Receive FIFO Index Flags: (read-only)</p> <p>These read-only flags indicate which data packets are present in the receive FIFO (see Table 7-5 on page 7-26). The RXFIF bits are updated after each write to RXCNT to reflect the addition of a data packet. Likewise, the RXFIF bits are cleared in sequence after each setting of the RXFFRC bit. 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† When set, all transmissions are NAKed.

Figure 7-16. RXFLG: Receive FIFO Flag Register

RXFLG (Continued)
(Endpoint-indexed)

Address: S:E5H
Reset State: 00xx 1000B

Receive FIFO Flag Register. These flags indicate the status of data packets in the receive FIFO specified by EPINDEX.

7

0

RXFIF1	RXFIF0	—	—	RXEMP	RXFULL	RXURF	RXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
2	RXFULL	<p>Receive FIFO Full Flag (read-only):</p> <p>Hardware sets this flag when the write pointer has rolled over and equals the read pointer. Hardware clears the bit when the full condition no longer exists. This is not a sticky bit and always tracks the current status of the receive FIFO, regardless of ISO or non-ISO mode.</p>
1	RXURF	<p>Receive FIFO Underrun Flag†:</p> <p>Hardware sets this bit when an additional byte is read from an empty receive FIFO or RXCNT. Hardware does not clear this bit, so you must clear it in firmware. When the receive FIFO underruns, the read pointer will not advance — it remains locked in the empty position.</p> <p>In ISO mode, RXOVF, RXURF, and RXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since underrun can only be caused by firmware, RXURF is updated immediately. You must check the RXURF flag after reads from the receive FIFO before setting the RXFFRC bit in RXCON.</p> <p>NOTE: When this bit is set, the FIFO is in an unknown state. It is recommended that you reset the FIFO in the error management routine using the RXCLR bit in the RXCON register.</p>
0	RXOVF	<p>Receive FIFO Overrun Flag†:</p> <p>This bit is set when the FIU writes an additional byte to a full receive FIFO or writes a byte count to RXCNT with FIF1:0 = 11. This is a sticky bit that <i>must</i> be cleared through firmware, although it can be cleared by hardware if a SETUP packet is received after an RXOVF error had already occurred.†</p> <p>When this bit is set, the FIFO is in an unknown state, thus it is recommended that you reset the FIFO in the error management routine using the RXCLR bit in the RXCON register. When the receive FIFO overruns, the write pointer will not advance — it remains locked in the full position.</p> <p>In ISO mode, RXOVF, RXURF, and RXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since overrun can only be caused by the USB, RXOVF is updated only at the next SOF regardless of where the overrun occurred during the current frame.†</p>

† When set, all transmissions are NAKed.

Figure 7-16. RXFLG: Receive FIFO Flag Register (Continued)

7.4 SIE DETAILS

The USB employs differential data signaling; refer to the signaling levels table in the “Electrical” chapter of *Universal Serial Bus Specification*. The specification defines: differential ‘1’, differential ‘0’, idle (‘J’ state), non-idle (‘K’ state), start-of-packet, end-of-packet, disconnect, connect, reset, and resume. The USB employs NRZI data encoding when transmitting packets. Refer to “Data Encoding/Decoding” in the *Universal Serial Bus Specification* for a description of NRZI data encoding and decoding. To ensure adequate signal transitions, bit stuffing is employed by the SIE when transmitting data. The SIE also does bit unstuffing when receiving data. Consult the “Flow Diagram for Bit Stuffing” figure in the “Bit Stuffing” section of the “Electrical” chapter for more information on bit stuffing.

Bits are sent out onto the bus, least significant bit (LSb) first, followed by the next LSb, and so on. Bytes are sent out onto the bus least significant byte (LSB) first, followed by the next LSB and so on. The SIE ensures that the LSb is first, but the 8x930 programmer must ensure the order of the bytes.

The SIE decodes and takes care of all packet types and packet fields mentioned in “Protocol Layer” chapter of *Universal Serial Bus Specification*. The FIU communicates data information and handshaking instructions to the SIE. Programmers should consult the “Interconnect Description,” “USB Devices,” and “USB Host” chapters of *Universal Serial Bus Specification* for detailed information on how the host and function communicate.

7.5 SETUP TOKEN RECEIVE FIFO HANDLING

SETUP tokens received by a control endpoint must be ACKed even if the receive FIFO is not empty. When a SETUP token is detected by the FIU, the FIU sets the STOVW bit of RXSTAT and then flushes the receive FIFO by hardware, setting the RXCLR bit of RXCON. The STOVW indicates a SETUP-initiated over-write (flush) is in progress. After the SETUP transaction is completed (i.e., ACK handshake), the FIU clears STOVW and sets EDOVW, indicating the receive FIFO over-write is complete and FIFO contents are stable. Reception of any SETUP packet, regardless of whether the receive FIFO is full or empty always sequences through the STOVW, EDOVW sequence described above.

Note that if the receive FIFO flush occurs in the middle of an 8x930 CPU data read cycle (from a previous USB transaction), the receive FIFO could underrun, thus setting the RXURF bit of RXFLG and positioning the read pointer in an unknown state. To prevent this, STOVW resets and locks the read pointer. The read pointer will remain locked until both the STOVW and EDOVW bits are cleared.

CAUTION

For SETUP packets only, firmware must clear EDOVW prior to reading data from the FIFO. If this is not done, data read from the FIFO will be invalid.

After processing a SETUP packet, firmware should always check the STOVW and EDOVW flags before setting the RXFFRC bit. When a SETUP packet either has been or is being received, setting of RXFFRC has no effect if either STOVW or EDOVW is set. It is up to the user to clear EDOVW which disables the RXFFRC blocking mechanism. Also note that the RXSETUP = 1 condition causes IN and OUT tokens to be NAKed automatically until RXSETUP is cleared. This

is true even if the transmit and/or receive endpoint is stalled (TXSTL = 1, RXSTL = 1), and is done to allow the clearing of a stall condition on a control endpoint.

NOTE

To simplify firmware development, it is recommended that you utilize control endpoints in single-packet mode only.

7.6 ISO DATA MANAGEMENT

ISO data management must always be performed in dual-packet mode. Interrupts are not generated when an ISO transmit or receive cycle is completed; ISO protocols should always be synchronized to the SOF interrupt. When transmitting, data written into the transmit FIFO at frame n is pre-buffered to be transmitted in frame $n+1$. This guarantees that data is always available to the host when requested anytime in a frame. When receiving, data written into the receive FIFO at frame n is pre-buffered to be read-out in frame $n+1$. This guarantees that data from the host is always available to the function every frame.

Isochronous data transfer is always guaranteed if the OUT or IN tokens from the host are not corrupted. When IN or OUT tokens to a function are corrupted, the host does not re-send the token. Function firmware needs to recognize this error condition and reconfigure the endpoints accordingly.

7.6.1 Transmit FIFO ISO Data Management

When an IN token is corrupted, the data to be transmitted from the transmit FIFO for an isochronous endpoint in the current frame will be flushed. Due to latency concerns, this is handled by hardware. This error condition can be detected by checking TXFIF1:0 = 11 at SOF. When this occurs, the oldest data packet will be flushed and the transmit FIFO read-pointers and read-markers will be advanced to the start "address" of the second data packet. The TXFIF will also be updated. Therefore, the second packet will be ready to be transmitted for the next frame. The first data packet is lost. The transmit flush bit, TXFLUSH in TXSTAT, is also set when this occurs.

For firmware traceability of FIFO status flags, some flags are updated immediately while others are updated only at SOF. TXOVF, TXURF, and TXFIF are handled using the following rule: firmware events cause status change immediately while USB events only cause status change at SOF. For example:

- TXOVF: Since overrun can only be caused by firmware, TXOVF is updated immediately.
- TXURF: Since underrun can only be caused by SIE, TXURF is updated at SOF.
- TXFIF: TXFIF is "incremented" by firmware and "decremented" by hardware. Therefore, writes to TxCNT will "increment" TXFIF immediately. However, a successful USB transaction anytime in a frame will only "decrement" TXFIF at SOF.

The following bits do not follow the above rule:

- TXEMP/TXFULL: These always reflect the current status of the FIFO.
- TXFLUSH: Firmware can detect a flush by monitoring this bit.

7.6.2 Receive FIFO ISO Data Management

For firmware traceability of FIFO status flags, some flags are updated immediately while others are updated only at SOF. RXOVF, RXURF, and RXFIF are handled using the following rule: firmware events cause status change immediately while USB events only cause status change at SOF. For example:

- **RXURF:** Since underrun can only be caused by firmware, RXURF is updated immediately.
- **RXOVF:** Since overrun can only be caused by SIE, RXOVF is updated at SOF.
- **RXFIF:** RXFIF is “incremented” by hardware and “decremented” by firmware. Therefore, setting RXFFRC will “decrement” RXFIF immediately. However, a successful USB transaction anytime in a frame will only “increment” RXFIF at SOF.
- **RXEMP/RXFULL:** The rule does not apply to the RXEMP and RXFULL flags, which always reflect the current status of the FIFO.

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8

USB Hub



CHAPTER 8 USB HUB

This chapter describes the operation of the Intel Universal Serial Bus (USB) on-chip hub, as implemented in the 8x930Hx. This chapter introduces on-chip hub operation and includes information on bus enumeration, hub endpoint status and configuration, hub port control, hub suspend and resume, and hub power control.

The 8x930Ax microcontroller does not include a hub feature. Hence, this chapter does not apply to the 8x930Ax. To see how the hub fits in the 8x930Hx architecture, see Chapter 2, “Architectural Overview.”

8.1 HUB FUNCTIONAL OVERVIEW

The on-chip hub provides an electrical interface between the USB host and the downstream ports. In many cases, this relationship exists as an interface between a USB host and other discrete USB devices. Besides serving as a control interface between the host and the downstream ports, the hub is also a USB device and must respond to the standard USB requests (described in Chapter 9 of *Universal Serial Bus Specification*) as well as hub class-specific requests (defined in Chapter 11 of *Universal Serial Bus Specification*).

The functionality between the PC host and the downstream ports that is handled by the hub includes:

- Connectivity management
- Downstream device connect/disconnect detection
- Power management, including suspend and resume functions
- Bus fault detection and recovery
- Full and low-speed device support

The hub functionality can be divided into two sub-functions: the hub repeater and the hub controller. The hub architecture is described in “The 8x930Hx USB Module” on page 2-14. A diagram of the hub architecture is shown in Figure 2-4 on page 2-7.

The hub controller function is split between four modules:

- Hub interface unit (HIU)
- Serial bus interface engine (SIE)
- Transmit and receive FIFOs for hub endpoint 0 and endpoint 1
- 8x930Hx CPU

A functional diagram of the hub is shown in Figure 8-1 on page 8-2. The diagram shows the root port, which is the upstream port (port 0); the repeater, which is responsible for managing connectivity on a per packet basis; the hub controller, which provides status and control and permits host access to the hub; three external downstream ports, which provide a means of expanding the USB by permitting the connection of additional PC peripherals; and the internal downstream port, which provides an interface to the embedded function.

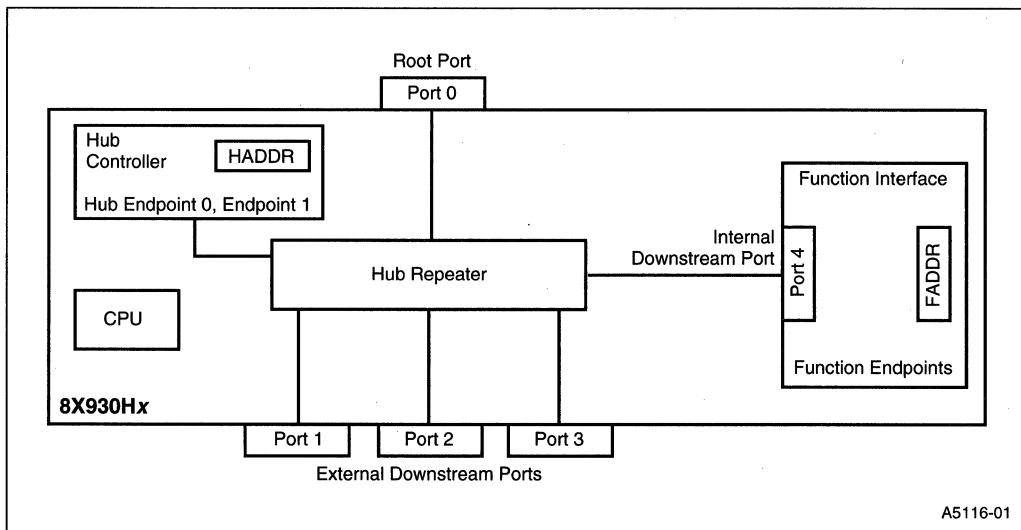


Figure 8-1. 8X930Hx Hub Functional Diagram

Refer to chapter 11 of *Universal Serial Bus Specification* for a more detailed description of the hub and its functionality. For a description of the transceiver see the “Driver Characteristics” and “Receiver Characteristics” sections of the “Electrical” chapter of the *Universal Serial Bus Specification*. For electrical characteristics and data signal timing, see the “Bus Timing/Electrical Characteristics” and “Timing Diagram” sections of the same chapter.

Table 8-1. USB Hub SFRs

Mnemonic	Name	Address
HADDR	Hub Address Register. Used by the HIU to perform token address decoding.	S:97H
HIE	Hub Interrupt Enable Register. Contains the hub interrupt enable bits. See “USB Hub Interrupt” on page 6-15.	S:A1H
HIFLG	Hub Interrupt Flag Register. Contains the hub interrupt status flags. See “USB Hub Interrupt” on page 6-15.	S:E8H
HPCON	Hub Port Control. Enables, disables, resets, suspends, and resumes the four hub ports. USB port-indexed using HPINDEX.	S:CFH

Table 8-1. USB Hub SFRs (Continued)

Mnemonic	Name	Address
HPINDEX	Hub Port Index Register. Provides port indexing into the HPSC, HPSTAT, and HPCON registers. See "Hub Port Indexing Using HPINDEX" on page 8-23 for details.	S:D4H
HPPWR	Hub Port Power Control. Controls power to the three downstream ports.	S:9AH
HPSC	Hub Port Status Change. Indicates a change in reset, suspend, enable, disable, or connect status. USB port-indexed using HPINDEX.	S:D5H
HPSTAT	Hub Port Status. Provides D_p , D_M , low-speed device, power, reset, suspend, enable, and disable status for the four hub ports. USB port-indexed using HPINDEX.	S:D7H
HSTAT	Hub Status and Configuration. Used to examine or enable remote wake-up, stall feature, endpoint 1, over-current status, and local power status	S:AEH

8.1.1 Port Connectivity States

In addition to the root port (port 0) the hub contains three external downstream ports, ports 1 through 3 and one internal downstream port, port 4.

Hub downstream ports may be in one of five possible states:

- powered off — Power-switched ports are a USB option supported by the 8x930Hx. A powered off port supplies no power downstream, ignores all upstream-directed bus activity on the port, and its signal output buffers are placed in the Hi-Z state.
- disconnected — Initial state upon power-up or reset, the port cannot propagate any upstream or downstream signaling. The port can detect a connect event, which causes it to transition to the disabled state.
- disabled — Port can only propagate downstream-directed signaling arising from a reset request. A disabled port does not propagate upstream signaling if the hub is awake, but will detect disconnects and initiate resume signaling to the root port if the hub is suspended.
- enabled — Port propagates all downstream and upstream signaling.
- suspended — When suspended, the port will not stop propagating in the middle of a transaction. If hub is awake, no upstream or downstream connectivity can propagate through the port, except for downstream-directed reset signaling. If hub is suspended, idle-to-resume is propagated.

The transitions between these states are shown in Figure 8-2.

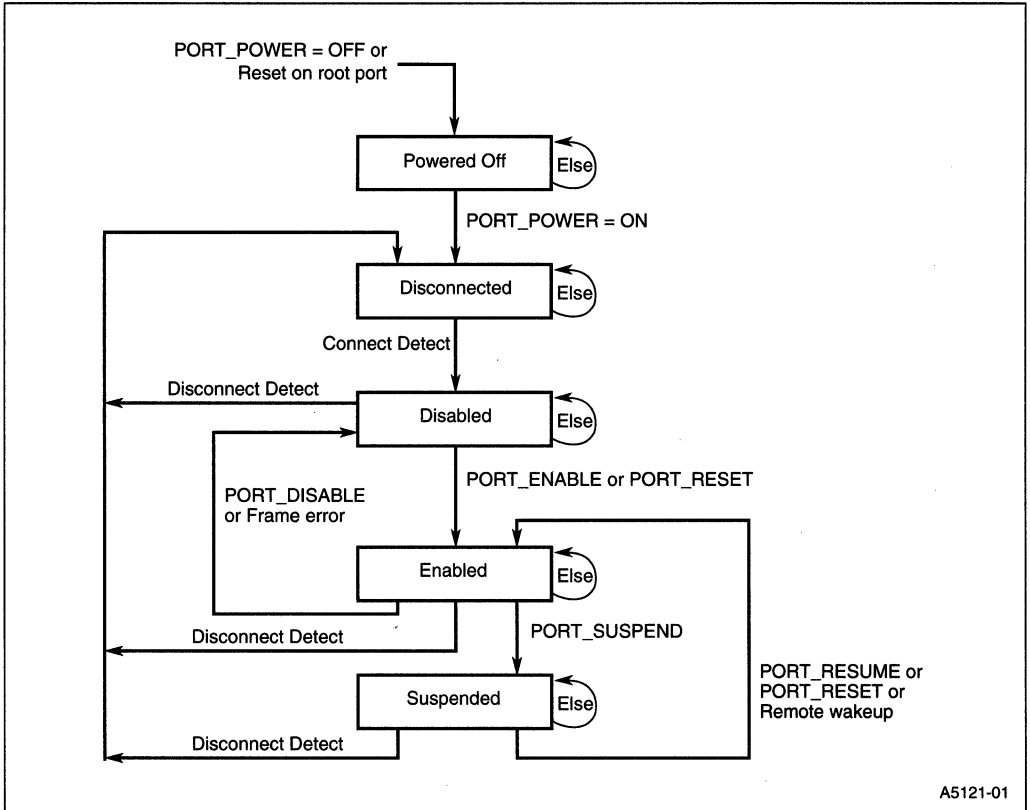


Figure 8-2. Hub State Flow

These port states are tracked and managed in the hub repeater based on hardware events (e.g., physical connection/disconnection of a device on a port) and firmware execution of host commands. Normal packet traffic is allowed to propagate through ports that are in the “enabled” state only, as described in “Per-packet Signaling Connectivity” on page 8-5.

The root port is the only upstream port; it is permanently powered on and enabled. Ports 1 through 3 are external downstream ports. They are power-switched ports that must be powered-on by host command, detect a device connection and then become enabled via host command prior to propagating USB packet traffic. Port 4 is an internal downstream port that is always powered on and always physically connected. It functionally supports port enabling. That is, the downstream port connectivity will not be enabled unless a port enable has been received from the host.

8.1.2 Per-packet Signaling Connectivity

The hub repeater establishes connectivity between ports for upstream and downstream traffic on a per-packet basis. Packet signaling connectivity for downstream, upstream, and idle traffic is illustrated in Figure 8-3. While the host can communicate with all the downstream ports simultaneously, as shown in the “downstream connectivity” illustration in Figure 8-3, only one port can communicate with the host at one time, as shown in the “Upstream Connectivity” illustration of the same figure. The host selects one of the downstream ports for upstream communication.

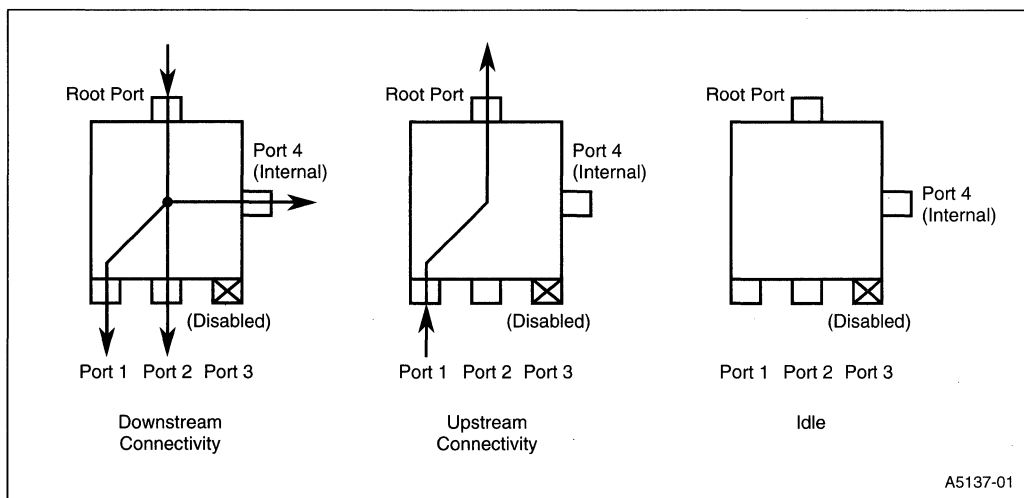


Figure 8-3. Packet Signaling Connectivity

Connections made by the repeater also depend on whether the port is attached to a full-speed or low-speed device and whether the USB packet is a full-speed or low-speed packet (with low-speed packets being identified by a PReamble token). Connections are made by the repeater using asynchronous control logic in order to meet the USB signal propagation requirements.

8.1.2.1 Connectivity to Downstream Ports Attached With Full-speed Devices

Downstream connectivity is established upon detection of a start of packet (SOP) transmitted on the root or upstream port by the USB host. As shown in Figure 8-3, the connection is made from the root port (port 0) to all enabled downstream ports attached with full-speed devices (ports 1, 2, & 3 in this case). Connectivity is *not* established to any enabled ports attached with low-speed devices. Upon detection of the end-of-packet (EOP), the repeater terminates the connectivity, reverting to the idle state, as shown in Figure 8-3.

Upstream connectivity is established upon detection of a SOP transmitted on any enabled downstream port. The connection is only made between a single downstream port and the root port by the repeater, as shown in “upstream connectivity” in Figure 8-3. The USB protocol does not allow packets to be transmitted by more than one downstream port simultaneously, but in an error scenario where this happens, the repeater would choose only one downstream port to connect upstream. Once again, upon detection of an EOP, the connectivity is terminated.

8.1.2.2 Connectivity to Downstream Ports attached with Low-speed Devices

Downstream connectivity is established in the same fashion for low-speed packets as for full-speed packets, with the following exceptions:

1. Downstream low-speed packets are routed to all enabled ports, including ports attached with low-speed and full-speed devices.
2. Downstream low-speed packets contain a low-speed PReamble field which is recognized by the SIE. Upon detection of the PReamble, the repeater establishes the connection to all enabled low-speed downstream ports.
3. Packet data is inverted at the ports attached to low-speed devices for both upstream and downstream traffic.

Upstream connectivity is established in the same fashion for low-speed packets as for full-speed packets, with the exception that no PReamble is propagated prior to low-speed packets. The root port propagates low-speed packets upstream using full-speed signaling (edge rates).

8.2 BUS ENUMERATION

The USB host manages bus enumeration at system start-up or whenever a new USB device is attached to the host or to a hub's downstream port. Initially, the USB hub is in the unenumerated state and the hub address register (HADDR) contains the default value 00H. The host PC performs bus enumeration in which it identifies and addresses devices attached to the bus. During enumeration, a unique address assigned by the host is written to the HADDR of every hub device. The steps of the bus enumeration process are given in "Bus Enumeration" on page 9-16.

Information on descriptors and the HADDR register, required for bus enumeration, is provided in the following subsections.

8.2.1 Hub Descriptors

The 8x930Hx has five descriptors, as shown in Table 8-2. All are standard USB descriptors except the hub descriptor, which is class-specific. There is no descriptor for endpoint 0. A hub has only one valid configuration and interface. The actual descriptor field values are given in the section of *Universal Serial Bus Specification* referenced in the table.

The host reads the hub descriptors during bus enumeration. The host uses the values within the descriptors to determine device configuration. The hub descriptor is divided into several parts, which are shown in Table 8-3.

Table 8-2. 8x930Hx Descriptors

Descriptor	Size	<i>Universal Serial Bus Specification Reference</i>
Device	18 bytes	Section 9.7.1
Configuration	9 bytes	Section 9.7.2
Interface	9 bytes	Section 9.7.3
Endpoint	7 bytes	Section 9.7.4
Hub	9 bytes	Section 11.11.2

Table 8-3. Hub Descriptors

Field	Size	Offset	Description
bDescLength	1 byte	0	Number of bytes in this descriptor, including this byte.
bDescriptorType	1 byte	1	Descriptor Type
bNbrPorts	1 byte	2	Number of downstream ports this hub supports.
wHubCharacteristics	2 bytes	3	Determines power switching mode, identifies device as a compound device, and describes the over-current protection mode used by the device.
bPwrOn2PwrGood	1 byte	5	Time elapsed from when the power on sequence begins on a port until power is good on that port.
bHubContrCurrent	1 byte	6	Maximum current requirements of the hub controller.
DeviceRemovable	1 byte	7	Indicates if a port has a removable device attached.
PortPwrCtrlMask	1 byte	Variable	Indicates if a port is affected by a gang-mode power control request.

8.2.2 The Hub Address Register (HADDR)

During bus enumeration, the host PC communicates a unique address for the hub through hub endpoint 0 using the set address command. Device firmware must interpret and write this hub address to the Hub Address register (HADDR, as shown in Figure 8-4). This procedure is outlined in “Bus Enumeration” on page 9-16.

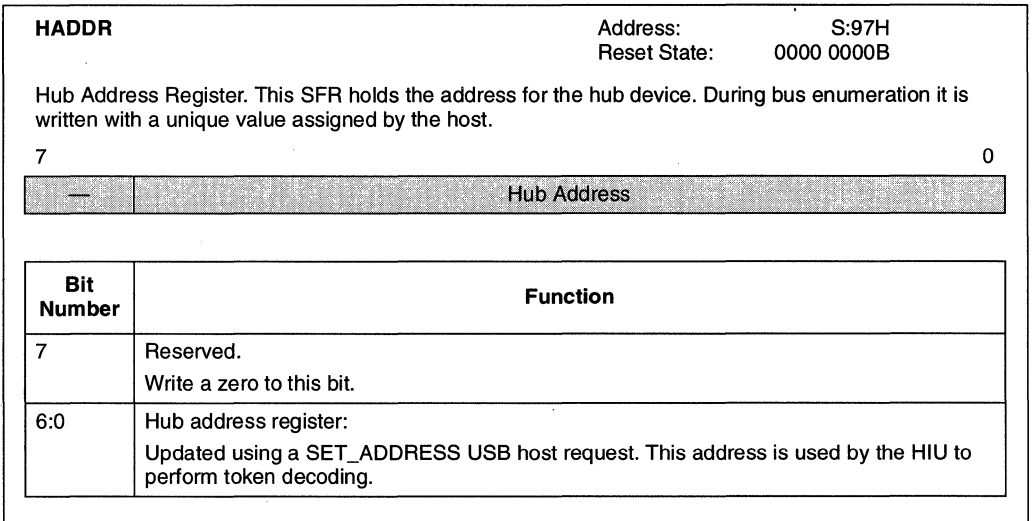


Figure 8-4. HADDR: Hub Address Register

8.3 HUB STATUS

Status and configuration of the USB hub function is performed by both standard and hub class-specific USB requests. These requests, generated by the host PC, manage and configure the status of the hub and its downstream ports. These USB requests are listed and explained in “Hub Status and Configuration” on page 9-17.

The hub has an internal downstream port (port 4) which operates differently than the external downstream ports. Because port 4 is physically connected to the embedded function and is powered-on at all times, USB requests intended for internal downstream port 4 are handled differently than similar requests to the other downstream ports. The management of the individual hub ports is discussed in “USB Hub Ports” on page 8-14.

The host PC may request that firmware check and change bits of the HSTAT SFR (Figure 8-5). See Table 9-1 on page 9-17 for a list of USB requests and their associated firmware actions.

HSTAT		Address: S:AEH	
		Reset State: x000 0000B	
<p>Hub Status and Configuration Register. This SFR contains bits for remote wake-up request, status and status change indicators for over-current and hub endpoint 1 stall and enable.</p>			
7			0
—	HRWUPE	EP1STL	EP1EN
—	OVISC	—	OVI
—			—
Bit Number	Bit Mnemonic	Function	
7	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.	
6	HRWUPE	Hub Remote Wake-up Enable Bit: Set if the device is currently enabled to request remote wake-up. This bit is modified through the SetFeature and ClearFeature requests using the DEVICE_REMOTE_WAKEUP feature selector. When '0,' the hub blocks resume signaling for connect/disconnect and resume events detected on downstream ports. NOTE: Do not set this bit until after the hub is enumerated and the host issues a SET_FEATURE command with a DEVICE_REMOTE_WAKEUP feature selector.	
5	EP1STL	Hub Endpoint 1 Stall Field: Set to '1' via the USB SetFeature request with endpoint stall feature selector. When '1,' will force a stall response when endpoint 1 is addressed. Reset with USB ClearFeature request with endpoint stall feature selector.	
4	EP1EN	Hub Endpoint 1 Enable: Set to '1' upon receipt of a USB SetConfiguration request value of 0001H. Endpoint 1 cannot respond unless this bit is set. Bit is reset upon receipt of configuration value other than 0001H or a system or USB reset. NOTE: This bit must be set in order for the UPWEN# pin to enable power to the downstream ports. Downstream power cannot be applied until this is done.	
3	OVISC	Hub Over-current Indicator Status Change (read/clear-only): † Set to '1' if change is detected in the over-current status, even if the condition goes away before it is detected by firmware. Cleared via a USB ClearFeature request with C_HUB_OVER_CURRENT feature selector. Cleared to '0' if no change.	
2	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.	

† Bits 1 and 3 are returned in response to a Get Hub Status request from the USB host. This response is a four-byte field with zero padding (MSB at left): 0000 0000 0000 00[3] 0 0000 0000 0000 00[1] 0.

Figure 8-5. HSTAT: Hub Status and Configuration Register

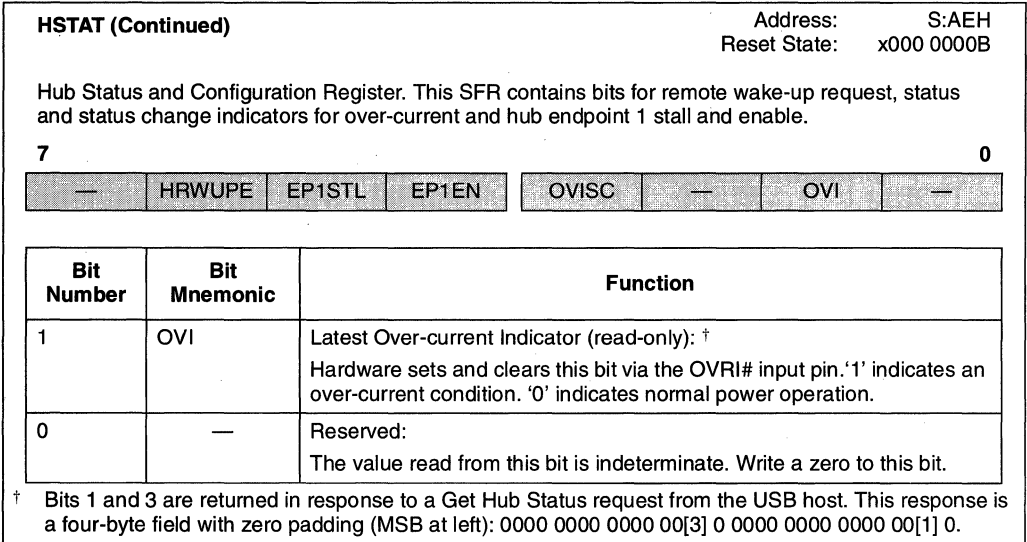


Figure 8-5. HSTAT: Hub Status and Configuration Register (Continued)

8.4 USB HUB ENDPOINTS

Table 8-4 gives the packet size, transfer type and implementation of the 8x930Hx hub endpoints. Bulk and isochronous transfers are not supported by the hub endpoints. The hub handles control transfers using endpoint 0 with a maximum packet size of eight bytes.

Hub endpoint 1 supports interrupt transfers only and has no endpoint receive buffer. Endpoint 1 is used to inform the host of a hub or port status change. Figure 8-7 on page 8-13 illustrates the format used to transmit status change information to the host. Since endpoint 1 transmits a single byte of information, TXDAT (Figure 8-6 on page 8-12) serves as the data buffer. Endpoint 1 operations are primarily controlled by hardware and do not involve firmware, except for the EP1STL and EP1EN bits in HSTAT (Figure 8-5).

Table 8-4. Hub Endpoint Configuration

Hub Endpoint	Max Packet Size	Transfer Type	Implementation
0	8 bytes	Control	Firmware-controlled
1	1 byte	Status Change Interrupt	Hardware-controlled

8.4.1 Hub Endpoint Indexing Using EPINDEX

The 8x930Hx hub endpoint 0 uses the same communication registers (TXCNTL, RXCNTL, TXDAT, RXDAT, TXFLG, RXFLG, TXSTAT, RXSTAT, TXCON, and RXCON) as the embedded USB function endpoints. The EPINDEX register (Figure 7-2 on page 7-6), used to access the registers of the USB function endpoints, is also used to access the registers for hub endpoints.

To access the communication SFRs for the hub endpoints, first write a '1' to bit 7 of EPINDEX. To access the internal USB function's registers, write '0' to EPINDEX' bit 7. Regardless of whether you are accessing the hub or function endpoints, the LSBs of EPINDEX are used to control which endpoint's registers are accessed.

For additional information on how to use EPINDEX, see "Endpoint Selection" on page 7-3.

8.4.2 Hub Endpoint Control

Hub endpoint 1 of the 8x930Hx is controlled primarily by hardware, with these exceptions:

- Firmware can read endpoint 1's TXDAT SFR
- Firmware can stall hub endpoint 1 in response to a Set_Feature (ENDPOINT_STALL) request from the host by setting the EP1STL bit in HSTAT (Figure 8-5). Firmware can also clear this bit in response to a Clear_Feature request.
- Firmware can enable hub endpoint 1 in response to a Set_Configuration request from the host by setting the EPIEN bit in HSTAT (Figure 8-5 on page 8-9)

Firmware can control hub endpoint 0 through its EPCON register (Figure 7-3 on page 7-7) when EPINDEX has previously been set to 80H. Hub endpoint control for endpoint 0 behaves identically to function endpoint control, except that hub endpoint 0 is always a single-packet, control endpoint. Therefore, the corresponding bits (CTLEP and RXSPM) of its EPCON SFR are hardwired to '1'.

8.4.3 Hub Endpoint Transmit and Receive Operations

The 8x930Hx hardware uses hub endpoint 1's TXDAT register (Figure 8-6) to transmit a port status change interrupt to the host. Figure 8-7 shows how a hub or port status change is reflected in TXDAT.

TXDAT is cleared by firmware upon a ClearPortFeature request from the host. See "Monitoring Port Status Change Using HPSC" on page 8-20 for a description of how firmware interacts with the host to communicate a change in port status.

NOTE

Although the bits of hub endpoint 1's TXDAT SFR are firmware read-only, bits 4:0 of TXDAT can be cleared indirectly by writing to a port's HPSC SFR. Clearing all bits in a port's HPSC causes hardware to clear the bit associated with that port in hub endpoint 1's TXDAT.

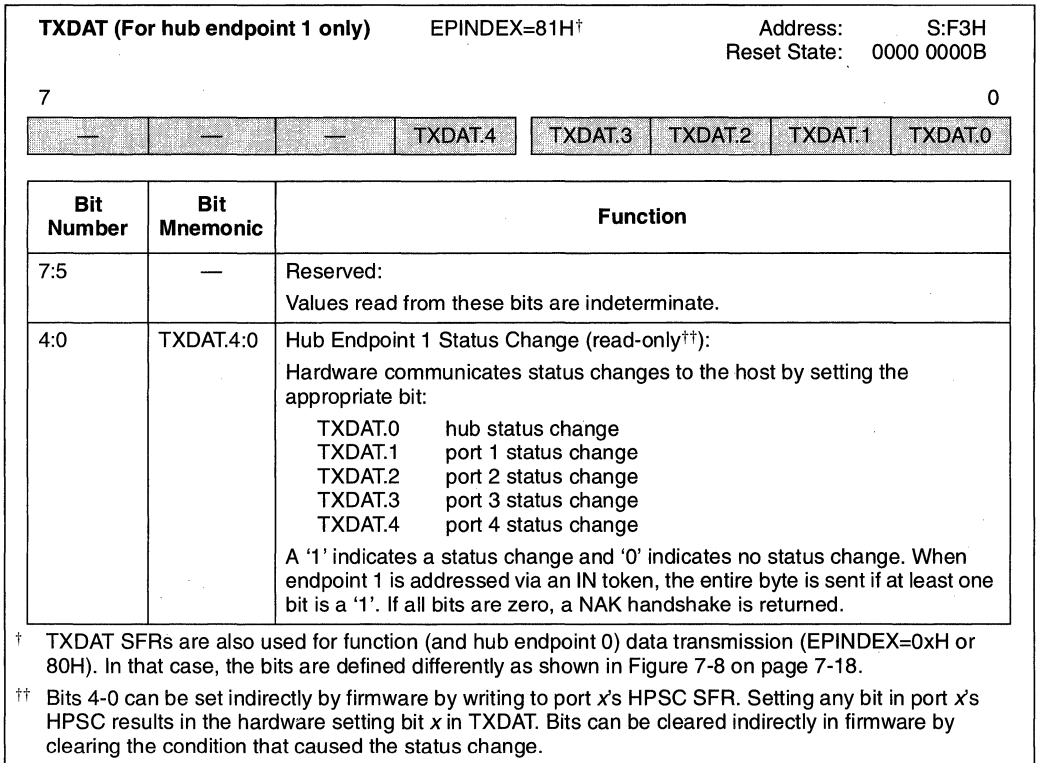


Figure 8-6. TXDAT: Hub Transmit Data Buffer (Endpoint 1)

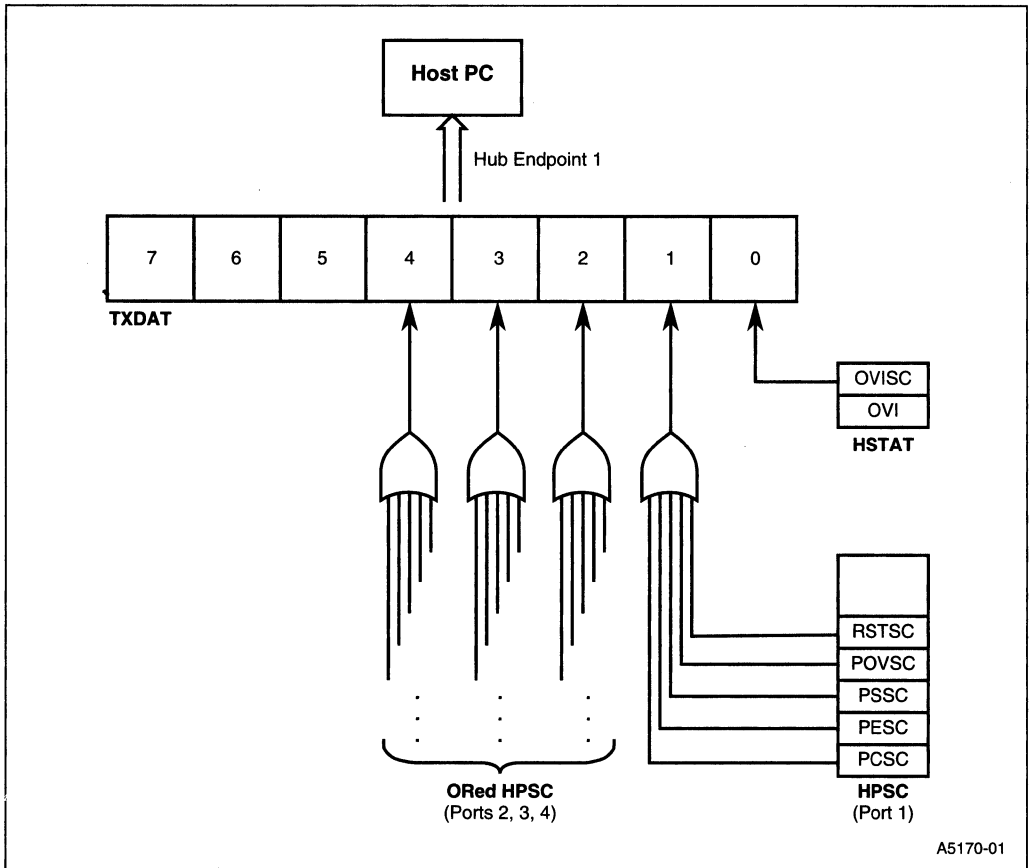


Figure 8-7. Status Change Communication To Host

The remaining hub transmit and receive registers communicate control information between the host and either the internal function or the downstream ports. The 8x930Hx communicates this control information through endpoint 0 using procedures identical to those outlined for the function control endpoint 0 (function endpoint 0) in “Transmit FIFOs” on page 7-15 and “Receive FIFOs” on page 7-24.

NOTE

Hub endpoint 0’s TX SFRs (e.g., TXDAT, TXCNTL, TXFLG, and TXSTAT) behave identically to their function counterparts. For example, when firmware writes to endpoint 0’s TXDAT, hardware automatically transfers the byte into the transmit FIFO before the next write to TXDAT. Placing the byte count into hub endpoint 0’s TXCNTL prepares the bytes to be transmitted from the FIFO through hub endpoint 0 at the next IN token.

8.5 USB HUB PORTS

In addition to the root port (port 0) and the embedded function addressed by port 4, the hub contains three external downstream ports, ports 1 through 3.

8.5.1 Controlling a Port Using HPCON

You can change a port's status by writing an encoded hub port control command to the hub port control register (HPCON, as shown in Figure 8-8). All four ports can be controlled by HPCON using the HPINDEX SFR for indexing. See "Hub Port Indexing Using HPINDEX" on page 8-23 for a description of how port indexing works. Table 8-6 on page 8-16 gives a complete description of the encoded hub port control commands. The 8x930Hx hardware can also change the status of a port, and some port features (i.e., low-speed/full-speed and connect/disconnect) can only be changed by hardware.

8x930Hx hardware ignores certain USB port requests if the request has no meaning within the context of the current port state. For example, there is no need to activate power to a port that is enabled, disabled, or suspended, because a port in one of these states already has power applied. An activate power request (SetPortFeature with a port power feature selector) is supported for a given port only when that port is in the powered-off state. For all other states, the request is ignored by hardware. Table 8-5 depicts the state-related USB requests and the port states for which they are ignored. Upon receipt of a state-related USB request, firmware must examine the HPSTAT SFR to determine the current port state. If the port is in a state where the request will be ignored by hardware, firmware must respond to the host by sending a STALL during the transaction status stage to indicate the command was not completed. Port states are discussed in "Port Connectivity States" on page 8-3 and shown in Figure 8-2 on page 8-4.

Table 8-5. USB Requests Ignored by Hardware (by Port State)

USB Request	Response by Port State [indicated by bit in HPSTAT]				
	Powered-Off [PPSTAT = 0]	Disconnected [PCSTAT = 0]	Disabled [PESTAT = 0]	Enabled [PESTAT = 1]	Suspended [PSSTAT = 1]
SetPortFeature (Port Power)		Ignored	Ignored	Ignored	Ignored
ClearPortFeature (Port Power)	Ignored				
SetPortFeature (Port Enable)	Ignored	Ignored		Ignored	Ignored
ClearPortFeature (Port Enable)	Ignored	Ignored	Ignored		Ignored
SetPortFeature (Port Reset)	Ignored	Ignored			
SetPortFeature (Port Suspend)	Ignored	Ignored	Ignored		Ignored
ClearPortFeature (Port Suspend)	Ignored	Ignored	Ignored	Ignored	

After you request a port status change through HPCON, it may take the 8x930Hx hardware a period of time to affect the change, depending on the current state of the hub port and its current operation. You can check the HPSC SFR to see that your latest change has taken effect, as described in “Monitoring Port Status Change Using HPSC” on page 8-20.

NOTE

Port connect status cannot be changed through HPCON. This port feature is controlled by physically connecting or disconnecting a device from the port.

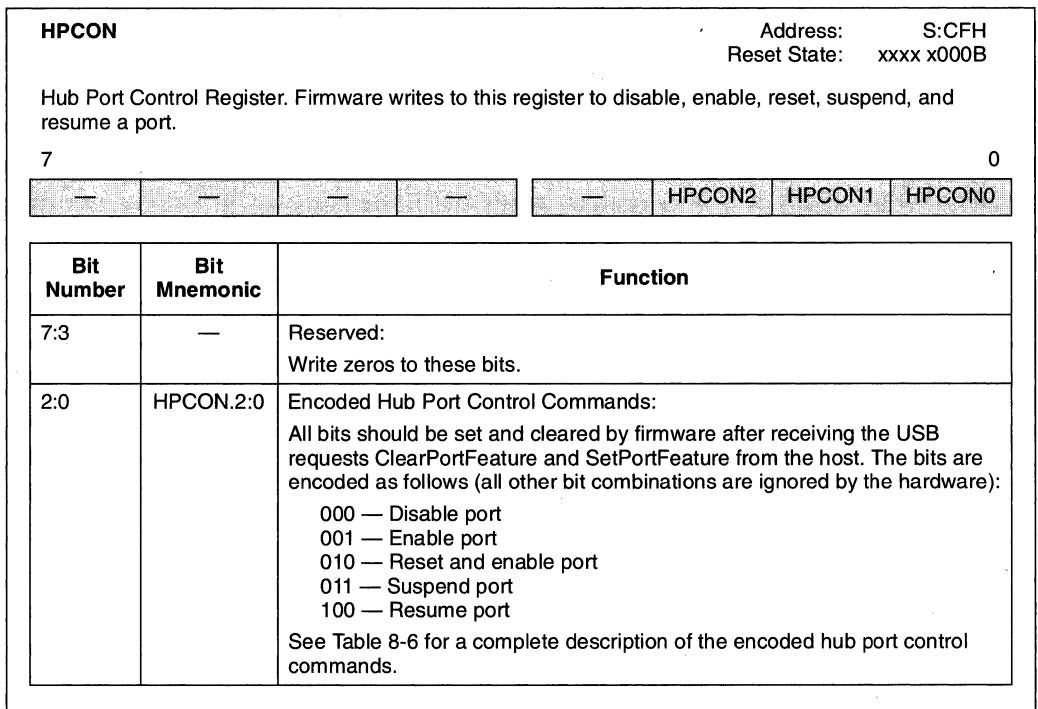


Figure 8-8. HPCON: Hub Port Control Register

Port 4 represents the internal downstream port and differs from the three downstream ports. The internal downstream port is always connected (and cannot be disconnected). Hub port control commands have a different effect on port 4 than they do on the external downstream ports, as shown in Table 8-6.

Table 8-6. Encoded Hub Port Control Commands

Code	Command	Condition	Results [Port x (x=1,2,3)]	Results [Port 4]
000	Disable port	Firmware should write '000' to HPCON upon receipt of a ClearPortFeature with a PORT_ENABLE feature selector.	Places port in the disabled state the next time the bus is idle.	Same
001	Enable port	Firmware should write '001' to HPCON upon receipt of a SetPortFeature with a PORT_ENABLE feature selector.	Places port in the enabled state the next time the bus is idle.	Same
010	Reset and enable port	Firmware should write '010' to HPCON upon receipt of SetPortFeature with PORT_RESET feature selector.	Causes port x to immediately drive an SE0 downstream for at least 15 msec and then places the port in the enabled state.	Causes an internal hardware reset of the FIU and FIFO circuitry relating to the embedded function. Certain embedded function SFRs are reset to their default values (as listed in "Embedded Function Reset" on page 8-24). After at least 15 ms, hardware automatically places the port in the enabled state. Firmware should handle reset of any other firmware and hardware features relating to the embedded function immediately after initiating the reset and enable through this SFR (must be complete by 15 ms from start of reset).
011	Suspend port	Firmware should write '011' to HPCON upon receipt of SetPortFeature with PORT_SUSPEND feature selector.	Places the port in an idle "J" state the next time the bus is idle and prevents the port from propagating USB traffic.	Suspends the embedded function's port the next time the bus is idle, preventing port 4 from generating any USB traffic. Firmware should suspend port 4 only after doing any necessary processing (i.e., putting any external components in a low-power state) to place the embedded function into a suspended state.
100	Resume port	Firmware should write '100' to HPCON upon receipt of ClearPortFeature with PORT_SUSPEND feature selector.	Causes port x to immediately drive a "K" state downstream for at least 20 msec followed by a low-speed EOP, and then places the port back in the enabled state.	Places port 4 into the enabled state after 20 ms. Firmware should resume port 4 only after doing any necessary processing to take the embedded function out of the suspended (low-power) state.

8.5.2 Examining a Port's Status Using HPSTAT

You can examine a port's status using the hub port status register (HPSTAT, as shown in Figure 8-9 on page 8-18). The HPSTAT SFR can show the status for any of the four ports by using the HPINDEX SFR for indexing. See "Hub Port Indexing Using HPINDEX" on page 8-23 for a description of how this indexing works.

HPSTAT gives the current D_p and D_m values for the selected port; these implement the Get Bus State diagnostic aid to facilitate system debug (See the *Universal Serial Bus Specification*). HPSTAT contains a bit that indicates when a low-speed device is attached to a port. HPSTAT also shows a given port's reset status, and whether the port is powered on or off, connected or disconnected, enabled or disabled, or suspended.

NOTE

Firmware-initiated port status changes are not reflected in HPSTAT until the next end-of-frame.

The HPSTAT SFR is read-only. To change the status of a port feature, you must do so indirectly using the HPCON SFR. The 8x930Hx hardware can also change the status of a port, and some features can only be changed by hardware. See "Controlling a Port Using HPCON" on page 8-14.

HPSTAT

Address: S:D7H
Reset State: 0x00 0100B

Hub Port Status Register. This register indicates the current status for a port, including power, reset, suspend, low-speed device, enable, connect, D_p , and D_M status.

7

0

DPSTAT	DMSTAT	LSSTAT	PPSTAT	PRSTAT	PSSTAT	PESTAT	PCSTAT
--------	--------	--------	--------	--------	--------	--------	--------

Bit Number	Bit Mnemonic	Function
7	DPSTAT	<p>D_p Status (read-only):</p> <p>Value of D_p for port x at end of last frame. Firmware must return this bit in response to a GetBusState request from the host.</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware at the EOF2 point near the end of a frame (used for diagnostics).</p> <p>Port 4: Hard-wired to '1', since there is no D_p signal for the embedded port</p>
6	DMSTAT	<p>D_M Status (read-only):</p> <p>Value of D_M for port x at end of last frame. Firmware must return this bit in response to a GetBusState request from the host.</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware at the EOF2 point near the end of a frame (used for diagnostics).</p> <p>Port 4: Hard-wired to '0', since there is no D_M signal for the embedded port.</p>
4	PPSTAT	<p>Port Power Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware based on the present power status of the port, as controlled either by firmware using the HPPWR register, or by an overcurrent condition in hardware. '1' = port x is powered on. '0' = port x is powered off. The port x power status is only sampled at the EOF2 point near end-of-frame.</p> <p>Port 4: Hard-wired to '1', since the internal function is always powered-on.</p>
5	LSSTAT	<p>Low-speed Device Attach Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware upon detection of the presence or absence of a low-speed device at the EOF2 point near end-of-frame. '1' = low-speed device is attached to port x. '0' = full-speed device is attached to port x.</p> <p>Port 4: Hard-wired to '0' (full-speed), since port 4 is permanently attached to the embedded USB function.</p>

NOTES:

Firmware returns the bits of this register in the first word of the 8x930Hx' response to the host's GetPortStatus request. See "GetPortStatus Request Firmware" on page 9-24.

Overcurrent indication is not represented on a per-port basis because the 8x930Hx supports ganged power control and overcurrent indication.

Figure 8-9. HPSTAT: Hub Port Status Register

HPSTAT (Continued)

Address: S:D7H
Reset State: 0x00 0100B

Hub Port Status Register. This register indicates the current status for a port, including power, reset, suspend, low-speed device, enable, connect, D_p, and D_M status.

7

0

DPSTAT	DMSTAT	LSSTAT	PPSTAT	PRSTAT	PSSTAT	PESTAT	PCSTAT
--------	--------	--------	--------	--------	--------	--------	--------

Bit Number	Bit Mnemonic	Function
3	PRSTAT	<p>Port Reset Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware as a result of initiating a port x reset by writing to HPCON. '1' = reset signaling is currently asserted for port x. '0' = reset signaling is not asserted. Sampled only at the EOF2 point near end of frame.</p> <p>Port 4: Same as port x.</p>
2	PSSTAT	<p>Port Suspend Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware as controlled by firmware via HPCON. '1' = port x is currently suspended. '0' = not suspended. Sampled only at the EOF2 point near end of frame.</p> <p>Port 4: Same as port x.</p>
1	PESTAT	<p>Port Enable/Disable Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware as controlled by firmware via HPCON. '1' = port x is currently enabled. '0' = port is disabled. Sampled only at the EOF2 point near end of frame.</p> <p>Port 4: Same as port x.</p>
0	PCSTAT	<p>Port Connect Status (read-only):</p> <p>Port x connect status from previous frame time.</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware after sampling the connect state at EOF2 near the end of the present frame. '1' = device is present on port x. '0' = device is not present. This bit will be set if either a physical connection is detected, or during a hub reset when a downstream device is already connected. This bit will be cleared if a disconnect is detected.</p> <p>Port 4: Hard-wired to '1', since the internal function is permanently connected.</p>

NOTES:

Firmware returns the bits of this register in the first word of the 8x930Hx' response to the host's GetPortStatus request. See "GetPortStatus Request Firmware" on page 9-24.

Overcurrent indication is not represented on a per-port basis because the 8x930Hx supports ganged power control and overcurrent indication.

Figure 8-9. HPSTAT: Hub Port Status Register (Continued)

8.5.3 Monitoring Port Status Change Using HPSC

When firmware changes the status of a port, there may be a delay between the time firmware requests the status change (using the HPCON register, as described in “Controlling a Port Using HPCON” on page 8-14) and the time hardware actually changes the state. This occurs because some port changes require hardware to perform auxiliary functions (such as driving a state downstream for up to 20ms). Additionally, some status changes are initiated by hardware. Firmware can determine when a port status change has occurred by monitoring the HPSC register (Figure 8-10 on page 8-21).

NOTE

Firmware-initiated port status changes are not reflected in HPSC until the next end-of-frame.

The 8x930Hx uses the 1-byte TXDAT register associated with endpoint 1 to communicate a port status change to the host (Figure 8-6 on page 8-12). Bits in this register are set by the 8x930Hx hardware to indicate which ports (or the hub itself) have changed status.

After receiving notification of a port status change through endpoint 1, the host may request additional information regarding the status change using a GetPortStatus request. 8x930Hx firmware must respond to the GetPortStatus request by transmitting the contents of the HPSTAT and HPSC registers to the host in a two-word format. This process is described in “GetPortStatus Request Firmware” on page 9-24.

The HPSC register (Figure 8-10) indicates which port feature has changed status. Port features whose status changes are reflected by HPSC include reset, suspend, enable, and connect.

HPSC		Address: S:D5H	
		Reset State: xxx0 000B	
<p>Hub Port Status Change Register. This register indicates a change in status for a port, including over-current, reset, suspend, enable and connect status.</p>			
7	0		
—	—	—	RSTSC
—	—	PSSC	PESC
—	—	—	PCSC

Bit Number	Bit Mnemonic	Function
7:5	—	Reserved: Write zeros to these bits.
4	RSTSC	<p>Reset Status Change (read-, clear-only):</p> <p>This bit is cleared in firmware via the USB host request ClearPortFeature with a C_PORT_RESET feature selector. '1' indicates reset of port complete; '0' indicates no change.</p> <p>Port x ($x=1,2,3$): This bit is set by hardware approximately 10 msec after receipt of a port reset and enable command (SetPortFeature with PORT_RESET feature selector).</p> <p>Port 4: This bit is set by hardware at the EOF2 point near the end of a frame after completion of the hardware-timed reset due to firmware execution of a port reset and enable command (SetPortFeature with PORT_RESET feature selector).</p>
3	—	Reserved: Write a zero to this bit.
2	PSSC	<p>Port Suspend Status Change (read-, clear-only):</p> <p>This bit is cleared by firmware upon a USB host request ClearPortFeature with C_PORT_SUSPEND feature selector. '1' = resume process complete; '0' = no change. The resume process is initiated by firmware upon reception of a SetPortFeature request with a PORT_SUSPEND feature selector.</p> <p>Port x ($x=1,2,3$): This bit is set by hardware upon completion of the firmware-initiated resume process.</p> <p>Port 4: This bit is set by hardware 20 msec after the next EOF2 point after completion of the resume process.</p>

NOTE: Bits are returned as part of the second word (2 bytes) in response to a Get Port Status request from the USB host. The upper 11 MSBs are reserved and always '0' per USB 1.0: 0000 0000 000.4.3.2.1.0 (MSB at left)

Figure 8-10. HPSC: Hub Port Status Change Register

HPSC (Continued)		Address: S:D5H Reset State: xxx0 0000B
Hub Port Status Change Register. This register indicates a change in status for a port, including over-current, reset, suspend, enable and connect status.		
7	0	
—	—	—
—	RSTSC	—
—	PSSC	—
—	PESC	—
—	PCSC	—

Bit Number	Bit Mnemonic	Function
1	PESC	Port Enable/Disable Status Change (read, clear-only): This bit's status does not change due to USB requests. This bit is cleared by firmware via the USB host request ClearPortFeature with a C_PORT_ENABLE feature selector. '1' indicates port enabled/ disabled status change; '0' indicates no change. Port x (x=1,2,3): This bit is set by hardware due to hardware events only (this bit indicates the port was disabled due to babble, physical disconnects, or overcurrent). Port 4: This bit is set by hardware at the EOF2 point near the end of frame due to hardware events only (e.g., the port was disabled due to babble).
0	PCSC	Port Connect Status Change (read-, clear-only): This bit is cleared by firmware via a USB host request ClearPortFeature with C_PORT_CONNECTION feature selector. '1' indicates connect status change; '0' indicates no change. Port x (x=1,2,3): This bit is set by hardware at the EOF2 point near the end of a frame due to hardware connects and disconnects. Port 4: This bit is set by hardware at the next EOF2 after completion of a hub reset (since the internal port is always connected).

NOTE: Bits are returned as part of the second word (2 bytes) in response to a Get Port Status request from the USB host. The upper 11 MSBs are reserved and always '0' per USB 1.0: 0000 0000 000.4.3.2.1.0 (MSB at left)

Figure 8-10. HPSC: Hub Port Status Change Register (Continued)

NOTE

While the HPSC register indicates which port features have changed status, it does not show the current status of any feature. Firmware must examine the HPSTAT register to determine if a given port is currently reset, suspended, powered on or off, connected or disconnected, enabled or disabled. See "Examining a Port's Status Using HPSTAT" on page 8-17 for details.

8.5.4 Hub Port Indexing Using HPINDEX

A port indexing scheme is used for port-specific SFRs for reasons similar to those described in “Endpoint Selection” on page 7-3 for endpoint-specific registers. Three sets of SFRs have been mapped into the port-indexed scheme: HPSC, HPSTAT, and HPCON.

Ports 1-4 are indexed by the binary value of the two lower bits of HPINDEX (Figure 8-11). Port 0 is reserved for the root port, but it is not indexed by HPINDEX since there are no port-specific SFRs for the root port.

CAUTION

Firmware writers may choose to set the contents of HPINDEX once at the start of each routine instead of writing to HPINDEX prior to each access of a port-indexed SFR. Because of this, interrupt service routines must save the contents of the HPINDEX register at the start of the routine and restore the contents at the end of the ISR. This will prevent HPINDEX from being corrupted.

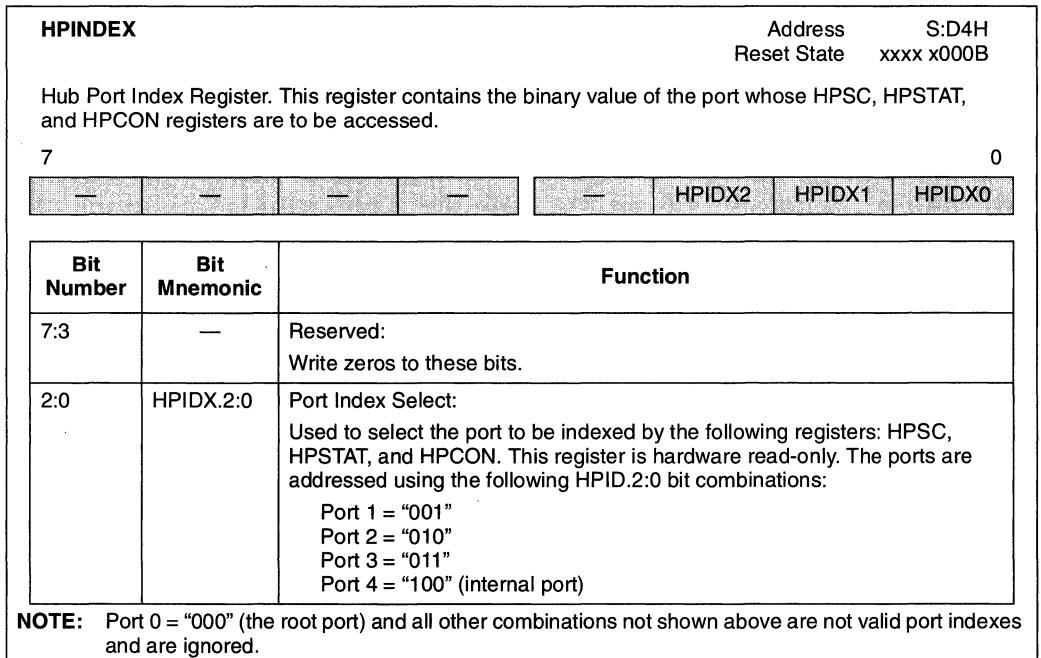


Figure 8-11. HPINDEX: Hub Port Index Register

8.5.5 Embedded Function

The following subsections discuss considerations involved with the embedded function on internal downstream port 4. See “Embedded Function Suspend and Resume” on page 8-26 for additional embedded function information.

8.5.5.1 Embedded Function Reset

The USB host can generate an embedded port reset command to the hub to reset the 8x930Hx' embedded function. When this command is received, the embedded function's EPCON, FIFLG, FIE, TXSTAT, RXSTAT, TXCON, RXCON, FADDR, and PCON1 SFRs are reset to their default values, as are the SOFACK, ASOF, SOFIE, and SOFODIS bits of SOFH. The EPINDEX and SOFL SFRs remain unchanged. These SFRs are reset immediately after the write to HPCON, however bus traffic to the embedded function remains inactive for 15 ms. You may use this time frame to initialize the embedded function.

After an embedded function reset, the internal function must be re-enumerated by the host. This procedure is given in “Unenumerated State” on page 9-2.

8.5.5.2 Embedded Function Remote Wake-up

The HRWUPE bit in HSTAT (Figure 8-5 on page 8-9) must be set in order for any downstream port to initiate resume signaling. This includes port 4, the internal downstream port. Port 4 must be suspended and the HRWUPE bit in HSTAT must be set before the embedded function can initiate a remote wake-up. This is done by setting the RWU bit in PCON1 (Figure 15-2 on page 15-4).

8.6 SUSPEND AND RESUME

8.6.1 Hub Global Suspend and Resume

USB requirements state that a USB device must be capable of being placed in a low-power suspend mode in which the device draws less than 500 μ A from the USB lines. The hub and the embedded function are placed in suspend mode when a continuous idle state of more than 3.0 msec is detected on the hub root port. For an in-depth discussion of 8x930 suspend and resume, see “USB Power Control” on page 15-8.

Once the suspend has been detected, the GSUS bit in the PCON1 SFR is set and a microcontroller interrupt is generated (See “USB Global Suspend/Resume Interrupt” on page 6-18).

Firmware services the global suspend interrupt by setting the PD bit of the PCON SFR. This shuts off the device's clocks and crystal oscillator, placing the hub and embedded function in a USB suspend mode.

A resume event can be signaled in any of three ways:

1. The hub repeater asynchronously detects a resume state due to resume signaling or a connect/disconnect on the bus
2. The hub repeater detects a reset state on the bus' root port
3. An external interrupt powers-up the entire device, with a resume sequence initiated in firmware by setting the RWU bit in the PCON1 SFR (Figure 15-2 on page 15-4)

NOTE

Do not initiate a remote wake-up (by setting the RWU bit in PCON1) prior to 5ms after the last bus activity is detected (2ms after the 8x930Hx is suspended).

8.6.2 Remote Connectivity

During the suspend state of the hub, logical connectivity can also be established if a physical connection/disconnection is made on one of the downstream ports, or if a resume condition is signaled on a port, as shown in Figure 8-12 on page 8-26.

8.6.2.1 Resume Connectivity

The HRWUPE bit must be set in the HSTAT register (Figure 8-5 on page 8-9) before the connect or disconnect of a downstream device can initiate a remote wake-up. If this bit is not set, the downstream connect or disconnect will be ignored as a remote wake-up event. If a remote wake-up device signals a resume on a downstream port when the hub is in the suspend state (see Figure 8-12), the following process occurs:

1. The resume signaling causes the hub to wake up.
2. The repeater then establishes a connection from the port with the resume signal to the root port and all other enabled downstream ports.
3. The connectivity is then changed to downstream-only from the root port to all enabled downstream ports. This allows the host to drive the resume signaling downstream to the rest of the USB bus.

NOTE

The 8x930Hx hub cannot request a remote wake-up, although its embedded function can. For this to happen, the HRWUPE bit must be set in HSTAT and the embedded function must be enabled. The embedded function triggers the remote wake-up by setting the RWU bit in PCON1.

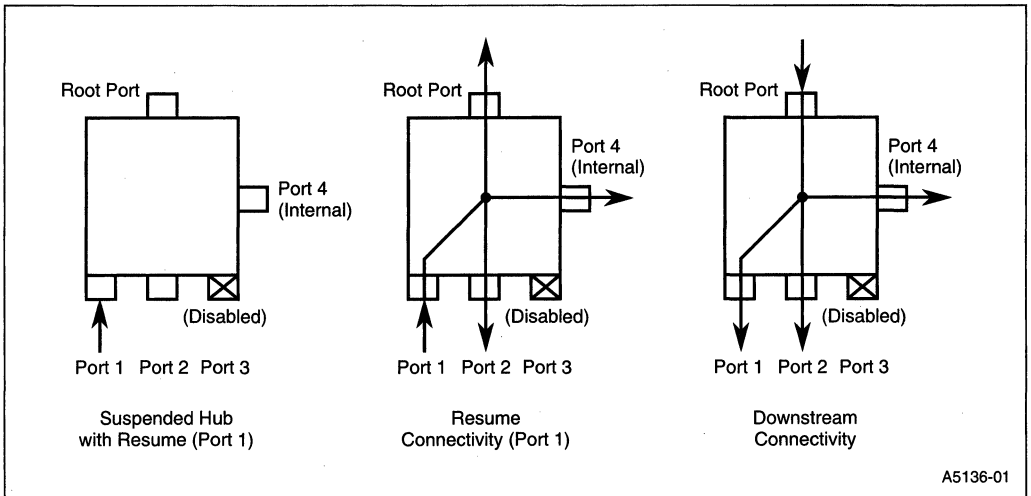


Figure 8-12. Resume Connectivity

8.6.2.2 Connectivity Due to Physical Connect/Disconnect

If a disconnect is made to a disabled port and the hub is in a global suspend state, a resume state is signaled as described in “Resume Connectivity” on page 8-25.

8.6.3 Embedded Function Suspend and Resume

Selective suspend is initiated on a downstream port when a SetPortFeature (suspend) command is received from the host via the USB bus. Individual external ports or the internal port can be suspended by USB command; however, the hub cannot be suspended by command. Refer to *Universal Serial Bus Specification* for more detail on the behavior of selective suspend in the USB system.

USB requirements state that the host can suspend the embedded function by issuing a SetPortFeature (PORT_SUSPEND) request to the hub's port 4. Since the hub and function share hardware such as the SIE, it is not possible to simply shut-off the clock to all circuitry associated with the function when the hub is to remain operational.

When placed into the suspended state, the embedded function must behave as if it were connected to a hub whose actual downstream port was suspended. This means that the embedded function must not respond to SOFs or any normal bus traffic. This is done automatically by hardware. Firmware should place any external circuitry associated with the embedded function in a low-power state, if one exists. The embedded function should remain in this suspended state until the host initiates a ClearPortFeature (PORT_SUSPEND) or a SetPortFeature (PORT_RESET) request to the hub, or until a remote wake-up is signaled by the embedded function via an external interrupt.

8.7 HUB POWER DISTRIBUTION

USB hubs can supply a specified amount of power to their downstream components and are responsible for reporting their power distribution capabilities to the host during enumeration. Hubs may be either locally powered, bus powered, or a combination of the two. The distinction is made depending on how the user implements the power scheme at the board level, which should be indicated in the value of the `bmAttributes` field of the configuration descriptor.

A hub can only supply power in a downstream direction and must never drive power upstream. Bus-powered hubs must have port power switching for the downstream ports and are required to power off all downstream ports when the hub comes out of power-up or when it receives a reset on its root port. Port power can also be switched on or off under control of the host PC. Port power switching is optional for self-powered devices.

NOTE

Port power switching and over-current detection (discussed in the following subsections) are mutually exclusive. Over-current detection is required only for self-powered hubs, while port power switching is required only for bus-powered hubs.

8.7.1 Port Power Switching

Port power switching is only supported on a ganged basis, therefore there is only one output pin used to enable power to the downstream devices.

From a USB perspective, power can be enabled on a per-port basis, but the power enable is active if any of the three ports are powered-on by the host. The host PC can selectively switch power on or off for a given port using a `Set_Feature` request with a `Port_Power` feature selector. The 8X930Hx firmware must respond to this port power request by setting or clearing the appropriate bit in the `HPPWR` SFR (Figure 8-13). An exception to this is the internal downstream port, Port 4, which is statically powered-on. The host PC may inquire about a port's power status using `Get_Feature (Port_Power)`. Firmware must respond to this inquiry by checking and reporting on the `PPSTAT` bit (bit 4) of `HPSTAT` (on page 8-19).

HPPWR		Address: S:9AH
		Reset State: xxx1 000xB
Hub Port Power Control Register. This register is used to control power to the hub's downstream ports.		
7		0
—	—	—
—	HPPWR.4	HPPWR.3 HPPWR.2 HPPWR.1 —
Bit Number	Bit Mnemonic	Function
7:5	—	Reserved: The value read from these bits is indeterminate. Write zeros to these bits.
4	HPPWR.4	Port Power Control Register for USB Port 4 (read-only): Port 4 is an internal port and is always powered on. This bit is hard-wired to '1.'
3:1	HPPWR.3.1	Port Power Control Register for USB Ports 1-3: Bit 3 is power control for port 3, bit 2 for port 2, and bit 1 for port 1. These bits are set and cleared by firmware via a USB host request SetPortFeature with the PORT_POWER feature selector. These bits will also be cleared by hardware upon detection of an over-current condition. This is done to prevent oscillation of the UPWEN# pin during an over-current condition with bus-powered devices. A value of '1' enables power to the downstream port and puts the port in a disconnected state. A value of '0' turns the downstream port power off. NOTE: The UPWEN# pin is set to '1' only if all three port power enable bits (bits 3:1) are '0,' due to the use of a ganged (shared) power enable scheme.
0	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.

Figure 8-13. HPPWR: Hub Port Power Control

8.7.2 Overcurrent Detection

The OVRI# pin is an input pin that indicates when an overcurrent condition has been detected on one of the downstream devices at the board level. It is used to asynchronously disable the UPWEN# output pin, which switches power off to all three external ports. When the overcurrent condition is removed, the OVRI# pin is deasserted to a '1' state; however, the UPWEN# signal remains inactive since the HPPWR3:1 bits are reset when an overcurrent condition is detected (*unless* firmware has asserted one or more of these bits since the time the overcurrent was first detected). Due to the asynchronous nature of this signal, the user must be careful to guarantee that the OVRI# input is not "glitchy" or noisy, since glitches on this signal could have a detrimental impact on the system.

The state of the OVRI# pin can be read by the USB host via firmware, using the HSTAT (Figure 8-5 on page 8-9) OVI (HSTAT.1 — latest overcurrent indicator) and OVISC (HSTAT.3 — hub overcurrent status change) bits. OVI indicates if the overcurrent bit is presently asserted ('0') or

de-asserted ('1'). OVISC indicates whether the overcurrent status has changed since this bit was first cleared by firmware (i.e., this bit acts as a “sticky” bit which must be cleared in firmware).

Another fact to consider about the overcurrent condition is that all external ports are placed in the “powered off” state. This is true for both bus-powered and self-powered ports, even though self-powered ports may still be powered. This condition will remain until the host enables power to the ports via one of the HPPWR.3:1 bits.

8.7.3 Ganged Power Enable

The 8x930Hx uses a ganged power enable scheme to enable power to the three external downstream ports. This means that a single output pin, UPWEN# (pin 60) should be used at the board-level to switch power to all three of the downstream ports. The state of this power enable pin is controlled in two ways:

- by the collective ORed value of bits 3:1 of the HPPWR SFR (Figure 8-13) under control of firmware, and
- by the present state of the overcurrent sense input pin, OVRI# (pin 59).

If any of the HPPWR[3:1] bits are set, then the UPWEN# signal will be asserted (to a '0') as long as the OVRI# signal is not asserted (i.e., OVRI # = '1'). If the OVRI# signal is asserted ('0'), or if all three of the power enable bits in HPPWR are cleared, then the UPWEN# signal will be deasserted (to a '1').

Table 8-7 describes the state of the UPWEN# signal for all conditions of the HPPWR[3:1] signals and the OVRI# pin. Port power enable bits in the HPPWR SFR (Figure 8-13 on page 8-28) are set via the SetPortFeature PORT_POWER request from the USB host. They are cleared via the ClearPortFeature PORT_POWER request, or by hardware upon detection of an overcurrent condition.

Table 8-7. UPWIN# Pin State Truth Table

HPPWR.3	HPPWR.2	HPPWR.1	OVRI#	UPWEN#
0 (disabled)	0 (disabled)	0 (disabled)	1 (disabled)	1 (disabled)
X	X	1	1	0 (enabled)
X	1	X	1	0
1	X	X	1	0
X	X	X	0 (enabled)	1

Since a single power enable output is used for three ports, the value of the corresponding HPPWR bit does *not* necessarily reflect the actual state of the port power, since all three bits must be disabled for power to be disabled. Similarly, a '1' bit in the HPPWR SFR might not reflect that power is actually enabled to any devices in the event of an overcurrent condition.

Note that the power enable signal for the internal port, HPPWR (for port 4), does not affect the state of the UPWEN# pin. Also, note that bus-powered devices *must* use the UPWEN# signal to switch power to downstream ports, however, port power switching for self-powered devices is optional.

NOTE

Before the UPWEN# pin can be enabled, the EPIEN bit in the HSTAT SFR (Figure 8-5 on page 8-9) must be set. See Section 11.9 of the *Universal Serial Bus Specification*.

8.8 HUB DEVICE SIGNALS

Table 8-8 lists device signals associated with the hub. Pin assignments are shown in Appendix B.

Table 8-8. Signal Descriptions

Signal Name	Type	Description	Alternate Function
D _{P0} , D _{M0}	I/O	USB (Upstream) Port 0. D _{P0} and D _{M0} are the data plus and data minus lines of differential USB port 0. These lines do not have internal pullup resistors. For low-speed devices, provide an external 1.5 K Ω pullup resistor at D _{M0} . For full-speed devices, provide an external 1.5 K Ω pullup resistor at D _{P0} . NOTE: For the 8x930Hx, provide an external 1.5 K Ω pullup resistor at D _{P0} so the device indicates to the host that it is a full-speed device.	—
D _{P1} , D _{M1}	I/O	USB (Downstream) Port 1. D _{P1} and D _{M1} are the voltage plus and voltage minus lines of differential USB port 1. You must supply an external 15 K Ω pulldown resistor for these lines.	—
D _{P2} , D _{M2}	I/O	USB (Downstream) Port 2. D _{P2} and D _{M2} are the voltage plus and voltage minus lines of differential USB port 2. You must supply an external 15 K Ω pulldown resistor for these lines.	—
D _{P3} , D _{M3}	I/O	USB (Downstream) Port 3. D _{P3} and D _{M3} are the voltage plus and voltage minus lines of differential USB port 3. You must supply an external 15 K Ω pulldown resistor for these lines.	—



9

USB Programming Models



CHAPTER 9

USB PROGRAMMING MODELS

This chapter describes the programming models of the USB function interface and the hub interface. It provides flow charts of firmware routines needed to perform data transfers between the host PC and the embedded function, as well as routines needed to handle hub-oriented USB requests. It also describes briefly how the firmware interacts with the USB module hardware during these operations. Data operations refer to data transfers over the USB, whereas event operations are hardware operations such as attach and detach. For a description of the USB function interface as well as its FIFOs and special functions registers (SFRs), refer to Chapter 7, “USB Function.” For further information about the USB hub interface, see Chapter 8, “USB Hub.” For details on data flow in USB transactions refer to Appendix D.

Section 9.1 through section 9.5 discuss programming models for the 8x930Ax. These models also apply to the embedded function of the 8x930Hx. Section 9.6 contains the hub programming models for the 8x930Hx.

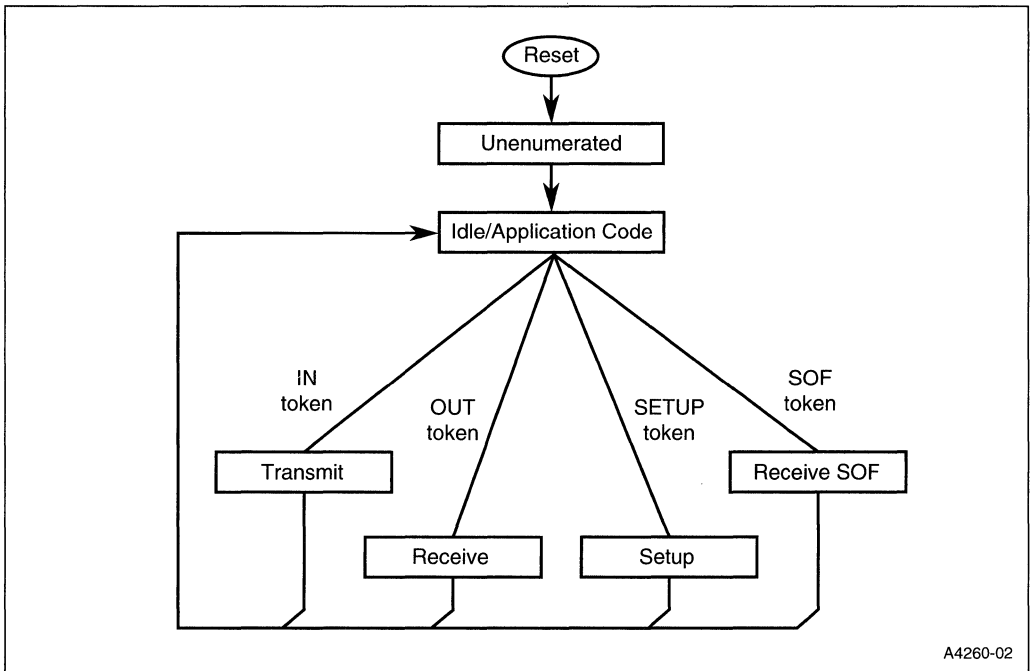


Figure 9-1. Program Flow

9.1 OVERVIEW OF PROGRAMMING MODELS

The USB function interface employs four types of routines: receive, transmit, setup, and receive SOF. Program flow is depicted in Figure 9-1 along with the type of token associated with each routine. Following device reset, the USB function enters the unenumerated state and after enumeration by the host, the idle state. From the idle state, it can enter any of the four routines.

9.1.1 Unenumerated State

Following device reset, the USB function enters the unenumerated state. Initially, the function address register FADDR contains the default value 00H. The host PC performs bus enumeration in which it identifies and addresses devices attached to the bus. During enumeration, a unique address assigned by the host is written to FADDR.

NOTE

Although the 8x930Hx performs the following enumeration process for its embedded function, this process is only part of a larger enumeration process for the hub. 8x930Hx firmware must perform the hub enumeration process outlined in “Bus Enumeration” on page 9-16 before performing the following process.

The 8x930Ax bus enumeration process has four steps:

1. Get descriptor. The host requests and reads the device descriptor to determine such information as device class, USB specification compliance level, maximum packet size for endpoint 0, vendor id, product id, etc. For detailed information on device descriptors, see the “Device Framework” chapter in *Universal Serial Bus Specification*.
2. Set address. The host sends the 8x930's function address in a data packet using function endpoint 0. Device firmware interprets the data and instructs the CPU to write the function address to FADDR.
3. Get configuration. The host requests and reads the device configuration descriptor to determine such information as the number of interfaces and endpoints; endpoint transfer type, packet size, and direction; power source; maximum power; etc. For detailed information on configuration descriptors, see the “Device Framework” chapter in *Universal Serial Bus Specification*. When the host requests the configuration descriptor, all related interface and endpoint descriptors are returned.
4. Set configuration. The host assigns a configuration value to the device to establish the current configuration. Devices can have multiple configurations.

9.1.2 Idle State

Following bus enumeration, the USB function enters the idle state. In this state, the 8x930 executes application code associated with the embedded function. Upon receipt of a token with the assigned address, the module enters the designated routine. The 8x930 remains in the idle state when not processing USB transmissions.

9.1.3 Transmit and Receive Routines

When the 8x930 is sending and receiving packets in the transmit and receive modes, its operation depends on the type of data that is transferred—*isochronous* or *non-isochronous*—and the adjustment of the FIFO markers and pointers—*automatic* or *manual*. These differences affect both the 8x930 firmware and the operation of the 8x930 hardware. For *isochronous* data, a failed transfer is not retried (*lossy* data). For *non-isochronous* data, a failed transfer can be repeated. Data that can be repeated is considered *lossless* data. Automatic adjustment of the FIFO markers and pointers is accomplished by the function interface hardware. Manual adjustment is accomplished by the 8x930 firmware.

9.1.4 USB Interrupts

For an explanation of the USB global suspend/resume, function, hub, and SOF interrupts, see Chapter 6, “Interrupt System.”

9.2 TRANSMIT OPERATIONS

9.2.1 Overview

A transmit operation occurs in three major steps:

1. Pre-transmit data preparation by firmware
2. Data packet transmission by function interface hardware
3. Post-transmit management by firmware

These steps are depicted in a high-level view of transmit operations (Figure 9-2). The pre-transmit and post-transmit operations are executed by the two firmware routines shown on the left side of the figure. Function interface hardware (right side of the figure) transmits the data packet over the USB line. Details of these operations are described in “Pre-transmit Operations” on page 9-6 and “Post-transmit Operations” on page 9-7.

Transmit operations for *non-isochronous* data begin with an interrupt request from the embedded function (e.g., a keyboard entry). The pre-transmit routine (ISR) for the function writes the data from the function to the transmit FIFO where it is held until the next IN token. Upon receipt of the next valid IN token, the function interface shifts the data out of the FIFO and transmits it over the USB. If the data packet is not ready for transmission, 8x930 hardware responds to the IN token with a NAK. The post-transmit routine checks the transmission status and performs data management tasks.

Completion of data transmission is indicated by a handshake returned by the host. This is then used to generate a transmit done interrupt to signal the end of data transmission to the CPU. The interrupt can also be used for activity tracking and fail-safe management. Fail-safe management permits recovery from lockups that can only be cleared by firmware.

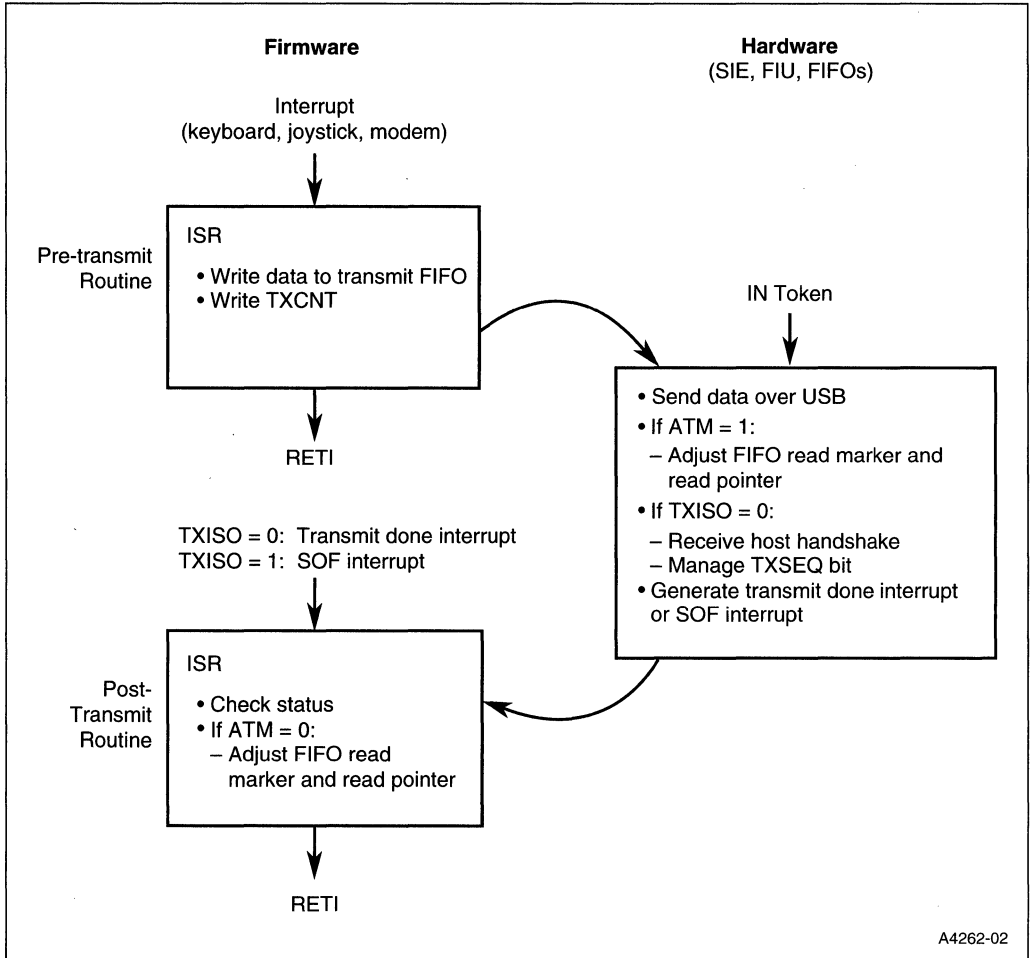
Because a transmit done interrupt is generated regardless of transmission errors, this condition means either:

1. The transmit data has been transmitted and the host has sent an acknowledgment to indicate that it was successfully received; or
2. A transmit data error occurred during transmission of the data packet, which requires servicing by firmware to be cleared. You must check for these conditions and respond accordingly in the ISR.

For ISO data transmission, the cycle is similar. The significant differences are: the cycle is initiated by a start-of-frame (SOF) interrupt, there is no handshake associated with ISO transfer, and a transmit done interrupt is not generated. For ISO data transfers, the transaction status is updated at the end of the USB frame. The 8x930 supports one ISO packet per frame per endpoint.

Two bits in the transmit FIFO control register (TXCON, Figure 7-12 on page 7-24) have a major influence on transmit operation:

- The TXISO bit (TXCON.3) determines whether the transmission is for isochronous data (TXISO = 1) or non-isochronous data (TXISO = 0). For non-isochronous data only, the function interface receives a handshake from the host, toggles or does not toggle the sequence bit, and generates a transmission done interrupt (Figure 9-2). Also, for non-isochronous data, the post-transmit routine is an ISR; for isochronous data the post-transmit routine is an ISR initiated by an SOF token.
- The ATM bit (TXCON.2) determines whether the FIFO read marker and read pointer are managed automatically by the FIFO hardware (ATM = 1) or manually by the second firmware routine (ATM = 0). Use of the ATM mode is recommended. The ADVRM and REVRP bits, which control the read marker and read pointer when ATM = 0, are used primarily for test purposes. See bit definitions in TXCON (Figure 7-12).



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Figure 9-2. High-level View of Transmit Operations

9.2.2 Pre-transmit Operations

Transmitted data originates in the embedded function, which might be a keyboard, mouse, joystick, scanner, etc. In event-control applications, the end function signals the availability of data with an interrupt request for the pre-transmit interrupt service routine (ISR). The ISR should prepare the data for transmission and initiate the transmission process. The flow chart in Figure 9-3 illustrates a typical pre-transmit ISR.

For the case of isochronous data, the interrupt is triggered by the USB function in response to a start-of-frame (SOF) packet.

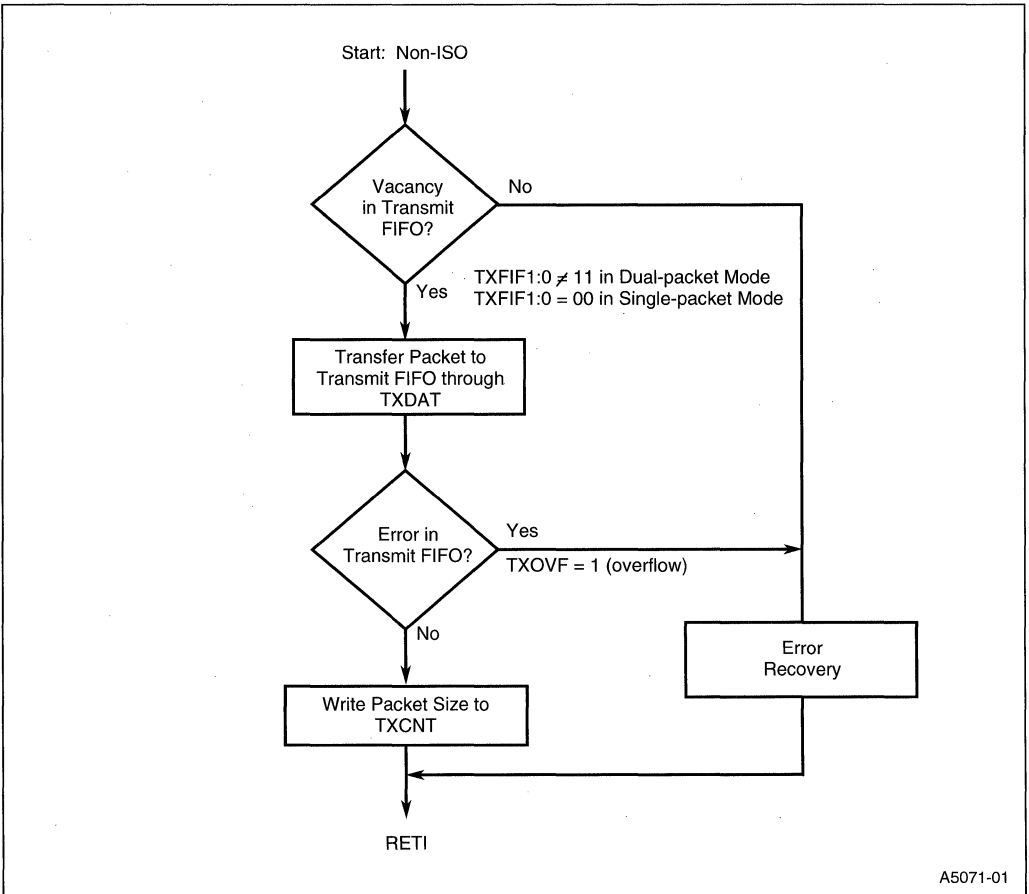


Figure 9-3. Pre-transmit ISR (Non-Isochronous)

9.2.3 Post-transmit Operations

Transmission status is updated at the end of data transmission based on the handshake received from the host (non-isochronous data) or based on the transmission process itself (isochronous data). For a non-isochronous transfer, the function interface generates a transmit done interrupt. The purpose of the post-transmit service routines is to manage the transmitter's state and to ensure data integrity for the next transmission. For isochronous data, the post-transmit routine should be embedded within the transfer request routine because both are triggered by an SOF. The flow of operations of typical post-transmit ISRs is illustrated in Figure 9-4 (non-isochronous data) and Figure 9-5 (isochronous data).

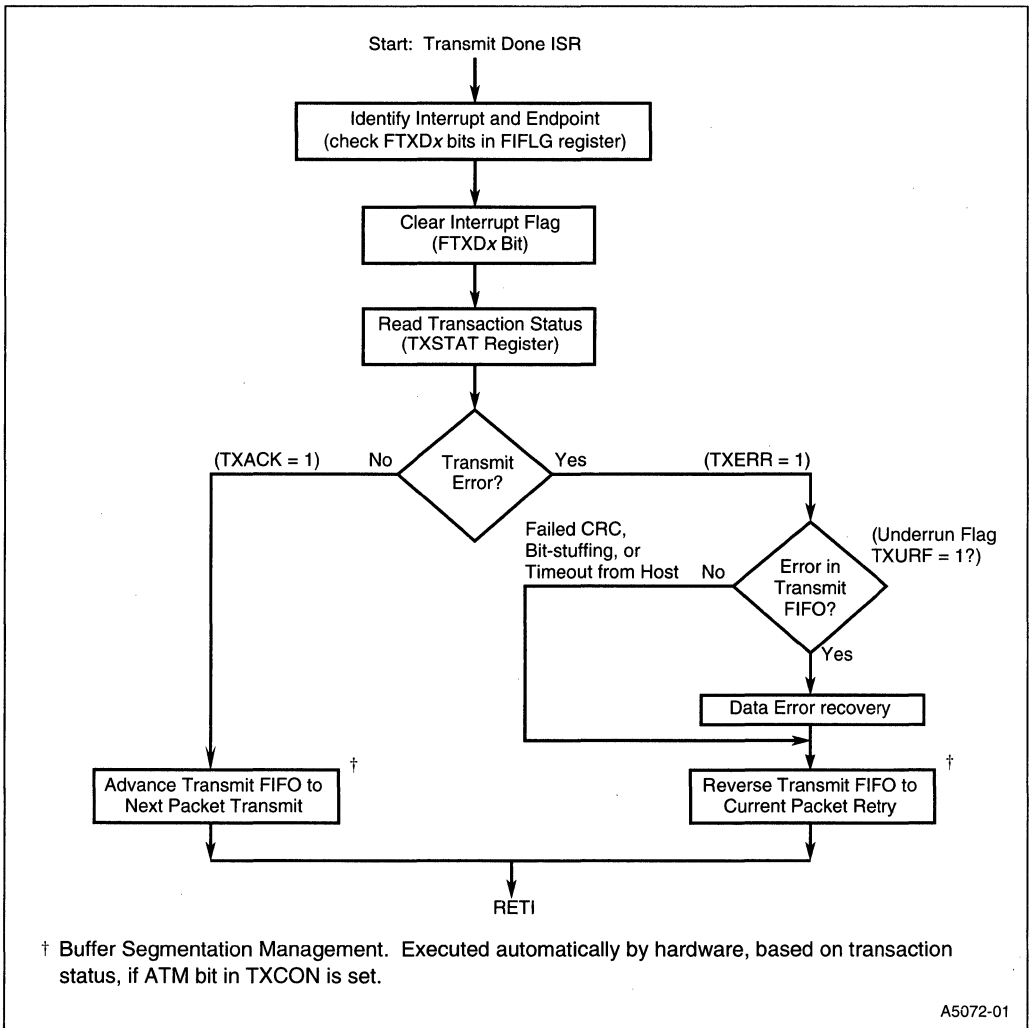


Figure 9-4. Post-transmit ISR (Non-isochronous)

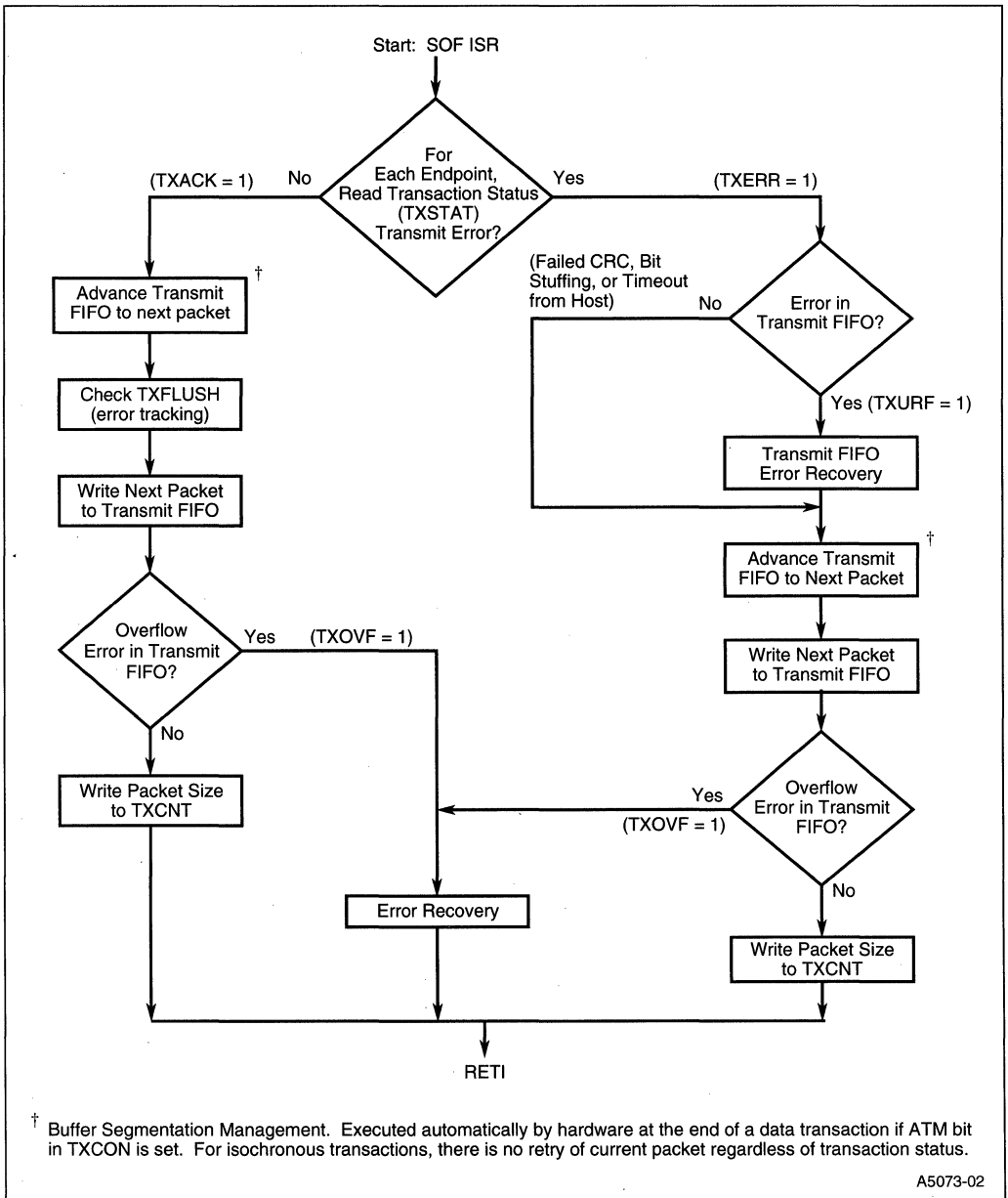


Figure 9-5. Post-transmit ISR (Isochronous)

9.3 RECEIVE OPERATIONS

9.3.1 Overview

A receive operation is always initiated by the host, which sends an OUT token to the 8x930. The operation occurs in two major steps:

1. Data packet reception by the function interface (hardware)
2. Post-receive management by firmware

These steps are depicted in a high-level view of the receive operations in Figure 9-6. The post-receive operations are executed by the firmware routine shown on the left side of the figure. For details see “Post-receive Operations” on page 9-10. Function interface hardware (right side of figure) receives the data packet over the USB line.

Receive operations for non-isochronous data begin when the 8x930 receives a valid OUT token from the host. The received data is written to a data buffer FIFO. The 8x930 indicates completion of data received by returning a handshake to the host.

At the end of the receive cycle, the 8x930 generates a receive done interrupt to notify the CPU that a receive operation has occurred. Program execution branches to the interrupt service routine and transfers the data packet from the receive FIFO to its destination. The interrupt can also be used for fail-safe management and activity tracking.

For isochronous data, receive cycles are somewhat different. Data transactions are initiated by an OUT token. At the end of the OUT transaction, the 8x930Ax does not return handshake to the host and the receive done interrupt is not generated. Instead, the SOF interrupt is used for post receive management. The data reception status is updated at the next SOF. The 8x930 supports one ISO packet per frame per endpoint.

Two bits in the receive FIFO control register (RXCON, Figure 7-15 on page 7-29) have a major influence on receive operation:

- The ISO bit (RXCON.3) determines whether the reception is for isochronous data (ISO = 1) or non-isochronous data (ISO = 0). For non-isochronous data only, the function interface sends a handshake to the host, checks the sequence bit, and generates a receive-done (FRXD_x) interrupt. Also, for non-isochronous data, the post-receive routine is an ISR; for isochronous data the post-receive routine can be a normal subroutine or ISR initiated by an SOF token.
- The ARM bit (RXCON.2) determines whether the FIFO write marker and write pointer are managed automatically by the FIFO hardware (ARM = 1) or manually by the firmware routine (ARM = 0). Use of the ARM mode is recommended. The ADVWM and REVWP bits, which control the write marker and write pointer when ARM = 0, are used primarily for test purposes. See bit definitions in RXCON (Figure 7-15).

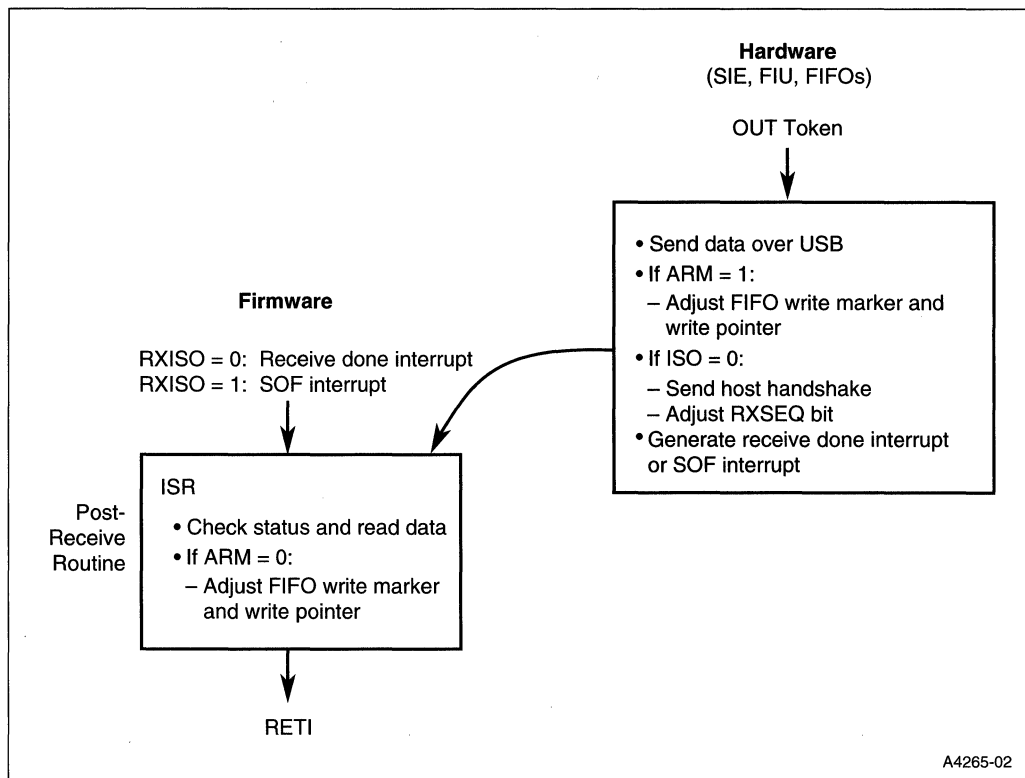


Figure 9-6. High-level View of Receive Operations

9.3.2 Post-receive Operations

Reception status is updated at the end of data reception based on the handshake received from the host (non-isochronous data) or based on the transmission process itself (isochronous data). For a non-isochronous transfer, the function interface generates a receive done interrupt (FRXD_x). The purpose of the post-receive service routine is to manage the receiver's state to ensure data integrity and latency for the next reception. The post-receive routine also transfers the data in the receive FIFO to the end function. For isochronous data, the post-receive routine should be called by the SOF ISR.

Flow diagrams for typical post-receive routines are presented in Figure 9-7 (non-isochronous data) and Figure 9-8 (isochronous data).

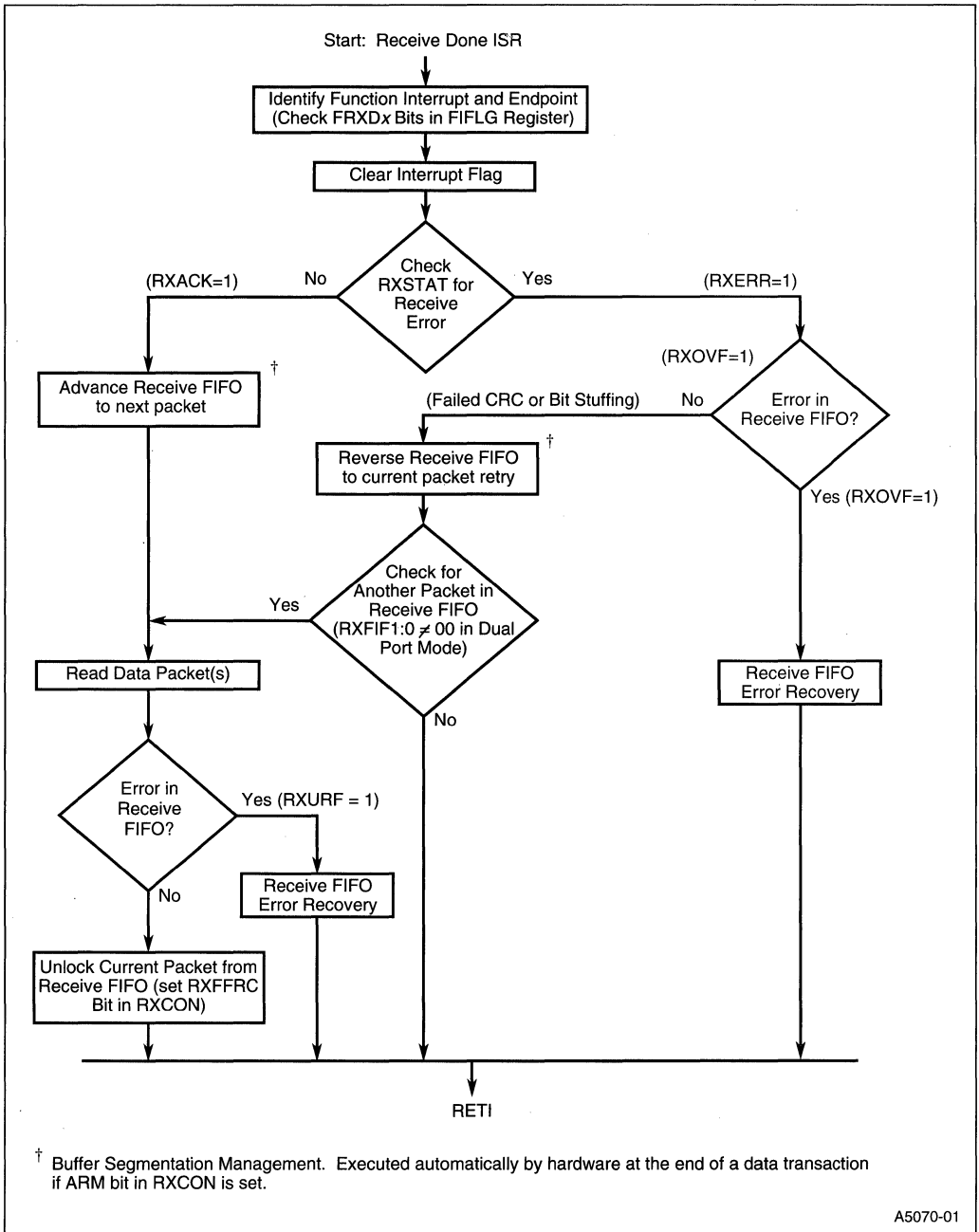


Figure 9-7. Post-Receive ISR (Non-isochronous)

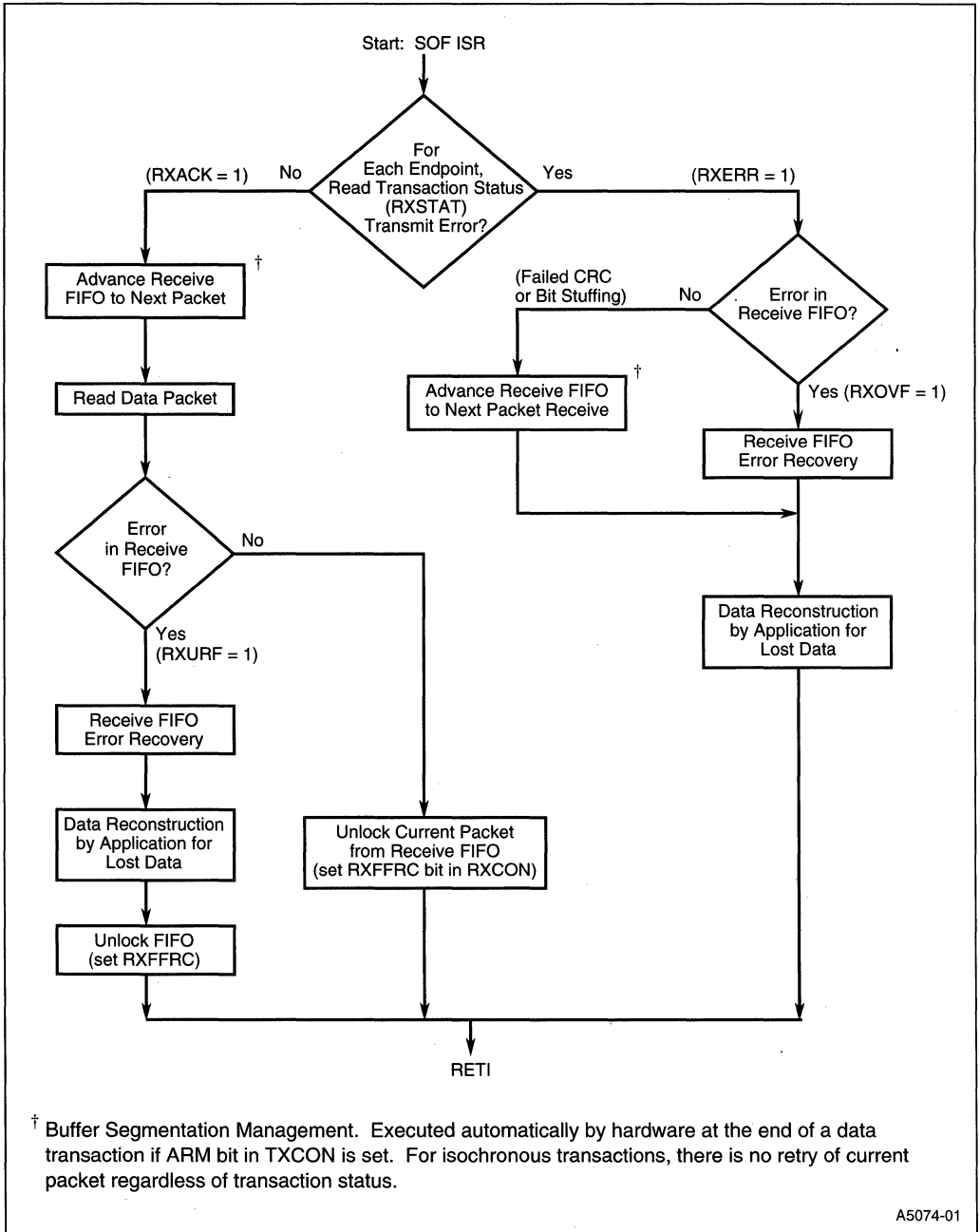


Figure 9-8. Receive SOF ISR (Isochronous)

9.4 SETUP TOKEN

An endpoint must be configured as a control endpoint in order to respond to SETUP tokens. (This will only be endpoint 0, since it must serve as a control endpoint.) Refer to the “Protocol Layer” section of the *Universal Serial Bus Specification* for details of SETUP token transactions and protocol.

A control data transfer is initiated by a valid SETUP token (i.e., the token PID received is good). Receive data transfer operations for a control endpoint are very similar to data transfers on non-control endpoints for non-setup tokens. However, the response of a control endpoint is different when it receives a setup token.

USB protocol specifies that setup tokens must be received and ACKed. Following receipt of a setup token, a control endpoint flushes the contents of the receive FIFO before writing it with received setup data. This may create an error condition in the FIFO due to the asynchronous nature of FIFO reads by the CPU and simultaneous writes by the function interface. To prevent this, STOVW and EDOVW are used to track when an overwrite is occurring. When the overwrite is complete, the user must clear EDOVW to read the SETUP packet. If EDOVW is not cleared, user firmware will only be able to read the first byte of the SETUP packet. Figure 9-9 illustrates the operations of a typical post-receive routine for a control endpoint.

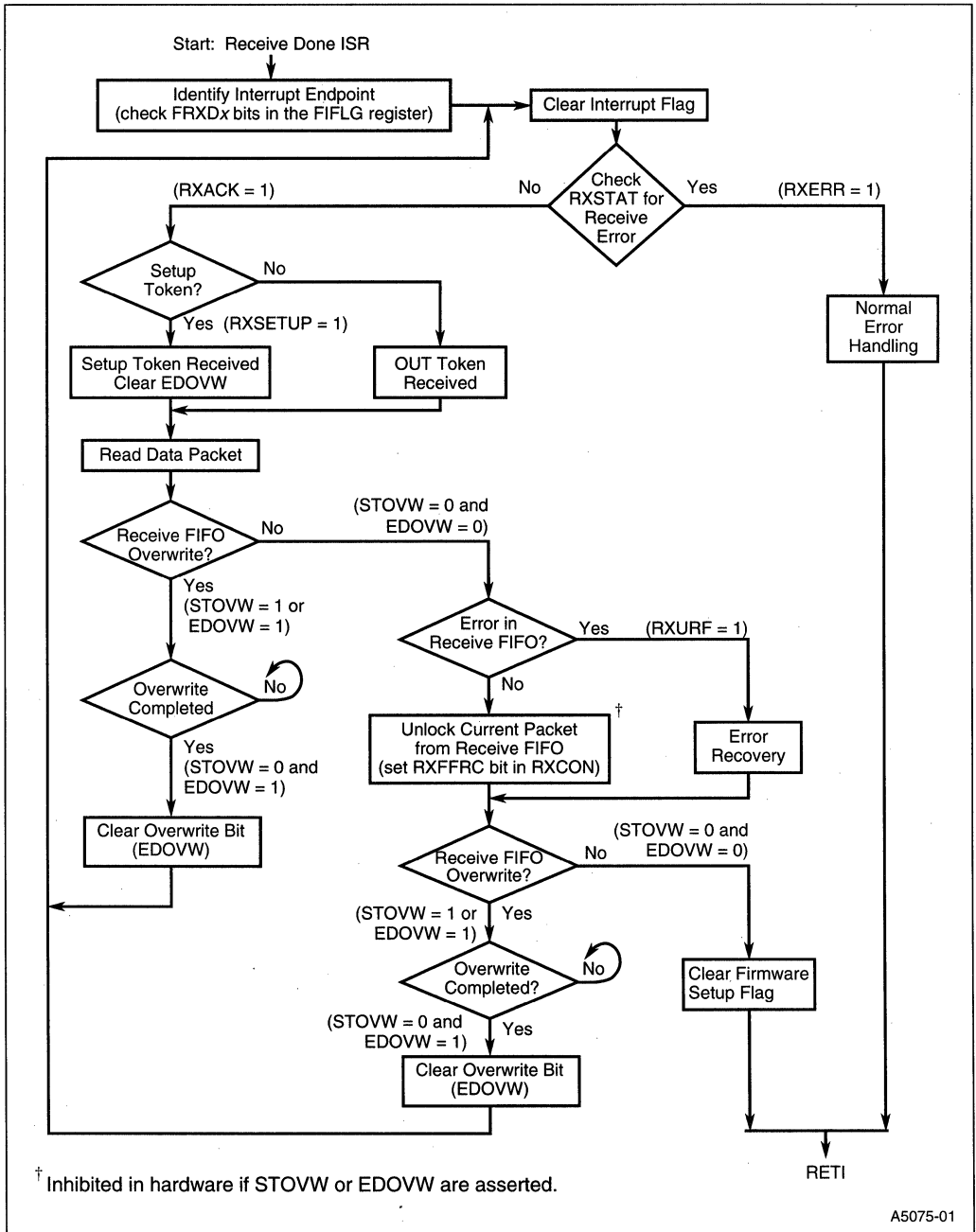


Figure 9-9. Post-receive ISR (Control)

9.5 START-OF-FRAME (SOF) TOKEN

Figure 9-10 illustrates the hardware operations performed by the function interface for a start-of-frame (SOF) token. The host issues an SOF token at a nominal rate of once every 1.0 ms. An SOF token is valid if the PID is good. The SOF token is not endpoint-specific; it should be received by every node on the bus.

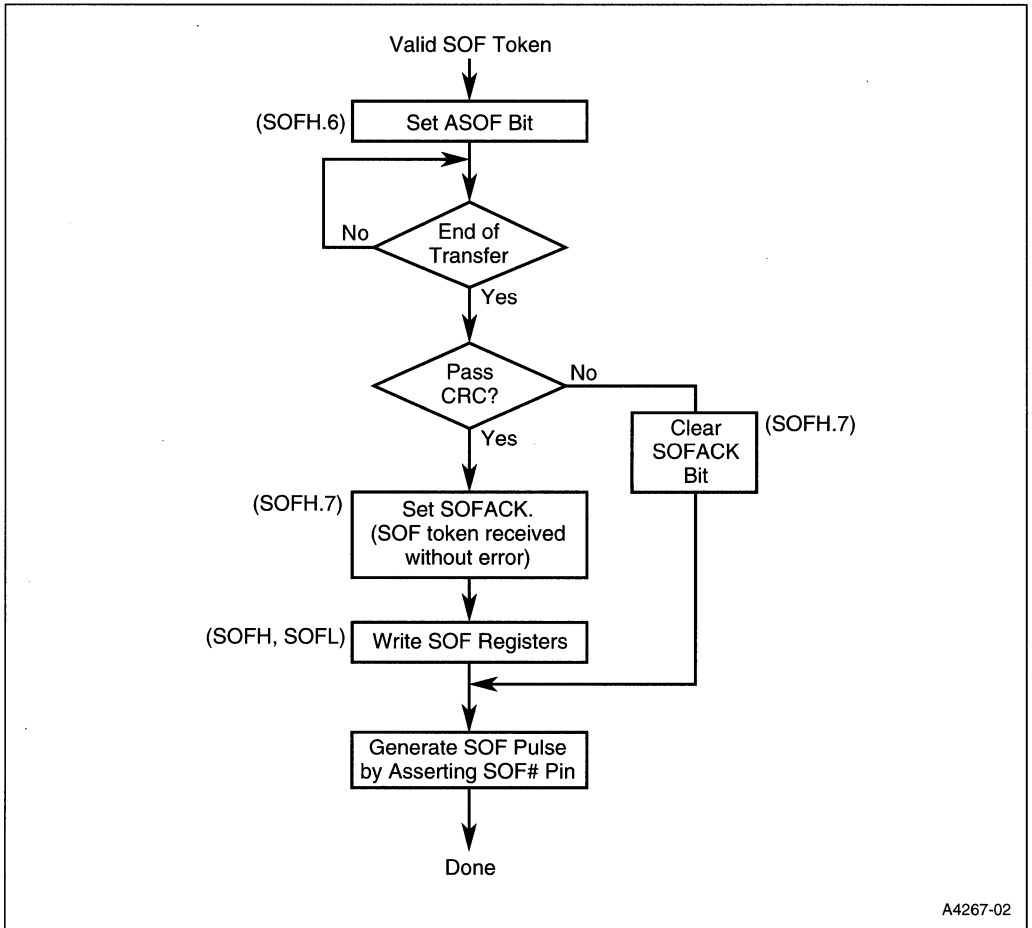


Figure 9-10. Hardware Operations for SOF Token

9.6 HUB OPERATION

The primary objective of the programming model suggested here is to explain the linkage between the hardware and firmware of the 8x930Hx in operation.

9.6.1 Bus Enumeration

The USB host manages bus enumeration at system start-up or whenever a new USB device is attached to the host or to a hub's downstream port. Initially, the USB hub is in the unenumerated state and the hub address register HADDR contains the default value 00H. The host PC performs bus enumeration in which it identifies and addresses devices attached to the bus. During enumeration, a unique address assigned by the host is written to the HADDR of the hub device. An example enumeration for the hub and downstream ports is given here:

1. Get device descriptor. The host requests and reads the device descriptor to determine such information as device class, USB specification compliance level, maximum packet size for endpoint 0, vendor id, product id, etc. For additional information on the 8x930Hx descriptors, see "Hub Descriptors" on page 8-6.
2. Set address. The host sends the 8x930Hx's hub address in a data packet using hub endpoint 0. Device firmware interprets the data and instructs the CPU to write the hub address to HADDR. See "The Hub Address Register (HADDR)" on page 8-8.
3. Get configuration descriptor. The host requests and reads the device's configuration descriptor to determine such information as the number of interfaces and endpoints; endpoint transfer type, packet size, and direction; power source; maximum power; etc. When the host requests the configuration descriptor, all related interface, endpoint, and hub descriptors are returned. For additional information on the 8x930Hx descriptors, see "Hub Descriptors" on page 8-6.
4. Set configuration. The host assigns a configuration value to the device to establish the current configuration.
5. Next, the hub downstream ports start the state flow shown in Figure 8-2 on page 8-4. The host issues a SetPortPowerFeature request to the downstream ports that were declared in the hub descriptor. This moves the hub downstream ports to the disconnect state.
6. As connect detects occur, the host is notified through hub endpoint 1 (status change endpoint). The host then issues a GetPortStatus command retrieving the contents of HPSTAT and HPSC to determine the change for a specific downstream port. The host then issues a ClearPortConnectionFeature command which should cause the firmware to clear the PCSC bit in the HPSC register. This will indirectly clear the appropriate bit in TXDAT for hub endpoint 1. This moves the hub downstream port to the disabled state.
7. The host sends a SetPortResetFeature request for the specified downstream port. The host receives a response through hub endpoint 1 (status change endpoint). The host issues a GetPortStatus command retrieving the contents of HPSTAT and HPSC to determine the change for the specified downstream port. The host then issues a ClearPortResetFeature command which should cause the firmware to clear the RSTSC bit in the HPSC register. This moves the hub downstream port to the enabled state.

8. At this point, the device connected to the downstream port goes through the enumeration process discussed in “Unenumerated State” on page 9-2 (i.e., GetDeviceDescriptor, SetAddress, GetConfigurationDescriptor, and SetConfiguration).
9. The remaining external ports must go through steps 6 through 8.

9.6.2 Hub Status and Configuration

USB communication with the USB hub function is performed via the standard and hub class-specific USB requests. These requests control status management and configuration of the hub and its downstream ports. Since the hub is part of a compound device, it has an internal downstream port (port 4) which is unique from the external downstream ports. This is because port 4 is physically connected to the embedded function and is powered-on at all times. Thus several USB requests intended for internal downstream port 4 are handled differently from similar requests to the other downstream ports, as shown in Table 8-6 on page 8-16.

Table 9-1 is a summary of firmware actions required for standard USB requests sent to hub endpoint 0.

Table 9-1. Firmware Actions for USB Requests Sent to Hub

USB Request	Feature Selector / Type	Firmware Action Required
SET_FEATURE	DEVICE_REMOTE_WAKEUP	Set the HRWUPE bit of the HSTAT SFR. See “Hub Status” on page 8-8.
	ENDPOINT_STALL	Stall the endpoint specified in the Setup PID. See “Hub Endpoint Control” on page 8-11. Endpoint 0 specified: 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set RXSTL and TXSTL bits of EPCON SFR. Endpoint 1 specified: Set EP1STL bit of HSTAT SFR.
CLEAR_FEATURE	DEVICE_REMOTE_WAKEUP	Clear HRWUPE bit of HSTAT SFR. See “Hub Status” on page 8-8.
	ENDPOINT_STALL	Cancel stall for the specified endpoint. See “Hub Endpoint Control” on page 8-11. Endpoint 0 specified: 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Clear RXSTL and TXSTL bits of EPCON SFR Endpoint 1 specified: Clear EP1STL bit of HSTAT SFR.
SET_CONFIGURATION	N/A	1. Store hub endpoint 1 configuration value from value field in memory 2. Set EP1EN bit of HSTAT SFR (Figure 8-5 on page 8-9) after the Status stage if 2-byte configuration value = 0001H
GET_CONFIGURATION	N/A	Read configuration value (one byte) from memory and send to the host.

Table 9-1. Firmware Actions for USB Requests Sent to Hub (Continued)

USB Request	Feature Selector / Type	Firmware Action Required
GET_DESCRIPTOR	Device	Read device descriptor from memory and transmit to USB host through hub endpoint 0.
	Configuration	Read configuration, interface, endpoint, and hub descriptors from memory and transmit to USB host through hub endpoint 0.
GET_INTERFACE	N/A	Optional request for hubs which is not supported. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
GET_STATUS	Device	Read HSTAT SFR bit HRWUPE (Figure 8-5 on page 8-9) and power configuration from memory and transmit to USB host using hub endpoint 0.
	Interface	Load 2 bytes of zero into transmit buffer and transmit to USB host. These bits are reserved in the initial version of USB.
	Endpoint	Endpoint 0 specified: Load transmit buffer with value of zero if endpoint 0 is not stalled. No data can be returned if endpoint 0 is stalled, since STALL will be transmitted instead. Endpoint 1 specified: Load value of EP1STL bit of HSTAT SFR into transmit buffer (Figure 8-5 on page 8-9).
SET_ADDRESS	N/A	Read address value contained in request value field and store in HADDR SFR (Figure 8-4 on page 8-8) after successful completion of control transaction status stage.
SET_DESCRIPTOR	N/A	Optional request for hubs which is not supported. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
SET_INTERFACE	N/A	Optional request for hubs which is not supported. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
SYNCH_FRAME	N/A	Optional request for hubs which is not supported. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage

Table 9-2 summarizes firmware action for hub class-specific USB requests.

NOTE

Upon receipt of a state-related USB request (i.e., SetPortFeature, ClearPortFeature), firmware must examine the HPSTAT SFR to determine the current port state. If the port is in a state where the request will be ignored by

hardware, instead of performing the action given in Table 9-2, firmware must respond to the host by sending a STALL during the transaction status stage to indicate the command was not completed. Table 8-5 depicts the state-related USB requests and the port states for which they are ignored. See “Controlling a Port Using HPCON” on page 8-14 for additional information.

Table 9-2. Firmware Action for Hub Class-Specific Requests

USB Requests	Feature Selector / Type / Index	Firmware Action Required
SetHubFeature	—	Unsupported request since there are no current feature selectors to match this request in the initial version of USB. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
ClearHubFeature	C_HUB_OVER_CURRENT	Clear HSTAT SFR bit OVISC (hub over-current status change bit). HSTAT is shown in Figure 8-5 on page 8-9.
	C_HUB_LOCAL_POWER	Unsupported request. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
GetBusState	Port 1,2,3 or 4	Transfer the port bus signal values (D_p and D_M) to the host for diagnostic purposes. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Transfer the DPSTAT and DMSTAT bits of HPSTAT (Figure 8-9 on page 8-18) to the transmit buffer of hub endpoint 0. Transmit these bits in a single byte, with DMSTAT as bit 0, DPSTAT as bit 1, and bits 2-7 as '0'.
GetHubDescriptor	N/A	Read hub descriptor from memory and transmit to USB host using hub endpoint 0.
SetHubDescriptor	N/A	Optional request for hubs which is not supported. 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
GetHubStatus	N/A	Communicate the hub over-current status change, local power status change, current-overcurrent indicator, and current local power status to the host: Load HSTAT bits OVISC and OVI into transmit buffer, with LPS as the Lsb. The HSTAT SFR is shown in Figure 8-5 on page 8-9.
GetPortStatus	Port 1,2,3 or 4	Load the HPSTAT and HPSC SFRs for hub port 1,2,3 or 4 into the transmit buffer. See “GetPortStatus Request Firmware” on page 9-24 for additional information, including bit ordering and a flowchart.

Table 9-2. Firmware Action for Hub Class-Specific Requests (Continued)

USB Requests	Feature Selector / Type / Index	Firmware Action Required
SetPortFeature	PORT_ENABLE	<p>Enables address and endpoint decoding for the downstream ports. For hub port 4, this enables address and endpoint decoding for the embedded function.</p> <ol style="list-style-type: none"> 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Write "001" to bits 2:0 of the port's HPCON SFR (Figure 8-8 on page 8-15)
	PORT_SUSPEND	<p>Write "011" to bits 2:0 of the port's HPCON SFR.</p> <p>If hub port 4 is specified, the user cannot suspend the embedded function without also suspending the hub. Firmware must suspend any non-hub functionality associated with the embedded function prior to writing to HPCON. This is done by placing any external device hardware into a low-power suspend mode.</p> <p>See "SetPortFeature (PORT_SUSPEND) Firmware" on page 9-26 for additional information and a flowchart.</p>
	PORT_RESET	<p>Write "010" to bits 2:0 of the port's HPCON SFR.</p> <p>If port 4 is specified, firmware needs to reset all non-hub functionality in the microcontroller. Upon writing to port 4's HPCON SFR, a hardware reset is generated to the FIU and function FIFOs. Firmware must gracefully shut-down the application code, peripherals, etc. prior to writing to port 4's HPCON. Once written, the reset will be active in hardware for 10-11 ms.</p> <p>See "SetPortFeature (PORT_RESET) Firmware" on page 9-27 for additional information and a flowchart.</p>
	PORT_POWER	<p>Set bit x of HPPWR (where x is the port specified in the request index field)</p> <p>Port power-on is also supported for port 4, but only for reasons of port compatibility since power for the embedded function cannot be switched (i.e., writing bit 4 of HPPWR does not affect any hardware).</p>

Table 9-2. Firmware Action for Hub Class-Specific Requests (Continued)

USB Requests	Feature Selector / Type / Index	Firmware Action Required
ClearPortFeature	PORT_ENABLE	Requests port disable. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Write "000" to bits 2:0 of the port's HPCON SFR (Figure 8-8 on page 8-15) For hub port 4, this will disable address and endpoint decoding for the embedded function.
	PORT_SUSPEND	Requests port resume. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Write "100" to bits 2:0 of the port's HPCON SFR (Figure 8-8 on page 8-15) If port 4 is specified, firmware must also resume any non-hub functionality associated with the embedded function prior to writing to port 4's HPCON. This requires taking any external device hardware out of a low-power suspend mode.
	PORT_POWER	Request port power off. If any port other than port 4 is specified: Clear bit x of HPPWR (where x is the port specified in the request index field) Port power off is not supported for port 4. If port 4 is specified: 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
	C_PORT_CONNECTION	Request to clear port connect status change. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Clear PCSC bit of HPSC SFR (Figure 8-10 on page 8-21)
	C_PORT_ENABLE	Request to clear hardware-initiated port enable/disable status change. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Clear PESCB bit of HPSC SFR (Figure 8-10 on page 8-21)
	C_PORT_SUSPEND	Request to clear port suspend status change. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Clear PSSC bit of HPSC SFR (Figure 8-10 on page 8-21)
	C_PORT_OVERCURRENT	Unsupported request to clear port over-current status change. The 8x930Hx implements over-current detection on a hub-wide basis, not on a per-port basis. If received: 1. Load 80H into EPINDEX (for hub endpoint 0) 2. Set TXSTL bit of EPCON SFR so STALL is sent during status stage
	C_PORT_RESET	Request to clear port reset status change. 1. Load xxxB into HPINDEX.2:0, where xxx is the binary representation of the port index 2. Clear RSTSC bit of HPSC SFR (Figure 8-10 on page 8-21)

9.6.3 Port Status Change Communication

The flowchart in Figure 9-11 shows how the hub communicates a change in port status to the host. This process involves 8X930Hx hardware, 8X930Hx firmware, and PC host firmware. The flowchart illustrates the complete process at a high level. The process contains the following steps:

1. Any change in a port's reset, suspend, enable, or connect status is communicated to the host via hub endpoint 1's TXDAT register, as shown in Figure 8-7 on page 8-13. The information passed through hub endpoint 1 is sufficient to indicate which port (or the hub itself) changed status, but it does not indicate which status value changed or the current value of any status indicator.

Firmware has no involvement with USB communication to hub endpoint 1 (status change endpoint 1). This communication is handled completely in hardware and is discussed in "USB Hub Endpoints" on page 8-10

2. After the host receives notice of a change in port status through hub endpoint 1, host firmware can determine which status value changed and the current value of all the port's status indicators by transmitting a GetPortStatus request through hub endpoint 0. This request includes a Port_Index to tell the 8X930Hx which port is of interest to the host. See the *Universal Serial Bus Specification* for additional information.
3. The host's GetPortStatus request triggers the 8x930Hx' GetPortStatus routine. The firmware response to the GetPortStatus request provides the host with the port's current status along with an indication of any status changes that have occurred. See "GetPortStatus Request Firmware" on page 9-24 for a complete description of this routine.
4. The host resets the port status change indicators by issuing a separate ClearPortFeature request for each bit in HPSC that showed a change. Each ClearPortFeature request will include one of the following feature selectors:
 - a. C_PORT_CONNECTION — to clear HPSC.PCSC
 - b. C_PORT_ENABLE — to clear HPSC.PESC
 - c. C_PORT_SUSPEND— to clear HPSC.PSSC
 - d. C_PORT_RESET — to clear HPSC.RSTSC
5. 8x930Hx firmware responds to each ClearPortFeature request by performing the actions shown in Table 9-2 on page 9-19.
6. Finally, the host must perform any actions necessitated by the status change.

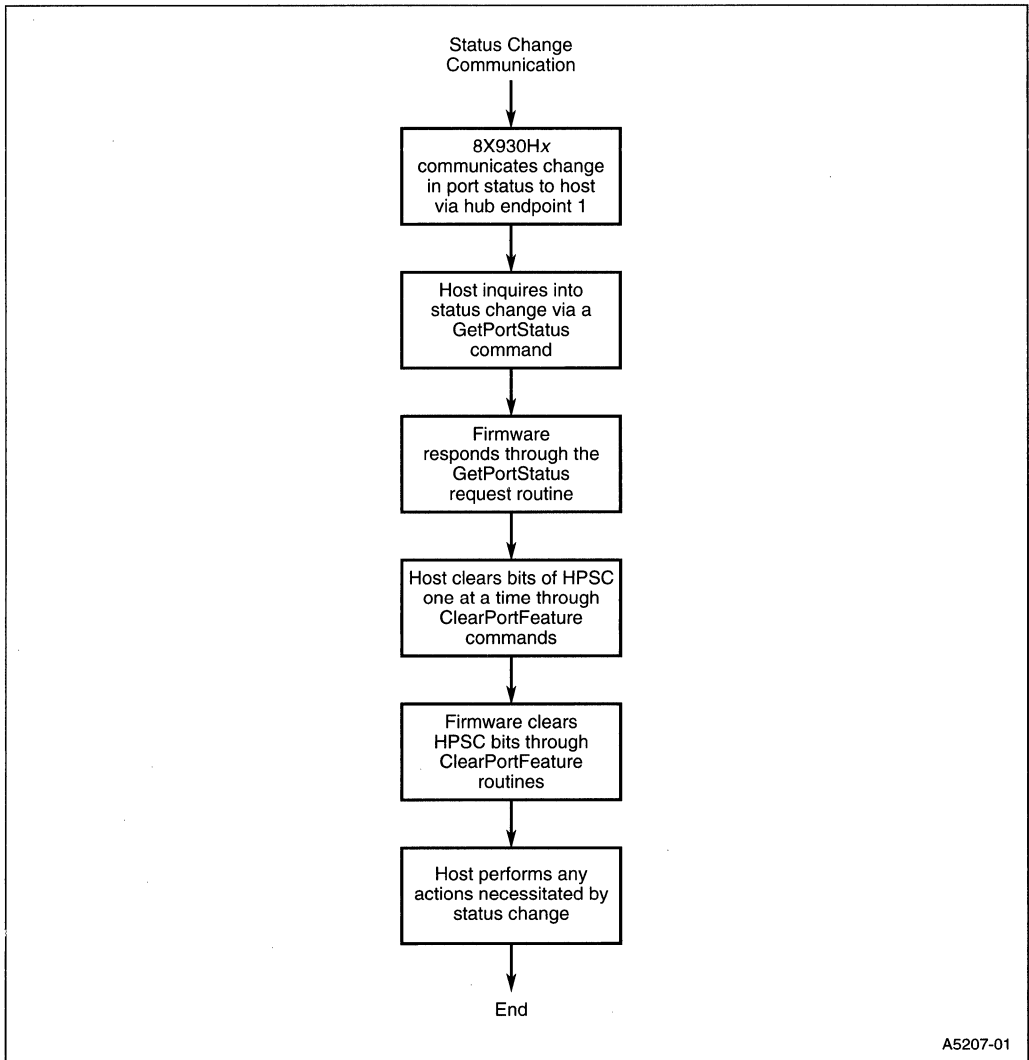


Figure 9-11. Hub-to-host Port Status Communication

9.6.4 Hub Firmware Examples

Several of the firmware routines given in Table 9-2 have been selected as examples. The remaining routines should be coded similarly. The following subsections contain a flowchart and an additional explanation for these routines:

- GetPortStatus (Port_Index)

- SetPortFeature (PORT_SUSPEND)
- SetPortFeature (PORT_RESET)

9.6.4.1 GetPortStatus Request Firmware

Firmware responds to a GetPortStatus call by returning four bytes to the host using the flowchart procedure shown in Figure 9-12. The four bytes are arranged into a two-byte port status field and a two-byte port change field containing the contents of the HPSTAT and HPSC SFRs, respectively. Figure 9-13 shows the relationship between the four bytes returned by firmware and the contents of the HPSTAT and HPSC registers.

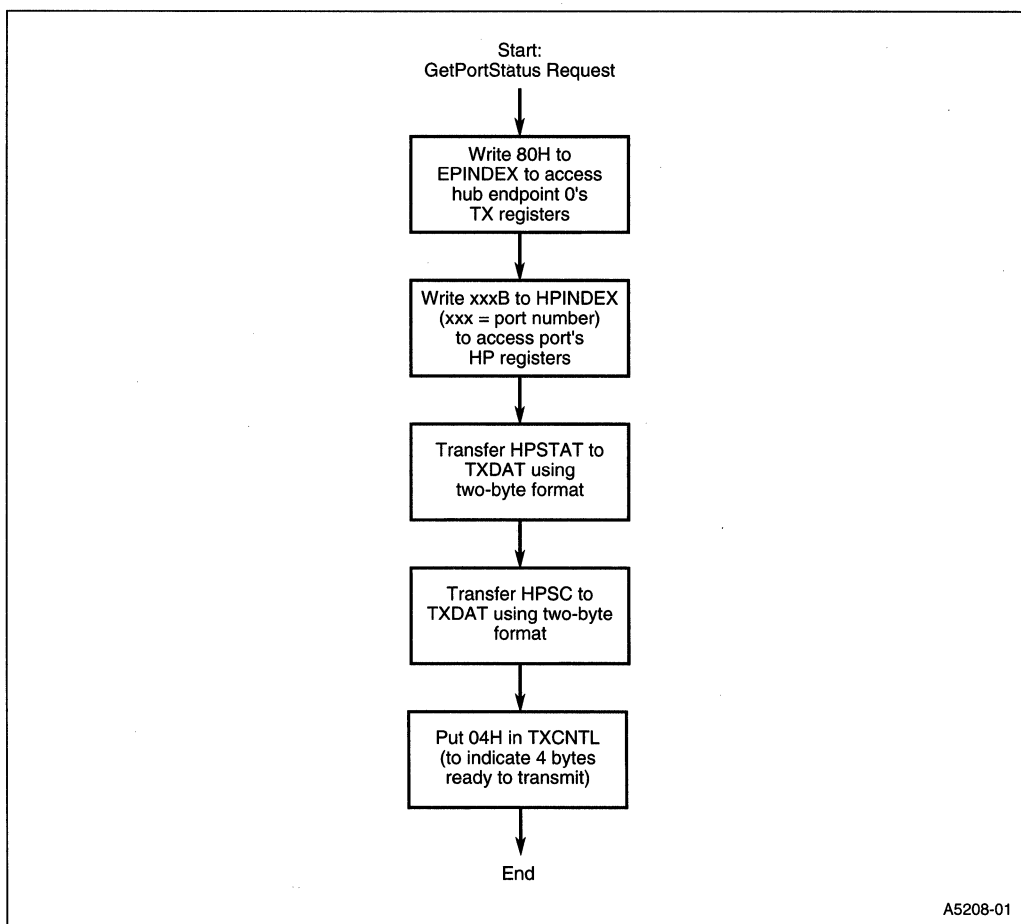


Figure 9-12. GetPortStatus Request

Transferring the contents of HPSTAT and HPSC into TXDAT requires additional code not shown in the flowchart. The bits of HPSTAT must be “converted” into a two-byte port status field, as

shown in Figure 9-13, and transmitted to the host LSB first. The bits of HPSC must also be transmitted in a two-byte format, called the port change field.

The bit names are given in Figure 9-13, along with their position in the register (shown below the bit name) and their position in the transmitted two-byte field (shown above the bit names). Firmware must transmit the four bytes to the host in the byte order indicated (above the bit position).

NOTE

The HPSTAT bits are not directly mapped into the port status field. Firmware must clear bit three of byte one to indicate that power is normal (not overcurrent) for the port. This is done because the 8x930Hx indicates overcurrent on a ganged, not per-port, basis.

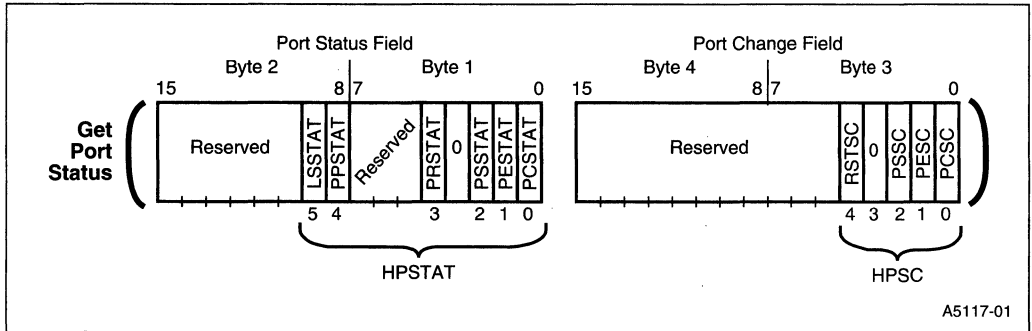


Figure 9-13. Firmware Response to GetPortStatus

9.6.4.2 SetPortFeature (PORT_SUSPEND) Firmware

This USB request suspends the downstream ports. The number of the port to be suspended is included in the request from the host. If hub port 4 is specified, firmware must also suspend any non-hub functionality associated with the embedded function and place any external device hardware into low-power suspend mode prior to writing to hub port 4's HPCON SFR.

To implement this routine, firmware must write "011" to bits 2:0 of the port's HPCON SFR. The flowchart in Figure 9-14 illustrates the process.

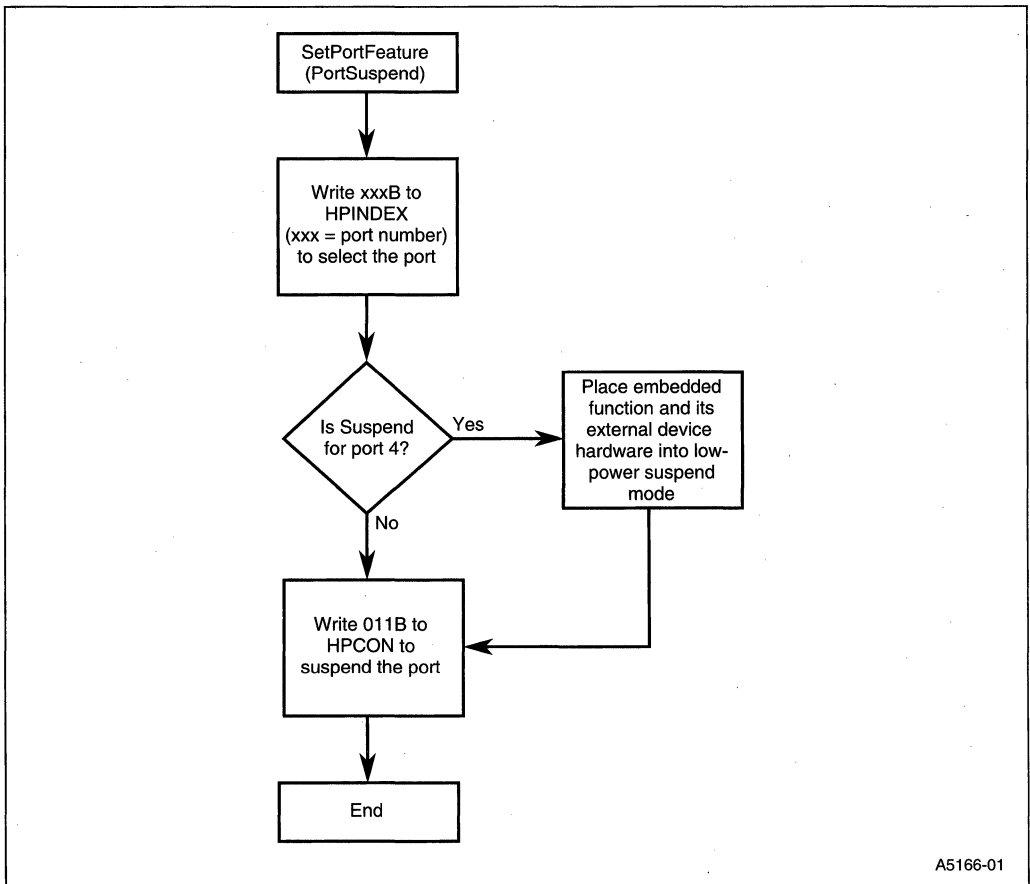


Figure 9-14. SetPortFeature (PORT_SUSPEND) Routine

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9.6.4.3 SetPortFeature (PORT_RESET) Firmware

This USB request resets the downstream ports. The number of the port to be reset is included in the request from the host. To implement this routine, firmware must write “010” to bits 2:0 of the port’s HPCON SFR. The flowchart in Figure 9-15 illustrates the process. Refer to Section 11.6.2 of the *Universal Serial Bus Specification* for a detailed description of this USB command.

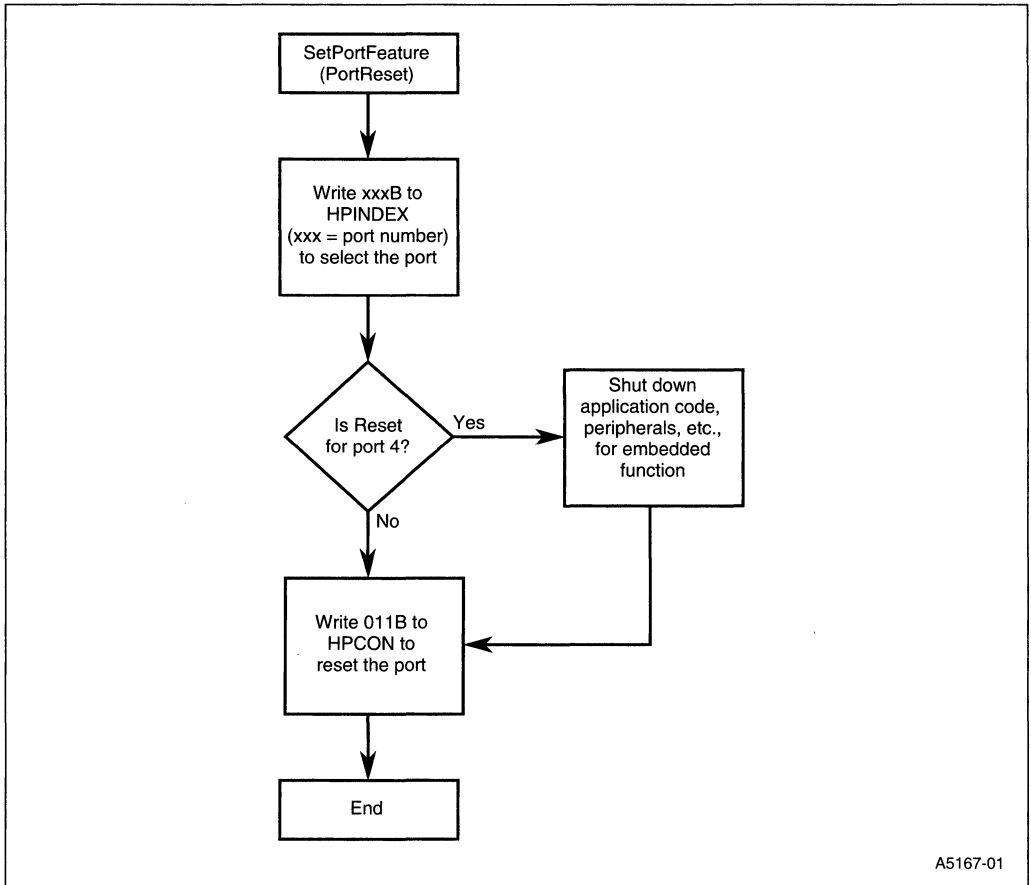


Figure 9-15. SetPortFeature (PORT_RESET) Routine

If port 4 is specified, firmware must reset all non-hub functionality in the microcontroller. Firmware must gracefully shut-down the application code, peripherals, etc. prior to writing to port 4’s HPCON.

Upon writing to port 4’s HPCON SFR, a hardware reset is applied to the FIU and function FIFOs. When this reset is applied, the embedded function’s EPCON, FIFLG, FIE, TXSTAT, RXSTAT, TXCON, RXCON, FADDR, and PCON1 SFRs are reset to their default values, as are the SOFACK, ASOF, SOFIE, and SOFODIS bits of SOFH. The EPINDEX and SOFL SFRs remain un-

changed. These SFRs are reset immediately after the write to HPCON, however bus traffic to the embedded function remains inactive for 15 ms. You may use this time frame to initialize the embedded function.

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10

Input/Output Ports





CHAPTER 10 INPUT/OUTPUT PORTS

The 8x930 has four 8-bit input/output (I/O) ports for general-purpose I/O, external memory operations, and specific alternate functions (see Table 10-1). This chapter describes the ports and provides information on port loading, read-modify-write instructions, and external memory accesses. Chapter 16, “External Memory Interface,” contains additional information about external memory operations.

10.1 INPUT/OUTPUT PORT OVERVIEW

All four 8x930 I/O ports are bidirectional. Each port contains a latch, an output driver, and an input buffer. Port 0 and port 2 output drivers and input buffers facilitate external memory operations. Port 0 drives the lower address byte onto the parallel address bus, and port 2 drives the upper address byte onto the bus. In nonpage mode, the data is multiplexed with the lower address byte on port 0. In page mode, the data is multiplexed with the upper address byte on port 2. Port 1 and port 3 provide both general-purpose I/O and special alternate functions.

Table 10-1. Input/Output Port Pin Descriptions

Pin Name	Type	Alternate Pin Name	Alternate Description	Alternate Type
P0.7:0	I/O	AD7:0	Address/Data (Nonpage Mode), Address (Page Mode)	I/O
P1.0	I/O	T2	Timer 2 Clock Input/Output	I/O
P1.1	I/O	T2EX	Timer 2 External Input	I
P1.2	I/O	ECI	PCA External Clock Input	I
P1.3	I/O	CEX0	PCA Module 0 I/O	I/O
P1.4	I/O	CEX1	PCA Module 1 I/O	I/O
P1.5	I/O	CEX2	PCA Module 2 I/O	I/O
P1.6	I/O	CEX3/WAIT#	PCA Module 3 I/O	I/O
P1.7	I/O	CEX4/A17/WCLK	PCA Module 4 I/O or 18th Address Bit	I/O(O)
P2.7:0	I/O	A15:8	Address (Nonpage Mode), Address/Data (Page Mode)	I/O
P3.0	I/O	RXD	Serial Port Receive Data Input	I (I/O)
P3.1	I/O	TXD	Serial Port Transmit Data Output	O (O)
P3.2	I/O	INT0#	External Interrupt 0	I
P3.3	I/O	INT1#	External Interrupt 1	I
P3.4	I/O	T0	Timer 0 Input	I
P3.5	I/O	T1	Timer 1 Input	I
P3.6	I/O	WR#	Write Signal to External Memory	O
P3.7	I/O	RD#/A16	Read Signal to External Memory or 17th Address Bit	O

10.2 I/O CONFIGURATIONS

Each port SFR operates via type-D latches, as illustrated in Figure 10-1 for ports 1 and 3. A CPU “write to latch” signal initiates transfer of internal bus data into the type-D latch. A CPU “read latch” signal transfers the latched Q output onto the internal bus. Similarly, a “read pin” signal transfers the logical level of the port pin. Some port data instructions activate the “read latch” signal while others activate the “read pin” signal. Latch instructions are referred to as read-modify-write instructions (see “Read-Modify-Write Instructions” on page 10-5). Each I/O line may be independently programmed as input or output.

10.3 PORT 1 AND PORT 3

Figure 10-1 shows the structure of ports 1 and 3, which have internal pullups. An external source can pull the pin low. Each port pin can be configured either for general-purpose I/O or for its alternate input or output function (Table 10-1).

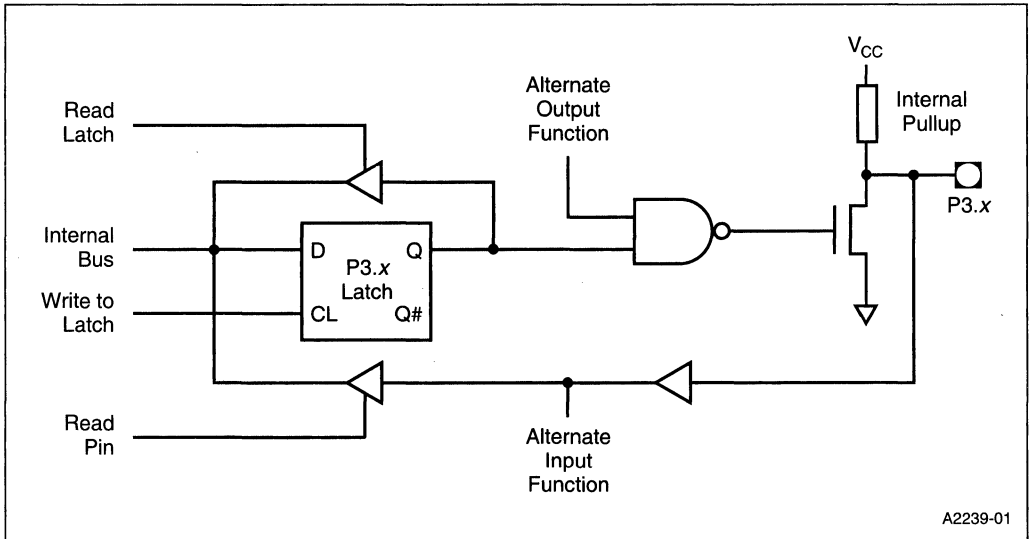
To use a pin for general-purpose output, set or clear the corresponding bit in the P_x register ($x = 1, 3$). To use a pin for general-purpose input, set the bit in the P_x register. This turns off the output driver FET.

To configure a pin for its alternate function, set the bit in the P_x register. When the latch is set, the “alternate output function” signal controls the output level (Figure 10-1). The operation of ports 1 and 3 is discussed further in “Quasi-bidirectional Port Operation” on page 10-5.

10.4 PORT 0 AND PORT 2

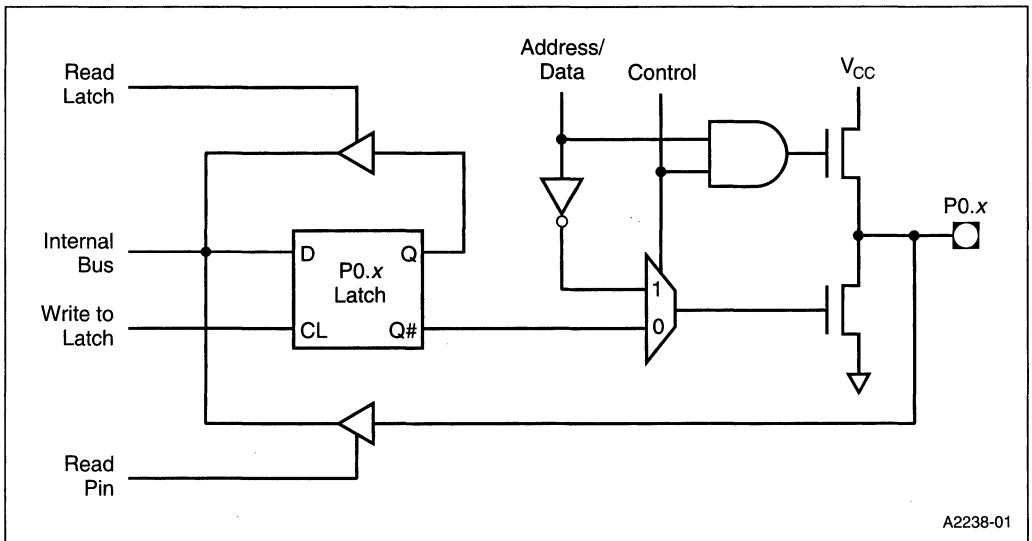
Ports 0 and 2 are used for general-purpose I/O or as the external address/data bus. Port 0, shown in Figure 10-2, differs from the other ports in not having internal pullups. Figure 10-3 on page 10-4 shows the structure of port 2. An external source can pull a port 2 pin low.

To use a pin for general-purpose output, set or clear the corresponding bit in the P_x register ($x = 0, 2$). To use a pin for general-purpose input, set the bit in the P_x register to turn off the output driver FET.



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Figure 10-1. Port 1 and Port 3 Structure



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Figure 10-2. Port 0 Structure

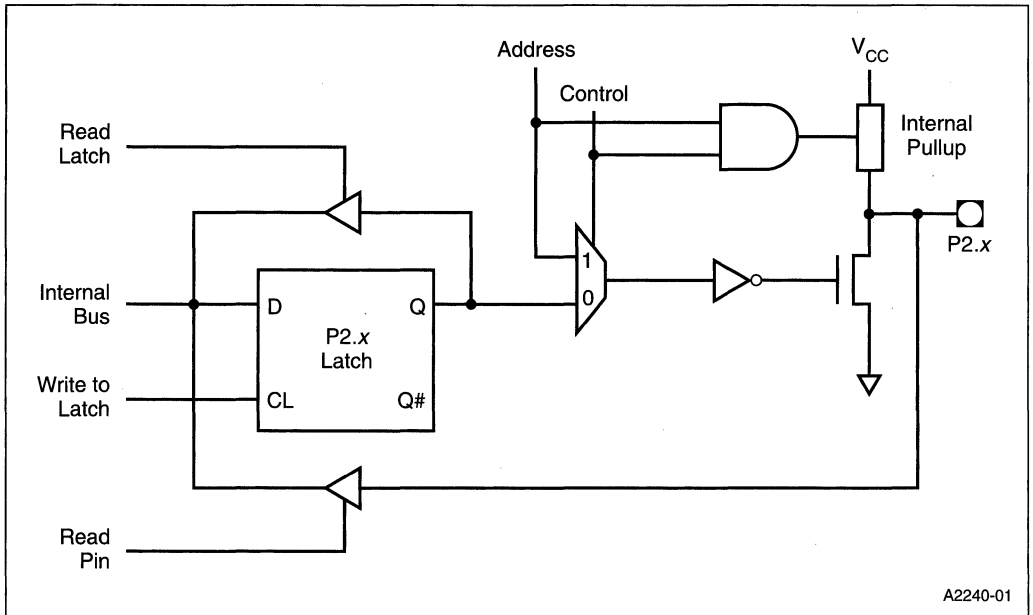


Figure 10-3. Port 2 Structure

When port 0 and port 2 are used for an external memory cycle, an internal control signal switches the output-driver input from the latch output to the internal address/data line. "External Memory Access" on page 10-7 discusses the operation of port 0 and port 2 as the external address/data bus.

NOTE

Port 0 and port 2 are precluded from use as general purpose I/O ports when used as address/data bus drivers.

Port 0 internal pullups assist the logic-one output for memory bus cycles only. Except for these bus cycles, the pullup FET is off. All other port 0 outputs are open drain.

10.5 READ-MODIFY-WRITE INSTRUCTIONS

Some instructions read the latch data rather than the pin data. The latch based instructions read the data, modify the data, and then rewrite the latch. These are called “read-modify-write” instructions. Table 10-2 contains a complete list of these special instructions. When the destination operand is a port, or a port bit, these instructions read the latch rather than the pin.

Table 10-2. Read-Modify-Write Instructions

Instruction	Description
ANL	logical AND, e.g., ANL P1, A
ORL	logical OR, e.g., ORL P2, A
XRL	logical EX-OR, e.g., XRL P3, A
JBC	jump if bit = 1 and clear bit, e.g., JBC P1.1, LABEL
CPL	complement bit, e.g., CPL P3.0
INC	increment, e.g., INC P2
DEC	decrement, e.g., DEC P2
DJNZ	decrement and jump if not zero, e.g., DJNZ P3, LABEL
MOV PX.Y, C	move carry bit to bit Y of port X
CLR PX.Y	clear bit Y of port X
SETB PX.Y	set bit Y of port x

It is not obvious that the last three instructions in Table 10-2 are read-modify-write instructions. These instructions read the port (all eight bits), modify the specifically addressed bit, and write the new byte back to the latch. These read-modify-write instructions are directed to the latch rather than the pin in order to avoid possible misinterpretation of voltage (and therefore, logic) levels at the pin. For example, a port bit used to drive the base of an external bipolar transistor cannot rise above the transistor’s base-emitter junction voltage (a value lower than V_{IL}). With a logic one written to the bit, attempts by the CPU to read the port at the pin are misinterpreted as logic zero. A read of the latch rather than the pin returns the correct logic-one value.

10.6 QUASI-BIDIRECTIONAL PORT OPERATION

Port 1, port 2, and port 3 have fixed internal pullups and are referred to as “quasi-bidirectional” ports. When configured as an input, the pin impedance appears as logic one and sources current (see the 8x930 datasheet) in response to an external logic-zero condition. Port 0 is a “true bidirectional” pin. The pin floats when configured as input. Resets write logical one to all port latches. If logical zero is subsequently written to a port latch, it can be returned to input conditions by a logical one written to the latch. For additional electrical information, refer to the current 8x930 datasheet.

NOTE

Port latch values change near the end of read-modify-write instruction cycles. Output buffers (and therefore the pin state) update early in the instruction after the read-modify-write instruction cycle.

Logical zero-to-one transitions in port 1, port 2, and port 3 utilize an additional pullup to aid this logic transition (see Figure 10-4). This increases switch speed. The extra pullup briefly sources 100 times the normal internal circuit current. The internal pullups are field-effect transistors rather than linear resistors. Pullups consist of three p-channel FET (pFET) devices. A pFET is on when the gate senses logical zero and off when the gate senses logical one. pFET #1 is turned on for two oscillator periods immediately after a zero-to-one transition in the port latch. A logic one at the port pin turns on pFET #3 (a weak pullup) through the inverter. This inverter and pFET pair form a latch to drive logic one. pFET #2 is a very weak pullup switched on whenever the associated nFET is switched off. This is a traditional CMOS switch convention. Current strengths are 1/10 that of pFET #3.

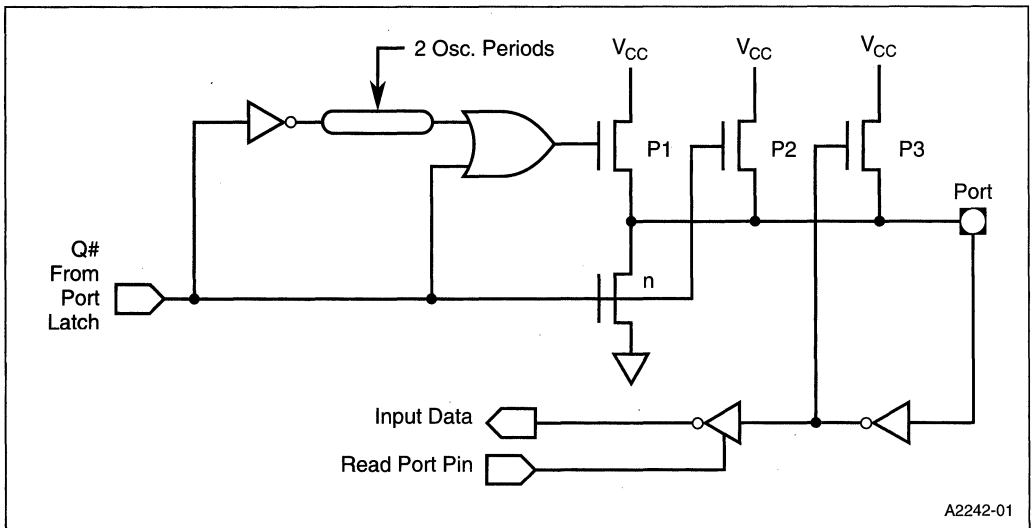


Figure 10-4. Internal Pullup Configurations

10.7 PORT LOADING

Output buffers of port 1, port 2, and port 3 can each sink 1.6 mA at logic zero (see V_{OL} specifications in the 8x930 data sheet). These port pins can be driven by open-collector and open-drain devices. Logic zero-to-one transitions occur slowly as limited current pulls the pin to a logic-one condition (Figure 10-4 on page 10-6). A logic-zero input turns off pFET #3. This leaves only pFET #2 weakly in support of the transition. In external bus mode, port 0 output buffers each sink 3.2 mA at logic zero (see V_{OL1} in the 8x930 data sheet). However, the port 0 pins require external pullups to drive external gate inputs. See the latest revision of the 8x930 datasheet for complete electrical design information. External circuits must be designed to limit current requirements to these conditions.

10.8 EXTERNAL MEMORY ACCESS

The external bus structure is different for page mode and nonpage mode. In nonpage mode (used by MCS 51 microcontrollers), port 2 outputs the upper address byte; the lower address byte and the data are multiplexed on port 0. In page mode, the upper address byte and the data are multiplexed on port 2, while port 0 outputs the lower address byte.

The 8x930 CPU writes FFH to the P0 register for all external memory bus cycles. This overwrites previous information in P0. In contrast, the P2 register is unmodified for external bus cycles. When address bits or data bits are not on the port 2 pins, the bit values in P2 appear on the port 2 pins.

In nonpage mode, port 0 uses a strong internal pullup FET to output ones or a strong internal pull-down FET to output zeros for the lower address byte and the data. Port 0 is in a high-impedance state for data input.

In page mode, port 0 uses a strong internal pullup FET to output ones or a strong internal pull-down FET to output zeros for the lower address byte or a strong internal pulldown FET to output zeros for the upper address byte.

In nonpage mode, port 2 uses a strong internal pullup FET to output ones or a strong internal pull-down FET to output zeros for the upper address byte. In page mode, port 2 uses a strong internal pullup FET to output ones or a strong internal pulldown FET to output zeros for the upper address byte and data. Port 2 is in a high-impedance state for data input.

NOTE

In external bus mode port 0 outputs do not require external pullups.

There are two types of external memory accesses: external program memory and external data memory (see Chapter 16, “External Memory Interface”). External program memories utilize signal PSEN# as a read strobe. MCS 51 microcontrollers use RD# (read) or WR# (write) to strobe memory for data accesses. Depending on its RD1:0 configuration bits, the 8x930 uses PSEN# or RD# for data reads (See “Configuration Bits RD1:0” on page 4-8).

During instruction fetches, external program memory can transfer instructions with 16-bit addresses for binary-compatible code or with the external bus configured for extended memory addressing (17-bit or 18-bit).

External data memory transfers use an 8-, 16-, 17-, or 18-bit address bus, depending on the instruction and the configuration of the external bus. Table 10-3 lists the instructions that can be used for these bus widths.

Table 10-3. Instructions for External Data Moves

Bus Width	Instructions
8	MOVX @Ri; MOV @Rm; MOV dir8
16	MOVX @DPTR; MOV @WRj; MOV @WRj+dis; MOV dir16
17	MOV @DRk; MOV @DRk+dis
18	MOV @DRk; MOV @DRk+dis

NOTE

Avoid MOV P0 instructions for external memory accesses. These instructions can corrupt input code bytes at port 0.

External signal ALE (address latch enable) facilitates external address latch capture. The address byte is valid after the ALE pin drives V_{OL} . For write cycles, valid data is written to port 0 just prior to the write (WR#) pin asserting V_{OL} . Data remains valid until WR# is undriven. For read cycles, data returned from external memory must appear at port 0 before the read (RD#) pin is undriven (refer to the 8x930 datasheet for specifications). Wait states, by definition, affect bus-timing.



11

Timer/Counters and Watchdog Timer



CHAPTER 11

TIMER/COUNTERS AND WATCHDOG TIMER

This chapter describes the timer/counters and the watchdog timer (WDT) included as peripherals on the 8x930. When operating as a timer, a timer/counter runs for a programmed length of time, then issues an interrupt request. When operating as a counter, a timer/counter counts negative transitions on an external pin. After a preset number of counts, the counter issues an interrupt request.

The watchdog timer provides a way to monitor system operation. It causes a system reset if a firmware malfunction allows it to expire. The watchdog timer is covered in “Watchdog Timer” on page 11-16.

11.1 TIMER/COUNTER OVERVIEW

The 8x930 contains three general-purpose, 16-bit timer/counters. Although they are identified as timer 0, timer 1, and timer 2, you can independently configure each to operate in a variety of modes as a timer or as an event counter. Each timer employs two 8-bit timer registers, used separately or in cascade, to maintain the count. The timer registers and associated control and capture registers are implemented as addressable special function registers (SFRs). Four of the SFRs provide programmable control of the timers as follows:

- Timer/counter mode control register (TMOD) and timer/counter control register (TCON) control timer 0 and timer 1
- Timer/counter 2 mode control register (T2MOD) and timer/counter 2 control register (T2CON) control timer 2

Table 11-1 describes the external signals referred to in this chapter. Table 11-2 briefly describes the SFRs referred to in this chapter. For a map of the SFR address space, see Table 3-5 on page 3-16.

11.2 TIMER/COUNTER OPERATION

The block diagram in Figure 11-1 depicts the basic logic of the timers. Here timer registers TH_x and TL_x ($x = 0, 1, \text{ and } 2$) connect in cascade to form a 16-bit timer. Setting the run control bit (TR_x) turns the timer on by allowing the selected input to increment TL_x. When TL_x overflows it increments TH_x; when TH_x overflows it sets the timer overflow flag (TF_x) in the TCON or T2CON register. Setting the run control bit does not clear the TH_x and TL_x timer registers. The timer registers can be accessed to obtain the current count or to enter preset values. Timer 0 and timer 1 can also be controlled by external pin INT_x# to facilitate pulse width measurements.

The C/T_x# control bit selects timer operation or counter operation by selecting the divided-down system clock or external pin Tx as the source for the counted signal.

For timer operation (C/T_x# = 0), the timer register counts the divided-down system clock. The timer register is incremented once every peripheral cycle (once every six states). That is, at the internal clock frequency divided by six ($F_{CLK}/6$). Exceptions are the timer 2 clock-out and baud

rate modes, in which the timer register is incremented at the internal clock rate (F_{CLK}). See “Clock and Reset Unit” on page 2-9. Table 2-4 on page 2-10 and Figures 2-7, and 2-8 on page 2-11 show the relationship between F_{OSC} , F_{CLK} , state times, and peripheral cycles. Also see the 8x930 clock circuit block diagram in Figure 2-6 on page 2-9.

NOTE

The timing calculations in this chapter are based on the value of F_{CLK} , which is a function of PLLSEL2:0. See Table 2-4 on page 2-10.

For counter operation ($C/Tx\# = 1$), the timer register counts the negative transitions on the Tx external input pin. The external input is sampled during every S5P2 state. “Clock and Reset Unit” on page 2-9 describes the notation for the states in a peripheral cycle. When the sample is high in one cycle and low in the next, the counter is incremented. The new count value appears in the register during the next S3P1 state after the transition was detected. Since it takes two peripheral cycles to recognize a negative transition, the maximum count rate is $F_{CLK}/12$. There are no restrictions on the duty cycle of the external input signal, but to ensure that a given level is sampled at least once before it changes, it should be held for at least one full peripheral cycle.

Table 11-1. External Signals

Signal Name	Type	Description	Alternate Function
T2	I/O	Timer 2 Clock Input/Output. This signal is the external clock input for the timer 2 capture mode; and it is the timer 2 clock-output for the clock-out mode.	P1.0
T2EX	I	Timer 2 External Input. In timer 2 capture mode, a falling edge initiates a capture of the timer 2 registers. In auto-reload mode, a falling edge causes the timer 2 registers to be reloaded. In the up-down counter mode, this signal determines the count direction: high = up, low = down.	P1.1
INT1:0#	I	External Interrupts 1:0. These inputs set the IE1:0 interrupt flags in the TCON register. TCON bits IT1:0 select the triggering method: IT1:0 = 1 selects edge-triggered (high-to-low); IT1:0 = 0 selects level-triggered (active low). INT1:0# also serves as external run control for timer 1:0 when selected by TCON bits GATE1:0#.	P3.3:2
T1:0	I	Timer 1:0 External Clock Inputs. When timer 1:0 operates as a counter, a falling edge on the T1:0 pin increments the count.	P3.5:4

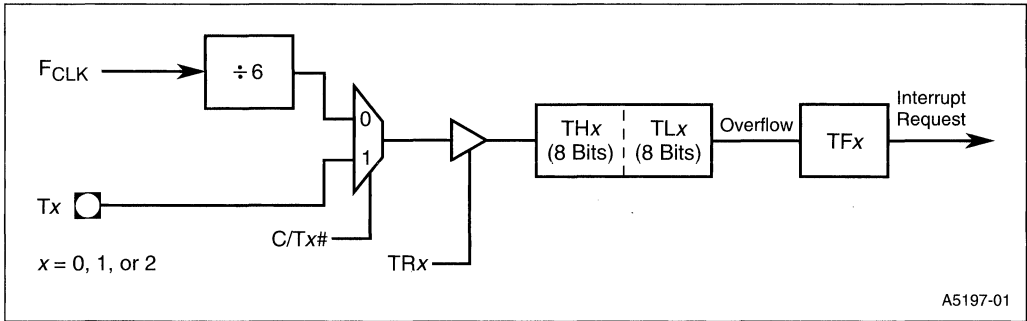


Figure 11-1. Basic Logic of the Timer/Counters

Table 11-2. Timer/Counter and Watchdog Timer SFRs

Mnemonic	Description	Address
TL0 TH0	Timer 0 Timer Registers. Used separately as 8-bit counters or in cascade as a 16-bit counter. Counts an internal clock signal with frequency $F_{CLK}/6$ (timer operation) or an external input (event counter operation).	S:8AH S:8CH
TL1 TH1	Timer 1 Timer Registers. Used separately as 8-bit counters or in cascade as a 16-bit counter. Counts an internal clock signal with frequency $F_{CLK}/6$ (timer operation) or an external input (event counter operation).	S:8BH S:8DH
TL2 TH2	Timer 2 Timer Registers. TL2 and TH2 connect in cascade to provide a 16-bit counter. Counts an internal clock signal with frequency $F_{CLK}/6$ (timer operation) or an external input (event counter operation).	S:CCH S:CDH
TCON	Timer 0/1 Control Register. Contains the run control bits, overflow flags, interrupt flags, and interrupt-type control bits for timer 0 and timer 1.	S:88H
TMOD	Timer 0/1 Mode Control Register. Contains the mode select bits, counter/timer select bits, and external control gate bits for timer 0 and timer 1.	S:89H
T2CON	Timer 2 Control Register. Contains the receive clock, transmit clock, and capture/reload bits used to configure timer 2. Also contains the run control bit, counter/timer select bit, overflow flag, external flag, and external enable for timer 2.	S:C8H
T2MOD	Timer 2 Mode Control Register. Contains the timer 2 output enable and down count enable bits.	S:C9H
RCAP2L RCAP2H	Timer 2 Reload/Capture Registers (RCAP2L, RCAP2H). Provide values to and receive values from the timer registers (TL2, TH2).	S:CAH S:CBH
WDTRST	Watchdog Timer Reset Register (WDTRST). Used to reset and enable the WDT.	S:A6H

11.3 TIMER 0

Timer 0 functions as either a timer or event counter in four modes of operation. Figures 11-2, 11-3, and 11-4 show the logical configuration of each mode.

Timer 0 is controlled by the four low-order bits of the TMOD register (Figure 11-5) and bits 5, 4, 1, and 0 of the TCON register (Figure 11-6). The TMOD register selects the method of timer gating (GATE0), timer or counter operation (T/C0#), and mode of operation (M10 and M00). The TCON register provides timer 0 control functions: overflow flag (TF0), run control (TR0), interrupt flag (IE0), and interrupt type control (IT0).

For normal timer operation (GATE0 = 0), setting TR0 allows TL0 to be incremented by the selected input. Setting GATE0 and TR0 allows external pin INT0# to control timer operation. This setup can be used to make pulse width measurements. See "Pulse Width Measurements" on page 11-10.

Timer 0 overflow (count rolls over from all 1s to all 0s) sets the TF0 flag generating an interrupt request.

11.3.1 Mode 0 (13-bit Timer)

Mode 0 configures timer 0 as a 13-bit timer which is set up as an 8-bit timer (TH0 register) with a modulo 32 prescaler implemented with the lower five bits of the TL0 register (Figure 11-2). The upper three bits of the TL0 register are indeterminate and should be ignored. Prescaler overflow increments the TH0 register.

11.3.2 Mode 1 (16-bit Timer)

Mode 1 configures timer 0 as a 16-bit timer with TH0 and TL0 connected in cascade (Figure 11-2). The selected input increments TL0.

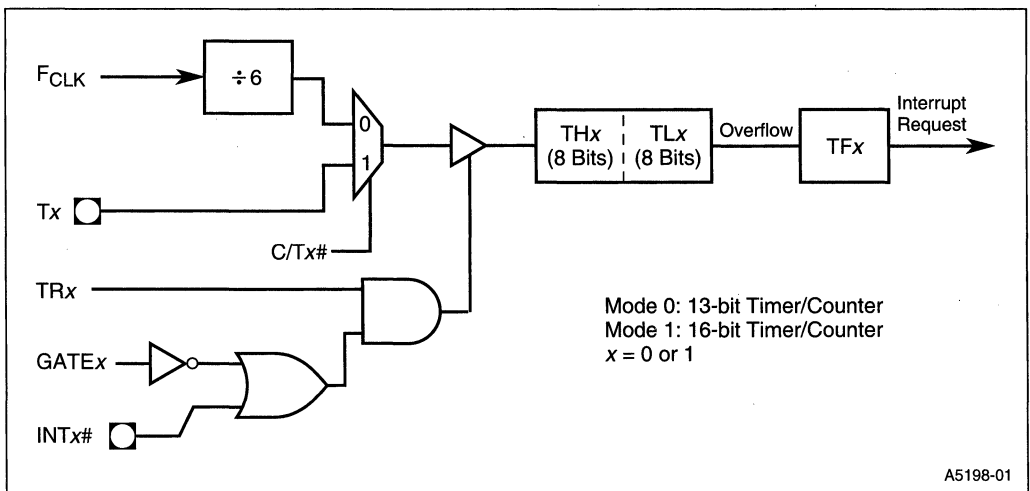


Figure 11-2. Timer 0/1 in Mode 0 and Mode 1

11.3.3 Mode 2 (8-bit Timer With Auto-reload)

Mode 2 configures timer 0 as an 8-bit timer (TL0 register) that automatically reloads from the TH0 register (Figure 11-3). TL0 overflow sets the timer overflow flag (TF0) in the TCON register and reloads TL0 with the contents of TH0, which is preset by firmware. When the interrupt request is serviced, hardware clears TF0. The reload leaves TH0 unchanged. See “Auto-reload Setup Example” on page 11-9.

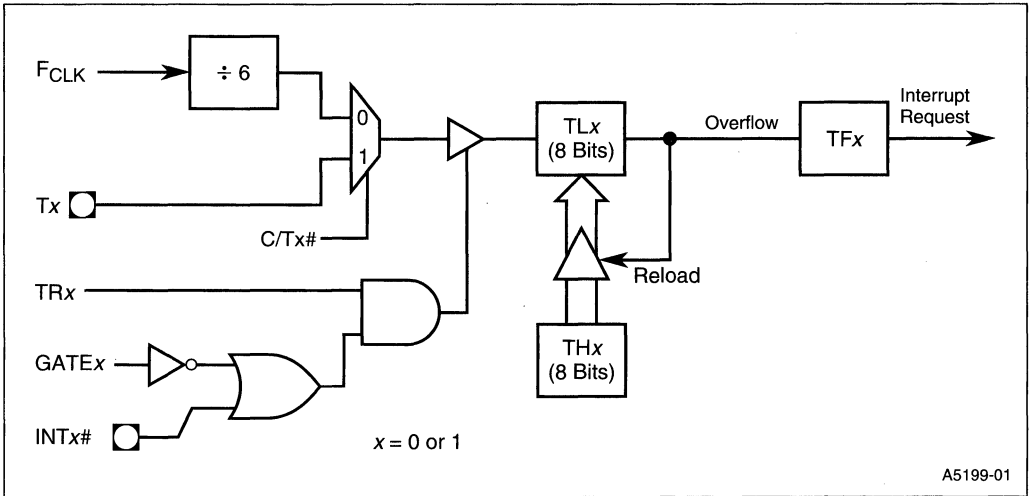


Figure 11-3. Timer 0/1 in Mode 2, Auto-reload

11.3.4 Mode 3 (Two 8-bit Timers)

Mode 3 configures timer 0 such that registers TL0 and TH0 operate as separate 8-bit timers (Figure 11-4). This mode is provided for applications requiring an additional 8-bit timer or counter. TL0 uses the timer 0 control bits C/T0# and GATE0 in TMOD, and TR0 and TF0 in TCON in the normal manner. TH0 is locked into a timer function (counting $F_{CLK}/6$) and takes over use of the timer 1 interrupt (TF1) and run control (TR1) bits. Thus, operation of timer 1 is restricted when timer 0 is in mode 3. See the last paragraph of “Timer 1” on page 11-6 and “Mode 3 (Halt)” on page 11-9.

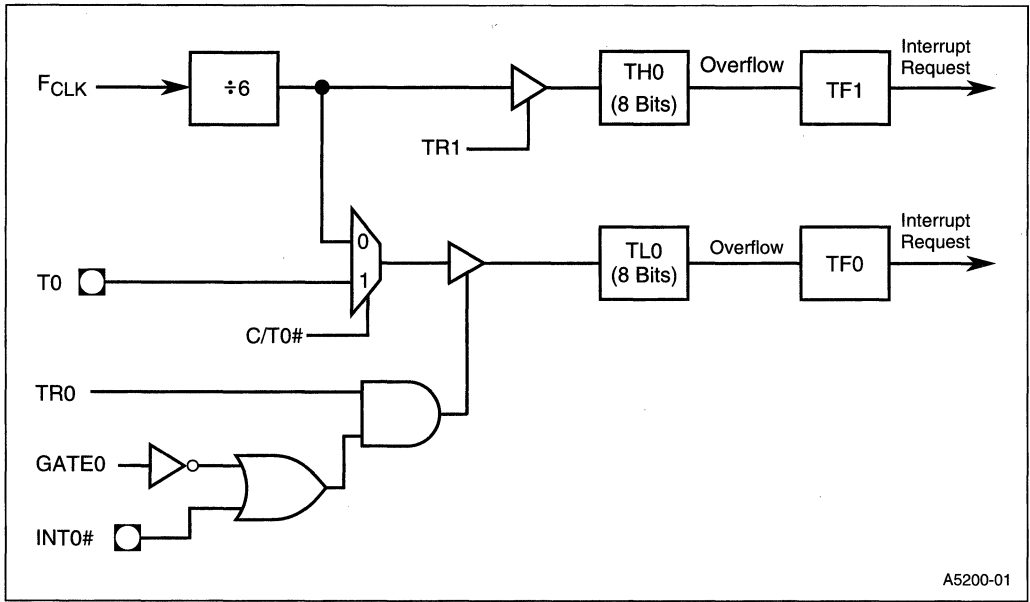


Figure 11-4. Timer 0 in Mode 3, Two 8-bit Timers

11.4 TIMER 1

Timer 1 functions as either a timer or event counter in three modes of operation. Figures 11-2 and 11-3 show the logical configuration for modes 0, 1, and 2. Timer 1's mode 3 is a hold-count mode.

Timer 1 is controlled by the four high-order bits of the TMOD register (Figure 11-5) and bits 7, 6, 3, and 2 of the TCON register (Figure 11-6). The TMOD register selects the method of timer gating (GATE1), timer or counter operation (T/C1#), and mode of operation (M11 and M01). The TCON register provides timer 1 control functions: overflow flag (TF1), run control (TR1), interrupt flag (IE1), and interrupt type control (IT1).

Timer 1 operation in modes 0, 1, and 2 is identical to timer 0. Timer 1 can serve as the baud rate generator for the serial port. Mode 2 is best suited for this purpose.

For normal timer operation (GATE1 = 0), setting TR1 allows timer register TL1 to be incremented by the selected input. Setting GATE1 and TR1 allows external pin INT1# to control timer operation. This setup can be used to make pulse width measurements. See "Pulse Width Measurements" on page 11-10.

Timer 1 overflow (count rolls over from all 1s to all 0s) sets the TF1 flag, generating an interrupt request.

When timer 0 is in mode 3, it uses timer 1's overflow flag (TF1) and run control bit (TR1). For this situation, use timer 1 only for applications that do not require an interrupt (such as a baud rate generator for the serial interface port) and switch timer 1 in and out of mode 3 to turn it off and on.

TMOD				Address: S:89H Reset State: 0000 0000B			
Timer/Counter Mode Control Register. Contains mode select, run control select, and counter/timer select bits for controlling timer 0 and timer 1.							
7				0			
GATE1	C/T1#	M11	M01	GATE0	C/T0#	M10	M00
Bit Number	Bit Mnemonic	Function					
7	GATE1	Timer 1 Gate: When GATE1 = 0, run control bit TR1 gates the input signal to the timer register. When GATE1 = 1 and TR1 = 1, external signal INT1 gates the timer input.					
6	C/T1#	Timer 1 Counter/Timer Select: C/T1# = 0 selects timer operation: timer 1 counts the divided-down system clock. C/T1# = 1 selects counter operation: timer 1 counts negative transitions on external pin T1.					
5, 4	M11, M01	Timer 1 Mode Select: M11 M01 0 0 Mode 0: 8-bit timer/counter (TH1) with 5-bit prescaler (TL1) 0 1 Mode 1: 16-bit timer/counter 1 0 Mode 2: 8-bit auto-reload timer/counter (TL1). Reloaded from TH1 at overflow. 1 1 Mode 3: Timer 1 halted. Retains count.					
3	GATE0	Timer 0 Gate: When GATE0 = 0, run control bit TR0 gates the input signal to the timer register. When GATE0 = 1 and TR0 = 1, external signal INT0 gates the timer input.					
2	C/T0#	Timer 0 Counter/Timer Select: C/T0# = 0 selects timer operation: timer 0 counts the divided-down system clock. C/T0# = 1 selects counter operation: timer 0 counts negative transitions on external pin T0.					
1, 0	M10, M00	Timer 0 Mode Select: M10 M00 0 0 Mode 0: 8-bit timer/counter (T0) with 5-bit prescaler (TL0) 0 1 Mode 1: 16-bit timer/counter 1 0 Mode 2: 8-bit auto-reload timer/counter (TL0). Reloaded from TH0 at overflow. 1 1 Mode 3: TL0 is an 8-bit timer/counter. TH0 is an 8-bit timer using timer 1's TR1 and TF1 bits.					

Figure 11-5. TMOD: Timer/Counter Mode Control Register

TCON		Address:	S:88H
		Reset State:	0000 0000B
Timer/Counter Control Register. Contains the overflow and external interrupt flags and the run control and interrupt transition select bits for timer 0 and timer 1.			
7			0
TF1	TR1	TF0	TR0
IE1	IT1	IE0	IT0
Bit Number	Bit Mnemonic	Function	
7	TF1	Timer 1 Overflow Flag: Set by hardware when the timer 1 register overflows. Cleared by hardware when the processor vectors to the interrupt routine.	
6	TR1	Timer 1 Run Control Bit: Set/cleared by firmware to turn timer 1 on/off.	
5	TF0	Timer 0 Overflow Flag: Set by hardware when the timer 0 register overflows. Cleared by hardware when the processor vectors to the interrupt routine.	
4	TR0	Timer 0 Run Control Bit: Set/cleared by firmware to turn timer 1 on/off.	
3	IE1	Interrupt 1 Flag: Set by hardware when an external interrupt is detected on the INT1# pin. Edge- or level- triggered (see IT1). Cleared when interrupt is processed if edge-triggered.	
2	IT1	Interrupt 1 Type Control Bit: Set this bit to select edge-triggered (high-to-low) for external interrupt 1. Clear this bit to select level-triggered (active low).	
1	IE0	Interrupt 0 Flag: Set by hardware when an external interrupt is detected on the INTO# pin. Edge- or level- triggered (see IT0). Cleared when interrupt is processed if edge-triggered.	
0	IT0	Interrupt 0 Type Control Bit: Set this bit to select edge-triggered (high-to-low) for external interrupt 0. Clear this bit to select level-triggered (active low).	

Figure 11-6. TCON: Timer/Counter Control Register

11.4.1 Mode 0 (13-bit Timer)

Mode 0 configures timer 0 as a 13-bit timer, which is set up as an 8-bit timer (TH1 register) with a modulo-32 prescaler implemented with the lower five bits of the TL1 register (Figure 11-2). The upper three bits of the TL1 register are ignored. Prescaler overflow increments the TH1 register.

11.4.2 Mode 1 (16-bit Timer)

Mode 1 configures timer 1 as a 16-bit timer with TH1 and TL1 connected in cascade (Figure 11-2). The selected input increments TL1.

11.4.3 Mode 2 (8-bit Timer with Auto-reload)

Mode 2 configures timer 1 as an 8-bit timer (TL1 register) with automatic reload from the TH1 register on overflow (Figure 11-3). Overflow from TL1 sets overflow flag TF1 in the TCON register and reloads TL1 with the contents of TH1, which is preset by firmware. The reload leaves TH1 unchanged. See “Auto-reload Setup Example” on page 11-9.

11.4.4 Mode 3 (Halt)

Placing timer 1 in mode 3 causes it to halt and hold its count. This can be used to halt timer 1 when the TR1 run control bit is not available (i.e., when timer 0 is in mode 3). See the final paragraph of “Timer 1” on page 11-6.

11.5 TIMER 0/1 APPLICATIONS

Timer 0 and timer 1 are general purpose timers that can be used in a variety of ways. The timer applications presented in this section are intended to demonstrate timer setup, and do not represent the only arrangement nor necessarily the best arrangement for a given task. These examples employ timer 0, but timer 1 can be set up in the same manner using the appropriate registers.

11.5.1 Auto-reload Setup Example

Timer 0 can be configured as an eight-bit timer (TL0) with automatic reload as follows:

1. Program the four low-order bits of the TMOD register (Figure 11-5) to specify: mode 2 for timer 0, C/T0# = 0 to select $F_{CLK}/6$ as the timer input, and GATE0 = 0 to select TR0 as the timer run control.
2. Enter an eight-bit initial value (n_0) in timer register TL0, so that the timer overflows after the desired number of peripheral cycles.
3. Enter an eight-bit reload value (n_R) in register TH0. This can be the same as n_0 or different, depending on the application.
4. Set the TR0 bit in the TCON register (Figure 11-6) to start the timer. Timer overflow occurs after $FFH + 1 - n_0$ peripheral cycles, setting the TF0 flag and loading n_R into TL0 from TH0. When the interrupt is serviced, hardware clears TF0.

5. The timer continues to overflow and generate interrupt requests every $FFH + 1 - n_R$ peripheral cycles.
6. To halt the timer, clear the TR0 bit.

11.5.2 Pulse Width Measurements

For timer 0 and timer 1, setting $GATE_x$ and TR_x allows an external waveform at pin $INT_x\#$ to turn the timer on and off. This setup can be used to measure the width of a positive-going pulse present at pin $INT_x\#$. Pulse width measurements using timer 0 in mode 1 can be made as follows:

1. Program the four low-order bits of the TMOD register (Figure 11-5) to specify: mode 1 for timer 0, $C/T0\# = 0$ to select $F_{CLK}/6$ as the timer input, and $GATE0 = 1$ to select INTO as timer run control.
2. Enter an initial value of all zeros in the 16-bit timer register TH0/TL0, or read and store the current contents of the register.
3. Set the TR0 bit in the TCON register (Figure 11-6) to enable INTO.
4. Apply the pulse to be measured to pin INTO. The timer runs when the pulse waveform is high.
5. Clear the TR0 bit to disable INTO.
6. Read timer register TH0/TL0 to obtain the new value.
7. Calculate pulse width = $6T_{CLK} \times (\text{new value} - \text{initial value})$.
8. Example 1, PLLSEL2:0 = 100 (low speed): $F_{OSC} = 12 \text{ MHz}$, $F_{CLK} = 6 \text{ MHz}$, $T_{CLK} = 0.16667 \mu\text{s}$. If the new value = $10,000_{10}$ counts and the initial value = 0, the pulse width = $6(0.16667) \times (10,000 - 0) = 1 \mu\text{s} \times 10,000 = 10 \text{ ms}$.

Example 2, PLLSEL2:0 = 110 (full speed): $F_{OSC} = 12 \text{ MHz}$, $F_{CLK} = 12 \text{ MHz}$, $T_{CLK} = 0.08333 \mu\text{s}$. If the new value = $10,000_{10}$ counts and the initial value = 0, the pulse width = $6(0.08333) \times (10,000 - 0) = 0.5 \mu\text{s} \times 10,000 = 5 \text{ ms}$.

11.6 TIMER 2

Timer 2 is a 16-bit timer/counter. The count is maintained by two 8-bit timer registers, TH2 and TL2, connected in cascade. The timer/counter 2 mode control register (T2MOD) as shown in Figure 11-11 on page 11-16) and the timer/counter 2 control register (T2CON) as shown in Figure 11-12 on page 11-17) control the operation of timer 2.

Timer 2 provides the following operating modes: capture mode, auto-reload mode, baud rate generator mode, and programmable clock-out mode. Select the operating mode with T2MOD and TCON register bits as shown in Table 11-3 on page 11-15. Auto-reload is the default mode. Setting RCLK and/or TCLK selects the baud rate generator mode.

Timer 2 operation is similar to timer 0 and timer 1. $C/T2\#$ selects the divided-down system clock (timer operation) or external pin T2 (counter operation) as the timer register input. Setting TF2 allows TL2 to be incremented by the selected input.

The operating modes are described in the following paragraphs. Block diagrams in Figures 11-7 through 11-10 show the timer 2 configuration for each mode.

11.6.1 Capture Mode

In the capture mode, timer 2 functions as a 16-bit timer or counter (Figure 11-7). An overflow condition sets bit TF2, which you can use to request an interrupt. Setting the external enable bit EXEN2 allows the RCAP2H and RCAP2L registers to capture the current value in timer registers TH2 and TL2 in response to a 1-to-0 transition at external input T2EX. The transition at T2EX also sets bit EXF2 in T2CON. The EXF2 bit, like TF2, can generate an interrupt.

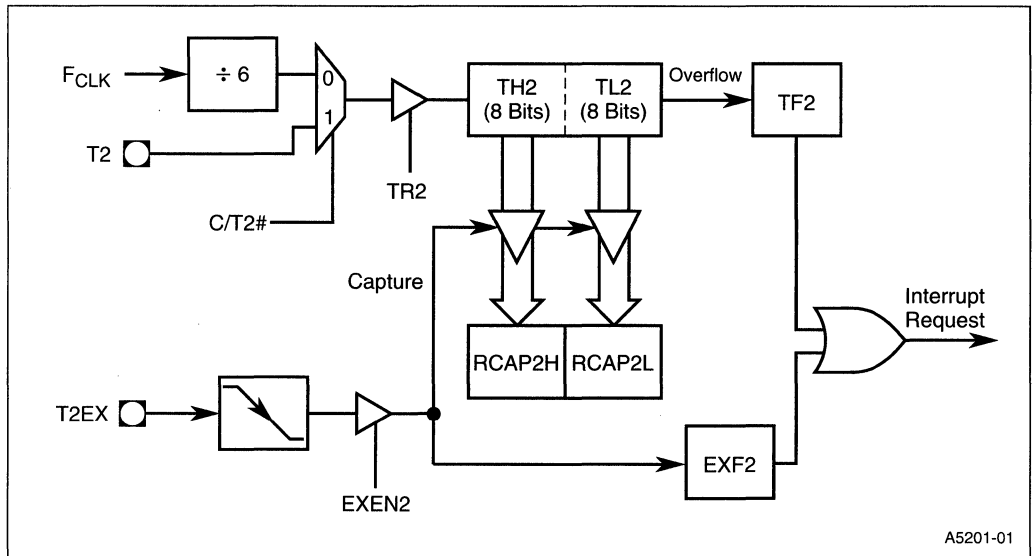


Figure 11-7. Timer 2: Capture Mode

11.6.2 Auto-reload Mode

The auto-reload mode configures timer 2 as a 16-bit timer or event counter with automatic reload. The timer operates as an up counter or as an up/down counter, as determined by the down counter enable bit (DCEN). At device reset, DCEN is cleared, so in the auto-reload mode, timer 2 defaults to operation as an up counter.

11.6.2.1 Up Counter Operation

When DCEN = 0, timer 2 operates as an up counter (Figure 11-8). The external enable bit EXEN2 in the T2CON register provides two options (Figure 11-12). If EXEN2 = 0, timer 2 counts up to FFFFH and sets the TF2 overflow flag. The overflow condition loads the 16-bit value in the reload/capture registers (RCAP2H, RCAP2L) into the timer registers (TH2, TL2). The values in RCAP2H and RCAP2L are preset by firmware.

If EXEN2 = 1, the timer registers are reloaded by either a timer overflow or a high-to-low transition at external input T2EX. This transition also sets the EXF2 bit in the T2CON register. Either TF2 or EXF2 bit can generate a timer 2 interrupt request.

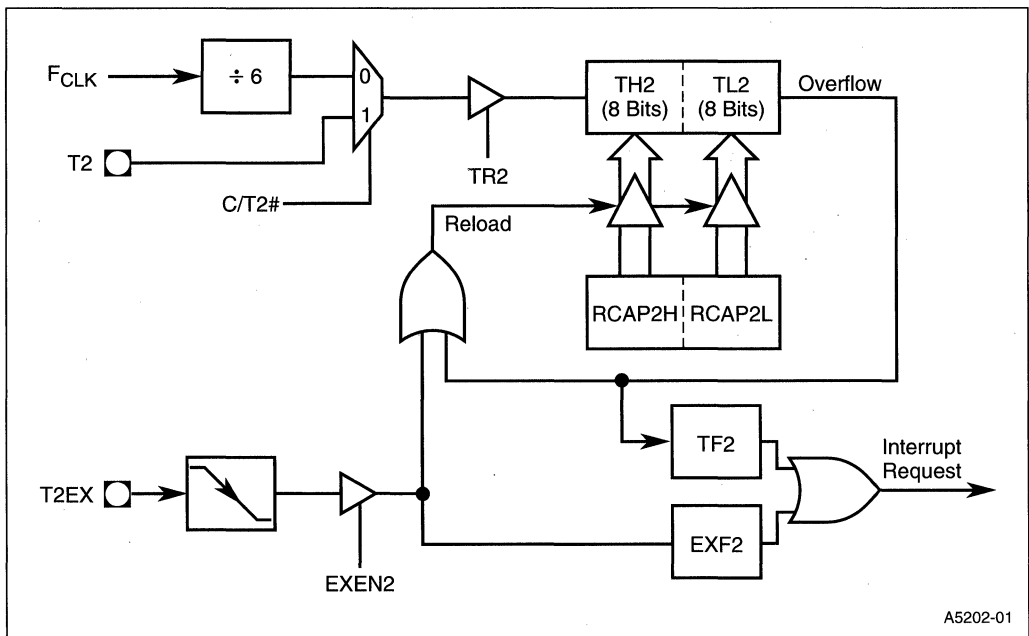


Figure 11-8. Timer 2: Auto-reload Mode (DCEN = 0)

11.6.3 Up/Down Counter Operation

When DCEN = 1, timer 2 operates as an up/down counter (Figure 11-9). External pin T2EX controls the direction of the count (Table 11-1 on page 11-2). When T2EX is high, timer 2 counts up. The timer overflow occurs at FFFFH which sets the timer 2 overflow flag (TF2) and generates an interrupt request. The overflow also causes the 16-bit value in RCAP2H and RCAP2L to be loaded into the timer registers TH2 and TL2.

When T2EX is low, timer 2 counts down. Timer underflow occurs when the count in the timer registers (TH2, TL2) equals the value stored in RCAP2H and RCAP2L. The underflow sets the TF2 bit and reloads FFFFH into the timer registers.

The EXF2 bit toggles when timer 2 overflows or underflows, changing the direction of the count. When timer 2 operates as an up/down counter, EXF2 does not generate an interrupt. This bit can be used to provide 17-bit resolution.

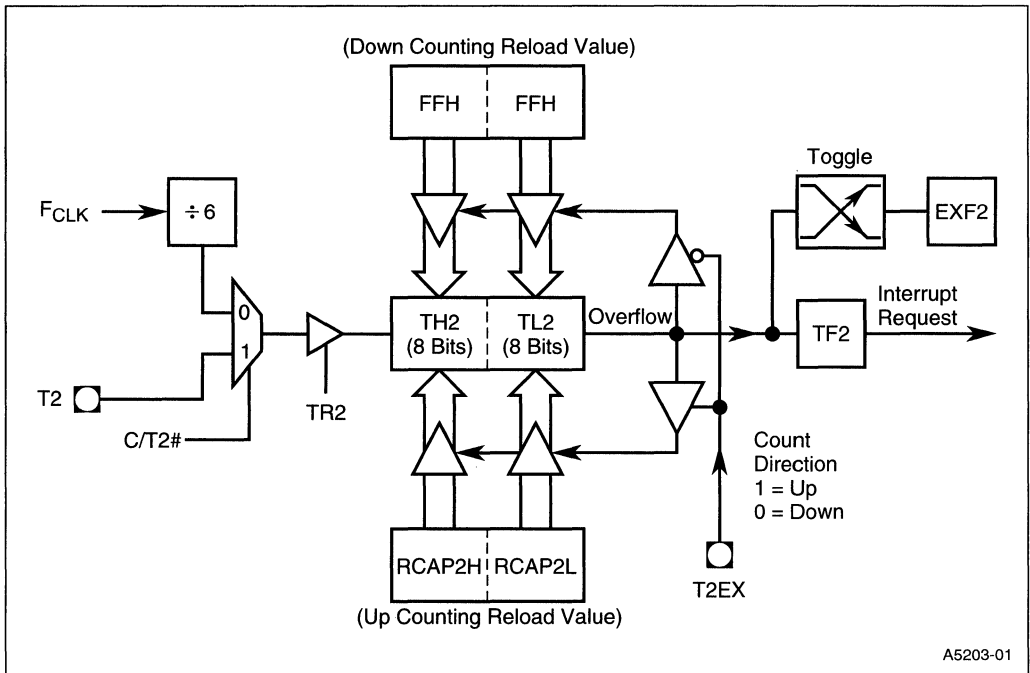


Figure 11-9. Timer 2: Auto-reload Mode (DCEN = 1)

11.6.4 Baud Rate Generator Mode

This mode configures timer 2 as a baud rate generator for use with the serial port. Select this mode by setting the RCLK and/or TCLK bits in T2CON. See Table 11-3. For details regarding this mode of operation, refer to “Baud Rates” on page 13-10.

11.6.5 Clock-out Mode

In the clock-out mode, timer 2 functions as a 50%-duty-cycle, variable-frequency clock (Figure 11-10). The generated clock signal appears on pin T2. The input clock increments TL0 at the internal clock frequency (F_{CLK}). The timer repeatedly counts to overflow from a preloaded value. At overflow, the contents of the RCAP2H and RCAP2L registers are loaded into TH2/TL2. In this mode, timer 2 overflows do not generate interrupts. The formula gives the clock-out frequency as a function of F_{CLK} (Table 2-4 on page 2-10) and the value in the RCAP2H and RCAP2L registers:

$$\text{Clock-out Frequency} = \frac{F_{CLK}}{2 \times (65535 - \text{RCAP2H}, \text{RCAP2L})}$$

For PLLSEL2:0 = 100 (low speed, $F_{CLK} = 6$ MHz), timer 2 has a programmable frequency range of 45.8 Hz to 3 MHz. For PLLSEL2:0 = 110 (full speed, $F_{CLK} = 12$ MHz), timer 2 has a programmable frequency range of 91.6 Hz to 6 MHz.

Timer 2 is programmed for the clock-out mode as follows:

1. Set the T2OE bit in T2MOD. This gates the timer register overflow to the $\div 2$ counter.
2. Clear the C/T2# bit in T2CON to select F_{CLK} as the timer input signal. This also gates the output of the $\div 2$ counter to pin T2.
3. Determine the 16-bit reload value from the formula and enter in the RCAP2H/RCAP2L registers.
4. Enter a 16-bit initial value in timer register TH2/TL2. This can be the same as the reload value, or different, depending on the application.
5. To start the timer, set the TR2 run control bit in T2CON.

Operation is similar to timer 2 operation as a baud rate generator. It is possible to use timer 2 as a baud rate generator and a clock generator simultaneously. For this configuration, the baud rates and clock frequencies are not independent since both functions use the values in the RCAP2H and RCAP2L registers.

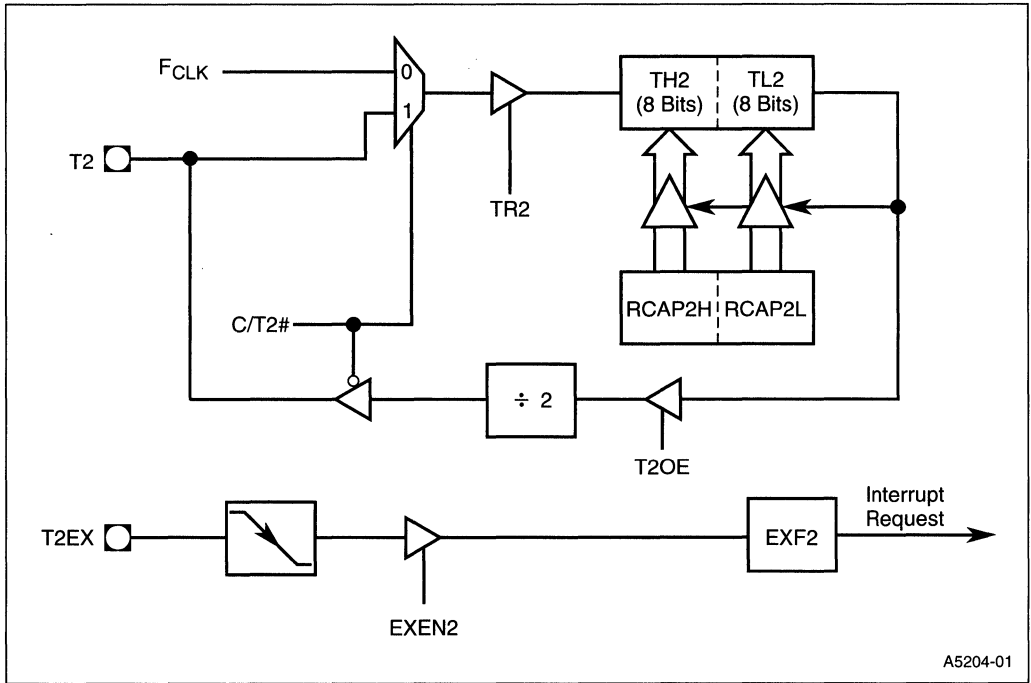


Figure 11-10. Timer 2: Clock Out Mode

Table 11-3. Timer 2 Modes of Operation

Mode	RCLK OR TCLK (in T2CON)	CP/RL2# (in T2CON)	T2OE (in T2MOD)
Auto-reload Mode	0	0	0
Capture Mode	0	1	0
Baud Rate Generator Mode	1	X	X
Programmable Clock-Out	X	0	1

T2MOD		Address:	S:C9H
		Reset State:	xxxx xx00B
Timer 2 Mode Control Register. Contains the timer 2 down count enable and clock-out enable bits for timer 2 .			
7		0	
— — — —		— — T2OE DCEN	
Bit Number	Bit Mnemonic	Function	
7:2	—	Reserved: Values read from these bits are indeterminate. Write zeros to these bits.	
1	T2OE	Timer 2 Output Enable Bit: In the timer 2 clock-out mode, connects the programmable clock output to external pin T2.	
0	DCEN	Down Count Enable Bit: Configures timer 2 as an up/down counter.	

Figure 11-11. T2MOD: Timer 2 Mode Control Register

11.7 WATCHDOG TIMER

The peripheral section of the 8x930 contains a dedicated, hardware watchdog timer (WDT) that automatically resets the chip if it is allowed to time out. The WDT provides a means of recovering from routines that do not complete successfully due to firmware malfunctions. The WDT described in this section is not associated with the PCA watchdog timer, which is implemented in firmware.

11.7.1 Description

The WDT is a 14-bit counter that counts peripheral cycles, i.e., $(F_{CLK}/6)$. The WDTRST special function register at address S:A6H provides control access to the WDT. Two operations control the WDT:

- Device reset clears and disables the WDT (see “Reset” on page 14-5).
- Writing a specific two-byte sequence to the WDTRST register clears and enables the WDT.

If it is not cleared, the WDT overflows on count $3FFFH + 1$. For $PLLSEL2:0 = 100$ ($F_{CLK} = 6$ MHz, a peripheral cycle is $1 \mu s$), the WDT overflows in $1 \mu s \times 16384 = 16.384$ ms. For $PLLSEL2:0 = 110$ ($F_{CLK} = 12$ MHz, a peripheral cycle is $0.5 \mu s$), the WDT overflows in $0.5 \mu s \times 16384 = 8.192$ ms.

The WDTRST is a write-only register. Attempts to read it return FFH. The WDT itself is not read or write accessible. The WDT does *not* drive the external RESET pin.

T2CON				Address: S:C8H			
				Reset State: 0000 0000B			
<p>Timer 2 Control Register. Contains the receive clock, transmit clock, and capture/reload bits used to configure timer 2. Also contains the run control bit, counter/timer select bit, overflow flag, external flag, and external enable for timer 2.</p>							
7				0			
TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2#	CP/RL2#
Bit Number	Bit Mnemonic	Function					
7	TF2	<p>Timer 2 Overflow Flag: Set by timer 2 overflow. Must be cleared by firmware. TF2 is not set if RCLK = 1 or TCLK = 1.</p>					
6	EXF2	<p>Timer 2 External Flag: If EXEN2 = 1, capture or reload caused by a negative transition on T2EX sets EXF2. EXF2 does not cause an interrupt in up/down counter mode (DCEN = 1).</p>					
5	RCLK	<p>Receive Clock Bit: Selects timer 2 overflow pulses (RCLK = 1) or timer 1 overflow pulses (RCLK = 0) as the baud rate generator for serial port modes 1 and 3.</p>					
4	TCLK	<p>Transmit Clock Bit: Selects timer 2 overflow pulses (TCLK = 1) or timer 1 overflow pulses (TCLK = 0) as the baud rate generator for serial port modes 1 and 3.</p>					
3	EXEN2	<p>Timer 2 External Enable Bit: Setting EXEN2 causes a capture or reload to occur as a result of a negative transition on T2EX unless timer 2 is being used as the baud rate generator for the serial port. Clearing EXEN2 causes timer 2 to ignore events at T2EX.</p>					
2	TR2	<p>Timer 2 Run Control Bit: Setting this bit starts the timer.</p>					
1	C/T2#	<p>Timer 2 Counter/Timer Select: C/T2# = 0 selects timer operation: timer 2 counts the divided-down system clock. C/T2# = 1 selects counter operation: timer 2 counts negative transitions on external pin T2.</p>					
0	CP/RL2#	<p>Capture/Reload Bit: When set, captures occur on negative transitions at T2EX if EXEN2 = 1. When cleared, auto-reloads occur on timer 2 overflows or negative transitions at T2EX if EXEN2 = 1. The CP/RL2# bit is ignored and timer 2 forced to auto-reload on timer 2 overflow, if RCLK = 1 or TCLK = 1.</p>					

Figure 11-12. T2CON: Timer 2 Control Register

11.7.2 Using the WDT

To use the WDT to recover from system malfunctions, the user program should control the WDT as follows:

1. Following device reset, write the two-byte sequence 1EH-E1H to the WDTRST register to enable the WDT. The WDT begins counting from 0.
2. Repeatedly for the duration of program execution, write the two-byte sequence 1EH-E1H to the WDTRST register to clear and enable the WDT before it overflows. The WDT starts over at 0.

If the WDT overflows, it initiates a device reset (see "Reset" on page 14-5). Device reset clears the WDT and disables it.

11.7.3 WDT During Idle Mode

Operation of the WDT during the power reduction modes deserves special attention. The WDT continues to count while the microcontroller is in idle mode. This means the user must service the WDT during idle. One approach is to use a peripheral timer to generate an interrupt request when the timer overflows. The interrupt service routine then clears the WDT, reloads the peripheral timer for the next service period, and puts the microcontroller back into idle.

11.7.4 WDT During PowerDown

The powerdown mode stops all phase clocks. This causes the WDT to stop counting and to hold its count. The WDT resumes counting from where it left off if the powerdown mode is terminated by INTO/INT1. To ensure that the WDT does not overflow shortly after exiting the powerdown mode, clear the WDT just before entering powerdown. The WDT is cleared and disabled if the powerdown mode is terminated by a reset.



12

**Programmable
Counter Array**





CHAPTER 12

PROGRAMMABLE COUNTER ARRAY

This chapter describes the programmable counter array (PCA), an on-chip peripheral of the 8x930 that performs a variety of timing and counting operations, including pulse width modulation (PWM). The PCA provides the capability for a firmware watchdog timer (WDT).

12.1 PCA DESCRIPTION

The programmable counter array (PCA) consists of a 16-bit timer/counter and five 16-bit compare/capture modules. The timer/counter serves as a common time base and event counter for the compare/capture modules, distributing the current count to the modules by means of a 16-bit bus. A special function register (SFR) pair, CH/CL, maintains the count in the timer/counter, while five SFR pairs, CCAPxH/CCAPxL, store values for the modules (see Figure 12-1). Additional SFRs provide control and mode select functions as follows:

- The PCA timer/counter mode register (CMOD) and the PCA timer/counter control register (CCON) control the operation of the timer/counter. See Figure 12-7 on page 12-13 and Figure 12-8 on page 12-14.
- Five PCA module mode registers (CCAPMx) specify the operating modes of the compare/capture modules. See Figure 12-9 on page 12-16.

For a list of SFRs associated with the PCA, see Table 12-1. For an SFR address map, see Table 3-5 on page 3-16. Port 1 provides external I/O for the PCA on a shared basis with other functions. Table 12-2 identifies the port pins associated with the timer/counter and compare/capture modules. When not used for PCA I/O, these pins can be used for standard I/O functions.

The operating modes of the five compare/capture modules determine the functions performed by the PCA. Each module can be independently programmed to provide input capture, output compare, or pulse width modulation. Module 4 only also has a watchdog-timer mode.

The PCA timer/counter and the five compare/capture modules share a single interrupt vector. The EC bit in the IEN0 special function register is a global interrupt enable for the PCA. Capture events, compare events in some modes, and PCA timer/counter overflows all set flags in the CCON register. Setting the overflow flag (CF) generates a PCA interrupt request if the PCA timer/counter interrupt enable bit (ECF) in the CMOD register is set (Figure 12-1). Setting a compare/capture flag (CCFx) generates a PCA interrupt request if the ECCFx interrupt enable bit in the corresponding CCAPMx register is set (Figures 12-2 and 12-3). For a description of the 8x930 interrupt system see Chapter 6, "Interrupt System".

12.1.1 Alternate Port Usage

PCA modules 3 and 4 share port pins with the real-time wait state and address functions as follows:

- PCA module 3 — P1.6/CEX3/WAIT#
- PCA module 4 — P1.7/CEX4/A17/WCLK

When the real-time wait state functions are enabled (using the WCON register), the corresponding PCA modules are automatically disabled. Configuring the 8x930 to use address line A17 (specified by UCONFIG0, bits RD1:0) overrides the PCA module 3 and WCLK functions. When a real-time wait state function is enabled, do not use the corresponding PCA module.

NOTE

It is not advisable to alternate between PCA operations and real-time wait state operations at port 1.6 (CEX3/WAIT#) or port 1.7 (CEX4/WCLK). See “External Bus Cycles with Real-time Wait States” on page 16-11.

12.2 PCA TIMER/COUNTER

Figure 12-1 depicts the basic logic of the timer/counter portion of the PCA. The CH/CL special function register pair operates as a 16-bit timer/counter. The selected input increments the CL (low byte) register. When CL overflows, the CH (high byte) register increments after two oscillator periods; when CH overflows it sets the PCA overflow flag (CF in the CCON register) generating a PCA interrupt request if the ECF bit in the CMOD register is set.

The CPS1 and CPS0 bits in the CMOD register select one of four signals as the input to the timer/counter (Figure 12-7 on page 12-13):

- $F_{CLK}/6$. Provides a clock pulse at S5P2 of every peripheral cycle. With PLLSEL2:0 = 100 and $F_{OSC} = 12$ MHz, the timer/counter increments every 1000 nanoseconds. With PLLSEL2:0 = 110 and $F_{OSC} = 12$ MHz, the timer/counter increments every 500 nanoseconds.
- $F_{CLK}/2$. Provides clock pulses at S1P2, S3P2, and S5P2 of every peripheral cycle. With PLLSEL2:0 = 100 and $F_{OSC} = 12$ MHz, the timer/counter increments every 333 $1/3$ nanoseconds. With PLLSEL2:0 = 110 and $F_{OSC} = 12$ MHz, the timer/counter increments every 166 $2/3$ nanoseconds.
- Timer 0 overflow. The CL register is incremented at S5P2 of the peripheral cycle when timer 0 overflows. This selection provides the PCA with a programmable frequency input.
- External signal on P1.2/ECl. The CPU samples the ECI pin at S1P2, S3P2, and S5P2 of every peripheral cycle. The first clock pulse (S1P2, S3P2, or S5P2) that occurs following a high-to-low transition at the ECI pin increments the CL register. The maximum input frequency for this input selection is $F_{OSC}/8$.

For a description of peripheral cycle timing, see “Clock and Reset Unit” on page 2-9.

Setting the run control bit (CR in the CCON register) turns the PCA timer/counter on, if the output of the NAND gate (Figure 12-1) equals logic 1. The PCA timer/counter continues to operate during idle mode unless the CIDL bit of the CMOD register is set. The CPU can read the contents of the CH and CL registers at any time. However, writing to them is inhibited while they are counting (i.e., when the CR bit is set).

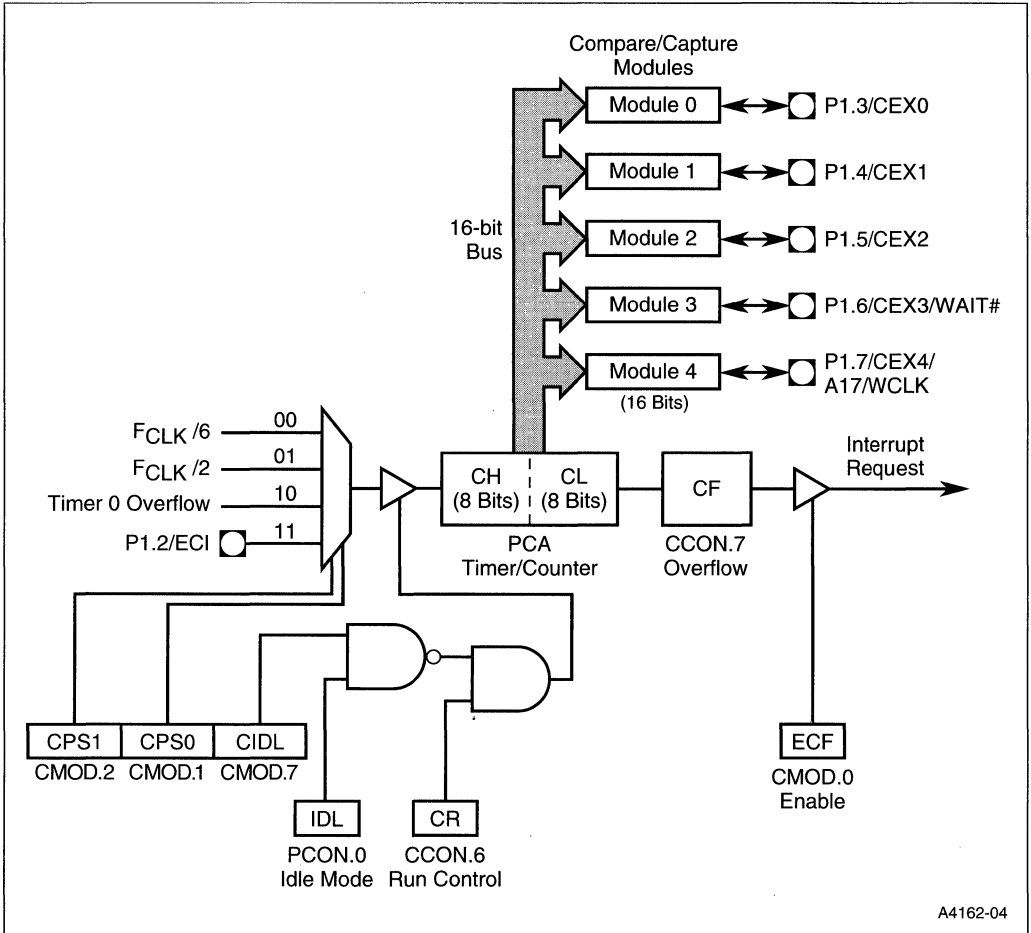


Figure 12-1. Programmable Counter Array†

† This figure depicts the case of PLL off (PLLSEL2:0 = 001 or 100). For the case of PLL on (PLLSEL2:0 = 110), the clock frequencies at inputs 00 and 01 of the CPS_x selector are twice that for PLLSEL2:0 = 100 (PLL off). See Table 2-4 on page 2-10.

Table 12-1. PCA Special Function Registers (SFRs)

Mnemonic	Description	Address
CL CH	PCA Timer/Counter. These registers serve as a common 16-bit timer or event counter for the five compare/capture modules. Counts $F_{OSC}/12$, $F_{OSC}/4$, timer 0 overflow, or the external signal on P1.2/ECl, as selected by CMOD. In PWM mode CL operates as an 8-bit timer.	S:E9H S:F9H
CCON	PCA Timer/Counter Control Register. Contains the run control bit and the overflow flag for the PCA timer/counter, and interrupt flags for the five compare/capture modules.	S:D8H
CMOD	PCA Timer/Counter Mode Register. Contains bits for disabling the PCA timer/counter during idle mode, enabling the PCA watchdog timer (module 4), selecting the timer/counter input, and enabling the PCA timer/counter overflow interrupt.	S:D9H
CCAP0H CCAP0L	PCA Module 0 Compare/Capture Registers. This register pair stores the comparison value or the captured value. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.	S:FAH S:EAH
CCAP1H CCAP1L	PCA Module 1 Compare/Capture Registers. This register pair stores the comparison value or the captured value. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.	S:FBH S:EBH
CCAP2H CCAP2L	PCA Module 2 Compare/Capture Registers. This register pair stores the comparison value or the captured value. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.	S:FCH S:ECH
CCAP3H CCAP3L	PCA Module 3 Compare/Capture Registers. This register pair stores the comparison value or the captured value. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.	S:FDH S:EDH
CCAP4H CCAP4L	PCA Module 4 Compare/Capture Registers. This register pair stores the comparison value or the captured value. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.	S:FEH S:EEH
CCAPM0 CCAPM1 CCAPM2 CCAPM3 CCAPM4	PCA Compare/Capture Module Mode Registers. Contain bits for selecting the operating mode of the compare/capture modules and enabling the compare/capture flag. See Table 12-3 on page 12-15 for mode select bit combinations.	S:DAH S:DBH S:DCH S:DDH S:DEH

Table 12-2. External Signals

Signal Name	Type	Description	Alternate Function
ECl	I	PCA Timer/counter External Input. This signal is the external clock input for the PCA timer/counter.	P1.2
CEX0 CEX1 CEX2 CEX3 CEX4	I/O	Compare/Capture Module External I/O. Each compare/capture module connects to a Port 1 pin for external I/O. When not used by the PCA, these pins can handle standard I/O.	P1.3 P1.4 P1.5 P1.6/WAIT# P1.7/A17/WCLK

12.3 PCA COMPARE/CAPTURE MODULES

Each compare/capture module is made up of a compare/capture register pair (CCAPxH/CCAPxL), a 16-bit comparator, and various logic gates and signal transition selectors. The registers store the time or count at which an external event occurred (capture) or at which an action should occur (comparison). In the PWM mode, the low-byte register controls the duty cycle of the output waveform.

The logical configuration of a compare/capture module depends on its mode of operation (Figures 12-2 through 12-5). Each module can be independently programmed for operation in any of the following modes:

- 16-bit capture mode with triggering on the positive edge, negative edge, or either edge.
- Compare modes: 16-bit software timer, 16-bit high-speed output, 16-bit WDT (module 4 only), or 8-bit pulse width modulation.
- No operation.

Bit combinations programmed into a compare/capture module's mode register (CCAPMx) determine the operating mode. Figure 12-9 on page 12-16 provides bit definitions and Table 12-3 lists the bit combinations of the available modes. Other bit combinations are invalid and produce undefined results.

The compare/capture modules perform their programmed functions when their common time base, the PCA timer/counter, runs. The timer/counter is turned on and off with the CR bit in the CCON register. To disable any given module, program it for the no operation mode. The occurrence of a capture, firmware timer, or high-speed output event in a compare/capture module sets the module's compare/capture flag (CCFx) in the CCON register and generates a PCA interrupt request if the corresponding enable bit in the CCAPMx register is set.

The CPU can read or write the CCAPxH and CCAPxL registers at any time.

12.3.1 16-bit Capture Mode

The capture mode (Figure 12-2) provides the PCA with the ability to measure periods, pulse widths, duty cycles, and phase differences at up to five separate inputs. External I/O pins CEX0 through CEX4 are sampled for signal transitions (positive and/or negative as specified). When a compare/capture module programmed for the capture mode detects the specified transition, it captures the PCA timer/counter value. This records the time at which an external event is detected, with a resolution equal to the timer/counter clock period.

To program a compare/capture module for the 16-bit capture mode, program the CAPPx and CAPNx bits in the module's CCAPMx register as follows:

- To trigger the capture on a positive transition, set CAPPx and clear CAPNx.
- To trigger the capture on a negative transition, set CAPNx and clear CAPPx.
- To trigger the capture on a positive or negative transition, set both CAPPx and CAPNx.

Table 12-3 on page 12-15 lists the bit combinations for selecting module modes. For modules in the capture mode, detection of a valid signal transition at the I/O pin (CEX_x) causes hardware to load the current PCA timer/counter value into the compare/capture registers (CCAP_xH/CCAP_xL) and to set the module's compare/capture flag (CCF_x) in the CCON register. If the corresponding interrupt enable bit (ECCF_x) in the CCAPM_x register is set (Figure 12-9 on page 12-16), the PCA sends an interrupt request to the interrupt handler.

Since hardware does not clear the event flag when the interrupt is processed, the user must clear the flag in firmware. A subsequent capture by the same module overwrites the existing captured value. To preserve a captured value, save it in RAM with the interrupt service routine before the next capture event occurs.

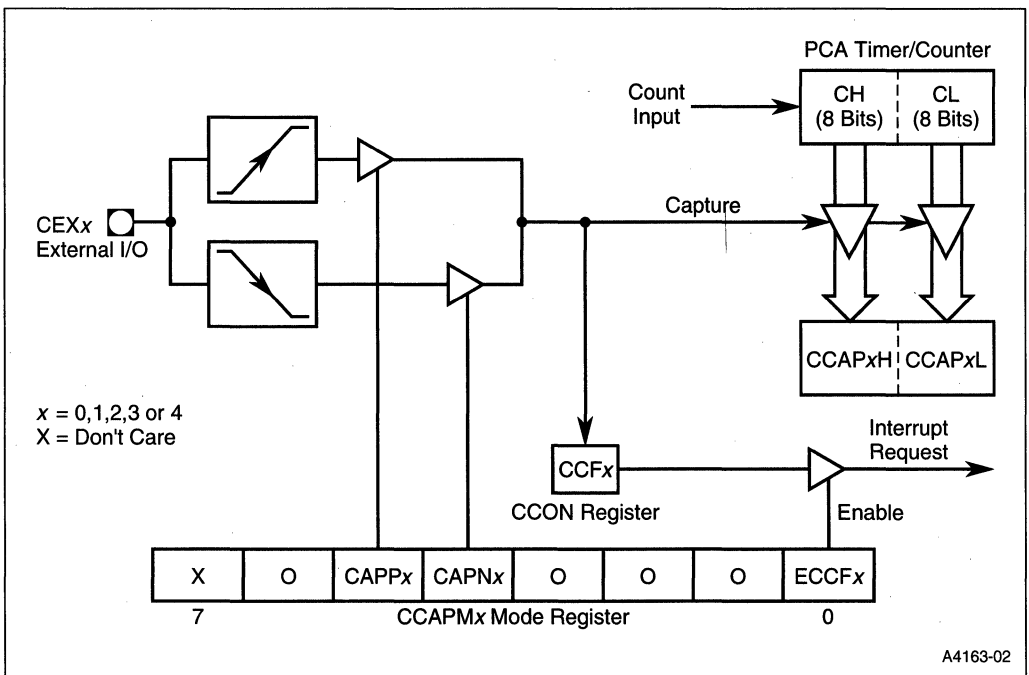


Figure 12-2. PCA 16-bit Capture Mode

12.3.2 Compare Modes

The compare function provides the capability for operating the five modules as timers, event counters, or pulse width modulators. Four modes employ the compare function: 16-bit firmware timer mode, high-speed output mode, WDT mode, and PWM mode. In the first three of these, the compare/capture module continuously compares the 16-bit PCA timer/counter value with the 16-bit value pre-loaded into the module's CCAPxH/CCAPxL register pair. In the PWM mode, the module continuously compares the value in the low-byte PCA timer/counter register (CL) with an 8-bit value in the CCAPxL module register. Comparisons are made three times per peripheral cycle to match the fastest PCA timer/counter clocking rate ($F_{OSC}/4$). For a description of peripheral cycle timing, see "Clock and Reset Unit" on page 2-9.

Setting the ECOMx bit in a module's mode register (CCAPMx) selects the compare function for that module (Figure 12-9 on page 12-16). To use the modules in the compare modes, observe the following general procedure:

1. Select the module's mode of operation.
2. Select the input signal for the PCA timer/counter.
3. Load the comparison value into the module's compare/capture register pair.
4. Set the PCA timer/counter run control bit.
5. After a match causes an interrupt, clear the module's compare/capture flag.

12.3.3 16-bit Software Timer Mode

To program a compare/capture module for the 16-bit software timer mode (Figure 12-3), set the ECOMx and MATx bits in the module's CCAPMx register. Table 12-3 lists the bit combinations for selecting module modes.

A match between the PCA timer/counter and the compare/capture registers (CCAPxH/CCAPxL) sets the module's compare/capture flag (CCFx in the CCON register). This generates an interrupt request if the corresponding interrupt enable bit (ECCFx in the CCAPMx register) is set. Since hardware does not clear the compare/capture flag when the interrupt is processed, the user must clear the flag in firmware. During the interrupt routine, a new 16-bit compare value can be written to the compare/capture registers (CCAPxH/CCAPxL).

NOTE

To prevent an invalid match while updating these registers, user firmware should write to CCAPxL first, then CCAPxH. A write to CCAPxL clears the ECOMx bit disabling the compare function, while a write to CCAPxH sets the ECOMx bit re-enabling the compare function.

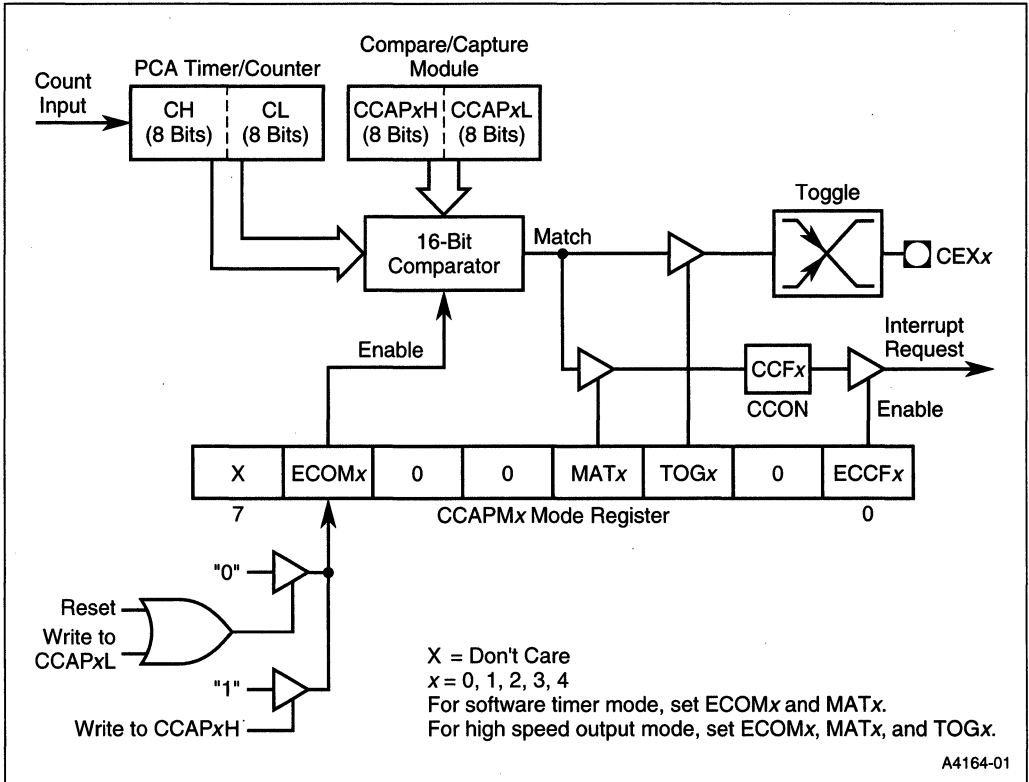


Figure 12-3. PCA Software Timer and High-speed Output Modes

12.3.4 High-speed Output Mode

The high-speed output mode (Figure 12-3) generates an output signal by toggling the module's I/O pin (CEX_x) when a match occurs. This provides greater accuracy than toggling pins in firmware because the toggle occurs *before* the interrupt request is serviced. Thus, interrupt response time does not affect the accuracy of the output.

To program a compare/capture module for the high-speed output mode, set the ECOM_x, MAT_x, TOG_x bits in the module's CCAPM_x register. Table 12-3 on page 12-15 lists the bit combinations for selecting module modes. A match between the PCA timer/counter and the compare/capture registers (CCAP_xH/CCAP_xL) toggles the CEX_x pin and sets the module's compare/capture flag (CCF_x in the CCON register). By setting or clearing the CEX_x pin in firmware, the user selects whether the match toggles the pin from low to high or vice versa.

The user also has the option of generating an interrupt request when the match occurs by setting the corresponding interrupt enable bit (ECCF_x in the CCAPM_x register). Since hardware does not clear the compare/capture flag when the interrupt is processed, the user must clear the flag in firmware.

If the user does not change the compare/capture registers in the interrupt routine, the next toggle occurs after the PCA timer/counter rolls over and the count again matches the comparison value. During the interrupt routine, a new 16-bit compare value can be written to the compare/capture registers (CCAPxH/CCAPxL).

NOTE

To prevent an invalid match while updating these registers, user firmware should write to CCAPxL first, then CCAPxH. A write to CCAPxL clears the ECOMx bit disabling the compare function, while a write to CCAPxH sets the ECOMx bit re-enabling the compare function.

12.3.5 PCA Watchdog Timer Mode

A watchdog timer (WDT) provides the means to recover from routines that do not complete successfully. A WDT automatically invokes a device reset if it does not regularly receive hold-off signals. WDTs are used in applications that are subject to electrical noise, power glitches, electrostatic discharges, etc., or where high reliability is required.

In addition to the 8x930's 14-bit hardware WDT, the PCA provides a programmable-frequency 16-bit WDT as a mode option on compare/capture module 4. This mode generates a device reset when the count in the PCA timer/counter matches the value stored in the module 4 compare/capture registers. A PCA WDT reset has the same effect as an external reset. Module 4 is the only PCA module that has the WDT mode. When not programmed as a WDT, it can be used in the other modes.

To program module 4 for the PCA WDT mode (Figure 12-4), set the ECOM4 and MAT4 bits in the CCAPM4 register and the WDTE bit in the CMOD register. Table 12-3 lists the bit combinations for selecting module modes. Also select the desired input for the PCA timer/counter by programming the CPS0 and CPS1 bits in the CMOD register (see Figure 12-7 on page 12-13). Enter a 16-bit comparison value in the compare/capture registers (CCAP4H/CCAP4L). Enter a 16-bit initial value in the PCA timer/counter (CH/CL) or use the reset value (0000H). The difference between these values multiplied by the PCA input pulse rate determines the running time to “expiration.” Set the timer/counter run control bit (CR in the CCON register) to start the PCA WDT.

The PCA WDT generates a reset signal each time a match occurs. To hold off a PCA WDT reset, the user has three options:

- periodically change the comparison value in CCAP4H/CCAP4L so a match never occurs
- periodically change the PCA timer/counter value so a match never occurs
- disable the module 4 reset output signal by clearing the WDTE bit before a match occurs, then later re-enable it

The first two options are more reliable because the WDT is not disabled as in the third option. The second option is not recommended if other PCA modules are in use, since the five modules share a common time base. Thus, in most applications the first option is the best one.

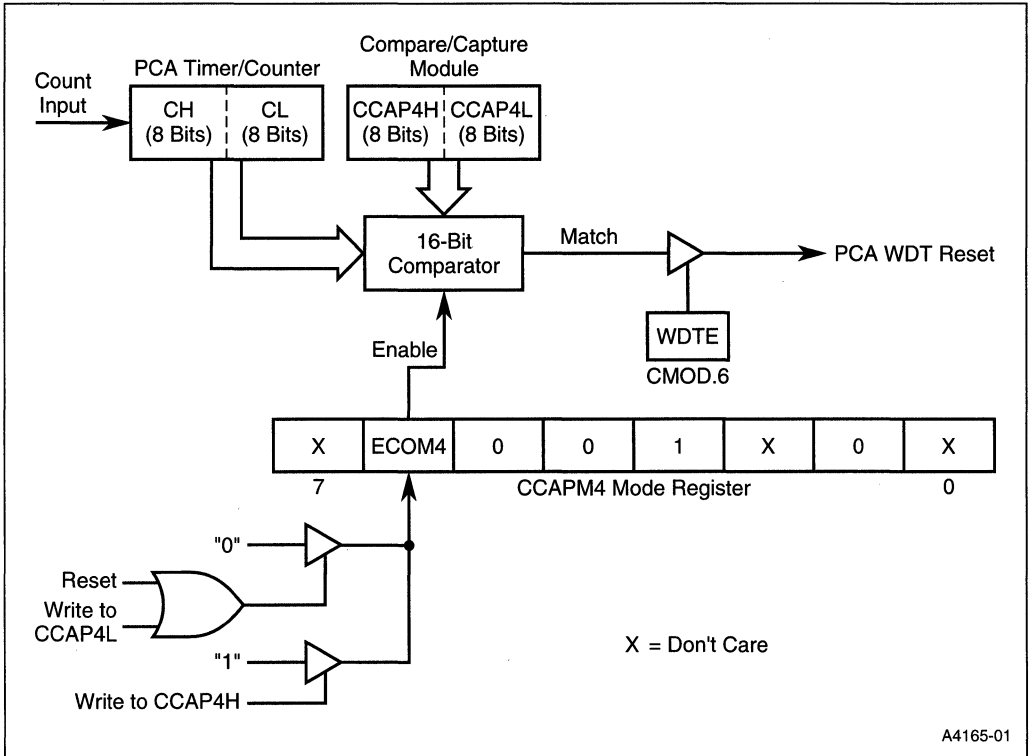


Figure 12-4. PCA Watchdog Timer Mode

12.3.6 Pulse Width Modulation Mode

The five PCA comparator/capture modules can be independently programmed to function as pulse width modulators (Figure 12-5). The modulated output, which has a pulse width resolution of eight bits, is available at the CEX_x pin. The PWM output can be used to convert digital data to an analog signal with simple external circuitry.

In this mode the value in the low byte of the PCA timer/counter (CL) is continuously compared with the value in the low byte of the compare/capture register (CCAP_xL). When CL < CCAP_xL, the output waveform (Figure 12-6) is low. When a match occurs (CL = CCAP_xL), the output waveform goes high and remains high until CL rolls over from FFH to 00H, ending the period. At roll over the output returns to a low, the value in CCAP_xH is loaded into CCAP_xL, and a new period begins.

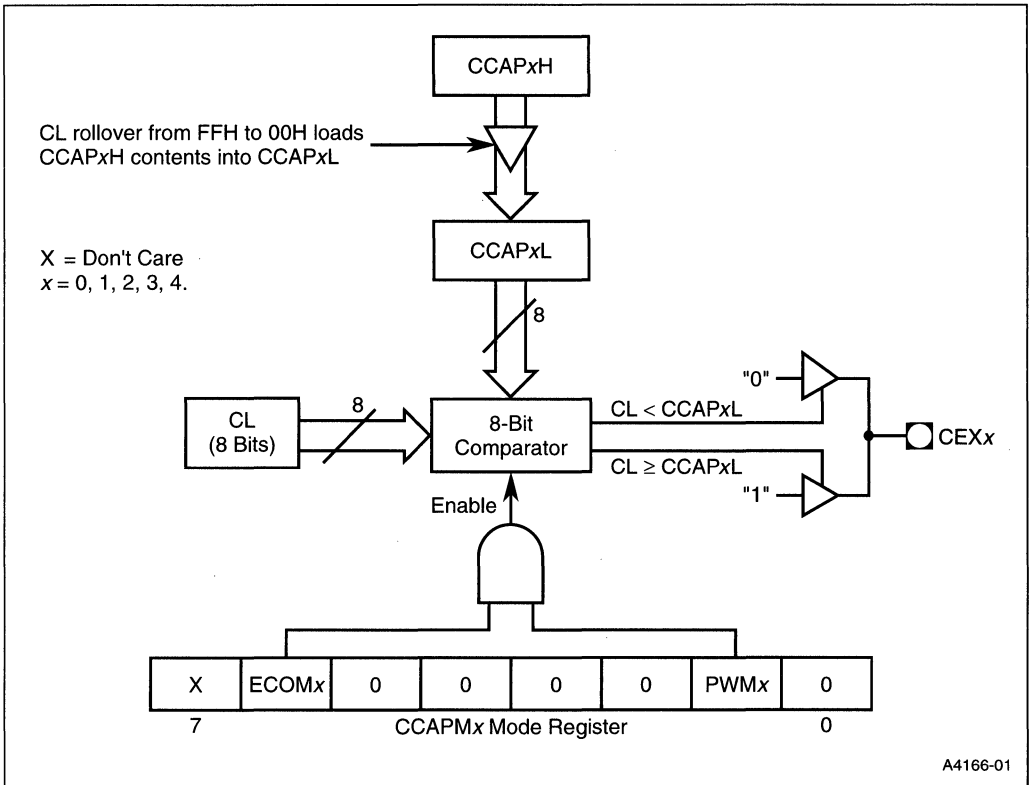


Figure 12-5. PCA 8-bit PWM Mode

The value in CCAPxL determines the duty cycle of the current period. The value in CCAPxH determines the duty cycle of the following period. Changing the value in CCAPxL over time modulates the pulse width. As depicted in Figure 12-6, the 8-bit value in CCAPxL can vary from 0 (100% duty cycle) to 255 (0.4% duty cycle).

NOTE

To change the value in CCAPxL without glitches, write the new value to the high byte register (CCAPxH). This value is shifted by hardware into CCAPxL when CL rolls over from FFH to 00H.

The frequency of the PWM output equals the frequency of the PCA timer/counter input signal divided by 256. The highest frequency occurs when the $F_{OSC}/4$ input is selected for the PCA timer/counter. For PLLSEL2:0 = 100 and $F_{OSC} = 12$ MHz, this is 11.7 KHz. For PLLSEL2:0 = 110 and $F_{OSC} = 12$ MHz, this is 23.4 KHz.

To program a compare/capture module for the PWM mode, set the $ECOM_x$ and PWM_x bits in the module's $CCAPM_x$ register. Table 12-3 on page 12-15 lists the bit combinations for selecting module modes. Also select the desired input for the PCA timer/counter by programming the $CPS0$ and $CPS1$ bits in the $CMOD$ register (see Figure 12-7). Enter an 8-bit value in $CCAPxL$ to specify the duty cycle of the first period of the PWM output waveform. Enter an 8-bit value in $CCAPxH$ to specify the duty cycle of the second period. Set the timer/counter run control bit (CR in the $CCON$ register) to start the PCA timer/counter.

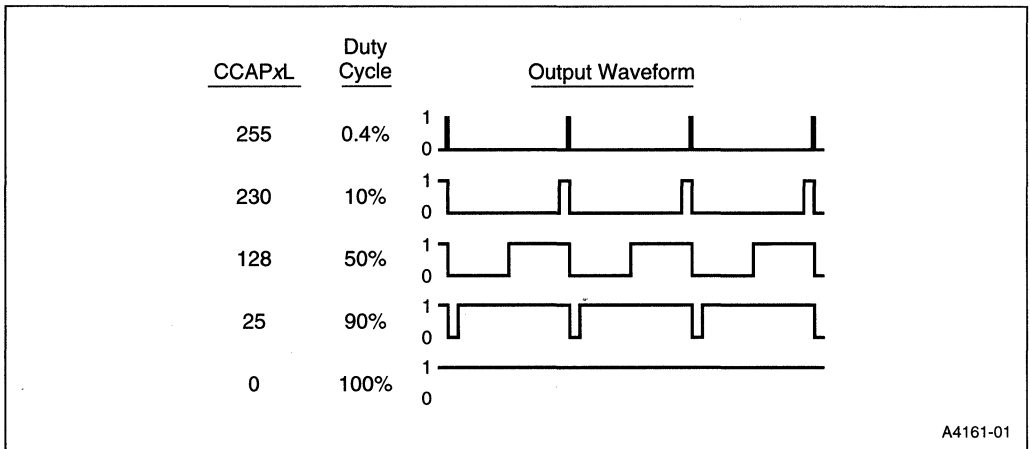


Figure 12-6. PWM Variable Duty Cycle

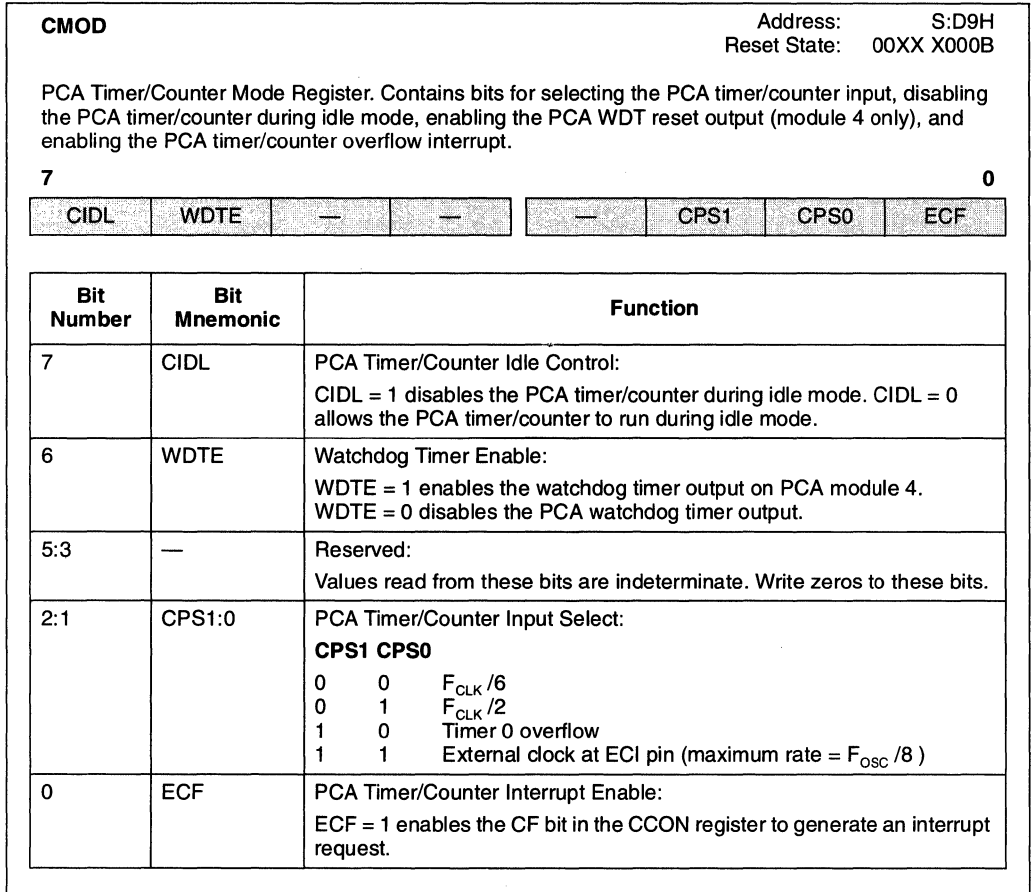


Figure 12-7. CMOD: PCA Timer/Counter Mode Register

CCON		Address: S:D8H
		Reset State: 00X0 0000B
PCA Timer/Counter Control Register. Contains the run control bit and overflow flag for the PCA timer/counter, and the compare/capture flags for the five PCA compare/capture modules.		
7		0
CF	CR	—
CCF4	CCF3	CCF2
CCF1	CCF0	
Bit Number	Bit Mnemonic	Function
7	CF	PCA Timer/Counter Overflow Flag: Set by hardware when the PCA timer/counter rolls over. This generates an interrupt request if the ECF interrupt enable bit in CMOD is set. CF can be set by hardware or firmware but can be cleared only by firmware.
6	CR	PCA Timer/Counter Run Control Bit: Set and cleared by firmware to turn the PCA timer/counter on and off.
5	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.
4:0	CCF4:0	PCA Module Compare/Capture Flags: Set by hardware when a match or capture occurs. This generates a PCA interrupt request if the ECCFx interrupt enable bit in the corresponding CCAPMx register is set. Must be cleared by firmware.

Figure 12-8. CCON: PCA Timer/Counter Control Register

Table 12-3. PCA Module Modes

ECOM _x	CAPP _x	CAPN _x	MAT _x	TOG _x	PWM _x	ECCF _x	Module Mode
0	0	0	0	0	0	0	No operation
X	1	0	0	0	0	X	16-bit capture on positive-edge trigger at CEX _x
X	0	1	0	0	0	X	16-bit capture on negative-edge trigger at CEX _x
X	1	1	0	0	0	X	16-bit capture on positive- or negative-edge trigger at CEX _x
1	0	0	1	0	0	X	Compare: firmware timer
1	0	0	1	1	0	X	Compare: high-speed output
1	0	0	0	0	1	0	Compare: 8-bit PWM
1	0	0	1	X	0	X	Compare: PCA WDT (CCAPM4 only) (Note 3)

NOTES:

1. This table shows the CCAPM_x register bit combinations for selecting the operating modes of the PCA compare/capture modules. Other bit combinations are invalid. See Figure 12-9 for bit definitions.
2. X = 0–4, X = Don't care.
3. For PCA WDT mode, also set the WDTE bit in the CMOD register to enable the reset output signal.

CCAPM_x (x = 0-4)

Address: CCAPM0 S:DAH
 CCAPM1 S:DBH
 CCAPM2 S:DCH
 CCAPM3 S:DDH
 CCAPM4 S:DEH
 Reset State: x000 0000B

PCA Module Compare/Capture Registers. These five register pairs store the 16-bit comparison value or captured value for the corresponding compare/capture modules. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.

7 0



Bit Number	Bit Mnemonic	Function
7	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.
6	ECOM _x	Compare Modes: ECOM _x = 1 enables the module comparator function. The comparator is used to implement the firmware timer, high-speed output, pulse width modulation, and watchdog timer modes.
5	CAPP _x	Capture Mode (Positive): CAPP _x = 1 enables the capture function with capture triggered by a positive edge on pin CEX _x .
4	CAPN _x	Capture Mode (Negative): CAPN _x = 1 enables the capture function with capture triggered by a negative edge on pin CEX _x .
3	MAT _x	Match: Set ECOM _x and MAT _x to implement the firmware timer mode. When MAT _x = 1, a match of the PCA timer/counter with the compare/capture register sets the CCF _x bit in the CCON register, flagging an interrupt.
2	TOG _x	Toggle: Set ECOM _x , MAT _x , and TOG _x to implement the high-speed output mode. When TOG _x = 1, a match of the PCA timer/counter with the compare/capture register toggles the CEX _x pin.
1	PWM _x	Pulse Width Modulation Mode: PWM _x = 1 configures the module for operation as an 8-bit pulse width modulator with output waveform on the CEX _x pin.
0	ECCF _x	Enable CCF _x Interrupt: Enables compare/capture flag CCF _x in the CCON register to generate an interrupt request.

Figure 12-9. CCAPM_x: PCA Compare/Capture Module Mode Registers

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13

Serial I/O Port





CHAPTER 13

SERIAL I/O PORT

The serial input/output port supports communication with modems and other external peripheral devices. This chapter provides instructions for programming the serial port and generating the serial I/O baud rates with timer 1 and timer 2.

13.1 OVERVIEW

The serial I/O port provides both synchronous and asynchronous communication modes. It operates as a universal asynchronous receiver and transmitter (UART) in three full-duplex modes (modes 1, 2, and 3). Asynchronous transmission and reception can occur simultaneously and at different baud rates. The UART supports framing-bit error detection, multiprocessor communication, and automatic address recognition. The serial port also operates in a single synchronous mode (mode 0).

The synchronous mode (mode 0) operates at a single baud rate. Mode 2 operates at two baud rates. Modes 1 and 3 operate over a wide range of baud rates, which are generated by timer 1 and timer 2. Baud rates are detailed in “Baud Rates” on page 13-10.

NOTE

The baud rate calculations in this chapter are based on the value of F_{CLK} which is a function of PLLSEL2:0. See Table 2-4 and Figure 2-6 on page 2-9.

The serial port signals are defined in Table 13-1, and the serial port special function registers are described in Table 13-2. Figure 13-1 is a block diagram of the serial port.

For the three asynchronous modes, the UART transmits on the TXD pin and receives on the RXD pin. For the synchronous mode (mode 0), the UART outputs a clock signal on the TXD pin and sends and receives messages on the RXD pin (Figure 13-1). The SBUF register, which holds received bytes and bytes to be transmitted, actually consists of two physically different registers. To send, firmware writes a byte to SBUF; to receive, firmware reads SBUF. The receive shift register allows reception of a second byte before the first byte has been read from SBUF. However, if firmware has not read the first byte by the time the second byte is received, the second byte will overwrite the first. The UART sets interrupt bits TI and RI on transmission and reception, respectively. These two bits share a single interrupt request and interrupt vector.

The serial port control (SCON) register (Figure 13-2) configures and controls the serial port.

Table 13-1. Serial Port Signals

Function Name	Type	Description	Multiplexed With
TXD	O	Transmit Data. In mode 0, TXD transmits the clock signal. In modes 1, 2, and 3, TXD transmits serial data.	P3.1
RXD	I/O	Receive Data. In mode 0, RXD transmits and receives serial data. In modes 1, 2, and 3, RXD receives serial data.	P3.0

Table 13-2. Serial Port Special Function Registers

Mnemonic	Description	Address
SBUF	Serial Buffer. Two separate registers, accessed with same address comprise the SBUF register. Writing to SBUF loads the transmit buffer; reading SBUF accesses the receive buffer.	S:99H
SCON	Serial Port Control. Selects the serial port operating mode. SCON enables and disables the receiver, framing bit error detection, multiprocessor communication, automatic address recognition, and the serial port interrupt bits.	S:98H
SADDR	Serial Address. Defines the individual address for a slave device.	S:A8H
SADEN	Serial Address Enable. Specifies the mask byte that is used to define the given address for a slave device.	S:B8H

13.2 MODES OF OPERATION

The serial I/O port can operate in one synchronous and three asynchronous modes.

13.2.1 Synchronous Mode (Mode 0)

Mode 0 is a half-duplex, synchronous mode, which is commonly used to expand the I/O capabilities of a device with shift registers. The transmit data (TXD) pin outputs a set of eight clock pulses while the receive data (RXD) pin transmits or receives a byte of data. The eight data bits are transmitted and received least-significant bit (LSb) first. Shifts occur in the last phase (S6P2) of every peripheral cycle, which corresponds to a baud rate of $F_{CLK}/6$. Figure 13-3 on page 13-6 shows the timing for transmission and reception in mode 0.

13.2.1.1 Transmission (Mode 0)

Follow these steps to begin a transmission:

1. Write to the SCON register, clearing bits SM0, SM1, and REN.
2. Write the byte to be transmitted to the SBUF register. This write starts the transmission.

Hardware executes the write to SBUF in the last phase (S6P2) of a peripheral cycle. At S6P2 of the following cycle, hardware shifts the LSb (D0) onto the RXD pin. At S3P1 of the next cycle, the TXD pin goes low for the first clock-signal pulse. Shifts continue every peripheral cycle. In the ninth cycle after the write to SBUF, the MSB (D7) is on the RXD pin. At the beginning of the

tenth cycle, hardware drives the RXD pin high and asserts TI (S1P1) to indicate the end of the transmission.

13.2.1.2 Reception (Mode 0)

To start a reception in mode 0, write to the SCON register. Clear bits SM0, SM1, and RI and set the REN bit.

Hardware executes the write to SCON in the last phase (S6P2) of a peripheral cycle (Figure 13-3). In the second peripheral cycle following the write to SCON, TXD goes low at S3P1 for the first clock-signal pulse, and the LSb (D0) is sampled on the RXD pin at S5P2. The D0 bit is then shifted into the shift register. After eight shifts at S6P2 of every peripheral cycle, the LSb (D7) is shifted into the shift register, and hardware asserts RI (S1P1) to indicate a completed reception. Firmware can then read the received byte from SBUF.

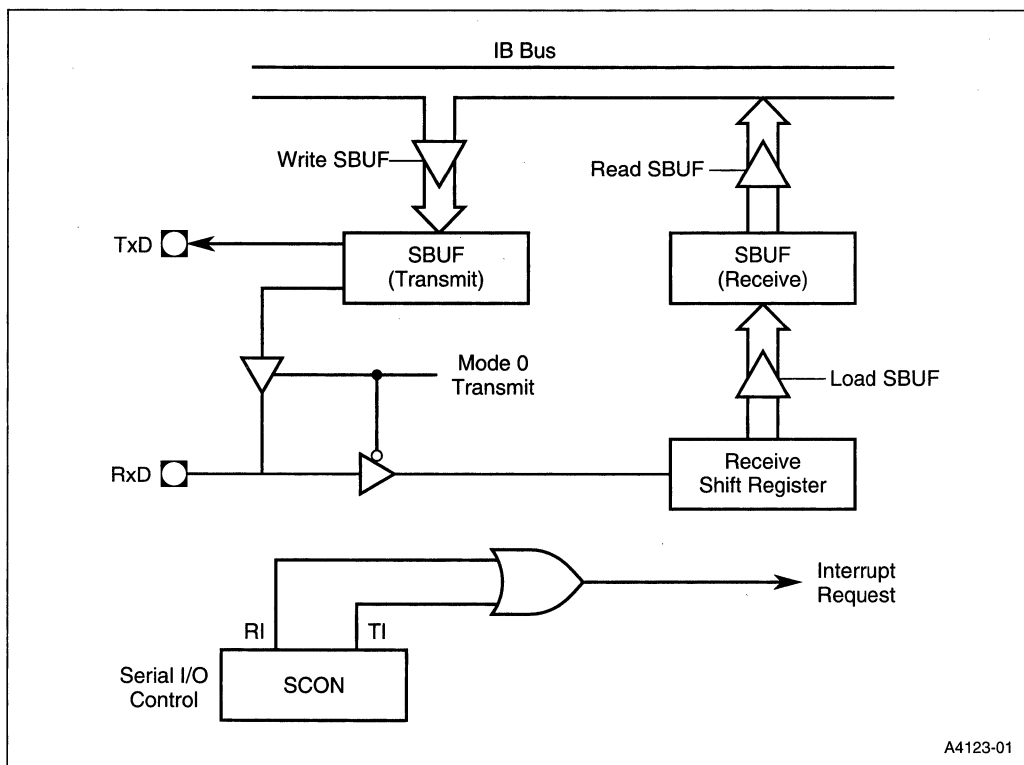


Figure 13-1. Serial Port Block Diagram

A4123-01

SCON	Address: S:98H	
	Reset State: 0000 0000B	
Serial Port Control Register. SCON contains serial I/O control and status bits, including the mode select bits and the interrupt flag bits.		
7		0
FE/SM0	SM1	SM2
REN	TB8	RB8
	TI	RI

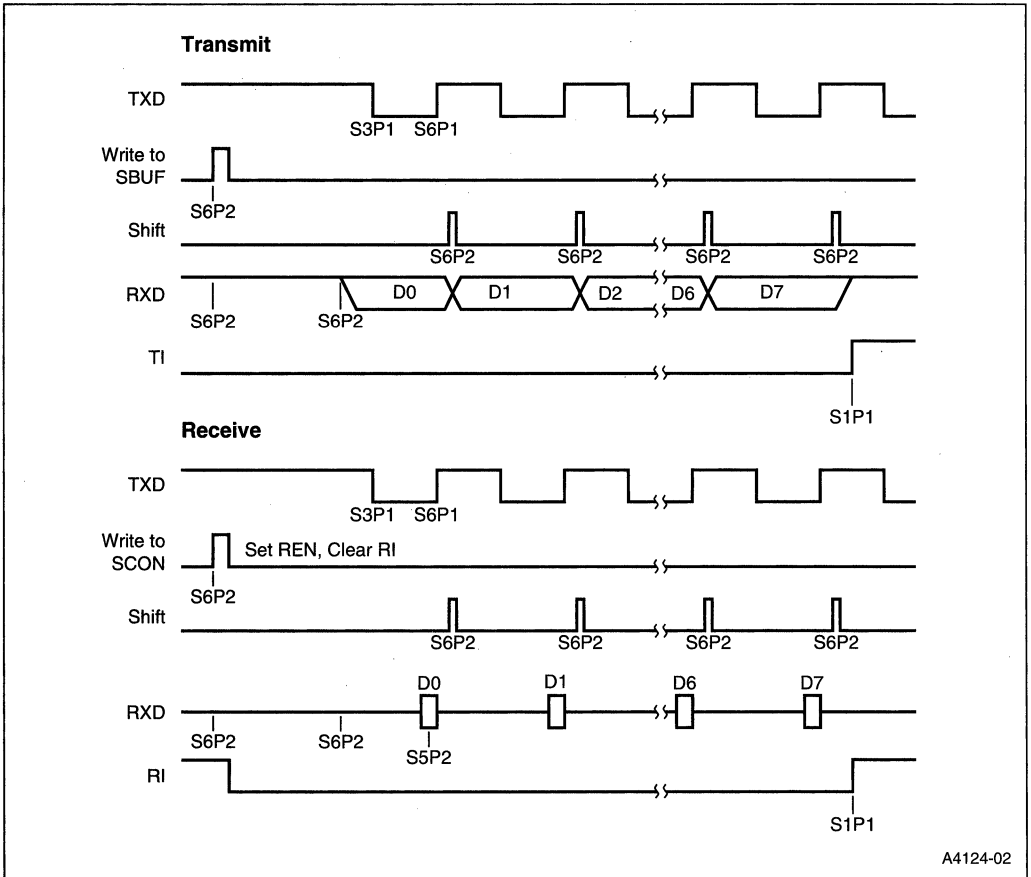
Bit Number	Bit Mnemonic	Function																									
7	FE	<p>Framing Error Bit:</p> <p>To select this function, set the SMOD0 bit in the PCON register. Set by hardware to indicate an invalid stop bit. Cleared by firmware, not by valid frames.</p>																									
	SM0	<p>Serial Port Mode Bit 0:</p> <p>To select this function, clear the SMOD0 bit in the PCON register. Firmware writes to bits SM0 and SM1 to select the serial port operating mode. Refer to the SM1 bit for the mode selections.</p>																									
6	SM1	<p>Serial Port Mode Bit 1:</p> <p>Firmware writes to bits SM1 and SM0 (above) to select the serial port operating mode.</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 10%;">SM0</th> <th style="width: 10%;">SM1</th> <th style="width: 15%;">Mode</th> <th style="width: 30%;">Description</th> <th style="width: 35%;">Baud Rate[†]</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0</td> <td>Shift register</td> <td>$F_{CLK}/6$</td> </tr> <tr> <td style="text-align: center;">0</td> <td style="text-align: center;">1</td> <td style="text-align: center;">1</td> <td>8-bit UART</td> <td>Variable</td> </tr> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">0</td> <td style="text-align: center;">2</td> <td>9-bit UART</td> <td>$F_{CLK}/16^{††}$ or $F_{CLK}/32^{††}$</td> </tr> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">1</td> <td style="text-align: center;">3</td> <td>9-bit UART</td> <td>Variable</td> </tr> </tbody> </table> <p>[†]The baud rate calculations in this chapter are based on the value of F_{CLK} which is a function of PLLSEL2:0. See Table 2-4 and Figure 2-6 on page 2-9.</p> <p>^{††}Select by programming the SMOD bit in the PCON register (see section "Baud Rates" on page 13-10).</p>	SM0	SM1	Mode	Description	Baud Rate [†]	0	0	0	Shift register	$F_{CLK}/6$	0	1	1	8-bit UART	Variable	1	0	2	9-bit UART	$F_{CLK}/16^{††}$ or $F_{CLK}/32^{††}$	1	1	3	9-bit UART	Variable
SM0	SM1	Mode	Description	Baud Rate [†]																							
0	0	0	Shift register	$F_{CLK}/6$																							
0	1	1	8-bit UART	Variable																							
1	0	2	9-bit UART	$F_{CLK}/16^{††}$ or $F_{CLK}/32^{††}$																							
1	1	3	9-bit UART	Variable																							
5	SM2	<p>Serial Port Mode Bit 2:</p> <p>Firmware writes to bit SM2 to enable and disable the multiprocessor communication and automatic address recognition features. This allows the serial port to differentiate between data and command frames and to recognize slave and broadcast addresses.</p>																									
4	REN	<p>Receiver Enable Bit:</p> <p>To enable reception, set this bit. To enable transmission, clear this bit.</p>																									
3	TB8	<p>Transmit Bit 8:</p> <p>In modes 2 and 3, firmware writes the ninth data bit to be transmitted to TB8. Not used in modes 0 and 1.</p>																									

Figure 13-2. SCON: Serial Port Control Register

SCON (Continued)		Address: S:98H
		Reset State: 0000 0000B
<p>Serial Port Control Register. SCON contains serial I/O control and status bits, including the mode select bits and the interrupt flag bits.</p>		
7	0	
FE/SM0	SM1	SM2
REN	TB8	RB8
TI	RI	

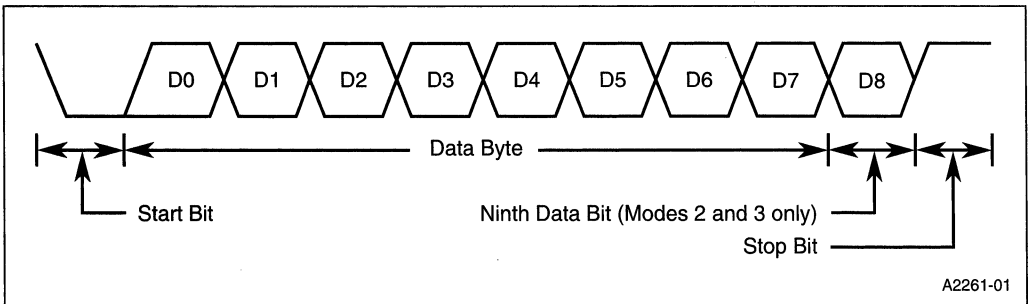
Bit Number	Bit Mnemonic	Function
2	RB8	Receiver Bit 8: Mode 0: Not used. Mode 1 (SM2 clear): Set or cleared by hardware to reflect the stop bit received. Modes 2 and 3 (SM2 set): Set or cleared by hardware to reflect the ninth data bit received.
1	TI	Transmit Interrupt Flag Bit: Set by the transmitter after the last data bit is transmitted. Cleared by firmware.
0	RI	Receive Interrupt Flag Bit: Set by the receiver after the last data bit of a frame has been received. Cleared by firmware.

Figure 13-2. SCON: Serial Port Control Register (Continued)



A4124-02

Figure 13-3. Mode 0 Timing



A2261-01

Figure 13-4. Data Frame (Modes 1, 2, and 3)

13.2.2 Asynchronous Modes (Modes 1, 2, and 3)

The serial port has three asynchronous modes of operation:

- **Mode 1.** Mode 1 is a full-duplex, asynchronous mode. The data frame (Figure 13-4) consists of 10 bits: one start bit, eight data bits, and one stop bit. Serial data is transmitted on the TXD pin and received on the RXD pin. When a message is received, the stop bit is read in the RB8 bit in the SCON register. The baud rate is generated by overflow of timer 1 or timer 2 (see “Baud Rates” on page 13-10).
- **Modes 2 and 3.** Modes 2 and 3 are full-duplex, asynchronous modes. The data frame (Figure 13-4) consists of 11 bits: one start bit, eight data bits (transmitted and received LSb first), one programmable ninth data bit, and one stop bit. Serial data is transmitted on the TXD pin and received on the RXD pin. On receive, the ninth bit is read from the RB8 bit in the SCON register. On transmit, the ninth data bit is written to the TB8 bit in the SCON register. Alternatively, you can use the ninth bit as a command/data flag.
 - In mode 2, the baud rate is programmable to 1/16 or 1/32 internal frequency, F_{CLK} .
 - In mode 3, the baud rate is generated by overflow of timer 1 or timer 2.

13.2.2.1 Transmission (Modes 1, 2, 3)

Follow these steps to initiate a transmission:

1. Write to the SCON register. Select the mode with the SM0 and SM1 bits, and clear the REN bit. For modes 2 and 3, also write the ninth bit to the TB8 bit.
2. Write the byte to be transmitted to the SBUF register. This write starts the transmission.

13.2.2.2 Reception (Modes 1, 2, 3)

To prepare for a reception, set the REN bit in the SCON register. The actual reception is then initiated by a detected high-to-low transition on the RXD pin.

13.3 FRAMING BIT ERROR DETECTION (MODES 1, 2, AND 3)

Framing bit error detection is provided for the three asynchronous modes. To enable the framing bit error detection feature, set the SMOD0 bit in the PCON register (see Figure 15-1 on page 15-3). When this feature is enabled, the receiver checks each incoming data frame for a valid stop bit. An invalid stop bit may result from noise on the serial lines or from simultaneous transmission by two CPUs. If a valid stop bit is not found, the firmware sets the FE bit in the SCON register (see Figure 13-2).

Firmware may examine the FE bit after each reception to check for data errors. Once set, only firmware or a reset can clear the FE bit. Subsequently received frames with valid stop bits cannot clear the FE bit.

13.4 MULTIPROCESSOR COMMUNICATION (MODES 2 AND 3)

Modes 2 and 3 provide a ninth-bit mode to facilitate multiprocessor communication. To enable this feature, set the SM2 bit in the SCON register (see Figure 13-2). When the multiprocessor communication feature is enabled, the serial port can differentiate between data frames (ninth bit clear) and address frames (ninth bit set). This allows the microcontroller to function as a slave processor in an environment where multiple slave processors share a single serial line.

When the multiprocessor communication feature is enabled, the receiver ignores frames with the ninth bit clear. The receiver examines frames with the ninth bit set for an address match. If the received address matches the slave's address, the receiver hardware sets the RB8 bit and the RI bit in the SCON register, generating an interrupt.

NOTE

The ES bit must be set in the IEN0 register to allow the RI bit to generate an interrupt. The IEN0 register is described in Chapter 8, Interrupts.

The addressed slave's firmware then clears the SM2 bit in the SCON register and prepares to receive the data bytes. The other slaves are unaffected by these data bytes because they are waiting to respond to their own addresses.

13.5 AUTOMATIC ADDRESS RECOGNITION

The automatic address recognition feature is enabled when the multiprocessor communication feature is enabled (i.e., the SM2 bit is set in the SCON register).

Implemented in hardware, automatic address recognition enhances the multiprocessor communication feature by allowing the serial port to examine the address of each incoming command frame. Only when the serial port recognizes its own address does the receiver set the RI bit in the SCON register to generate an interrupt. This ensures that the CPU is not interrupted by command frames addressed to other devices.

If desired, you may enable the automatic address recognition feature in mode 1. In this configuration, the stop bit takes the place of the ninth data bit. The RI bit is set only when the received command frame address matches the device's address and is terminated by a valid stop bit.

NOTE

The multiprocessor communication and automatic address recognition features cannot be enabled in mode 0 (i.e., setting the SM2 bit in the SCON register in mode 0 has no effect).

To support automatic address recognition, a device is identified by a *given* address and a *broad-cast* address.

13.5.1 Given Address

Each device has an *individual* address that is specified in the SADDR register; the SADEN register is a mask byte that contains don't-care bits (defined by zeros) to form the device's *given* address. These don't-care bits provide the flexibility to address one or more slaves at a time. To address a device by its individual address, the SADEN mask byte must be 1111 1111. The following example illustrates how a given address is formed:

```
SADDR = 0101 0110
SADEN = 1111 1100
Given  = 0101 01XX
```

The following is an example of how to use given addresses to address different slaves:

Slave A:	SADDR = 1111 0001	Slave C:	SADDR = 1111 0010
	SADEN = 1111 1010		SADEN = 1111 1101
	Given = 1111 0X0X		Given = 1111 00X1
Slave B:	SADDR = 1111 0011		
	SADEN = 1111 1001		
	Given = 1111 0XX1		

The SADEN byte is selected so that each slave may be addressed separately. For Slave A, bit 0 (the LSb) is a don't-care bit; for Slaves B and C, bit 0 is a 1. To communicate with Slave A only, the master must send an address where bit 0 is clear (e.g., 1111 0000).

For Slave A, bit 1 is a 0; for Slaves B and C, bit 1 is a don't-care bit. To communicate with Slaves B and C, but not Slave A, the master must send an address with bits 0 and 1 both set (e.g., 1111 0011).

For Slaves A and B, bit 2 is a don't-care bit; for Slave C, bit 2 is a 0. To communicate with Slaves A and B, but not Slave C, the master must send an address with bit 0 set, bit 1 clear, and bit 2 set (e.g., 1111 0101).

To communicate with Slaves A, B, and C, the master must send an address with bit 0 set, bit 1 clear, and bit 2 clear (e.g., 1111 0001).

13.5.2 Broadcast Address

A *broadcast* address is formed from the logical OR of the SADDR and SADEN registers with zeros defined as don't-care bits, e.g.:

```
SADDR          = 0101 0110
SADEN          = 1111 1100
(SADDR) OR (SADEN) = 1111 111X
```

The use of don't-care bits provides flexibility in defining the broadcast address, however, in most applications, a broadcast address is OFFH.

The following is an example of using broadcast addresses:

Slave A:	SADDR = 1111 0001	Slave C:	SADDR = 1111 0010
	SADEN = 1111 1010		SADEN = 1111 1101
	Broadcast = 1111 1X11		Broadcast = 1111 1111
Slave B:	SADDR = 1111 0011		
	SADEN = 1111 1001		
	Broadcast = 1111 1X11		

For Slaves A and B, bit 2 is a don't-care bit; for Slave C, bit 2 is set. To communicate with all of the slaves, the master must send an address FFH.

To communicate with Slaves A and B, but not Slave C, the master can send an address FBH.

13.5.3 Reset Addresses

On reset, the SADDR and SADEN registers are initialized to 00H, that is, the given and broadcast addresses are xxxx xxxx (all don't-care bits). This ensures that the serial port is backwards-compatible with MCS[®] 51 microcontrollers that do not support automatic address recognition.

13.6 BAUD RATES

You must select the baud rate for the serial port transmitter and receiver when operating in modes 1, 2, and 3. (The baud rate is preset for mode 0.) In its asynchronous modes, the serial port can transmit and receive simultaneously. Depending on the mode, the transmission and reception rates can be the same or different. Table 13-3 summarizes the baud rates that can be used for the four serial I/O modes.

NOTE

The baud rate calculations in this chapter are based on the value of F_{CLK} which is a function of PLLSEL2:0. See Table 2-4 and Figure 2-6 on page 2-9.

13.6.1 Baud Rate for Mode 0

The baud rate for mode 0 is fixed at $F_{CLK}/6$.

Table 13-3. Summary of Baud Rates

Mode	No. of Baud Rates	Send and Receive at the Same Rate	Send and Receive at Different Rates
0	1	N/A	N/A
1	Many ^{††}	Yes	Yes
2	2	Yes	No
3	Many ^{††}	Yes	Yes

^{††} Baud rates are determined by overflow of timer 1 and/or timer 2.

13.6.2 Baud Rates for Mode 2

Mode 2 has two baud rates, which are selected by the SMOD1 bit in the PCON register (Figure 15-1 on page 15-3). The following expression defines the baud rate:

$$\text{Serial I/O Mode 2 Baud Rate} = 2^{\text{SMOD1}} \times \frac{F_{\text{CLK}}}{32}$$

13.6.3 Baud Rates for Modes 1 and 3

In modes 1 and 3, the baud rate is generated by overflow of timer 1 (default) and/or timer 2. You may select either or both timer(s) to generate the baud rate(s) for the transmitter and/or the receiver.

13.6.3.1 Timer 1 Generated Baud Rates (Modes 1 and 3)

Timer 1 is the default baud rate generator for the transmitter and the receiver in modes 1 and 3. The baud rate is determined by the timer 1 overflow rate and the value of SMOD, as shown in the following formula:

$$\text{Serial I/O Modes 1 and 3 Baud Rate} = 2^{\text{SMOD1}} \times \frac{\text{Timer 1 Overflow Rate}}{32}$$

13.6.3.2 Selecting Timer 1 as the Baud Rate Generator

To select timer 1 as the baud rate generator:

- Disable the timer interrupt by clearing the ET1 bit in the IEN0 register (Figure 6-12 on page 6-25).
- Configure timer 1 as a timer or an event counter (set or clear the C/T# bit in the TMOD register, Figure 11-5 on page 11-7).
- Select timer mode 0–3 by programming the M1 and M0 bits in the TMOD register.

In most applications, timer 1 is configured as a timer in auto-reload mode (high nibble of TMOD = 0010B). The resulting baud rate is defined by the following expression:

$$\text{Serial I/O Modes 1 and 3 Baud Rate} = 2^{\text{SMOD1}} \times \frac{F_{\text{CLK}}}{16 \times 12 \times [256 - (\text{TH1})]}$$

Timer 1 can generate very low baud rates with the following setup:

- Enable the timer 1 interrupt by setting the ET1 bit in the IEN0 register.
- Configure timer 1 to run as a 16-bit timer (high nibble of TMOD = 0001B).
- Use the timer 1 interrupt to initiate a 16-bit firmware reload.

Table 13-4 lists commonly used baud rates and shows how they are generated by timer 1.

Table 13-4. Timer 1 Generated Baud Rates for Serial I/O Modes 1 and 3

Baud Rate	Oscillator Frequency (F _{CLK})	SMOD1	Timer 1		
			C/T#	Mode	Reload Value
125.0 Kbaud (max) †	12.0 MHz	1	0	2	FFH
62.5 Kbaud †	6.0 MHz	1	0	2	FFH
110.0 Baud	3.0 MHz	0	0	2	72H
110.0 Baud †	6.0 MHz	0	0	1	FEFBH

† The baud rate calculations in this chapter are based on the value of F_{CLK} which is a function of PLLSEL2:0. See Table 2-4 and Figure 2-6 on page 2-9.

13.6.3.3 Timer 2 Generated Baud Rates (Modes 1 and 3)

Timer 2 may be selected as the baud rate generator for the transmitter and/or receiver (Figure 13-5). The timer 2 baud rate generator mode is similar to the auto-reload mode. A rollover in the TH2 register reloads registers TH2 and TL2 with the 16-bit value in registers RCAP2H and RCAP2L, which are preset by firmware.

The timer 2 baud rate is expressed by the following formula:

$$\text{Serial I/O Modes 1 and 3 Baud Rate} = \frac{\text{Timer 2 Overflow Rate}}{16}$$

13.6.3.4 Selecting Timer 2 as the Baud Rate Generator

To select timer 2 as the baud rate generator for the transmitter and/or receiver, program the RCLK and TCLK bits in the T2CON register as shown in Table 13-5. (You may select different baud rates for the transmitter and receiver.) Setting RCLK and/or TCLK puts timer 2 into its baud rate generator mode (Figure 13-5). In this mode, a rollover in the TH2 register does not set the TF2 bit in the T2CON register. Also, a high-to-low transition at the T2EX pin sets the EXF2 bit in the T2CON register but does not cause a reload from (RCAP2H, RCAP2L) to (TH2, TL2). You can use the T2EX pin as an additional external interrupt by setting the EXEN2 bit in T2CON.

NOTE

Turn the timer off (clear the TR2 bit in the T2CON register) before accessing registers TH2, TL2, RCAP2H, and RCAP2L.

You may configure timer 2 as a timer or a counter. In most applications, it is configured for timer operation (i.e., the C/T2# bit is clear in the T2CON register).

Table 13-5. Selecting the Baud Rate Generator(s)

RCLK Bit	TCLK Bit	Receiver Baud Rate Generator	Transmitter Baud Rate Generator
0	0	Timer 1	Timer 1
0	1	Timer 1	Timer 2
1	0	Timer 2	Timer 1
1	1	Timer 2	Timer 2

Note that timer 2 increments every state time ($4F_{CLK}$) when it is in the baud rate generator mode. In the baud rate formula that follows, “RCAP2H, RCAP2L” denotes the contents of RCAP2H and RCAP2L taken as a 16-bit unsigned integer:

$$\text{Serial I/O Modes 1 and 3 Baud Rate} = \frac{F_{CLK}}{16 \times [65536 - (RCAP2H, RCAP2L)]}$$

NOTE

When timer 2 is configured as a timer and is in baud rate generator mode, do not read or write the TH2 or TL2 registers. The timer is being incremented every state time, and the results of a read or write may not be accurate. In addition, you may read, but not write to, the RCAP2 registers; a write may overlap a reload and cause write and/or reload errors.

Table 13-6 lists commonly used baud rates and shows how they are generated by timer 2.

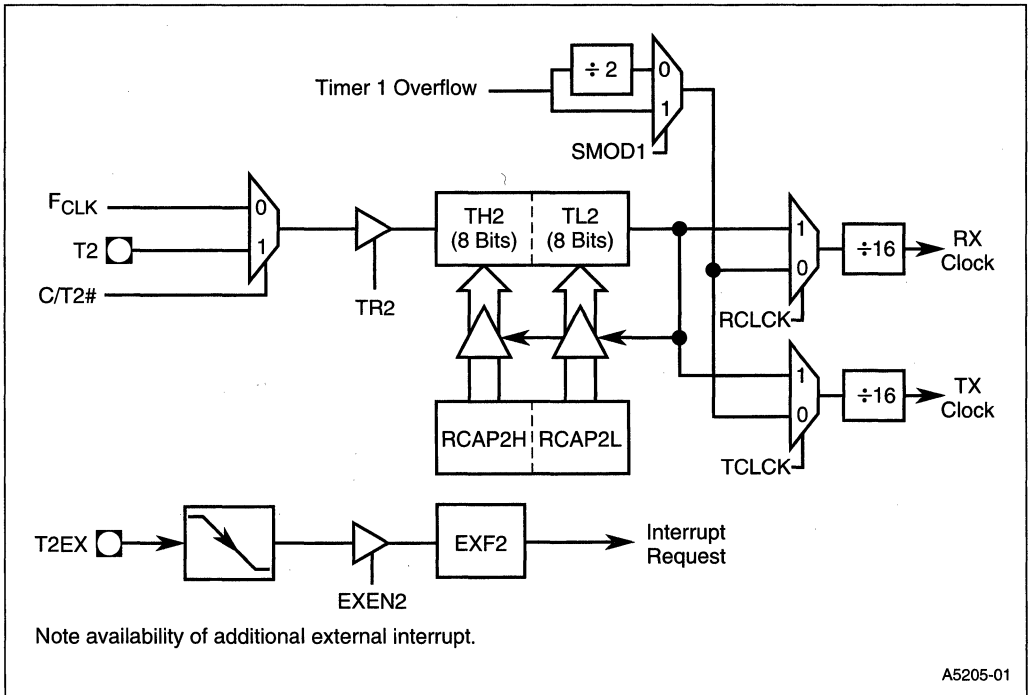


Figure 13-5. Timer 2 in Baud Rate Generator Mode

Table 13-6. Timer 2 Generated Baud Rates

Baud Rate	Internal Frequency (F _{CLK})	RCAP2H	RCAP2L
750.0 Kbaud ††	12 MHz	FF	FF
375.0 Kbaud ††	6 MHz	FFH	FFH
9.6 Kbaud ††	6 MHz	FFH	D9H
4.8 Kbaud ††	6 MHz	FFH	B2H
2.4 Kbaud ††	6 MHz	FFH	64H
1.2 Kbaud ††	6 MHz	FEH	C8H
300.0 baud ††	6 MHz	FBH	1EH
110.0 baud ††	6 MHz	F2H	AFH
300.0 baud	3 MHz	FDH	8FH
110.0 baud	3 MHz	F9H	57H

†† See note on page page 13-1.



14

Minimum Hardware Setup



CHAPTER 14

MINIMUM HARDWARE SETUP

This chapter discusses the basic operating requirements of the 8x930 and describes a minimum hardware setup. Topics covered include power, ground, clock source, and device reset. For parameter values, refer to the device data sheet.

14.1 MINIMUM HARDWARE SETUP

Figure 14-1 shows a minimum hardware setup that employs the on-chip oscillator for the system clock and provides power-on reset. Control signals, Ports 0–3, and the USB port are not shown. See “Clock Sources” on page 14-2 and “Power-on Reset” on page 14-7. PLLSEL.2:0 selects the USB operating rate. Refer to Table 2-4 on page 2-10.

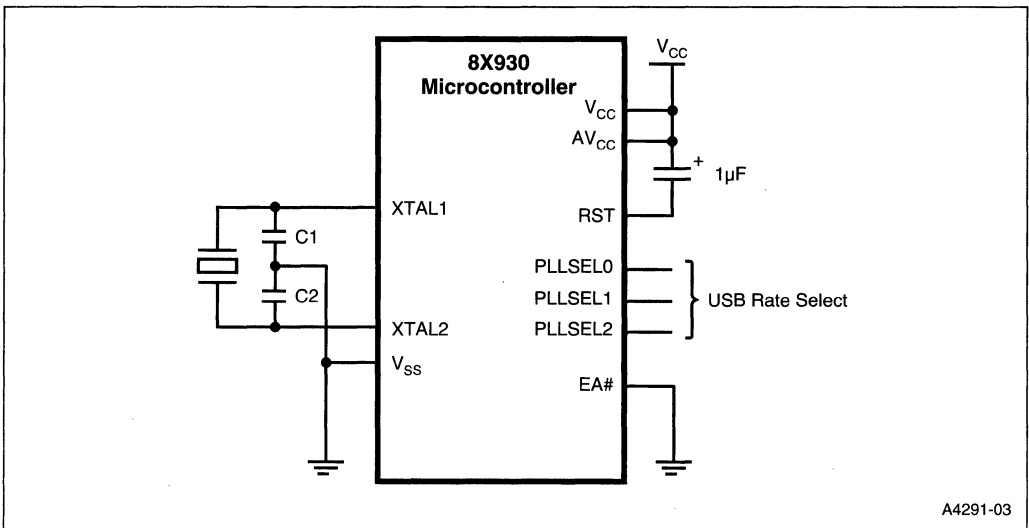


Figure 14-1. Minimum Setup

14.2 ELECTRICAL ENVIRONMENT

The 8x930 is a high-speed CHMOS device. To achieve satisfactory performance, its operating environment should accommodate the device signal waveforms without introducing distortion or noise. Design considerations relating to device performance are discussed in this section. See the device data sheet for voltage and current requirements, operating frequency, and waveform timing.

14.2.1 Power and Ground Pins

Power the 8x930 from a well-regulated power supply designed for high-speed digital loads. Use short, low impedance connections to the power (V_{CC}) and ground (V_{SS}) pins.

14.2.2 Unused Pins

To provide stable, predictable performance, connect unused input pins to V_{SS} or V_{CC} . Unterminated input pins can float to a mid-voltage level and draw excessive current. Unterminated interrupt inputs may generate spurious interrupts.

14.2.3 Noise Considerations

The fast rise and fall times of high-speed CHMOS logic may produce noise spikes on the power supply lines and signal outputs. To minimize noise and waveform distortion, follow good board layout techniques. Use sufficient decoupling capacitors and transient absorbers to keep noise within acceptable limits. Connect 0.01 μF bypass capacitors between V_{CC} and each V_{SS} pin. Place the capacitors close to the device to minimize path lengths.

Multi-layer printed circuit boards with separate V_{CC} and ground planes help minimize noise. For additional information on noise reduction, see Application Note AP-125, "Designing Microcontroller Systems for Electrically Noisy Environments."

14.3 CLOCK SOURCES

The 8x930 can use an external clock (Figure 14-3), an on-chip oscillator with crystal or ceramic resonator (Figure 14-2), or an on-chip phase-locked oscillator (locked to the external clock or the on-chip oscillator) as its clock source. For USB operating rates, see Table 2-4 on page 2-10.

14.3.1 On-chip Oscillator (Crystal)

This clock source uses an external quartz crystal connected from XTAL1 to XTAL2 as the frequency-determining element (Figure 14-2). The crystal operates in its fundamental mode as an inductive reactance in parallel resonance with capacitance external to the crystal. Oscillator design considerations include crystal specifications, operating temperature range, and parasitic board capacitance. Consult the crystal manufacturer's data sheet for parameter values. With high quality components, $C1 = C2 = 30 \text{ pF}$ is adequate for this application.

Pins XTAL1 and XTAL2 are protected by on-chip electrostatic discharge (ESD) devices, D1 and D2, which are diodes parasitic to the R_F FETs. They serve as clamps to V_{CC} and V_{SS} . Feedback resistor R_F in the inverter circuit, formed from paralleled n- and p- channel FETs, permits the PD bit in the PCON register (Figure 15-1 on page 15-3) to disable the clock during powerdown.

Noise spikes at XTAL1 and XTAL2 can disrupt microcontroller timing. To minimize coupling between other digital circuits and the oscillator, locate the crystal and the capacitors near the chip and connect to XTAL1, XTAL2, and V_{SS} with short, direct traces. To further reduce the effects of noise, place guard rings around the oscillator circuitry and ground the metal crystal case.

For a more in-depth discussion of crystal specifications, ceramic resonators, and the selection of C1 and C2 see Applications Note AP-155, "Oscillators for Microcontrollers," in the Embedded Applications handbook.

14.3.2 On-chip Oscillator (Ceramic Resonator)

In cost-sensitive applications, you may choose a ceramic resonator instead of a crystal. Ceramic resonator applications may require slightly different capacitor values and circuit configuration. Consult the manufacturer's data sheet for specific information.

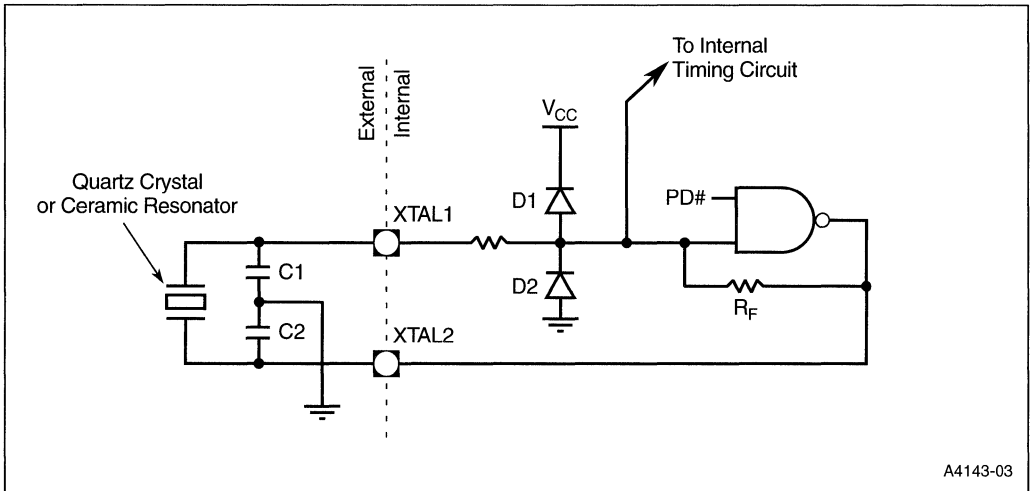


Figure 14-2. CHMOS On-chip Oscillator

14.3.3 External Clock

To operate the 8x930 from an external clock, connect the clock source to the XTAL1 pin as shown in Figure 14-3. Leave the XTAL2 pin floating. The external clock driver can be a CMOS gate. If the clock driver is a TTL device, its output must be connected to V_{CC} through a 4.7 k Ω pullup resistor.

For external clock drive requirements, see the device data sheet. Figure 14-4 shows the clock drive waveform. The external clock source must meet the minimum high and low times (T_{CHCX} and T_{CLCX}) and the maximum rise and fall times (T_{CLCH} and T_{CHCL}) to minimize the effect of external noise on the clock generator circuit. Long rise and fall times increase the chance that external noise will affect the clock circuitry and cause unreliable operation.

The external clock driver may encounter increased capacitance loading at XTAL1 when power is applied, due to the interaction between the internal amplifier and its feedback capacitance (i.e., the Miller effect). Once the input waveform requirements are met, the input capacitance remains under 20 pF.

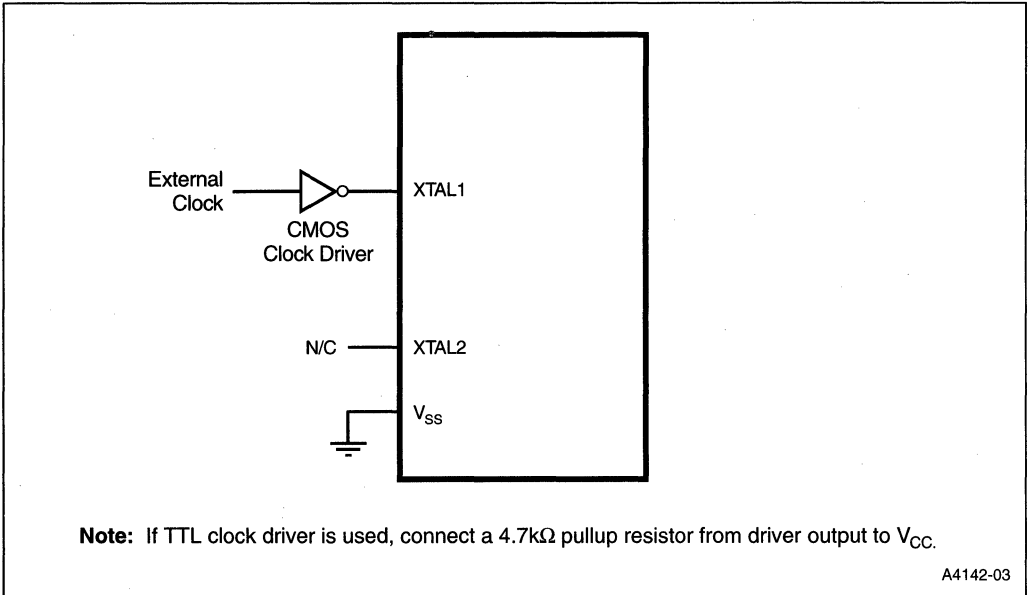


Figure 14-3. External Clock Connection for the 8x930

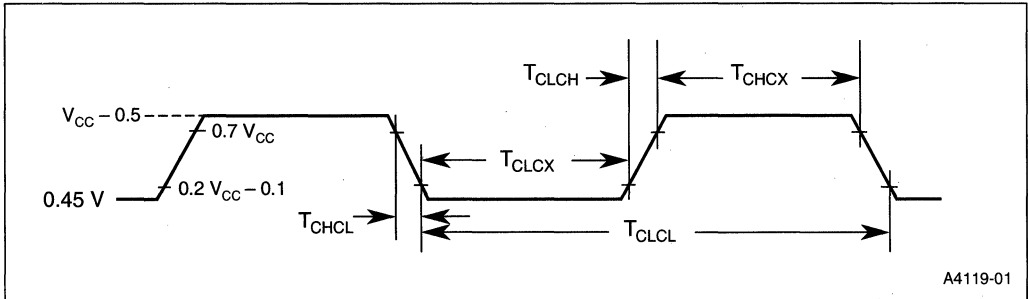


Figure 14-4. External Clock Drive Waveforms

14.4 RESET

A device reset initializes the 8x930 and vectors the CPU to address FF:0000H. A reset is a means of exiting the idle and powerdown modes or recovering from firmware malfunctions, and could be a USB reset initiated by the host or upstream hub.

NOTE

A reset is required after applying power.

To achieve a valid reset, V_{CC} must be within its normal operating range (see device data sheet) and the reset signal must be maintained for 64 clock cycles ($64T_{OSC}$) after the oscillator has stabilized.

Device reset is initiated in three ways:

- externally, by asserting the RST pin
- internally, if the hardware WDT or the PCA WDT expires
- over the bus, by a USB-initiated reset

These three reset mechanisms are ORed to create a single reset signal for the 8x930.

The power off flag (POF) in the PCON register indicates whether a reset is a warm start or a cold start. A cold start reset ($POF = 1$) is a reset that occurs after power has been off or V_{CC} has fallen below 3 V, so the contents of volatile memory are indeterminate. POF is set by hardware when V_{CC} rises from less than 3 V to its normal operating level. See “Power Off Flag” on page 15-2. A warm start reset ($POF = 0$) is a reset that occurs while the chip is at operating voltage, for example, a reset initiated by a WDT overflow or an external reset used to terminate the idle or power-down modes.

14.4.1 Externally-Initiated Resets

To reset the 8x930, hold the RST pin at a logic high for at least 64 clock cycles ($64T_{OSC}$) while the oscillator is running. Reset can be accomplished automatically at the time power is applied by capacitively coupling RST to V_{CC} (see Figure 14-1 and “Power-on Reset” on page 14-7). The RST pin has a Schmitt trigger input and a pulldown resistor.

14.4.2 WDT-initiated Resets

Expiration of the hardware WDT (overflow) or the PCA WDT (comparison match) generates a reset signal. WDT initiated resets have the same effect as an external reset. See “Watchdog Timer” on page 11-16 and section “PCA Watchdog Timer Mode” on page 12-9.

14.4.3 USB-initiated Resets

The 8x930 can be reset by the host or upstream hub if a reset signal is detected by the SIE. This reset signal is defined as an SE0 held longer than 2.5 μ s. A USB-initiated reset will reset all of the 8x930 hardware, even if the device is suspended (in which case it would first wake-up, then reset). See “USB Power Control” on page 15-8 for additional information about USB-related suspend and resume.

A peripheral that is reset must be re-enumerated. This procedure is given in “Unenumerated State” on page 9-2.

NOTE

You must ensure that the time from connection of this USB device to the bus until the entire reset process is complete (including firmware initialization of the 8x930) is less than 10 ms. After 10 ms, the host may attempt to communicate with the 8x930 to set its device address. If the 8x930 firmware cannot respond to the host at this time, the host may disable the device after three attempts to communicate.

14.4.3.1 8x930Ax USB Reset Separation

The 8x930Ax features an optional USB reset that functions independently from the chip reset. When the PCON1 SFR's URDIS bit is set, the MCS 251 core and peripherals will not reset when a USB reset signal is detected. After an 8x930Ax with URDIS set detects a USB reset signal, it resets all the USB blocks (including the USB SFRs), sets the URST bit in PCON1, and generates a USB reset interrupt. For a complete description of the optional USB reset for the 8x930Ax, see “8x930Ax USB Reset Separation” on page 6-18.

14.4.4 Reset Operation

When a reset is initiated, whether externally, over the bus, or by a WDT, the port pins are immediately forced to their reset condition as a fail-safe precaution, whether the clock is running or not.

The external reset signal and the WDT- and USB- initiated reset signals are combined internally. For an external reset the voltage on the RST pin must be held high for 32 internal clock cycles (T_{CLK}) after the oscillator and on-chip PLL stabilize (approximately 5 ms). For WDT and USB-initiated resets, a 5-bit counter in the reset logic maintains the signal for the required 32 clock cycles (T_{CLK}). Refer to Table 2-4 on page 2-10.

The CPU checks for the presence of the combined reset signal every $2T_{OSC}$. When a reset is detected, the CPU responds by triggering the internal reset routine. The reset routine loads the SFRs, including the ACC, B, stack pointer, and data pointer registers, with their reset values (see Table 3-5 on page 3-16). Reset does not affect on-chip data RAM or the register file. (However, following a cold start reset, these are indeterminate because V_{CC} has fallen too low or has been off.) Following a synchronizing operation and the configuration fetch, the CPU vectors to address FF:0000. Figure 14-5 shows the reset timing sequence.

While the RST pin is high ALE, PSEN#, and the port pins are weakly pulled high. The first ALE occurs 16 internal clock cycles (T_{CLK}) after the reset signal goes low. For this reason, other devices can not be synchronized to the internal timings of the 8x930.

NOTE

Externally driving the ALE and/or PSEN# pins to 0 during the reset routine may cause the device to go into an indeterminate state.

Powering up the 8x930 without a reset may improperly initialize the program counter and SFRs and cause the CPU to execute instructions from an undetermined memory location.

14.4.5 Power-on Reset

To automatically generate a reset when power is applied, connect the RST pin to the V_{CC} pin through a 1- μ F capacitor as shown in Figure 14-1 on page 14-1.

When V_{CC} is applied, the RST pin rises to V_{CC} , then decays exponentially as the capacitor charges. The time constant must be such that RST remains high (above the turn-off threshold of the Schmitt trigger) long enough for the oscillator to start and stabilize, plus $64T_{OSC}$. At power up, V_{CC} should rise within approximately 10 ms. Oscillator start-up time is a function of the crystal frequency.

During power up, the port pins are in a random state until forced to their reset state by the asynchronous logic.

Reducing V_{CC} quickly to 0 causes the RST pin voltage to momentarily fall below 0 V. This voltage is internally limited and does not harm the device.

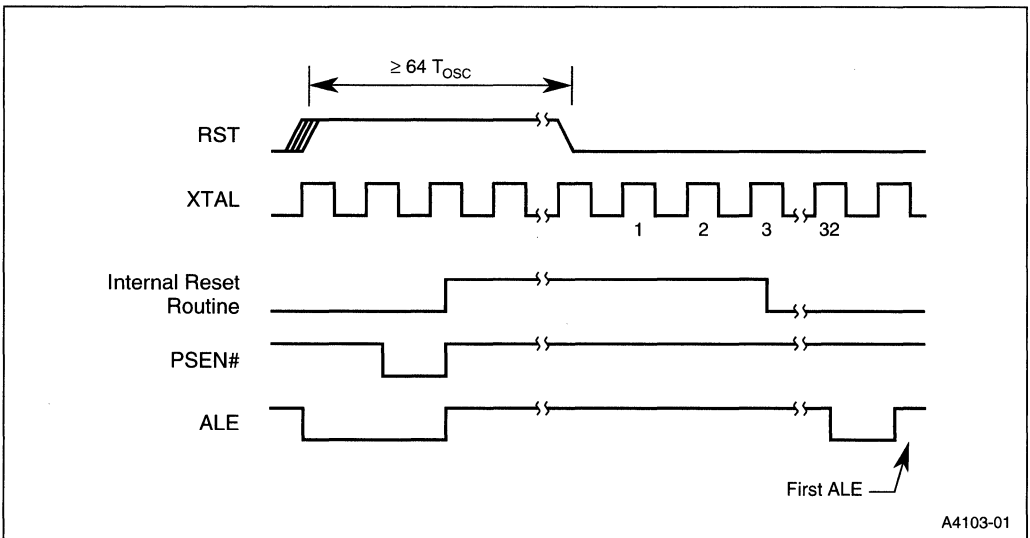


Figure 14-5. Reset Timing Sequence



15

Special Operating Modes





CHAPTER 15

SPECIAL OPERATING MODES

This chapter describes the idle, powerdown, low-clock, and on-circuit emulation (ONCE) device operating modes and the USB function suspend and resume operations. The SFRs associated with these operations (PCON and PCON1) are also described.

15.1 GENERAL

The idle, low clock, and powerdown modes are power reduction modes for use in applications where power consumption is a concern. User instructions activate these modes by setting bits in the PCON register. Program execution halts, but resumes when the mode is exited by an interrupt. While in idle or powerdown modes, the V_{CC} pin is the input for backup power.

Following chip reset, the 8x930 operates in low-clock mode, wherein the CPU and on-chip peripherals are clocked at a reduced rate until bus enumeration is accomplished. This reduces I_{CC} to meet the 100 mA USB requirement.

Suspend and resume are low current modes used when the USB bus is idle. The 8x930 enters suspend when there is a continuous idle state on the bus lines for more than 3.0 msec. When a device is in suspend state, it draws less than 500 μA from the bus. Once a device is in the suspend state, its operation can be resumed by receiving resume signaling on the bus.

ONCE is a test mode that electrically isolates the 8x930 from the system in which it operates.

Table 15-1 on page 15-6 lists the condition of the out pins for the various operating modes.

15.2 POWER CONTROL REGISTERS

The PCON special function register (Figure 15-1) provides two control bits for the serial I/O function; bits for selecting: the idle, low-clock, and powerdown modes, the power off flag, and two general purpose flags.

The PCON1 SFR (Figure 15-2) provides USB power control, including the USB global suspend/resume and USB function suspend. The PCON1 SFR is discussed further in “USB Power Control” on page 15-8.

15.2.1 Serial I/O Control Bits

The SMOD1 bit in the PCON register is a factor in determining the serial I/O baud rate. See Figure 15-1 and “Baud Rates” on page 13-10.

The SMOD0 bit in the PCON register determines whether bit 7 of the SCON register provides read/write access to the framing error (FE) bit (SMOD0 = 1) or to SM0, a serial I/O mode select bit (SMOD0 = 0). See Figure 15-1 and Figure 13-2 on page 13-4 (SCON).

15.2.2 Power Off Flag

Hardware sets the Power Off Flag (POF) in PCON when V_{CC} rises from $< 3\text{ V}$ to $> 3\text{ V}$ to indicate that on-chip volatile memory is indeterminate (e.g., at power-on). The POF can be set or cleared by firmware. After a reset, check the status of this bit to determine whether a cold start reset or a warm start reset occurred (see “Reset” on page 14-5). After a cold start, user firmware should clear the POF. If $\text{POF} = 1$ is detected at other times, do a reset to re-initialize the chip, since for $V_{CC} < 3\text{ V}$ data may have been lost or some logic may have malfunctioned.

15.2.3 8x930Ax USB Reset Separation

The 8x930Ax features an optional USB reset that functions independently from the chip reset. When the PCON1 SFR's URDIS bit is set, the MCS 251 core and peripherals will not reset when a USB reset signal is detected. After an 8x930Ax with URDIS set detects a USB reset signal, it resets all the USB blocks (including the USB SFRs), sets the URST bit in PCON1, and generates a USB reset interrupt. For a complete description of the optional USB reset for the 8x930Ax, see “8x930Ax USB Reset Separation” on page 6-18.

PCON		Address: S:87H	
		Reset State: 00xx 0000B	
<p>Power Control Register. Contains the power off flag (POF) and bits for enabling the idle and powerdown modes. Also contains two general-purpose flags and two bits that control serial I/O functions—the double baud rate bit and a bit that selects whether accesses to SCON.7 are to the FE bit or the SM0 bit.</p>			
7			0
SMOD1	SMOD0	LC	POF
		GF1	GF0
		PD	IDL

Bit Number	Bit Mnemonic	Function
7	SMOD1	Double Baud Rate Bit: When set, doubles the baud rate when timer 1 is used and mode 1, 2, or 3 is selected in the SCON register. See “Baud Rates” on page 13-10.
6	SMOD0	SCON.7 Select: When set, read/write accesses to SCON.7 are to the FE bit. When clear, read/write accesses to SCON.7 are to the SM0 bit. See the SCON register (Figure 13-2 on page 13-4).
5	LC	Low-clock Mode Enable: Setting this bit forces the internal clock (F_{CLK}) distributed to the CPU and peripherals (but not the USB module) to 3 MHz. This bit is automatically set after a reset. Clearing this bit through firmware returns F_{CLK} to the clock frequency determined by pins PLLSEL2:0.
4	POF	Power Off Flag: Set by hardware as V_{CC} rises above 3 V to indicate that power has been off or V_{CC} had fallen below 3 V and that on-chip volatile memory is indeterminate. Set or cleared by firmware.
3	GF1	General Purpose Flag: Set or cleared by firmware. One use is to indicate whether an interrupt occurred during normal operation or during idle mode.
2	GF0	General Purpose Flag: Set or cleared by firmware. One use is to indicate whether an interrupt occurred during normal operation or during idle mode.
1	PD	Powerdown Mode Bit: When set, activates powerdown mode. This bit should only be set if the GSUS bit is also set. Cleared by hardware when an interrupt or reset occurs.
0	IDL	Idle Mode Bit: When set, activates idle mode. Cleared by hardware when an interrupt or reset occurs. If IDL and PD are both set, PD takes precedence.

Figure 15-1. PCON: Power Control Register

PCON1

Address: S:0DFH
Reset State: xxx0 000B

USB Power Control Register. Facilitates the control and status relating to global suspend and resume, USB reset separation, and remote wake-up of the 8x930.

7

0

			URDIS	URST	RWU	GRSM	GSUS
--	--	--	-------	------	-----	------	------

Bit Number	Bit Mnemonic	Function
7:5	—	Reserved: The value read from these bits are indeterminate. Write zeroes to these bits.
4	URDIS (8x930Ax)	USB Reset Disable: When clear by firmware, a chip reset occurs upon receiving of a USB reset signal. This resets the MCS [®] 251 core, USB blocks and all peripherals. When set by firmware, the MCS 251 core and peripherals will not reset when a USB reset signal is detected. Upon detecting a USB reset signal, the 8x930Ax resets all the USB blocks (FIFOs, FIU, SIE, and transceiver), sets the URST bit and generates a USB reset interrupt (refer to the description of URST).
	URDIS (8x930Hx)	Reserved: The value read from these bits are indeterminate. Write zeroes to these bits.
3	URST (8x930Ax)	USB Reset Flag: This flag will be set by hardware when a USB reset occurs, regardless of whether the ESR bit in the IEN1 register is enabled or disabled. The URST also serves as the interrupt bit, ORed with GRSM and GSUS bits to generate an interrupt. Should be cleared by firmware when serving the USB reset interrupt.
	URST (8x930Hx)	Reserved: The value read from these bits are indeterminate. Write zeroes to these bits.
2	RWU	Remote Wake-up Bit: 1 = wake-up. This bit is used by the USB function to initiate a remote wake-up. Set by firmware to drive resume signaling on the USB lines to the host or upstream hub. Cleared by hardware when resume signaling is done. NOTE: Do not set this bit unless the USB function is suspended (GSUS = 1 and GRSM = 0). See Figure 15-3 on page 15-11.

† Firmware should prioritize GRSM over GSUS if both bits are set simultaneously.

Figure 15-2. PCON1: USB Power Control Register

PCON1 (Continued)		Address: S:0DFH	
		Reset State: xxx0 0000B	
<p>USB Power Control Register. Facilitates the control and status relating to global suspend and resume, USB reset separation, and remote wake-up of the 8x930.</p>			
7			0
—	—	—	URDIS
		URST	RWU
		GRSM	GSUS
1	GRSM	<p>Global Resume Bit:</p> <p>1 = resume. Set by hardware when a global resume is detected on the USB lines. This bit is ORed with GSUS to generate the interrupt[†]. Cleared by firmware when servicing the global suspend/resume interrupt. (This bit can also be set/cleared by firmware for testability.) This bit is not set if remote wakeup is used (see RWU). See Figure 15-3 on page 15-11.</p>	
0	GSUS	<p>Global Suspend Bit:</p> <p>1 = suspend. This bit is set by hardware when global suspend is detected on the USB lines. This bit is ORed with the GRSM bit to generate the interrupt.[†] During the global suspend ISR, firmware should set the PD bit to enter the suspend mode. Cleared by firmware when a resume occurs. See Figure 15-3 on page 15-11.</p>	
<p>[†] Firmware should prioritize GRSM over GSUS if both bits are set simultaneously.</p>			

Figure 15-2. PCON1: USB Power Control Register (Continued)

Table 15-1. Pin Conditions in Various Modes

Pin	Reset	Idle Mode			Powerdown Mode			Once Mode
	—	Internal Program Memory	External Memory (page mode)	External Memory (nonpage mode)	Internal Program Memory	External Memory (page mode)	External Memory (nonpage mode)	—
ALE	Weak High	1	1	1	0	0	0	Float
PSEN#	Weak High	1	1	1	0	0	0	Float
Port 0 Pins	Float	Data	Float	Float	Data	Float	Float	Float
Port 1 Pins	Weak High	Data	Data	Data	Data	Data	Data	Weak High
Port 2 Pins	Weak High	Data	Float	Weak High	Data	Float	Weak High	Weak High
Port 3 Pins	Weak High	Data	Data	Data	Data	Data	Data	Weak High
SOF#	Weak High	Data	Data	Data	Data	Data	Data	Weak High
D _{P0}	Float	Data	Data	Data	Float	Float	Float	Weak High
D _{M0}	Float	Data	Data	Data	Float	Float	Float	Float
D _{P3:1}	Float	Data	Data	Data	Data J	Data J	Data J	Float
D _{M3:1}	Float	Data	Data	Data	Data J	Data J	Data J	Float
UPWEN#	Weak High	Data	Data	Data	Data	Data	Data	Float

15.3 IDLE MODE

Idle mode is a power reduction mode that reduces power consumption to approximately 40% of normal. In this mode, program execution halts. Idle mode freezes the clocks to the CPU at known states while the peripherals continue to be clocked (Figure 2-6 on page 2-9). The CPU status before entering idle mode is preserve. That is, the program counter, program status word register, and register file retain their data for the duration of idle mode. The contents of the SFRs and RAM are also retained. The status of the port pins depends upon the location of the program memory:

- Internal program memory: the ALE and PSEN# pins are pulled high and the ports 0, 1, 2, and 3 pins are driving the port SFR value (Table 15-1).
- External program memory: the ALE and PSEN# pins are pulled high; the port 0 pins are floating; and the pins of ports 1, 2, and 3 are driving the port SFR value (Table 15-1).

NOTE

If desired, the PCA may be instructed to pause during idle mode by setting the CIDL bit in the CMOD register (Figure 12-7 on page 12-13).

15.3.1 Entering Idle Mode

To enter idle mode, set the PCON register IDL bit. The 8x930 enters idle mode upon execution of the instruction that sets the IDL bit. The instruction that sets the IDL bit is the last instruction executed.

CAUTION

If the IDL bit and the PD bit are set simultaneously, the 8x930 enters powerdown mode.

15.3.2 Exiting Idle Mode

There are two ways to exit idle mode:

- Generate an enabled interrupt. Hardware clears the PCON register IDL bit which restores the clocks to the CPU. Execution resumes with the interrupt service routine. Upon completion of the interrupt service routine, program execution resumes with the instruction immediately following the instruction that activated idle mode. The general purpose flags (GF1 and GF0 in the PCON register) may be used to indicate whether an interrupt occurred during normal operation or during idle mode. When idle mode is exited by an interrupt, the interrupt service routine may examine GF1 and GF0.
- Reset the chip. See “Reset” on page 14-5. A logic high on the RST pin clears the IDL bit in the PCON register directly and asynchronously. This restores the clocks to the CPU. Program execution momentarily resumes with the instruction immediately following the instruction that activated the idle mode and may continue for a number of clock cycles before the internal reset algorithm takes control. Reset initializes the 8x930 and vectors the CPU to address FF:0000H.

NOTE

During the time that execution resumes, the internal RAM cannot be accessed; however, it is possible for the port pins to be accessed. To avoid unexpected outputs at the port pins, the instruction immediately following the instruction that activated idle mode should not write to a port pin or to the external RAM.

15.4 USB POWER CONTROL

The 8x930 supports USB power control through firmware, including global suspend/resume and remote wake-up. For flow charts of these operations, see Figure 15-3 on page 15-11.

15.4.1 Global Suspend Mode

When a global suspend is detected by the 8x930, the global suspend bit (GSUS in PCON1) is set and the global suspend/resume interrupt is generated. Global suspend is defined as bus inactivity for more than 3 ms on the USB lines. A device that is already in suspend mode will not change state. Hardware does not invoke any particular power-saving mode on detection of a global suspend. You must implement power control through firmware within the global suspend/resume ISR.

NOTE

Firmware must set the PD bit (PCON.1 in Figure 15-1 on page 15-3).

For global suspend on a bus powered device, firmware must put the 8x930 into powerdown mode to meet the USB limit of 500 μ A. For consistency, it is recommended that you put self-powered devices into powerdown mode as well.

15.4.1.1 Powerdown (Suspend) Mode

The powerdown mode places the 8x930 in a very low power state. Powerdown mode stops the oscillator and freezes all clocks at known states (Figure 2-6 on page 2-9). The CPU status prior to entering powerdown mode is preserved, i.e., the program counter, program status word register, and register file retain their data for the duration of powerdown mode. In addition, the SFRs and RAM contents are preserved. The status of the port pins depends on the location of the program memory:

- Internal program memory: the ALE and PSEN# pins are pulled low and the ports 0, 1, 2, and 3 pins are reading data (Table 15-1 on page 15-6).
- External program memory: the ALE and PSEN# pins are pulled low; the port 0 pins are floating; and the pins of ports 1, 2, and 3 are reading data (Table 15-1).

NOTE

V_{CC} may be reduced to as low as 2 V during powerdown to further reduce power dissipation. Take care, however, that V_{CC} is not reduced until powerdown is invoked.

15.4.1.2 Entering Powerdown (Suspend) Mode

To enter powerdown mode, set the PCON register PD bit. The 8x930 enters powerdown mode upon execution of the instruction that sets the PD bit. The instruction that sets the PD bit is the last instruction executed.

CAUTION

Do not put the 8x930 into powerdown mode unless the USB suspend signal is detected on the USB lines (GSUS = 1). Otherwise, the device will not be able to wake up from powerdown mode by a resume signal sent through the USB lines. See “USB Power Control” on page 15-8.

15.4.1.3 Exiting Powerdown (Suspend) Mode

CAUTION

If V_{CC} was reduced during the powerdown mode, do not exit powerdown until V_{CC} is restored to the normal operating level.

There are two ways (other than USB signaling) to exit the powerdown mode:

1. Generate an enabled external interrupt. The interrupt signal must be held active long enough for the oscillator to restart and stabilize (normally less than 10 ms). Hardware clears the PD bit in the PCON register which starts the oscillator and restores the clocks to the CPU and peripherals. Execution resumes with the interrupt service routine. Upon completion of the interrupt service routine, program execution resumes with the instruction immediately following the instruction that activated powerdown mode.

To enable an external interrupt, set the IEN0 register EX0 and/or EX1 bit[s]. The external interrupt used to exit powerdown mode must be configured as level-sensitive and must be assigned the highest priority. Holding the interrupt pin (INT0# or INT1#) low restarts the oscillator and bringing the pin high completes the exit. The duration of the interrupt signal must be long enough to allow the oscillator to stabilize (normally less than 10 ms).

2. Generate a reset. See “Reset” on page 14-5. A logic high on the RST pin clears the PD bit in the PCON register directly and asynchronously. This starts the oscillator and restores the clocks to the CPU and peripherals. Program execution momentarily resumes with the instruction immediately following the instruction that activated powerdown and may continue for a number of clock cycles before the internal reset algorithm takes control. Reset initializes the 8x930 and vectors the CPU to address FF:0000H.

NOTE

During the time that execution resumes, the internal RAM cannot be accessed; however, it is possible for the port pins to be accessed. To avoid unexpected outputs at the port pins, the instruction immediately following the instruction that activated the powerdown mode should not write to a port pin or to the external RAM.

15.4.2 Global Resume Mode

When a global resume is detected by the 8x930, the global resume bit (GRSM of PCON1) is set, the global suspend bit (GSUS of PCON1) is cleared, and the global suspend/resume interrupt is generated. As soon as resume signaling is detected on the USB lines, the oscillator is restarted. A resume condition is defined as a “J to anything” transition. This could be a K transition, or reset signaling on the root port. For the 8x930Hx, a resume condition could be an enabled downstream port or connect/disconnect of a downstream port in the disconnected, disabled, or suspended states.

Upon detection of a resume condition, the 8x930 applies power to the USB transceivers, the crystal oscillator, and the PLL (although the PLL output is still gated-off). The device begins timing two different time points, T1 and T2, as described in Chapter 11 of the *Universal Serial Bus Specification*.

After the clocks are restarted, the CPU program continues execution from where it was when the device was put into powerdown mode. The device then services the resume interrupt service routine. After executing the resume ISR, the 8x930 continues operation from the point where it was interrupted by the suspend interrupt.

15.4.3 USB Remote Wake-up

The 8x930 can initiate resume signaling to the USB lines through remote wake-up of the USB function while it is in powerdown/idle mode. While in powerdown mode, remote wake-up has to be initiated through assertion of an enabled external interrupt. The external interrupt has to be enabled and it must be configured with level trigger and with higher priority than a Suspend/Resume interrupt. A function resume restarts the clocks to the 8x930 and program execution branches to an external interrupt service routine.

Within this external interrupt service routine, you must ensure GRSM = 0. If GRSM is clear, set the remote wake-up bit (RWU in PCON1 — Figure 15-2) to drive resume signaling on the USB lines to the host or upstream hub (as well as to the enabled downstream ports for the 8x930Hx). After executing the external ISR, the program continues execution from where it was put into powerdown mode and the 8x930 resumes normal operation.

The procedure is similar for remote wake-up initiated from idle mode. For idle mode, enabled interrupts from the USB function should also initiate wake-up.

NOTE

Do not initiate a remote wake-up (by setting the RWU bit in PCON1) prior to 5ms after the last bus activity is detected (2ms after the 8x930Hx is suspended).

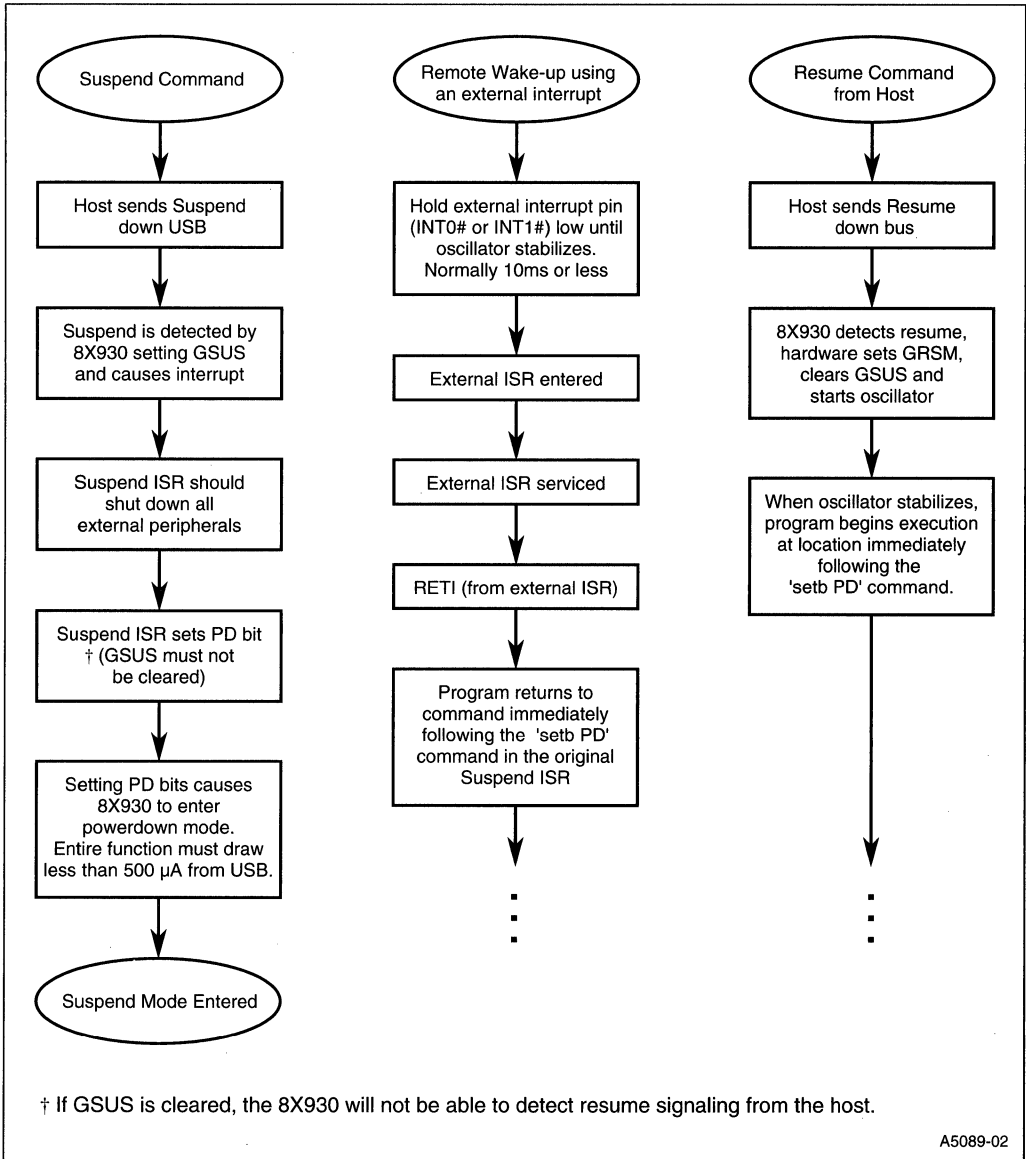
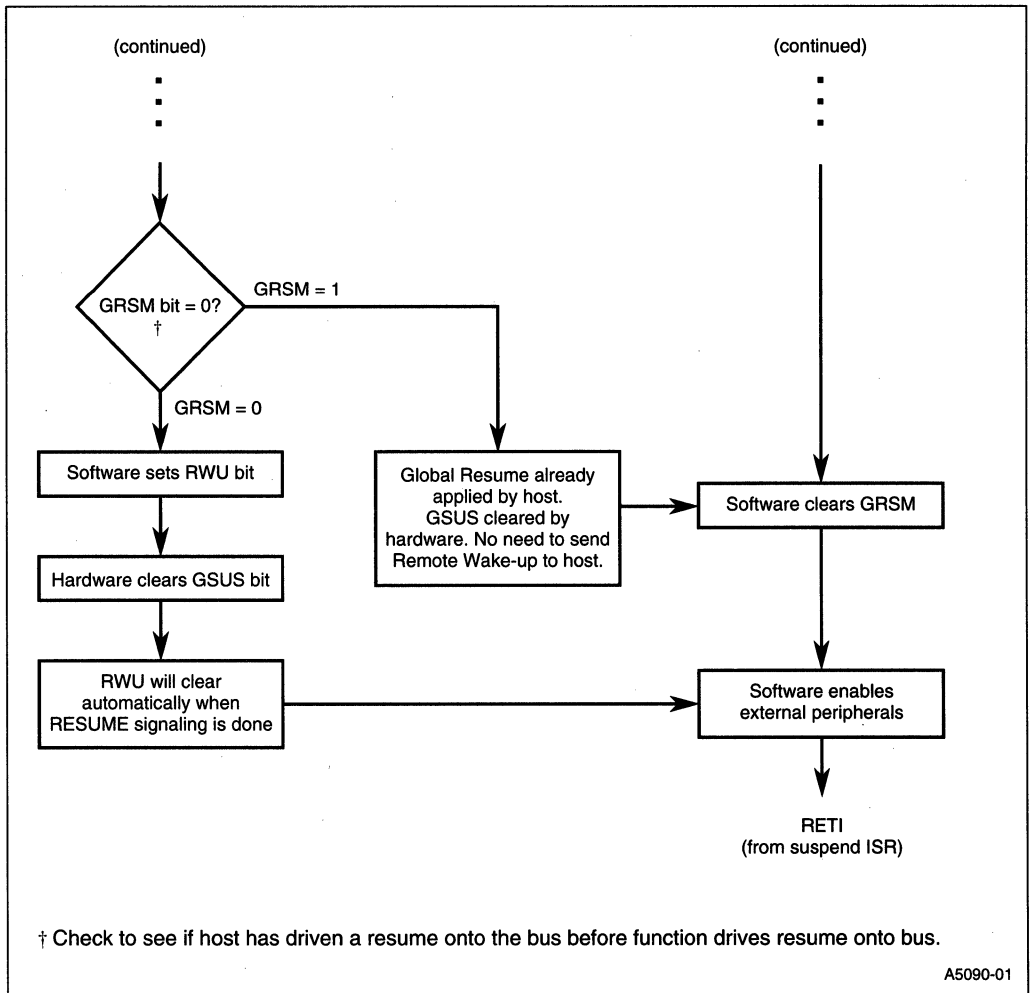


Figure 15-3. Suspend/Resume Program with/without Remote Wake-up



Suspend/Resume Program with/without Remote Wake-up (Continued)

15.5 LOW-CLOCK MODE

Low-clock mode is the default operation mode for the 8x930 upon reset. After reset, the CPU and peripherals (excluding the USB module) default to a 3 MHz clock rate. The USB module always operates at the clock rate selected by pins PLLSEL2:0. Low-clock mode ensures that the I_{CC} drawn by the 8x930, while in the unenumerated state following chip reset, is less than one unit load (100 mA).

After USB enumeration (and given that the request for more than one unit load of I_{CC} is granted), firmware can clear the LC bit in PCON to clock the CPU and on-chip peripherals at the rate selected by pin PLLSEL2:0.

15.5.1 Entering Low-clock Mode

Low-clock mode can be invoked through firmware anytime the device is unconfigured by the host PC. To invoke low-clock mode, set the LC bit in the PCON register (Figure 15-1).

NOTE

The device reset routine sets the LC bit placing the 8x930 in low-clock mode.

15.5.2 Exiting Low-clock Mode

To switch the clock of the CPU and the peripherals to the hardware-selected clock rate, clear the LC bit in the PCON register (Figure 15-1). The hardware clock rate selection determines the highest operating clock rate for the 8x930.

15.6 ON-CIRCUIT EMULATION (ONCE) MODE

The on-circuit emulation (ONCE) mode permits external testers to test and debug 8x930-based systems without removing the chip from the circuit board. A clamp-on emulator or test CPU is used in place of the 8x930 which is electrically isolated from the system.

15.6.1 Entering ONCE Mode

To enter the ONCE mode:

1. Assert RST to initiate a device reset. See “Externally-Initiated Resets” on page 14-5 and the reset waveforms in Figure 14-5 on page 14-7.
2. While holding RST asserted, apply and hold logic levels to I/O pins as follows: PSEN# = low, P0.7:5 = low, P0.4 = high, P0.3:0 = low (i.e., port 0 = 10H).
3. Deassert RST, then remove the logic levels from PSEN# and port 0.

These actions cause the 8x930 to enter the ONCE mode. Port 1, 2, and 3 pins are weakly pulled high and port 0, ALE, and PSEN# pins are floating (Table 15-1 on page 15-6). Thus the device is electrically isolated from the remainder of the system which can then be tested by an emulator or test CPU. Note that in the ONCE mode the device oscillator remains active.

15.6.2 Exiting ONCE Mode

To exit ONCE mode, reset the device.





16

External Memory Interface





CHAPTER 16

EXTERNAL MEMORY INTERFACE

This chapter covers various aspects of the external memory interface. It describes the signals associated with external memory operations, page mode/nonpage mode operation, and external bus cycle timing (for normal accesses, accesses with configurable wait states, accesses with real-time wait states, and configuration byte accesses). This chapter also describes the real-time wait state register (WCON), gives the status of the pins for ports P0 and P2 during bus cycles and bus idle, and includes several external memory design examples.

16.1 OVERVIEW

The 8x930 interfaces with a variety of external memory devices. It can be configured to have a 16-bit, 17-bit, or 18-bit external address bus. Data transfer operations (8 bits) are multiplexed on the address bus.

The external memory interface comprises the external bus (ports 0 and 2, and when so configured, address bits A17 and A16) and the bus control signals described in Table 16-1. Chip configuration bytes (see Chapter 4, “Device Configuration”) provide several interface options: page mode or nonpage mode for external code fetches; the number of external address bits (16, 17, or 18); the address ranges for RD#, WR#, and PSEN#; and the number of preprogrammed external wait states to extend RD#, WR#, PSEN#, or ALE. Real-time wait states can be enabled with special function register WCON.1:0. You can use these options to tailor the interface to your application. For additional information refer to “Configuring the External Memory Interface” on page 4-7.

The external memory interface operates in either page mode or nonpage mode. Figure 16-1 shows the structure of the external address bus for page mode and nonpage mode operation. Page mode provides increased performance by reducing the time for external code fetches. Page mode does not apply to code fetches from on-chip memory.

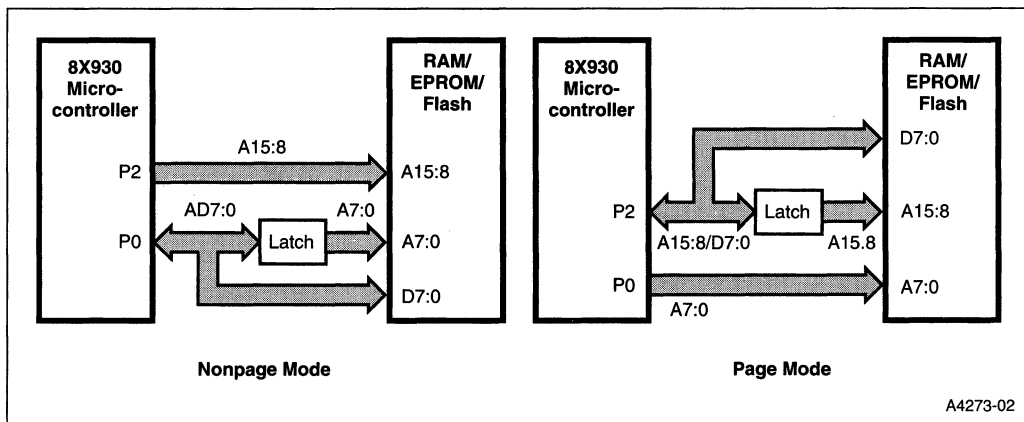


Figure 16-1. Bus Structure in Nonpage Mode and Page Mode

Table 16-1. External Memory Interface Signals

Signal Name	Type	Description	Alternate Function
A17	O	Address Line 17.	P1.7/CEX4/WCLK
A16	O	Address Line 16. See RD#.	P3.7/RD#
A15:8†	O	Address Lines. Upper address for external bus (non-page mode).	P2.7:0
AD7:0†	I/O	Address/Data Lines. Multiplexed lower address and data for the external bus (non-page mode).	P0.7:0
ALE	O	Address Latch Enable. ALE signals the start of an external bus cycle and indicates that valid address information is available on lines A15:8 and AD7:0.	PROG#
EA#	I	External Access. Directs program memory accesses to on-chip or off-chip code memory. For EA# strapped to ground, all program memory accesses are off-chip. For EA# = strapped to V _{CC} , an access is to on-chip ROM if the address is within the range of the on-chip ROM; otherwise the access is off-chip. The value of EA# is latched at reset. For devices without on-chip ROM, EA# must be strapped to ground.	V _{PP}
PSEN#	O	Program Store Enable. Read signal output. This output is asserted for a memory address range that depends on bits RD0 and RD1 in the configuration byte (see also RD#): RD1 RD0 Address Range for Assertion 0 0 All addresses 0 1 All addresses 1 0 All addresses 1 1 All addresses ≥ 80:0000H	—
RD#	O	Read or 17th Address Bit (A16). Read signal output to external data memory or 17th external address bit (A16), depending on the values of bits RD0 and RD1 in configuration byte. (See PSEN#): RD1 RD0 Function 0 0 The pin functions as A16 only. 0 1 The pin functions as A16 only. 1 0 The pin functions as P3.7 only. 1 1 RD# asserted for reads at all addresses ≤7F:FFFFH.	P3.7/A16
WAIT#	I	Real-time Wait State Input. The real-time WAIT# input is enabled by writing a logical '1' to the WCON.0 (RTWE) bit at S:A7H. During bus cycles, the external memory system can signal 'system ready' to the microcontroller in real time by controlling the WAIT# input signal on the port 1.6 input.	P1.6/CEX3
WCLK	O	Wait Clock Output. The real-time WCLK output is driven at port 1.7 (WCLK) by writing a logical '1' to the WCON.1 (RTWCE) bit at S:A7H. When enabled, the WCLK output produces a square wave signal with a period of one-half the oscillator frequency.	A17/P1.7/CEX4
WR#	O	Write. Write signal output to external memory. WR# is asserted for writes to all valid memory locations.	P3.6

† If the chip is configured for page-mode operation, port 0 carries the lower address bits (A7:0), and port 2 carries the upper address bits (A15:8) and the data (D7:0).

The reset routine configures the 8x930 for operation in page mode or nonpage mode according to bit 1 of configuration byte UCONFIG0. P0 carries address A7:0 while P2 carries address A15:8. Data D7:0 is multiplexed with A7:0 on P0 in nonpage mode and with A15:8 on P2 in page mode.

Table 16-1 describes the external memory interface signals. The address and data signals (AD7:0 on port 0 and A15:8 on port 2) are defined for nonpage mode.

16.2 EXTERNAL BUS CYCLES

This section describes the bus cycles the 8x930 executes to fetch code, read data, and write data in external memory. Both page mode and nonpage mode are described and illustrated. This section does not cover wait states (see “External Bus Cycles With Configurable Wait States” on page 16-8) or configuration byte bus cycles (see “Configuration Byte Bus Cycles” on page 16-15).

NOTE

For simplicity, the accompanying figures depict the bus cycle waveforms in idealized form and do not provide precise timing information. For bus cycle timing parameters refer to the 8x930Ax and 8x930Hx datasheets.

An “inactive external bus” exists when the 8x930 is not executing external bus cycles. This occurs under any of the three following conditions:

- Bus Idle (The chip is in normal operating mode but no external bus cycles are executing.)
- The chip is in idle mode
- The chip is in powerdown mode

16.2.1 Bus Cycle Definitions

Table 16-2 lists the types of external bus cycles. It also shows the activity on the bus for nonpage mode and page mode bus cycles with no wait states. There are three types of nonpage mode bus cycles: code fetch, data read, and data write. There are four types of page mode bus cycles: code fetch (page miss), code fetch (page hit), data read, and data write. The data read and data write cycles are the same for page mode and nonpage mode (except the multiplexing of D7:0 on ports 0 and 2).

16.2.2 Nonpage Mode Bus Cycles

In nonpage mode, the external bus structure is the same as for MCS 51 microcontrollers. The upper address bits (A15:8) are on port 2, and the lower address bits (A7:0) are multiplexed with the data (D7:0) on port 0. External code read bus cycles execute in approximately two state times. See Table 16-2 and Figure 16-2. External data read bus cycles (Figure 16-3) and external write bus cycles (Figure 16-4) execute in approximately three state times. For the write cycle (Figure 16-4), a third state is appended to provide recovery time for the bus. Note that the write signal WR# is asserted for all memory regions, except for the case of RD1:0 = 11, where WR# is asserted for regions 00:–01: but **not** for regions FE:–FF:.

Table 16-2. Bus Cycle Definitions (No Wait States)

Mode	Bus Cycle	Bus Activity		
		State 1	State 2	State 3
Nonpage Mode	Code Read	ALE	RD#/PSEN#, code in	
	Data Read (2)	ALE	RD#/PSEN#	data in
	Data Write (2)	ALE	WR#	WR# high, data out
Page Mode	Code Read, Page Miss	ALE	RD#/PSEN#, code in	
	Code Read, Page Hit (3)	PSEN#, code in		
	Data Read (2)	ALE	RD#/PSEN#	data in
	Data Write (2)	ALE	WR#	WR# high, data out

NOTES:

1. Signal timing implied by this table is approximate (idealized).
2. Data read (page mode) = data read (nonpage mode) and write (page mode) = write (nonpage mode) except that in page mode data appears on P2 (multiplexed with A15:0), whereas in nonpage mode data appears on P0 (multiplexed with A7:0).
3. The initial code read page hit bus cycle can execute only following a code read page miss cycle.

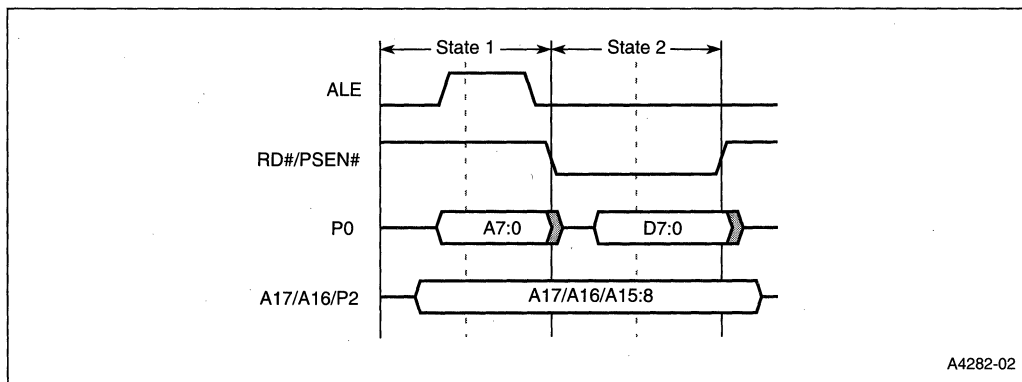


Figure 16-2. External Code Fetch (Nonpage Mode)

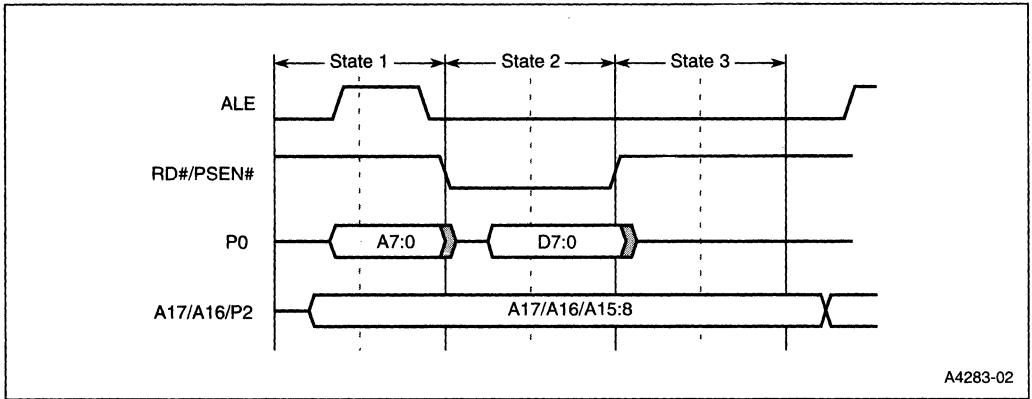


Figure 16-3. External Data Read (Nonpage Mode)

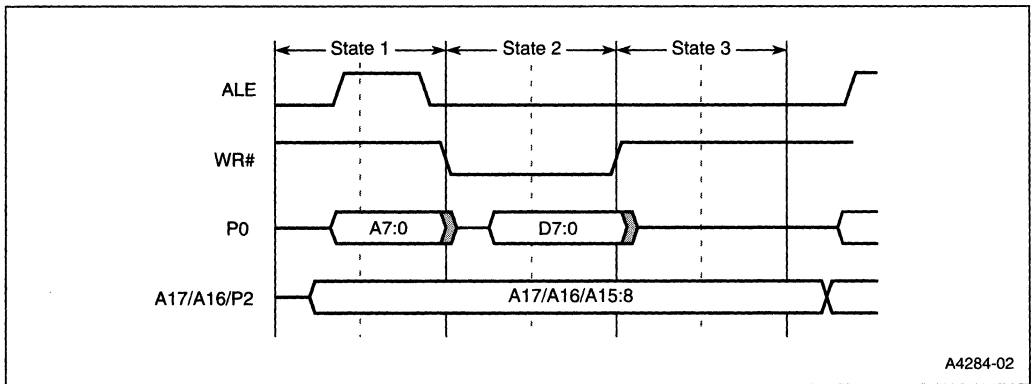


Figure 16-4. External Data Write (Nonpage Mode)

16.2.3 Page Mode Bus Cycles

Page mode increases performance by reducing the time for external code fetches. Under certain conditions the controller fetches an instruction from external memory in one state time instead of two (Table 16-2). Page mode does not affect internal code fetches.

The first code fetch to a 256-byte “page” of memory always uses a two-state bus cycle. Subsequent successive code fetches to the same page (*page hits*) require only a one-state bus cycle. When a subsequent fetch is to a different page (a *page miss*), it again requires a two-state bus cycle. The following external code fetches are always page-miss cycles:

- the first external code fetch after a page rollover†
- the first external code fetch after an external data bus cycle
- the first external code fetch after powerdown or idle mode
- the first external code fetch after a branch, return, interrupt, etc.

In page mode, the 8x930 bus structure differs from the bus structure in MCS 51 controllers (Figure 16-1). The upper address bits A15:8 are multiplexed with the data D7:0 on port 2, and the lower address bits (A7:0) are on port 0.

Figure 16-5 shows the two types of external bus cycles for code fetches in page mode. The *page-miss* cycle is the same as a code fetch cycle in nonpage mode (except D7:0 is multiplexed with A15:8 on P2.). For the *page-hit* cycle, the upper eight address bits are the same as for the preceding cycle. Therefore, ALE is not asserted, and the values of A15:8 are retained in the address latches. In a single state, the new values of A7:0 are placed on port 0, and memory places the instruction byte on port 2. Notice that a page hit reduces the available address access time by one state. Therefore, faster memories may be required to support page mode.

Figure 16-6 and Figure 16-7 show the bus cycles for data reads and data writes in page mode. These cycles are identical to those for nonpage mode, except for the different signals on ports 0 and 2.

† A page rollover occurs when the address increments from the top of one 256-byte page to the bottom of the next (e.g., from FF:FAFFH to FF:FB00H).

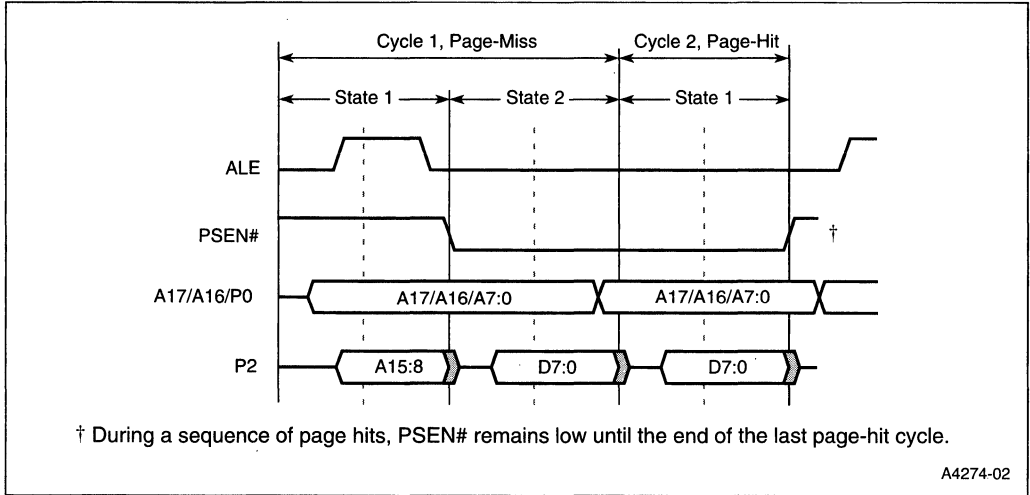


Figure 16-5. External Code Fetch (Page Mode)

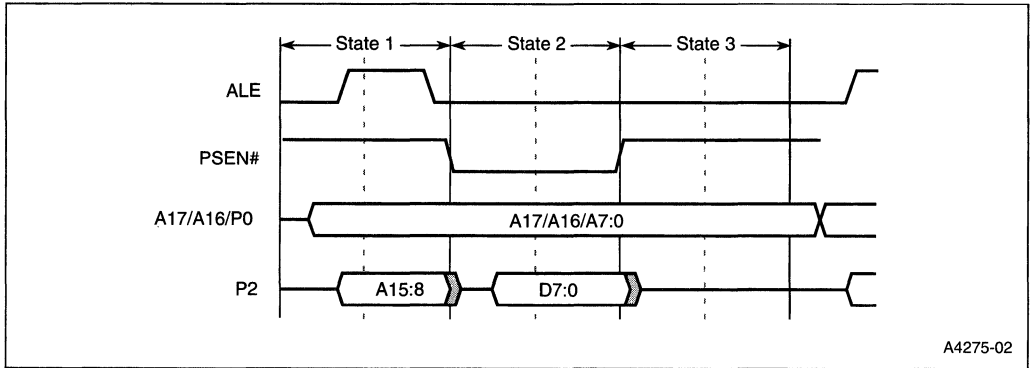


Figure 16-6. External Data Read (Page Mode)

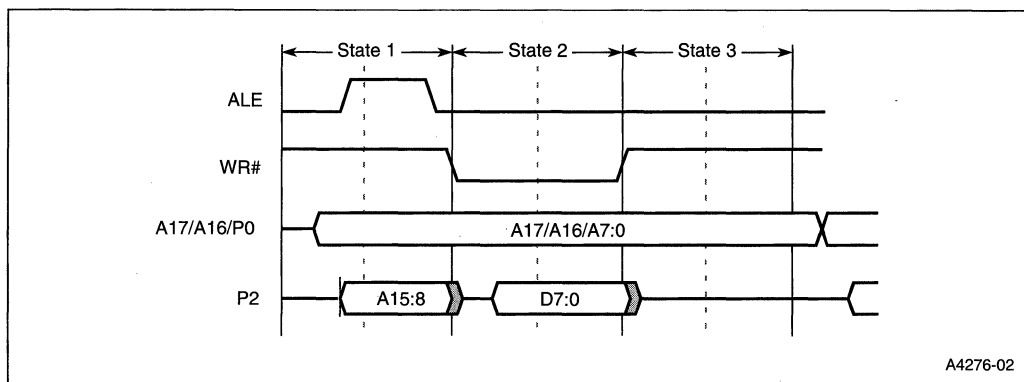


Figure 16-7. External Data Write (Page Mode)

16.3 WAIT STATES

The 8x930 provides three types of wait state solutions to external memory problems: real-time, RD#/WR#/PSEN#, and ALE wait states. The 8x930 supports traditional real-time wait state operations for dynamic bus control. Real-time wait state operations are controlled by means of the WCON special function register. See “External Bus Cycles with Real-time Wait States” on page 16-11.

In addition, the 8x930 device can be configured at reset to add wait states to external bus cycles by extending the ALE or RD#/WR#/PSEN# pulses. See “Wait State Configuration Bits” on page 4-11.

You can configure the chip to use multiple types of wait states. Accesses to on-chip code and data memory always use zero wait states. The following sections demonstrate wait state usage.

16.4 EXTERNAL BUS CYCLES WITH CONFIGURABLE WAIT STATES

This section describes the code fetch, read data, and write data external bus cycles with configurable wait states. Both page mode and nonpage mode operation are described and illustrated. For simplicity, the accompanying figures depict the bus cycle waveforms in idealized form and do not provide precise timing information.

16.4.1 Extending RD#/WR#/PSEN#

You can use bits WSA1:0# in configuration byte UCONFIG0 (Figure 4-3 on page 4-5) and WSB1:0# in UCONFIG1 (Figure 4-4 on page 4-6) to add 0, 1, 2, or 3 wait states to the RD#/WR#/PSEN# pulses. Figure 16-8 shows the nonpage mode code fetch bus cycle with one RD#/PSEN# wait state. The wait state extends the bus cycle to three states. Figure 16-9 shows the nonpage mode data write bus cycle with one WR# wait state. The wait state extends the bus cycle to four states. The waveforms in Figure 16-9 also apply to the nonpage mode data read external bus cycle if RD#/PSEN# is substituted for WR#.

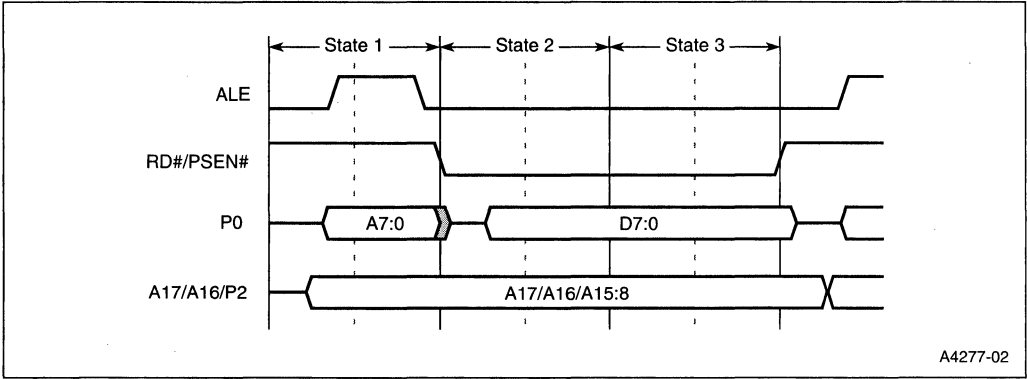


Figure 16-8. External Code Fetch (Nonpage Mode, One RD#/PSEN# Wait State)

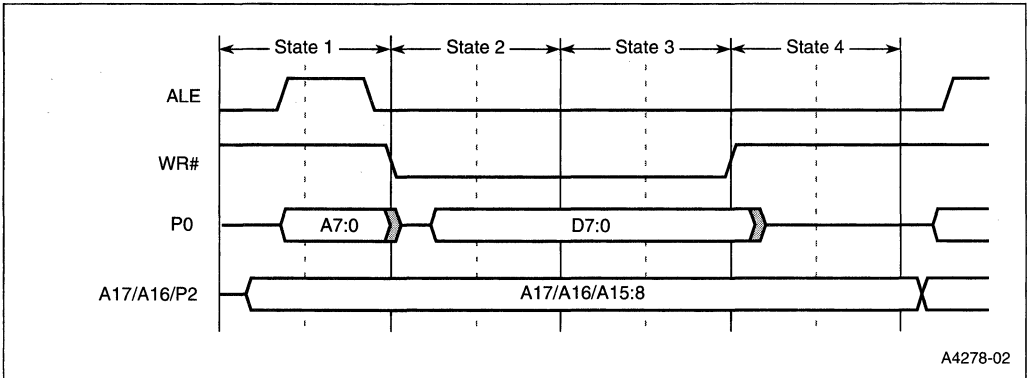


Figure 16-9. External Data Write (Nonpage Mode, One WR# Wait State)

16.4.2 Extending ALE

Use the XALE# bit of configuration byte UCONFIG0 to extend the ALE pulse 1 wait state. Figure 16-10 shows the nonpage mode code fetch external bus cycle with ALE extended. The wait state extends the bus cycle from two states to three. For read and write external bus cycles, the extended ALE extends the bus cycle from three states to four.

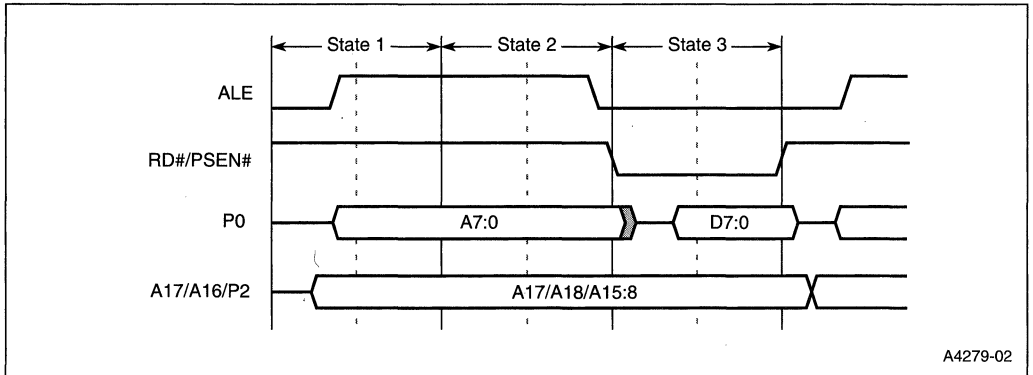


Figure 16-10. External Code Fetch (Nonpage Mode, One ALE Wait State)

16.5 EXTERNAL BUS CYCLES WITH REAL-TIME WAIT STATES

There are two ways of using real-time wait states: the WAIT# pin used as an input bus control and the WAIT# signal used in conjunction with the WCLK output signal. These two signals are enabled with the WCON special function register in the SFR space at S:0A7H. Refer to Figure 16-11.

NOTE

The WCLK and WAIT# signals are alternate functions for the port 1.7:6 input and output buffers. Use of the alternate functions may conflict with wait state operation.

When WAIT# is enabled, PCA module 3 is disabled on port 1.6 (CEX3) and resumes operation only when the WAIT# function is disabled. The same relationship exists between WCLK on port 1.7 (CEX4) and PCA module 4. It is not advisable to alternate between PCA operations and real-time wait-state operations at port 1.6 (CEX3/WAIT#) or port 1.7 (CEX4/WCLK).

Port 1.7 can also be configured to serve as address signal A17 (See UNCONFIG0 on page 4-5). The A17 address signal always takes priority over the alternate functions (CEX4 and WCLK). Even if RTWCE is enabled in WCON.1, the WCLK output does not appear during bus cycles enabled to drive address A17. The use of WAIT# as an input on port 1.6 is unaffected by address signals.

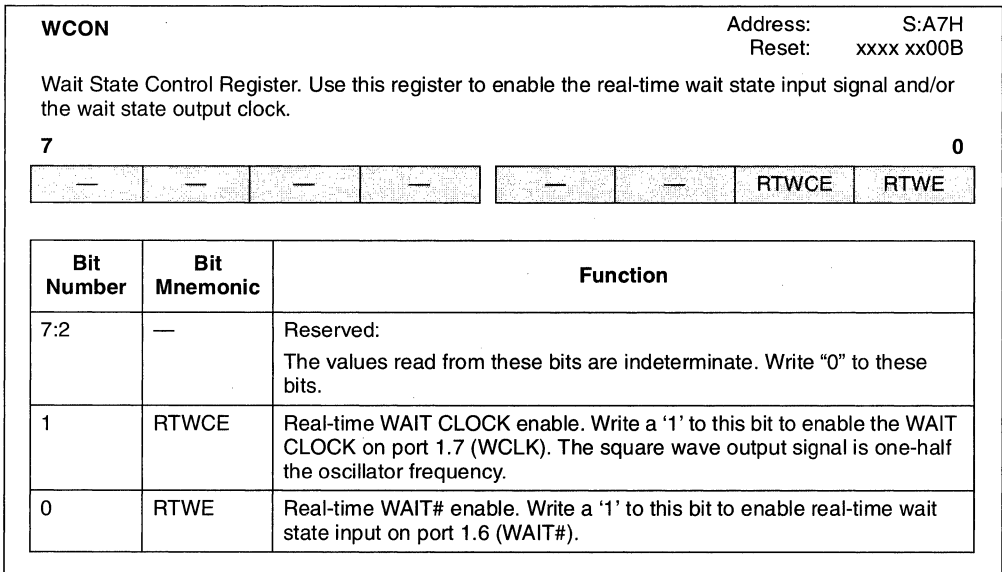


Figure 16-11. WCON: Real-time Wait State Control Register

16.5.1 Real-time WAIT# Enable (RTWE)

The real-time WAIT# input is enabled by writing a logical '1' to the WCON.0 (RTWE) bit at S:A7H. During bus cycles, the external memory system can signal "system ready" to the microcontroller in real time by controlling the WAIT# input signal on the port 1.6 input. Sampling of WAIT# is coincident with the activation of RD#/PSEN# or WR# signals driven low during a bus cycle. A "not-ready" condition is recognized by the WAIT# signal held at V_{IL} by the external memory system. Use of PCA module 3 may conflict with your design. Do not use the PCA module 3 I/O (CEX3) interchangeably with the WAIT# signal on the port 1.3 input. Setup and hold times are illustrated in the current datasheet.

16.5.2 Real-time WAIT CLOCK Enable (RTWCE)

The real-time WAIT CLOCK output is driven at port 1.7 (WCLK) by writing a logical '1' to the WCON.1 (RTWCE) bit at S:A7H. When enabled, the WCLK output produces a square wave signal with a period of one-half the oscillator frequency. Use of PCA module 4 may conflict with your design. Do not use the PCA module 4 I/O (CEX4) interchangeably with the WCLK output. Use of address signal A17 inhibits both WCLK and PCA module 4 usage of port 1.7.

16.5.3 Real-time Wait State Bus Cycle Diagrams

Figure 16-12 shows the code fetch/data read bus cycle in nonpage mode. Figure 16-14 depicts the data read cycle in page mode.

CAUTION

The real-time wait function has critical external timing for code fetch. For this reason, it is not advisable to use the real-time wait feature for code fetch in page mode.

The data write bus cycle in nonpage mode is shown in Figure 16-13. Figure 16-15 shows the data write bus cycle in page mode.

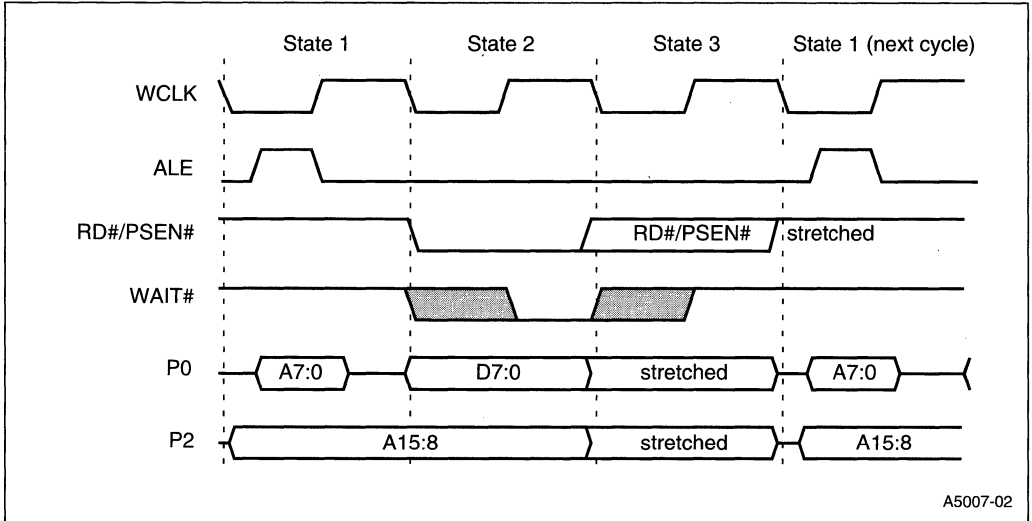


Figure 16-12. External Code Fetch/Data Read (Nonpage Mode, Real-time Wait State)

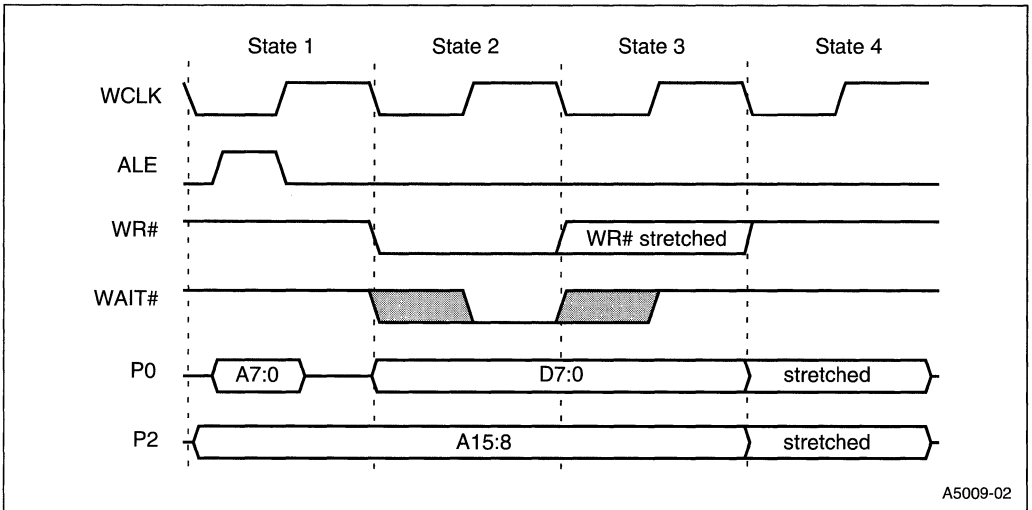


Figure 16-13. External Data Write (Nonpage Mode, Real-time Wait State)

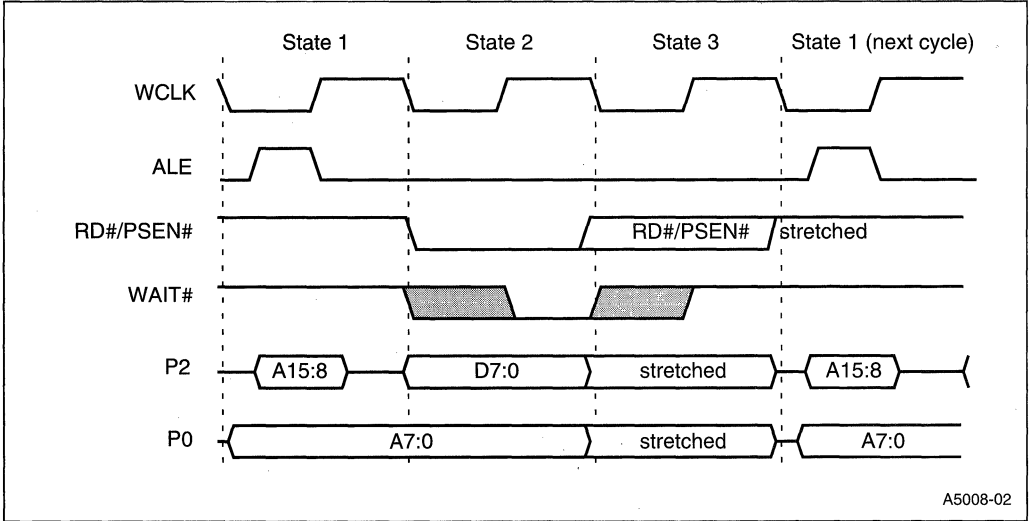


Figure 16-14. External Data Read (Page Mode, Real-time Wait State)

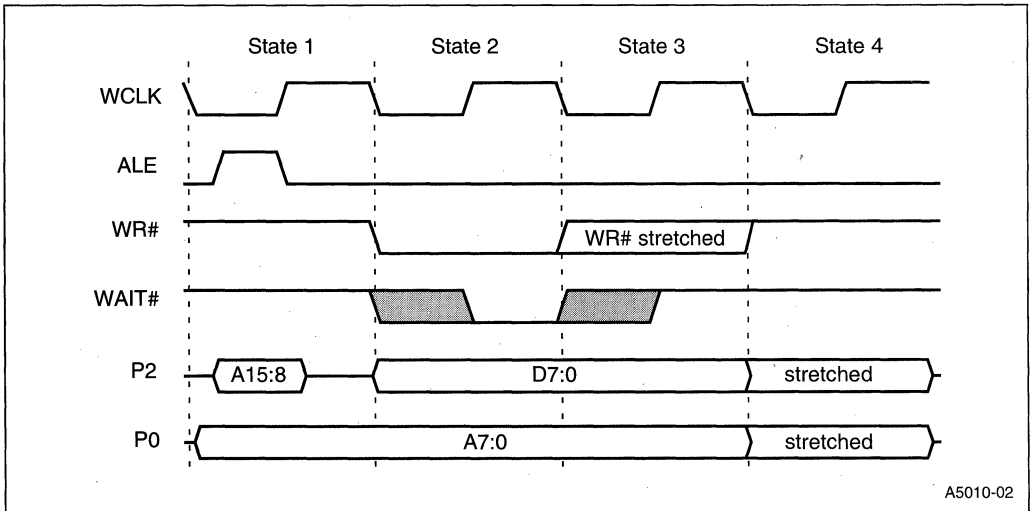


Figure 16-15. External Data Write (Page Mode, Real-time Wait State)

16.6 CONFIGURATION BYTE BUS CYCLES

If EA# = 0, devices obtain configuration information from a configuration array in external memory. This section describes the bus cycles executed by the reset routine to fetch user configuration bytes from external memory. Configuration bytes are discussed in Chapter 4, “Device Configuration.”

To determine whether the external memory is set up for page mode or nonpage mode operation, the 8x930 accesses external memory using internal address FF:FFF8H (UCONFIG0). See states 1–4 in Figure 16-16. If the external memory is set up for page mode, it places UCONFIG0 on P2 as D7:0, overwriting A15:8 (FFH). If external memory is set up for nonpage mode, A15:8 is not overwritten. The 8x930 examines P2 bit 1. Subsequent configuration byte fetches are in page mode if P2.1 = 0 and in nonpage mode if P2.1 = 1. The 8x930 fetches UCONFIG0 again (states 5–8 in Figure 16-16) and then UCONFIG1 via internal address FF:FFF9H.

The configuration byte bus cycles always execute with ALE extended and one PSEN# wait state.

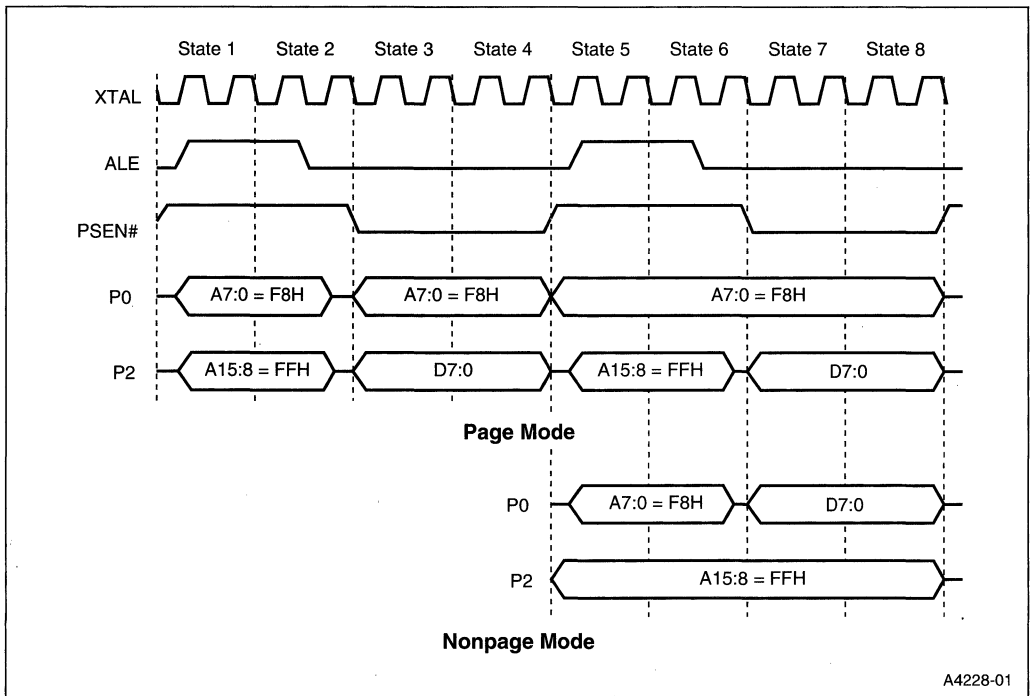


Figure 16-16. Configuration Byte Bus Cycles

16.7 PORT 0 AND PORT 2 STATUS

This section summarizes the status of the port 0 and port 2 pins when these ports are used as the external bus. A more comprehensive description of the ports and their use is given in Chapter 10, “Input/Output Ports.”

When port 0 and port 2 are used as the external memory bus, the signals on the port pins can originate from three sources:

- the 8x930 CPU (address bits, data bits)
- the port SFRs: P0 and P2 (logic levels)
- an external device (data bits)

The port 0 pins (but not the port 2 pins) can also be held in a high-impedance state. Table 16-3 lists the status of the port 0 and port 2 pins when the chip is in the normal operating mode and the external bus is idle or executing a bus cycle.

Table 16-3. Port 0 and Port 2 Pin Status In Normal Operating Mode

Port	8-bit/16-bit Addressing	Nonpage Mode		Page Mode	
		Bus Cycle	Bus Idle	Bus Cycle	Bus Idle
Port 0	8 or 16	AD7:0 (1)	High Impedance	A7:0 (1)	High Impedance
Port 2	8	P2 (2)	P2	P2/D7:0 (2)	High Impedance
	16	A15:8	P2	A15:8/D7:0	High Impedance

NOTES:

1. During external memory accesses, the CPU writes FFH to the P0 register and the register contents are lost.
2. The P2 register can be used to select 256-byte pages in external memory.

16.7.1 Port 0 and Port 2 Pin Status in Nonpage Mode

In nonpage mode, the port pins have the same signals as those on the 8XC51FX. For an external memory instruction using a 16-bit address, the port pins carry address and data bits during the bus cycle. However, if the instruction uses an 8-bit address (e.g., MOVX @Ri), the contents of P2 are driven onto the pins. These pin signals can be used to select 256-bit pages in external memory.

During a bus cycle, the CPU always writes FFH to P0, and the former contents of P0 are lost. A bus cycle does not change the contents of P2. When the bus is idle, the port 0 pins are held at high impedance, and the contents of P2 are driven onto the port 2 pins.

16.7.2 Port 0 and Port 2 Pin Status in Page Mode

In a page-mode bus cycle, the data is multiplexed with the upper address byte on port 2. However, if the instruction uses an 8-bit address (e.g., MOVX @Ri), the contents of P2 are driven onto the pins when data is not on the pins. These logic levels can be used to select 256-bit pages in external memory. During bus idle, the port 0 and port 2 pins are held at high impedance. For port pin status when the chip is in idle mode, powerdown mode, or reset, see Chapter 15, "Special Operating Modes."

16.8 EXTERNAL MEMORY DESIGN EXAMPLES

This section presents several external memory designs for 8x930 systems. These examples illustrate the design flexibility provided by the configuration options, especially for the PSEN# and RD# signals. Many designs are possible. The examples employ the 80930AD and 83930AE but also apply to the other 8x930Hx devices if the differences in on-chip memory are allowed for. For a general discussion on external memory see “Configuring the External Memory Interface” on page 4-7. Figure 4-5 on page 4-8 and Figure 4-6 on page 4-9 depict the mapping of internal memory space into external memory.

16.8.1 Example 1: RD1:0 = 00, 18-bit Bus, External Flash and RAM

In this example, an 80930AD operates in page mode with an 18-bit external address bus interfaced to 128 Kbytes of external flash memory and 128 Kbytes of external RAM (Figure 16-17). Figure 16-18 shows how the external flash and RAM are addressed in the internal memory space. On-chip data RAM (1056 bytes) occupies the lowest addresses in region 00:.

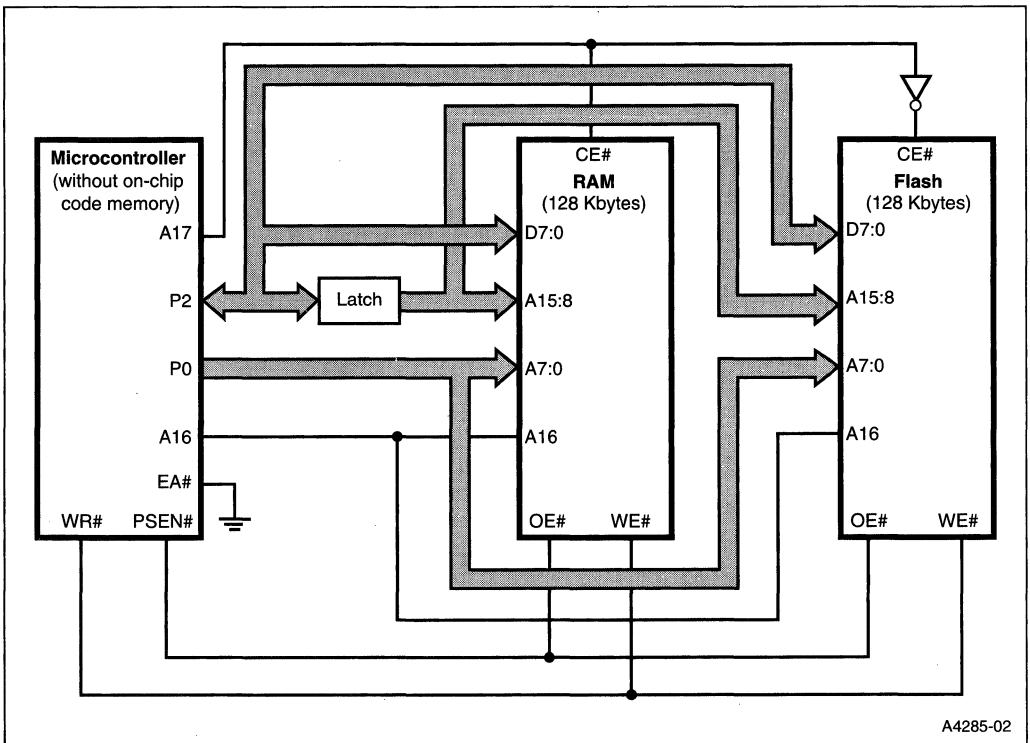


Figure 16-17. Bus Diagram for Example 1: 80930AD in Page Mode

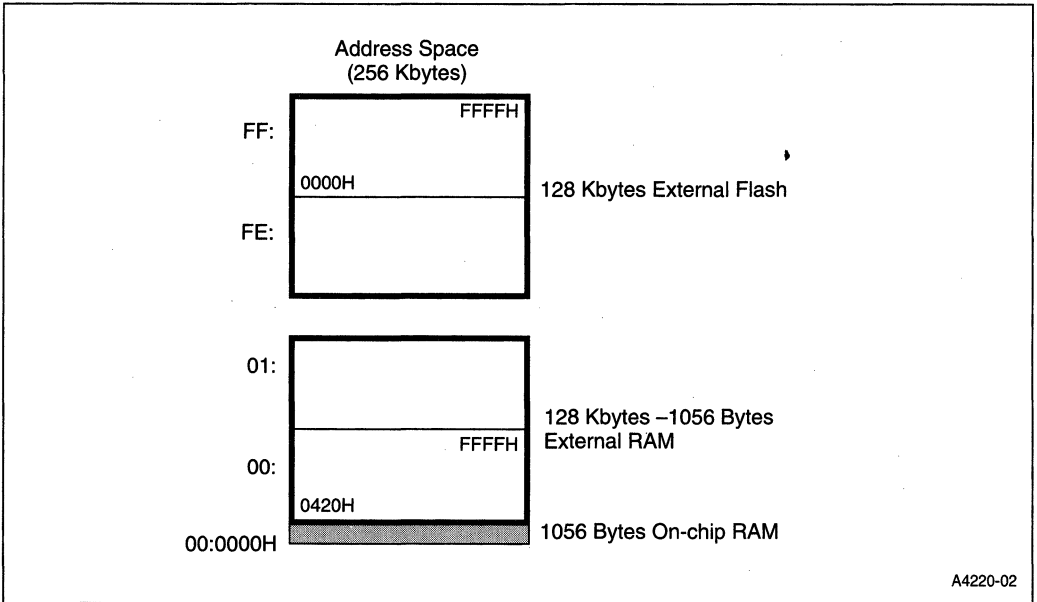


Figure 16-18. Address Space for Example 1

16.8.2 Example 2: RD1:0 = 01, 17-bit Bus, External Flash and RAM

In this example, an 80930AD operates in page mode with a 17-bit external address bus interfaced to 64 Kbytes of flash memory for code storage and 32 Kbytes of external RAM (Figure 16-19). The 80930AD is configured so that PSEN# is asserted for all reads, and RD# functions as A16 (RD1:0 = 01). Figure 16-20 shows how the external flash and RAM are addressed in the internal memory space. Addresses 0420H–7FFFH in external RAM are addressed in region 00:. On-chip data RAM (1056 bytes) occupies the lowest addresses in region 00:.

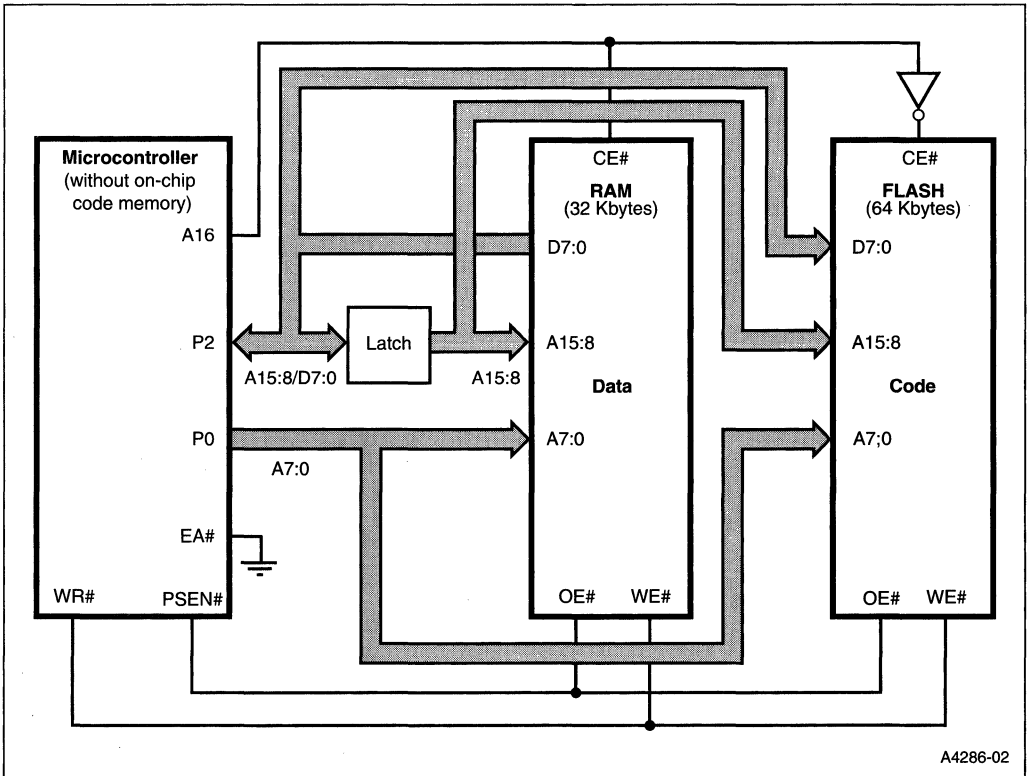
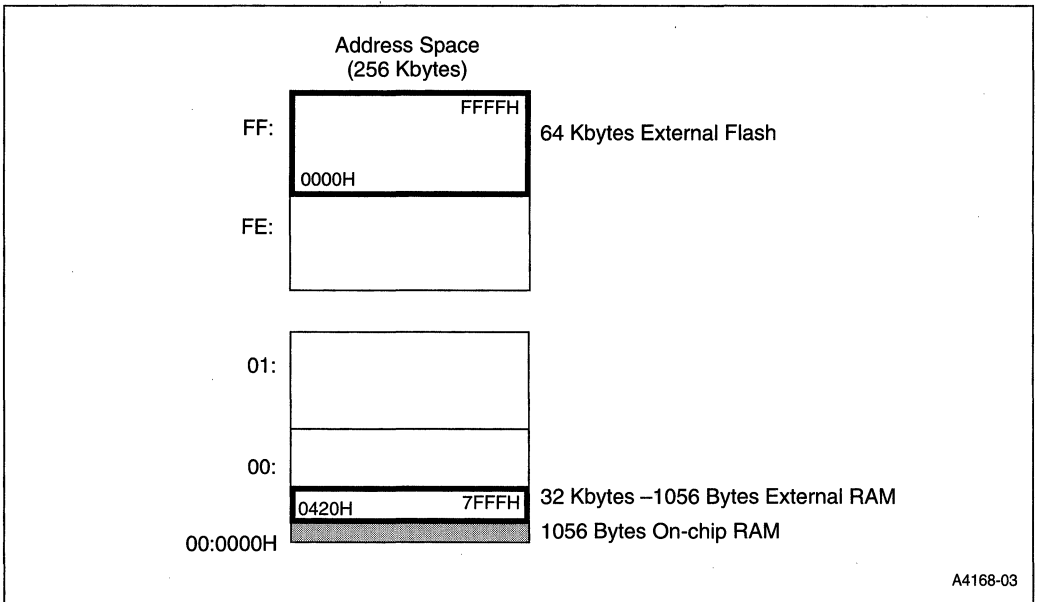


Figure 16-19. Bus Diagram for Example 2: 80930AD in Page Mode

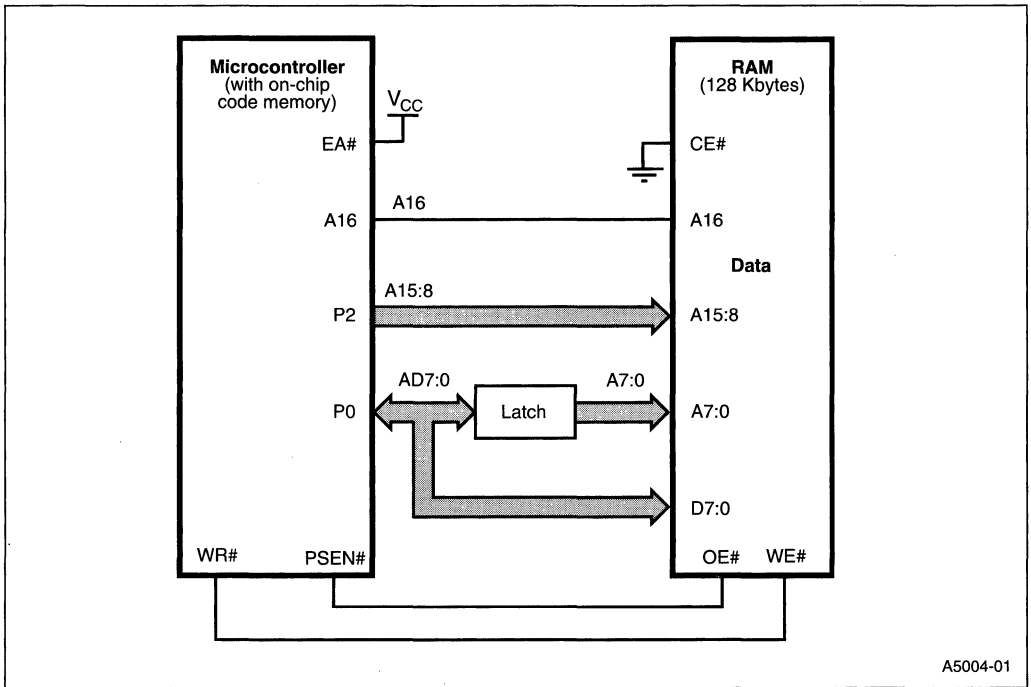


A4168-03

Figure 16-20. Address Space for Example 2

16.8.3 Example 3: RD1:0 = 01, 17-bit Bus, External RAM

In this example, an 83930AE operates in nonpage mode with a 17-bit external address bus interfaced to 128 Kbytes of external RAM (Figure 16-21). The 83930AE is configured so that RD# functions as A16, and PSEN# is asserted for all reads. Figure 16-22 shows how the external RAM is addressed in the internal memory space.



A5004-01

Figure 16-21. Bus Diagram for Example 3: 83930AE in Nonpage Mode

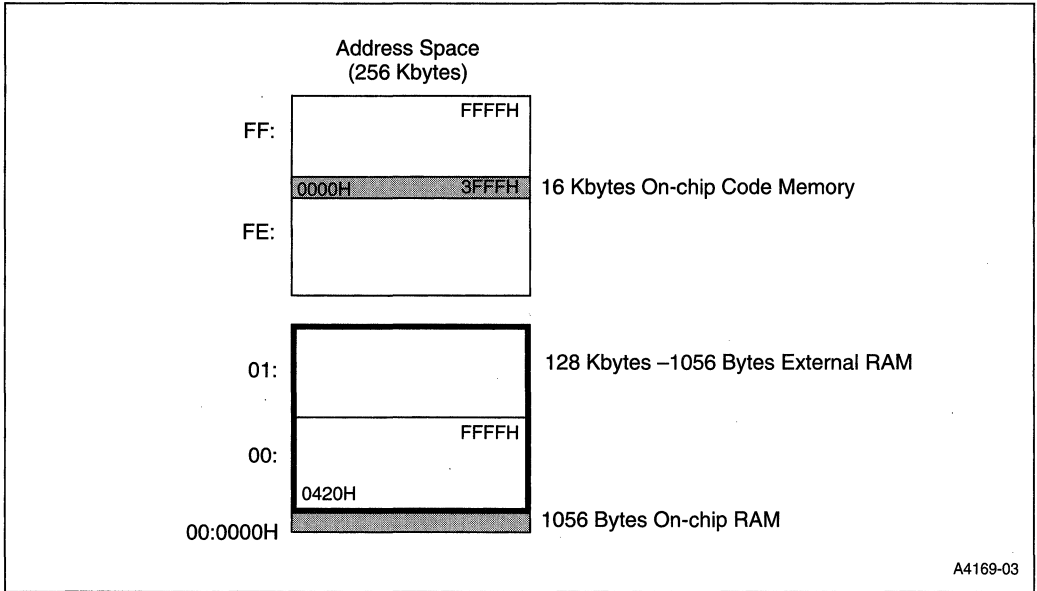


Figure 16-22. Memory Space for Example 3

16.8.4 Example 4: RD1:0 = 10, 16-bit Bus, External RAM

In this example, an 83930AE operates in nonpage mode with a 16-bit external address bus interfaced to 64 Kbytes of RAM (Figure 16-23). This configuration leaves P3.7/RD#/A16 available for general I/O (RD1:0 = 10). A maximum of 64 Kbytes of external memory can be used and all regions of internal memory map into the single 64-Kbyte region in external memory (see Figure 4-6 on page 4-9). Figure 16-24 shows how the external RAM is addressed in the internal memory space. User code is stored in on-chip ROM.

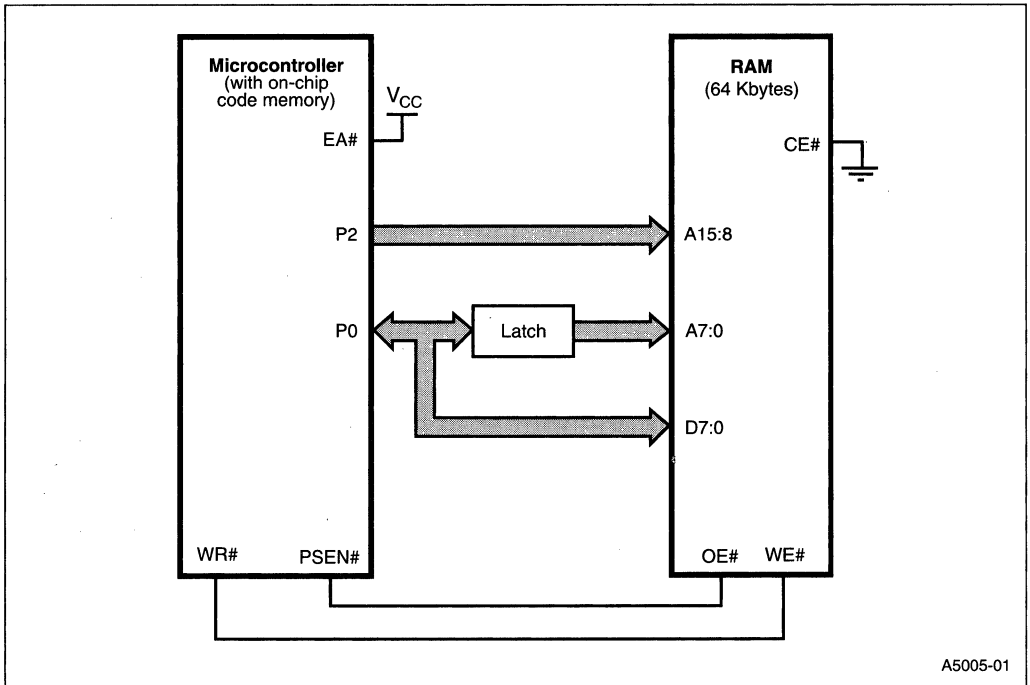


Figure 16-23. Bus Diagram for Example 4: 83930AE in Nonpage Mode

A5005-01

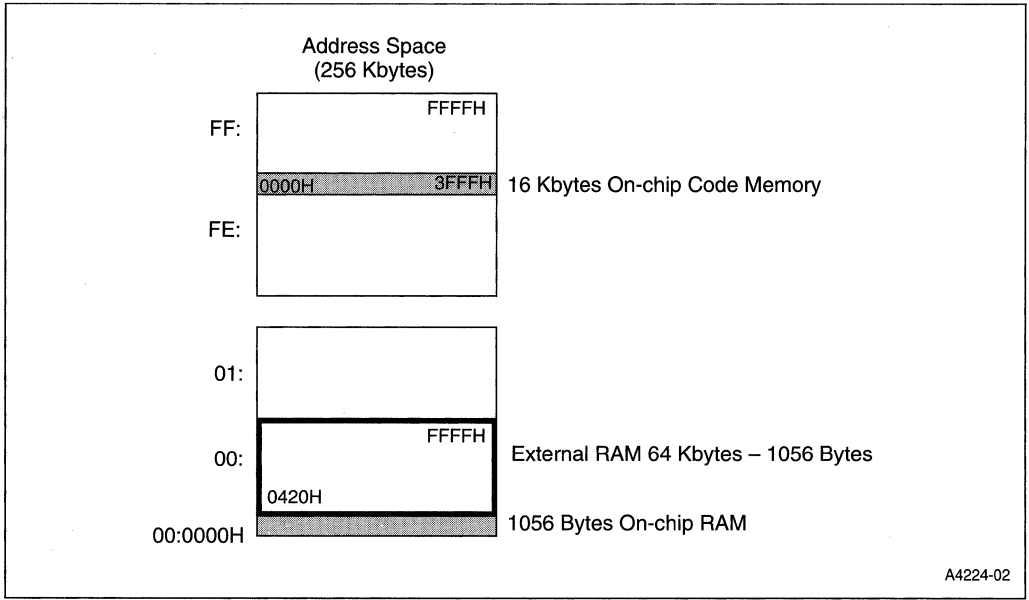


Figure 16-24. Address Space for Example 4

16.8.5 Example 5: RD1:0 = 11, 16-bit Bus, External EPROM and RAM

In this example, an 80930AD operates in nonpage mode with a 16-bit external address bus interfaced to 64 Kbytes of EPROM and 64 Kbytes of RAM (Figure 16-25). The 80930AD is configured so that RD# is asserted for addresses $\leq 7F:FFFFH$ and PSEN# is asserted for addresses $\geq 80:0000H$. Figure 16-26 shows two ways to address the external memory in the internal memory space.

Addressing external RAM locations in either region 00: or region 01: produces the same address at the external bus pins. However, if the external EPROM and the external RAM require different numbers of wait states, the external RAM must be addressed entirely in region 01:. Recall that the number of wait states for region 01: is independent of the remaining regions and always have the same number of wait states (see Table 4-3 on page 4-11) unless the real-time wait states are selected (see Figure 16-11 on page 16-11).

The examples that follow illustrate two possibilities for addressing the external RAM.

16.8.5.1 An Application Requiring Fast Access to the Stack

If an application requires fast access to the stack, the stack can reside in the fast on-chip data RAM (00:0020H–00:041FH) and, when necessary, roll out into the slower external RAM. See the left side of Figure 16-26. In this case, the external RAM can have wait states only if the EPROM has wait states. Otherwise, if the stack rolls out above location 00:041FH, the external RAM would be accessed with no wait state.

16.8.5.2 An Application Requiring Fast Access to Data

If fast access to a block of data is more important than fast access to the stack, the data can be stored in the on-chip data RAM, and the stack can be located entirely in external memory. If the external RAM requires a different number of wait states than the EPROM, address the external RAM entirely in region 01:. See the right side of Figure 16-26. Addresses above 00:041FH roll out to external memory beginning at 0420H.

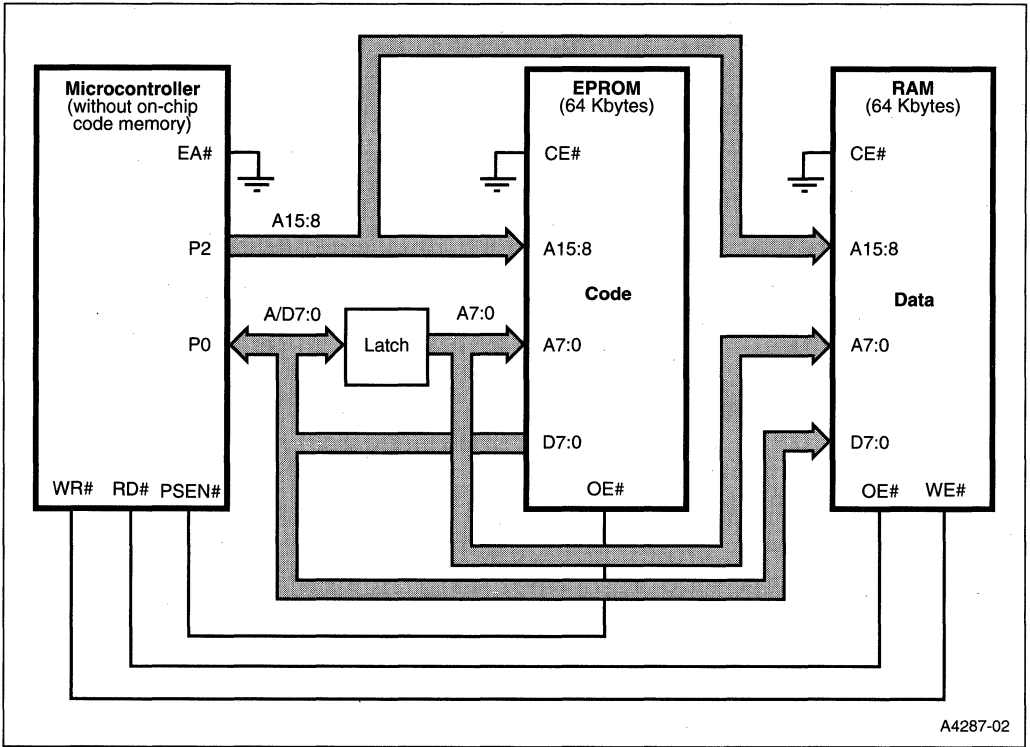


Figure 16-25. Bus Diagram for Example 5: 80930AD in Nonpage Mode

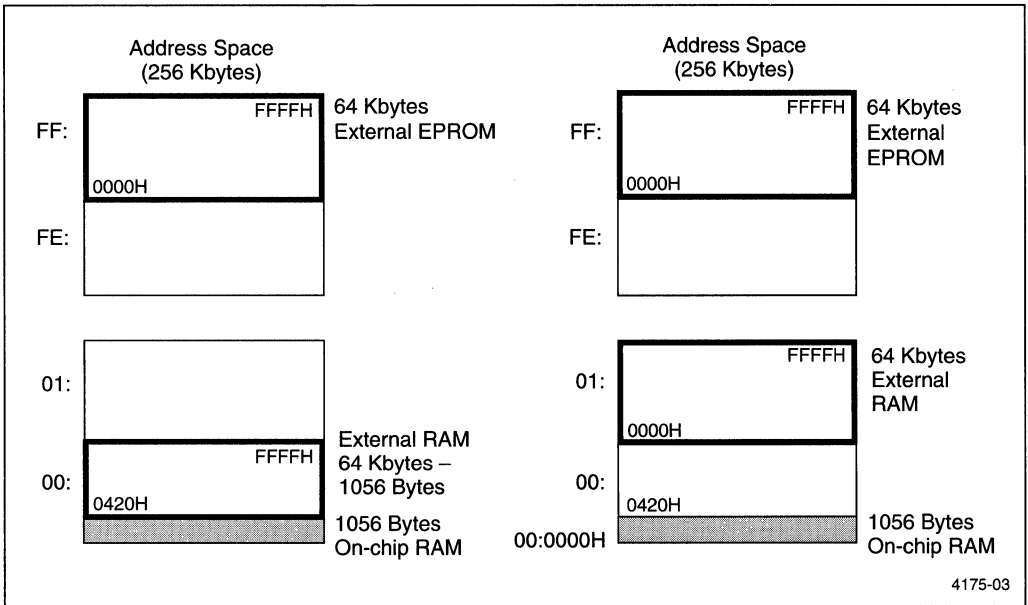


Figure 16-26. Address Space for Examples 5 and 6

16.8.6 Example 6: RD1:0 = 11, 16-bit Bus, External EPROM and RAM

In this example, an 80930AD operates in page mode with a 16-bit external address bus interfaced to 64 Kbytes of EPROM and 64 Kbytes of RAM (Figure 16-27). The 80930AD is configured so that RD# is asserted for addresses $\leq 7F:FFFFH$, and PSEN# is asserted for addresses $\geq 80:0000H$.

This system is the same as Example 5 (Figure 16-25) except that it operates in page mode. Accordingly, the two systems have the same memory map (Figure 16-26), and the comments on addressing external RAM apply here also.

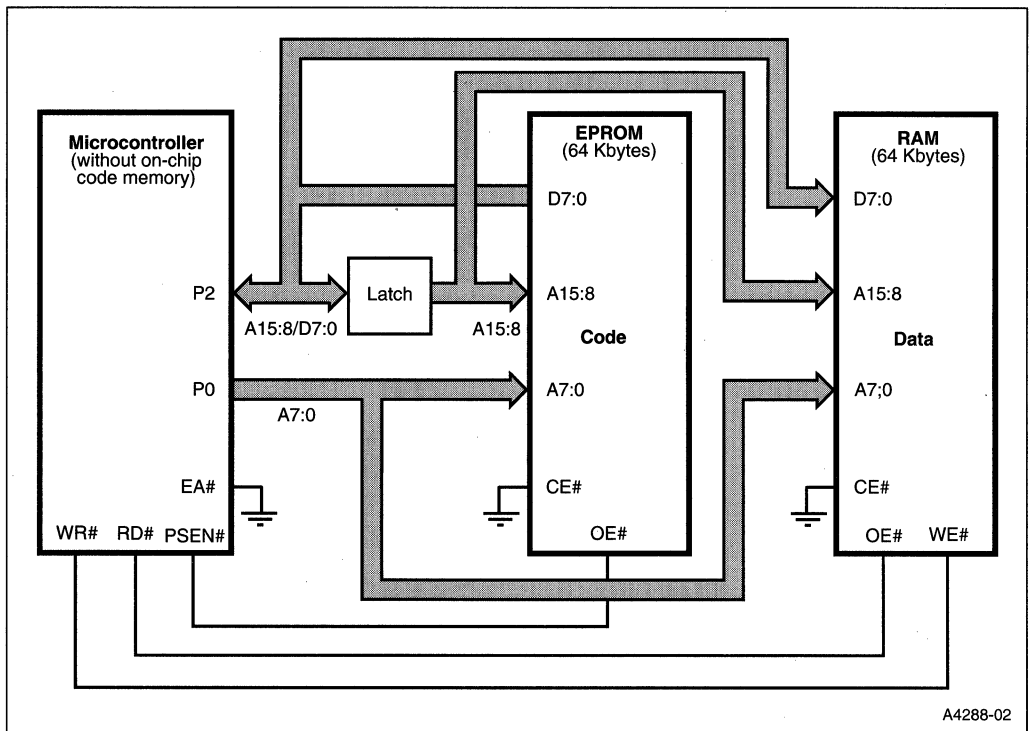
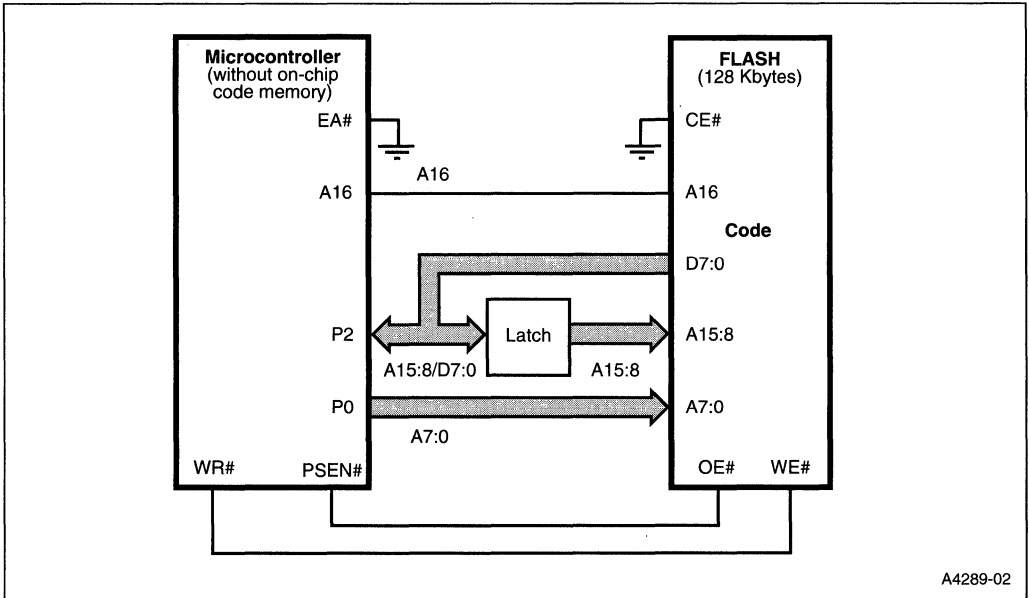


Figure 16-27. Bus Diagram for Example 6: 80930AD in Page Mode

16.8.7 Example 7: RD1:0 = 01, 17-bit Bus, External Flash

In this example, an 80930AD operates in page mode with a 17-bit external address bus interfaced to 128 Kbytes of flash memory (Figure 16-28). Port 2 carries both the upper address bits (A15:0) and the data (D7:0), while port 0 carries only the lower address bits (A7:0). The 80930AD is configured for a single read signal (PSEN#). The 128 Kbytes of external flash are accessed via internal memory regions FE: and FF: in the internal memory space.



A4289-02

Figure 16-28. Bus Diagram for Example 7: 80930AD in Page Mode





17

Verifying Nonvolatile Memory





CHAPTER 17

VERIFYING NONVOLATILE MEMORY

This chapter provides instructions for verifying on-chip nonvolatile memory on the 8x930. The verify instructions permit reading memory locations to verify their contents. Features covered in this chapter are:

- verifying the on-chip program code memory (8 Kbytes, 16 Kbytes)
- verifying the on-chip configuration bytes (8 bytes)
- verifying the lock bits (3 bits)
- using the encryption array (128 bytes)
- verifying the signature bytes (3 bytes)

17.1 GENERAL

The 8x930 is verified in the same manner as the 87C51FX and 87C251Sx microcontrollers. Verify operations differ from normal operation. Memory accesses are made one byte at a time, input/output port assignments are different, and ALE, EA#, and PSEN# are held high or low externally. See Tables 17-1 and 17-2 for lead usage during verify operations. For a complete list of device signal descriptions, see Appendix B.

In some applications, it is desirable that program code be secure from unauthorized access. The 8x930 offers two types of protection for program code stored in the on-chip array:

- Program code in the on-chip code memory area is encrypted when read out for verification if the encryption array is programmed.
- A three-level lock bit system restricts external access to the on-chip program code memory.

17.1.1 Considerations for On-chip Program Code Memory

On-chip, nonvolatile code memory is located at the lower end of the FF: region. (Example: for devices with 16 Kbytes of ROM, code memory is located at FF:0000H-FF:3FFFH.) The first instruction following device reset is fetched from FF:0000H. It is recommended that user program code start at address FF:0100H. Use a jump instruction to FF:0100H to begin execution of the program. For information on address spaces, see Chapter 3, “Address Spaces.”

Addresses outside the range of on-chip code memory access external memory. With EA# = 1 and both on-chip and external code memory implemented, you can place program code at the highest on-chip memory addresses. When the highest on-chip address is exceeded during execution, program code fetches automatically rollover from on-chip memory to external memory. See the dual note on page 3-8.

The top eight bytes of the memory address space (FF:FFF8H-FF:FFFFH) are reserved for device configuration. Do not read or write program code at these locations. For EA# = 1, the reset routine obtains configuration information from a configuration array located these addresses. (For

EA# = 0, the reset routine obtains configuration information from a configuration array in external memory using these internal addresses.) For a detailed discussion of device configuration, see Chapter 4, "Device Configuration".

With EA# = 1 and only on-chip program code memory, multi-byte instructions and instructions that result in call returns or prefetches should be located a few bytes below the maximum address to avoid inadvertently exceeding the top address. Use an EJPMP instruction, five or more addresses below the top of memory, to continue execution in other areas of memory. See the dual note on page 3-8

CAUTION

Execution of program code located in the top few bytes of the on-chip memory may cause prefetches from the next higher addresses (i.e., external memory). External memory fetches make use of port 0 and port 2 and may disrupt program execution if the program uses port 0 or port 2 for a different purpose.

Table 17-1. Signal Descriptions

Signal Name	Type	Description	Alternate Function
P0.7:0	I/O	Port 0. Eight-bit, open-drain, bidirectional I/O port. For verify operations, use to specify the verify mode. See Table 17-2 and Figures 17-1 and 17-2.	AD7:0
P1.0 P1.1 P1.2 P1.5:3 P1.6 P1.7	I/O	Port 1. Eight-bit, bidirectional I/O port with internal pullups. For verify operations, use for high byte of address. See Table 17-2 and Figures 17-1 and 17-2.	T2 T2EX ECI CEX2:0 CEX3/WAIT# CEX4/A17/WCLK
P2.7:0	I/O	Port 2. Eight-bit, bidirectional I/O port with internal pullups. For verify operations, use as the data port. See Table 17-2 and Figures 17-1 and 17-2.	A15:8
P3.0 P3.1 P3.3:2 P3.5:4 P3.6 P3.7	I/O	Port 3. Eight-bit, bidirectional I/O port with internal pullups. For verify operations, use for low byte of address. See Table 17-2 and Figures 17-1 and 17-2.	RXD TXD INT1:0# T1:0 WR# RD#/A16
ALE	—	Address Latch Enable. For verify operations, connect this pin to V _{CC}	—
EA#	—	External Enable. For verify operations, connect this pin to V _{CC}	—
PSEN#	—	Program Store Enable. For verify operations, connect this pin to V _{SS}	—

17.2 VERIFY MODES

Table 17-2 lists the verify modes and provides details about the setup. The value applied to port 0 determines the mode. The upper digit specifies verify and the lower digit selects the memory function to verify (e.g., on-chip program code memory, configuration bytes, etc.). The addresses applied to port 1 and port 3 address locations in the selected memory function. The encryption array, lock bits, and signature bytes reside in nonvolatile memory outside the memory address space. Configuration bytes, UCONFIG0 and UCONFIG1, reside in nonvolatile memory at the top of the memory address space (Figure 4-1 on page 4-2) for devices with on-chip ROM, and in external memory as shown in (Figure 4-2 on page 4-3) for devices without on-chip ROM.

17.3 GENERAL SETUP

Figure 17-1 shows the general setup for verifying nonvolatile memory on the 8x930. The controller must be running with an oscillator frequency of 4 MHz to 6 MHz. Set up the controller as shown in Table 17-2 with the mode of operation specified on port 0 and the address with respect to the starting address of the memory area applied to ports 1 and 3. Data appears on port 2. Connect RST, ALE, and EA# to V_{CC} and PSEN# to ground.

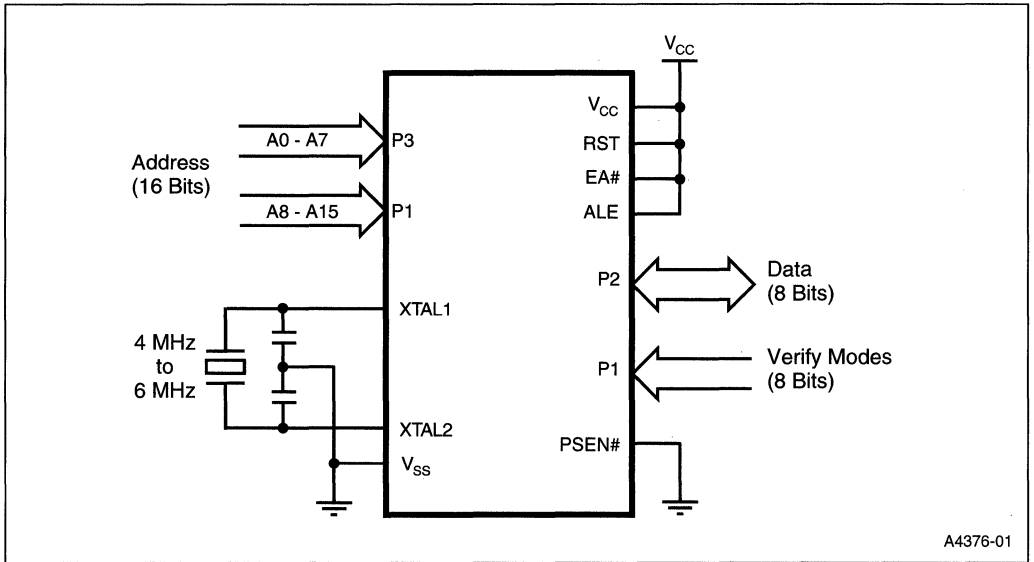
Figure 17-2 shows the bus cycle waveforms for the verify operations. Timing symbols are defined in Table 17-5 on page 17-6.

Table 17-2. Verify Modes

Mode	RST	PSEN#	EA#	ALE	Port 0	Port 2	Address Port 1 (high) Port 3 (low)	Notes
Verify Mode. On-chip program code Memory	High	Low	5 V	High	28H	data	0000H-3FFFFH	1
Verify Mode. Configuration Bytes (UCONFIG0, UCONFIG1)	High	Low	5 V	High	29H	data	FFF8H-FFFFH	1
Verify Mode. Lock bits	High	Low	5 V	High	2BH	data	0000H	2
Verify Mode. Signature Bytes	High	Low	5 V	High	29H	data	0030H, 0031H, 0060H, 0061H	

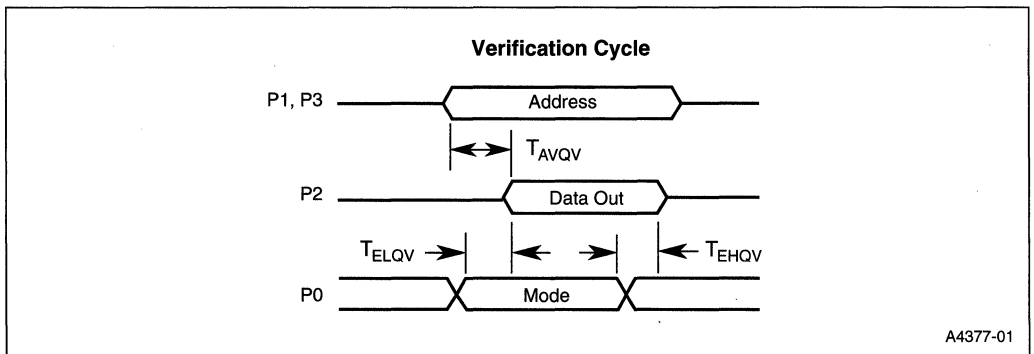
NOTES:

1. For these modes, the internal address is FF:xxxH.
2. The three lock bits are verified in a single operation. The states of the lock bits appear simultaneously at port 2 as follows: LB3 - P2.3, LB2 - P2.2. LB1 - P2.1. High = programmed.



A4376-01

Figure 17-1. Setup for Verifying Nonvolatile Memory



A4377-01

Figure 17-2. Verify Bus Cycles

17.4 VERIFY ALGORITHM

Use this procedure to verify program code, signature bytes, configuration bytes, and lock bits stored in nonvolatile memory on the 8x930. To preserve the secrecy of the encryption key byte sequence, the encryption array cannot be verified. Verification can be performed on a block of bytes. The procedure for verifying the 8x930 is as follows:

1. Set up the microcontroller for operation in the appropriate mode according to Table 17-2.
2. Input the 16-bit address on ports P1 and P3.
3. Wait for the data on port P2 to become valid ($T_{AVQV} = 48$ clock cycles, Figure 17-5), then compare the data with the expected value.
4. Repeat steps 1 through 3 until all memory locations are verified.

17.5 LOCK BIT SYSTEM

The 8x930 provides a three-level lock system for protecting program code stored in the on-chip program code memory from unauthorized access. To verify that the lock bits are correctly programmed, perform the procedure described in “Verify Algorithm” on page 17-5 using the verify lock bits mode (Table 17-2).

Table 17-3. Lock Bit Function

	Lock Bits Programmed			Protection Type
	LB3	LB2	LB1	
Level 1	U	U	U	No program lock features are enabled. On-chip program code is encrypted when verified, if encryption array is programmed.
Level 2	U	U	P	External program code is prevented from fetching program code bytes from on-chip code memory.
Level 3	U	P	P	Same as level 2, plus on-chip program code memory verify is disabled.
Level 4	P	P	P	Same as level 3, plus external memory execution is disabled.

NOTE: Other combinations of the lock bits are not defined.

17.5.1 Encryption Array

The 8x930 includes a 128-byte encryption array located in nonvolatile memory outside the memory address space. During verification of the on-chip program code memory, the seven low-order address bits also address the encryption array. As the byte of the program code memory is read, it is exclusive-NORed (XNOR) with the key byte from the encryption array. If the encryption array is not programmed (still all 1s), the program code is placed on the data bus in its original, unencrypted form. If the encryption array is programmed with key bytes, the program code is encrypted and can not be used without knowledge of the key byte sequence.

CAUTION

If the encryption feature is implemented, the portion of the on-chip program code memory that does not contain program code should be filled with “random” byte values other than FFH to prevent the encryption key sequence from being revealed. To preserve the secrecy of the encryption key byte sequence, the encryption array cannot be verified.

17.6 SIGNATURE BYTES

The 8x930 contains factory-programmed signature bytes. These bytes are located in nonvolatile memory outside the memory address space at 30H, 31H, 60H, and 61H. To read the signature bytes, perform the procedure described in “Verify Algorithm” on page 17-5 using the verify signature mode (Table 17-2). Signature byte values are listed in Table 17-4.

Table 17-4. Contents of the Signature Bytes

ADDRESS	CONTENTS	DEVICE TYPE
30H	89H	Indicates Intel devices
31H	41H	Indicates USB core product
60H	TBD	Indicates 8x930 device

Table 17-5. Timing Definitions

Symbol	Definition
$1/T_{CLCL}$	Oscillator Frequency
T_{AVQV}	Address to Data Valid
T_{EHQZ}	Data Float after ENABLE
T_{ELQV}	ENABLE Low to Data Valid

NOTE: A = Address, E = Enable, H = High, L = Low, Q = Data out, V = Valid, Z = Floating



A

Instruction Set Reference







APPENDIX A

INSTRUCTION SET REFERENCE

This appendix contains reference material for the 8x930 instruction set, which is identical to instruction set for the MCS[®] 251 architecture. The appendix includes an opcode map, a detailed description of each instruction, and the following tables that summarize notation, addressing, instructions types, instruction lengths and execution times:

- Tables A-1 through A-4 describe the notation used for the instruction operands. Table A-5 describes the notation used for control instruction destinations.
- Table A-6 and Table A-7 on page A-5 comprise the opcode map for the instruction set.
- Table A-8 on page A-6 through Table A-17 on page A-10 contain supporting material for the opcode map.
- Table A-18 on page A-11 lists execution times for a group of instructions that access the port SFRs.
- The following tables list the instructions giving length (in bytes) and execution time:
 - Add and Subtract Instructions, Table A-19 on page A-13
 - Compare Instructions, Table A-20 on page A-14
 - Increment and Decrement Instructions, Table A-21 on page A-14
 - Multiply, Divide, and Decimal-adjust Instructions, Table A-22 on page A-15
 - Logical Instructions, Table A-23 on page A-16
 - Move Instructions, Table A-24 on page A-18
 - Exchange, Push, and Pop Instructions, Table A-25 on page A-21
 - Bit Instructions, Table A-26 on page A-22
 - Control Instructions, Table A-27 on page A-23

“Instruction Descriptions” on page A-25 contains a detailed description of each instruction.

NOTE

The instruction execution times given in this appendix are for an internal `BASE_TIME` using data that is read from and written to on-chip RAM. These times do not include your application’s system bus performance time necessary to fetch and execute code from external memory, accessing peripheral SFRs, using wait states, or extending the ALE pulse.

For some instructions, accessing the port SFRs, `Px`, $x = 0-3$, increases the execution time beyond that of the `BASE_TIME`. These cases are listed in Table A-18 and are noted in the instruction summary tables and the instruction descriptions.

A.1 NOTATION FOR INSTRUCTION OPERANDS

Table A-1. Notation for Register Operands

Register Notation		8x930	MCS 51 Arch.
@Ri	A memory location (00H–FFH) addressed indirectly via byte register R0 or R1		4
Rn n r r r	Byte register R0–R7 of the currently selected register bank Byte register index: n = 0–7 Binary representation of n		4
Rm Rmd Rms m, md, ms s s s s S S S S	Byte register R0–R15 of the currently selected register file Destination register Source register Byte register index: m, md, ms = 0–15 Binary representation of m or md Binary representation of ms	4	
WRj WRjd WRjs @WRj @WRj +dis16 j, jd, js t t t t T T T T	Word register WR0, WR2, ..., WR30 of the currently selected register file Destination register Source register A memory location (00:0000H–00:FFFFH) addressed indirectly through word register WR0–WR30 Data RAM location (00:0000H–00:FFFFH) addressed indirectly through a word register (WR0–WR30) + displacement value, where the displacement value is from 0 to 64 Kbytes. Word register index: j, jd, js = 0–30 Binary representation of j or jd Binary representation of js	4	
DRk DRkd DRks @DRk @DRk +dis24 k, kd, ks u u u u U U U U	Dword register DR0, DR4, ..., DR28, DR56, DR60 of the currently selected register file Destination Register Source Register A memory location (00:0000H–FF:FFFFH) addressed Indirectly through dword register DR0–DR28, DR56, DR60 Data RAM location (00:0000H–FF:FFFFH) addressed indirectly through a dword register (DR0–DR28, DR56, DR60) + displacement value, where the displacement value is from 0 to 64 Kbytes Dword register index: k, kd, ks = 0, 4, 8, ..., 28, 56, 60 Binary representation of k or kd Binary representation of ks	4	

Table A-2. Notation for Direct Addresses

Direct Address.	Description	8x930 Arch.	MCS 51 Arch.
dir8	An 8-bit direct address. This can be a memory address (00:0000H–00:007FH) or an SFR address (S:00H - S:FFH).	4	4
dir16	A 16-bit memory address (00:0000H–00:FFFFH) used in direct addressing.	4	

Table A-3. Notation for Immediate Addressing

Immediate Data	Description	8x930 Arch.	MCS 51 Arch.
#data	An 8-bit constant that is immediately addressed in an instruction.	4	4
#data16	A 16-bit constant that is immediately addressed in an instruction.	4	
#0data16 #1data16	A 32-bit constant that is immediately addressed in an instruction. The upper word is filled with zeros (#0data16) or ones (#1data16).	4	
#short	A constant, equal to 1, 2, or 4, that is immediately addressed in an instruction.	4	
v v	Binary representation of #short.		

Table A-4. Notation for Bit Addressing

Bit Address	Description	8x930 Arch.	MCS 51 Arch.
bit	A directly addressed bit in memory locations 00:0020H–00:007FH or in any defined SFR.	4	
y y y	A binary representation of the bit number (0–7) within a byte.		
bit51	A directly addressed bit (bit number = 00H–FFH) in memory or an SFR. Bits 00H–7FH are the 128 bits in byte locations 20H–2FH in the on-chip RAM. Bits 80H–FFH are the 128 bits in the 16 SFR’s with addresses that end in 0H or 8H: S:80H, S:88H, S:90H, . . . , S:F0H, S:F8H.		4

Table A-5. Notation for Destinations in Control Instructions

Destination Address	Description	8x930 Arch.	MCS 51 Arch.
rel	A signed (two’s complement) 8-bit relative address. The destination is -128 to +127 bytes relative to first byte of the next instruction.	4	4
addr11	An 11-bit destination address. The destination is in the same 2-Kbyte block of memory as the first byte of the next instruction.	4	4
addr16	A 16-bit destination address. A destination can be anywhere within the same 64-Kbyte region as the first byte of the next instruction.	4	4
addr24	A 24-bit destination address. A destination can be anywhere within the 16-Mbyte address space.	4	

A.2 OPCODE MAP AND SUPPORTING TABLES

Table A-6. Instructions for MCS® 51 Microcontrollers

Bin	0	1	2	3	4	5	6-7	8-F
Src	0	1	2	3	4	5	A5x6-A5x7	A5x8-A5xF
0	NOP	AJMP addr11	LJMP addr16	RR A	INC A	INC dir8	INC @Ri	INC Rn
1	JBC bit,rel	ACALL addr11	LCALL addr16	RRC A	DEC A	DEC dir8	DEC @Ri	DEC Rn
2	JB bit,rel	AJMP addr11	RET	RLA	ADD A,#data	ADD A,dir8	ADD A,@Ri	ADD A,Rn
3	JNB bit,rel	ACALL addr11	RETI	RLCA	ADDC A,#data	ADDC A,dir8	ADDC A,@Ri	ADDC A,Rn
4	JC rel	AJMP addr11	ORL dir8,A	ORL dir8,#data	ORL A,#data	ORL A,dir8	ORL A,@Ri	ORL A,Rn
5	JNC rel	ACALL addr11	ANL dir8,A	ANL dir8,#data	ANL A,#data	ANL A,dir8	ANL A,@Ri	ANL A,Rn
6	JZ rel	AJMP addr11	XRL dir8,A	XRL dir8,#data	XRL A,#data	XRL A,dir8	XRL A,@Ri	XRL A,Rn
7	JNZ rel	ACALL addr11	ORL CY,bit	JMP @A+DPTR	MOV A,#data	MOV dir8,#data	MOV @Ri,#data	MOV Rn,#data
8	SJMP rel	AJMP addr11	ANL CY,bit	MOVC A,@A+PC	DIV AB	MOV dir8,dir8	MOV dir8,@Ri	MOV dir8,Rn
9	MOV DPTR, #data16	ACALL addr11	MOV bit,CY	MOVC A,@A+DPTR	SUBB A,#data	SUBB A,dir8	SUBB A,@Ri	SUBB A,Rn
A	ORL CY,bit	AJMP addr11	MOV CY,bit	INC DPTR	MUL AB	ESC	MOV @Ri,dir8	MOV Rn,dir8
B	ANL CY,bit	ACALL addr11	CPL bit	CPL CY	CJNE A,#data,rel	CJNE A,dir8,rel	CJNE @Ri,#data, rel	CJNE Rn,#data, rel
C	PUSH dir8	AJMP addr11	CLR bit	CLR CY	SWAP A	XCH A,dir8	XCH A,@Ri	XCH A,Rn
D	POP dir8	ACALL addr11	SETB bit	SETB CY	DA A	DJNZ dir8,rel	XCHD A,@Ri	DJNZ Rn,rel
E	MOVX A,@DPTR	AJMP addr11		MOVX A,@Ri	CLR A	MOV A,dir8	MOV A,@Ri	MOV A,Rn
F	MOV @DPTR,A	ACALL addr11		MOVX @Ri,A	CPL A	MOV dir8,A	MOV @Ri,A	MOV Rn,A

Table A-7. Instructions for the 8x930 Architecture

Bin	A5x8	A5x9	A5xA	A5xB	A5xC	A5xD	A5xE	A5xF
Src	x8	x9	xA	xB	xC	xD	xE	xF
0	JSLE rel	MOV Rm, @WRj+dis	MOVZ WRj,Rm	INC R,#short (1) MOV reg,ind			SRA reg	
1	JSG rel	MOV @WRj+dis,Rm	MOVS WRj,Rm	DEC R,#short (1) MOV ind,reg			SRL reg	
2	JLE rel	MOV Rm, @DRk+dis			ADD Rm,Rm	ADD WRj,WRj	ADD reg,op2 (2)	ADD DRk,DRk
3	JG rel	MOV @DRk+dis,Rm					SLL reg	
4	JSL rel	MOV WRj, @WRj+dis			ORL Rm,Rm	ORL WRj,WRj	ORL reg,op2 (2)	
5	JSGE rel	MOV @WRj+dis,WRj			ANL Rm,Rm	ANL WRj,WRj	ANL reg,op2 (2)	
6	JE rel	MOV WRj, @DRk+dis			XRL Rm,Rm	XRL WRj,WRj	XRL reg,op2 (2)	
7	JNE rel	MOV @DRk+dis,WRj	MOV op1,reg (2)		MOV Rm,Rm	MOV WRj,WRj	MOV reg,op2 (2)	MOV DRk,DRk
8		LJMP @WRj EJMP @DRk	EJMP addr24		DIV Rm,Rm	DIV WRj,WRj		
9		LCALL@WRj ECALL @DRk	ECALL addr24		SUB Rm,Rm	SUB WRj,WRj	SUB reg,op2 (2)	SUB DRk,DRk
A		Bit Instructions (3)	ERET		MUL Rm,Rm	MUL WRj,WRj		
B		TRAP			CMP Rm,Rm	CMP WRj,WRj	CMP reg,op2 (2)	CMP DRk,DRk
C			PUSH op1 (4) MOV DRk,PC					
D			POP op1 (4)					
E								
F								

NOTES:

1. R = Rm/WRj/DRk.
2. op1, op2 are defined in Table A-8.
3. See Tables A-10 and A-11.
4. See Table A-12.

Table A-8. Data Instructions

Instruction	Byte 0	Byte 1		Byte 2		Byte 3
Oper Rmd,Rms	x C	md	ms			
Oper WRjd,WRjs	x D	jd/2	js/2			
Oper DRkd,DRks	x F	kd/4	ks/4			
Oper Rm,#data	x E	m	0000	#data		
Oper WRj,#data16	x E	j/2	0100	#data (high)		#data (low)
Oper DRk,#data16	x E	k/4	1000	#data (high)		#data (low)
MOV DRk(h),#data16 MOV DRk,#1data16 CMP DRk,#1data16	7 A 7 E B E	k/4	1100	#data (high)		#data (low)
Oper Rm,dir8	x E	m	0001	dir8 addr		
Oper WRj,dir8	x E	j/2	0101	dir8 addr		
Oper DRk,dir8	x E	k/4	1101	dir8 addr		
Oper Rm,dir16	x E	m	0011	dir16 addr (high)		dir16 addr (low)
Oper WRj,dir16	x E	j/2	0111	dir16 addr (high)		dir16 addr (low)
Oper DRk,dir16 (1)	x E	k/4	1111	dir16 addr (high)		dir16 addr (low)
Oper Rm,@WRj	x E	j/2	1001	m	00	
Oper Rm,@DRk	x E	k/4	1011	m	00	

NOTE:

1. For this instruction, the only valid operation is MOV.

Table A-9. High Nibble, Byte 0 of Data Instructions

x	Operation	Notes
2	ADD reg,op2	All addressing modes are supported.
9	SUB reg,op2	
B	CMP reg,op2 (1)	
4	ORL reg,op2 (2)	
5	ANL reg,op2 (2)	
6	XRL reg,op2 (2)	
7	MOV reg,op2	
8	DIV reg,op2	Two modes only: reg,op2 = Rmd,Rms reg,op2 = Wjd,Wjs
A	MUL reg,op2	

NOTES:

1. The CMP operation does not support DRk, direct16.
2. For the ORL, ANL, and XRL operations, neither reg nor op2 can be DRk.

All of the bit instructions in the 8x930 architecture (Table A-7) have opcode A9, which serves as an escape byte (similar to A5). The high nibble of byte 1 specifies the bit instruction, as given in Table A-10.

Table A-10. Bit Instructions

Instruction		Byte 0(x)		Byte 1			Byte 2		Byte 3	
1	Bit Instr (dir8)	A	9	xxxx	0	bit	dir8 addr		rel addr	

Table A-11. Byte 1 (High Nibble) for Bit Instructions

xxxx	Bit Instruction
0001	JBC bit
0010	JB bit
0011	JNB bit
0111	ORL CY,bit
1000	ANL CY,bit
1001	MOV bit,CY
1010	MOV CY,bit
1011	CPL bit
1100	CLR bit
1101	SETB bit
1110	ORL CY, /bit
1111	ANL CY, /bit

Table A-12. PUSH/POP Instructions

Instruction	Byte 0(x)		Byte 1		Byte 2	Byte 3
PUSH #data	C	A	0000	0010	#data	
PUSH #data16	C	A	0000	0110	#data16 (high)	#data16 (low)
PUSH Rm	C	A	m	1000		
PUSH WRj	C	A	j/2	1001		
PUSH DRk	C	A	k/4	1011		
MOV DRk,PC	C	A	k/4	0001		
POP Rm	D	A	m	1000		
POP WRj	D	A	j/2	1001		
POP DRk	D	A	k/4	1011		

Table A-13. Control Instructions

Instruction	Byte 0(x)		Byte 1		Byte 2	Byte 3
EJMP addr24	8	A	addr[23:16]		addr[15:8]	addr[7:0]
ECALL addr24	9	A	addr[23:16]		addr[15:8]	addr[7:0]
LJMP @WRj	8	9	j/2	0100		
LCALL @WRj	9	9	j/2	0100		
EJMP @DRk	8	9	k/4	1000		
ECALL @DRk	9	9	k/4	1000		
ERET	A	A				
JE rel	8	8	rel			
JNE rel	7	8	rel			
JLE rel	2	8	rel			
JG rel	3	8	rel			
JSL rel	4	8	rel			
JSGE rel	5	8	rel			
JSLE rel	0	8	rel			
JSG rel	1	8	rel			
TRAP	B	9				

Table A-14. Displacement/Extended MOVs

Instruction	Byte 0		Byte 1		Byte 2		Byte 3	
MOV Rm, @WRj+dis	0	9	m	j/2	dis[15:8]		dis[7:0]	
MOV WRk, @WRj+dis	4	9	j/2	k/2	dis[15:8]		dis[7:0]	
MOV Rm, @DRk+dis	2	9	m	k/4	dis[15:8]		dis[7:0]	
MOV WRj, @DRk+dis	6	9	j/2	k/4	dis[15:8]		dis[7:0]	
MOV @WRj+dis, Rm	1	9	m	j/2	dis[15:8]		dis[7:0]	
MOV @WRj+dis, WRk	5	9	j/2	k/2	dis[15:8]		dis[7:0]	
MOV @DRk+dis, Rm	3	9	m	k/4	dis[15:8]		dis[7:0]	
MOV @DRk+dis, WRj	7	9	j/2	k/4	dis[15:8]		dis[7:0]	
MOVS WRj, Rm	1	A	j/2	m				
MOVZ WRj, Rm	0	A	j/2	m				
MOV WRj, @WRj	0	B	j/2	1000	j/2	0000		
MOV WRj, @DRk	0	B	k/4	1010	j/2	0000		
MOV @WRj, WRj	1	B	j/2	1000	j/2	0000		
MOV @DRk, WRj	1	B	k/4	1010	j/2	0000		
MOV dir8, Rm	7	A	m	0001	dir8 addr			
MOV dir8, WRj	7	A	j/2	0101	dir8 addr			
MOV dir8, DRk	7	A	k/4	1101	dir8 addr			
MOV dir16, Rm	7	A	m	0011	dir16 addr (high)		dir16 addr (low)	
MOV dir16, WRj	7	A	j/2	0111	dir16 addr (high)		dir16 addr (low)	
MOV dir16, DRk	7	A	k/4	1111	dir16 addr (high)		dir16 addr (low)	
MOV @WRj, Rm	7	A	j/2	1001	m	0000		
MOV @DRk, Rm	7	A	k/4	1011	m	0000		

Table A-15. INC/DEC

	Instruction	Byte 0		Byte 1		
1	INC Rm,#short	0	B	m	00	ss
2	INC WRj,#short	0	B	j/2	01	ss
3	INC DRk,#short	0	B	k/4	11	ss
4	DEC Rm,#short	1	B	m	00	ss
5	DEC WRj,#short	1	B	j/2	01	ss
6	DEC DRk,#short	1	B	k/4	11	ss

Table A-16. Encoding for INC/DEC

ss	#short
00	1
01	2
10	4

Table A-17. Shifts

	Instruction	Byte 0		Byte 1	
1	SRA Rm	0	E	m	0000
2	SRA WRj	0	E	j/2	0100
3	SRL Rm	1	E	m	0000
4	SRL WRj	1	E	j/2	0100
5	SLL Rm	3	E	m	0000
6	SLL WRj	3	E	j/2	0100

A.3 INSTRUCTION SET SUMMARY

This section contains tables that summarize the instruction set. For each instruction there is a short description, its length in bytes, and its execution time in states.

NOTE

Execution times are increased by executing code from external memory, accessing peripheral SFRs, accessing data in external memory, using a wait state, or extending the ALE pulse.

For some instructions, accessing the port SFRs, P_x , $x = 0-3$, increases the execution time. These cases are noted individually in the tables.

A.3.1 Execution Times for Instructions Accessing the Port SFRs

Table A-18 lists these instructions and the execution times.

- Case 1. Code executes from external memory with no wait state and a short ALE (not extended) and accesses a port SFR.
- Case 2. Code executes from external memory with one wait state and a short ALE (not extended) and accesses a port SFR.
- Case 3. Code executes from external memory with one wait state and an extended ALE, and accesses a port SFR.

Times for each case are expressed as the number of state times to be added to the BASE_TIME.

Table A-18. State Times to Access the Port SFRs

Instruction	BASE_TIME		Additional State Times (Add to the BASE_TIME column)		
	Binary	Source	Case 1	Case 2	Case 3
ADD A,dir8	1	1	2	3	4
ADD Rm,dir8	3	2	2	3	4
ADDC A,dir8	1	1	2	3	4
ANL A,dir8	1	1	2	3	4
ANL CY,bit	3	2	2	3	4
ANL CY,bit51	1	1	2	3	4
ANL CY,/bit	3	2	2	3	4
ANL CY,/bit51	1	1	2	3	4
ANL dir8,#data	3	3	4	6	8
ANL dir8,A	2	2	4	6	8
ANL Rm,dir8	3	2	2	3	4
CLR bit	4	3	4	6	8
CLR bit51	2	2	4	6	8

Table A-18. State Times to Access the Port SFRs (Continued)

Instruction	BASE_TIME		Additional State Times (Add to the BASE_TIME column)		
	Binary	Source	Case 1	Case 2	Case 3
CMP Rm,dir8	3	2	2	3	4
CPL bit	4	3	4	6	8
CPL bit51	2	2	4	6	8
DEC dir8	2	2	4	6	8
INC dir8	2	2	4	6	8
MOV A,dir8	1	1	2	3	4
MOV bit,CY	4	3	4	6	8
MOV bit51,CY	2	2	4	6	8
MOV CY,bit	3	2	2	3	4
MOV CY,bit51	1	1	2	3	4
MOV dir8,#data	3	3	2	3	4
MOV dir8,A	2	2	2	3	4
MOV dir8,Rm	4	3	2	3	4
MOV dir8,Rn	2	3	2	3	4
MOV Rm,dir8	3	2	2	3	4
MOV Rn,dir8	1	2	2	3	4
ORL A,dir8	1	1	2	3	4
ORL CY,bit	3	2	2	3	4
ORL CY,bit51	1	1	2	3	4
ORL CY,/bit	3	2	2	3	4
ORL CY,/bit51	1	1	2	3	4
ORL dir8,#data	3	3	2	3	4
ORL dir8,A	2	2	4	6	8
ORL Rm,dir8	3	2	2	3	4
SETB bit	4	3	4	6	8
SETB bit51	2	2	4	6	8
SUB Rm,dir8	3	2	2	3	4
SUBB A,dir8	1	1	2	3	4
XCH A,dir8	3	3	4	6	8
XRL A,dir8	1	1	2	3	4
XRL dir8,#data	3	3	4	6	8
XRL dir8,A	2	2	4	6	8
XRL Rm,dir8	3	2	2	3	4

A.3.2 Instruction Summaries

Table A-19. Summary of Add and Subtract Instructions

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
ADD	A,Rn	Reg to acc	1	1	2	2
	A,dir8	Dir byte to acc	2	1 (2)	2	1 (2)
	A,@Ri	Indir addr to acc	1	2	2	3
	A,#data	Immediate data to acc	2	1	2	1
ADD; SUBB	Rmd,Rms	Byte reg to/from byte reg	3	2	2	1
	WRjd,WRjs	Word reg to/from word reg	3	3	2	2
	DRkd,DRks	Dword reg to/from dword reg	3	5	2	4
	Rm,#data	Immediate 8-bit data to/from byte reg	4	3	3	2
	WRj,#data16	Immediate 16-bit data to/from word reg	5	4	4	3
	DRk,#0data16	16-bit unsigned immediate data to/from dword reg	5	6	4	5
	Rm,dir8	Dir addr to/from byte reg	4	3 (2)	3	2 (2)
	WRj,dir8	Dir addr to/from word reg	4	4	3	3
	Rm,dir16	Dir addr (64K) to/from byte reg	5	3	4	2
	WRj,dir16	Dir addr (64K) to/from word reg	5	4	4	3
	Rm,@WRj	Indir addr (64K) to/from byte reg	4	3	3	2
Rm,@DRk	Indir addr (16M) to/from byte reg	4	4	3	3	
ADDC; SUBB	A,Rn	Reg to/from acc with carry	1	1	2	2
	A,dir8	Dir byte to/from acc with carry	2	1 (2)	2	1 (2)
	A,@Ri	Indir RAM to/from acc with carry	1	2	2	3
	A,#data	Immediate data to/from acc with carry	2	1	2	1

NOTES:

1. A shaded cell denotes an instruction in the MCS® 51 architecture.
2. If this instruction addresses an I/O port (Px, x = 3:0), add 1 to the number of states.

Table A-20. Summary of Compare Instructions

Compare		CMP <dest>,<src>	dest opnd – src opnd			
Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
CMP	Rmd,Rms	Reg with reg	3	2	2	1
	WRjd,WRjs	Word reg with word reg	3	3	2	2
	DRkd,DRks	Dword reg with dword reg	3	5	2	4
	Rm,#data	Reg with immediate data	4	3	3	2
	WRj,#data16	Word reg with immediate 16-bit data	5	4	4	3
	DRk,#0data16	Dword reg with zero-extended 16-bit immediate data	5	6	4	5
	DRk,#1data16	Dword reg with one-extended 16-bit immediate data	5	6	4	5
	Rm,dir8	Dir addr from byte reg	4	3†	3	2†
	WRj,dir8	Dir addr from word reg	4	4	3	3
	Rm,dir16	Dir addr (64K) from byte reg	5	3	4	2
	WRj,dir16	Dir addr (64K) from word reg	5	4	4	3
	Rm,@WRj	Indir addr (64K) from byte reg	4	3	3	2
Rm,@DRk	Indir addr (16M) from byte reg	4	4	3	3	

† If this instruction addresses an I/O port (Px, x = 3:0), add 1 to the number of states.

Table A-21. Summary of Increment and Decrement Instructions

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
Increment	INC DPTR	(DPTR) ← (DPTR) + 1				
Increment	INC byte	byte ← byte + 1				
Increment	INC <dest>,<src>	dest opnd ← dest opnd + src opnd				
Decrement	DEC byte	byte ← byte – 1				
Decrement	DEC <dest>,<src>	dest opnd ← dest opnd - src opnd				
INC; DEC	A	acc	1	1	1	1
	Rn	Reg	1	1	2	2
	dir8	Dir byte	2	2 (2)	2	2 (2)
	@Ri	Indir RAM	1	3	2	4
	Rm,#short	Byte reg by 1, 2, or 4	3	2	2	1
	WRj,#short	Word reg by 1, 2, or 4	3	2	2	1
	DRk,#short	Double word reg by 1, 2, or 4	3	4	2	3

NOTES:

1. A shaded cell denotes an instruction in the MCS® 51 architecture.
2. If this instruction addresses an I/O port (Px, x = 0–3), add 2 to the number of states.

Table A-21. Summary of Increment and Decrement Instructions (Continued)

Increment	INC DPTR	(DPTR) ← (DPTR) + 1				
Increment	INC byte	byte ← byte + 1				
Increment	INC <dest>,<src>	dest opnd ← dest opnd + src opnd				
Decrement	DEC byte	byte ← byte - 1				
Decrement	DEC <dest>,<src>	dest opnd ← dest opnd - src opnd				
Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
INC	DPTR	Data pointer	1	1	1	1

NOTES:

1. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
2. If this instruction addresses an I/O port (Px, x = 0–3), add 2 to the number of states.

Table A-22. Summary of Multiply, Divide, and Decimal-adjust Instructions

Multiply	MUL <reg1,reg2>	(2)				
	MUL AB	(B:A) = A x B				
Divide	DIV <reg1>,<reg2>	(2)				
	DIV AB	(A) = Quotient; (B) =Remainder				
Decimal-adjust ACC for Addition (BCD)	DA A	(2)				
Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
MUL	AB	Multiply A and B	1	5	1	5
	Rmd,Rms	Multiply byte reg and byte reg	3	6	2	5
	WRjd,WRjs	Multiply word reg and word reg	3	12	2	11
DIV	AB	Divide A by B	1	10	1	10
	Rmd,Rms	Divide byte reg by byte reg	3	11	2	10
	WRjd,WRjs	Divide word reg by word reg	3	21	2	20
DA	A	Decimal adjust acc	1	1	1	1

NOTES:

1. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
2. See “Instruction Descriptions” on page A-25.

Table A-23. Summary of Logical Instructions (Continued)

Logical AND		ANL <dest>,<src>	dest opnd ← dest opnd ∧ src opnd			
Logical OR		ORL <dest>,<src>	dest opnd ← dest opnd ∨ src opnd			
Logical Exclusive OR		XRL <dest>,<src>	dest opnd ← dest opnd ∨ src opnd			
Clear		CLR A	(A) ← 0			
Complement		CPL A	(Ai) ← Ø(Ai)			
Rotate		RXX A	(1)			
Shift		SXX Rm or Wj	(1)			
SWAP		A	A3:0 ↔ A7:4			

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
SRA	Rm	Shift byte reg right through the MSB	3	2	2	1
	WRj	Shift word reg right through the MSB	3	2	2	1
SRL	Rm	Shift byte reg right	3	2	2	1
	WRj	Shift word reg right	3	2	2	1
SWAP	A	Swap nibbles within the acc	1	2	1	2

NOTES:

1. See "Instruction Descriptions" on page A-25.
2. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
3. If this instruction addresses an I/O port (Px, x = 0–3), add 1 to the number of states.
4. If this instruction addresses an I/O port (Px, x = 0–3), add 2 to the number of states.

Table A-24. Summary of Move Instructions

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
Move (2)		MOV <dest>,<src>			destination ← src opnd	
Move with Sign Extension		MOVS <dest>,<src>			destination ← src opnd with sign extend	
Move with Zero Extension		MOVZ <dest>,<src>			destination ← src opnd with zero extend	
Move Code Byte		MOVC <dest>,<src>			A ← code byte	
Move to External Mem		MOVX <dest>,<src>			external mem ← (A)	
Move from External Mem		MOVX <dest>,<src>			A ← source opnd in external mem	
MOV	A,Rn	Reg to acc	1	1	2	2
	A,dir8	Dir byte to acc	2	1 (3)	2	1 (3)
	A,@Ri	Indir RAM to acc	1	2	2	3
	A,#data	Immediate data to acc	2	1	2	1
	Rn,A	Acc to reg	1	1	2	2
	Rn,dir8	Dir byte to reg	2	1 (3)	3	2 (3)
	Rn,#data	Immediate data to reg	2	1	3	2
	dir8,A	Acc to dir byte	2	2 (3)	2	2 (3)
	dir8,Rn	Reg to dir byte	2	2 (3)	3	3 (3)
	dir8,dir8	Dir byte to dir byte	3	3	3	3
	dir8,@Ri	Indir RAM to dir byte	2	3	3	4
	dir8,#data	Immediate data to dir byte	3	3 (3)	3	3 (3)
	@Ri,A	Acc to indir RAM	1	3	2	4
	@Ri,dir8	Dir byte to indir RAM	2	3	3	4
	@Ri,#data	Immediate data to indir RAM	2	3	3	4
	DPTR,#data16	Load Data Pointer with a 16-bit const	3	2	3	2
	Rmd,Rms	Byte reg to byte reg	3	2	2	1
	WRjd,WRjs	Word reg to word reg	3	2	2	1
	DRkd,DRks	Dword reg to dword reg	3	3	2	2
	Rm,#data	8-bit immediate data to byte reg	4	3	3	2
WRj,#data16	16-bit immediate data to word reg	5	3	4	2	
DRk,#0data16	zero-extended 16-bit immediate data to dword reg	5	5	4	4	
DRk,#1data16	one-extended 16-bit immediate data to dword reg	5	5	4	4	

NOTES:

1. A shaded cell denotes an instruction in the MCS® 51 architecture.
2. Instructions that move bits are in Table A-26.
3. If this instruction addresses an I/O port (Px, x = 0–3), add 1 to the number of states.
4. External memory addressed by instructions in the MCS 51 architecture is in the region specified by DPXL (reset value = 01H). See "Compatibility with the MCS® 51 Architecture" on page 3-2.

Table A-24. Summary of Move Instructions (Continued)

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
			Move (2) Move with Sign Extension Move with Zero Extension Move Code Byte Move to External Mem Move from External Mem	MOV <dest>,<src> MOVS <dest>,<src> MOVZ <dest>,<src> MOVC <dest>,<src> MOVX <dest>,<src> MOVX <dest>,<src>	destination ← src opnd destination ← src opnd with sign extend destination ← src opnd with zero extend A ← code byte external mem ← (A) A ← source opnd in external mem	
MOV	DRk,dir8	Dir addr to dword reg	4	6	3	5
	DRk,dir16	Dir addr (64K) to dword reg	5	6	4	5
	Rm,dir8	Dir addr to byte reg	4	3 (3)	3	2 (3)
	WRj,dir8	Dir addr to word reg	4	4	3	3
	Rm,dir16	Dir addr (64K) to byte reg	5	3	4	2
	WRj,dir16	Dir addr (64K) to word reg	5	4	4	3
	Rm,@WRj	Indir addr (64K) to byte reg	4	2	3	2
	Rm,@DRk	Indir addr (16M) to byte reg	4	4	3	3
	WRjd,@WRjs	Indir addr(64K) to word reg	4	4	3	3
	WRj,@DRk	Indir addr(16M) to word reg	4	5	3	4
	dir8,Rm	Byte reg to dir addr	4	4 (3)	3	3 (3)
	dir8,WRj	Word reg to dir addr	4	5	3	4
	dir16,Rm	Byte reg to dir addr (64K)	5	4	4	3
	dir16,WRj	Word reg to dir addr (64K)	5	5	4	4
	@WRj,Rm	Byte reg to indir addr (64K)	4	4	3	3
	@DRk,Rm	Byte reg to indir addr (16M)	4	5	3	4
	@WRjd,WRjs	Word reg to indir addr (64K)	4	5	3	4
	@DRk,WRj	Word reg to indir addr (16M)	4	6	3	5
	dir8,DRk	Dword reg to dir addr	4	7	3	6
	dir16,DRk	Dword reg to dir addr (64K)	5	7	4	6
	Rm,@WRj+dis16	Indir addr with disp (64K) to byte reg	5	6	4	5
	WRj,@WRj+dis16	Indir addr with disp (64K) to word reg	5	7	4	6
	Rm,@DRk+dis16	Indir addr with disp (16M) to byte reg	5	7	4	6
	WRj,@DRk+dis16	Indir addr with disp (16M) to word reg	5	8	4	7
@WRj+dis16,Rm	Byte reg to Indir addr with disp (64K)	5	6	4	5	

NOTES:

1. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
2. Instructions that move bits are in Table A-26.
3. If this instruction addresses an I/O port (Px, x = 0–3), add 1 to the number of states.
4. External memory addressed by instructions in the MCS 51 architecture is in the region specified by DPXL (reset value = 01H). See "Compatibility with the MCS[®] 51 Architecture" on page 3-2.

Table A-24. Summary of Move Instructions (Continued)

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
Move (2)		MOV <dest>,<src>				destination ← src opnd
Move with Sign Extension		MOVS <dest>,<src>				destination ← src opnd with sign extend
Move with Zero Extension		MOVZ <dest>,<src>				destination ← src opnd with zero extend
Move Code Byte		MOVC <dest>,<src>				A ← code byte
Move to External Mem		MOVX <dest>,<src>				external mem ← (A)
Move from External Mem		MOVX <dest>,<src>				A ← source opnd in external mem
MOV	@WRj+dis16,WRj	Word reg to Indir addr with disp (64K)	5	7	4	6
	@DRk+dis16,Rm	Byte reg to Indir addr with disp (16M)	5	7	4	6
	@DRk+dis16,WRj	Word reg to Indir addr with disp (16M)	5	8	4	7
MOVH	DRk(hi), #data16	16-bit immediate data into upper word of dword reg	5	3	4	2
MOVS	WRj,Rm	Byte reg to word reg with sign extension	3	2	2	1
MOVZ	WRj,Rm	Byte reg to word reg with zeros extension	3	2	2	1
MOVC	A,@A+DPTR	Code byte relative to DPTR to acc	1	6	1	6
	A,@A+PC	Code byte relative to PC to acc	1	6	1	6
MOVX	A,@Ri	External mem (8-bit addr) to acc (4)	1	4	2	5
	A,@DPTR	External mem (16-bit addr) to acc (4)	1	5	1	5
	@Ri,A	Acc to external mem (8-bit addr) (4)	1	4	1	4
	@DPTR,A	Acc to external mem (16-bit addr) (4)	1	5	1	5

NOTES:

1. A shaded cell denotes an instruction in the MCS® 51 architecture.
2. Instructions that move bits are in Table A-26.
3. If this instruction addresses an I/O port (Px, x = 0–3), add 1 to the number of states.
4. External memory addressed by instructions in the MCS 51 architecture is in the region specified by DPXL (reset value = 01H). See "Compatibility with the MCS® 51 Architecture" on page 3-2.

Table A-25. Summary of Exchange, Push, and Pop Instructions

Exchange Contents		XCH <dest>,<src>	A ↔ src opnd			
Exchange Digit		XCHD <dest>,<src>	A3:0 ↔ on-chip RAM bits 3:0			
Push		PUSH <src>	SP ← SP + 1; (SP) ← src			
Pop		POP <dest>	dest ← (SP); SP ← SP - 1			
Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States	Bytes	States
XCH	A,Rn	Acc and reg	1	3	2	4
	A,dir8	Acc and dir addr	2	3 (2)	2	3 (2)
	A,@Ri	Acc and on-chip RAM (8-bit addr)	1	4	2	5
XCHD	A,@Ri	Acc and low nibble in on-chip RAM (8-bit addr)	1	4	2	5
PUSH	dir8	Push dir byte onto stack	2	2	2	2
	#data	Push immediate data onto stack	4	4	3	3
	#data16	Push 16-bit immediate data onto stack	5	5	4	5
	Rm	Push byte reg onto stack	3	4	2	3
	WRj	Push word reg onto stack	3	6	2	5
	DRk	Push double word reg onto stack	3	10	2	9
POP	Dir	Pop dir byte from stack	2	3/3	2	3/3
	Rm	Pop byte reg from stack	3	3	2	2
	WRj	Pop word reg from stack	3	5	2	4
	DRk	Pop double word reg from stack	3	9	2	8

NOTES:

1. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
2. If this instruction addresses an I/O port (Px, x = 0–3), add 2 to the number of states.

Table A-26. Summary of Bit Instructions

Mnemonic	<src>,<dest>	Notes	Binary Mode		Source Mode		
			Bytes	States	Bytes	States	
Clear Bit Set Bit Complement Bit AND Carry with Bit AND Carry with Complement of Bit OR Carry with Bit ORL Carry with Complement of Bit Move Bit to Carry Move Bit from Carry			CLR bit SETB bit CPL bit ANL CY,bit ANL CY,/bit ORL CY,bit ORL CY,/bit MOV CY,bit MOV bit,CY			bit ← 0 bit ← 1 bit ← 0bit CY ← CY ∧ bit CY ← CY ∧ 0bit CY ← CY ∨ bit CY ← CY ∨ 0bit CY ← bit bit ← CY	
CLR	CY	Clear carry	1	1	1	1	
	bit51	Clear dir bit	2	2 (2)	2	2 (2)	
	bit	Clear dir bit	4	4	3	3	
SETB	CY	Set carry	1	1	1	1	
	bit51	Set dir bit	2	2 (2)	2	2 (2)	
	bit	Set dir bit	4	4 (2)	3	3 (2)	
CPL	CY	Complement carry	1	1	1	1	
	bit51	Complement dir bit	2	2 (2)	2	2 (2)	
	bit	Complement dir bit	4	4 (2)	3	3 (2)	
ANL	CY,bit51	AND dir bit to carry	2	1 (3)	2	1 (3)	
	CY,bit	AND dir bit to carry	4	3 (3)	3	2 (3)	
ANL/	CY/bit51	AND complemented dir bit to carry	2	1 (3)	2	1 (3)	
	CY,/bit	AND complemented dir bit to carry	4	3 (3)	3	2 (3)	
ORL	CY,bit51	OR dir bit to carry	2	1 (3)	2	1 (3)	
	CY,bit	OR dir bit to carry	4	3 (3)	3	2 (3)	
ORL/	CY/bit51	OR complemented dir bit to carry	2	1 (3)	2	1 (3)	
	CY,/bit	OR complemented dir bit to carry	4	3 (3)	3	2 (3)	
MOV	CY,bit51	Move dir bit to carry	2	1 (3)	2	1 (3)	
	CY,bit	Move dir bit to carry	4	3 (3)	3	2 (3)	
	bit51,CY	Move carry to dir bit	2	2 (2)	2	2 (2)	
	bit,CY	Move carry to dir bit	4	4 (2)	3	3 (2)	

NOTES:

1. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
2. If this instruction addresses an I/O port (Px, x = 0–3), add 2 to the number of states.
3. If this instruction addresses an I/O port (Px, x = 0–3), add 1 to the number of states.

Table A-27. Summary of Control Instructions

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States (2)	Bytes	States (2)
ACALL	addr11	Absolute subroutine call	2	9	2	9
ECALL	@DRk	Extended subroutine call, indirect	3	12	2	11
	addr24	Extended subroutine call	5	14	4	13
LCALL	@WRj	Long subroutine call, indirect	3	9	2	8
	addr16	Long subroutine call	3	9	3	9
RET		Return from subroutine	1	6	1	6
ERET		Extended subroutine return	3	10	2	9
RETI		Return from interrupt	1	6	1	6
AJMP	addr11	Absolute jump	2	3	2	3
EJMP	addr24	Extended jump	5	6	4	5
	@DRk	Extended jump, indirect	3	7	2	6
LJMP	@WRj	Long jump, indirect	3	6	2	5
	addr16	Long jump	3	4	3	4
SJMP	rel	Short jump (relative addr)	2	3	2	3
JMP	@A+DPTR	Jump indir relative to the DPTR	1	5	1	5
JC	rel	Jump if carry is set	2	1/4	2	1/4
JNC	rel	Jump if carry not set	2	1/4	2	1/4
JB	bit51,rel	Jump if dir bit is set	3	2/5	3	2/5
	bit,rel	Jump if dir bit of 8-bit addr location is set	5	4/7	4	3/6
JNB	bit51,rel	Jump if dir bit is not set	3	2/5	3	2/5
	bit,rel	Jump if dir bit of 8-bit addr location is not set	5	4/7	4	3/6
JBC	bit51,rel	Jump if dir bit is set & clear bit	3	4/7	3	4/7
	bit,rel	Jump if dir bit of 8-bit addr location is set and clear bit	5	7/10	4	6/9
JZ	rel	Jump if acc is zero	2	2/5	2	2/5
JNZ	rel	Jump if acc is not zero	2	2/5	2	2/5
JE	rel	Jump if equal	3	2/5	2	1/4
JNE	rel	Jump if not equal	3	2/5	2	1/4
JG	rel	Jump if greater than	3	2/5	2	1/4
JLE	rel	Jump if less than or equal	3	2/5	2	1/4
JSL	rel	Jump if less than (signed)	3	2/5	2	1/4

NOTES:

1. A shaded cell denotes an instruction in the MCS[®] 51 architecture.
2. For conditional jumps, times are given as not-taken/taken.

Table A-27. Summary of Control Instructions (Continued)

Mnemonic	<dest>,<src>	Notes	Binary Mode		Source Mode	
			Bytes	States (2)	Bytes	States (2)
JSLE	rel	Jump if less than or equal (signed)	3	2/5	2	1/4
JSG	rel	Jump if greater than (signed)	3	2/5	2	1/4
JSGE	rel	Jump if greater than or equal (signed)	3	2/5	2	1/4
CJNE	A,dir8,rel	Compare dir byte to acc and jump if not equal	3	2/5	3	2/5
	A,#data,rel	Compare immediate to acc and jump if not equal	3	2/5	3	2/5
	Rn,#data,rel	Compare immediate to reg and jump if not equal	3	2/5	4	3/6
	@Ri,#data,rel	Compare immediate to indir and jump if not equal	3	3/6	4	4/7
DJNZ	Rn,rel	Decrement reg and jump if not zero	2	2/5	3	3/6
	dir8,rel	Decrement dir byte and jump if not zero	3	3/6	3	3/6
TRAP	—	Jump to the trap interrupt vector	2	10	1	9
NOP	—	No operation	1	1	1	1

NOTES:

1. A shaded cell denotes an instruction in the MCS® 51 architecture.
2. For conditional jumps, times are given as not-taken/taken.

A.4 INSTRUCTION DESCRIPTIONS

This section describes each instruction in the 8x930 architecture. See the note on page A-11 regarding execution times.

Table A-28 defines the symbols (—, ✓, 1, 0,?) used to indicate the effect of the instruction on the flags in the PSW and PSW1 registers. For a conditional jump instruction, “!” indicates that a flag influences the decision to jump.

Table A-28. Flag Symbols

Symbol	Description
—	The instruction does not modify the flag.
3	The instruction sets or clears the flag, as appropriate.
1	The instruction sets the flag.
0	The instruction clears the flag.
?	The instruction leaves the flag in an indeterminate state.
!	For a conditional jump instruction: The state of the flag before the instruction executes influences the decision to jump or not jump.

ACALL <addr11>

Function: Absolute call

Description: Unconditionally calls a subroutine at the specified address. The instruction increments the 3-byte PC twice to obtain the address of the following instruction, then pushes bytes 0 and 1 of the result onto the stack (byte 0 first) and increments the stack pointer twice. The destination address is obtained by successively concatenating bits 15–11 of the incremented PC, opcode bits 7–5, and the second byte of the instruction. The subroutine called must therefore start within the same 2-Kbyte “page” of the program memory as the first byte of the instruction following ACALL.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The stack pointer (SP) contains 07H and the label "SUBRTN" is at program memory location 0345H. After executing the instruction

ACALL SUBRTN

at location 0123H, SP contains 09H; on-chip RAM locations 08H and 09H contain 01H and 25H, respectively; and the PC contains 0345H.

Binary Mode Source Mode

Bytes: 2 2
States: 9 9



[Encoding]	a10 a9 a8 1	0 0 0 1	a7 a6 a5 a4	a3 a2 a1 a0
------------	-------------	---------	-------------	-------------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ACALL
(PC) ← (PC) + 2
(SP) ← (SP) + 1
((SP)) ← (PC.7:0)
(SP) ← (SP) + 1
((SP)) ← (PC.15:8)
(PC.10:0) ← page address

ADD <dest>,<src>

Function: Add

Description: Adds the source operand to the destination operand, which can be a register or the accumulator, leaving the result in the register or accumulator. If there is a carry out of bit 7 (CY), the CY flag is set. If byte variables are added, and if there is a carry out of bit 3 (AC), the AC flag is set. For addition of unsigned integers, the CY flag indicates that an overflow occurred.

If there is a carry out of bit 6 but not out of bit 7, or a carry out of bit 7 but not bit 6, the OV flag is set. When adding signed integers, the OV flag indicates a negative number produced as the sum of two positive operands, or a positive sum from two negative operands.

Bit 6 and bit 7 in this description refer to the most significant byte of the operand (8, 16, or 32 bit).

Four source operand addressing modes are allowed: register, direct, register-indirect, and immediate.

Flags:

CY	AC	OV	N	Z
3	3	3	3	3

Example: Register 1 contains 0C3H (11000011B) and register 0 contains 0AAH (10101010B). After executing the instruction

ADD R1,R0

register 1 contains 6DH (01101101B), the AC flag is clear, and the CY and OV flags are set.

Variations

ADD A,#data

	Binary Mode	Source Mode
Bytes:	2	2
States:	1	1

[Encoding]	0 0 1 0	0 1 0 0	immed. data
------------	---------	---------	-------------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ADD
 $(A) \leftarrow (A) + \#data$

ADD A,dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	1 [†]	1 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

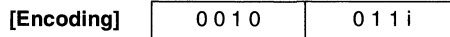


Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ADD
 $(A) \leftarrow (A) + (dir8)$

ADD A,@Ri

	Binary Mode	Source Mode
Bytes:	1	2
States:	2	3

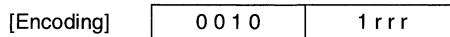


Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: ADD
 $(A) \leftarrow (A) + ((Ri))$

ADD A,Rn

	Binary Mode	Source Mode
Bytes:	1	2
States:	1	2



Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: ADD
 $(A) \leftarrow (A) + (Rn)$

ADD Rmd,Rms

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 1 0	1 1 0 0	s s s s	S S S S
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ADD
(Rmd) ← (Rmd) + (Rms)

ADD WRjd,WRjs

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	3	2		
[Encoding]	0 0 1 0	1 1 0 1	t t t t	T T T T

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ADD
(WRjd) ← (WRjd) + (WRjs)

ADD DRkd,DRks

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	5	4		
[Encoding]	0 0 1 0	1 1 1 1	u u u u	U U U U

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ADD
(DRkd) ← (DRkd) + (DRks)

ADD Rm,#data

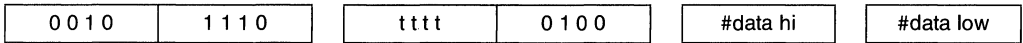
	Binary Mode	Source Mode			
Bytes:	4	3			
States:	3	2			
[Encoding]	0 0 1 0	1 1 1 0	s s s s	0 0 0 0	#data

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ADD
(Rm) ← (Rm) + #data

ADD WRj,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

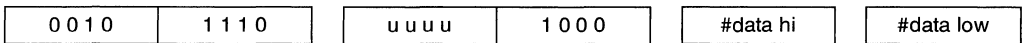
[Encoding]


Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: **ADD**
 $(WRj) \leftarrow (WRj) + \#data16$

ADD DRk,#0data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

[Encoding]


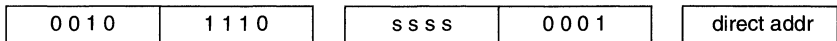
Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: **ADD**
 $(DRk) \leftarrow (DRk) + \#data16$

ADD Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3†	2†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

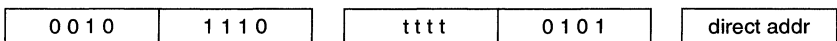
[Encoding]


Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: **ADD**
 $(Rm) \leftarrow (Rm) + (dir8)$

ADD WRj,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]




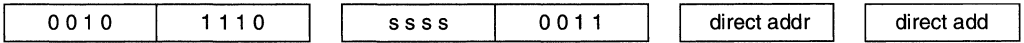
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ADD
 $(WRj) \leftarrow (WRj) + (dir8)$

ADD Rm,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2

[Encoding]



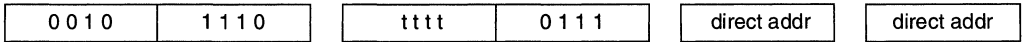
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ADD
 $(Rm) \leftarrow (Rm) + (dir16)$

ADD WRj,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]



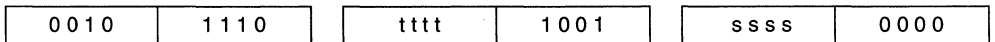
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ADD
 $(WRj) \leftarrow (WRj) + (dir16)$

ADD Rm,@WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]

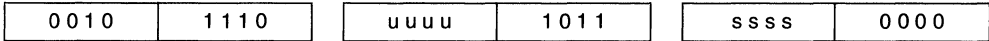


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ADD
 $(Rm) \leftarrow (Rm) + ((WRj))$

ADD Rm,@DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3
[Encoding]		



Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ADD
 $(Rm) \leftarrow (Rm) + ((DRk))$

ADDC A,<src>

Function: Add with carry

Description: Simultaneously adds the specified byte variable, the CY flag, and the accumulator contents, leaving the result in the accumulator. If there is a carry out of bit 7 (CY), the CY flag is set; if there is a carry out of bit 3 (AC), the AC flag is set. When adding unsigned integers, the CY flag indicates that an overflow occurred.

If there is a carry out of bit 6 but not out of bit 7, or a carry out of bit 7 but not bit 6, the OV flag is set. When adding signed integers, the OV flag indicates a negative number produced as the sum of two positive operands, or a positive sum from two negative operands.

Bit 6 and bit 7 in this description refer to the most significant byte of the operand (8, 16, or 32 bit)

Four source operand addressing modes are allowed: register, direct, register-indirect, and immediate.

Flags:

CY	AC	OV	N	Z
3	3	3	3	3

Example: The accumulator contains 0C3H (11000011B), register 0 contains 0AAH (10101010B), and the CY flag is set. After executing the instruction

ADDC A,R0

the accumulator contains 6EH (01101110B), the AC flag is clear, and the CY and OV flags are set.

Variations

ADDC A,#data

	Binary Mode	Source Mode
Bytes:	2	2
States:	1	1

[Encoding]

0 0 1 1	0 1 0 0
---------	---------

immed. data

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ADDC
(A) ← (A) + (CY) + #data

ADDC A,dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	1†	1†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

0 0 1 1	0 1 0 1
---------	---------

direct addr

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ADDC
(A) ← (A) + (CY) + (dir8)

ADDC A,@Ri

	Binary Mode	Source Mode
Bytes:	1	2
States:	2	3

[Encoding]

0 0 1 1	0 1 1 i
---------	---------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: ADDC
(A) ← (A) + (CY) + ((Ri))

ADDC A,Rn

	Binary Mode	Source Mode
Bytes:	1	2
States:	1	2

[Encoding]

0 0 1 1	1 r r r
---------	---------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: ADDC
(A) ← (A) + (CY) + (Rn)

AJMP addr11

Function: Absolute jump

Description: Transfers program execution to the specified address, which is formed at run time by concatenating the upper five bits of the PC (after incrementing the PC twice), opcode bits 7–5, and the second byte of the instruction. The destination must therefore be within the same 2-Kbyte “page” of program memory as the first byte of the instruction following AJMP.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The label "JMPADR" is at program memory location 0123H. After executing the instruction
AJMP JMPADR
at location 0345H, the PC contains 0123H.

	Binary Mode	Source Mode
Bytes:	2	2
States:	3	3

[Encoding]	a10 a9 a8 0	0 0 0 1	a7 a6 a5 a4	a3 a2 a1 a0
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Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: AJMP
(PC) ← (PC) + 2
(PC.10:0) ← page address

ANL <dest>,<src>

Function: Logical-AND

Description: Performs the bitwise logical-AND (\wedge) operation between the specified variables and stores the results in the destination variable.

The two operands allow 10 addressing mode combinations. When the destination is the register or accumulator, the source can use register, direct, register-indirect, or immediate addressing; when the destination is a direct address, the source can be the accumulator or immediate data.

Note: When this instruction is used to modify an output port, the value used as the original port data is read from the output data latch, not the input pins.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: Register 1 contains 0C3H (11000011B) and register 0 contains 55H (01010101B). After executing the instruction

ANL R1,R0

register 1 contains 41H (01000001B).

When the destination is a directly addressed byte, this instruction clears combinations of bits in any RAM location or hardware register. The mask byte determining the pattern of bits to be cleared would either be an immediate constant contained in the instruction or a value computed in the register or accumulator at run time. The instruction

ANL P1,#01110011B

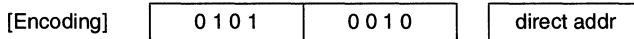
clears bits 7, 3, and 2 of output port 1.

Variations

ANL dir8,A

	Binary Mode	Source Mode
Bytes:	2	2
States:	2 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 2 states.



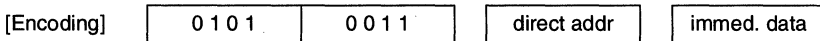
Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(dir8) \leftarrow (dir8) \wedge (A)$

ANL dir8,#data

	Binary Mode	Source Mode
Bytes:	3	3
States:	3 [†]	3 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

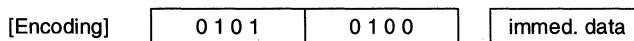


Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(dir8) \leftarrow (dir8) \wedge \#data$

ANL A,#data

	Binary Mode	Source Mode
Bytes:	2	2
States:	1	1



Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(A) \leftarrow (A) \wedge \#data$

ANL A,dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	1 [†]	1 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

0 1 0 1

0 1 0 1

direct addr

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(A) \leftarrow (A) \wedge (\text{dir8})$

ANL A,@Ri

	Binary Mode	Source Mode
Bytes:	1	2
States:	2	3

[Encoding]

0 1 0 1

0 1 1 i

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: ANL
 $(A) \leftarrow (A) \wedge ((Ri))$

ANL A,Rn

	Binary Mode	Source Mode
Bytes:	1	2
States:	1	2

[Encoding]

0 1 0 1

1 r r r

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: ANL
 $(A) \leftarrow (A) \wedge (Rn)$

ANL Rmd,Rms

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]

0 1 0 1

1 1 0 0

s s s s

S S S S



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 (Rmd) ← (Rmd) ∧ (Rms)

ANL WRjd,WRjs

	Binary Mode	Source Mode
Bytes:	3	2
States:	3	2

[Encoding]	0 1 0 1	1 1 0 1	t t t t	T T T T
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 (WRjd) ← (WRjd) ∧ (WRjs)

ANL Rm,#data

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]	0 1 0 1	1 1 1 0	s s s s	0 0 0 0	#data
------------	---------	---------	---------	---------	-------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 (Rm) ← (Rm) ∧ #data

ANL WRj,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]

0 1 0 1	1 1 1 0	t t t t	0 1 0 0	#data hi	#data low
---------	---------	---------	---------	----------	-----------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 (WRj) ← (WRj) ∧ #data16

ANL Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	0 1 0 1	1 1 1 0	s s s s	0 0 0 1	direct addr
------------	---------	---------	---------	---------	-------------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(Rm) \leftarrow (Rm) \wedge (\text{dir8})$

ANL WRj,dir8

	Binary Mode	Source Mode			
Bytes:	4	3			
States:	4	3			
[Encoding]	0 1 0 1	1 1 1 0	t t t t	0 1 0 1	direct addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(WRj) \leftarrow (WRj) \wedge (\text{dir8})$

ANL Rm,dir16

	Binary Mode	Source Mode			
Bytes:	5	4			
States:	3	2			
[Encoding]	0 1 0 1	1 1 1 0	s s s s	0 0 1 1	direct
					direct

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(Rm) \leftarrow (Rm) \wedge (\text{dir16})$

ANL WRj,dir16

	Binary Mode	Source Mode			
Bytes:	5	4			
States:	4	3			
[Encoding]	0 1 0 1	1 1 1 0	t t t t	0 1 1 1	direct
					direct

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ANL
 $(WRj) \leftarrow (WRj) \wedge (\text{dir16})$

ANL Rm,@WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]

0 1 0 1	1 1 1 0	t t t t	1 0 0 1	s s s s	0 0 0 0
---------	---------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ANL
(Rm) ← (Rm) ∧ ((WRj))

ANL Rm,@DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]

0 1 0 1	1 1 1 0	u u u u	1 0 1 1	s s s s	0 0 0 0
---------	---------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ANL
(Rm) ← (Rm) ∧ ((DRk))

ANL CY,<src-bit>

Function: Logical-AND for bit variables

Description: If the Boolean value of the source bit is a logical 0, clear the CY flag; otherwise leave the CY flag in its current state. A slash ("/") preceding the operand in the assembly language indicates that the logical complement of the addressed bit is used as the source value, but the source bit itself is not affected.

Only direct addressing is allowed for the source operand.

Flags:

CY	AC	OV	N	Z
3	—	—	—	—

Example: Set the CY flag if, and only if, P1.0 = 1, ACC. 7 = 1, and OV = 0:

```
MOV CY,P1.0 ;Load carry with input pin state
ANL CY,ACC.7 ;AND carry with accumulator bit 7
ANL CY,/OV ;AND with inverse of overflow flag
```

ANL CY,bit51

	Binary Mode	Source Mode
Bytes:	2	2
States:	1 [†]	1 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

1 0 0 0

0 0 1 0

bit addr

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ANL
(CY) ← (CY) ∧ (bit51)

ANL CY,/bit51

	Binary Mode	Source Mode
Bytes:	2	2
States:	1 [†]	1 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

1 0 1 1

0 0 0 0

bit addr

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ANL
(CY) ← (CY) ∧ Ø (bit51)

ANL CY,bit

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

1 0 1 0

1 0 0 1

1 0 0 0

0

y y y

dir addr

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ANL
(CY) ← (CY) ∧ (bit)

ANL CY,/bit

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.



[Encoding]

1 0 1 0	1 0 0 1	1 1 1 1	0	y y y	dir addr
---------	---------	---------	---	-------	----------

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ANL
 (CY) ← (CY) ∧ Ø (bit)

CJNE <dest>,<src>,rel

Function: Compare and jump if not equal.

Description: Compares the magnitudes of the first two operands and branches if their values are not equal. The branch destination is computed by adding the signed relative displacement in the last instruction byte to the PC, after incrementing the PC to the start of the next instruction. If the unsigned integer value of <dest-byte> is less than the unsigned integer value of <src-byte>, the CY flag is set. Neither operand is affected.

The first two operands allow four addressing mode combinations: the accumulator may be compared with any directly addressed byte or immediate data, and any indirect RAM location or working register can be compared with an immediate constant.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example: The accumulator contains 34H and R7 contains 56H. After executing the first instruction in the sequence

```

    CJNE    R7,#60H,NOT_EQ
;          ...          ...          ;R7 = 60H
NOT_EQ:   JC     REQ_LOW    ; IF R7 < 60H
;          ...          ...          ;R7 > 60H
    
```

the CY flag is set and program execution continues at label NOT_EQ. By testing the CY flag, this instruction determines whether R7 is greater or less than 60H.

If the data being presented to Port 1 is also 34H, then executing the instruction,

```
WAIT: CJNE A,P1,WAIT
```

clears the CY flag and continues with the next instruction in the sequence, since the accumulator does equal the data read from P1. (If some other value was being input on P1, the program loops at this point until the P1 data changes to 34H.)

Variations

CJNE A,#data,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	3	3
States:	2	5	2	5
[Encoding]	1 0 1 1		0 1 0 0	
			immed. data	rel. addr

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: (PC) ← (PC) + 3
 IF (A) ≠ #data
 THEN (PC) ← (PC) + relative offset
 IF (A) < #data
 THEN (CY) ← 1
 ELSE (CY) ← 0

CJNE A,dir8,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	3	3
States:	3	6	3	6
[Encoding]	1 0 1 1		0 1 0 1	
			direct addr	rel. addr

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: (PC) ← (PC) + 3
 IF (A) ≠ dir8
 THEN (PC) ← (PC) + relative offset
 IF (A) < dir8
 THEN (CY) ← 1
 ELSE (CY) ← 0

CJNE @Ri,#data,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	4	4
States:	3	6	4	7
[Encoding]	1 0 1 1	0 1 1 i	immed. data	rel. addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: (PC) ← (PC) + 3
IF ((Ri)) ≠ #data
THEN
 (PC) ← (PC) + relative offset
IF ((Ri)) < #data
THEN
 (CY) ← 1
ELSE
 (CY) ← 0

CJNE Rn,#data,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	4	4
States:	2	5	3	6
[Encoding]	1 0 1 1	1 r r r	immed. data	rel. addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: (PC) ← (PC) + 3
IF (Rn) ≠ #data
THEN
 (PC) ← (PC) + relative offset
IF (Rn) < #data
THEN
 (CY) ← 1
ELSE
 (CY) ← 0

CLR A

Function: Clear accumulator

Description: Clears the accumulator (i.e., resets all bits to zero).

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The accumulator contains 5CH (01011100B). The instruction

CLR A

clears the accumulator to 00H (00000000B).

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1"> <tr> <td>1 1 1 0</td> <td>0 1 0 0</td> </tr> </table>	1 1 1 0	0 1 0 0
1 1 1 0	0 1 0 0			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: CLR
(A) ← 0

CLR bit

Function: Clear bit

Description: Clears the specified bit. CLR can operate on the CY flag or any directly addressable bit.

Flags: Only for instructions with CY as the operand.

CY	AC	OV	N	Z
3	—	—	—	—

Example: Port 1 contains 5DH (01011101B). After executing the instruction

CLR P1.2

port 1 contains 59H (01011001B).

Variations

CLR bit51

	Binary Mode	Source Mode			
Bytes:	4	3			
States:	2 [†]	2 [†]			
	[†] If this instruction addresses a port (Px, x = 0–3), add 2 states.				
	[Encoding]	<table border="1"> <tr> <td>1 1 0 0</td> <td>0 0 1 0</td> <td>Bit addr</td> </tr> </table>	1 1 0 0	0 0 1 0	Bit addr
1 1 0 0	0 0 1 0	Bit addr			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: CLR
(bit51) ← 0

CLR CY

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 1 0 0</td> <td style="padding: 2px 10px;">0 0 1 1</td> </tr> </table>	1 1 0 0	0 0 1 1
1 1 0 0	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: CLR
 (CY) ← 0

CLR bit

	Binary Mode	Source Mode
Bytes:	4	4
States:	4 [†]	3 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

1 0 1 0	1 0 0 1	1 1 0 0	0	y y y	dir addr
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Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CLR
 (bit) ← 0

CMP <dest>, <src>

Function: Compare

Description: Subtracts the source operand from the destination operand. The result is not stored in the destination operand. If a borrow is needed for bit 7, the CY (borrow) flag is set; otherwise it is clear.

When subtracting signed integers, the OV flag indicates a negative result when a negative value is subtracted from a positive value, or a positive result when a positive value is subtracted from a negative value.

Bit 7 in this description refers to the most significant byte of the operand (8, 16, or 32 bit)

The source operand allows four addressing modes: register, direct, immediate and indirect.

Flags:

CY	AC	OV	N	Z
3	3	3	3	3

Example: Register 1 contains 0C9H (11001001B) and register 0 contains 54H (01010100B). The instruction

CMP R1,R0

clears the CY and AC flags and sets the OV flag.

Variations

CMP Rmd,Rms

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	2	1		
[Encoding]	1 0 1 1	1 1 0 0	s s s s	S S S S

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (Rmd) – (Rms)

CMP WRjd,WRjs

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	3	2		
[Encoding]	1 0 1 1	1 1 1 0	t t t t	T T T T

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (WRjd) – (WRjs)

CMP DRkd,DRks

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	5	4		
[Encoding]	1 0 1 1	1 1 1 1	u u u u	U U U U

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (DRkd) – (DRks)



CMP Rm,#data

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]	1 0 1 1	1 1 1 0	s s s s	0 0 0 0	# data
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Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (Rm) – #data

CMP WRj,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]	1 0 1 1	1 1 1 0	t t t t	0 1 0 0	#data hi	#data low
------------	---------	---------	---------	---------	----------	-----------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (WRj) – #data16

CMP DRk,#0data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

[Encoding]	1 0 1 1	1 1 1 0	u u u u	1 0 0 0	#data hi	#data low
------------	---------	---------	---------	---------	----------	-----------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (DRk) – #0data16

CMP DRk,#1data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

[Encoding]	1 0 1 1	1 1 1 0	u u u u	1 1 0 0	#data hi	#data hi
------------	---------	---------	---------	---------	----------	----------

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: CMP
 (DRk) – #1data16

CMP Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.



Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: CMP
 (Rm) – (dir8)

CMP WRj,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

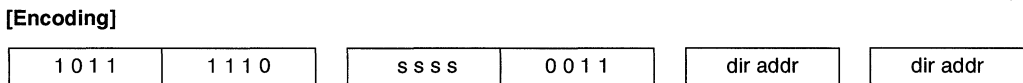


Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: CMP
 (WRj) – (dir8)

CMP Rm,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2



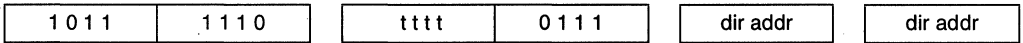
Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: CMP
 (Rm) – (dir16)

CMP WRj,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]



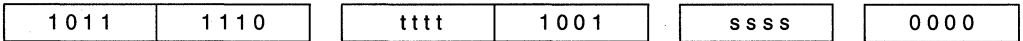
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (WRj) – (dir16)

CMP Rm,@WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]



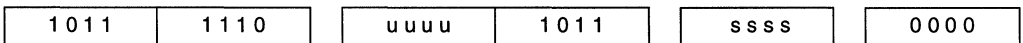
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (Rm) – ((WRj))

CMP Rm,@DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: CMP
 (Rm) – ((DRk))

CPL A

Function: Complement accumulator

Description: Logically complements (Ø) each bit of the accumulator (one's complement). Clear bits are set and set bits are cleared.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The accumulator contains 5CH (01011100B). After executing the instruction
 CPL A
 the accumulator contains 0A3H (10100011B).

	Binary Mode	Source Mode	
Bytes:	1	1	
States:	1	1	
	[Encoding]	1 1 1 1	0 1 0 0

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: CPL
 (A) ← Ø(A)

CPL bit

Function: Complement bit
Description: Complements (Ø) the specified bit variable. A clear bit is set, and a set bit is cleared. CPL can operate on the CY or any directly addressable bit.

Note: When this instruction is used to modify an output pin, the value used as the original data is read from the output data latch, not the input pin.

Flags: Only for instructions with CY as the operand.

CY	AC	OV	N	Z
3	—	—	—	—

Example: Port 1 contains 5BH (01011101B). After executing the instruction sequence
 CPL P1.1
 CPL P1.2
 port 1 contains 5BH (01011011B).

Variations
CPL bit51

	Binary Mode	Source Mode	
Bytes:	2	2	
States:	2†	2†	
	[Encoding]	1 0 1 1	0 0 1 0
			bit addr

†If this instruction addresses a port (Px, x = 0–3), add 2 states.



Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: CPL
(bit51) ← Ø(bit51)

CPL CY

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 0 1 1</td> <td style="padding: 2px 10px;">0 0 1 1</td> </tr> </table>	1 0 1 1	0 0 1 1
1 0 1 1	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: CPL
(CY) ← Ø(CY)

CPL bit

	Binary Mode	Source Mode
Bytes:	4	3
States:	4†	3†

†If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

1 0 1 0	1 0 0 1	1 0 1 1	0	y y y	dir addr
---------	---------	---------	---	-------	----------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: CPL
(bit) ← Ø(bit)

DA A

Function: Decimal-adjust accumulator for addition

Description: Adjusts the 8-bit value in the accumulator that resulted from the earlier addition of two variables (each in packed-BCD format), producing two 4-bit digits. Any ADD or ADDC instruction may have been used to perform the addition.

If accumulator bits 3:0 are greater than nine (XXXX1010–XXXX1111), or if the AC flag is set, six is added to the accumulator, producing the proper BCD digit in the low nibble. This internal addition sets the CY flag if a carry out of the lowest 4 bits propagated through all higher bits, but it does not clear the CY flag otherwise.

If the CY flag is now set, or if the upper four bits now exceed nine (1010XXXX–1111XXXX), these four bits are incremented by six, producing the proper BCD digit in the high nibble.

Again, this sets the CY flag if there was a carry out of the upper four bits, but does not clear the carry. The CY flag thus indicates if the sum of the original two BCD variables is greater than 100, allowing multiple-precision decimal addition. The OV flag is not affected.

All of this occurs during one instruction cycle. Essentially, this instruction performs the decimal conversion by adding 00H, 06H, 60H, or 66H to the accumulator, depending on initial accumulator and PSW conditions.

Note: DA A cannot simply convert a hexadecimal number in the accumulator to BCD notation, nor does DA A apply to decimal subtraction.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example:

The accumulator contains 56H (01010110B), which represents the packed BCD digits of the decimal number 56. Register 3 contains 67H (01100111B), which represents the packed BCD digits of the decimal number 67. The CY flag is set. After executing the instruction sequence

```
ADDC A,R3
DA A
```

the accumulator contains 0BEH (10111110) and the CY and AC flags are clear. The Decimal Adjust instruction then alters the accumulator to the value 24H (00100100B), indicating the packed BCD digits of the decimal number 24, the lower two digits of the decimal sum of 56, 67, and the carry-in. The CY flag is set by the Decimal Adjust instruction, indicating that a decimal overflow occurred. The true sum of 56, 67, and 1 is 124.

BCD variables can be incremented or decremented by adding 01H or 99H. If the accumulator contains 30H (representing the digits of 30 decimal), then the instruction sequence,

```
ADD A,#99H
DA A
```

leaves the CY flag set and 29H in the accumulator, since $30 + 99 = 129$. The low byte of the sum can be interpreted to mean $30 - 1 = 29$.

	Binary Mode	Source Mode	
Bytes:	1	1	
States:	1	1	
	[Encoding]	1 1 0 1	0 1 0 0

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: DA
(Contents of accumulator are BCD)
IF $[(A.3:0) > 9] \vee [(AC) = 1]$
THEN $(A.3:0) \leftarrow (A.3:0) + 6$
AND
IF $[(A.7:4) > 9] \vee [(CY) = 1]$
THEN $(A.7:4) \leftarrow (A.7:4) + 6$

DEC byte**Function:** Decrement**Description:** Decrements the specified byte variable by 1. An original value of 00H underflows to 0FFH. Four operands addressing modes are allowed: accumulator, register, direct, or register-indirect.**Note:** When this instruction is used to modify an output port, the value used as the original port data is read from the output data latch, not the input pins.**Flags:**

CY	AC	OV	N	Z
—	—	—	3	3

Example: Register 0 contains 7FH (0111111B). On-chip RAM locations 7EH and 7FH contain 00H and 40H, respectively. After executing the instruction sequence

```
DEC @R0
DEC R0
DEC @R0
```

register 0 contains 7EH and on-chip RAM locations 7EH and 7FH are set to 0FFH and 3FH, respectively.

Variations**DEC A**

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1"> <tr> <td>0 0 0 1</td> <td>0 1 0 0</td> </tr> </table>	0 0 0 1	0 1 0 0
0 0 0 1	0 1 0 0			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]**Operation:** DEC
(A) ← (A) - 1**DEC dir8**

	Binary Mode	Source Mode			
Bytes:	2	2			
States:	2†	2†			
	†if this instruction addresses a port (Px, x = 0-3), add 2 states.				
	[Encoding]	<table border="1"> <tr> <td>0 0 0 1</td> <td>0 1 0 1</td> <td>dir addr</td> </tr> </table>	0 0 0 1	0 1 0 1	dir addr
0 0 0 1	0 1 0 1	dir addr			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: DEC
 $(dir8) \leftarrow (dir8) - 1$

DEC @Ri

	Binary Mode	Source Mode		
Bytes:	1	2		
States:	3	4		
	[Encoding]		0 0 0 1	0 1 1 i

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: DEC
 $((Ri)) \leftarrow ((Ri)) - 1$

DEC Rn

	Binary Mode	Source Mode		
Bytes:	1	2		
States:	1	2		
	[Encoding]		0 0 0 1	1 r r r

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: DEC
 $(Rn) \leftarrow (Rn) - 1$

DEC <dest>,<src>

Function: Decrement

Description: Decrements the specified variable at the destination operand by 1, 2, or 4. An original value of 00H underflows to 0FFH.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: Register 0 contains 7FH (01111111B). After executing the instruction sequence

DEC R0,#1

register 0 contains 7EH.

Variations

DEC Rm,#short

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 1	1 0 1 1	ssss	0 1	vv
------------	---------	---------	------	-----	----

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: DEC
(Rm) ← (Rm) – #short

DEC WRj,#short

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 1	1 0 1 1	tttt	0 1	vv
------------	---------	---------	------	-----	----

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: DEC
(WRj) ← (WRj) – #short

DEC DRk,#short

	Binary Mode	Source Mode
Bytes:	3	2
States:	5	4

[Encoding]	0 0 0 1	1 0 1 1	uuuu	1 1	vv
------------	---------	---------	------	-----	----

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: DEC
(DRk) ← (DRk) – #short

DIV <dest>,<src>

Function: Divide

Description: Divides the unsigned integer in the register by the unsigned integer operand in register addressing mode and clears the CY and OV flags.

For byte operands (<dest>,<src> = Rmd,Rms) the result is 16 bits. The 8-bit quotient is stored in the higher byte of the word where Rmd resides; the 8-bit remainder is stored in the lower byte of the word where Rmd resides. For example: Register 1 contains 251 (0FBH or 11111011B) and register 5 contains 18 (12H or 00010010B). After executing the instruction

DIV R1,R5

register 1 contains 13 (0DH or 00001101B); register 0 contains 17 (11H or 00010001B), since $251 = (13 \times 18) + 17$; and the CY and OV bits are clear (see Flags).

Flags: The CY flag is cleared. The N flag is set if the MSB of the quotient is set. The Z flag is set if the quotient is zero.

CY	AC	OV	N	Z
0	—	3	3	3

Exception: if <src> contains 00H, the values returned in both operands are undefined; the CY flag is cleared, OV flag is set, and the rest of the flags are undefined.

CY	AC	OV	N	Z
0	—	1	?	?

Variations

DIV Rmd Rms

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	11	10		
[Encoding]	1 0 0 0	1 1 0 0	s s s s	S S S S

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: DIV (8-bit operands)
 (Rmd) ← remainder (Rmd) / (Rms) if <dest> md = 0,2,4,...,14
 (Rmd+1) ← quotient (Rmd) / (Rms)

 (Rmd-1) ← remainder (Rmd) / (Rms) if <dest> md = 1,3,5,...,15
 (Rmd) ← quotient (Rmd) / (Rms)

DIV WRjd,WRjs

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	22	21		
[Encoding]	1 0 0 0	1 1 0 1	t t t t	T T T T

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]



Operation: DIV (16-bit operands)
 (WRjd) ← remainder (WRjd) / (WRjs) if <dest> jd = 0, 4, 8,... 28
 (WRjd+2) ← quotient (WRjd) / (WRjs)

 (WRjd-2) ← remainder (WRjd) / (WRjs) if <dest> jd = 2, 6, 10,... 30
 (WRjd) ← quotient (WRjd) / (WRjs)

For word operands (<dest>, <src> = WRjd, WRjs) the 16-bit quotient is in WR(jd+2), and the 16-bit remainder is in WRjd. For example, for a destination register WR4, assume the quotient is 1122H and the remainder is 3344H. Then, the results are stored in these register file locations:

Location	4	5	6	7
Contents	33H	44H	11H	22H

DIV AB

Function: Divide

Description: Divides the unsigned 8-bit integer in the accumulator by the unsigned 8-bit integer in register B. The accumulator receives the integer part of the quotient; register B receives the integer remainder. The CY and OV flags are cleared.

Exception: if register B contains 00H, the values returned in the accumulator and register B are undefined; the CY flag is cleared and the OV flag is set.

Flags:

CY	AC	OV	N	Z
0	—	3	3	3

For division by zero:

CY	AC	OV	N	Z
0	—	1	?	?

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Example: The accumulator contains 251 (0FBH or 11111011B) and register B contains 18 (12H or 00010010B). After executing the instruction

DIV AB

the accumulator contains 13 (0DH or 00001101B); register B contains 17 (11H or 00010001B), since 251 = (13 X 18) + 17; and the CY and OV flags are clear.

Binary Mode Source Mode

Bytes: 1 1
States: 10 10

[Encoding]	1 0 0 0	0 1 0 0
------------	---------	---------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: DIV
(A) ← quotient (A)/(B)
(B) ← remainder (A)/(B)

DJNZ <byte>,<rel-addr>

Function: Decrement and jump if not zero

Description: Decrements the specified location by 1 and branches to the address specified by the second operand if the resulting value is not zero. An original value of 00H underflows to 0FFH. The branch destination is computed by adding the signed relative-displacement value in the last instruction byte to the PC, after incrementing the PC to the first byte of the following instruction.

The location decremented may be a register or directly addressed byte.

Note: When this instruction is used to modify an output port, the value used as the original port data is read from the output data latch, not the input pins.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The on-chip RAM locations 40H, 50H, and 60H contain 01H, 70H, and 15H, respectively. After executing the following instruction sequence

```
DJNZ 40H,LABEL1
DJNZ 50H,LABEL2
DJNZ 60H,LABEL
```

on-chip RAM locations 40H, 50H, and 60H contain 00H, 6FH, and 14H, respectively, and program execution continues at label LABEL2. (The first jump was not taken because the result was zero.)

This instruction provides a simple way of executing a program loop a given number of times, or for adding a moderate time delay (from 2 to 512 machine cycles) with a single instruction.

The instruction sequence,

```
MOV R2,#8
TOGGLE: CPL P1.7
DJNZ R2,TOGGLE
```

toggles P1.7 eight times, causing four output pulses to appear at bit 7 of output Port 1. Each pulse lasts three states: two for DJNZ and one to alter the pin.

Variations

DJNZ dir8,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	3	3
States:	3	6	3	6
[Encoding]	1 1 0 1	0 1 0 1	direct addr	rel. addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: DJNZ
 $(PC) \leftarrow (PC) + 2$
 $(dir8) \leftarrow (dir8) - 1$
 IF $(dir8) > 0$ or $(dir8) < 0$
 THEN
 $(PC) \leftarrow (PC) + rel$

DJNZ Rn,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	2	2	3	3
States:	2	5	3	6
[Encoding]	1 1 0 1	1 rrr	rel. addr	

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: DJNZ
 $(PC) \leftarrow (PC) + 2$
 $(Rn) \leftarrow (Rn) - 1$
 IF $(Rn) > 0$ or $(Rn) < 0$
 THEN
 $(PC) \leftarrow (PC) + rel$

ECALL <dest>

Function: Extended call

Description: Calls a subroutine located at the specified address. The instruction adds four to the program counter to generate the address of the next instruction and then pushes the 24-bit result onto the stack (high byte first), incrementing the stack pointer by three. The 8 bits of the high word and the 16 bits of the low word of the PC are then loaded, respectively, with the second, third and fourth bytes of the ECALL instruction. Program execution continues with the instruction at this address. The subroutine may therefore begin anywhere in the full 16-Mbyte memory space.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The stack pointer contains 07H and the label "SUBRTN" is assigned to program memory location 123456H. After executing the instruction

ECALL SUBRTN

at location 012345H, SP contains 0AH; on-chip RAM locations 08H, 09H and 0AH contain 01H, 23H and 45H, respectively; and the PC contains 123456H.

Variations
ECALL addr24

	Binary Mode	Source Mode			
Bytes:	5	4			
States:	14	13			
[Encoding]	1 0 0 1	1 0 1 0	addr23– addr16	addr15– addr8	addr7–addr0

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ECALL
(PC) ← (PC) + 4
(SP) ← (SP) + 1
((SP)) ← (PC.23:16)
(SP) ← (SP) + 1
((SP)) ← (PC.15:8)
(SP) ← (SP) + 1
((SP)) ← (PC.7:0)
(PC) ← (addr.23:0)

ECALL @DRk

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	12	11		
[Encoding]	1 0 0 1	1 0 0 1	u u u u	

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ECALL
(PC) ← (PC) + 4
(SP) ← (SP) + 1
((SP)) ← (PC.23:16)
(SP) ← (SP) + 1
((SP)) ← (PC.15:8)
(SP) ← (SP) + 1
((SP)) ← (PC.7:0)
(PC) ← ((DRk))

EJMP <dest>

Function: Extended jump

Description: Causes an unconditional branch to the specified address by loading the 8 bits of the high order and 16 bits of the low order words of the PC with the second, third, and fourth instruction bytes. The destination may be therefore be anywhere in the full 16-Mbyte memory space.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

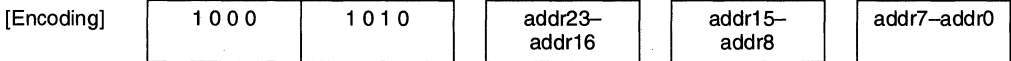
Example: The label "JMPADR" is assigned to the instruction at program memory location 123456H. The instruction is

EJMP JMPADR

Variations

EJMP addr24

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

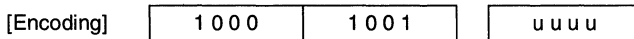


Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: EJMP
(PC) ← (addr.23:0)

EJMP @DRk

	Binary Mode	Source Mode
Bytes:	3	2
States:	7	6



Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: EJMP
(PC) ← ((DRk))

ERET

Function: Extended return

Description: Pops byte 2, byte 1, and byte 0 of the 3-byte PC successively from the stack and decrements the stack pointer by 3. Program execution continues at the resulting address, which normally is the instruction immediately following ECALL.

Flags: No flags are affected.

Example: The stack pointer contains 0BH. On-chip RAM locations 08H, 09H and 0AH contain 01H, 23H and 49H, respectively. After executing the instruction

ERET

the stack pointer contains 08H and program execution continues at location 012349H.

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	10	9		
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">1 0 1 0</td> <td style="padding: 2px 10px;">1 0 1 0</td> </tr> </table>	1 0 1 0	1 0 1 0
1 0 1 0	1 0 1 0			

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ERET
(PC.23:16) ← ((SP))
(SP) ← (SP) - 1
(PC.15:8) ← ((SP))
(SP) ← (SP) - 1
(PC.7:0) ← ((SP))
(SP) ← (SP) - 1

INC <Byte>

Function: Increment

Description: Increments the specified byte variable by 1. An original value of FFH overflows to 00H. Three addressing modes are allowed for 8-bit operands: register, direct, or register-indirect.

Note: When this instruction is used to modify an output port, the value used as the original port data is read from the output data latch, not the input pins.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: Register 0 contains 7EH (01111110B) and on-chip RAM locations 7EH and 7FH contain 0FFH and 40H, respectively. After executing the instruction sequence

INC @R0
INC R0
INC @R0

register 0 contains 7FH and on-chip RAM locations 7EH and 7FH contain 00H and 41H, respectively.

Variations

INC A

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">0 0 0 0</td> <td style="padding: 2px 10px;">0 1 0 0</td> </tr> </table>	0 0 0 0	0 1 0 0
0 0 0 0	0 1 0 0			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]
Operation: INC
 (A) ← (A) + 1

INC dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	2†	2†

†If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

0 0 0 0

0 1 0 1

direct addr

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: INC
 (dir8) ← (dir8) + 1

INC @Ri

	Binary Mode	Source Mode
Bytes:	1	2
States:	3	4

[Encoding]

0 0 0 0

0 1 1 i

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: INC
 ((Ri) ← ((Ri)) + 1

INC Rn

	Binary Mode	Source Mode
Bytes:	1	2
States:	1	2

[Encoding]

0 0 0 0

1 r r r

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: INC
 (Rn) ← (Rn) + 1

INC <dest>,<src>

Function: Increment

Description: Increments the specified variable by 1, 2, or 4. An original value of 0FFH overflows to 00H.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: Register 0 contains 7EH (011111110B). After executing the instruction

INC R0,#1

register 0 contains 7FH.

Variations
INC Rm,#short

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 0	1 0 1 1	s s s s	0 0	v v
------------	---------	---------	---------	-----	-----

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: INC
 (Rm) ← (Rm) + #short

INC WRj,#short

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 0	1 0 1 1	t t t t	0 1	v v
------------	---------	---------	---------	-----	-----

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: INC
 (WRj) ← (WRj) + #short

INC DRk,#short

	Binary Mode	Source Mode
Bytes:	3	2
States:	4	3

[Encoding]	0 0 0 0	1 0 1 1	u u u u	1 1	v v
------------	---------	---------	---------	-----	-----

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: INC
 (DRk) ← (DRk) + #shortdata pointer

INC DPTR

Function: Increment data pointer

Description: Increments the 16-bit data pointer by one. A 16-bit increment (modulo 2^{16}) is performed; an overflow of the low byte of the data pointer (DPL) from 0FFH to 00H increments the high byte of the data pointer (DPH) by one. An overflow of the high byte (DPH) does not increment the high word of the extended data pointer (DPX = DR56).

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: Registers DPH and DPL contain 12H and 0FEH, respectively. After the instruction sequence

```
INC DPTR
INC DPTR
INC DPTR
```

DPH and DPL contain 13H and 01H, respectively.

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>1 0 1 0</td><td>0 0 1 1</td></tr></table>	1 0 1 0	0 0 1 1
1 0 1 0	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: INC
(DPTR) ← (DPTR) + 1

JB bit51,rel
JB bit,rel

Function: Jump if bit set

Description: If the specified bit is a one, jump to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the third instruction byte to the PC, after incrementing the PC to the first byte of the next instruction. The bit tested is not modified.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: Input port 1 contains 11001010B and the accumulator contains 56 (01010110B). After the instruction sequence

```
JB P1.2,LABEL1
JB ACC.2,LABEL2
```

program execution continues at label LABEL2.

Variations

JB bit51,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	3	3
States:	2	5	2	5
[Encoding]	0 0 1 0 0 0 0 0		bit addr	rel. addr

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: JB
 $(PC) \leftarrow (PC) + 3$
 IF (bit51) = 1
 THEN
 $(PC) \leftarrow (PC) + rel$

JB bit,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	5	5	4	4
States:	4	7	3	6
[Encoding]	1 0 1 0 1 0 0 1	0 0 1 0 0	y y	direct addr rel. addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: JB
 $(PC) \leftarrow (PC) + 3$
 IF (bit) = 1
 THEN
 $(PC) \leftarrow (PC) + rel$

JBC bit51,rel
JBC bit,rel

Function: Jump if bit is set and clear bit

Description: If the specified bit is one, branch to the specified address; otherwise proceed with the next instruction. The bit is not cleared if it is already a zero. The branch destination is computed by adding the signed relative displacement in the third instruction byte to the PC, after incrementing the PC to the first byte of the next instruction.

Note: When this instruction is used to test an output pin, the value used as the original data is read from the output data latch, not the input pin.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The accumulator contains 56H (01010110B). After the instruction sequence

```
JBC ACC.3,LABEL1
JBC ACC.2,LABEL2
```

the accumulator contains 52H (01010010B) and program execution continues at label LABEL2.

Variations

JBC bit51,rel

	Binary Mode		Source Mode					
	Not Taken	Taken	Not Taken	Taken				
Bytes:	3	3	3	3				
States:	4	7	4	7				
[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">0 0 0 1</td> <td style="padding: 2px 10px;">0 0 0 0</td> </tr> </table>		0 0 0 1	0 0 0 0	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">bit addr</td> </tr> </table>	bit addr	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">rel. addr</td> </tr> </table>	rel. addr
0 0 0 1	0 0 0 0							
bit addr								
rel. addr								

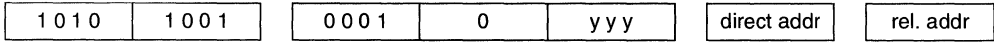
Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: JBC
 $(PC) \leftarrow (PC) + 3$
 IF (bit51) = 1
 THEN
 (bit51) \leftarrow 0
 $(PC) \leftarrow (PC) + rel$

JBC bit,rel

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	5	5	4	4
States:	4	7	3	6

[Encoding]



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: JBC
 $(PC) \leftarrow (PC) + 3$
 IF (bit51) = 1
 THEN
 $(bit51) \leftarrow 0$
 $(PC) \leftarrow (PC) + rel$

JC rel

Function: Jump if carry is set

Description: If the CY flag is set, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.

Flags:

CY	AC	OV	N	Z
!	—	—	—	—

Example: The CY flag is clear. After the instruction sequence

```
JC          LABEL1
CPL CY
JC LABEL 2
```

the CY flag is set and program execution continues at label LABEL2.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	2	2	2	2
States:	1	4	1	4

[Encoding]	0 1 0 0	0 0 0 0	rel. addr
------------	---------	---------	-----------

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: JC
 $(PC) \leftarrow (PC) + 2$
 IF (CY) = 1
 THEN
 $(PC) \leftarrow (PC) + rel$

JE rel**Function:** Jump if equal**Description:** If the Z flag is set, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.**Flags:**

CY	AC	OV	N	Z
—	—	—	—	!

Example: The Z flag is set. After executing the instruction

JE LABEL1

program execution continues at label LABEL1.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 1 1 0	1 0 0 0	rel. addr

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]**Operation:** JE
(PC) ← (PC) + 2
IF (Z) = 1
THEN (PC) ← (PC) + rel**JG rel****Function:** Jump if greater than**Description:** If the Z flag and the CY flag are both clear, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.**Flags:**

CY	AC	OV	N	Z
—	—	—	!	—

Example: The instruction

JG LABEL1

causes program execution to continue at label LABEL1 if the Z flag and the CY flag are both clear.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 0 1 1	1 0 0 0	rel. addr

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: JG
 $(PC) \leftarrow (PC) + 2$
 IF $(Z) = 0$ AND $(CY) = 0$
 THEN $(PC) \leftarrow (PC) + \text{rel}$

JLE rel

Function: Jump if less than or equal

Description: If the Z flag or the CY flag is set, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.

Flags:

CY	AC	OV	N	Z
—	—	—	!	!

Example: The instruction

JLE LABEL1

causes program execution to continue at LABEL1 if the Z flag or the CY flag is set.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 0 1 0	1 0 0 0	rel. addr

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: JLE
 $(PC) \leftarrow (PC) + 2$
 IF $(Z) = 1$ OR $(CY) = 1$
 THEN $(PC) \leftarrow (PC) + \text{rel}$



JMP @A+DPTR

Function: Jump indirect

Description: Add the 8-bit unsigned contents of the accumulator with the 16-bit data pointer and load the resulting sum into the lower 16 bits of the program counter. This is the address for subsequent instruction fetches. The contents of the accumulator and the data pointer are not affected.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The accumulator contains an even number from 0 to 6. The following sequence of instructions branch to one of four AJMP instructions in a jump table starting at JMP_TBL:

```

MOV     DPTR,#JMP_TBL
JMP     @A+DPTR
JMP_TBL: AJMP LABEL0
         AJMP LABEL1
         AJMP LABEL2
         AJMP LABEL3
    
```

If the accumulator contains 04H at the start this sequence, execution jumps to LABEL2. Remember that AJMP is a two-byte instruction, so the jump instructions start at every other address.

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	5	5		
	[Encoding]	<table border="1"> <tr> <td>0 1 1 1</td> <td>0 0 1 1</td> </tr> </table>	0 1 1 1	0 0 1 1
0 1 1 1	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: JMP
 (PC.15:0) ← (A) + (DPTR)

JNB bit51,rel
JNB bit,rel

Function: Jump if bit not set

Description: If the specified bit is clear, branch to the specified address; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the third instruction byte to the PC, after incrementing the PC to the first byte of the next instruction. The bit tested is not modified.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: Input port 1 contains 11001010B and the accumulator contains 56H (01010110B). After executing the instruction sequence

```
JNB P1.3,LABEL1
JNB ACC.3,LABEL2
```

program execution continues at label LABEL2.

Variations

JNB bit51,rel

	Binary Mode		Source Mode					
	Not Taken	Taken	Not Taken	Taken				
Bytes:	3	3	3	3				
States:	2	5	2	5				
[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">0 0 1 1</td> <td style="padding: 2px 10px;">0 0 0 0</td> </tr> </table>		0 0 1 1	0 0 0 0	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">bit addr</td> <td style="padding: 2px 10px;">rel. addr</td> </tr> </table>		bit addr	rel. addr
0 0 1 1	0 0 0 0							
bit addr	rel. addr							

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: JNB
(PC) ← (PC) + 3
IF (bit51) = 0
THEN (PC) ← (PC) + rel

JNB bit,rel

	Binary Mode		Source Mode									
	Not Taken	Taken	Not Taken	Taken								
Bytes:	5	5	4	4								
States:	4	7	3	6								
[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 0 1 0</td> <td style="padding: 2px 10px;">1 0 0 1</td> </tr> </table>		1 0 1 0	1 0 0 1	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">0 0 1 1</td> <td style="padding: 2px 10px;">0</td> <td style="padding: 2px 10px;">y y</td> <td style="padding: 2px 10px;">direct addr</td> <td style="padding: 2px 10px;">rel. addr</td> </tr> </table>			0 0 1 1	0	y y	direct addr	rel. addr
1 0 1 0	1 0 0 1											
0 0 1 1	0	y y	direct addr	rel. addr								

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: JNB
(PC) ← (PC) + 3
IF (bit) = 0
THEN
(PC) ← (PC) + rel

JNC rel**Function:** Jump if carry not set**Description:** If the CY flag is clear, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice to point to the next instruction. The CY flag is not modified.**Flags:**

CY	AC	OV	N	Z
!	—	—	—	—

Example: The CY flag is set. The instruction sequence

```
JNC LABEL1
CPL CY
JNC LABEL2
```

clears the CY flag and causes program execution to continue at label LABEL2.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	2	2	2	2
States:	1	4	1	4
	[Encoding]	0 1 0 1	0 0 0 0	rel. addr

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: JNC
 $(PC) \leftarrow (PC) + 2$
 IF $(CY) = 0$
 THEN $(PC) \leftarrow (PC) + rel$

JNE rel**Function:** Jump if not equal**Description:** If the Z flag is clear, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.**Flags:**

CY	AC	OV	N	Z
—	—	—	—	!

Example: The instruction

```
JNE LABEL1
```

causes program execution to continue at LABEL1 if the Z flag is clear.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 1 1 1	1 0 0 0	rel. addr

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: JNE
 $(PC) \leftarrow (PC) + 2$
 IF $(Z) = 0$
 THEN $(PC) \leftarrow (PC) + rel$

JNZ rel

Function: Jump if accumulator not zero

Description: If any bit of the accumulator is set, branch to the specified address; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice. The accumulator is not modified.

Flags:

CY	AC	OV	N	Z
—	—	—	—	!

Example: The accumulator contains 00H. After executing the instruction sequence

```
JNZ LABEL1
INC A
JNZ LABEL2
```

the accumulator contains 01H and program execution continues at label LABEL2.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	2	2	2	2
States:	2	5	2	5
	[Encoding]	0 1 1 1	0 0 0 0	rel. addr

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: JNZ
 $(PC) \leftarrow (PC) + 2$
 IF $(A) \neq 0$
 THEN $(PC) \leftarrow (PC) + rel$

JSG rel**Function:** Jump if greater than (signed)**Description:** If the Z flag is clear AND the N flag and the OV flag have the same value, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.**Flags:**

CY	AC	OV	N	Z
—	—	!	!	!

Example: The instruction

JSG LABEL1

causes program execution to continue at LABEL1 if the Z flag is clear AND the N flag and the OV flag have the same value.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 0 0 1	1 0 0 0	rel. addr

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]**Operation:** JSG
 $(PC) \leftarrow (PC) + 2$
IF [(N) = 0 AND (N) = (OV)]
THEN $(PC) \leftarrow (PC) + \text{rel}$ **JSGE rel****Function:** Jump if greater than or equal (signed)**Description:** If the N flag and the OV flag have the same value, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.**Flags:**

CY	AC	OV	N	Z
—	—	!	!	!

Example: The instruction

JSGE LABEL1

causes program execution to continue at LABEL1 if the N flag and the OV flag have the same value.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 1 0 1	1 0 0 0	rel. addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: JSGE
 $(PC) \leftarrow (PC) + 2$
 IF [(N) = (OV)]
 THEN $(PC) \leftarrow (PC) + rel$

JSL rel

Function: Jump if less than (signed)

Description: If the N flag and the OV flag have different values, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.

Flags:

CY	AC	OV	N	Z
—	—	!	!	!

Example: The instruction

JSL LABEL1

causes program execution to continue at LABEL1 if the N flag and the OV flag have different values.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 1 0 0	1 0 0 0	rel. addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: JSL
 $(PC) \leftarrow (PC) + 2$
 IF $(N) \neq (OV)$
 THEN $(PC) \leftarrow (PC) + rel$

JSLE rel

Function: Jump if less than or equal (signed)

Description: If the Z flag is set OR if the the N flag and the OV flag have different values, branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice.

Flags:

CY	AC	OV	N	Z
—	—	!	!	!

Example: The instruction

JSLE LABEL1

causes program execution to continue at LABEL1 if the Z flag is set OR if the the N flag and the OV flag have different values.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	3	3	2	2
States:	2	5	1	4
	[Encoding]	0 0 0 0	1 0 0 0	rel. addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: JSLE
 $(PC) \leftarrow (PC) + 2$
 IF $\{(Z) = 1 \text{ OR } [(N) \neq (OV)]\}$
 THEN $(PC) \leftarrow (PC) + rel$

JZ rel

Function: Jump if accumulator zero

Description: If all bits of the accumulator are clear (zero), branch to the address specified; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative displacement in the second instruction byte to the PC, after incrementing the PC twice. The accumulator is not modified.

Flags:

CY	AC	OV	N	Z
—	—	—	—	!



Example: The accumulator contains 01H. After executing the instruction sequence

```
JZ LABEL1
DEC A
JZ LABEL2
```

the accumulator contains 00H and program execution continues at label LABEL2.

	Binary Mode		Source Mode	
	Not Taken	Taken	Not Taken	Taken
Bytes:	2	2	2	2
States:	2	5	2	5
	[Encoding]	0 1 1 0	0 0 0 0	rel. addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: JZ
(PC) ← (PC) + 2
IF (A) = 0
THEN (PC) ← (PC) + rel

LCALL <dest>

Function: Long call

Description: Calls a subroutine located at the specified address. The instruction adds three to the program counter to generate the address of the next instruction and then pushes the 16-bit result onto the stack (low byte first). The stack pointer is incremented by two. The high and low bytes of the PC are then loaded, respectively, with the second and third bytes of the LCALL instruction. Program execution continues with the instruction at this address. The subroutine may therefore begin anywhere in the 64-Kbyte region of memory where the next instruction is located.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The stack pointer contains 07H and the label "SUBRTN" is assigned to program memory location 1234H. After executing the instruction

```
LCALL SUBRTN
```

at location 0123H, the stack pointer contains 09H, on-chip RAM locations 08H and 09H contain 01H and 26H, and the PC contains 1234H.

LCALL addr16

	Binary Mode	Source Mode		
Bytes:	3	3		
States:	9	9		
	[Encoding]	0 0 0 1	0 0 1 0	addr15– addr8
				addr7–addr0

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: LCALL
 (PC) ← (PC) + 3
 (SP) ← (SP) + 1
 ((SP)) ← (PC.7:0)
 (SP) ← (SP) + 1
 ((SP)) ← (PC.15:8)
 (PC) ← (addr.15:0)

LCALL @WRj

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	9	8		
[Encoding]	1 0 0 1	1 0 0 1	t t t t	0 1 0 0

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: LCALL
 (PC) ← (PC) + 3
 (SP) ← (SP) + 1
 ((SP)) ← (PC.7:0)
 (SP) ← (SP) + 1
 ((SP)) ← (PC.15:8)
 (PC) ← ((WRj))

LJMP <dest>

Function: Long Jump

Description: Causes an unconditional branch to the specified address, by loading the high and low bytes of the PC (respectively) with the second and third instruction bytes. The destination may therefore be anywhere in the 64-Kbyte memory region where the next instruction is located.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The label "JMPADR" is assigned to the instruction at program memory location 1234H. After executing the instruction

LJMP JMPADR

at location 0123H, the program counter contains 1234H.

LJMP addr16

	Binary Mode	Source Mode		
Bytes:	3	3		
States:	5	5		
[Encoding]	0 0 0 0	0 0 1 0	addr15– addr8	addr7–addr0

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: LJMP
(PC) ← (addr.15:0)

LJMP @WRj

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	6	5		
[Encoding]	1 0 0 0	1 0 0 1	tttt	0 1 0 0

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: LJMP
(PC) ← ((WRj))

MOV <dest>,<src>

Function: Move byte variable

Description: Copies the byte variable specified by the second operand into the location specified by the first operand. The source byte is not affected.

This is by far the most flexible operation. Twenty-four combinations of source and destination addressing modes are allowed.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: On-chip RAM location 30H contains 40H, on-chip RAM location 40H contains 10H, and input port 1 contains 11001010B (0CAH). After executing the instruction sequence

```

MOV    R0,#30H    ;R0 <= 30H
MOV    A,@R0     ;A <= 40H
MOV    R1,A       ;R1 <= 40H
MOV    B,@R1     ;B <= 10H
MOV    @R1,P1    ;RAM (40H) <= 0CAH
MOV    P2,P1     ;P2 #0CAH
    
```

register 0 contains 30H, the accumulator and register 1 contain 40H, register B contains 10H, and on-chip RAM location 40H and output port 2 contain 0CAH (11001010B).

Variations

MOV A,#data

	Binary Mode	Source Mode	
Bytes:	2	2	
States:	1	1	
	[Encoding]	0 1 1 1 0 1 0 0	immed. data

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (A) ← #data

MOV dir8,#data

	Binary Mode	Source Mode	
Bytes:	3	3	
States:	3 [†]	3 [†]	
	[Encoding]	0 1 1 1 0 1 0 1	direct addr immed. data

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir8) ← #data

MOV @Ri,#data

	Binary Mode	Source Mode	
Bytes:	2	3	
States:	3	4	
	[Encoding]	0 1 1 1 0 1 1 i	immed. data

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: MOV
((Ri)) ← #data

MOV Rn,#data

	Binary Mode	Source Mode				
Bytes:	2	3				
States:	1	2				
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">0 1 1 1</td> <td style="padding: 2px 10px;">1 r r r r</td> </tr> </table>	0 1 1 1	1 r r r r	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">immed. data</td> </tr> </table>	immed. data
0 1 1 1	1 r r r r					
immed. data						

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: MOV
(Rn) ← #data

MOV dir8,dir8

	Binary Mode	Source Mode						
Bytes:	3	3						
States:	3	3						
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 0 0 0</td> <td style="padding: 2px 10px;">0 1 0 1</td> </tr> </table>	1 0 0 0	0 1 0 1	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">direct addr</td> </tr> </table>	direct addr	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">direct addr</td> </tr> </table>	direct addr
1 0 0 0	0 1 0 1							
direct addr								
direct addr								

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: MOV
(dir8) ← (dir8)

MOV dir8,@Ri

	Binary Mode	Source Mode				
Bytes:	2	3				
States:	3	4				
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 0 0 0</td> <td style="padding: 2px 10px;">0 1 1 i</td> </tr> </table>	1 0 0 0	0 1 1 i	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">direct addr</td> </tr> </table>	direct addr
1 0 0 0	0 1 1 i					
direct addr						

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: MOV
(dir8) ← ((Ri))

MOV dir8,Rn

	Binary Mode	Source Mode				
Bytes:	2	3				
States:	2 [†]	3 [†]				
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 0 0 0</td> <td style="padding: 2px 10px;">1 r r r</td> </tr> </table>	1 0 0 0	1 r r r	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">direct addr</td> </tr> </table>	direct addr
1 0 0 0	1 r r r					
direct addr						

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: MOV
 (dir8) ← (Rn)

MOV @Ri,dir8

	Binary Mode	Source Mode
Bytes:	2	3
States:	3	4

[Encoding]	1 0 1 0	0 1 1 i	direct addr
------------	---------	---------	-------------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: MOV
 ((Ri)) ← (dir8)

MOV Rn,dir8

	Binary Mode	Source Mode
Bytes:	2	3
States:	1†	2†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	1 0 1 0	1 r r r	direct addr
------------	---------	---------	-------------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: MOV
 (Rn) ← (dir8)

MOV A,dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	1†	1†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	1 1 1 0	0 1 0 1	direct addr
------------	---------	---------	-------------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: MOV
 (A) ← (dir8)

MOV A, @Ri

	Binary Mode	Source Mode		
Bytes:	1	2		
States:	2	3		
	[Encoding]	<table border="1"> <tr> <td>1 1 1 0</td> <td>0 1 1 i</td> </tr> </table>	1 1 1 0	0 1 1 i
1 1 1 0	0 1 1 i			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: MOV
 (A) ← ((Ri))

MOV A, Rn

	Binary Mode	Source Mode		
Bytes:	1	2		
States:	1	2		
	[Encoding]	<table border="1"> <tr> <td>1 1 1 0</td> <td>1 r r r</td> </tr> </table>	1 1 1 0	1 r r r
1 1 1 0	1 r r r			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: MOV
 (A) ← (Rn)

MOV dir8, A

	Binary Mode	Source Mode			
Bytes:	2	2			
States:	2†	2†			
	[Encoding]	<table border="1"> <tr> <td>1 1 1 1</td> <td>0 1 0 1</td> <td>direct addr</td> </tr> </table>	1 1 1 1	0 1 0 1	direct addr
1 1 1 1	0 1 0 1	direct addr			

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir8) ← (A)

MOV @Ri, A

	Binary Mode	Source Mode		
Bytes:	1	2		
States:	3	4		
	[Encoding]	<table border="1"> <tr> <td>1 1 1 1</td> <td>0 1 1 i</td> </tr> </table>	1 1 1 1	0 1 1 i
1 1 1 1	0 1 1 i			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: MOV
 ((Ri)) ← (A)

MOV Rn,A

	Binary Mode	Source Mode		
Bytes:	1	2		
States:	1	2		
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">1 1 1 1</td> <td style="padding: 2px 10px;">1 1 1 r</td> </tr> </table>	1 1 1 1	1 1 1 r
1 1 1 1	1 1 1 r			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: MOV
 (Rn) ← (A)

MOV Rmd,Rms

	Binary Mode	Source Mode				
Bytes:	3	2				
States:	2	1				
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">0 1 1 1</td> <td style="padding: 2px 10px;">1 1 0 0</td> </tr> </table> <table border="1" style="display: inline-table; vertical-align: middle; margin-left: 20px;"> <tr> <td style="padding: 2px 10px;">s s s s</td> <td style="padding: 2px 10px;">S S S S</td> </tr> </table>	0 1 1 1	1 1 0 0	s s s s	S S S S
0 1 1 1	1 1 0 0					
s s s s	S S S S					

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (Rmd) ← (Rms)

MOV WRjd,WRjs

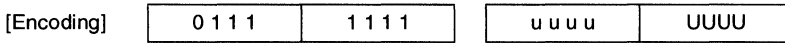
	Binary Mode	Source Mode				
Bytes:	3	2				
States:	2	1				
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">0 1 1 1</td> <td style="padding: 2px 10px;">1 1 0 1</td> </tr> </table> <table border="1" style="display: inline-table; vertical-align: middle; margin-left: 20px;"> <tr> <td style="padding: 2px 10px;">t t t t</td> <td style="padding: 2px 10px;">T T T T</td> </tr> </table>	0 1 1 1	1 1 0 1	t t t t	T T T T
0 1 1 1	1 1 0 1					
t t t t	T T T T					

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (WRjd) ← (WRjs)

MOV DRkd,DRks

	Binary Mode	Source Mode
Bytes:	3	2
States:	3	2



Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: MOV
 (DRkd) ← (DRks)

MOV Rm,#data

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2



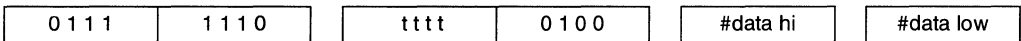
Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: MOV
 (Rm) ← #data

MOV WRj,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2

[Encoding]



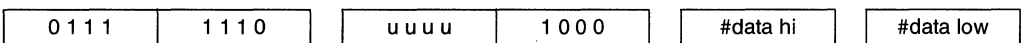
Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: MOV
 (WRj) ← #data16

MOV DRk,#0data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	5	4

[Encoding]



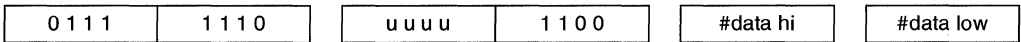
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (DRk) ← #0data16

MOV DRk,#1data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	5	4

[Encoding]



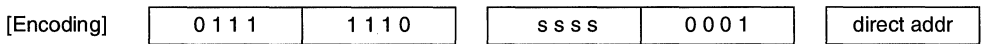
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (DRk) ← #1data16

MOV Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3†	2†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

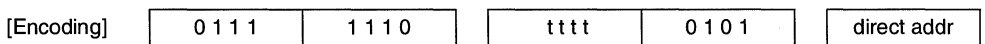


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (Rm) ← (dir8)

MOV WRj,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (WRj) ← (dir8)

MOV DRk,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	6	5

[Encoding]

0 1 1 1

1 1 1 0

u u u u

1 1 0 1

direct addr

Hex Code in: **Binary Mode = [A5][Encoding]**
 Source Mode = [Encoding]

Operation: MOV
 (DRk) ← (dir8)

MOV Rm,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2

[Encoding]

0 1 1 1

1 1 1 0

s s s s

0 0 1 1

direct addr

direct addr

Hex Code in: **Binary Mode = [A5][Encoding]**
 Source Mode = [Encoding]

Operation: MOV
 (Rm) ← (dir16)

MOV WRj,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]

0 1 1 1

1 1 1 0

t t t t

0 1 1 1

direct addr

direct addr

Hex Code in: **Binary Mode = [A5][Encoding]**
 Source Mode = [Encoding]

Operation: MOV
 (WRj) ← (dir16)

MOV DRk,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

[Encoding]

0 1 1 1

1 1 1 0

u u u u

1 1 1 1

direct addr

direct addr

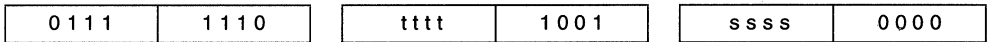
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (DRk) ← (dir16)

MOV Rm,@WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	2	2

[Encoding]



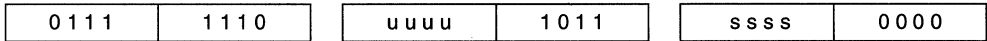
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (Rm) ← ((WRj))

MOV Rm,@DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]



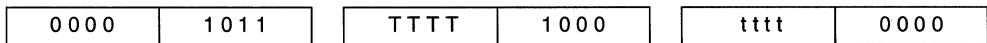
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (Rm) ← ((DRk))

MOV WRjd,@WRjs

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]



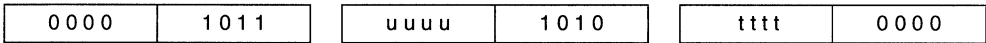
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (WRjd) ← ((WRjs))

MOV WRj, @DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	5	4

[Encoding]



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (WRj) ← ((DRk))

MOV dir8, Rm

	Binary Mode	Source Mode
Bytes:	4	3
States:	4†	3†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir8) ← (Rm)

MOV dir8, WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	5	4

[Encoding]



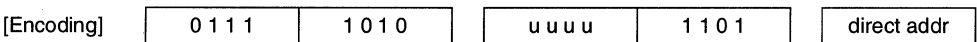
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir8) ← (WRj)

MOV dir8, DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	7	6

[Encoding]





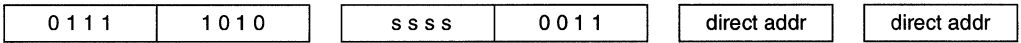
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir8) ← (DRk)

MOV dir16,Rm

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]



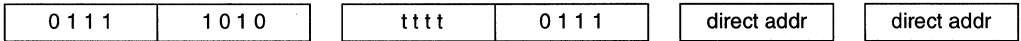
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir16) ← (Rm)

MOV dir16,WRj

	Binary Mode	Source Mode
Bytes:	5	4
States:	5	4

[Encoding]



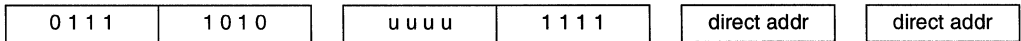
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir16) ← (WRj)

MOV dir16,DRk

	Binary Mode	Source Mode
Bytes:	5	4
States:	7	6

[Encoding]

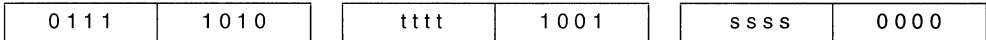


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (dir16) ← (DRk)

MOV @WRj,Rm

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]


Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: MOV
 ((WRj)) ← (Rm)

MOV @DRk,Rm

	Binary Mode	Source Mode
Bytes:	4	3
States:	5	4

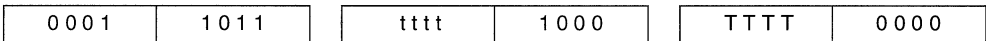
[Encoding]


Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: MOV
 ((DRk)) ← (Rm)

MOV @WRjd,WRjs

	Binary Mode	Source Mode
Bytes:	4	3
States:	5	4

[Encoding]


Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: MOV
 ((WRjd)) ← (WRjs)

MOV @DRk,WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	6	5

[Encoding]

0001	1011	uuuu	1010	tttt	0000
------	------	------	------	------	------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
((DRk)) ← (WRj)

MOV Rm,@WRj + dis16

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

[Encoding]

0000	1001	ssss	tttt	dis hi	dis low
------	------	------	------	--------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
(Rm) ← ((WRj)) + (dis)

MOV WRj,@WRj + dis16

	Binary Mode	Source Mode
Bytes:	5	4
States:	7	6

[Encoding]

0100	1001	tttt	TTTT	dis hi	dis low
------	------	------	------	--------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
(WRj) ← ((WRj)) + (dis)

MOV Rm,@DRk + dis16

	Binary Mode	Source Mode
Bytes:	5	4
States:	7	6

[Encoding]

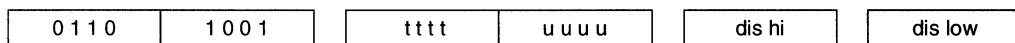
0010	1001	ssss	uuuu	dis hi	dis low
------	------	------	------	--------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
(Rm) ← ((DRk)) + (dis)

MOV WRj,@DRk + dis16

	Binary Mode	Source Mode
Bytes:	5	4
States:	8	7

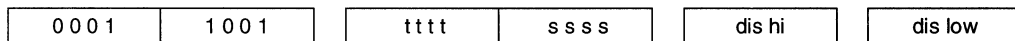
[Encoding]


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 (WRj) ← ((DRk) + (dis))

MOV @WRj + dis16,Rm

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

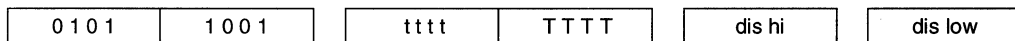
[Encoding]


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 ((WRj) + (dis)) ← (Rm)

MOV @WRj + dis16,WRj

	Binary Mode	Source Mode
Bytes:	5	4
States:	7	6

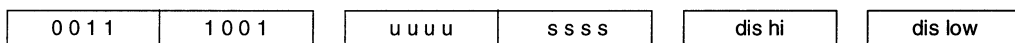
[Encoding]


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOV
 ((WRj) + (dis)) ← (WRj)

MOV @DRk + dis16,Rm

	Binary Mode	Source Mode
Bytes:	5	4
States:	7	6

[Encoding]


Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
((DRk) + (dis) ← (Rm))

MOV @DRk + dis16,WRj

	Binary Mode	Source Mode
Bytes:	5	4
States:	8	7

[Encoding]

0 1 1 1	1 0 0 1	u u u u	t t t t	dis hi	dis low
---------	---------	---------	---------	--------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
((DRk) + (dis) ← (WRj))

MOV <dest-bit>, <src-bit>

Function: Move bit data

Description: Copies the Boolean variable specified by the second operand into the location specified by the first operand. One of the operands must be the CY flag; the other may be any directly addressable bit. Does not affect any other register.

Flags:

CY	AC	OV	N	Z
3	—	—	—	—

Example: The CY flag is set, input Port 3 contains 11000101B, and output Port 1 contains 35H (00110101B). After executing the instruction sequence

```
MOV P1.3,CY
MOV CY,P3.3
MOV P1.2,CY
```

the CY flag is clear and Port 1 contains 39H (00111001B).

Variations

MOV bit51,CY

	Binary Mode	Source Mode
Bytes:	2	2
States:	2†	2†

†If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]	1 0 0 1	0 0 1 0	bit addr
------------	---------	---------	----------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: MOV
(bit51) ← (CY)

MOV CY,bit51

	Binary Mode	Source Mode
Bytes:	2	2
States:	1 [†]	1 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	1 0 1 0	0 0 1 0	bit addr
------------	---------	---------	----------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: MOV
(CY) ← (bit51)

MOV bit,CY

	Binary Mode	Source Mode
Bytes:	4	3
States:	4 [†]	3 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

1 0 1 0	1 0 0 1	1 0 0 1	0	y y y	direct addr
---------	---------	---------	---	-------	-------------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
(bit) ← (CY)

MOV CY,bit

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

1 0 1 0	1 0 0 1	1 0 1 0	0	y y y	direct addr
---------	---------	---------	---	-------	-------------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MOV
(CY) ← (bit)

MOV DPTR,#data16

Function: Load data pointer with a 16-bit constant

Description: Loads the 16-bit data pointer (DPTR) with the specified 16-bit constant. The high byte of the constant is loaded into the high byte of the data pointer (DPH). The low byte of the constant is loaded into the low byte of the data pointer (DPL).

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: After executing the instruction

```
MOV DPTR,#1234H
```

DPTR contains 1234H (DPH contains 12H and DPL contains 34H).

Binary Mode Source Mode

Bytes: 3 3
States: 2 2

[Encoding]	1 0 0 1	0 0 0 0	data hi	data low
------------	---------	---------	---------	----------

Hex Code in: **Binary Mode = [Encoding]**
 Source Mode = [Encoding]

Operation: MOV
 (DPTR) ← #data16

MOVC A,@A+<base-reg>

Function: Move code byte

Description: Loads the accumulator with a code byte or constant from program memory. The address of the byte fetched is the sum of the original unsigned 8-bit accumulator contents and the contents of a 16-bit base register, which may be the 16 LSBs of the data pointer or PC. In the latter case, the PC is incremented to the address of the following instruction before being added with the accumulator; otherwise the base register is not altered. Sixteen-bit addition is performed.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The accumulator contains a number between 0 and 3. The following instruction sequence translates the value in the accumulator to one of four values defined by the DB (define byte) directive.

```
RELPC:  INC      A
        MOVC    A,@A+PC
        RET
        DB      66H
        DB      77H
        DB      88H
        DB      99H
```

If the subroutine is called with the accumulator equal to 01H, it returns with 77H in the accumulator. The INC A before the MOVC instruction is needed to “get around” the RET instruction above the table. If several bytes of code separated the MOVC from the table, the corresponding number would be added to the accumulator instead.

Variations
MOVC A,@A+PC

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	6	6		
	[Encoding]	<table border="1"> <tr> <td>1 0 0 0</td> <td>0 0 1 1</td> </tr> </table>	1 0 0 0	0 0 1 1
1 0 0 0	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: MOVC
 $(PC) \leftarrow (PC) + 1$
 $(A) \leftarrow ((A) + (PC))$

MOVC A,@A+DPTR

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	6	6		
	[Encoding]	<table border="1"> <tr> <td>1 0 0 1</td> <td>0 0 1 1</td> </tr> </table>	1 0 0 1	0 0 1 1
1 0 0 1	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: MOVC
 $(A) \leftarrow ((A) + (DPTR))$

MOVH DRk,#data16

Function: Move immediate 16-bit data to the high word of a dword (double-word) register

Description: Moves 16-bit immediate data to the high word of a dword (32-bit) register. The low word of the dword register is unchanged.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The dword register DRk contains 5566 7788H. After the instruction
 MOVH DRk,#1122H
 executes, DRk contains 1122 7788H.

Variations**MOVH DRk,#data16**

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2

[Encoding]

0 1 1 1	1 0 1 0	u u u u	1 1 0 0	#data hi	#data low
---------	---------	---------	---------	----------	-----------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOVH
 (DRk).31:16 ← #data16

MOVS WRj,Rm

Function: Move 8-bit register to 16-bit register with sign extension

Description: Moves the contents of an 8-bit register to the low byte of a 16-bit register. The high byte of the 16-bit register is filled with the sign extension, which is obtained from the MSB of the 8-bit source register.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: Eight-bit register Rm contains 055H (01010101B) and the 16-bit register WRj contains 0FFFFH (11111111 11111111B). The instruction

MOVS WRj,Rm

moves the contents of register Rm (01010101B) to register WRj (i.e., WRj contains 00000000 01010101B).

Variations

MOVS WRj,Rm

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	2	1		
[Encoding]	0 0 0 1	1 0 1 0	t t t t	s s s s

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOVS
 (WRj).7-0 ← (Rm).7-0
 (WRj).15-8 ← MSB

MOVX <dest>,<src>

Function: Move external

Description: Transfers data between the accumulator and a byte in external data RAM. There are two types of instructions. One provides an 8-bit indirect address to external data RAM; the second provides a 16-bit indirect address to external data RAM.

In the first type of MOVX instruction, the contents of R0 or R1 in the current register bank provides an 8-bit address on port 0. Eight bits are sufficient for external I/O expansion decoding or for a relatively small RAM array. For larger arrays, any port pins can be used to output higher address bits. These pins would be controlled by an output instruction preceding the MOVX.

In the second type of MOVX instruction, the data pointer generates a 16-bit address. Port 2 outputs the upper eight address bits (from DPH) while port 0 outputs the lower eight address bits (from DPL).

For both types of moves in nonpage mode, the data is multiplexed with the lower address bits on port 0. In page mode, the data is multiplexed with the contents of P2 on port 2 (8-bit address) or with the upper address bits on port 2 (16-bit address).

It is possible in some situations to mix the two MOVX types. A large RAM array with its upper address lines driven by P2 can be addressed via the data pointer, or with code to output upper address bits to P2 followed by a MOVX instruction using R0 or R1.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The 8x930 controller is operating in nonpage mode. An external 256-byte RAM using multiplexed address/data lines (e.g., an Intel 8155 RAM/I/O/Timer) is connected to port 0. Port 3 provides control lines for the external RAM. ports 1 and 2 are used for normal I/O. R0 and R1 contain 12H and 34H. Location 34H of the external RAM contains 56H. After executing the instruction sequence

```
MOVX A,@R1
MOVX @R0,A
```

the accumulator and external RAM location 12H contain 56H.

Variations

MOVX A,@DPTR

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	5	5		
	[Encoding]	<table border="1"><tr><td>1 1 1 0</td><td>0 0 0 0</td></tr></table>	1 1 1 0	0 0 0 0
1 1 1 0	0 0 0 0			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: MOVX
(A) ← ((DPTR))

MOVX A,@Ri

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	3	3		
	[Encoding]	<table border="1"><tr><td>1 1 1 0</td><td>0 0 1 i</td></tr></table>	1 1 1 0	0 0 1 i
1 1 1 0	0 0 1 i			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: MOVX
(A) ← ((Ri))

MOVX @DPTR,A

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	5	5		
	[Encoding]	<table border="1"><tr><td>1 1 1 1</td><td>0 0 0 0</td></tr></table>	1 1 1 1	0 0 0 0
1 1 1 1	0 0 0 0			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: MOVX
((DPTR)) ← (A)

MOVX @Ri,A

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	4	4		
	[Encoding]	<table border="1"><tr><td>1 1 1 1</td><td>0 0 1 i</td></tr></table>	1 1 1 1	0 0 1 i
1 1 1 1	0 0 1 i			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: MOVX
 ((Ri)) ← (A)

MOVZ WRj,Rm

Function: Move 8-bit register to 16-bit register with zero extension

Description: Moves the contents of an 8-bit register to the low byte of a 16-bit register. The upper byte of the 16-bit register is filled with zeros.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: Eight-bit register Rm contains 055H (01010101B) and 16-bit register WRj contains 0FFFFH (11111111 11111111B). The instruction

MOVZ WRj,Rm

moves the contents of register Rm (01010101B) to register WRj. At the end of the operation, WRj contains 00000000 01010101B.

Variations
MOVZ WRj,Rm

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]

0 0 0 0	1 0 1 0	t t t t	s s s s
---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: MOVZ
 (WRj)7–0 ← (Rm)7–0
 (WRj)15–8 ← 0

MUL <dest>,<src>

Function: Multiply

Description: Multiplies the unsigned integer in the source register with the unsigned integer in the destination register. Only register addressing is allowed.

For 8-bit operands, the result is 16 bits. The most significant byte of the result is stored in the low byte of the word where the destination register resides. The least significant byte is stored in the following byte register. The OV flag is set if the product is greater than 255 (0FFH); otherwise it is cleared.

For 16-bit operands, the result is 32 bits. The most significant word is stored in the low word of the dword where the destination register resides. The least significant word is stored in the following word register. In this operation, the OV flag is set if the product is greater than 0FFFFH, otherwise it is cleared. The CY flag is always cleared. The N flag is set when the MSB of the result is set. The Z flag is set when the result is zero.

Flags:

CY	AC	OV	N	Z
0	—	3	3	3

Example: Register R1 contains 80 (50H or 10010000B) and register R0 contains 160 (0A0H or 10010000B). After executing the instruction

MUL R1,R0

which gives the product 12,800 (3200H), register R0 contains 32H (00110010B), register R1 contains 00H, the OV flag is set, and the CY flag is clear.

MUL Rmd,Rms

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	6	5		
[Encoding]	1 0 1 0	1 1 0 0	s s s s	S S S S

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MUL (8-bit operands)
if <dest> md = 0, 2, 4, ..., 14
Rmd ← high byte of the Rmd X Rms
Rmd+1 ← low byte of the Rmd X Rms
if <dest> md = 1, 3, 5, ..., 15
Rmd-1 ← high byte of the Rmd X Rms
Rmd ← low byte of the Rmd X Rms

MUL WRjd,WRjs

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	12	11		
[Encoding]	1 0 1 0	1 1 0 1	t t t t	t t t t

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: MUL (16-bit operands)
if <dest> jd = 0, 4, 8, ..., 28
WRjd ← high word of the WRjd X WRjs
WRjd+2 ← low word of the WRjd X WRjs
if <dest> jd = 2, 6, 10, ..., 30
WRjd-2 ← high word of the WRjd X WRjs
WRjd ← low word of the WRjd X WRjs

MUL AB
Function: Multiply

Description: Multiplies the unsigned 8-bit integers in the accumulator and register B. The low byte of the 16-bit product is left in the accumulator, and the high byte is left in register B. If the product is greater than 255 (0FFH) the OV flag is set; otherwise it is clear. The CY flag is always clear.

Flags:

CY	AC	OV	N	Z
0	—	3	3	3

Example: The accumulator contains 80 (50H) and register B contains 160 (0A0H). After executing the instruction

MUL AB

which gives the product 12,800 (3200H), register B contains 32H (00110010B), the accumulator contains 00H, the OV flag is set, and the CY flag is clear.

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	5	5		
	[Encoding]	<table border="1"> <tr> <td>1 0 1 0</td> <td>0 1 0 0</td> </tr> </table>	1 0 1 0	0 1 0 0
1 0 1 0	0 1 0 0			

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [Encoding]

Operation: MUL
 (A) ← low byte of (A) X (B)
 (B) ← high byte of (A) X (B)

NOP
Function: No operation

Description: Execution continues at the following instruction. Affects the PC register only.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: You want to produce a low-going output pulse on bit 7 of Port 2 that lasts exactly 11 states. A simple CLR-SETB sequence generates an eight-state pulse. (Each instruction requires four states to write to a port SFR.) You can insert three additional states (if no interrupts are enabled) with the following instruction sequence:

```
CLR P2.7
NOP
NOP
NOP
SETB P2.7
```

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding: 2px 10px;">0 0 0 0</td> <td style="padding: 2px 10px;">0 0 0 0</td> </tr> </table>	0 0 0 0	0 0 0 0
0 0 0 0	0 0 0 0			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: NOP
(PC) ← (PC) + 1

ORL <dest> <src>

Function: Logical-OR for byte variables

Description: Performs the bitwise logical-OR operation (V) between the specified variables, storing the results in the destination operand.

The destination operand can be a register, an accumulator or direct address.

The two operands allow twelve addressing mode combinations. When the destination is the accumulator, the source can be register, direct, register-indirect, or immediate addressing; when the destination is a direct address, the source can be the accumulator or immediate data. When the destination is register the source can be register, immediate, direct and indirect addressing.

Note: When this instruction is used to modify an output port, the value used as the original port data is read from the output data latch, not the input pins.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The accumulator contains 0C3H (11000011B) and R0 contains 55H (01010101B). After executing the instruction

```
ORL A,R0
```

the accumulator contains 0D7H (11010111B).

When the destination is a directly addressed byte, the instruction can set combinations of bits in any RAM location or hardware register. The pattern of bits to be set is determined by a mask byte, which may be a constant data value in the instruction or a variable computed in the accumulator at run time. After executing the instruction

ORL P1,#00110010B

sets bits 5, 4, and 1 of output Port 1.

ORL dir8,A

	Binary Mode	Source Mode
Bytes:	2	2
States:	2 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]	0 1 0 0	0 0 1 0	direct addr
------------	---------	---------	-------------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: ORL
(dir8) ← (dir8) V (A)

ORL dir8,#data

	Binary Mode	Source Mode
Bytes:	3	3
States:	3 [†]	3 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	0 1 0 0	0 0 1 1	direct addr	immed. data
------------	---------	---------	-------------	-------------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: ORL
(dir8) ← (dir8) V #data

ORL A,#data

	Binary Mode	Source Mode
Bytes:	2	2
States:	1	1

[Encoding]	0 1 0 0	0 1 0 0	immed. data
------------	---------	---------	-------------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: ORL
(A) ← (A) V #data

ORL A,dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	1†	1†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

0 1 0 0

0 1 0 1

direct addr

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: ORL
 (A) ← (A) V (dir8)

ORL A,@Ri

	Binary Mode	Source Mode
Bytes:	1	2
States:	2	3

[Encoding]

0 1 0 0

0 1 1 i

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: ORL
 (A) ← (A) V ((Ri))

ORL A,Rn

	Binary Mode	Source Mode
Bytes:	1	2
States:	1	2

[Encoding]

0 1 0 0

1 r r r

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: ORL
 (A) ← (A) V (Rn)

ORL Rmd,Rms

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]

0 1 0 0

1 1 0 0

s s s s

S S S S

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (Rmd) ← (Rmd) V (Rms)

ORL WRjd,WRjs

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	3	2		
[Encoding]	0 1 0 0	1 1 0 1	t t t t	T T T T

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (WRjd) ← (WRjd) V (WRjs)

ORL Rm,#data

	Binary Mode	Source Mode			
Bytes:	4	3			
States:	3	2			
[Encoding]	0 1 0 0	1 1 1 0	s s s s	0 0 0 0	#data

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (Rm) ← (Rm) V #data

ORL WRj,#data16

	Binary Mode	Source Mode				
Bytes:	5	4				
States:	4	3				
[Encoding]	0 1 0 0	1 1 1 0	t t t t	0 1 0 0	#data hi	#data low

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (WRj) ← (WRj) V #data16

ORL Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0-3), add 1 state.

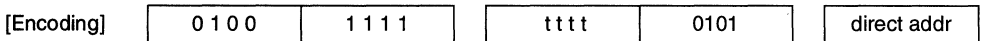


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (Rm) ← (Rm) V (dir8)

ORL WRj,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

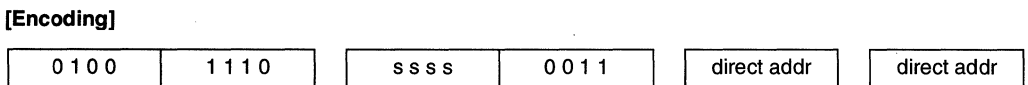


Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (WRj) ← (WRj) V (dir8)

ORL Rm,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: ORL
 (Rm) ← (Rm) V (dir16)

ORL WRj,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]

0100	1110	tttt	0111	direct addr	direct addr
------	------	------	------	-------------	-------------

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ORL
 $(WRj) \leftarrow (WRj) \vee (\text{dir16})$

ORL Rm,@WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]

0100	1110	tttt	1001	ssss	0000
------	------	------	------	------	------

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ORL
 $(Rm) \leftarrow (Rm) \vee ((WRj))$

ORL Rm,@DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]

0100	1110	uuuu	1011	ssss	0000
------	------	------	------	------	------

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ORL
 $(Rm) \leftarrow (Rm) \vee ((DRk))$

ORL CY,<src-bit>

Function: Logical-OR for bit variables

Description: Sets the CY flag if the Boolean value is a logical 1; leaves the CY flag in its current state otherwise. A slash ("/") preceding the operand in the assembly language indicates that the logical complement of the addressed bit is used as the source value, but the source bit itself is not affected.

Flags:

CY	AC	OV	N	Z
3	—	—	—	—

Example: Set the CY flag if and only if P1.0 = 1, ACC. 7 = 1, or OV = 0:

```
MOV CY,P1.0          ;LOAD CARRY WITH INPUT PIN P10
ORL CY,ACC.7 ;OR CARRY WITH THE ACC. BIT 7
ORL CY,OV           ;OR CARRY WITH THE INVERSE OF OV.
```

Variations

ORL CY,bit51

	Binary Mode	Source Mode
Bytes:	2	2
States:	1†	1†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	0 1 1 1	0 0 1 0	bit addr
------------	---------	---------	----------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: ORL
(CY) ← (CY) V (bit51)

ORL CY,/bit51

	Binary Mode	Source Mode
Bytes:	2	2
States:	1†	1†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]	1 0 1 0	0 0 0 0	bit addr
------------	---------	---------	----------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: ORL
(CY) ← (CY) V¬ (bit51)

ORL CY,bit

	Binary Mode	Source Mode
Bytes:	4	3
States:	3†	2†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

1 0 1 0	1 0 0 1	0 1 1 1	0	y y y	direct addr
---------	---------	---------	---	-------	-------------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: ORL
(CY) ← (CY) V (bit)

ORL CY/bit

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

1 0 1 0	1 0 0 1	1 1 1 0	0	y y y	direct addr
---------	---------	---------	---	-------	-------------

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: ORL
 (CY) ← (CY) V ← (bit)

POP <src>

Function: Pop from stack

Description: Reads the contents of the on-chip RAM location addressed by the stack pointer, then decrements the stack pointer by one. The value read at the original RAM location is transferred to the newly addressed location, which can be 8-bit or 16-bit.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The stack pointer contains 32H and on-chip RAM locations 30H through 32H contain 01H, 23H, and 20H, respectively. After executing the instruction sequence

```
POP DPH
POP DPL
```

the stack pointer contains 30H and the data pointer contains 0123H. After executing the instruction

```
POP SP
```

the stack pointer contains 20H. Note that in this special case the stack pointer was decremented to 2FH before it was loaded with the value popped (20H).

Variations
POP dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	3	3

[Encoding]

1 1 0 1	0 0 0 0	direct addr
---------	---------	-------------

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]



Operation: POP
 (dir8) ← ((SP))
 (SP) ← (SP) - 1

POP Rm

Bytes: 3 2
States: 3 2

[Encoding]	1101	1010	ssss	1000
------------	------	------	------	------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: POP
 (Rm) ← ((SP))
 (SP) ← (SP) - 1

POP WRj

	Binary Mode	Source Mode
Bytes:	3	2
States:	5	4

[Encoding]	1101	1010	tttt	1001
------------	------	------	------	------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: POP
 (SP) ← (SP) - 1
 (WRj) ← ((SP))
 (SP) ← (SP) - 1

POP DRk

	Binary Mode	Source Mode
Bytes:	3	2
States:	10	9

[Encoding]	1101	1010	uuuu	1011
------------	------	------	------	------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: POP
 (SP) ← (SP) - 3
 (DRk) ← ((SP))
 (SP) ← (SP) - 1

PUSH <dest>

Function: Push onto stack

Description: Increments the stack pointer by one. The contents of the specified variable are then copied into the on-chip RAM location addressed by the stack pointer.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: On entering an interrupt routine, the stack pointer contains 09H and the data pointer contains 0123H. After executing the instruction sequence

PUSH DPL
PUSH DPH

the stack pointer contains 0BH and on-chip RAM locations 0AH and 0BH contain 01H and 23H, respectively.

Variations
PUSH dir8

	Binary Mode	Source Mode	
Bytes:	2	2	
States:	4	4	
[Encoding]	1 1 0 0	0 0 0 0	direct addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: PUSH
(SP) ← (SP) + 1
((SP)) ← (dir8)

PUSH #data

	Binary Mode	Source Mode			
Bytes:	4	3			
States:	4	3			
[Encoding]	1 1 0 0	1 0 1 0	0 0 0 0	0 0 1 0	#data

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: PUSH
(SP) ← (SP) + 1
((SP)) ← #data

PUSH #data16

	Binary Mode	Source Mode				
Bytes:	5	4				
States:	6	5				
[Encoding]	1 1 0 0	1 0 1 0	0 0 0 0	0 1 1 0	#data hi	#data lo

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: PUSH
 $(SP) \leftarrow (SP) + 2$
 $((SP)) \leftarrow \text{MSB of \#data16}$
 $((SP)) \leftarrow \text{LSB of \#data16}$

PUSH Rm

	Binary Mode	Source Mode
Bytes:	3	2
States:	4	3

[Encoding]	1 1 0 0	1 0 1 0	s s s s	1 0 0 0
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: PUSH
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (Rm)$

PUSH WRj

	Binary Mode	Source Mode
Bytes:	3	2
States:	5	4

[Encoding]	1 1 0 0	1 0 1 0	t t t t	1 0 0 1
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: PUSH
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (WRj)$
 $(SP) \leftarrow (SP) + 1$

PUSH DRk

	Binary Mode	Source Mode
Bytes:	3	2
States:	9	8

[Encoding]	1 1 0 0	1 0 1 0	u u u u	1 0 1 1
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: PUSH
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (DRk)$
 $(SP) \leftarrow (SP) + 3$

RET

Function: Return from subroutine

Description: Pops the high and low bytes of the PC successively from the stack, decrementing the stack pointer by two. Program execution continues at the resulting address, which normally is the instruction immediately following ACALL or LCALL.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The stack pointer contains 0BH and on-chip RAM locations 0AH and 0BH contain 01H and 23H, respectively. After executing the instruction,

RET

the stack pointer contains 09H and program execution continues at location 0123H.

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	7	7		
	[Encoding]	<table border="1"> <tr> <td>0 0 1 0</td> <td>0 0 1 0</td> </tr> </table>	0 0 1 0	0 0 1 0
0 0 1 0	0 0 1 0			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: RET
(PC).15:8 ← ((SP))
(SP) ← (SP) - 1
(PC).7:0 ← ((SP))
(SP) ← (SP) - 1

RETI

Function: Return from interrupt

Description: This instruction pops two or four bytes from the stack, depending on the INTR bit in the CONFIG1 register.

If INTR = 0, RETI pops the high and low bytes of the PC successively from the stack and uses them as the 16-bit return address in region FF:. The stack pointer is decremented by two. No other registers are affected, and neither PSW nor PSW1 is automatically restored to its pre-interrupt status.

If INTR = 1, RETI pops four bytes from the stack: PSW1 and the three bytes of the PC. The three bytes of the PC are the return address, which can be anywhere in the 16-Mbyte memory space. The stack pointer is decremented by four. PSW1 is restored to its pre-interrupt status, but PSW is **not** restored to its pre-interrupt status. No other registers are affected.

For either value of INTR, hardware restores the interrupt logic to accept additional interrupts at the same priority level as the one just processed. Program execution continues at the return address, which normally is the instruction immediately after the point at which the interrupt request was detected. If an interrupt of the same or lower priority is pending when the RETI instruction is executed, that one instruction is executed before the pending interrupt is processed.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: INTR = 0. The stack pointer contains 0BH. An interrupt was detected during the instruction ending at location 0122H. On-chip RAM locations 0AH and 0BH contain 01H and 23H, respectively. After executing the instruction

RETI

the stack pointer contains 09H and program execution continues at location 0123H.

	Binary Mode	Source Mode
Bytes:	1	1
States (INTR = 0):	9	9
States (INTR = 1):	12	12

[Encoding]

0 0 1 1	0 0 1 0
---------	---------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation for INTR = 0:

RETI
 $(PC).15:8 \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$
 $(PC).7:0 \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$

Operation for INTR = 1:

RETI
 $(PC).15:8 \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$
 $PC.7:0 \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$
 $(PC).23:16 \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$
 $PSW1 \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$

RL A

Function: Rotate accumulator left

Description: Rotates the eight bits in the accumulator one bit to the left. Bit 7 is rotated into the bit 0 position.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The accumulator contains 0C5H (11000101B). After executing the instruction,

RL A

the accumulator contains 8BH (10001011B); the CY flag is unaffected.

	Binary Mode	Source Mode	
Bytes:	1	1	
States:	1	1	
	[Encoding]	0 0 1 0	0 0 1 1

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: RL
(A).a+1 ← (A).a
(A).0 ← (A).7

RLC A

Function: Rotate accumulator left through the carry flag

Description: Rotates the eight bits in the accumulator and the CY flag one bit to the left. Bit 7 moves into the CY flag position and the original state of the CY flag moves into bit 0 position.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example: The accumulator contains 0C5H (11000101B) and the CY flag is clear. After executing the instruction

RLC A

the accumulator contains 8AH (10001010B) and the CY flag is set.

	Binary Mode	Source Mode	
Bytes:	1	1	
States:	1	1	
	[Encoding]	0 0 1 1	0 0 1 1

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: RLC
(A).a+1 ← (A).a
(A).0 ← (CY)
(CY) ← (A).7

RR A

Function: Rotate accumulator right

Description: Rotates the 8 or 16 bits in the accumulator one bit to the right. Bit 0 is moved into the bit 7 or 15 position.

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The accumulator contains 0C5H (11000101B). After executing the instruction
RR A

the accumulator contains 0E2H (11100010B) and the CY flag is unaffected.

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1"> <tr> <td>0 0 0 0</td> <td>0 0 1 1</td> </tr> </table>	0 0 0 0	0 0 1 1
0 0 0 0	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: RR
(A).a ← (A).a+1
(A).7 ← (A).0

RRC A

Function: Rotate accumulator right through carry flag

Description: Rotates the eight bits in the accumulator and the CY flag one bit to the right. Bit 0 moves into the CY flag position; the original value of the CY flag moves into the bit 7 position.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example: The accumulator contains 0C5H (11000101B) and the CY flag is clear. After executing the instruction

RRC A

the accumulator contains 62 (01100010B) and the CY flag is set.

	Binary Mode	Source Mode		
Bytes:	1	1		
States:	1	1		
	[Encoding]	<table border="1"> <tr> <td>0 0 0 1</td> <td>0 0 1 1</td> </tr> </table>	0 0 0 1	0 0 1 1
0 0 0 1	0 0 1 1			

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: RRC
(A).a ← (A).a+1
(A).7 ← (CY)
(CY) ← (A).0

SETB <bit>

Function: Set bit

Description: Sets the specified bit to one. SETB can operate on the CY flag or any directly addressable bit.

Flags: No flags are affected except the CY flag for instruction with CY as the operand.

CY	AC	OV	N	Z
3	—	—	—	—

Example: The CY flag is clear and output Port 1 contains 34H (00110100B). After executing the instruction sequence

```
SETB CY
SETB P1.0
```

the CY flag is set and output Port 1 contains 35H (00110101B).

SETB bit51

Binary Mode Source Mode

Bytes: 2 2
States: 2† 2†

†If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

1 1 0 1

0 0 1 0

bit addr

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: SETB
 (bit51) ← 1

SETB CY

Binary Mode Source Mode

Bytes: 1 1
States: 1 1

[Encoding]

1 1 0 1

0 0 1 1

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: SETB
 (CY) ← 1

SETB bit

Binary Mode Source Mode

Bytes: 4 3
States: 4† 3†

†If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

1 0 1 0

1 0 0 1

1 1 0 1

0

y y y

direct addr

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: SETB
(bit) ← 1

SJMP rel

Function: Short jump

Description: Program control branches unconditionally to the specified address. The branch destination is computed by adding the signed displacement in the second instruction byte to the PC, after incrementing the PC twice. Therefore, the range of destinations allowed is from 128 bytes preceding this instruction to 127 bytes following it.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The label "RELADR" is assigned to an instruction at program memory location 0123H. The instruction

SJMP RELADR

assembles into location 0100H. After executing the instruction, the PC contains 0123H.

(Note: In the above example, the instruction following SJMP is located at 102H. Therefore, the displacement byte of the instruction is the relative offset (0123H–0102H) = 21H. Put another way, an SJMP with a displacement of 0FEH would be a one-instruction infinite loop.)

	Binary Mode	Source Mode	
Bytes:	2	2	
States:	4	4	
	[Encoding]	1 0 0 0	0 0 0 0 rel. addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: SJMP
(PC) ← (PC) + 2
(PC) ← (PC) + rel

SLL <src>

Function: Shift logical left by 1 bit

Description: Shifts the specified variable to the left by 1 bit, replacing the LSB with zero. The bit shifted out (MSB) is stored in the CY bit.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example: Register 1 contains 0C5H (11000101B). After executing the instruction
SLL register 1

Register 1 contains 8AH (10001010B) and CY = 1.

Variations

SLL Rm

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	2	1		
[Encoding]	0 0 1 1	1 1 1 0	s s s s	0 0 0 0

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: SLL
(Rm).a+1 ← (Rm).a
(Rm).0 ← 0
CY ← (Rm).7

SLL WRj

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	2	1		
[Encoding]	0 0 1 1	1 1 1 0	t t t t	0 1 0 0

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: SLL
WRj).b+1 ← (WRj).b
(WRj).0 ← 0
CY ← (WRj).15

SRA <src>

Function: Shift arithmetic right by 1 bit

Description: Shifts the specified variable to the arithmetic right by 1 bit. The MSB is unchanged. The bit shifted out (LSB) is stored in the CY bit.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example: Register 1 contains 0C5H (11000101B). After executing the instruction

SRA register 1

Register 1 contains 0E2H (11100010B) and CY = 1.

Variations

SRA Rm

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 0	1 1 1 0	s s s s	0 0 0 0
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SRA
 (Rm).7 ← (Rm).7
 (Rm).a ← (Rm).a+1
 CY ← (Rm).0

SRA WRj

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 0	1 1 1 0	t t t t	0 1 0 0
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SRA
 (WRj).15 ← (WRj).15
 (WRj).b ← (WRj).b+1
 CY ← (WRj).0

SRL <src>

Function: Shift logical right by 1 bit

Description: SRL shifts the specified variable to the right by 1 bit, replacing the MSB with a zero. The bit shifted out (LSB) is stored in the CY bit.

Flags:

CY	AC	OV	N	Z
3	—	—	3	3

Example: Register 1 contains 0C5H (11000101B). After executing the instruction

SRL register 1

Register 1 contains 62H (01100010B) and CY = 1.

SRL Rm

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 1	1 1 1 0	s s s s	0 0 0 0
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SRL
 (Rm).7 ← 0
 (Rm).a ← (Rm).a+1
 CY ← (Rm).0

SRL WRj

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]	0 0 0 1	1 1 1 0	t t t t	0 1 0 0
------------	---------	---------	---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SRL
 (WRj).15 ← 0
 (WRj).b ← (WRj).b+1
 CY ← (WRj).0

SUB <dest>,<src>

Function: Subtract

Description: Subtracts the specified variable from the destination operand, leaving the result in the destination operand. SUB sets the CY (borrow) flag if a borrow is needed for bit 7. Otherwise, CY is clear.

When subtracting signed integers, the OV flag indicates a negative number produced when a negative value is subtracted from a positive value, or a positive result when a positive number is subtracted from a negative number.

Bit 7 in this description refers to the most significant byte of the operand (8, 16, or 32 bit).

The source operand allows four addressing modes: immediate, indirect, register and direct.

Flags:

CY	AC	OV	N	Z
3	✓†	3	3	3

†For word and dword subtractions, AC is not affected.

Example: Register 1 contains 0C9H (11001001B) and register 0 contains 54H (01010100B). After executing the instruction

SUB R1,R0

register 1 contains 75H (01110101B), the CY and AC flags are clear, and the OV flag is set.

Variations

SUB Rmd,Rms

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	2	1		
[Encoding]	1 0 0 1	1 1 0 0	s s s s	S S S S

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (Rmd) ← (Rmd) – (Rms)

SUB WRjd,WRjs

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	3	2		
[Encoding]	1 0 0 1	1 1 0 1	t t t t	T T T T

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (WRjd) ← (WRjd) – (WRjs)

SUB DRkd,DRks

	Binary Mode	Source Mode		
Bytes:	3	2		
States:	5	4		
[Encoding]	1 0 0 1	1 1 1 1	u u u u	U U U U

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (DRkd) ← (DRkd) – (DRks)

SUB Rm,#data

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2



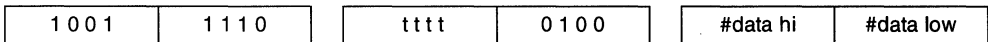
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (Rm) ← (Rm) – #data

SUB WRj,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]



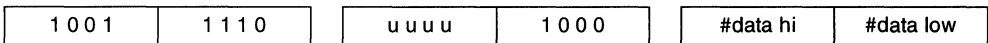
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (WRj) ← (WRj) – #data16

SUB DRk,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	6	5

[Encoding]



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (DRk) ← (DRk) – #data16

SUB Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]



Operation: SUB
 $(Rm) \leftarrow (Rm) - (dir8)$

SUB WRj,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]

1 0 0 1	1 1 1 0
---------	---------

tttt	0 1 0 1
------	---------

direct addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 $(WRj) \leftarrow (WRj) - (dir8)$

SUB Rm,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2

[Encoding]

1 0 0 1	1 1 1 0
---------	---------

s s s s	0 0 1 1
---------	---------

direct addr

direct addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 $(Rm) \leftarrow (Rm) - (dir16)$

SUB WRj,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]

1 0 0 1	1 1 1 0
---------	---------

tttt	0 1 1 1
------	---------

direct addr

direct addr

Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 $(WRj) \leftarrow (WRj) - (dir16)$

SUB Rm,@WRj

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]

1 0 0 1	1 1 1 0
---------	---------

tttt	1 0 0 1
------	---------

s s s s	0 0 0 0
---------	---------

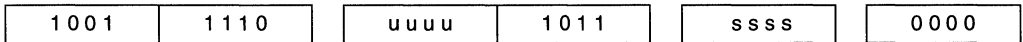
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (Rm) ← (Rm) – ((WRj))

SUB Rm,@DRk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]



Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: SUB
 (Rm) ← (Rm) – ((DRk))

SUBB A,<src-byte>

Function: Subtract with borrow

Description: SUBB subtracts the specified variable and the CY flag together from the accumulator, leaving the result in the accumulator. SUBB sets the CY (borrow) flag if a borrow is needed for bit 7, and clears CY otherwise. (If CY was set before executing a SUBB instruction, this indicates that a borrow was needed for the previous step in a multiple precision subtraction, so the CY flag is subtracted from the accumulator along with the source operand.) AC is set if a borrow is needed for bit 3, and cleared otherwise. OV is set if a borrow is needed into bit 6, but not into bit 7, or into bit 7, but not bit 6.

When subtracting signed integers the OV flag indicates a negative number produced when a negative value is subtracted from a positive value, or a positive result when a positive number is subtracted from a negative number.

Bit 6 and bit 7 in this description refer to the most significant byte of the operand (8, 16, or 32 bit).

The source operand allows four addressing modes: register, direct, register-indirect, or immediate.

Flags:

CY	AC	OV	N	Z
3	3	3	3	3

Example: The accumulator contains 0C9H (11001001B), register 2 contains 54H (01010100B), and the CY flag is set. After executing the instruction

SUBB A,R2

the accumulator contains 74H (01110100B), the CY and AC flags are clear, and the OV flag is set.

Notice that 0C9H minus 54H is 75H. The difference between this and the above result is due to the CY (borrow) flag being set before the operation. If the state of the carry is not known before starting a single or multiple-precision subtraction, it should be explicitly cleared by a CLR CY instruction.

Variations

SUBB A,#data

	Binary Mode	Source Mode	
Bytes:	2	2	
States:	1	1	
	[Encoding]	1 0 0 1	0 1 0 0
			immed. data

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: SUBB
(A) ← (A) – (CY) – #data

SUBB A,dir8

	Binary Mode	Source Mode	
Bytes:	2	2	
States:	1†	1†	
		†If this instruction addresses a port (Px, x = 0–3), add 1 state.	
	[Encoding]	1 0 0 1	0 1 0 1
			direct addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: SUBB
(A) ← (A) – (CY) – (dir8)

SUBB A,@Ri

	Binary Mode	Source Mode	
Bytes:	1	2	
States:	2	3	
	[Encoding]	1 0 0 1	0 1 1 i

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: SUBB
(A) ← (A) – (CY) – ((Ri))

SUBB A,Rn

	Binary Mode	Source Mode	
Bytes:	1	2	
States:	1	2	
	[Encoding]	1 0 0 1	1 r r r

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [A5][Encoding]

Operation: SUBB
 $(A) \leftarrow (A) - (CY) - (Rn)$

SWAP A

Function: Swap nibbles within the accumulator

Description: Interchanges the low and high nibbles (4-bit fields) of the accumulator (bits 3–0 and bits 7–4). This operation can also be thought of as a 4-bit rotate instruction.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The accumulator contains 0C5H (11000101B). After executing the instruction
 SWAP A
 the accumulator contains 5CH (01011100B).

	Binary Mode	Source Mode	
Bytes:	1	1	
States:	2	2	
	[Encoding]	1 1 0 0	0 1 0 0

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: SWAP
 $(A).3:0 \rightarrow \leftarrow (A).7:4$

TRAP

Function: Causes interrupt call

Description: Causes an interrupt call that is vectored through location 0FF007BH. The operation of this instruction is not affected by the state of the interrupt enable flag in PSW0 and PSW1. Interrupt calls can not occur immediately following this instruction. This instruction is intended for use by Intel-provided development tools. These tools do not support user application of this instruction.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: The instruction
 TRAP
 causes an interrupt call to location 0FF007BH during normal operation.

	Binary Mode	Source Mode
Bytes:	2	1
States (2 bytes):	11	10
States (4 bytes):	16	15

[Encoding]

1 0 1 1

1 0 0 1

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: TRAP
SP ← SP - 2
(SP) ← PC
PC ← (0FF007BH)

XCH A,<byte>

Function: Exchange accumulator with byte variable

Description: Loads the accumulator with the contents of the specified variable, at the same time writing the original accumulator contents to the specified variable. The source/destination operand can use register, direct, or register-indirect addressing.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: R0 contains the address 20H, the accumulator contains 3FH (00111111B) and on-chip RAM location 20H contains 75H (01110101B). After executing the instruction

XCH A,@R0

RAM location 20H contains 3FH (00111111B) and the accumulator contains 75H (01110101B).

Variations**XCH A,dir8**

	Binary Mode	Source Mode
Bytes:	2	2
States:	3†	3†

†if this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

1 1 0 0

0 1 0 1

direct addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: XCH
(A) → ← (dir8)

XCH A,@Ri

	Binary Mode	Source Mode			
Bytes:	1	2			
States:	4	5			
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 1 0 0</td> <td style="padding: 2px 10px;">0 1 1 i</td> </tr> </table>		1 1 0 0	0 1 1 i
1 1 0 0	0 1 1 i				

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: XCH
 (A) → ← ((Ri))

XCH A,Rn

	Binary Mode	Source Mode			
Bytes:	1	2			
States:	3	4			
	[Encoding]	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">1 1 0 0</td> <td style="padding: 2px 10px;">1 r r r</td> </tr> </table>		1 1 0 0	1 r r r
1 1 0 0	1 r r r				

Hex Code in: Binary Mode = [Encoding]
 Source Mode = [A5][Encoding]

Operation: XCH
 (A) → ← (Rn)

Variations

XCHD A,@Ri

Function: Exchange digit

Description: Exchanges the low nibble of the accumulator (bits 3-0), generally representing a hexadecimal or BCD digit, with that of the on-chip RAM location indirectly addressed by the specified register. Does not affect the high nibble (bits 7-4) of either register.

Flags:

CY	AC	OV	N	Z
—	—	—	—	—

Example: R0 contains the address 20H, the accumulator contains 36H (00110110B), and on-chip RAM location 20H contains 75H (01110101B). After executing the instruction

XCHD A,@R0

on-chip RAM location 20H contains 76H (01110110B) and 35H (00110101B) in the accumulator.

	Binary Mode	Source Mode
Bytes:	1	2
States:	4	5

[Encoding]

1 1 0 1

0 1 1 i

Hex Code in: **Binary Mode = [Encoding]**
Source Mode = [Encoding]

Operation: XCHD
 (A).3:0 → ← ((Ri)).3:0

XRL <dest>,<src>

Function: Logical Exclusive-OR for byte variables

Description: Performs the bitwise logical Exclusive-OR operation (∨) between the specified variables, storing the results in the destination. The destination operand can be the accumulator, a register, or a direct address.

The two operands allow 12 addressing mode combinations. When the destination is the accumulator or a register, the source addressing can be register, direct, register-indirect, or immediate; when the destination is a direct address, the source can be the accumulator or immediate data.

(Note: When this instruction is used to modify an output port, the value used as the original port data is read from the output data latch, not the input pins.)

Flags:

CY	AC	OV	N	Z
—	—	—	3	3

Example: The accumulator contains 0C3H (11000011B) and R0 contains 0AAH (10101010B). After executing the instruction

```
XRL A,R0
```

the accumulator contains 69H (01101001B).

When the destination is a directly addressed byte, this instruction can complement combinations of bits in any RAM location or hardware register. The pattern of bits to be complemented is then determined by a mask byte, either a constant contained in the instruction or a variable computed in the accumulator at run time. The instruction

```
XRL P1,#00110001B
```

complements bits 5, 4, and 0 of output Port 1.

Variations**XRL dir8,A**

	Binary Mode	Source Mode
Bytes:	2	2
States:	2 [†]	2 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 2 states.

[Encoding]

0 1 1 0

0 0 1 0

direct addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: XRL
(dir8) ← (dir8) ∨ (A)

XRL dir8,#data

	Binary Mode	Source Mode
Bytes:	3	3
States:	3 [†]	3 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

0 1 1 0

0 0 1 1

direct addr

immed. data

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: XRL
(dir8) ← (dir8) ∨ #data

XRL A,#data

	Binary Mode	Source Mode
Bytes:	2	2
States:	1	1

[Encoding]

0 1 1 0

0 1 0 0

immed. data

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: XRL
(A) ← (A) ∨ #data

XRL A,dir8

	Binary Mode	Source Mode
Bytes:	2	2
States:	1 [†]	1 [†]

[†]If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

0 1 1 0

0 1 0 1

direct addr

Hex Code in: Binary Mode = [Encoding]
Source Mode = [Encoding]

Operation: XRL
(A) ← (A) ∨ (dir8)

XRL A,@Ri

	Binary Mode	Source Mode
Bytes:	1	2
States:	2	3

[Encoding]

0 1 1 0	0 1 1 i
---------	---------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: XRL
(A) ← (A) ∨ ((Ri))

XRL A,Rn

	Binary Mode	Source Mode
Bytes:	1	2
States:	1	2

[Encoding]

0 1 1 0	1 r r r
---------	---------

Hex Code in: Binary Mode = [Encoding]
Source Mode = [A5][Encoding]

Operation: XRL
(A) ← (A) ∨ (Rn)

XRL Rmd,Rms

	Binary Mode	Source Mode
Bytes:	3	2
States:	2	1

[Encoding]

0 1 1 0	1 1 0 0
---------	---------

s s s s	S S S S
---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: XRL
(Rmd) ← (Rmd) ∨ (Rms)

XRL WRjd,WRjs

	Binary Mode	Source Mode
Bytes:	3	2
States:	3	2

[Encoding]

0 1 1 0	1 1 0 1
---------	---------

t t t t	T T T T
---------	---------

Hex Code in: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: XRL
(WRds) ← (WRjd) ∨ (WRjs)

XRL Rm,#data

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]

0 1 1 0	1 1 1 0
---------	---------

s s s s	0 0 0 0
---------	---------

#data

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: XRL
 (Rm) ← (Rm) ∨ #data

XRL WRj,#data16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]

0 1 1 0	1 1 1 0
---------	---------

t t t t	0 1 0 0
---------	---------

#data hi

#data low

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: XRL
 (WRj) ← (WRj) ∨ #data16

XRL Rm,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	3†	2†

†If this instruction addresses a port (Px, x = 0–3), add 1 state.

[Encoding]

0 1 1 0	1 1 1 0
---------	---------

s s s s	0 0 0 1
---------	---------

direct addr

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

Operation: XRL
 (Rm) ← (Rm) ∨ (dir8)

XRL WRj,dir8

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]

0 1 1 0	1 1 1 0
---------	---------

t t t t	0 1 0 1
---------	---------

direct addr

Hex Code in: **Binary Mode = [A5][Encoding]**
Source Mode = [Encoding]

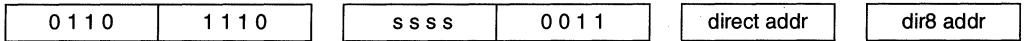
Operation: XRL
 (WRj) ← (WRj) ∨ (dir8)



XRL Rm,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	3	2

[Encoding]



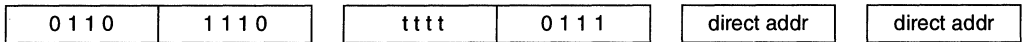
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: XRL
 (Rm) ← (Rm) ∨ (dir16)

XRL WRj,dir16

	Binary Mode	Source Mode
Bytes:	5	4
States:	4	3

[Encoding]



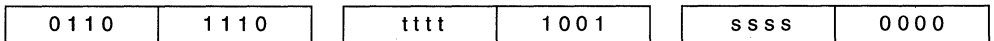
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: XRL
 (WRj) ← (WRj) ∨ (dir16)

XRL Rm,@Wrj

	Binary Mode	Source Mode
Bytes:	4	3
States:	3	2

[Encoding]



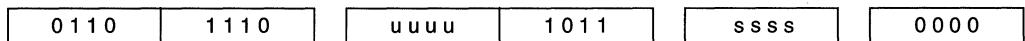
Hex Code in: Binary Mode = [A5][Encoding]
 Source Mode = [Encoding]

Operation: XRL
 (Rm) ← (Rm) ∨ ((WRj))

XRL Rm,@Drk

	Binary Mode	Source Mode
Bytes:	4	3
States:	4	3

[Encoding]





Hex Code In: Binary Mode = [A5][Encoding]
Source Mode = [Encoding]

Operation: XRL
(Rm) ← (Rm) ∨ ((DRk))





B

Signal Descriptions







APPENDIX B SIGNAL DESCRIPTIONS

This appendix provides reference information for the external signals of the 8x930. Pin assignments for the device are shown in Figure B-1 (8x930Ax) and Figure B-2 (8x930Hx) and are listed by functional category in Table B-1.

Table B-2 describes each of the signals. It lists the signal type (input, output, power, or ground) and the alternative functions of multi-function pins. Table B-3 shows how configuration bits RD1:0 (referred to in Table B-2) configure the A17, A16, RD#, WR# and PSEN# pins for external memory accesses.

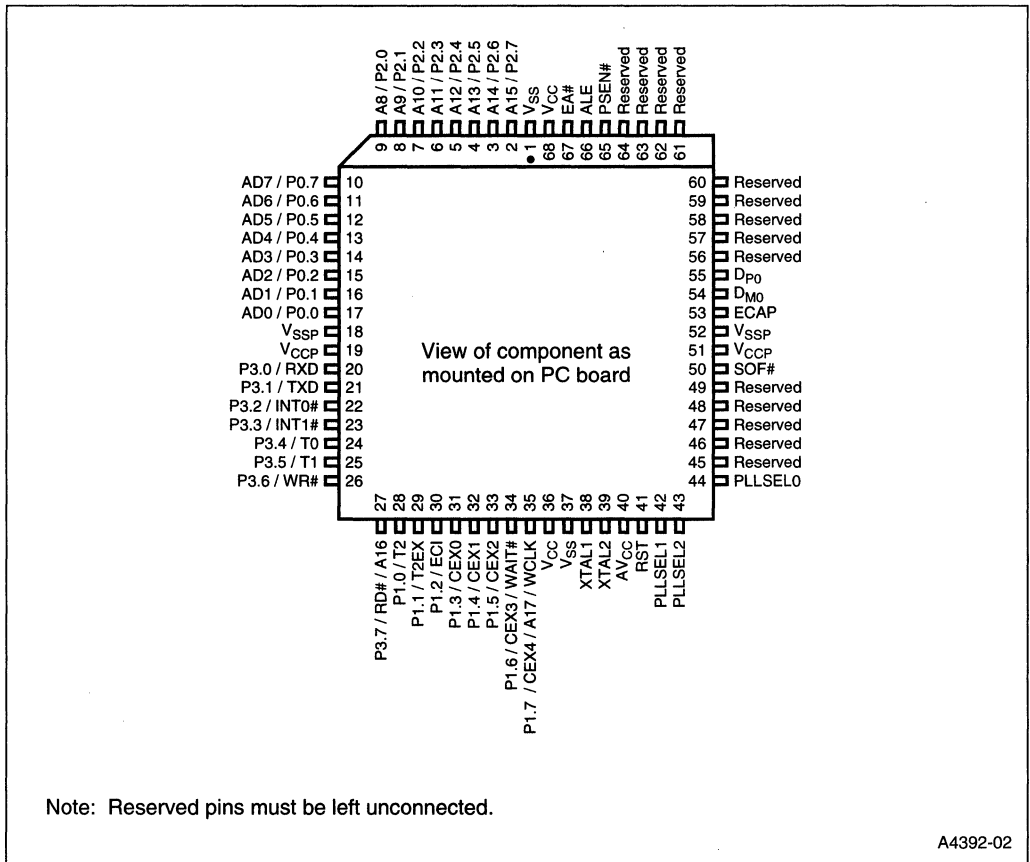


Figure B-1. 8x930Ax 68-pin PLCC Package

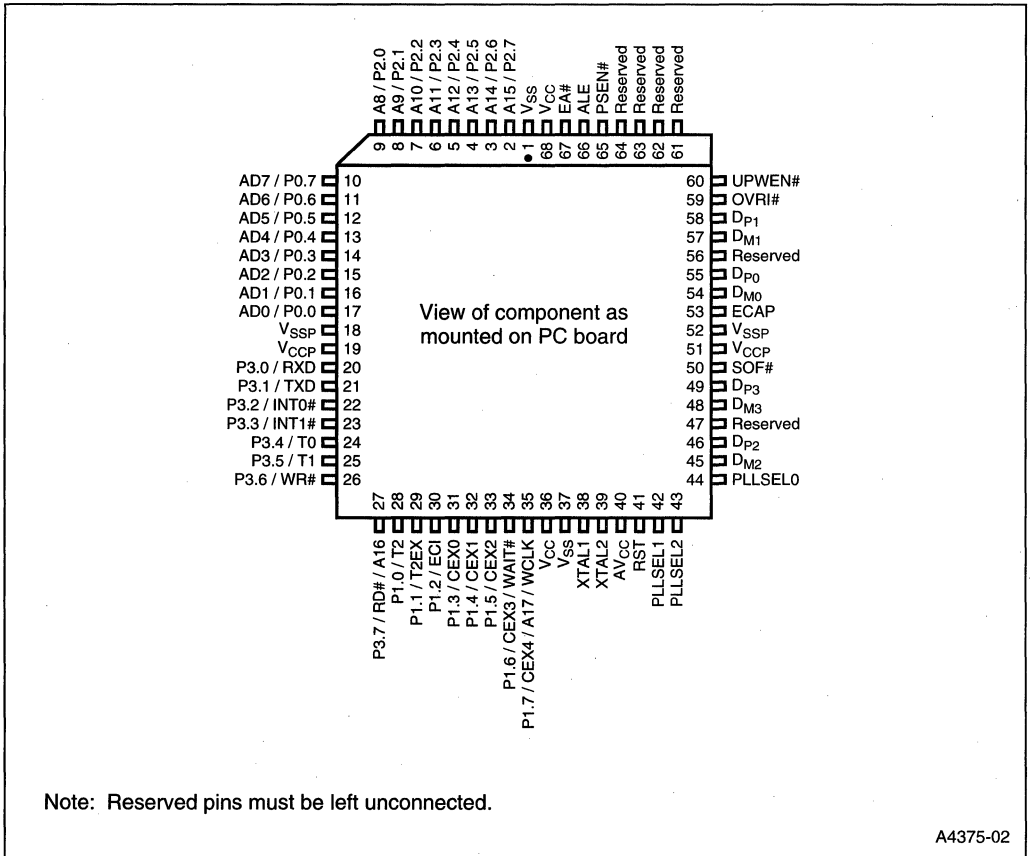


Figure B-2. 8x930Hx 68-pin PLCC Package

Table B-1. 68-pin PLCC Signal Assignments Arranged by Functional Category

Address & Data		Input/Output		USB	
Name	Pin	Name	Pin	Name	Pin
AD0/P0.0	17	P1.0/T2	28	PLLSEL0	44
AD1/P0.1	16	P1.1/T2EX	29	PLLSEL1	42
AD2/P0.2	15	P1.2/ECI	30	PLLSEL2	43
AD3/P0.3	14	P1.3/CEX0	31	D _{M0}	54
AD4/P0.4	13	P1.4/CEX1	32	D _{P0}	55
AD5/P0.5	12	P1.5/CEX2	33	D _{M1} †	57
AD6/P0.6	11	P1.6/CEX3/WAIT#	34	D _{P1} †	58
AD7/P0.7	10	P1.7/CEX4/A17/WCLK	35	D _{M2} †	45
A8/P2.0	9	P3.0/RXD	20	D _{P2} †	46
A9/P2.1	8	P3.1/TXD	21	D _{M3} †	48
A10/P2.2	7	P3.4/T0	24	D _{P3} †	49
A11/P2.3	6	P3.5/T1	25	SOF#	50
A12/P2.4	5			ECAP	53
A13/P2.5	4			OVRI# †	59
A14/P2.6	3			UPWEN# †	60
A15/P2.7	2				
P3.7/RD#/A16	27				
P1.7/CEX4/A17/WCLK	35				

Processor Control		Power & Ground		Bus Control & Status	
Name	Pin	Name	Pin	Name	Pin
P3.2/INT0#	22	V _{CC}	36, 68	P3.6/WR#	26
P3.3/INT1#	23	V _{CCP}	19, 51	P3.7/RD#/A16	27
EA#	67	AV _{CC}	40	ALE	66
RST	41	EA#	67		
XTAL1	38	V _{SS}	1, 37		
XTAL2	39	V _{SSP}	18, 52		

† 8x930Hx only.

Table B-2. Signal Descriptions

Signal Name	Type	Description	Alternate Function
A17	O	Address Line 17. Output to memory as 18th external address bit in extended bus applications. Selected with bits RD1:0 in configuration byte UCONFIG0. See Table B-3.	P1.7/CEX4/WCLK
A16	O	Address Line 16. Output to memory as 17th external address bit in extended bus applications. Selected with bits RD1:0 in configuration byte UCONFIG0. See Table B-3 and RD#, WR#, and PSEN#.	RD#
A15:8†	O	Address Lines. Upper address lines for external memory.	P2.7:0
AD7:0†	I/O	Address/Data Lines. Multiplexed lower address lines and data lines for external memory.	P0.7:0
ALE	O	Address Latch Enable. ALE signals the start of an external bus cycle and indicates that valid address information is available on lines A15:8 and AD7:0. An external latch can use ALE to demultiplex the address from the address/data bus.	—
AV _{CC}	PWR	Analog V_{CC}. A separate V _{CC} input for the phase-locked loop circuitry.	—
CEX2:0 CEX3 CEX4	I/O	Programmable Counter Array (PCA) Input/Output Pins. These are input signals for the PCA capture mode and output signals for the PCA compare mode and PCA PWM mode.	P1.5:3 P1.6/WAIT# P1.7/A17/WCLK
D _{M0} , D _{P0}	I/O	USB Port 0. D _{P0} and D _{M0} are the data plus and data minus lines of USB port 0, the upstream differential port. These lines do not have internal pullup resistors. For low-speed devices, provide an external 1.5 K Ω pullup resistor at D _{M0} . For full-speed devices, provide an external 1.5 K Ω pullup resistor at D _{P0} . NOTE: For the 8x930Ax, either D _{P0} or D _{M0} must be pulled high. Otherwise a continuous SEO (USB reset) will be applied to these inputs causing the 8x930Ax to stay in reset. For the 8x930Hx, provide an external 1.5 K Ω pullup resistor at D _{P0} so the device indicates to the host that it is a full-speed device.	—
D _{M1} , D _{P1} D _{M2} , D _{P2} D _{M3} , D _{P3}	I/O	USB Ports 1, 2, 3 (8X930Hx only). D _{P1} , D _{P2} , D _{P3} , D _{M1} , D _{M2} , and D _{M3} , are the data plus and data minus lines of USB ports 1, 2, and 3, the three downstream differential ports. These lines do not have internal pulldown resistors. Provide an external 15 K Ω pulldown resistor at each of these pins.	—
EA#	I	External Access. Directs program memory accesses to on-chip or off-chip code memory. For EA# strapped to ground, all program memory accesses are off-chip. For EA# strapped to V _{CC} , program accesses on-chip ROM if the address is within the range of the on-chip ROM; otherwise the access is off-chip. The value of EA# is latched at reset. For devices without on-chip ROM, EA# must be strapped to ground.	—

† The descriptions of A15:8/P2.7:0 and AD7:0/P0.7:0 are for the nonpage-mode chip configuration. If the chip is configured for page-mode operation, port 0 carries the lower address bits (A7:0), and port 2 carries the upper address bits (A15:8) and the data (D7:0).

Table B-2. Signal Descriptions (Continued)

Signal Name	Type	Description	Alternate Function
ECAP	I	External Capacitor. Connect a 1 μ F or larger capacitor between this pin and V_{SS} to ensure proper operation of the differential line drivers.	—
ECl	I	PCA External Clock Input. External clock input to the 16-bit PCA timer.	P1.2
INT1:0#	I	External Interrupts 0 and 1. These inputs set the IE1:0 interrupt flags in the TCON register. Bits IT1:0 in TCON select the triggering method: edge-triggered (high-to-low) or level triggered (active low). INT1:0 also serves as external run control for timer1:0 when selected by GATE1:0# in TCON.	P3.3:2
OVRI#	I	Overcurrent Sense (8X930Hx only). Sense input to indicate an overcurrent condition for a bus-powered USB device on an external down-stream port. Active low.	—
P0.7:0	I/O	Port 0. This is an 8-bit, open-drain, bidirectional I/O port.	AD7:0
P1.0 P1.1 P1.2 P1.5:3 P1.6 P1.7	I/O	Port 1. This is an 8-bit, bidirectional I/O port with internal pullups.	T2 T2EX ECl CEX2:0 CEX3/WAIT# CEX4/A17/WCLK
P2.7:0	I/O	Port 2. This is an 8-bit, bidirectional I/O port with internal pullups.	A15:8
P3.0 P3.1 P3.3:2 P3.5:4 P3.6 P3.7	I/O	Port 3. This is an 8-bit, bidirectional I/O port with internal pullups.	RXD TXD INT1:0# T1:0 WR# RD#/A16
PLLSEL2:0	I	Phase-locked Loop Select. Three-bit code selects USB data rate (see Table 2-4 on page 2-10).	—
PSEN#	O	Program Store Enable. Read signal output. Asserted for the memory address range determined by bits RD0:1 in configuration byte UCONFIG0 (see RD# and Table B-3).	—
RD#	O	Read. Read signal output to external data memory. Asserted as determined by bits RD0:1 in configuration byte UCONFIG0. (See PSEN# and Table B-3).	P3.7/A16

† The descriptions of A15:8/P2.7:0 and AD7:0/P0.7:0 are for the nonpage-mode chip configuration. If the chip is configured for page-mode operation, port 0 carries the lower address bits (A7:0), and port 2 carries the upper address bits (A15:8) and the data (D7:0).

Table B-2. Signal Descriptions (Continued)

Signal Name	Type	Description	Alternate Function
RST	I	Reset. Reset input to the chip. Holding this pin high for 64 oscillator periods while the oscillator is running resets the device. The port pins are driven to their reset conditions when a voltage greater than V_{IH1} is applied, whether or not the oscillator is running. This pin has an internal pulldown resistor which allows the device to be reset by connecting a capacitor between this pin and V_{CC} . Asserting RST when the chip is in idle mode or powerdown mode returns the chip to normal operation.	—
RXD	I/O	Receive Serial Data. RXD sends and receives data in serial I/O mode 0 and receives data in serial I/O modes 1, 2, and 3.	P3.0
SOF#	O	Start of Frame. Start of frame pulse. Active low. Asserted for 8 states (see Table 2-4 on page 2-10) when frame timer is locked to USB frame timing and SOF token or artificial SOF is detected.	—
T1:0	I	Timer 1:0 External Clock Input. When timer 1:0 operates as a counter, a falling edge on the T1:0 pin increments the count.	P3.5:4
T2	I/O	Timer 2 Clock Input/Output. For the timer 2 capture mode, this signal is the external clock input. For the clock-out mode, it is the timer 2 clock output.	P1.0
T2EX	I	Timer 2 External Input. In timer 2 capture mode, a falling edge initiates a capture of the timer 2 registers. In auto-reload mode, a falling edge causes the timer 2 registers to be reloaded. In the up-down counter mode, this signal determines the count direction: 1 = up, 0 = down.	P1.1
TXD	O	Transmit Serial Data. TXD outputs the shift clock in serial I/O mode 0 and transmits serial data in serial I/O modes 1, 2, and 3.	P3.1
UPWEN#	O	USB Power Enable (8X930Hx only). A low signal on this pin applies power to all three external downstream ports.	—
V_{CC}	PWR	Supply Voltage. Connect this pin to the +5V supply voltage.	—
V_{CCP}	PWR	Supply Voltage for I/O buffers. Connect this pin to the +5V supply voltage.	—
V_{SS}	GND	Circuit Ground. Connect this pin to ground.	—
V_{SSP}	GND	Circuit Ground for I/O buffers. Connect this pin to ground.	—
WAIT#	I	Real-time Wait State Input. The real-time WAIT# input is enabled by writing a logical '1' to the WCON.0 (RTWE) bit at S:A7H. During bus cycles, the external memory system can signal 'system ready' to the microcontroller in real time by controlling the WAIT# input signal on the port 1.6 input.	P1.6/CEX3

† The descriptions of A15:8/P2.7:0 and AD7:0/P0.7:0 are for the nonpage-mode chip configuration. If the chip is configured for page-mode operation, port 0 carries the lower address bits (A7:0), and port 2 carries the upper address bits (A15:8) and the data (D7:0).

Table B-2. Signal Descriptions (Continued)

Signal Name	Type	Description	Alternate Function
WCLK	O	Wait Clock Output. The real-time WCLK output is driven at port 1.7 (WCLK) by writing a logical '1' to the WCON.1 (RTWCE) bit at S:A7H. When enabled, the WCLK output produces a square wave signal with a period of one-half the oscillator frequency.	P1.7/CEX4/A17
WR#	O	Write. Write signal output to external memory (Table B-3)	P3.6
XTAL1	I	Oscillator Amplifier Input. When implementing the on-chip oscillator, connect the external crystal/resonator across XTAL1 and XTAL2. If an external clock source is used, connect it to this pin.	—
XTAL2	O	Oscillator Amplifier Output. When implementing the on-chip oscillator, connect the external crystal/resonator across XTAL1 and XTAL2. If an external oscillator is used, leave XTAL2 unconnected.	—

† The descriptions of A15:8/P2.7:0 and AD7:0/P0.7:0 are for the nonpage-mode chip configuration. If the chip is configured for page-mode operation, port 0 carries the lower address bits (A7:0), and port 2 carries the upper address bits (A15:8) and the data (D7:0).

Table B-3. Memory Signal Selections (RD1:0)

RD1:0	A17/P1.7/CEX4/WCLK	A16/P3.7/RD#	PSEN#	P3.6/WR#	Features
0 0	A17	A16	Asserted for all addresses	Asserted for writes to all memory locations	256-Kbyte external memory
0 1	P1.7/CEX4/WCLK	A16	Asserted for all addresses	Asserted for writes to all memory locations	128-Kbyte external memory
1 0	P1.7/CEX4/WCLK	P3.7 only	Asserted for all addresses	Asserted for writes to all memory locations	64-Kbyte external memory. One additional port pin.
1 1	P1.7/CEX4/WCLK	RD# asserted for addresses ≤ 7F:FFFFH	Asserted for addresses ≥ 80:0000H	Asserted only for writes to MCS [®] 51 microcontroller data memory locations.	64-Kbyte external memory. Compatible with MCS 51 microcontrollers.

NOTE: RD1:0 are bits 3:2 of configuration byte UCONFIG0 (Figure 4-3 on page 4-5).



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C

Registers







APPENDIX C REGISTERS

This appendix contains reference information for the 8x930 special function registers (SFRs). The SFR map in Table C-1 provides the address and reset value for 8x930Ax SFRs. SFRs with double borders are endpoint-indexed. For further information, see “Special Function Registers (SFRs)” on page 3-15.

Table C-2 depicts the 8x930Hx SFRs. SFRs with bold borders are port-indexed. SFRs with double borders are endpoint-indexed.

Tables C-3 through C-10 list the SFRs by functional category. “SFR Descriptions” on page C-8 contains descriptive tables of the SFRs arranged alphabetically.

NOTE

Use the prefix “S:” with SFR addresses to distinguish them from other addresses.

“Configuration Bytes” on page C-78 shows the two configuration bytes, UCONFIG0 and UCONFIG1. For information on device configuration, see Chapter 4.

Table C-1. 8x930Ax SFR Map

	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	
F8		CH 00000000	CCAP0H xxxxxxx	CCAP1H xxxxxxx	CCAP2H xxxxxxx	CCAP3H xxxxxxx	CCAP4H xxxxxxx		FF
F0	B 00000000	EPINDEX 1xxx000	TXSTAT 00000000	TXDAT xxxxxxx	TXCON 000x0100 [†]	TXFLG 00xx1000	TXCNTL 00000000 [†]	TXCNTH xxxxxx00	F7
E8		CL 00000000	CCAP0L xxxxxxx	CCAP1L xxxxxxx	CCAP2L xxxxxxx	CCAP3L xxxxxxx	CCAP4L xxxxxxx		EF
E0	ACC 00000000	EPCON 00x10000 [†]	RXSTAT 00000000	RXDAT xxxxxxx	RXCON 0x000100	RXFLG 00xx1000	RXCNTL 00000000 [†]	RXCNTH xxxxxx00	E7
D8	CCON 00x00000	CMOD 00xxx000	CCAPM0 x0000000	CCAPM1 x0000000	CCAPM2 x0000000	CCAPM3 x0000000	CCAPM4 x0000000	PCON1 xxx00000	DF
D0	PSW 00000000	PSW1 00000000	SOFL 00000000	SOFH 00000000					D7
C8	T2CON 00000000	T2MOD xxxxxx00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000			CF
C0	FIFLG 00000000	FIFLG1 00000000						EPCONFIG xxxxxx0	C7
B8	IPL0 x0000000	SADEN 00000000					SPH 00000000		BF
B0	P3 11111111	IEN1 xxx0000	IPL1 x0000000	IPH1 x0000000				IPH0 x0000000	B7
A8	IEN0 00000000	SADDR 00000000							AF
A0	P2 11111111		FIE 00000000	FIE1 00000000			WDTRST xxxxxxx	WCON xxxxxx0	A7
98	SCON 00000000	SBUF xxxxxxx							9F
90	P1 11111111								97
88	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000		FADDR 00000000	8F
80	P0 11111111	SP 00000111	DPL 00000000	DPH 00000000		DPXL 00000001		PCON 00XX0000	87
	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	

MCS 251 microcontroller SFRs Endpoint-indexed SFRs

[†] For EPCON, TXCON, TXCNTL, and RXCNTL, the reset value depends on the endpoint pair selected. Refer to the register definition tables in Appendix C or Chapter 7, "USB Function."

Table C-2. 8X930Hx SFR Map

	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	
F8		CH 00000000	CCAP0H xxxxxxx	CCAP1H xxxxxxx	CCAP2H xxxxxxx	CCAP3H xxxxxxx	CCAP4H xxxxxxx		FF
F0	B 00000000	EPINDEX 1xxxxx00	TXSTAT 00000000	TXDAT ^{††} xxxxxxxx [†]	TXCON 00x0100 [†]	TXFLG 00xx1000	TXCNTL 00000000 [†]	TXCNTH xxxxxx00	F7
E8	HIFLG 0xxxxx00	CL 00000000	CCAP0L xxxxxxx	CCAP1L xxxxxxx	CCAP2L xxxxxxx	CCAP3L xxxxxxx	CCAP4L xxxxxxx		EF
E0	ACC 00000000	EPCON 00x10000 [†]	RXSTAT 00000000	RXDAT xxxxxxxx	RXCON 0x000100	RXFLG 00xx1000	RXCNTL 00000000 [†]	RXCNTH xxxxxx00	E7
D8	CCON 00x000000	CMOD 00xxx000	CCAPM0 x0000000	CCAPM1 x0000000	CCAPM2 x0000000	CCAPM3 x0000000	CCAPM4 x0000000	PCON1 xxx00000	DF
D0	PSW 00000000	PSW1 00000000	SOFL 00000000	SOFH 00000000	HPINDEX xxxxx000	HPSC xxx00000		HPSTAT 0x000100	D7
C8	T2CON 00000000	T2MOD xxxxxx00	RCAP2L 00000000	RCAP2H 00000000	TL2 00000000	TH2 00000000		HPCON xxxxx000	CF
C0	FIFLG 00000000								C7
B8	IPL0 x0000000	SADEN 00000000					SPH 00000000		BF
B0	P3 11111111	IEN1 xxxxx000	IPL1 x0000000	IPH1 x0000000				IPH0 x0000000	B7
A8	IEN0 00000000	SADDR 00000000					HSTAT x0000000		AF
A0	P2 11111111	HIE 0xxxxx00	FIE 00000000				WDTRST xxxxxxx	WCON xxxxxx00	A7
98	SCON 00000000	SBUF xxxxxxx	HPPWR xxx1000x						9F
90	P1 11111111							HADDR 00000000	97
88	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000		FADDR 00000000	8F
80	P0 11111111	SP 00000111	DPL 00000000	DPH 00000000		DPXL 00000001		PCON 00XX0000	87

0/8 1/9 2/A 3/B 4/C 5/D 6/E 7/F

MCS 251 microcontroller SFRs

Port-indexed SFRs

Endpoint-indexed SFRs

[†] For EPCON, TXCON, TXDAT, TXCNTL, and RXCNTL the reset value depends on the endpoint pair selected. Refer to the register definition tables in Appendix C or Chapter 7, "USB Function."

^{††} For hub endpoint 1 (EPINDEX = 1000 0001), the only endpoint SFR implemented is TXDAT. A separate TXDAT register definition table is provided for this endpoint (see Chapter 8, "USB Hub.")

C.1 SFRS BY FUNCTIONAL CATEGORY

Table C-3. Core SFRs

Mnemonic	Name	Address
ACC [†]	Accumulator	S:E0H
B [†]	B register	S:F0H
PSW	Program Status Word	S:D0H
PSW1	Program Status Word 1	S:D1H
SP [†]	Stack Pointer – LSB of SPX	S:81H
SPH [†]	Stack Pointer High – MSB of SPX	S:BEH
DPTR [†]	Data Pointer (2 bytes)	—
DPL [†]	Low Byte of DPTR	S:82H
DPH [†]	High Byte of DPTR	S:83H
DPXL [†]	Data Pointer Extended, Low	S:85H
PCON	Power Control	S:87H
PCON1	USB Power Control.	S:DFH
WCON	Wait State Control Register	S:A7H

[†]These SFRs can also be accessed by their corresponding registers in the register file.

Table C-4. Interrupt System SFRs

Mnemonic	Description	Address
FIE	USB Function Interrupt Enable Register.	S:A2H
FIE1	USB Function Interrupt Enable Register.	S:A3H
FIFLG	USB Function Interrupt Flag Register.	S:C0H
FIFLG1	USB Function Interrupt Flag Register.	S:C1H
HIE	Hub Interrupt Enable Register.	S:A1H
HIFLG	Hub Interrupt Flag Register.	S:E8H
IEN0	Interrupt Enable Register 0.	S:A8H
IEN1	Interrupt Enable Register1.	S:B1H
IPL0	Interrupt Priority Low Register 0.	S:B8H
IPH0	Interrupt Priority High Register 0.	S:B7H
IPL1	Interrupt Priority Low Register 1.	S:B2H
IPH1	Interrupt Priority High Register 1.	S:B3H
SOFH	Start of Frame High Register.	S:D3H
SOFL	Start of Frame Low Register.	S:D2H

Table C-5. I/O Port SFRs

Mnemonic	Name	Address
P0	Port 0	S:80H
P1	Port 1	S:90H
P2	Port 2	S:A0H
P3	Port 3	S:B0H

Table C-6. Serial I/O SFRs

Mnemonic	Name	Address
SCON	Serial Control	S:98H
SBUF	Serial Data Buffer	S:99H
SADEN	Slave Address Mask	S:B9H
SADDR	Slave Address	S:A9H

Table C-7. USB Function SFRs

Mnemonic	Name	Address
EPCON	Endpoint Control Register.	S:E1H
EPCONFIG	Endpoint Configuration Register	S:C7H
EPINDEX	Endpoint Index Register.	S:F1H
FADDR	Function Address Register.	S:8FH
RXCNTH	Receive FIFO Byte-Count High Register.	S:E7H
RXCNTL	Receive FIFO Byte-Count Low Register.	S:E6H
RXCON	Receive FIFO Control Register.	S:E4H
RXDAT	Receive FIFO Data Register.	S:E3H
RXFLG	Receive FIFO Flag Register.	S:E5H
RXSTAT	Endpoint Receive Status Register.	S:E2H
TXCNTH	Transmit Count High Register.	S:F7H
TXCNTL	Transmit Count Low Register.	S:F6H
TXCON	Transmit FIFO Control Register.	S:F4H
TXDAT	Transmit FIFO Data Register.	S:F3H
TXFLG	Transmit Flag Register.	S:F5H
TXSTAT	Endpoint Transmit Status Register.	S:FAH

Table C-8. USB Hub SFRs

Mnemonic	Name	Address
HADDR	Hub Address Register.	S:97H
HPCON	Hub Port Control.	S:CFH
HPINDEX	Hub Port Index Register.	S:D4H
HPPWR	Hub Port Power Control.	S:9AH
HPSC	Hub Port Status Change.	S:D5H
HPSTAT	Hub Port Status.	S:D7H
HSTAT	Hub Status and Configuration.	S:AEH

Table C-9. Timer/Counter and Watchdog Timer SFRs

Mnemonic	Name	Address
TL0	Timer/Counter 0 Low Byte	S:8AH
TH0	Timer/Counter 0 High Byte	S:8CH
TL1	Timer/Counter 1 Low Byte	S:8BH
TH1	Timer/Counter 1 High Byte	S:8DH
TL2	Timer/Counter 2 Low Byte	S:CCH
TH2	Timer/Counter 2 High Byte	S:CDH
TCON	Timer/Counter 0 and 1 Control	S:88H
TMOD	Timer/Counter 0 and 1 Mode Control	S:89H
T2CON	Timer/Counter 2 Control	S:C8H
T2MOD	Timer/Counter 2 Mode Control	S:C9H
RCAP2L	Timer 2 Reload/Capture Low Byte	S:CAH
RCAP2H	Timer 2 Reload/Capture High Byte	S:CBH
WDTRST	WatchDog Timer Reset	S:A6H

Table C-10. Programmable Counter Array (PCA) SFRs

Mnemonic	Name	Address
CCON	PCA Timer/Counter Control	S:D8H
CMOD	PCA Timer/Counter Mode	S:D9H
CCAPM0	PCA Timer/Counter Mode 0	S:DAH
CCAPM1	PCA Timer/Counter Mode 1	S:DBH
CCAPM2	PCA Timer/Counter Mode 2	S:DCH
CCAPM3	PCA Timer/Counter Mode 3	S:DDH
CCAPM4	PCA Timer/Counter Mode 4	S:DEH
CL	PCA Timer/Counter Low Byte	S:E9H
CH	PCA Timer/Counter High Byte	S:F9H
CCAP0L	PCA Compare/Capture Module 0 Low Byte	S:EAH
CCAP1L	PCA Compare/Capture Module 1 Low Byte	S:EBH
CCAP2L	PCA Compare/Capture Module 2 Low Byte	S:ECH
CCAP3L	PCA Compare/Capture Module 3 Low Byte	S:EDH
CCAP4L	PCA Compare/Capture Module 4 Low Byte	S:EEH
CCAP0H	PCA Compare/Capture Module 0 High Byte	S:FAH
CCAP1H	PCA Compare/Capture Module 1 High Byte	S:FBH
CCAP2H	PCA Compare/Capture Module 2 High Byte	S:FCH
CCAP3H	PCA Compare/Capture Module 3 High Byte	S:FDH
CCAP4H	PCA Compare/Capture Module 4 High Byte	S:FEH

C.2 SFR DESCRIPTIONS

This section contains descriptions of all 8x930 SFRs. They are presented in alphabetical order.

NOTE

SFR bits are firmware read/write unless otherwise noted in the bit definition. SFRs may be accessed only as bytes; they may not be accessed as words or dwords

ACC	Address: S:E0H Reset State: 0000 0000B	
<p>Accumulator. ACC provides SFR access to the accumulator, which resides in the register file as byte register R11 (also named ACC). Instructions in the MCS[®] 51 architecture use the accumulator as both source and destination for calculations and moves. Instructions in the MCS 251 architecture assign no special significance to R11. These instructions can use byte registers R_m ($m = 0-15$) interchangeably.</p>		
7	0	
Accumulator Contents		
Bit Number	Bit Mnemonic	Function
7:0	ACC.7:0	Accumulator.

B	Address: S:F0H Reset State: 0000 0000B	
<p>B Register. The B register provides SFR access to byte register R10 (also named B) in the register file. The B register is used as both a source and destination in multiply and divide operations. For all other operations, the B register is available for use as one of the byte registers R_m, $m = 0-15$.</p>		
7	0	
B Register Contents		
Bit Number	Bit Mnemonic	Function
7:0	B.7:0	B Register.

CCAPxH, CCAPxL (x = 0–4)

Address: CCAP0H,L S:FAH, S:EAH
 CCAP1H,L S:FBH, S:EBH
 CCAP2H,L S:FCH, S:ECH
 CCAP3H,L S:FDH, S:EDH
 CCAP4H,L S:FEH, S:EEH

Reset State: xxxx xxxxB

PCA Module Compare/Capture Registers. These five register pairs store the 16-bit comparison value or captured value for the corresponding compare/capture modules. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.

7 0

High/Low Byte of Compare/Capture Values

Bit Number	Bit Mnemonic	Function
7:0	CCAPxH.7:0	High byte of PCA comparison or capture values.
	CCAPxL.7:0	Low byte of PCA comparison or capture values.

CCAPM_x (x = 0–4)

Address: CCAPM0 S:DAH
 CCAPM1 S:DBH
 CCAPM2 S:DCH
 CCAPM3 S:DDH
 CCAPM4 S:DEH

Reset State: x000 0000B

PCA Module Compare/Capture Registers. These five register pairs store the 16-bit comparison value or captured value for the corresponding compare/capture modules. In the PWM mode, the low-byte register controls the duty cycle of the output waveform.

7

0

—	ECOM _x	CAPP _x	CAPN _x	MAT _x	TOG _x	PWM _x	ECCF _x
---	-------------------	-------------------	-------------------	------------------	------------------	------------------	-------------------

Bit Number	Bit Mnemonic	Function
7	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.
6	ECOM _x	Compare Modes: ECOM _x = 1 enables the module comparator function. The comparator is used to implement the firmware timer, high-speed output, pulse width modulation, and watchdog timer modes.
5	CAPP _x	Capture Mode (Positive): CAPP _x = 1 enables the capture function with capture triggered by a positive edge on pin CEX _x .
4	CAPN _x	Capture Mode (Negative): CAPN _x = 1 enables the capture function with capture triggered by a negative edge on pin CEX _x .
3	MAT _x	Match: Set ECOM _x and MAT _x to implement the firmware timer mode. When MAT _x = 1, a match of the PCA timer/counter with the compare/capture register sets the CCF _x bit in the CCON register, flagging an interrupt.
2	TOG _x	Toggle: Set ECOM _x , MAT _x , and TOG _x to implement the high-speed output mode. When TOG _x = 1, a match of the PCA timer/counter with the compare/capture register toggles the CEX _x pin.
1	PWM _x	Pulse Width Modulation Mode: PWM _x = 1 configures the module for operation as an 8-bit pulse width modulator with output waveform on the CEX _x pin.
0	ECCF _x	Enable CCF _x Interrupt: Enables compare/capture flag CCF _x in the CCON register to generate an interrupt request.

CCON	Address:	S:D8H					
	Reset State:	00x0 0000B					
<p>PCA Timer/Counter Control Register. Contains the run control bit and overflow flag for the PCA timer/counter, and the compare/capture flags for the five PCA compare/capture modules.</p>							
7		0					
CF	CR	—	CCF4	CCF3	CCF2	CCF1	CCF0
Bit Number	Bit Mnemonic	Function					
7	CF	PCA Timer/Counter Overflow Flag: Set by hardware when the PCA timer/counter rolls over. This generates an interrupt request if the ECF interrupt enable bit in CMOD is set. CF can be set by hardware or firmware but can be cleared only by firmware.					
6	CR	PCA Timer/Counter Run Control Bit: Set and cleared by firmware to turn the PCA timer/counter on and off.					
5	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.					
4:0	CCF4:0	PCA Module Compare/Capture Flags: Set by hardware when a match or capture occurs. This generates a PCA interrupt request if the ECCFx interrupt enable bit in the corresponding CCAPMx register is set. Must be cleared by firmware.					

CH, CL	Address:	S:F9H S:E9H
	Reset State:	0000 0000B
<p>CH, CL Registers. These registers operate in cascade to form the 16-bit PCA timer/counter.</p>		
7		0
High/Low Byte PCA Timer/Counter		
Bit Number	Bit Mnemonic	Function
7:0	CH.7:0 CL.7:0	High byte of the PCA timer/counter Low byte of the PCA timer/counter

CMOD

Address: S:D9H
 Reset State: 00xx x000B

PCA Timer/Counter Mode Register. Contains bits for selecting the PCA timer/counter input, disabling the PCA timer/counter during idle mode, enabling the PCA WDT reset output (module 4 only), and enabling the PCA timer/counter overflow interrupt.

7	0						
CIDL	WDTE	—	—	—	CPS1	CPS0	ECF

Bit Number	Bit Mnemonic	Function
7	CIDL	PCA Timer/Counter Idle Control: CIDL = 1 disables the PCA timer/counter during idle mode. CIDL = 0 allows the PCA timer/counter to run during idle mode.
6	WDTE	Watchdog Timer Enable: WDTE = 1 enables the watchdog timer output on PCA module 4. WDTE = 0 disables the PCA watchdog timer output.
5:3	—	Reserved: Values read from these bits are indeterminate. Write zeros to these bits.
2:1	CPS1:0	PCA Timer/Counter Input Select: CPS1 CPS0 0 0 $F_{CLK} / 6$ 0 1 $F_{CLK} / 2$ 1 0 Timer 0 overflow 1 1 External clock at ECI pin (maximum rate = $F_{OSC} / 8$)
0	ECF	PCA Timer/Counter Interrupt Enable: ECF = 1 enables the CF bit in the CCON register to generate an interrupt request.

DPH	Address: S:83H	
	Reset State: 0000 0000B	
<p>Data Pointer High. DPH provides SFR access to register file location 58 (also named DPH). DPH is the upper byte of the 16-bit data pointer, DPTR. Instructions in the MCS[®] 51 architecture use DPTR for data moves, code moves, and for a jump instruction (JMP @A+DPTR). See also DPL and DPXL.</p>		
7		0
DPH Contents		
Bit Number	Bit Mnemonic	Function
7:0	DPH.7:0	Data Pointer High: Bits 8–15 of the extended data pointer, DPX (DR56).

DPL	Address: S:82H	
	Reset State: 0000 0000B	
<p>Data Pointer Low. DPL provides SFR access to register file location 59 (also named DPL). DPL is the low byte of the 16-bit data pointer, DPTR. Instructions in the MCS[®] 51 architecture use the 16-bit data pointer for data moves, code moves, and for a jump instruction (JMP @A+DPTR). See also DPH and DPXL.</p>		
7		0
DPL Contents		
Bit Number	Bit Mnemonic	Function
7:0	DPL.7:0	Data Pointer Low: Bits 0–7 of the extended data pointer, DPX (DR56).



DPXL

Address: S:85H
 Reset State: 0000 0001B

Data Pointer Extended Low. DPXL provides SFR access to register file location 57 (also named DPXL). Location 57 is the lower byte of the upper word of the extended data pointer, DPX = DR56, whose lower word is the 16-bit data pointer, DPTR. See also DPH and DPL.

7

0

DPXL Contents

Bit Number	Bit Mnemonic	Function
7:0	DPXL.7:0	Data Pointer Extended Low: Bits 16–23 of the extended data pointer, DPX (DR56).

EPCON Address: S:E1H
 (Endpoint-indexed) Reset State: Endpoint 0 0011 0101B
 Function Endpoints 1, 2, 3 0001 0000B

Endpoint Control Register. This SFR configures the operation of the endpoint specified by EPINDEX.

7

0

RXSTL	TXSTL	CTLEP	RXSPM	RXIE	RXEPEN	TXOE	TXEPEN
-------	-------	-------	-------	------	--------	------	--------

Bit Number	Bit Mnemonic	Function
7	RXSTL	Stall Receive Endpoint: Set this bit to stall the receive endpoint. Clear this bit only when the host has intervened through commands sent down endpoint 0. When this bit is set and RXSETUP is clear, the receive endpoint will respond with a STALL handshake to a valid OUT token. When this bit is set and RXSETUP is set, the receive endpoint will NAK. This bit does not affect the reception of SETUP tokens by a control endpoint.
6	TXSTL	Stall Transmit Endpoint: Set this bit to stall the transmit endpoint. This bit should be cleared only when the host has intervened through commands sent down endpoint 0. When this bit is set and RXSETUP is clear, the receive endpoint will respond with a STALL handshake to a valid IN token. When this bit is set and RXSETUP is set, the receive endpoint will NAK.
5	CTLEP	Control Endpoint:[†] Set this bit to configure the endpoint as a control endpoint. Only control endpoints are capable of receiving SETUP tokens.
4	RXSPM	Receive Single Packet Mode:[†] Set this bit to configure the receive endpoint for single data packet operation. When enabled, only a single data packet is allowed to reside in the receive FIFO. NOTE: For control endpoints (CTLEP=1), this bit should be set for single packet mode operation as the recommended firmware model. However, it is possible to have a control endpoint configured in dual packet mode as long as the firmware handles the endpoint correctly.
3	RXIE	Receive Input Enable: Set this bit to enable data from the USB to be written into the receive FIFO. If cleared, the endpoint will not write the received data into the receive FIFO and at the end of reception, but will return a NAK handshake on a valid OUT token if the RXSTL bit is not set. This bit does not affect a valid SETUP token. A valid SETUP token and packet overrides this bit if it is cleared, and place the receive data in the FIFO.

[†] For hub endpoint 0 (EPINDEX = 1000 0000, 8x930Hx only), bits 5 and 4 are hard-wired to '1' since hub endpoint 0 is always a control endpoint.



EPCON (Continued)
(Endpoint-indexed)

Address: S:E1H
Reset State: Endpoint 0 0011 0101B
Function Endpoints 1, 2, 3 0001 0000B

Endpoint Control Register. This SFR configures the operation of the endpoint specified by EPINDEX.

7

0

RXSTL	TXSTL	CTLEP	RXSPM	RXIE	RXEPEN	TXOE	TXEPEN
-------	-------	-------	-------	------	--------	------	--------

Bit Number	Bit Mnemonic	Function
2	RXEPEN	Receive Endpoint Enable: Set this bit to enable the receive endpoint. When disabled, the endpoint does not respond to a valid OUT or SETUP token. This bit is hardware read-only and has the highest priority among RXIE and RXSTL. Note that endpoint 0 is enabled for reception upon reset.
1	TXOE	Transmit Output Enable: This bit is used to enable the data in TXDAT to be transmitted. If cleared, the endpoint returns a NAK handshake to a valid IN token if the TXSTL bit is not set.
0	TXEPEN	Transmit Endpoint Enable: This bit is used to enable the transmit endpoint. When disabled, the endpoint does not respond to a valid IN token. This bit is hardware read only. Note that endpoint 0 is enabled for transmission upon reset.

† For hub endpoint 0 (EPINDEX = 1000 0000, 8x930Hx only), bits 5 and 4 are hard-wired to '1' since hub endpoint 0 is always a control endpoint.

EPCONFIG[†]

Address: S:C7H
Reset State: xxxx xxx0B

Endpoint Configuration Register. Selects the six-endpoint pair option or four-endpoint pair option as the 8x930Ax function endpoint pair configuration.

7

0



Bit Number	Bit Mnemonic	Function																																																												
7:1	—	Reserved: Write zeroes to these bits.																																																												
0	SIXEPPEN	<p>Six-endpoint pair enable:^{††} Set this bit to select the six-endpoint pair (6EPP) configuration, which provides the following FIFO sizes (bytes).</p> <table border="1"> <thead> <tr> <th>EPINDEX</th> <th>FFSZ1:0</th> <th>Transmit FIFO</th> <th>Receive FIFO</th> </tr> </thead> <tbody> <tr> <td>0xxx x000</td> <td>xx</td> <td>16</td> <td>16</td> </tr> <tr> <td>0xxx x001</td> <td>00^{†††}</td> <td>256</td> <td>256</td> </tr> <tr> <td>0xxx x010</td> <td>xx</td> <td>32</td> <td>32</td> </tr> <tr> <td>0xxx x011</td> <td>xx</td> <td>32</td> <td>32</td> </tr> <tr> <td>0xxx x100</td> <td>xx</td> <td>32</td> <td>32</td> </tr> <tr> <td>0xxx x101</td> <td>xx</td> <td>16</td> <td>16</td> </tr> </tbody> </table> <p>Clear this bit to select the four-endpoint pair (4EPP) configuration, which provides the following FIFO sizes (bytes).</p> <table border="1"> <thead> <tr> <th>EPINDEX</th> <th>FFSZ1:0</th> <th>Transmit FIFO</th> <th>Receive FIFO</th> </tr> </thead> <tbody> <tr> <td>0xxx xx00</td> <td>xx</td> <td>16</td> <td>16</td> </tr> <tr> <td>0xxx xx01</td> <td>00</td> <td>256</td> <td>256</td> </tr> <tr> <td></td> <td>01</td> <td>512</td> <td>512</td> </tr> <tr> <td></td> <td>10</td> <td>1024</td> <td>0</td> </tr> <tr> <td></td> <td>11</td> <td>0</td> <td>1024</td> </tr> <tr> <td>0xxx xx10</td> <td>xx</td> <td>16</td> <td>16</td> </tr> <tr> <td>0xxx xx11</td> <td>xx</td> <td>16</td> <td>16</td> </tr> </tbody> </table>	EPINDEX	FFSZ1:0	Transmit FIFO	Receive FIFO	0xxx x000	xx	16	16	0xxx x001	00 ^{†††}	256	256	0xxx x010	xx	32	32	0xxx x011	xx	32	32	0xxx x100	xx	32	32	0xxx x101	xx	16	16	EPINDEX	FFSZ1:0	Transmit FIFO	Receive FIFO	0xxx xx00	xx	16	16	0xxx xx01	00	256	256		01	512	512		10	1024	0		11	0	1024	0xxx xx10	xx	16	16	0xxx xx11	xx	16	16
EPINDEX	FFSZ1:0	Transmit FIFO	Receive FIFO																																																											
0xxx x000	xx	16	16																																																											
0xxx x001	00 ^{†††}	256	256																																																											
0xxx x010	xx	32	32																																																											
0xxx x011	xx	32	32																																																											
0xxx x100	xx	32	32																																																											
0xxx x101	xx	16	16																																																											
EPINDEX	FFSZ1:0	Transmit FIFO	Receive FIFO																																																											
0xxx xx00	xx	16	16																																																											
0xxx xx01	00	256	256																																																											
	01	512	512																																																											
	10	1024	0																																																											
	11	0	1024																																																											
0xxx xx10	xx	16	16																																																											
0xxx xx11	xx	16	16																																																											

[†] 8x930Ax only. Early sample devices did not have this SFR.

^{††} Select the endpoint configuration during initialization and do not change during program execution.

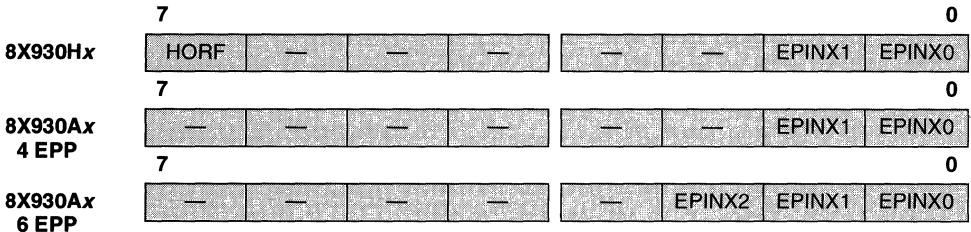
^{†††} When using function endpoint 1 in the six-endpoint pair configuration, clear the FFSZ1:0 bits in TXCON to select the 256-byte size for the transmit and receive FIFOs.



EPINDEX

Address: S:F1H
Reset State: 1xxx x000B

Endpoint Index Register. This register identifies the endpoint pair. Its contents select the transmit and receive FIFO pair and serve as an index to endpoint-specific SFRs.



Bit Number	Bit Mnemonic	Function
7	HORF (8X930Hx)	Hub/function Bit: 1 = Hub. Selects USB hub FIFOs and SFRs. 0 = Function. Selects USB function FIFOs and SFRs.
	— (8X930Ax)	Reserved: Although the reset state for this bit is “1”, always write a zero to this bit for 8X930Ax applications.
6:3	—	Reserved: Write zeros to these bits.
2	— 8X930Hx or 8X930Ax (4 EPP)	Reserved: Write a zero to this bit. 8x930Hx
1:0	EPINX1:0 8X930Hx or 8X930Ax (4 EPP)	Endpoint Index: EPINDEX [†] 0xxx xx00 Function Endpoint 0 0xxx xx01 Function Endpoint 1 0xxx xx10 Function Endpoint 2 0xxx xx11 Function Endpoint 3 EPINDEX [†] (8x930Hx only) 1xxx xx00 Hub Endpoint 0 1xxx xx01 Hub Endpoint 1
2:0	EPINX2:0 8X930Ax (6 EPP)	Endpoint Index: EPINDEX [†] 0xxx x000 Function Endpoint 0 0xxx x001 Function Endpoint 1 0xxx x010 Function Endpoint 2 0xxx x011 Function Endpoint 3 0xxx x100 Function Endpoint 4 0xxx x101 Function Endpoint 5

[†] The EPINDEX register identifies the endpoint pair and selects the associated transmit and receive FIFO pair. The value in this register plus SFR addresses select the associated bank of endpoint-indexed SFRs (TXDAT, TXCON, TXFLG, TXCNTH/L, RXDAT, RXCON, RXFLG, RXCNTH/L, EPCON, TXSTAT, and RXSTAT).

FADDR

Address: S:8FH
 Reset State: 0000 0000B

Function Address Register. This SFR holds the address for the USB function. During bus enumeration it is written with a unique value assigned by the host.

7

0



Bit Number	Bit Mnemonic	Function
7	—	Reserved: Write a zero to this bit.
6:0	A6:0	7-bit Programmable Function Address: This register is programmed through the commands received via endpoint 0 on configuration, which should be the only time the firmware should change the value of this register. This register is read-only by hardware.

FIE

Address: S:A2H
Reset State: 0000 0000B

Function Interrupt Enable Register. Enables and disables the receive and transmit done interrupts for the four function endpoints.

7

0

FRXIE3	FTXIE3	FRXIE2	FTXIE2	FRXIE1	FTXIE1	FRXIE0	FTXIE0
--------	--------	--------	--------	--------	--------	--------	--------

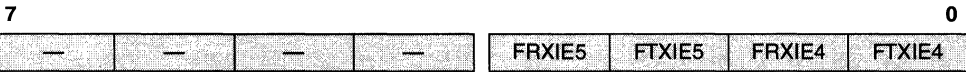
Bit Number	Bit Mnemonic	Function
7	FRXIE3	Function Receive Interrupt Enable 3: Enables receive done interrupt for endpoint 3 (FRXD3).
6	FTXIE3	Function Transmit Interrupt Enable 3: Enables transmit done interrupt for endpoint 3 (FTXD3).
5	FRXIE2	Function Receive Interrupt Enable 2: Enables the receive done interrupt for endpoint 2 (FRXD2).
4	FTXIE2	Function Transmit Interrupt Enable 2: Enables the transmit done interrupt for endpoint 2 (FTXD2).
3	FRXIE1	Function Receive Interrupt Enable 1: Enables the receive done interrupt for endpoint 1 (FRXD1).
2	FTXIE1	Function Transmit Interrupt Enable 1: Enables the transmit done interrupt for endpoint 1 (FTXD1).
1	FRXIE0	Function Receive Interrupt Enable 0: Enables the receive done interrupt for endpoint 0 (FRXD0).
0	FTXIE0	Function Transmit Interrupt Enable 0: Enables the transmit done interrupt for endpoint 0 (FTXD0).

NOTE: For all bits, a '1' means the interrupt is enabled and will cause an interrupt to be signaled to the microcontroller. A '0' means the associated interrupt source is disabled and cannot cause an interrupt, even though the interrupt bit's value is still reflected in the FIFLG register.

FIE1

Address: S:A3H
 Reset State: 0000 0000B

Function Interrupt Enable Register 1. Available on the 8x930Ax only, this register enables and disables the receive and transmit done interrupts for function endpoints four and five.



Bit Number	Bit Mnemonic	Function
7:4	—	Reserved:
3	FRXIE5	Function Receive Done Interrupt Enable 5: Enables receive done interrupt for endpoint 5 (FTXD5).
2	FTXIE5	Function Transmit Interrupt Enable 5: Enables the transmit done interrupt for endpoint 5 (FTXD5).
1	FRXIE4	Function Receive Interrupt Enable 4: Enables the receive done interrupt for endpoint 4 (FRXD4).
0	FTXIE4	Function Transmit Interrupt Enable 4: Enables the transmit done interrupt for endpoint 4 (FTXD4).

NOTE: When the FRXIE.5:4 or FTXIE.5:4 is set, the interrupt is enabled and it will cause an interrupt to the CPU, when a transmit of receive done flag is set. If the FRXIE.5:4 and FTXIE.5:4 is cleared, the interrupt is disabled. All these bits can be read/write by firmware.



FIFLG

Address: S:C0H
 Reset State: 0000 0000B

Function Interrupt Flag Register. Contains the USB Function's Transmit and Receive Done interrupt flags for non-isochronous endpoints.

7

0

FRXD3	FTXD3	FRXD2	FTXD2	FRXD1	FTXD1	FRXD0	FTXD0
-------	-------	-------	-------	-------	-------	-------	-------

Bit Number	Bit Mnemonic	Function
7	FRXD3	Function Receive Done Flag, Endpoint 3
6	FTXD3	Function Transmit Done Flag, Endpoint 3
5	FRXD2	Function Receive Done Flag, Endpoint 2
4	FTXD2	Function Transmit Done Flag, Endpoint 2
3	FRXD1	Function Receive Done Flag, Endpoint 1
2	FTXD1	Function Transmit Done Flag, Endpoint 1
1	FRXD0	Function Receive Done Flag, Endpoint 0
0	FTXD0	Function Transmit Done Flag, Endpoint 0

NOTES:

- For all bits in the Interrupt Flag Register, a '1' indicates that an interrupt is actively pending; a '0' indicates that the interrupt is not active. The interrupt status is shown regardless of the state of the corresponding interrupt enable bit in the FIE.
- Bits are set-only by hardware and clearable in firmware. Firmware can also set the bits for test purposes, allowing the interrupt to be generated in firmware.
- A set bit indicates either:
 Valid data waiting to be serviced in the RX FIFO for the indicated endpoint and that the data was received without error and has been acknowledged; or
 Data was received with a Receive Data Error requiring firmware intervention to be cleared.

FIFLG1

 Address: S:C1H
 Reset State: 0000 0000B

Function Interrupt Flag Register 1. Available on the 8x930Ax only, this register contains the USB Function's Transmit and Receive Done interrupt flags for non-isochronous endpoints.

 7 0

—	—	—	—	FRXD5	FTXD5	FRXD4	FTXD4
---	---	---	---	-------	-------	-------	-------

Bit Number	Bit Mnemonic	Function
7:4	—	Reserved: Write zeros to these bits.
3	FTXD5	Function Receive Done Flag, Endpoint 5:
2	FTXD5	Function Transmit Done Flag, Endpoint 5:
1	FRXD4	Function Receive Done Flag, Endpoint 4:
0	FTXD4	Function Transmit Done Flag, Endpoint 4:

NOTES:

1. For all bits in the Interrupt Flag Register, a '1' indicates that an interrupt is actively pending; a '0' indicates that the interrupt is not active. The interrupt status is shown regardless of the state of the corresponding interrupt enable bit in the FIE.
2. Bits are set-only by hardware and clearable in firmware. Firmware can also set the bits for test purposes, allowing the interrupt to be generated in firmware.
3. A set bit indicates either:
 Valid data waiting to be serviced in the RX FIFO for the indicated endpoint and that the data was received without error and has been acknowledged; or
 Data was received with a Receive Data Error requiring firmware intervention to be cleared.



HADDR Address: S:97H
Reset State: 0000 0000B

Hub Address Register. This SFR holds the address for the hub device. During bus enumeration it is written with a unique value assigned by the host.

7 0

—	Hub Address
---	-------------

Bit Number	Function
7	Reserved. Write a zero to this bit.
6:0	Hub address register: Updated using a SET_ADDRESS USB host request. This address is used by the HIU to perform token decoding.

HIE Address: S:A1H
Reset State: 0xxx xx00B

Hub Interrupt Enable Register. Enables and disables the receive and transmit done interrupts for hub endpoint 0.

7 0

—	—	—	—	—	—	HRXE0	HTXE0
---	---	---	---	---	---	-------	-------

Bit Number	Bit Mnemonic	Function
7:2	—	Reserved: Write zeros to these bits.
1	HRXE0	HRXE0: Enable the hub endpoint 0 receive done interrupt (HRXD0). [†]
0	HTXE0	HTXE0: Enable the hub endpoint 0 transmit done interrupt (HTXD0). [†]

[†] For both bits, a '1' means the interrupt is enabled, and will cause an interrupt to be signaled to the microcontroller. A '0' means the associated interrupt source is disabled and cannot cause an interrupt, even though its value is still reflected in the HIFLG register.

HIFLG	Address: S:E8H	
	Reset State: 0xxx xx00B	
Hub Interrupt Flag Register. Contains the hub's transmit and receive done interrupt flags for hub endpoint 0.		
7	0	
—	—	—
—	—	HRXD0 HTXD0

Bit Number	Bit Mnemonic	Function
7:2	—	Reserved: Write zeros to these bits.
1	HRXD0	Hub Receive Done, Endpoint 0.: Hardware sets this bit to indicate that there is either: (1) valid data waiting to be serviced in the receive data buffer for hub endpoint 0 and that the data was received without error and has been acknowledged; or (2) that data was received with a FIFO error requiring firmware intervention to be cleared.
0	HTXD0	Hub Transmit Done, Endpoint 0: Hardware sets this bit to indicate that one of two conditions exists in the transmit data buffer for hub endpoint 0: (1) the transmit data has been transmitted and the host has sent acknowledgment which was successfully received; or (2) a FIFO-related error occurred during transmission of the data packet, which requires servicing by firmware to be cleared.

NOTES:

- Note that because the HIFLG appears in the first SFR column, it is a bit-addressable SFR. All bits are set in hardware and cleared by firmware. Firmware can also set these bits for test purposes, allowing the interrupt to be generated by firmware.
- For both HRXD0 and HTXD0, a '1' indicates that an interrupt is actively pending; a '0' indicates that the interrupt is not active. The interrupt status is shown regardless of the state of the corresponding interrupt enable bit in the HIE.



HPCON

Address: S:CFH
 Reset State: xxxx x000B

Hub Port Control Register. Firmware writes to this register to disable, enable, reset, suspend, and resume a port.

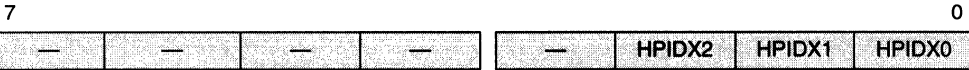


Bit Number	Bit Mnemonic	Function
7:3	—	Reserved: Write zeros to these bits.
2:0	HPCON.2:0	Encoded Hub Port Control Commands: All bits should be set and cleared by firmware after receiving the USB requests ClearPortFeature and SetPortFeature from the host. The bits are encoded as follows (all other bit combinations are ignored by the hardware): 000 — Disable port 001 — Enable port 010 — Reset and enable port 011 — Suspend port 100 — Resume port See Table 8-6 for a complete description of the encoded hub port control commands.

HPINDEX

Address S:D4H
Reset State xxxx x00B

Hub Port Index Register. This register contains the binary value of the port whose HPSC, HPSTAT, and HPCON registers are to be accessed.



Bit Number	Bit Mnemonic	Function
7:3	—	Reserved: Write zeros to these bits.
2:0	HPIDX.2:0	Port Index Select: Used to select the port to be indexed by the following registers: HPSC, HPSTAT, and HPCON. This register is hardware read-only. The ports are addressed using the following HPID.2:0 bit combinations: Port 1 = "001" Port 2 = "010" Port 3 = "011" Port 4 = "100" (internal port)

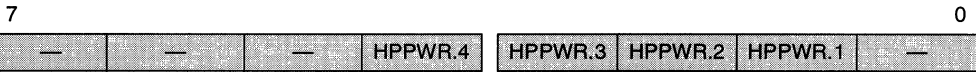
NOTE: Port 0 = "000" (the root port) and all other combinations not shown above are not valid port indexes and are ignored.



HPPWR

Address: S:9AH
 Reset State: xxx1 000xB

Hub Port Power Control Register. This register is used to control power to the hub's downstream ports.



Bit Number	Bit Mnemonic	Function
7:5	—	Reserved: The value read from these bits is indeterminate. Write zeros to these bits.
4	HPPWR.4	Port Power Control Register for USB Port 4 (read-only): Port 4 is an internal port and is always powered on. This bit is hard-wired to '1.'
3:1	HPPWR.3.1	Port Power Control Register for USB Ports 1-3: Bit 3 is power control for port 3, bit 2 for port 2, and bit 1 for port 1. These bits are set and cleared by firmware via a USB host request SetPortFeature with the PORT_POWER feature selector. These bits will also be cleared by hardware upon detection of an over-current condition. This is done to prevent oscillation of the UPWEN# pin during an over-current condition with bus-powered devices. A value of '1' enables power to the downstream port and puts the port in a disconnected state. A value of '0' turns the downstream port power off. NOTE: The UPWEN# pin is set to '1' only if all three port power enable bits (bits 3:1) are '0,' due to the use of a ganged (shared) power enable scheme.
0	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.

HPSC

 Address: S:D5H
 Reset State: xxx0 0000B

Hub Port Status Change Register. This register indicates a change in status for a port, including over-current, reset, suspend, enable and connect status.



Bit Number	Bit Mnemonic	Function
7:5	—	Reserved: Write zeros to these bits.
4	RSTSC	Reset Status Change (read-, clear-only): This bit is cleared in firmware via the USB host request ClearPortFeature with a C_PORT_RESET feature selector. '1' indicates reset of port complete; '0' indicates no change. Port x ($x=1,2,3$): This bit is set by hardware approximately 10 msec after receipt of a port reset and enable command (SetPortFeature with PORT_RESET feature selector). Port 4: This bit is set by hardware at the EOF2 point near the end of a frame after completion of the hardware-timed reset due to firmware execution of a port reset and enable command (SetPortFeature with PORT_RESET feature selector).
3	—	Reserved: Write a zero to this bit.
2	PSSC	Port Suspend Status Change (read-, clear-only): This bit is cleared by firmware upon a USB host request ClearPortFeature with C_PORT_SUSPEND feature selector. '1' = resume process complete; '0' = no change. The resume process is initiated by firmware upon reception of a SetPortFeature request with a PORT_SUSPEND feature selector. Port x ($x=1,2,3$): This bit is set by hardware upon completion of the firmware-initiated resume process. Port 4: This bit is set by hardware 20 msec after the next EOF2 point after completion of the resume process.

NOTE: Bits are returned as part of the second word (2 bytes) in response to a Get Port Status request from the USB host. The upper 11 MSBs are reserved and always '0' per USB 1.0: 0000 0000 000.4.3.2.1.0 (MSB at left)



HPSC (Continued)

Address: S:D5H
 Reset State: xxx0 0000B

Hub Port Status Change Register. This register indicates a change in status for a port, including over-current, reset, suspend, enable and connect status.



Bit Number	Bit Mnemonic	Function
1	PESC	<p>Port Enable/Disable Status Change (read, clear-only):</p> <p>This bit's status does not change due to USB requests. This bit is cleared by firmware via the USB host request ClearPortFeature with a C_PORT_ENABLE feature selector. '1' indicates port enabled/ disabled status change; '0' indicates no change.</p> <p>Port x (x=1,2,3): This bit is set by hardware due to hardware events only (this bit indicates the port was disabled due to babble, physical disconnects, or overcurrent).</p> <p>Port 4: This bit is set by hardware at the EOF2 point near the end of frame due to hardware events only (e.g., the port was disabled due to babble).</p>
0	PCSC	<p>Port Connect Status Change (read-, clear-only):</p> <p>This bit is cleared by firmware via a USB host request ClearPortFeature with C_PORT_CONNECTION feature selector. '1' indicates connect status change; '0' indicates no change.</p> <p>Port x (x=1,2,3): This bit is set by hardware at the EOF2 point near the end of a frame due to hardware connects and disconnects.</p> <p>Port 4: This bit is set by hardware at the next EOF2 after completion of a hub reset (since the internal port is always connected).</p>

NOTE: Bits are returned as part of the second word (2 bytes) in response to a Get Port Status request from the USB host. The upper 11 MSBs are reserved and always '0' per USB 1.0: 0000 0000 000.4.3.2.1.0 (MSB at left)

HPSTAT

 Address: S:D7H
 Reset State: 0x00 0100B

Hub Port Status Register. This register indicates the current status for a port, including power, reset, suspend, low-speed device, enable, connect, D_p , and D_M status.

 7 0

DPSTAT	DMSTAT	LSSTAT	PPSTAT	PRSTAT	PSSTAT	PESTAT	PCSTAT
--------	--------	--------	--------	--------	--------	--------	--------

Bit Number	Bit Mnemonic	Function
7	DPSTAT	<p>D_p Status (read-only):</p> <p>Value of D_p for port x at end of last frame. Firmware must return this bit in response to a GetBusState request from the host.</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware at the EOF2 point near the end of a frame (used for diagnostics).</p> <p>Port 4: Hard-wired to '1', since there is no D_p signal for the embedded port</p>
6	DMSTAT	<p>D_M Status (read-only):</p> <p>Value of D_M for port x at end of last frame. Firmware must return this bit in response to a GetBusState request from the host.</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware at the EOF2 point near the end of a frame (used for diagnostics).</p> <p>Port 4: Hard-wired to '0', since there is no D_M signal for the embedded port.</p>
4	PPSTAT	<p>Port Power Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware based on the present power status of the port, as controlled either by firmware using the HPPWR register, or by an overcurrent condition in hardware. '1' = port x is powered on. '0' = port x is powered off. The port x power status is only sampled at the EOF2 point near end-of-frame.</p> <p>Port 4: Hard-wired to '1', since the internal function is always powered-on.</p>
5	LSSTAT	<p>Low-speed Device Attach Status (read-only):</p> <p>Port x ($x=1,2,3$): Set and cleared by hardware upon detection of the presence or absence of a low-speed device at the EOF2 point near end-of-frame. '1' = low-speed device is attached to port x. '0' = full-speed device is attached to port x.</p> <p>Port 4: Hard-wired to '0' (full-speed), since port 4 is permanently attached to the embedded USB function.</p>

NOTES:

Firmware returns the bits of this register in the first word of the 8x930Hx' response to the host's GetPortStatus request. See "GetPortStatus Request Firmware" on page 9-24.

Overcurrent indication is not represented on a per-port basis because the 8x930Hx supports ganged power control and overcurrent indication.



HPSTAT (Continued)

Address: S:D7H
 Reset State: 0x00 0100B

Hub Port Status Register. This register indicates the current status for a port, including power, reset, suspend, low-speed device, enable, connect, D_p, and D_M status.

7

0

DPSTAT	DMSTAT	LSSTAT	PPSTAT	PRSTAT	PSSTAT	PESTAT	PCSTAT
--------	--------	--------	--------	--------	--------	--------	--------

Bit Number	Bit Mnemonic	Function
3	PRSTAT	<p>Port Reset Status (read-only):</p> <p>Port x (x=1,2,3): Set and cleared by hardware as a result of initiating a port x reset by writing to HPCON. '1' = reset signaling is currently asserted for port x. '0' = reset signaling is not asserted. Sampled only at the EOF2 point near end of frame.</p> <p>Port 4: Same as port x.</p>
2	PSSTAT	<p>Port Suspend Status (read-only):</p> <p>Port x (x=1,2,3): Set and cleared by hardware as controlled by firmware via HPCON. '1' = port x is currently suspended. '0' = not suspended. Sampled only at the EOF2 point near end of frame.</p> <p>Port 4: Same as port x.</p>
1	PESTAT	<p>Port Enable/Disable Status (read-only):</p> <p>Port x (x=1,2,3): Set and cleared by hardware as controlled by firmware via HPCON. '1' = port x is currently enabled. '0' = port is disabled. Sampled only at the EOF2 point near end of frame.</p> <p>Port 4: Same as port x.</p>
0	PCSTAT	<p>Port Connect Status (read-only):</p> <p>Port x connect status from previous frame time.</p> <p>Port x (x=1,2,3): Set and cleared by hardware after sampling the connect state at EOF2 near the end of the present frame. '1' = device is present on port x. '0' = device is not present. This bit will be set if either a physical connection is detected, or during a hub reset when a downstream device is already connected. This bit will be cleared if a disconnect is detected.</p> <p>Port 4: Hard-wired to '1', since the internal function is permanently connected.</p>

NOTES:

Firmware returns the bits of this register in the first word of the 8x930HX' response to the host's GetPortStatus request. See "GetPortStatus Request Firmware" on page 9-24.

Overcurrent indication is not represented on a per-port basis because the 8x930Hx supports ganged power control and overcurrent indication.

HSTAT

 Address: S:AEH
 Reset State: x000 0000B

Hub Status and Configuration Register. This SFR contains bits for remote wake-up request, status and status change indicators for over-current and hub endpoint 1 stall and enable.

 7 0

—	HRWUPE	EP1STL	EP1EN	OVISC	—	OVI	—
---	--------	--------	-------	-------	---	-----	---

Bit Number	Bit Mnemonic	Function
7	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.
6	HRWUPE	Hub Remote Wake-up Enable Bit: Set if the device is currently enabled to request remote wake-up. This bit is modified through the SetFeature and ClearFeature requests using the DEVICE_REMOTE_WAKEUP feature selector. When '0,' a hub cannot propagate resume signaling for connect/disconnect and resume events detected on downstream ports. NOTE: Do not set this bit until after the hub is enumerated and the host issues a SET_FEATURE command with a DEVICE_REMOTE_WAKEUP feature selector.
5	EP1STL	Hub Endpoint 1 Stall Field: Set to '1' via the USB SetFeature request with endpoint stall feature selector. When '1,' will force a stall response when endpoint 1 is addressed. Reset with USB ClearFeature request with endpoint stall feature selector.
4	EP1EN	Hub Endpoint 1 Enable: Set to '1' upon receipt of a USB SetConfiguration request value of 0001H. Endpoint 1 cannot respond unless this bit is set. Bit is reset upon receipt of configuration value other than 0001H or a system or USB reset. NOTE: This bit must be set in order for the UPWEN# pin to enable power to the downstream ports. Downstream power cannot be applied until this is done.
3	OVISC	Hub Over-current Indicator Status Change (read/clear-only): † Set to '1' if change is detected in the over-current status, even if the condition goes away before it is detected by firmware. Cleared via a USB ClearFeature request with C_HUB_OVER_CURRENT feature selector. Cleared to '0' if no change.
2	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.

† Bits 3:0 are returned in response to a Get Hub Status request from the USB host. This response is a four-byte field with zero padding (MSB at left): 0000 0000 0000 00[3] 0 0000 0000 0000 00[1] 0.



HSTAT (Continued)

Address: S:AEH
 Reset State: x000 0000B

Hub Status and Configuration Register. This SFR contains bits for remote wake-up request, status and status change indicators for over-current and hub endpoint 1 stall and enable.



Bit Number	Bit Mnemonic	Function
1	OVI	Latest Over-current Indicator (read-only): † Hardware sets and clears this bit via the OVRI# input pin. '1' indicates an over-current condition. '0' indicates normal power operation.
0	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.

† Bits 3:0 are returned in response to a Get Hub Status request from the USB host. This response is a four-byte field with zero padding (MSB at left): 0000 0000 0000 00[3] 0 0000 0000 0000 00[1] 0.

IEN0

 Address: S:A8H
 Reset State: 0000 0000B

Interrupt Enable Register 0. IEN0 contains two types of interrupt enable bits. The global enable bit (EA) enables/disables all of the interrupts (including those in IEN1), except the TRAP interrupt, which is always enabled. The remaining bits enable/disable the other individual interrupts.

7
0

EA	EC	ET2	ES	ET1	EX1	ET0	EX0
----	----	-----	----	-----	-----	-----	-----

Bit Number	Bit Mnemonic	Function
7	EA	Global Interrupt Enable: Setting this bit enables all interrupts that are individually enabled by bits 0–6 of this register, as well as the interrupts enabled by the bits in the IEN1 SFR. Clearing this bit disables all interrupts, except the TRAP interrupt, which is always enabled.
6	EC	PCA Interrupt Enable: Setting this bit enables the PCA interrupt.
5	ET2	Timer 2 Overflow Interrupt Enable: Setting this bit enables the timer 2 overflow interrupt.
4	ES	Serial I/O Port Interrupt Enable: Setting this bit enables the serial I/O port interrupt.
3	ET1	Timer 1 Overflow Interrupt Enable: Setting this bit enables the timer 1 overflow interrupt.
2	EX1	External Interrupt 1 Enable: Setting this bit enables external interrupt 1.
1	ET0	Timer 0 Overflow Interrupt Enable: Setting this bit enables the timer 0 overflow interrupt.
0	EX0	External Interrupt 0 Enable: Setting this bit enables external interrupt 0.

IEN1Address: S:B1H
Reset State: xxxx x000H

Interrupt Enable Register 1. Contains the enable bits for the USB interrupts.

7

0

—	—	—	—	—	ESR	EF	ESOF
---	---	---	---	---	-----	----	------

Bit Number	Bit Mnemonic	Function
7:3	—	Reserved: Values read from these bits are indeterminate. Write zeros to these bits.
2	ESR	Enable Suspend/Resume: USB global suspend/resume interrupt enable bit.
1	EF	Enable Function: Transmit/Receive Done interrupt enable bit for non-isochronous USB function endpoints.
0	ESOF	Enable USB Hub/Start of Frame: Any start-of-frame interrupt enable for isochronous endpoints, or USB hub interrupt enable.

IPH0

 Address: S:B7H
 Reset State: x000 0000B

Interrupt Priority High Control Register 0. IPH0, together with IPL0, assigns each interrupt in IEN0 a priority level from 0 (lowest) to 3 (highest):

IPH0.x	IPL0.x	Priority Level
0	0	0 (lowest priority)
0	1	1
1	0	2
1	1	3 (highest priority)

7
0

—	IPH0.6	IPH0.5	IPH0.4	IPH0.3	IPH0.2	IPH0.1	IPH0.0
---	--------	--------	--------	--------	--------	--------	--------

Bit Number	Bit Mnemonic	Function
7	—	Reserved. The value read from this bit is indeterminate. Write a zero to this bit.
6	IPH0.6	PCA Interrupt Priority Bit High
5	IPH0.5	Timer 2 Overflow Interrupt Priority Bit High
4	IPH0.4	Serial I/O Port Interrupt Priority Bit High
3	IPH0.3	Timer 1 Overflow Interrupt Priority Bit High
2	IPH0.2	External Interrupt 1 Priority Bit High
1	IPH0.1	Timer 0 Overflow Interrupt Priority Bit High
0	IPH0.0	External Interrupt 0 Priority Bit High

IPH1

Address: S:B3H
 Reset State: x000 0000B

Interrupt Priority High Control Register 1. IPH1, together with IPL1, assigns each interrupt in IEN1 a priority level from 0 (lowest) to 3 (highest):

IPH1.x	IPL1.x	Priority Level
0	0	0 (lowest priority)
0	1	1
1	0	2
1	1	3 (highest priority)

7

0

—	—	—	—	—	IPH1.2	IPH1.1	IPH1.0
---	---	---	---	---	--------	--------	--------

Bit Number	Bit Mnemonic	Function
7:3	—	Reserved: Values read from these bits are indeterminate. Write zeros to these bits.
2	IPH1.2	Global Suspend/Resume Interrupt Priority Bit High
1	IPH1.1	USB Function Interrupt Priority Bit High
0	IPH1.0	USB Hub/SOF Interrupt Priority Bit High

IPL0

 Address: S:B8H
 Reset State: x000 0000B

Interrupt Priority Low Control Register 0. IPL0, together with IPH0, assigns each interrupt in IEN0 a priority level from 0 (lowest) to 3 (highest):

IPH0.x	IPL0.x	Priority Level
0	0	0 (lowest priority)
0	1	1
1	0	2
1	1	3 (highest priority)

7
0

—	IPL0.6	IPL0.5	IPL0.4	IPL0.3	IPL0.2	IPL0.1	IPL0.0
---	--------	--------	--------	--------	--------	--------	--------

Bit Number	Bit Mnemonic	Function
7	—	Reserved. The value read from this bit is indeterminate. Write a zero to this bit.
6	IPL0.6	PCA Interrupt Priority Bit Low
5	IPL0.5	Timer 2 Overflow Interrupt Priority Bit Low
4	IPL0.4	Serial I/O Port Interrupt Priority Bit Low
3	IPL0.3	Timer 1 Overflow Interrupt Priority Bit Low
2	IPL0.2	External Interrupt 1 Priority Bit Low
1	IPL0.1	Timer 0 Overflow Interrupt Priority Bit Low
0	IPL0.0	External Interrupt 0 Priority Bit Low

IPL1

Address: S:B2H
Reset State: x000 0000B

Interrupt Priority Low Control Register 1. IPL1, together with IPH1, assigns each interrupt in IEN1 a priority level from 0 (lowest) to 3 (highest):

IPH1.x	IPL1.x	Priority Level
0	0	0 (lowest priority)
0	1	1
1	0	2
1	1	3 (highest priority)

7

0

—	—	—	—	—	IPL1.2	IPL1.1	IPL1.0
---	---	---	---	---	--------	--------	--------

Bit Number	Bit Mnemonic	Function
7:3	—	Reserved: Values read from these bits are indeterminate. Write zeros to these bits.
2	IPL1.2	Global Suspend/Resume Interrupt Priority Bit Low
1	IPL1.1	USB Function Interrupt Priority Bit Low
0	IPL1.0	USB Hub/SOF Interrupt Priority Bit Low

P0

Address: S:80H
Reset State: 1111 1111B

Port 0. P0 is the SFR that contains data to be driven out from the port 0 pins. Read-modify-write instructions that read port 0 read this register. The other instructions that read port 0 read the port 0 pins. When port 0 is used for an external bus cycle, the CPU always writes FFH to P0, and the former contents of P0 are lost.

7

0

P0 Contents							
-------------	--	--	--	--	--	--	--

Bit Number	Bit Mnemonic	Function
7:0	P0.7:0	Port 0 Register: Write data to be driven onto the port 0 pins to these bits.

P1 Address: S:90H
Reset State: 1111 1111B

Port 1. P1 is the SFR that contains data to be driven out from the port 1 pins. Read-modify-write instructions that read port 1 read this register. Other instructions that read port 1 read the port 1 pins.

7 0

P1 Contents

Bit Number	Bit Mnemonic	Function
7:0	P1.7:0	Port 1 Register: Write data to be driven onto the port 1 pins to these bits.

P2 Address: S:A0H
Reset State: 1111 1111B

Port 2. P2 is the SFR that contains data to be driven out from the port 2 pins. Read-modify-write instructions that read port 2 read this register. Other instructions that read port 2 read the port 2 pins.

7 0

P2 Contents

Bit Number	Bit Mnemonic	Function
7:0	P2.7:0	Port 2 Register: Write data to be driven onto the port 2 pins to these bits.



P3

Address: S:B0H
 Reset State: 1111 1111B

Port 3. P3 is the SFR that contains data to be driven out from the port 3 pins. Read-modify-write instructions that read port 3 read this register. Other instructions that read port 3 read the port 3 pins.

7

0

P3 Contents

Bit Number	Bit Mnemonic	Function
7:0	P3.7:0	Port 3 Register: Write data to be driven onto the port 3 pins to these bits.

PCON

 Address: S:87H
 Reset State: 00xx 0000B

Power Control Register. Contains the power off flag (POF) and bits for enabling the idle and powerdown modes. Also contains two general-purpose flags and two bits that control serial I/O functions—the double baud rate bit and a bit that selects whether accesses to SCON.7 are to the FE bit or the SM0 bit.

 7 0

SMOD1	SMOD0	LC	POF	GF1	GF0	PD	IDL
-------	-------	----	-----	-----	-----	----	-----

Bit Number	Bit Mnemonic	Function
7	SMOD1	Double Baud Rate Bit: When set, doubles the baud rate when timer 1 is used and mode 1, 2, or 3 is selected in the SCON register. See “Baud Rates” on page 13-10.
6	SMOD0	SCON.7 Select: When set, read/write accesses to SCON.7 are to the FE bit. When clear, read/write accesses to SCON.7 are to the SM0 bit. See the SCON register (Figure 13-2 on page 13-4).
5	LC	Low-clock Mode Enable: Setting this bit forces the internal clock (F_{CLK}) distributed to the CPU and peripherals (but not the USB module) to 3 MHz. This bit is automatically set after a reset. Clearing this bit through firmware returns F_{CLK} to the clock frequency determined by pins PLLSEL2:0.
4	POF	Power Off Flag: Set by hardware as V_{CC} rises above 3 V to indicate that power has been off or V_{CC} had fallen below 3 V and that on-chip volatile memory is indeterminate. Set or cleared by firmware.
3	GF1	General Purpose Flag: Set or cleared by firmware. One use is to indicate whether an interrupt occurred during normal operation or during idle mode.
2	GF0	General Purpose Flag: Set or cleared by firmware. One use is to indicate whether an interrupt occurred during normal operation or during idle mode.
1	PD	Powerdown Mode Bit: When set, activates powerdown mode. This bit should only be set if the GSUS bit is also set. Cleared by hardware when an interrupt or reset occurs.
0	IDL	Idle Mode Bit: When set, activates idle mode. Cleared by hardware when an interrupt or reset occurs. If IDL and PD are both set, PD takes precedence.

PCON1

Address: S:0DFH
Reset State: xxx0 000B

USB Power Control Register. Facilitates the control and status relating to global suspend and resume, USB reset separation, and remote wake-up of the 8x930.

7

0

—	—	—	URDIS	URST	RWU	GRSM	GSUS
---	---	---	-------	------	-----	------	------

Bit Number	Bit Mnemonic	Function
7:5	—	Reserved: The value read from these bits are indeterminate. Write zeroes to these bits.
4	URDIS (8x930Ax)	USB Reset Disable: When clear by firmware, a chip reset occurs upon receiving of a USB reset signal. This resets the MCS® 251 core, USB blocks and all peripherals. When set by firmware, the MCS 251 core and peripherals will not reset when a USB reset signal is detected. Upon detecting a USB reset signal, the 8x930Ax resets all the USB blocks (FIFOs, FIU, SIE, and transceiver), sets the URST bit and generates a USB reset interrupt (refer to the description of URST).
	URDIS (8x930Hx)	Reserved: The value read from these bits are indeterminate. Write zeroes to these bits.
3	URST (8x930Ax)	USB Reset Flag: This flag will be set by hardware when a USB reset occurs, regardless of whether the ESR bit in the IEN1 register is enabled or disabled. The URST also serves as the interrupt bit, ORed with GRSM and GSUS bits to generate an interrupt. Should be cleared by firmware when serving the USB reset interrupt.
	URST (8x930Hx)	Reserved: The value read from these bits are indeterminate. Write zeroes to these bits.
2	RWU	Remote Wake-up Bit: 1 = wake-up. This bit is used by the USB function to initiate a remote wake-up. Set by firmware to drive resume signaling on the USB lines to the host or upstream hub. Cleared by hardware. Note: do not set this bit unless the USB function is suspended (GSUS = 1 and GRSM = 0). See Figure 15-3 on page 15-11.

† Firmware should prioritize GRSM over GSUS if both bits are set simultaneously.

PCON1 (Continued)

Address: S:0DFH
 Reset State: xxx0 0000B

USB Power Control Register. Facilitates the control and status relating to global suspend and resume, USB reset separation, and remote wake-up of the 8x930.

7	—	—	—	URDIS	URST	RWU	GRSM	GSUS	0
---	---	---	---	-------	------	-----	------	------	---

1	GRSM	<p>Global Resume Bit:</p> <p>1 = resume. Set by hardware when a global resume is detected on the USB lines. This bit is ORed with GSUS to generate the interrupt[†]. Cleared by firmware when servicing the global suspend/resume interrupt. (This bit can also be set/cleared by firmware for testability.) This bit is not set if remote wakeup is used (see RWU). See Figure 15-3 on page 15-11.</p>
0	GSUS	<p>Global Suspend Bit:</p> <p>1 = suspend. This bit is set by hardware when global suspend is detected on the USB lines. This bit is ORed with the GRSM bit to generate the interrupt.[†] During this ISR, firmware should set the PD bit to enter the suspend mode. Cleared by firmware when a resume occurs. See Figure 15-3 on page 15-11.</p>

[†] Firmware should prioritize GRSM over GSUS if both bits are set simultaneously.

PSW

 Address: S:D0H
 Reset State: 0000 0000B

7

0

CY	AC	F0	RS1	RS0	OV	UD	P
----	----	----	-----	-----	----	----	---

Bit Number	Bit Mnemonic	Function																				
7	CY	Carry Flag: The carry flag is set by an addition instruction (ADD, ADDC) if there is a carry out of the MSB. It is set by a subtraction (SUB, SUBB) or compare (CMP) if a borrow is needed for the MSB. The carry flag is also affected by logical bit, bit move, multiply, decimal adjust, and some rotate and shift instructions (see Table 5-10).																				
6	AC	Auxiliary Carry Flag: The auxiliary carry flag is affected only by instructions that address 8-bit operands. The AC flag is set if an arithmetic instruction with an 8-bit operand produces a carry out of bit 3 (from addition) or a borrow into bit 3 (from subtraction). Otherwise, it is cleared. This flag is useful for BCD arithmetic (see Table 5-10).																				
5	F0	Flag 0: This general-purpose flag is available to the user.																				
4:3	RS1:0	Register Bank Select Bits 1 and 0: These bits select the memory locations that comprise the active bank of the register file (registers R0–R7). <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>RS1</th> <th>RS0</th> <th>Bank</th> <th>Address</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> <td>00H–07H</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>08H–0FH</td> </tr> <tr> <td>1</td> <td>0</td> <td>2</td> <td>10H–17H</td> </tr> <tr> <td>1</td> <td>1</td> <td>3</td> <td>18H–1FH</td> </tr> </tbody> </table>	RS1	RS0	Bank	Address	0	0	0	00H–07H	0	1	1	08H–0FH	1	0	2	10H–17H	1	1	3	18H–1FH
RS1	RS0	Bank	Address																			
0	0	0	00H–07H																			
0	1	1	08H–0FH																			
1	0	2	10H–17H																			
1	1	3	18H–1FH																			
2	OV	Overflow Flag: This bit is set if an addition or subtraction of signed variables results in an overflow error (i.e., if the magnitude of the sum or difference is too great for the seven LSBs in 2's-complement representation). The overflow flag is also set if a multiplication product overflows one byte or if a division by zero is attempted.																				
1	UD	User-definable Flag: This general-purpose flag is available to the user.																				
0	P	Parity Bit: This bit indicates the parity of the accumulator. It is set if an odd number of bits in the accumulator are set. Otherwise, it is cleared. Not all instructions update the parity bit. The parity bit is set or cleared by instructions that change the contents of the accumulator (ACC, Register R11).																				

PSW1

 Address: S:D1H
 Reset State: 0000 0000B

 7 0

CY	AC	N	RS1	RS0	OV	Z	—
----	----	---	-----	-----	----	---	---

Bit Number	Bit Mnemonic	Function
7	CY	Carry Flag: Identical to the CY bit in the PSW register.
6	AC	Auxiliary Carry Flag: Identical to the AC bit in the PSW register.
5	N	Negative Flag: This bit is set if the result of the last logical or arithmetic operation was negative (i.e., bit 15 = 1). Otherwise it is cleared.
4–3	RS1:0	Register Bank Select Bits 0 and 1: Identical to the RS1:0 bits in the PSW register.
2	OV	Overflow Flag: Identical to the OV bit in the PSW register.
1	Z	Zero Flag: This flag is set if the result of the last logical or arithmetic operation is zero. Otherwise it is cleared.
0	—	Reserved: The value read from this bit is indeterminate. Write a zero to this bit.

RCAP2H, RCAP2L

 Address: RCAP2H S:CBH
 RCAP2L S:CAH
 Reset State: 0000 0000B

Timer 2 Reload/Capture Registers. This register pair stores 16-bit values to be loaded into or captured from the timer register (TH2/TL2) in timer 2.

 7 0

High/Low Byte of Timer 2 Reload/Capture Value	
---	--

Bit Number	Bit Mnemonic	Function
7:0	RCAP2H.7:0 RCAP2L.7:0	High byte of the timer 2 reload/recapture register Low byte of the timer 2 reload/recapture register



**RXCNTH,
RXCNTL**
(Endpoint-indexed)

Address:

S:E7H
S:E6H

Reset States:

Endpoint 1	RXCNTH	xxxx xx00B
	RXCNTL	0000 0000B
Other Endpoints [†]	RXCNTL	xxx0 0000B

Receive FIFO Byte-count High and Low Registers. High and low register in a two-register ring buffer used to store the byte count for the data packets received in the receive FIFO specified by EPINDEX.

15 (RXCNT) **Endpoint 1** **8**

—	—	—	—	—	—	BC9	BC8
---	---	---	---	---	---	-----	-----

7 (RXCNTL) **0**

BC7	BC6	BC5	BC4	BC3	BC2	BC1	BC0
-----	-----	-----	-----	-----	-----	-----	-----

7 (RXCNTL) **Other Endpoints[†]** **0**

—	—	—	BC4	BC3	BC2	BC1	BC0
---	---	---	-----	-----	-----	-----	-----

Bit Number	Bit Mnemonic	Function
Endpoint 1		
15:10	—	Reserved. Write zeros to these bits.
9:0	BC9:0	Receive Byte Count. Ten-bit, ring buffer byte. Stores receive byte count (RXCNT). Implemented for function endpoint 1 only.
Other Endpoints[†]		
7:0	—	Reserved. Write zeros to these bits.
4:0	BC4:0	Receive Byte Count. Five-bit, ring buffer. Stores receive byte count (RXCNT). 3.

[†] Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (6EPP option, 8x930Ax only). Byte count registers are not implemented for hub endpoint 1.

RXCON

(Endpoint-indexed)

 Address: S:E4H
 Reset State: 0x00 0100B

Receive FIFO Control Register. Controls the receive FIFO specified by EPINDEX.

7

0

RXCLR	—	RXWS	RXFFRC	RXISO	ARM	ADVWM	REVWP
-------	---	------	--------	-------	-----	-------	-------

Bit Number	Bit Mnemonic	Function
7	RXCLR	Clear the Receive FIFO: Set this bit to flush the entire receive FIFO. All flags in RXFLG revert to their reset states (RXEMP is set; all other flags clear). The ARM, RXISO and RXWS bits in this register and the RXSEQ bit in the RXSTAT register are not affected by this operation. Hardware clears this bit when the flush operation is completed.
6	—	Reserved: Values read from this bit are indeterminate. Write zero to this bit.
5	RXWS	Receive FIFO Wait-state Read: At the 8x930 core frequency of 12 MHz, not all instructions that access the receive FIFO are guaranteed to work due to critical paths inherent in the 8x930 architecture. While all MOV instructions from the receive FIFO are guaranteed to work at 12 MHz, arithmetic instructions (e.g., ADD, SUB, etc.) where the receive FIFO is the source and the register file the destination may not work at this speed. For applications using arithmetic instructions, set the RXWS bit to read the receive FIFO with one wait state — this will eliminate the critical path. This bit is not reset when the RXCLR bit is set.
4	RXFFRC	FIFO Read Complete: [†] Set this bit to release the receive FIFO when a data set read is complete. Setting this bit “clears” the RXFIF “bit” (in the RXFLG register) corresponding to the data set that was just read. Hardware clears this bit after the RXFIF bit is cleared. All data from this data set must have been read. Note that FIFO Read Complete only works if STOVW and EDOVW are cleared.
3	RXISO	Isochronous Data Type: [†] Set this bit to indicate that the receive FIFO is programmed to receive isochronous data and to set up the USB Interface to handle an isochronous data transfer. This bit is not reset when the RXCLR bit is set; it must be cleared by firmware.

[†] ARM mode is recommended. ADVWM and REVWP, which control the write marker and write pointer when ARM = 0, are used for test purposes,



RXCON (Continued)
(Endpoint-indexed)

Address: S:E4H
Reset State: 0x00 0100B

Receive FIFO Control Register. Controls the receive FIFO specified by EPINDEX.

7

0

RXCLR	—	RXWS	RXFFRC	RXISO	ARM	ADVWM	REVWP
-------	---	------	--------	-------	-----	-------	-------

Bit Number	Bit Mnemonic	Function																
2	ARM	<p>Auto Receive Management:</p> <p>When set, the write pointer and write marker are adjusted automatically based on the following conditions:</p> <table border="1"> <thead> <tr> <th>RXISO</th> <th>RX Status</th> <th>Write Pointer</th> <th>Write Marker</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>ACK</td> <td>Unchanged</td> <td>Advanced</td> </tr> <tr> <td>0</td> <td>NAK</td> <td>Reversed</td> <td>Unchanged</td> </tr> <tr> <td>1</td> <td>NAK</td> <td>Unchanged</td> <td>Advanced</td> </tr> </tbody> </table> <p>When this bit is set, setting REVWP or ADVWM has no effect. Hardware neither clears nor sets this bit. This is a sticky bit that is not reset when RXCLR is set.</p> <p>NOTE: This bit should always be set, except for testing.</p>	RXISO	RX Status	Write Pointer	Write Marker	X	ACK	Unchanged	Advanced	0	NAK	Reversed	Unchanged	1	NAK	Unchanged	Advanced
RXISO	RX Status	Write Pointer	Write Marker															
X	ACK	Unchanged	Advanced															
0	NAK	Reversed	Unchanged															
1	NAK	Unchanged	Advanced															
1	ADVWM	<p>Advance Write Marker: †</p> <p>(For non-ARM mode only) Set this bit to advance the write marker to the origin of the next data set. Advancing the write marker is used for back-to-back receptions. Hardware clears this bit after the write marker is advanced. Setting this bit is effective only when the REVWP, ARM and RXCLR bits are clear.</p>																
0	REVWP	<p>Reverse Write Pointer: †</p> <p>(For non-ARM mode only) Set this bit to return the write pointer to the origin of the last data set received, as identified by the write marker. The FIU can then re-receive the last data packet and write to the receive FIFO starting from the same origin when the host re-sends the same data packet. Hardware clears this bit after the write pointer is reversed. Setting this bit is effective only when the ADVWM, ARM, and RXCLR bits are all clear.</p> <p>REVWP is used when a data packet is bad. When the function interface receives the data packet again, the write starts at the origin of the previous (bad) data set.</p>																

† ARM mode is recommended. ADVWM and REVWP, which control the write marker and write pointer when ARM = 0, are used for test purposes,

RXDAT
(Endpoint-indexed)

Address: S:E3H
Reset: xxxx xxxxB

Receive FIFO Data Register. Receive FIFO data specified by EPINDEX is stored and read from this register.

7

0

RXDAT.7:0

Bit Number	Bit Mnemonic	Function
7:0	RXDAT.7:0	To write data to the receive FIFO, the FIU writes to this register. To read data from the receive FIFO, the 8x930 reads from this register. The write pointer and read pointer are incremented automatically after a write and read, respectively.



RXFLG

(Endpoint-indexed)

Address: S:E5H
Reset State: 00xx 1000B

Receive FIFO Flag Register. These flags indicate the status of data packets in the receive FIFO specified by EPINDEX.

7

0

RXFIF1	RXFIF0	—	—	RXEMP	RXFULL	RXURF	RXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function																																													
7:6	RXFIF1:0	<p>Receive FIFO Index Flags: (read-only)</p> <p>These read-only flags indicate which data packets are present in the receive FIFO (see Table 7-5 on page 7-26). The RXFIF bits are updated after each write to RXCNT to reflect the addition of a data packet. Likewise, the RXFIF bits are cleared in sequence after each setting of the RXFFRC bit. The next-state table for RXFIF bits is shown below for operation in dual packet mode.</p> <table border="1"> <thead> <tr> <th>RXFIF1:0</th> <th>Operation</th> <th>Flag</th> <th>Next RXFIF1:0</th> <th>Next Flag</th> </tr> </thead> <tbody> <tr> <td>00</td> <td>Adv WM</td> <td>X</td> <td>01</td> <td>Unchanged</td> </tr> <tr> <td>01</td> <td>Adv WM</td> <td>X</td> <td>01</td> <td>Unchanged</td> </tr> <tr> <td>10</td> <td>Adv WM</td> <td>X</td> <td>11</td> <td>Unchanged</td> </tr> <tr> <td>00</td> <td>Set RXFFRC</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>01</td> <td>Set RXFFRC</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>11</td> <td>Set RXFFRC</td> <td>X</td> <td>10/01</td> <td>Unchanged</td> </tr> <tr> <td>10</td> <td>Set RXFFRC</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>XX</td> <td>Rev WP</td> <td>X</td> <td>Unchanged</td> <td>Unchanged</td> </tr> </tbody> </table> <p>When the receive FIFO is programmed to operate in single packet mode (RXSPM set in EPCON), valid RXFIF states are 00 and 01 only.</p> <p>In ISO mode, RXOVF, RXURF, and RXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. RXFIF is "incremented" by the USB and "decremented" by firmware. Therefore, setting RXFFRC "decrements" RXFIF immediately. However, a successful USB transaction within a frame "increments" RXFIF only at SOF. For traceability, you must check the RXFIF flags before and after reads from the receive FIFO and the setting of RXFFRC in RXCON.</p> <p>NOTE: To simplify firmware development, it is recommended that you utilize control endpoints in single-packet mode only.</p>	RXFIF1:0	Operation	Flag	Next RXFIF1:0	Next Flag	00	Adv WM	X	01	Unchanged	01	Adv WM	X	01	Unchanged	10	Adv WM	X	11	Unchanged	00	Set RXFFRC	X	00	Unchanged	01	Set RXFFRC	X	00	Unchanged	11	Set RXFFRC	X	10/01	Unchanged	10	Set RXFFRC	X	00	Unchanged	XX	Rev WP	X	Unchanged	Unchanged
RXFIF1:0	Operation	Flag	Next RXFIF1:0	Next Flag																																											
00	Adv WM	X	01	Unchanged																																											
01	Adv WM	X	01	Unchanged																																											
10	Adv WM	X	11	Unchanged																																											
00	Set RXFFRC	X	00	Unchanged																																											
01	Set RXFFRC	X	00	Unchanged																																											
11	Set RXFFRC	X	10/01	Unchanged																																											
10	Set RXFFRC	X	00	Unchanged																																											
XX	Rev WP	X	Unchanged	Unchanged																																											
5:4	—	<p>Reserved:</p> <p>Values read from these bits are indeterminate. Write zeros to these bits.</p>																																													
3	RXEMP	<p>Receive FIFO Empty Flag (read-only):</p> <p>Hardware sets this flag when the write pointer is at the same location as the read pointer and the write pointer equals the write marker and neither pointer has rolled over. Hardware clears the bit when the empty condition no longer exists. This is not a sticky bit and always tracks the current status of the receive FIFO, regardless of ISO or non-ISO mode.</p>																																													

† When set, all transmissions are NAKed.

RXFLG (Continued)
 (Endpoint-indexed)

 Address: S:E5H
 Reset State: 00xx 1000B

Receive FIFO Flag Register. These flags indicate the status of data packets in the receive FIFO specified by EPINDEX.

7

0

RXFIF1	RXFIF0	—	—	RXEMP	RXFULL	RXURF	RXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
2	RXFULL	Receive FIFO Full Flag (read-only): Hardware sets this flag when the write pointer has rolled over and equals the read pointer. Hardware clears the bit when the full condition no longer exists. This is not a sticky bit and always tracks the current status of the receive FIFO, regardless of ISO or non-ISO mode.
1	RXURF	Receive FIFO Underrun Flag†: Hardware sets this bit when an additional byte is read from an empty receive FIFO or RXCNT. Hardware does not clear this bit, so you must clear it in firmware. When the receive FIFO underruns, the read pointer will not advance — it remains locked in the empty position. In ISO mode, RXOVF, RXURF, and RXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since underrun can only be caused by firmware, RXURF is updated immediately. You must check the RXURF flag after reads from the receive FIFO before setting the RXFFRC bit in RXCON. NOTE: When this bit is set, the FIFO is in an unknown state. It is recommended that you reset the FIFO in the error management routine using the RXCLR bit in the RXCON register.
0	RXOVF	Receive FIFO Overrun Flag†: This bit is set when the FIU writes an additional byte to a full receive FIFO or writes a byte count to RXCNT with FIF1:0 = 11. This is a sticky bit that <i>must</i> be cleared through firmware, although it can be cleared by hardware if a SETUP packet is received after an RXOVF error had already occurred.† When this bit is set, the FIFO is in an unknown state, thus it is recommended that you reset the FIFO in the error management routine using the RXCLR bit in the RXCON register. When the receive FIFO overruns, the write pointer will not advance — it remains locked in the full position. In ISO mode, RXOVF, RXURF, and RXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since overrun can only be caused by the USB, RXOVF is updated only at the next SOF regardless of where the overrun occurred during the current frame.†

† When set, all transmissions are NAKed.



RXSTAT

(Endpoint-indexed)

Address: S:E2H
Reset State: 0000 0000B

Endpoint Receive Status Register. Contains the current endpoint status of the receive FIFO specified by EPINDEX. (Endpoint-indexed SFR)

7

0

RXSEQ	RXSETUP	STOVW	EDOVW	RXSOVW	RXVOID	RXERR	RXACK
-------	---------	-------	-------	--------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
7	RXSEQ	<p>Receiver Endpoint Sequence Bit (read, conditional write): †</p> <p>This bit will be toggled on completion of an ACK handshake in response to an OUT token. This bit will be set (or cleared) by hardware after reception of a SETUP token.</p> <p>This bit can be written by firmware if the RXSOVW bit is set when written along with the new RXSEQ value.</p> <p>NOTE: Always verify this bit after writing to ensure that there is no conflict with hardware, which could occur if a new SETUP token is received.</p>
6	RXSETUP	<p>Received Setup Token:</p> <p>This bit is set by hardware when a valid SETUP token has been received. When set, this bit causes received IN or OUT tokens to be NAKed until the bit is cleared to allow proper data management for the transmit and receive FIFOs from the previous transaction.</p> <p>IN or OUT tokens are NAKed even if the endpoint is stalled (RXSTL or TXSTL) to allow a control transaction to clear a stalled endpoint.</p> <p>Clear this bit upon detection of a SETUP token after the firmware is ready to complete the status stage of a control transaction.</p>
5	STOVW	<p>Start Overwrite Flag (read-only):</p> <p>Set by hardware upon receipt of a SETUP token for any control endpoint to indicate that the receive FIFO is being overwritten with new SETUP data. When set, the FIFO state (FIF and read pointer) resets and is locked for this endpoint until EDVW is set. This prevents a prior, ongoing firmware read from corrupting the read pointer as the receive FIFO is being cleared and new data is being written into it. This bit is cleared by hardware at the end of handshake phase transmission of the setup stage.</p> <p>This bit is used only for control endpoints.</p>

† Under normal operation, this bit should not be modified by the user.

†† For additional information on the operation of these bits see Appendix D, "Data Flow Model."

††† The SIE will handle all sequence bit tracking. This bit should be used only when initializing a new configuration or interface.

RXSTAT
(Endpoint-indexed)

Address: S:E2H
Reset State: 0000 0000B

Endpoint Receive Status Register. Contains the current endpoint status of the receive FIFO specified by EPINDEX. (Endpoint-indexed SFR)

7

0

RXSEQ	RXSETUP	STOVW	EDOVW	RXSOVW	RXVOID	RXERR	RXACK
-------	---------	-------	-------	--------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
4	EDOVW	<p>End Overwrite Flag:[†] This flag is set by hardware during the handshake phase of a SETUP stage. It is set after every SETUP packet is received and must be cleared prior to reading the contents of the FIFO. When set, the FIFO state (FIF and read pointer) remains locked for this endpoint until this bit is cleared. This prevents a prior, ongoing firmware read from corrupting the read pointer after the new data has been written into the receive FIFO.</p> <p>This bit is only used for control endpoints.</p> <p>NOTE: Make sure the ED OVW bit is cleared prior to reading the contents of the FIFO.</p>
3	RXSOVW	<p>Receive Data Sequence Overwrite Bit:[†]</p> <p>Write a '1' to this bit to allow the value of the RXSEQ bit to be overwritten. Writing a '0' to this bit has no effect on RXSEQ. This bit always returns '0' when read.^{†††}</p>
2	RXVOID	<p>Receive Void Condition (read-only):^{††}</p> <p>This bit is set when no valid data is received in response to a SETUP or OUT token due to one of the following conditions:</p> <ol style="list-style-type: none"> 1. The receive FIFO is still locked 2. The EPCON register's RXSTL bit is set <p>This bit is set and cleared by hardware. For non-isochronous transactions, this bit is updated by hardware at the end of the transaction in response to a valid OUT token. For isochronous transactions, it is not updated until the next SOF.</p>

[†] Under normal operation, this bit should not be modified by the user.

^{††} For additional information on the operation of these bits see Appendix D, "Data Flow Model."

^{†††} The SIE will handle all sequence bit tracking. This bit should be used only when initializing a new configuration or interface.



RXSTAT
(Endpoint-indexed)

Address: S:E2H
Reset State: 0000 0000B

Endpoint Receive Status Register. Contains the current endpoint status of the receive FIFO specified by EPINDEX. (Endpoint-indexed SFR)

7

0

RXSEQ	RXSETUP	STOVW	EDOVW	RXSOVW	RXVOID	RXERR	RXACK
-------	---------	-------	-------	--------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
1	RXERR	<p>Receive Error (read-only):^{††}</p> <p>Set when an error condition has occurred with the reception. Complete or partial data has been written into the receive FIFO. No handshake is returned. The error can be one of the following conditions:</p> <ol style="list-style-type: none"> 1. Data failed CRC check. 2. Bit stuffing error. 3. A receive FIFO goes into overrun or underrun condition while receiving. <p>This bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXDx bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXACK bit at the end of data reception and is mutually exclusive with RXACK.</p>
0	RXACK	<p>Receive Acknowledged (read-only):^{††}</p> <p>This bit is set when data is received completely into a receive FIFO and an ACK handshake is sent. This read-only bit is updated by hardware at the end of a valid SETUP or OUT token transaction (non-isochronous) or at the next SOF on each valid OUT token transaction (isochronous).</p> <p>The corresponding FRXDx bit of FIFLG or FIFLG1 (8x930Ax with 6EPP) is set when active. This bit is updated with the RXERR bit at the end of data reception and is mutually exclusive with RXERR.</p>

[†] Under normal operation, this bit should not be modified by the user.

^{††} For additional information on the operation of these bits see Appendix D, "Data Flow Model."

^{†††} The SIE will handle all sequence bit tracking. This bit should be used only when initializing a new configuration or interface.

SADDR Address: S:A9H
Reset State: 0000 0000B

Slave Individual Address Register. SADDR contains the device's individual address for multiprocessor communication.

7 0

Slave Individual Address

Bit Number	Bit Mnemonic	Function
7:0	SADDR.7:0	

SADEN Address: S:B9H
Reset State: 0000 0000B

Mask Byte Register. This register masks bits in the SADDR register to form the device's given address for multiprocessor communication.

7 0

Mask for SADDR

Bit Number	Bit Mnemonic	Function
7:0	SADEN.7:0	

SBUF Address: S:99H
Reset State: xxxx xxxxB

Serial Data Buffer. Writing to SBUF loads the transmit buffer of the serial I/O port. Reading SBUF reads the receive buffer of the serial I/O port.

7 0

Data Sent/Received by Serial I/O Port

Bit Number	Bit Mnemonic	Function
7:0	SBUF.7:0	



SCON

Address: S:98H
Reset State: 0000 0000B

Serial Port Control Register. SCON contains serial I/O control and status bits, including the mode select bits and the interrupt flag bits.

7

0

FE/SM0	SM1	SM2	REN	TB8	RB8	TI	RI
--------	-----	-----	-----	-----	-----	----	----

Bit Number	Bit Mnemonic	Function																									
7	FE SM0	<p>Framing Error Bit: To select this function, set the SMOD0 bit in the PCON register. Set by hardware to indicate an invalid stop bit. Cleared by firmware, not by valid frames.</p> <p>Serial Port Mode Bit 0: To select this function, clear the SMOD0 bit in the PCON register. Firmware writes to bits SM0 and SM1 to select the serial port operating mode. Refer to the SM1 bit for the mode selections.</p>																									
6	SM1	<p>Serial Port Mode Bit 1: Firmware writes to bits SM1 and SM0 (above) to select the serial port operating mode.</p> <table border="1"> <thead> <tr> <th>SM0</th> <th>SM1</th> <th>Mode</th> <th>Description</th> <th>Baud Rate[†]</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> <td>Shift register</td> <td>$F_{CLK}/6$</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>8-bit UART</td> <td>Variable</td> </tr> <tr> <td>1</td> <td>0</td> <td>2</td> <td>9-bit UART</td> <td>$F_{CLK}/16^{††}$ or $F_{CLK}/32^{††}$</td> </tr> <tr> <td>1</td> <td>1</td> <td>3</td> <td>9-bit UART</td> <td>Variable</td> </tr> </tbody> </table> <p>[†]See note on page 13-1. ^{††}Select by programming the SMOD bit in the PCON register (see section "Baud Rates" on page 13-10).</p>	SM0	SM1	Mode	Description	Baud Rate [†]	0	0	0	Shift register	$F_{CLK}/6$	0	1	1	8-bit UART	Variable	1	0	2	9-bit UART	$F_{CLK}/16^{††}$ or $F_{CLK}/32^{††}$	1	1	3	9-bit UART	Variable
SM0	SM1	Mode	Description	Baud Rate [†]																							
0	0	0	Shift register	$F_{CLK}/6$																							
0	1	1	8-bit UART	Variable																							
1	0	2	9-bit UART	$F_{CLK}/16^{††}$ or $F_{CLK}/32^{††}$																							
1	1	3	9-bit UART	Variable																							
5	SM2	<p>Serial Port Mode Bit 2: Firmware writes to bit SM2 to enable and disable the multiprocessor communication and automatic address recognition features. This allows the serial port to differentiate between data and command frames and to recognize slave and broadcast addresses.</p>																									
4	REN	<p>Receiver Enable Bit: To enable reception, set this bit. To enable transmission, clear this bit.</p>																									
3	TB8	<p>Transmit Bit 8: In modes 2 and 3, firmware writes the ninth data bit to be transmitted to TB8. Not used in modes 0 and 1.</p>																									

SCON (Continued)

 Address: S:98H
 Reset State: 0000 0000B

Serial Port Control Register. SCON contains serial I/O control and status bits, including the mode select bits and the interrupt flag bits.

7

0

FE/SM0	SM1	SM2	REN	TB8	RB8	TI	RI
--------	-----	-----	-----	-----	-----	----	----

Bit Number	Bit Mnemonic	Function
2	RB8	Receiver Bit 8: Mode 0: Not used. Mode 1 (SM2 clear): Set or cleared by hardware to reflect the stop bit received. Modes 2 and 3 (SM2 set): Set or cleared by hardware to reflect the ninth data bit received.
1	TI	Transmit Interrupt Flag Bit: Set by the transmitter after the last data bit is transmitted. Cleared by firmware.
0	RI	Receive Interrupt Flag Bit: Set by the receiver after the last data bit of a frame has been received. Cleared by firmware.

SOFH

Address: S:D3H
Reset State: 0000 0000B

Start of Frame High Register. Contains isochronous data transfer enable and interrupt bits and the upper three bits of the 11-bit time stamp received from the host.

7

0

SOFACK	ASOF	SOFIE	FTLOCK	SOFODIS	TS10	TS9	TS8
--------	------	-------	--------	---------	------	-----	-----

Bit Number	Bit Mnemonic	Function
7	SOFACK	<p>SOF Token Received without Error (read-only):</p> <p>When set, this bit indicates that the 11-bit time stamp stored in SOFL and SOFH is valid. This bit is updated every time a SOF token is received from the USB bus, and it is cleared when an artificial SOF is generated by the frame timer. This bit is set and cleared by hardware.</p>
6	ASOF	<p>Any Start of Frame:</p> <p>This bit is set by hardware to indicate that a new frame has started. The interrupt can result either from reception of an actual SOF packet or from an artificially-generated SOF from the frame timer. This interrupt is asserted in hardware even if the frame timer is not locked to the USB bus frame timing. When set, this bit is an indication that either an actual SOF packet was received or an artificial SOF was generated by the frame timer. This bit must be cleared by firmware or inverted and driven to the SOF# pin. The effect of setting this bit by firmware is the same as hardware: the external pin will be driven with an inverted ASOF value for eight T_{CLKS}.</p> <p>This bit also serves as the SOF interrupt flag. This interrupt is only asserted in hardware if the SOF interrupt is enabled (SOFIE set) and the interrupt channel is enabled.</p>
5	SOFIE	<p>SOF Interrupt Enable:</p> <p>When this bit is set, setting the ASOF bit causes an interrupt request to be generated if the interrupt channel is enabled. Hardware reads but does not write this bit.</p>
4	FTLOCK	<p>Frame Timer Locked (read-only):</p> <p>When set, this bit indicates that the frame timer is presently locked to the USB bus' frame time. When cleared, this bit indicates that the frame timer is attempting to synchronize to the frame time.</p>
3	SOFODIS	<p>SOF# Pin Output Disable:</p> <p>When set, no low pulse will be driven to the SOF# pin in response to setting the ASOF bit. The SOF# pin will be driven to '1' when SOFODIS is set. When this bit is clear, setting the ASOF bit causes the SOF# pin to be toggled with a low pulse for eight T_{CLKS}.</p>
2:0	TS10:8	<p>Time stamp received from host:</p> <p>TS10:8 are the upper three bits of the 11-bit frame number issued with an SOF token. This time stamp is valid only if the SOFACK bit is set.</p>

SOFL

 Address: S:D2H
 Reset State: 0000 0000B

Start-of-Frame Low Register. Contains the lower eight bits of the 11-bit time stamp received from the host.

 7 0

TS7:0

Bit Number	Bit Mnemonic	Function
7:0	TS7:0	Time stamp received from host: This time stamp is valid only if the SOFACK bit in the SOFH register is set. TS7:0 are the lower eight bits of the 11-bit frame number issued with a SOF token. If an artificial SOF is generated, the time stamp remains at its previous value and it is up to firmware to update it. These bits are set and cleared by hardware.

SP

 Address: S:81H
 Reset State: 0000 0111B

Stack Pointer. SP provides SFR access to location 63 in the register file (also named SP). SP is the lowest byte of the extended stack pointer (SPX = DR60). The extended stack pointer points to the current top of stack. When a byte is saved (PUSHed) on the stack, SPX is incremented, and then the byte is written to the top of stack. When a byte is retrieved (POPPed) from the stack, it is copied from the top of stack, and then SPX is decremented.

 7 0

SP Contents

Bit Number	Bit Mnemonic	Function
7:0	SP.7:0	Stack Pointer: Bits 0–7 of the extended stack pointer, SPX (DR60).

SPH

Address: S:BEH
 Reset State: 0000 0000B

Stack Pointer High. SPH provides SFR access to location 62 in the register file (also named SPH). SPH is the upper byte of the lower word of DR60, the extended stack pointer (SPX). The extended stack pointer points to the current top of stack. When a byte is saved (PUSHed) on the stack, SPX is incremented, and then the byte is written to the top of stack. When a byte is retrieved (POPped) from the stack, it is copied from the top of stack, and then SPX is decremented.

7

0

SPH Contents

Bit Number	Bit Mnemonic	Function
7:0	SPH.7:0	Stack Pointer High: Bits 8–15 of the extended stack pointer, SPX (DR(60)).

T2CON

 Address: S:C8H
 Reset State: 0000 0000B

Timer 2 Control Register. Contains the receive clock, transmit clock, and capture/reload bits used to configure timer 2. Also contains the run control bit, counter/timer select bit, overflow flag, external flag, and external enable for timer 2.

7
0

TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2#	CP/RL2#
-----	------	------	------	-------	-----	-------	---------

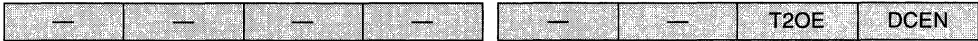
Bit Number	Bit Mnemonic	Function
7	TF2	Timer 2 Overflow Flag: Set by timer 2 overflow. Must be cleared by firmware. TF2 is not set if RCLK = 1 or TCLK = 1.
6	EXF2	Timer 2 External Flag: If EXEN2 = 1, capture or reload caused by a negative transition on T2EX sets EXF2. EXF2 does not cause an interrupt in up/down counter mode (DCEN = 1).
5	RCLK	Receive Clock Bit: Selects timer 2 overflow pulses (RCLK = 1) or timer 1 overflow pulses (RCLK = 0) as the baud rate generator for serial port modes 1 and 3.
4	TCLK	Transmit Clock Bit: Selects timer 2 overflow pulses (TCLK = 1) or timer 1 overflow pulses (TCLK = 0) as the baud rate generator for serial port modes 1 and 3.
3	EXEN2	Timer 2 External Enable Bit: Setting EXEN2 causes a capture or reload to occur as a result of a negative transition on T2EX unless timer 2 is being used as the baud rate generator for the serial port. Clearing EXEN2 causes timer 2 to ignore events at T2EX.
2	TR2	Timer 2 Run Control Bit: Setting this bit starts the timer.
1	C/T2#	Timer 2 Counter/Timer Select: C/T2# = 0 selects timer operation: timer 2 counts the divided-down system clock. C/T2# = 1 selects counter operation: timer 2 counts negative transitions on external pin T2.
0	CP/RL2#	Capture/Reload Bit: When set, captures occur on negative transitions at T2EX if EXEN2 = 1. When cleared, auto-reloads occur on timer 2 overflows or negative transitions at T2EX if EXEN2 = 1. The CP/RL2# bit is ignored and timer 2 forced to auto-reload on timer 2 overflow, if RCLK = 1 or TCLK = 1.

T2MOD

Address: S:C9H
 Reset State: xxxx xx00B

Timer 2 Mode Control Register. Contains the timer 2 down count enable and clock-out enable bits for timer 2 .

7 0



Bit Number	Bit Mnemonic	Function
7:2	—	Reserved: Values read from these bits are indeterminate. Write zeros to these bits.
1	T2OE	Timer 2 Output Enable Bit: In the timer 2 clock-out mode, connects the programmable clock output to external pin T2.
0	DCEN	Down Count Enable Bit: Configures timer 2 as an up/down counter.

TCON

 Address: S:88H
 Reset State: 0000 0000B

Timer/Counter Control Register. Contains the overflow and external interrupt flags and the run control and interrupt transition select bits for timer 0 and timer 1.

7
0

TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0
-----	-----	-----	-----	-----	-----	-----	-----

Bit Number	Bit Mnemonic	Function
7	TF1	Timer 1 Overflow Flag: Set by hardware when the timer 1 register overflows. Cleared by hardware when the processor vectors to the interrupt routine.
6	TR1	Timer 1 Run Control Bit: Set/cleared by firmware to turn timer 1 on/off.
5	TF0	Timer 0 Overflow Flag: Set by hardware when the timer 0 register overflows. Cleared by hardware when the processor vectors to the interrupt routine.
4	TR0	Timer 0 Run Control Bit: Set/cleared by firmware to turn timer 1 on/off.
3	IE1	Interrupt 1 Flag: Set by hardware when an external interrupt is detected on the INT1# pin. Edge- or level- triggered (see IT1). Cleared when interrupt is processed if edge-triggered.
2	IT1	Interrupt 1 Type Control Bit: Set this bit to select edge-triggered (high-to-low) for external interrupt 1. Clear this bit to select level-triggered (active low).
1	IE0	Interrupt 0 Flag: Set by hardware when an external interrupt is detected on the INT0# pin. Edge- or level- triggered (see IT0). Cleared when interrupt is processed if edge-triggered.
0	IT0	Interrupt 0 Type Control Bit: Set this bit to select edge-triggered (high-to-low) for external interrupt 0. Clear this bit to select level-triggered (active low).

TMOD

Address: S:89H
Reset State: 0000 0000B

Timer/Counter Mode Control Register. Contains mode select, run control select, and counter/timer select bits for controlling timer 0 and timer 1.

7

0

GATE1	C/T1#	M11	M01	GATE0	C/T0#	M10	M00
-------	-------	-----	-----	-------	-------	-----	-----

Bit Number	Bit Mnemonic	Function
7	GATE1	<p>Timer 1 Gate:</p> <p>When GATE1 = 0, run control bit TR1 gates the input signal to the timer register. When GATE1 = 1 and TR1 = 1, external signal INT1 gates the timer input.</p>
6	C/T1#	<p>Timer 1 Counter/Timer Select:</p> <p>C/T1# = 0 selects timer operation: timer 1 counts the divided-down system clock. C/T1# = 1 selects counter operation: timer 1 counts negative transitions on external pin T1.</p>
5, 4	M11, M01	<p>Timer 1 Mode Select:</p> <p>M11 M01</p> <p>0 0 Mode 0: 8-bit timer/counter (TH1) with 5-bit prescaler (TL1)</p> <p>0 1 Mode 1: 16-bit timer/counter</p> <p>1 0 Mode 2: 8-bit auto-reload timer/counter (TL1). Reloaded from TH1 at overflow.</p> <p>1 1 Mode 3: Timer 1 halted. Retains count.</p>
3	GATE0	<p>Timer 0 Gate:</p> <p>When GATE0 = 0, run control bit TR0 gates the input signal to the timer register. When GATE0 = 1 and TR0 = 1, external signal INT0 gates the timer input.</p>
2	C/T0#	<p>Timer 0 Counter/Timer Select:</p> <p>C/T0# = 0 selects timer operation: timer 0 counts the divided-down system clock. C/T0# = 1 selects counter operation: timer 0 counts negative transitions on external pin T0.</p>
1, 0	M10, M00	<p>Timer 0 Mode Select:</p> <p>M10 M00</p> <p>0 0 Mode 0: 8-bit timer/counter (T0) with 5-bit prescaler (TL0)</p> <p>0 1 Mode 1: 16-bit timer/counter</p> <p>1 0 Mode 2: 8-bit auto-reload timer/counter (TL0). Reloaded from TH0 at overflow.</p> <p>1 1 Mode 3: TL0 is an 8-bit timer/counter. TH0 is an 8-bit timer using timer 1's TR1 and TF1 bits.</p>

TH0, TL0	Address:	TH0 TL0	S:8CH S:8AH
	Reset State:		0000 0000B

TH0, TL0 Timer Registers. These registers operate in cascade to form the 16-bit timer register in timer 0 or separately as 8-bit timer/counters.

7 0

High/Low Byte of Timer 0 Register

Bit Number	Bit Mnemonic	Function
7:0	TH0.7:0 TL0.7:0	High byte of the timer 0 timer register. Low byte of the timer 0 timer register.

TH1, TL1	Address:	TH1 TL1	S:8DH S:8BH
	Reset State:		0000 0000B

TH1, TL1 Timer Registers. These registers operate in cascade to form the 16-bit timer register in timer 1 or separately as 8-bit timer/counters.

7 0

High/Low Byte of Timer 1 Register

Bit Number	Bit Mnemonic	Function
7:0	TH1.7:0 TL1.7:0	High byte of the timer 1 timer register. Low byte of the timer 1 timer register.

TH2, TL2

Address: TH2 S:CDH
 TL2 S:CCH
 Reset State: 0000 0000B

TH2, TL2 Timer Registers. These registers operate in cascade to form the 16-bit timer register in timer 2.

7 0

High/Low Byte of Timer 2 Register

Bit Number	Bit Mnemonic	Function
7:0	TH2.7:0	High byte of the timer 2 timer register.
	TL2.7:0	Low byte of the timer 2 timer register.

TXCNTH, TXCNTL (Endpoint-indexed) Address: S:F7H S:F6H

Reset States: Endpoint 1 TXCNTH xxxx xx00B TXCNTL 0000 0000B
 Other Endpoints† TXCNTL xxx0 0000B

Transmit FIFO Byte-count High and Low Registers. High and low register in a two-register ring buffer used to store the byte count for the data packets in the transmit FIFO specified by EPINDEX. Note that TXCNTH exists only for function endpoint 1 and is unavailable for all other endpoints.

15 (TXCNTH) Endpoint 1 8

—	—	—	—	—	—	BC9	BC8
---	---	---	---	---	---	-----	-----

7 (TXCNTL) 0

BC7	BC6	BC5	BC4	BC3	BC2	BC1	BC0
-----	-----	-----	-----	-----	-----	-----	-----

7 (TXCNTL) Other Endpoints 0

—	—	—	BC4	BC3	BC2	BC1	BC0
---	---	---	-----	-----	-----	-----	-----

Bit Number	Bit Mnemonic	Function
Function Endpoint 1		
15:10	—	Reserved. Write zeros to these bits.
9:0	BC9:0	Transmit Byte Count. (write, conditional read ^{††}) Ten-bit, ring buffer. Stores transmit byte count (TXCNT). Implemented for function endpoint 1 only.
Other Endpoints [†]		
7:0	—	Reserved. Write zeros to these bits.
4:0	BC4:0	Transmit Byte Count. (write, conditional read ^{††}) Five-bit, ring buffer. Stores transmit byte count (TXCNT) for endpoints 0, 2, and 3.

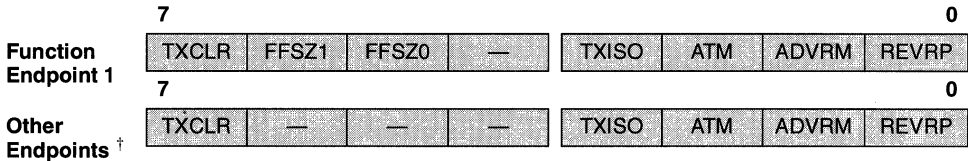
[†] Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (6EPP option, 8x930Ax only). Byte count registers are not implemented for hub endpoint 1.

^{††} Read these bits only if TXFIF1:0 = 0; otherwise underrun errors may occur.



TXCON Address: S:F4H
 (Endpoint-indexed) Reset State: Function Endpoint 1 000x 0100B
 Other Endpoints[†] 0xxx 0100B

USB Transmit FIFO Control Register. Controls the transmit FIFO specified by EPINDEX.



Bit Number	Bit Mnemonic	Function															
7	TXCLR	Transmit Clear: Setting this bit flushes the transmit FIFO, resets all the read/write pointers and markers, sets the EMPTY bit in TXFLG, and clears all other bits in TXFLG. After the flush, hardware clears this bit. Setting this bit does not affect the ATM, TXISO, and FFSZ bits, or the TXSEQ bit in the TXSTAT register.															
6:5	FFSZ1:0 Function Endpoint 1 only	FIFO Size: For function endpoint 1 only (EPINDEX = 0000 0001B), these bits select the sizes of both the transmit and receive FIFOs. (There are no FFSZ bits in the corresponding RXCON.) These bits are not reset when the TXCLR bit is set in the TXCON register. <table border="1" style="margin-left: 20px; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">FFSZ1:0</th> <th style="text-align: left;">Transmit Size</th> <th style="text-align: left;">Receive Size</th> </tr> </thead> <tbody> <tr> <td>00</td> <td>256</td> <td>256</td> </tr> <tr> <td>01</td> <td>512</td> <td>512</td> </tr> <tr> <td>10</td> <td>1024</td> <td>0</td> </tr> <tr> <td>11</td> <td>0</td> <td>1024</td> </tr> </tbody> </table>	FFSZ1:0	Transmit Size	Receive Size	00	256	256	01	512	512	10	1024	0	11	0	1024
FFSZ1:0	Transmit Size	Receive Size															
00	256	256															
01	512	512															
10	1024	0															
11	0	1024															
	— Other Endpoints [†]	Reserved: Values read from this bit are indeterminate. Write zero to this bit.															
4	—	Reserved: Values read from this bit are indeterminate. Write zero to this bit.															
3	TXISO	Transmit Isochronous Data: Firmware sets this bit to indicate that the transmit FIFO contains isochronous data. The FIU uses this bit to set up the handshake protocol at the end of a transmission. This bit is not reset when TXCLR is set and must be cleared by firmware.															

[†] Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (for 6EPP option, 8x930Ax only).

^{††} ATM mode is recommended. ADVRM and REVRP, which control the read marker and read pointer when ATM = 0, are used for test purposes,

TXCON (Continued)

(Endpoint-indexed)

Address:

Reset State:

Function Endpoint 1

 Other Endpoints[†]

S:F4H

000x 0100B

0xxx 0100B

USB Transmit FIFO Control Register. Controls the transmit FIFO specified by EPINDEX.

	7									0
Function Endpoint 1	TXCLR	FFSZ1	FFSZ0	—	TXISO	ATM	ADVRM	REVRP		
	7									0
Other Endpoints[†]	TXCLR	—	—	—	TXISO	ATM	ADVRM	REVRP		

Bit Number	Bit Mnemonic	Function												
2	ATM	Automatic Transmit Management: Setting this bit (the default value) causes the read pointer and read marker to be adjusted automatically as indicated: <table border="1"> <thead> <tr> <th>TXISOTX Status</th> <th>Read Pointer</th> <th>Read Marker</th> </tr> </thead> <tbody> <tr> <td>X ACK</td> <td>Unchanged</td> <td>Advanced (1)</td> </tr> <tr> <td>0 NAK</td> <td>Reversed (2)</td> <td>Unchanged</td> </tr> <tr> <td>1 NAK</td> <td>Unchanged</td> <td>Advanced (1)</td> </tr> </tbody> </table> 1. to origin of next data set 2. to origin of the data set last read This bit should always be set, except for test purposes. Setting this bit disables ADVRM and REVRP. This is a sticky bit that is not reset when TXCLR is set, but can be set and cleared by firmware. Hardware neither clears nor sets this bit.	TXISOTX Status	Read Pointer	Read Marker	X ACK	Unchanged	Advanced (1)	0 NAK	Reversed (2)	Unchanged	1 NAK	Unchanged	Advanced (1)
TXISOTX Status	Read Pointer	Read Marker												
X ACK	Unchanged	Advanced (1)												
0 NAK	Reversed (2)	Unchanged												
1 NAK	Unchanged	Advanced (1)												
1	ADVRM	Advance Read Marker Control (non-ATM mode only) ^{††} : Setting this bit prepares for the next packet transmission by advancing the read marker to the origin of the next data packet (the position of the read pointer). Hardware clears this bit after the read marker is advanced. This bit is effective only when the REVRP, ATM, and TXCLR bits are all clear.												
0	REVRP	Reverse Read Pointer Control (non-ATM mode only) ^{††} : In the case of a bad transmission, the same data stack may need to be available for retransmit. Setting this bit reverses the read pointer to point to the origin of the last data set (the position of the read marker) so that the FIU can reread the last set for retransmission. Hardware clears this bit after the read pointer is reversed. This bit is effective only when the ADVRM, ATM, and TXCLR bits are all clear.												

[†] Other endpoints = Hub endpoint 0; function endpoints 0, 3:2 or 0, 5:2 (for 6EPP option, 8x930Ax only).

^{††} ATM mode is recommended. ADVRM and REVRP, which control the read marker and read pointer when ATM = 0, are used for test purposes,

TXDAT (Endpoint-indexed)[†] Address: S:F3H
Reset State: xxxx xxxxB

USB Transmit FIFO Data Register. Data to be transmitted by the FIFO specified by EPINDEX is first written to this register.

7 0

Transmit Data Byte

Bit Number	Bit Mnemonic	Function
7:0	TXDAT.7:0	Transmit Data Byte (write-only): To write data to the transmit FIFO, write to this register. The write pointer is incremented automatically after a write.

[†] For hub endpoint 1, TXDAT is used in a different manner. See Figure 8-6 on page 8-12.

TXDAT (For hub endpoint 1 only) EPINDEX=81H[†] Address: S:F3H
Reset State: 0000 0000B

7 0

—

—

—

TXDAT.4

TXDAT.3

TXDAT.2

TXDAT.1

TXDAT.0

Bit Number	Bit Mnemonic	Function										
7:5	—	Reserved: Values read from these bits are indeterminate.										
4:0	TXDAT.4:0	Hub Endpoint 1 Status Change (read-only ^{††}): Hardware communicates status changes to the host by setting the appropriate bit: <table style="margin-left: 20px; border: none;"> <tr><td>TXDAT.0</td><td>hub status change</td></tr> <tr><td>TXDAT.1</td><td>port 1 status change</td></tr> <tr><td>TXDAT.2</td><td>port 2 status change</td></tr> <tr><td>TXDAT.3</td><td>port 3 status change</td></tr> <tr><td>TXDAT.4</td><td>port 4 status change</td></tr> </table> <p>A '1' indicates a status change and '0' indicates no status change. When endpoint 1 is addressed via an IN token, the entire byte is sent if at least one bit is a '1'. If all bits are zero, a NAK handshake is returned.</p>	TXDAT.0	hub status change	TXDAT.1	port 1 status change	TXDAT.2	port 2 status change	TXDAT.3	port 3 status change	TXDAT.4	port 4 status change
TXDAT.0	hub status change											
TXDAT.1	port 1 status change											
TXDAT.2	port 2 status change											
TXDAT.3	port 3 status change											
TXDAT.4	port 4 status change											

[†] TXDAT SFRs are also used for function (and hub endpoint 0) data transmission (EPINDEX=0xH or 80H). In that case, the bits are defined differently as shown in Figure 7-8 on page 7-18.

^{††} Bits 4-0 can be set indirectly by firmware by writing to port x's HPSC SFR. Setting any bit in port x's HPSC results in the hardware setting bit x in TXDAT. Bits can be cleared indirectly in firmware by clearing the condition that caused the status change.

TXFLG

(Endpoint-indexed)

 Address: S:F5H
 Reset State: 00xx 1000B

Transmit FIFO Flag Register. These flags indicate the status of data packets in the transmit FIFO specified by EPINDEX.

7

0

TXFIF1	TXFIF0	—	—	TXEMP	TXFULL	TXURF	TXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function																																																		
7:6	TXFIF1:0	<p>FIFO Index Flags (read-only):</p> <p>These flags indicate which data sets are present in the transmit FIFO. The FIF bits are set in sequence after each write to TXCNT to reflect the addition of a data set. Likewise, TXFIF1 and TXFIF0 are cleared in sequence after each advance of the read marker to indicate that the set is effectively discarded. The bit is cleared whether the read marker is advanced by firmware (setting ADVRM) or automatically by hardware (ATM = 1). The next-state table for the TXFIF bits is shown below:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;">TXFIF1:0</th> <th style="width: 20%;">Operation</th> <th style="width: 10%;">Flag</th> <th style="width: 15%;">Next TXFIF1:0</th> <th style="width: 40%;">Next Flag</th> </tr> </thead> <tbody> <tr> <td>00</td> <td>Wr TXCNT</td> <td>X</td> <td>01</td> <td>Unchanged</td> </tr> <tr> <td>01</td> <td>Wr TXCNT</td> <td>X</td> <td>11</td> <td>Unchanged</td> </tr> <tr> <td>10</td> <td>Wr TXCNT</td> <td>X</td> <td>11</td> <td>Unchanged</td> </tr> <tr> <td>11</td> <td>Wr TXCNT</td> <td>X</td> <td>11</td> <td>TXOVF = 1</td> </tr> <tr> <td>00</td> <td>Adv RM</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>01</td> <td>Adv RM</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>11</td> <td>Adv RM</td> <td>X</td> <td>10/01</td> <td>Unchanged</td> </tr> <tr> <td>10</td> <td>Adv RM</td> <td>X</td> <td>00</td> <td>Unchanged</td> </tr> <tr> <td>XX</td> <td>Rev RP</td> <td>X</td> <td>Unchanged</td> <td>Unchanged</td> </tr> </tbody> </table> <p>In ISO mode, TXOVF, TXURF, and TXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. TXFIF is "incremented" by firmware and "decremented" by the USB. Therefore, writes to TXCNT "increment" TXFIF immediately. However, a successful USB transaction any time within a frame "decrements" TXFIF only at SOF. You must check the TXFIF flags before and after writes to the transmit FIFO and TXCNT for traceability. See the TXFLUSH bit in TXSTST.</p> <p>NOTE: To simplify firmware development, configure control endpoints in single-packet mode.</p>	TXFIF1:0	Operation	Flag	Next TXFIF1:0	Next Flag	00	Wr TXCNT	X	01	Unchanged	01	Wr TXCNT	X	11	Unchanged	10	Wr TXCNT	X	11	Unchanged	11	Wr TXCNT	X	11	TXOVF = 1	00	Adv RM	X	00	Unchanged	01	Adv RM	X	00	Unchanged	11	Adv RM	X	10/01	Unchanged	10	Adv RM	X	00	Unchanged	XX	Rev RP	X	Unchanged	Unchanged
TXFIF1:0	Operation	Flag	Next TXFIF1:0	Next Flag																																																
00	Wr TXCNT	X	01	Unchanged																																																
01	Wr TXCNT	X	11	Unchanged																																																
10	Wr TXCNT	X	11	Unchanged																																																
11	Wr TXCNT	X	11	TXOVF = 1																																																
00	Adv RM	X	00	Unchanged																																																
01	Adv RM	X	00	Unchanged																																																
11	Adv RM	X	10/01	Unchanged																																																
10	Adv RM	X	00	Unchanged																																																
XX	Rev RP	X	Unchanged	Unchanged																																																
5:4	—	<p>Reserved:</p> <p>Values read from these bits are indeterminate. Write zeros to these bits.</p>																																																		
3	TXEMP	<p>Transmit FIFO Empty Flag (read-only):</p> <p>Hardware sets this bit when the write pointer has not rolled over and is at the same location as the read pointer. Hardware clears this bit when the pointers are at different locations.</p> <p>Regardless of ISO or non-ISO mode, this bit always tracks the current transmit FIFO status.</p>																																																		

† When set, all transmissions are NAKed.

TXFLG (Continued)
(Endpoint-indexed)

Address: S:F5H
Reset State: 00xx 1000B

Transmit FIFO Flag Register. These flags indicate the status of data packets in the transmit FIFO specified by EPINDEX.

7

0

TXFIF1	TXFIF0	—	—	TXEMP	TXFULL	TXURF	TXOVF
--------	--------	---	---	-------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
2	TXFULL	<p>Transmit FIFO Full Flag (read-only):</p> <p>Hardware sets this bit when the write pointer has rolled over and equals the read marker. Hardware clears this bit when the full condition no longer exists.</p> <p>Regardless of ISO or non-ISO mode, this bit always tracks the current transmit FIFO status. Check this bit to avoid causing a TXOVF condition.</p>
1	TXURF	<p>Transmit FIFO Underrun Flag[†]:</p> <p>Hardware sets this flag when an additional byte is read from an empty transmit FIFO or TXCNT [This is caused when the value written to TXCNT is greater than the number of bytes written to TXDAT.]. This is a sticky bit that must be cleared through firmware. When this flag is set, the FIFO is in an unknown state, thus it is recommended that you reset the FIFO in your error management routine using the TXCLR bit in TXCON.</p> <p>When the transmit FIFO underruns, the read pointer will not advance — it remains locked in the empty position.</p> <p>If the TXCNT doesn't agree with the data, hardware sets TXURF. This indicates that the transmitted data was corrupted by a bit-stuffing or CRC error.</p> <p>In ISO mode, TXOVF, TXURF, and TXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since underrun can only be caused by USB, TXURF is updated at the next SOF regardless of where the underrun occurs in the frame.</p>
0	TXOVF	<p>Transmit FIFO Overrun Flag[†]:</p> <p>This bit is set when an additional byte is written to a full FIFO or full TXCNT with TXFIF1:0 = 11. This is a sticky bit that must be cleared through firmware. When this bit is set, the FIFO is in an unknown state, thus it is recommended that you reset the FIFO in your error management routine using the TXCLR bit in TXCON.</p> <p>When the receive FIFO overruns, the write pointer will not advance — it remains locked in the full position. Check this bit after loading the FIFO prior to writing the byte count register.</p> <p>In ISO mode, TXOVF, TXURF, and TXFIF are handled using the following rule: Firmware events cause status change immediately, while USB events cause status change only at SOF. Since overrun can only be caused by firmware, TXOVF is updated immediately. Check the TXOVF flag after writing to the transmit FIFO before writing to TXCNT.</p>

[†] When set, all transmissions are NAKed.

TXSTAT
(Endpoint-indexed)

Address: S:F2H
Reset State: 0000 0000B

Endpoint Transmit Status Register. Contains the current endpoint status of the transmit FIFO specified by EPINDEX.

7

0

TXSEQ	—	—	TXFLUSH	TXSOVW	TXVOID	TXERR	TXACK
-------	---	---	---------	--------	--------	-------	-------

Bit Number	Bit Mnemonic	Function
7	TXSEQ	Transmitter's Current Sequence Bit (read, conditional write): † This bit will be transmitted in the next PID and toggled on a valid ACK handshake. This bit is toggled by hardware on a valid SETUP token. This bit can be written by firmware if the TXSOVW bit is set when written together with the new TXSEQ value.
6:5	—	Reserved: Write zeros to these bits.
4	TXFLUSH	Transmit FIFO Packet Flushed (read-only): When set, this bit indicates that hardware flushed a stale ISO data packet from the transmit FIFO due to a TXFIF1:0 = 11 at SOF. To guard against a missed IN token in ISO mode, if, with TXFIF1:0 = 11, no IN token is received for the current endpoint, hardware automatically flushes the oldest packet and decrements the TXFIF1:0 value.
3	TXSOVW	Transmit Data Sequence Overwrite Bit: † Write a '1' to this bit to allow the value of the TXSEQ bit to be overwritten. Writing a '0' to this bit has no effect on TXSEQ. This bit always returns '0' when read. ††
2	TXVOID	Transmit Void (read-only): ††† A void condition has occurred in response to a valid IN token. Transmit void is closely associated with the NAK/STALL handshake returned by the function after a valid IN token, due to the conditions that cause the transmit FIFO to be unenabled or not ready to transmit. Use this bit to check any NAK/STALL handshake returned by the function. This bit does not affect the FTXD _x , TXERR or TXACK bits. This bit is updated by hardware at the end of a non-isochronous transaction in response to a valid IN token. For isochronous transactions, this bit is not updated until the next SOF.

† Under normal operation, this bit should not be modified by the user.

†† The SIE will handle all sequence bit tracking. This bit should only be used when initializing a new configuration or interface.

††† For additional information on the operation of these bits see Appendix D, "Data Flow Model."



TXSTAT (Continued)
(Endpoint-indexed)

Address: S:F2H
Reset State: 0000 0000B

Endpoint Transmit Status Register. Contains the current endpoint status of the transmit FIFO specified by EPINDEX.

7	—	—	TXFLUSH	TXSOVW	TXVOID	TXERR	TXACK	0
---	---	---	---------	--------	--------	-------	-------	---

Bit Number	Bit Mnemonic	Function
1	TXERR	Transmit Error (read-only): ^{††} An error condition has occurred with the transmission. Complete or partial data has been transmitted. The error can be one of the following: 1. Data transmitted successfully but no handshake received 2. Transmit FIFO goes into underrun condition while transmitting The corresponding transmit done bit, FTXD _x in FIFLG or FIFLG1 (8x930Ax with 6EPP), is set when active. For non-isochronous transactions, this bit is updated by hardware along with the TXACK bit at the end of the data transmission (this bit is mutually exclusive with TXACK). For isochronous transactions, this bit is not updated until the next SOF.
0	TXACK	Transmit Acknowledge (read-only): ^{††} Data transmission completed and acknowledged successfully. The corresponding transmit done bit, FTXD _x in FIFLG or FIFLG1 (8x930Ax with 6EPP), is set when active. For non-isochronous transactions, this bit is updated by hardware along with the TXERR bit at the end of data transmission (this bit is mutually exclusive with TXERR). For isochronous transactions, this bit is not updated until the next SOF.

[†] Under normal operation, this bit should not be modified by the user.

^{††} The SIE will handle all sequence bit tracking. This bit should only be used when initializing a new configuration or interface.

^{†††} For additional information on the operation of these bits see Appendix D, "Data Flow Model."

WCON

Address: S:A7H
Reset: xxxx xx00B

Wait State Control Register. Use this register to enable the real-time wait state input signal and/or the wait state output clock.

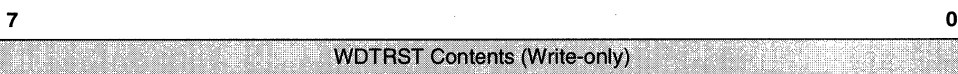


Bit Number	Bit Mnemonic	Function
7:2	—	Reserved: The values read from these bits are indeterminate. Write “0” to these bits.
1	RTWCE	Real-time WAIT CLOCK enable. Write a ‘1’ to this bit to enable the WAIT CLOCK on port 1.7 (WCLK). The square wave output signal is one-half the oscillator frequency.
0	RTWE	Real-time WAIT# enable. Write a ‘1’ to this bit to enable real-time wait state input on port 1.6 (WAIT#).

WDTRST

Address: S:A6H
Reset State: xxxx xxxxB

Watchdog Timer Reset Register. Writing the two-byte sequence 1EH-E1H to the WDTRST register clears and enables the hardware WDT. The WDTRST register is a write-only register. Attempts to read it return FFH. The WDT itself is not read or write accessible. See Chapter 11, “Timer/Counters and Watchdog Timer.”



Bit Number	Bit Mnemonic	Function
7:0	WDTRST.7:0	Provides user control of the hardware WDT.



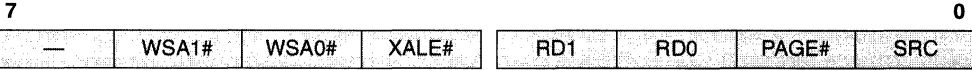
C.3 CONFIGURATION BYTES

The 8x930 reserves the top eight bytes of the memory address space for an eight-byte configuration array. The two lowest bytes of the configuration array are assigned to the two configuration bytes UCONFIG0 and UCONFIG1. The configuration bits contained in configuration bytes are used to select source mode or binary mode opcode configuration, select the bytes pushed onto the stack by interrupts, map on-chip code memory, and configure the external memory interface. The configuration bytes are discussed in more detail in Chapter 4, "Device Configuration."

UCONFIG0 (1), (3)				Address: FF:FFF8H (2)																		
7				0																		
—	WSA1#	WSA0#	XALE#	RD1	RD0	PAGE#	SRC															
Bit Number	Bit Mnemonic	Function																				
7	—	Reserved: Reserved for internal or future use. Set this bit when programming UCONFIG0.																				
6:5	WSA1:0#	Wait State A (all regions except 01:): For external memory accesses, selects the number of wait states for RD#, WR#, and PSEN#. <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: left;">WSA1#</td> <td style="text-align: left;">WSA0#</td> <td></td> </tr> <tr> <td>0</td> <td>0</td> <td>Inserts 3 wait states for all regions except 01:</td> </tr> <tr> <td>0</td> <td>1</td> <td>Inserts 2 wait states for all regions except 01:</td> </tr> <tr> <td>1</td> <td>0</td> <td>Inserts 1 wait state for all regions except 01:</td> </tr> <tr> <td>1</td> <td>1</td> <td>Zero wait states for all regions except 01:</td> </tr> </table>						WSA1#	WSA0#		0	0	Inserts 3 wait states for all regions except 01:	0	1	Inserts 2 wait states for all regions except 01:	1	0	Inserts 1 wait state for all regions except 01:	1	1	Zero wait states for all regions except 01:
WSA1#	WSA0#																					
0	0	Inserts 3 wait states for all regions except 01:																				
0	1	Inserts 2 wait states for all regions except 01:																				
1	0	Inserts 1 wait state for all regions except 01:																				
1	1	Zero wait states for all regions except 01:																				
4	XALE#	Extend ALE: Set this bit for $ALE = T_{OSC}$. Clear this bit for $ALE = 3T_{OSC}$ (adds one external wait state).																				
3:2	RD1:0	Memory Signal Selection: RD1:0 bit codes specify an 18-bit, 17-bit, or 16-bit external address bus and address ranges for RD#, WR#, and PSEN#. See Table 4-2 on page 4-7.																				
NOTES:																						
1. User configuration bytes UCONFIG0 and UCONFIG1 define the configuration of the 8x930.																						
2. Address. UCONFIG0 is the lowest byte of the 8-byte configuration array. When EA# = 1, the 8x930 fetches configuration information from an on-chip configuration array located in nonvolatile memory at the top of region FF. When EA# = 0, the 8x930 fetches configuration information from a configuration array located at the highest addresses implemented in external memory using addresses FF:FFF8H and FF:FFF9H. The physical location of the configuration array in external memory depends on the size and decode arrangement of the external memory (Table 4-1 and Figure 4-2).																						
3. Instructions for verifying on-chip configuration bytes are given in Chapter 17.																						

UCONFIG0
(1), (3)

Address: FF:FFF8H (2)



Bit Number	Bit Mnemonic	Function
1	PAGE#	Page Mode Select: Clear this bit for page mode enabled with A15:8/D7:0 on P2 and A7:0 on P0. Set this bit for page mode disabled with A15:8 on P2 and A7:0/D7:0 on P0.
0	SRC	Source Mode/Binary Mode Select: Set this bit for source mode. Clear this bit for binary mode (opcodes compatible with MCS 51 microcontrollers).

NOTES:

1. User configuration bytes UCONFIG0 and UCONFIG1 define the configuration of the 8x930.
2. Address. UCONFIG0 is the lowest byte of the 8-byte configuration array. When EA# = 1, the 8x930 fetches configuration information from an on-chip configuration array located in nonvolatile memory at the top of region FF:. When EA# = 0, the 8x930 fetches configuration information from a configuration array located at the highest addresses implemented in external memory using addresses FF:FFF8H and FF:FFF9H. The physical location of the configuration array in external memory depends on the size and decode arrangement of the external memory (Table 4-1 and Figure 4-2).
3. Instructions for verifying on-chip configuration bytes are given in Chapter 17.



**UCONFIG1
(1),(3)**

Address: FF:FFF9H (2)

7

0

—	—	—	INTR	—	WSB1#	WSB0#	EMAP#
---	---	---	------	---	-------	-------	-------

Bit Number	Bit Mnemonic	Function															
7:5	—	Reserved: Reserved for internal or future use. Set these bits when programming UCONFIG1.															
4	INTR	Interrupt Mode: If this bit is set, interrupts push 4 bytes onto the stack (the 3 bytes of the PC and PSW1). If this bit is clear, interrupts push the 2 lower bytes of the PC onto the stack. See "Interrupt Mode (INTR)" on page 4-14.															
3	—	Reserved. Write a '1' to this bit.															
2:1	WSB1:0#	External Wait State B (Region 01): <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;">WSB1#</td> <td style="width: 10%;">WSB0#</td> <td></td> </tr> <tr> <td>0</td> <td>0</td> <td>Inserts 3 wait states for region 01:</td> </tr> <tr> <td>0</td> <td>1</td> <td>Inserts 2 wait states for region 01:</td> </tr> <tr> <td>1</td> <td>0</td> <td>Inserts 1 wait state for region 01:</td> </tr> <tr> <td>1</td> <td>1</td> <td>Zero wait states for region 01:</td> </tr> </table>	WSB1#	WSB0#		0	0	Inserts 3 wait states for region 01:	0	1	Inserts 2 wait states for region 01:	1	0	Inserts 1 wait state for region 01:	1	1	Zero wait states for region 01:
WSB1#	WSB0#																
0	0	Inserts 3 wait states for region 01:															
0	1	Inserts 2 wait states for region 01:															
1	0	Inserts 1 wait state for region 01:															
1	1	Zero wait states for region 01:															
0	EMAP#	EPROM Map: For devices with 16 Kbytes of on-chip code memory, clear this bit to map the upper half of on-chip code memory to region 00: (data memory). This maps FF:2000H–FF:3FFFFH to 00:E000H–00:FFFFH. If this bit is set, mapping does not occur and addresses in the range 00:E000H–00:FFFFH access external RAM. See "Mapping On-chip Code Memory to Data Memory (EMAP#)" on page 14.															

NOTES:

1. User configuration bytes UCONFIG0 and UCONFIG1 define the configuration of the 8x930.
2. Address. UCONFIG1 is the second lowest byte of the 8-byte configuration array. When EA# = 1, the 8x930 fetches configuration information from an on-chip configuration array located in nonvolatile memory at the top of region FF:. When EA# = 0, the 8x930 fetches configuration information from a configuration array located at the highest addresses implemented in external memory using addresses FF:FFF8H and FF:FFF9H. The physical location of the configuration array in external memory depends on the size and decode arrangement of the external memory (Table 4-1 and Figure 4-2).
3. Instructions for verifying on-chip configuration bytes are given in Chapter 17.

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Data Flow Model

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APPENDIX D DATA FLOW MODEL

This appendix describes the data flow model for the 8x930 USB transactions. This data flow model, presented in truth table form, is intended to bridge the hardware and firmware layers of the 8x930. It describes the behavior of the 8x930 in response to a particular USB event, given a known state/configuration.

The types of data transfer supported by the 8x930 are:

- Non-isochronous transfer (interrupt, bulk)
- Isochronous transfer
- Control transfer

Table D-1. Non-isochronous Transmit Data Flow

TXFIF (1:0)	Event	New TXFIF (1:0)	TX ERR	TX ACK	TX Void	TX OVF (1)	TX URF (1)	TX Interrupt	USB Response	Comments
00	Received IN token, but no data or TXOE = 0	00	no chg	no chg	1	no chg	no chg	None	NAK	No data was loaded, so NAK
	Received IN token, RXSETUP = 1	00	no chg	no chg	1	no chg	no chg	None	NAK	Control endpoint only. Endpoint will NAK when RXSETUP = 1 even if TXSTL = 1
	Data loaded into FIFO from CPU, CNT written	01	no chg	no chg	no chg	no chg	no chg	None	N/A	Firmware should always check TXFIF bits before loading and TXOVF after loading.
	Data loaded into FIFO, FIFO error occurs	00	no chg	no chg	no chg	1	no chg	None	NAKs future transactions	Only overrun FIFO error can occur here. Firmware should always check TXOVF before write CNT.

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes TXEPEN and ATM are enabled.
2. Future transactions are NAKed even if the transmit endpoint is stalled when RXSETUP = 1.

Table D-1. Non-isochronous Transmit Data Flow (Continued)

TXFIF (1:0)	Event	New TXFIF (1:0)	TX ERR	TX ACK	TX Void	TX OVF (1)	TX URF (1)	TX Interrupt	USB Response	Comments
01/10	Received IN token, data transmitted, host ACKs	00	0	1	0	no chg	no chg	Set transmit interrupt	Send data	ACK received, so no errors. Read marker advanced
	Received IN token, data transmitted, no ACK (time-out)	01/10	1	0	0	no chg	no chg	Set transmit interrupt	Send data	SIE times-out. Read ptr reversed.
	Received IN token, but RXSETUP = 1 (or TXOE = 0)	01/10	no chg	no chg	1	no chg	no chg	None	NAK, NAKs future transactions except SETUP.	Received Setup token (or transmit disabled), so IN tokens are NAKed. (2)
	Received IN token, data transmitted, FIFO error occurs	01/10	1	0	0	no chg	1	Set transmit interrupt	Send data with bit-stuff error. NAKs future transactions.	Only underrun FIFO error can occur here. Read ptr reversed.
	Received IN token with existing FIFO error and TXERR set.	01/10	1 (no chg)	0 (no chg)	1	no chg	1 (no chg)	None	NAK	Treated like a "void" condition.
	Received IN token without existing FIFO error but TXERR set, data retransmitted, host ACKs	00	0	1	0	no chg	no chg	Set transmit interrupt	Send data	Data is retransmitted. TXACK is set and TXERR is cleared. The TXERR was set by previous transaction when host time-out.

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes TXEPEN and ATM are enabled.
2. Future transactions are NAKed even if the transmit endpoint is stalled when RXSETUP = 1.

Table D-1. Non-isochronous Transmit Data Flow (Continued)

TXFIF (1:0)	Event	New TXFIF (1:0)	TX ERR	TX ACK	TX Void	TX OVF (1)	TX URF (1)	TX Interrupt	USB Response	Comments
	Data loaded into FIFO from CPU, CNT written	11	no chg	no chg	no chg	no chg	no chg	None	N/A	Firmware should always check TXFIF bits before loading and TXOVF after loading.
	Data loaded into FIFO, FIFO error occurs. CNT not written yet.	01/10	no chg	no chg	no chg	1	no chg	None	NAKs future transactions	Only overrun FIFO error can occur here. Firmware should always check TXOVF before write CNT NOTE: no TXERR, but TXOVF set.
11	Received IN token, data transmitted, host ACKs	10/01	0	1	0	no chg	no chg	Set transmit interrupt	Send data	ACK received, so no errors. Read marker advanced.
	Received IN token, data transmitted, no ACK (time-out)	11	1	0	0	no chg	no chg	Set transmit interrupt	Send data	SIE times-out. Read ptr reversed.
	Received IN token, but RXSETUP = 1 (or TXOE = 0)	11	0	0	1	no chg	no chg	None	NAK, NAKs future transactions	Received Setup token (or transmit disabled), so IN tokens are NAKed. (2)
	Received IN token, data transmitted, FIFO error occurs	11	1	0	0	no chg	1	Set transmit interrupt	Send data with bit-stuff error, NAK future transactions	Only FIFO underrun error can occur here. Read ptr reversed.

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes TXEPEN and ATM are enabled.
2. Future transactions are NAKed even if the transmit endpoint is stalled when RXSETUP = 1.

Table D-1. Non-isochronous Transmit Data Flow (Continued)

TXFIF (1:0)	Event	New TXFIF (1:0)	TX ERR	TX ACK	TX Void	TX OVF (1)	TX URF (1)	TX Interrupt	USB Response	Comments
	Received IN token with existing FIFO error and TXERR set.	11	1 (no chg)	0 (no chg)	1	no chg	1 (no chg)	None	NAK	Treated like a "void" condition.
	Received IN token without existing FIFO error but TXERR set, data retransmitted, host ACKs	10/ 01	0	1	0	no chg	no chg	Set transmit interrupt	Send data	Data is retransmitted. TXACK is set and TXERR is cleared. The TXERR was set by previous transaction when host time-out.
	Data loaded into FIFO from CPU, CNT written	11	no chg	no chg	no chg	1	no chg	None	N/A	Writing into CNT when TXFIF = 11 sets TXOVF bit. Firmware should always check TXFIF bits before loading.

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes TXEPEN and ATM are enabled.
2. Future transactions are NAKed even if the transmit endpoint is stalled when RXSETUP = 1.

Table D-2. Isochronous Transmit Data Flow in Dual-packet Mode

TXFIF (1:0)	Event	New TX FIF (1:0) (2)	(at next SOF)			TX OVF (1,2)	TX URF (1,2)	TX Interrupt	USB Response	Comments
			TX ERR	TX ACK	TX Void					
00	Received IN token, but no data or TXOE=0	00	no chg	no chg	1	no chg	no chg	None	Send null data packet	No data was loaded, so send null data packet. This event should never happen.
	Data loaded into FIFO from CPU, CNT written	01	no chg	no chg	no chg	no chg	no chg	None	N/A	Firmware should always check TXFIF bits before loading and TXOVF after loading.
	Data loaded into FIFO, FIFO error	00	no chg	no chg	no chg	1	no chg	None	N/A	Only overrun FIFO error can occur here. Firmware should always check TXOVF before write CNT
01/10	Received IN token, data transmitted with or without transmission error	00	0	1	0	no chg	no chg	None	Send data	No ACK (time-out) for ISO. Read marker advanced.
	Received IN token, data transmitted, FIFO error occurs	00	1	0	0	no chg	1	None	Send CRC with bit-stuff error	Only underrun FIFO error can occur here. Read marker advanced.

NOTES:

- These are sticky bits, which must be cleared by firmware.
- TXFIF, TXOVF and TXURF are handled with the following golden rule: Firmware events cause status change immediately while USB events only cause status change at SOF.
 TXOVF: Since overrun can only be caused by firmware, TXOVF is updated immediately.
 TXURF: Since underrun can only be caused by USB, TXURF is updated at SOF.
 TXFIF: TXFIF is "incremented" by firmware and "decremented" by USB. Therefore, writes to TXCNT will "increment" TXFIF immediately. However, a successful USB transaction anytime in a frame will only "decrement" TXFIF at SOF.
 TXERR, TXACK, and TXVOID can only be caused by USB; thus they are updated at the end of every valid transaction.
- NOTE: This table assumes TXEPEN and ATM are enabled.

Table D-2. Isochronous Transmit Data Flow in Dual-packet Mode (Continued)

TXFIF (1:0)	Event	New TX FIF (1:0) (2)	(at next SOF)			TX OVF (1,2)	TX URF (1,2)	TX Inter- rupt	USB Response	Comments
			TX ERR	TX ACK	TX Void					
	Received IN token with existing FIFO error	01/10	1 (no chg)	0 (no chg)	1	no chg	1 (no chg)	None	Send null data packet	Treated like a "void" condition.
	Received IN token, but TXOE = 0	01/10	0	0	1	no chg	no chg	None	Send null data packet	Endpoint not enabled for transmit, but no NAK for ISO.
	Data loaded into FIFO from CPU, CNT written	11	no chg	no chg	no chg	no chg	no chg	None	N/A	Firmware should always check TXFIF bits before loading and TXOVF after loading.
	Data loaded into FIFO, FIFO error occurs	01/10	no chg	no chg	no chg	1	no chg	None	N/A	Only overrun FIFO error can occur here. Firmware should always check TXOVF before write CNT Note: no TXERR, but TXOVF set.
11	Received IN token, data transmitted with or without transmission error	10/01	0	1	0	no chg	no chg	None	Send data	No ACK (time-out) for ISO. Read marker advanced.

NOTES:

- These are sticky bits, which must be cleared by firmware.
- TXFIF, TXOVF and TXURF are handled with the following golden rule: Firmware events cause status change immediately while USB events only cause status change at SOF.
TXOVF: Since overrun can only be caused by firmware, TXOVF is updated immediately.
TXURF: Since underrun can only be caused by USB, TXURF is updated at SOF.
TXFIF: TXFIF is "incremented" by firmware and "decremented" by USB. Therefore, writes to TXCNT will "increment" TXFIF immediately. However, a successful USB transaction anytime in a frame will only "decrement" TXFIF at SOF.
TXERR, TXACK, and TXVOID can only be caused by USB; thus they are updated at the end of every valid transaction.
- NOTE: This table assumes TXEPEN and ATM are enabled.

Table D-2. Isochronous Transmit Data Flow in Dual-packet Mode (Continued)

TXFIF (1:0)	Event	New TX FIF (1:0) (2)	(at next SOF)			TX OVF (1,2)	TX URF (1,2)	TX Interrupt	USB Response	Comments
			TX ERR	TX ACK	TX Void					
	Received IN token, data transmitted, FIFO error occurs	10/01	1	0	0	no chg	1	None	Send data with bitstuff error	Only a FIFO underrun error can occur here. Read marker advanced.
	Received IN token with existing FIFO error	11	1 (no chg)	0 (no chg)	1	no chg	1 (no chg)	None	Send null data packet	Treated like a "void" condition.
	Received IN token, but TXOE = 0	11	0	0	1	no chg	no chg	None	Send null data packet	Endpoint not enabled for transmit, but no NAK for ISO.
	Receive SOF indication	10/01	no chg	no chg	no chg	no chg	no chg	None (SOF interrupt set) ASOF set.	None	Host never read last frame's ISO. packet. Read marker and ptr advanced, oldest packet is flushed from FIFO.
	Data loaded into FIFO from CPU, CNT written	11	no chg	no chg	no chg	1	no chg	None	N/A	CNT written when TXFIF=11 will set TXOVF bit. Firmware should always check TXFIF bits before loading.

NOTES:

- These are sticky bits, which must be cleared by firmware.
- TXFIF, TXOVF and TXURF are handled with the following golden rule: Firmware events cause status change immediately while USB events only cause status change at SOF.
 TXOVF: Since overrun can only be caused by firmware, TXOVF is updated immediately.
 TXURF: Since underrun can only be caused by USB, TXURF is updated at SOF.
 TXFIF: TXFIF is "incremented" by firmware and "decremented" by USB. Therefore, writes to TXCNT will "increment" TXFIF immediately. However, a successful USB transaction anytime in a frame will only "decrement" TXFIF at SOF.
 TXERR, TXACK, and TXVOID can only be caused by USB; thus they are updated at the end of every valid transaction.
- NOTE: This table assumes TXEPEN and ATM are enabled.

Table D-3. Non-isochronous Receive Data Flow in Single-packet Mode (RXSPM = 1)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
00	Received OUT token, but RXIE = 0	00	no chg	no chg	1	no chg	no chg	no chg	None	NAK	FIFO not ready.
	Received OUT token, but timed-out waiting for data	00	no chg	no chg	no chg	no chg	no chg	no chg	None	None	FIFO not loaded. Write ptr reversed.
	Received OUT token, no errors	01	0	1	0	0	no chg	no chg	Set receive interrupt	ACK	Received, no errors, advance write marker.
	Received OUT token, data CRC or bit-stuff error	00	1	0	0	0	no chg	no chg	Set receive interrupt	Time-out	Write ptr reversed. (Possible to have RXERR cleared by hardware before seen by firmware.)
	Received OUT token, FIFO error occurs	00	1	0	0	0	1	no chg	Set receive interrupt	Time-out, NAK future transactions	Only RXOVF FIFO error can occur, requires firmware intervention.
	Received OUT token with FIFO error already existing	00	1 (no chg)	0 (no chg)	1	0	1 (no chg)	no chg	None	NAK	Considered to be a "void" condition. Will NAK until firmware clears condition.
	Received OUT token, but data sequence mismatch	00	no chg	no chg	1	no chg	no chg	no chg	None	ACK	Last ACK corrupted, so send again but ignore the data.
	Received SETUP token, no errors	01	0	1	0	1	0	0	Set receive interrupt	ACK	RXIE or RXSTL has no effect.(2) RXSETUP will be set (control endpoints only).

NOTE:

- These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
- STOVV is set after a valid SETUP token is received and cleared during handshake phase. EDOVV is set during handshake phase.



Table D-3. Non-isochronous Receive Data Flow in Single-packet Mode (RXSPM = 1) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
	Received SETUP token, but timed-out waiting for data	00	1	0	0	0	0	0	Set receive interrupt	Time-out	FIFO is reset automatically and FIFO data is invalid. (2)
	Received SETUP token, data CRC or bit-stuff error	00	1	0	0	1	0	0	Set receive interrupt	Time-out	Write ptr reversed, (2)
	Received SETUP token, FIFO error occurs	00	1	0	0	1	1	0	Set receive interrupt	Time-out, NAK future transactions	(2)
	Received SETUP token with FIFO error already existing	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	CPU reads FIFO, causes FIFO error	00	no chg	no chg	no chg	no chg	no chg	1	None	NAK future transactions, except SETUP	FIFO was empty when read. Should always check RXFIF bits before reading.
01	Received OUT token	01	no chg	no chg	1	no chg	no chg	no chg	None	NAK	FIFO not ready, so data is ignored (CRC or FIFO error not possible)

NOTE:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.

Table D-3. Non-isochronous Receive Data Flow in Single-packet Mode (RXSPM = 1) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
	Received SETUP token, no errors	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token, but timed-out waiting for data	01	1	0	0	0	0	0	Set receive interrupt	Time-out	FIFO is reset automatically and FIFO data is invalid. (2)
	Received SETUP token, data CRC or bit-stuff error	00	1	0	0	1	0	0	Set receive interrupt	Time-out	Write ptr reversed. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token, FIFO error occurs	00	1	0	0	1	1	0	Set receive interrupt	Time-out, NAK future transactions	(2) (control endpoints only).
	Received SETUP token with FIFO error already existing	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	CPU reads FIFO, sets RXFFRC	00	no chg	no chg	no chg	no chg	no chg	no chg	None	None	

NOTE:

- These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
- STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVV is set during handshake phase.

Table D-3. Non-isochronous Receive Data Flow in Single-packet Mode (RXSPM = 1) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
	CPU reads FIFO, causes FIFO error. RXFFRC not set yet.	01	no chg	no chg	no chg	no chg	no chg	1	None	Time-out, NAK future transactions	Firmware should check RXURF bit before writing RXFFRC.
	CPU reads FIFO, causes FIFO error. Set RXFFRC.	00	no chg	no chg	no chg	no chg	no chg	1	None	Time-out, NAK future transactions	Firmware should check RXURF bit before writing RXFFRC.

- NOTE:**
1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
 2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
00	Received OUT token, but RXIE = 0	00	no chg	no chg	1	no chg	no chg	no chg	None	NAK	FIFO not ready.
	Received OUT token, but timed-out waiting for data	00	no chg	no chg	1	no chg	no chg	no chg	None	None	FIFO not loaded. Write ptr reversed.
	Received OUT token, no errors	01	0	1	0	0	no chg	no chg	Set receive interrupt	ACK	Received, no errors, advance write marker.

- NOTES:**
1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
 2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
 3. NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
	Received OUT token, data CRC or bit-stuff error	00	1	0	0	0	no chg	no chg	Set receive interrupt	Time-out	Write ptr reversed. (Possible to have RXERR cleared by hardware before seen by firmware.)
	Received OUT token, FIFO error occurs	00	1	0	0	0	1	no chg	Set receive interrupt	Time-out, NAK future transactions	Only RXOVF FIFO error can occur, requires firmware intervention.
	Received OUT token with FIFO error already existing	00	1 (no chg)	0 (no chg)	1	0	1 (no chg)	no chg	None	NAK	Considered to be a "void" condition. Will NAK until firmware clears condition.
	Received OUT token, but data sequence mismatch	00	no chg	no chg	no chg	no chg	no chg	no chg	None	ACK	Last ACK corrupted, so send again but ignore the data.
	Received SETUP token, no errors (dual packet mode not recommended!)	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token, but timed-out waiting for data	00	1	0	0	0	0	0	Set receive interrupt	Time-out	FIFO is reset automatically and FIFO data is invalid. (2)

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
3. NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Inter-rupt	USB Response	Comments
	Received SETUP token, data CRC or bit-stuff error (dual packet mode not recommended)	00	1	0	0	1	0	0	Set receive interrupt	Time-out	Write ptr reversed, RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token, FIFO error occurs	00	1	0	0	1	1	0	Set receive interrupt	Time-out, NAK future transactions	RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token with FIFO error already existing	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	CPU reads FIFO, causes FIFO error	00	no chg	no chg	no chg	no chg	no chg	1	None	NAK future transactions	FIFO was empty when read. Should always check RXFIF bits before reading.
01/10	Received OUT token, but RXIE = 0	01/10	no chg	no chg	1	no chg	no chg	no chg	None	NAK	FIFO not ready.
	Received OUT token, but timed-out waiting for data	01/10	no chg	no chg	1	no chg	no chg	no chg	None	None	FIFO not loaded. Write ptr reversed.
	Received OUT token, no errors	11	0	1	0	0	no chg	no chg	Set receive interrupt	ACK	Received, no errors, advance write marker.

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
3. NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
	Received OUT token, data CRC or bit-stuff error	01/10	1	0	0	0	no chg	no chg	Set receive interrupt	Time-out	Write ptr reversed. (Possible to have RXERR cleared by hardware before seen by firmware.)
	Received OUT token, FIFO error occurs	01/10	1	0	0	0	1	no chg	Set receive interrupt	Time-out, NAK future transactions	Only RXOVF FIFO error can occur, requires firmware intervention.
	Received OUT token with FIFO error already existing	01/10	1 (no chg)	0 (no chg)	1	0	1 (no chg)	no chg	None	NAK	Considered to be a "void" condition. Will NAK until firmware clears condition.
	Received OUT token, but data sequence mismatch	01/10	no chg	no chg	no chg	no chg	no chg	no chg	None	ACK	Last ACK corrupted, so send again but ignore the data.
	Received SETUP token, no errors (dual-packet mode not recommended)	01/10	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token, but timed-out waiting for data	01/10	1	0	0	0	0	0	Set receive interrupt	Time-out	FIFO is reset automatically, forcing new SETUP to be received. (2)

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
3. NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Inter-rupt	USB Response	Comments
	Received SETUP token, data CRC or bit-stuff error (dual-packet mode not recommended)	00	1	0	0	1	0	0	Set receive interrupt	Time-out	Write ptr reversed. RXIE or RXSTL has no effect. (2)
	Received SETUP token, FIFO error occurs	00	1	0	0	1	1	0	Set receive interrupt	Time-out, NAK future transactions	RXIE or RXSTL has no effect, (2) RXSETUP will be set (control endpoints only).
	Received SETUP token with FIFO error already existing	01/10	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. (2) RXSETUP will be set (control endpoints only).
	CPU reads FIFO, sets RXFFRC	00	no chg	no chg	no chg	no chg	no chg	no chg	None	None	
	CPU reads FIFO, causes FIFO error. RXFFRC not set yet.	01/10	no chg	no chg	no chg	no chg	no chg	1	None	Time-out, NAK future transactions	Firmware should check RXURF bit before writing RXFFRC.
	CPU reads FIFO, causes FIFO error. Set RXFFRC.	00	no chg	no chg	no chg	no chg	no chg	1	None	Time-out, NAK future transactions	Firmware should check RXURF bit before writing RXFFRC.
11	Received OUT token	11	no chg	no chg	1	no chg	no chg	no chg	None	NAK	FIFO not ready, so data is ignored (CRC or FIFO error not possible).

NOTES:

- These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
- STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
- NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Interrupt	USB Response	Comments
	Received SETUP token, no errors (dual-packet mode not recommended!)	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. (2) RXSETUP will be set. (control endpoints only).
	Received SETUP token, but timed-out waiting for data	11	1	0	0	0	0	0	Set receive interrupt	Time-out	FIFO is reset automatically and FIFO data is invalid. (2)
	Received SETUP token, data CRC or bit-stuff error (dual-packet mode not recommended).	00	1	0	0	1	0	0	Set receive interrupt	Time-out	Write ptr reversed. RXIE or RXSTL has no effect. (2)
	Received SETUP token, FIFO error (dual-packet mode not recommended).	00	1	0	0	1	1	0	Set receive interrupt	Time-out, NAK future transactions	RXIE or RXSTL has no effect. (2) RXSETUP will be set (control endpoints only).
	Received SETUP token with FIFO error already existing	01	0	1	0	1	0	0	Set receive interrupt	ACK	Causes FIFO to reset automatically, forcing new SETUP to be received. (2) RXSETUP will be set (control endpoints only).
	CPU reads FIFO, sets RXFFRC	10/01	no chg	no chg	no chg	no chg	no chg	no chg	None	None	

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
3. NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-4. Non-isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New FIF (1:0)	RX ERR	RX ACK	RX Void	RX Setup	RX OVF (1)	RX URF (1)	RX Inter-rupt	USB Response	Comments
	CPU reads FIFO, causes FIFO error. RXFFRC not written yet.	11	no chg	no chg	no chg	no chg	no chg	1	None	NAKs future transactions	Firmware should check RXURF bit before writing FFRC
	CPU reads FIFO, causes FIFO error. Set RXFFRC.	10/01	no chg	no chg	no chg	no chg	no chg	1	None	NAKs future transactions	Firmware should check RXURF bit before writing FFRC

NOTES:

1. These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
2. STOVW is set after a valid SETUP token is received and cleared during handshake phase. EDOVW is set during handshake phase.
3. NOTE: Dual-packet mode is NOT recommended for control endpoints.

Table D-5. Isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0)

FIF (1:0)	Event	New RXFIF (1:0) (2)	(at next SOF)			RX OVF (1,2)	RX URF (1,2)	RX Inter-rupt	USB Response	Comments
			RX ERR	RX ACK	RX Void					
00	Received OUT token, but RXIE = 0	00	no chg	no chg	1	no chg	no chg	None	None/ Time-out	FIFO not ready, or timed-out waiting for data packet, but no NAK sent
	Received OUT token, but timed-out waiting for data	00	no chg	no chg	no chg	no chg	no chg	None	None/ Time-out	FIFO not loaded.
	Received OUT token, no errors	01	0	1	0	no chg	no chg	None	None/ Time-out	Received, no errors, advance write marker
	Received OUT token, data CRC or bit-stuff error	01	1	0	0	no chg	no chg	None	None/ Time-out	Bad data still loaded into FIFO.
	Received OUT token, FIFO error occurs	01	1	0	0	1	no chg	None	None/ Time-out	Only RXOVF FIFO error can occur, requires firmware intervention.
	Received OUT token with FIFO error already existing	00	1 (no chg)	0 (no chg)	1	1 (no chg)	no chg	None	None/ Time-out	Treated like a "void" condition.
	CPU reads FIFO, causes FIFO error	00	no chg	no chg	no chg	no chg	1	None	None/ Time-out	FIFO was empty when read. Should always check RXFIF bits before reading.

NOTES:

- These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
- RXFIF, RXOVF and RXURF are handled with the following golden rule: Firmware events cause status change immediately while USB events only cause status change at SOF.
RXURF: Since underrun can only be caused by firmware, RXURF is updated immediately.
RXOVF: Since overrun can only be caused by USB, RXOVF is updated at SOF.
RXFIF: RXFIF is "incremented" by USB and "decremented" by firmware. Therefore, setting RXFFRC will "decrement" RXFIF immediately. However, a successful USB transaction anytime in a frame will only "increment" RXFIF at SOF.
RXERR, RXACK, and RXVOID can only be caused by USB, thus they are updated at the end of transaction.

Table D-5. Isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New RXFIF (1:0) (2)	(at next SOF)			RX OVF (1,2)	RX URF (1,2)	RX Interrupt	USB Response	Comments
			RX ERR	RX ACK	RX Void					
	Receive SOF indication	no chg/updated	updated	updated	updated	updated	no chg	None (SOF interrupt)	None/ Time-out	Flags are updated at SOF. Firmware must check for RXFIF = 00 condition to detect no ISO packet received this frame.
01/10	Received OUT token, but RXIE = 0	01/10	no chg	no chg	1	no chg	no chg	None	None/ Time-out	FIFO not ready.
	Received OUT token, but timed-out waiting for data	01/10	no chg	no chg	no chg	no chg	no chg	None	None/ Time-out	FIFO not loaded.
	Received OUT token, no errors	11	0	1	0	no chg	no chg	None	None/ Time-out	Received, no errors, advance write marker.
	Received OUT token, data CRC or bit-stuff error	11	1	0	0	no chg	no chg	None	None/ Time-out	Possible to have RXERR cleared by hardware before seen by firmware. Reverse write pointer.
	Received OUT token, FIFO error occurs	11	1	0	0	1	no chg	None	None/ Time-out	Only OVF FIFO error can occur, requires firmware intervention.
	Received OUT token with FIFO error already existing	01/10	no chg	no chg	1	no chg	no chg	None	None/ Time-out	Treated like a "void" condition.

- NOTES:**
- These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
 - RXFIF, RXOVF and RXURF are handled with the following golden rule: Firmware events cause status change immediately while USB events only cause status change at SOF.
 RXURF: Since underrun can only be caused by firmware, RXURF is updated immediately.
 RXOVF: Since overrun can only be caused by USB, RXOVF is updated at SOF.
 RXFIF: RXFIF is "incremented" by USB and "decremented" by firmware. Therefore, setting RXFFRC will "decrement" RXFIF immediately. However, a successful USB transaction anytime in a frame will only "increment" RXFIF at SOF.
 RXERR, RXACK, and RXVOID can only be caused by USB, thus they are updated at the end of transaction.

Table D-5. Isochronous Receive Data Flow in Dual-packet Mode (RXSPM = 0) (Continued)

FIF (1:0)	Event	New RXFIF (1:0) (2)	(at next SOF)			RX OVF (1,2)	RX URF (1,2)	RX Interrupt	USB Response	Comments
			RX ERR	RX ACK	RX Void					
	CPU reads FIFO, sets RXFFRC	00	no chg	no chg	no chg	no chg	no chg	None	None/ Time-out	
	CPU reads FIFO, causes FIFO error	00	no chg	no chg	no chg	no chg	1	None	None/ Time-out	Firmware should check RXURF bit before writing RXFFRC.
11	Received OUT token	11	no chg	no chg	1	no chg	no chg	None	None/ Time-out	FIFO not ready, but data must be taken. This situation should never happen.
	Received SOF indication	no chg/ up-dated	up-dated	up-dated	up-dated	up-dated	no chg	None (SOF interrupt)	None/ Time-out	Error condition (not handled by hardware). Firmware should not allow this condition.
	CPU reads FIFO, sets RXFFRC	10 or 01	no chg	no chg	no chg	no chg	no chg	None	None/ Time-out	
	CPU reads FIFO, causes FIFO error. RXFFRC not set yet.	11	no chg	no chg	no chg	no chg	1	None	None/ Time-out	Firmware should check RXURF bit before writing RXFFRC.
	CPU reads FIFO, causes FIFO error. Set RXFFRC.	10 or 01	no chg	no chg	no chg	no chg	1	None	None/ Time-out	Firmware should check RXURF bit before writing RXFFRC.

NOTES:

- These are sticky bits, which must be cleared by firmware. Also, this table assumes RXEPEN and ARM are enabled.
- RXFIF, RXOVF and RXURF are handled with the following golden rule: Firmware events cause status change immediately while USB events only cause status change at SOF.
 RXURF: Since underrun can only be caused by firmware, RXURF is updated immediately.
 RXOVF: Since overrun can only be caused by USB, RXOVF is updated at SOF.
 RXFIF: RXFIF is "incremented" by USB and "decremented" by firmware. Therefore, setting RXFFRC will "decrement" RXFIF immediately. However, a successful USB transaction anytime in a frame will only "increment" RXFIF at SOF.
 RXERR, RXACK, and RXVOID can only be caused by USB, thus they are updated at the end of transaction.



Glossary





GLOSSARY

This glossary defines acronyms, abbreviations, and terms that have special meaning in this manual. (Chapter 1, “Guide to this Manual,” discusses notational conventions and general terminology.)

#0data16	A 32-bit constant that is immediately addressed in an instruction. The upper word is filled with zeros.
#1data16	A 32-bit constant that is immediately addressed in an instruction. The upper word is filled with ones.
#data	An 8-bit constant that is immediately addressed in an instruction.
#data16	A 16-bit constant that is immediately addressed in an instruction.
#short	A constant, equal to 1, 2, or 4, that is immediately addressed in an instruction.
ACK	Acknowledgment. Handshake packet indicating a positive acknowledgment.
accumulator	A register or storage location that forms the result of an arithmetic or logical operation.
addr11	An 11-bit destination address. The destination can be anywhere in the same 2 Kbyte block of memory as the first byte of the next instruction.
addr16	A 16-bit destination address. The destination can be anywhere within the same 64 Kbyte region as the first byte of the next instruction.
addr24	A 24-bit destination address. The destination can be anywhere within the 16 Mbyte address space.
ALU	Arithmetic-logic unit. The part of the CPU that processes arithmetic and logical operations.
assert	The term <i>assert</i> refers to the act of making a signal active (enabled). The polarity (high/low) is defined by the signal name. Active-low signals are designated by a pound symbol (#) suffix; active-high signals have no suffix. To <i>assert</i> RD# is to drive it low; to <i>assert</i> ALE is to drive it high.

big endian form	Method of storing data that places the most significant byte at lower storage addresses.
binary-code compatibility	The ability of an 8x930 to execute, without modification, binary code written for an MCS 51 microcontroller.
binary mode	An operating mode, selected by a configuration bit, that enables an 8x930 to execute, without modification, binary code written for an MCS 51 microcontroller.
bit	A binary digit.
bit (operand)	An addressable bit in the 8x930 architecture.
bit51	An addressable bit in the MCS 51 architecture.
bit stuffing	Insertion of a '0' bit into a data stream to cause an electrical transition on the data wires allowing a PLL to remain locked.
bulk transfer	Non-periodic, large, "bursty" communication typically used for a transfer that can use any available bandwidth and can also be delayed until bandwidth is available.
bus enumeration	Detecting and identifying USB devices.
byte	Any 8-bit unit of data.
clear	The term <i>clear</i> refers to the value of a bit or the act of giving it a value. If a bit is <i>clear</i> , its value is "0"; <i>clearing</i> a bit gives it a "0" value.
code memory	See <i>program memory</i> .
configuration bytes	Bytes, residing in on-chip non-volatile memory, that determine a set of operating parameters for the 8x930.
control transfer	One of four Universal Serial Bus Transfer Types. Control transfers support configuration/command /status type communications between client and function.
dir8	An 8-bit direct address. This can be a memory address or an SFR address.
dir16	A 16-bit memory address (00:0000H–00:FFFFH) used in direct addressing.

DPTR	The 16-bit data pointer. In 8x930 microcontrollers, DPTR is the lower 16 bits of the 24-bit extended data pointer, DPX.
DPX	The 24-bit extended data pointer in 8x930 microcontrollers. See also <i>DPTR</i> .
deassert	The term <i>deassert</i> refers to the act of making a signal inactive (disabled). The polarity (high/low) is defined by the signal name. Active-low signals are designated by a pound symbol (#) suffix; active-high signals have no suffix. To <i>deassert</i> RD# is to drive it high; to <i>deassert</i> ALE is to drive it low.
device address	The address of a device on the Universal Serial Bus. The device address is the default address when the USB device is first powered or reset. Hubs and functions are assigned a unique device address by USB firmware.
doping	The process of introducing a periodic table Group III or Group V element into a Group IV element (e.g., silicon). A Group III impurity (e.g., indium or gallium) results in a <i>p-type</i> material. A Group V impurity (e.g., arsenic or antimony) results in an <i>n-type</i> material.
double word	A 32-bit unit of data. In memory, a double word comprises four contiguous bytes.
dword	See <i>double word</i> .
edge-triggered	The mode in which a device or component recognizes a falling edge (high-to-low transition), a rising edge (low-to-high transition), or a rising or falling edge of an input signal as the assertion of that signal. See also <i>level-triggered</i> .
encryption array	An array of key bytes used to encrypt user code as it is read from code memory; protects against unauthorized access to user's code.
endpoint	A uniquely identifiable portion of a USB device that is the source or sink of information in a communication flow between the host and the device.
EPP	Endpoint pair. See <i>endpoint</i> .
EPROM	Erasable, programmable read-only memory

external address	A 16-bit, 17-bit, or 18-bit address presented on the device pins. The address decoded by an external device depends on how many of these address bits the external system uses. See also <i>internal address</i> .
F_{CLK}	Microcontroller internal clock frequency distributed to the CPU and on-chip peripherals.
FET	Field-effect transistor.
FIFO	First-in, first-out data buffer. Each USB endpoint pair has a transmit FIFO and a receive FIFO.
FIU	Function Interface Unit. Its function is to manage the data transaction that goes between the 8x930Hx and the USB host based on the transfer type and the FIFOs condition.
F_{OSC}	Frequency at pin XTAL1. The frequency of the on-chip oscillator or external source.
frame	The time from the start of one SOF token to the start of the subsequent SOF token; consists of a series of transactions.
function	A USB device that provides a capability to the host. For example, an ISDN connection, a digital microphone, or speakers.
handshake packet	A packet that acknowledges or rejects a specific condition. For examples, see ACK and NACK.
HIU	Hub Interface Unit.
host	The host computer system where the USB host controller is installed. This includes the host hardware platform (CPU, bus, etc.) and the operating system in use.
Hub	A Universal Serial bus device that provides additional connections to the Universal Serial Bus.
idle mode	The power conservation mode that freezes the core clocks but leaves the peripheral clocks running.
input leakage	Current leakage from an input pin to power or ground.
integer	Any member of the set consisting of the positive and negative whole numbers and zero.

internal address	The 24-bit address that the device generates. See also <i>external address</i> .
interrupt handler	The module responsible for handling interrupts that are to be serviced by user-written interrupt service routines.
interrupt latency	The delay between an interrupt request and the time when the first instruction in the interrupt service routine begins execution.
interrupt response time	The time delay between an interrupt request and the resulting break in the current instruction stream.
interrupt service routine (ISR)	The firmware routine that services an interrupt.
interrupt transfer	One of four USB transfer types. Interrupt transfer characteristics are small data, non periodic, low frequency, bounded latency, device initiated communication typically used to notify the host of device service needs.
ISO	Isochronous
isochronous data	A stream of data whose timing is implied by its delivery rate.
isochronous transfer	One of four USB transfer types, isochronous transfers provide periodic, continuous communication between host and device.
level-triggered	The mode in which a device or component recognizes a high level (logic one) or a low level (logic zero) of an input signal as the assertion of that signal. See also <i>edge-triggered</i> .
low-clock mode	The default mode upon reset, low-clock mode ensures that the I_{CC} drawn by the 8x930 is less than one unit load.
LSB	Least-significant bit of a byte or least-significant byte of a word.
maskable interrupt	An interrupt that can be disabled (masked) by its individual mask bit in an interrupt enable register. All 8x930 interrupts, except the firmware trap (TRAP), are maskable.
MSB	Most-significant bit of a byte or most-significant byte of a word.

multiplexed bus	A bus on which the data is time-multiplexed with (some of) the address bits.
<i>n</i>-channel FET	A field-effect transistor with an <i>n</i> -type conducting path (channel).
<i>n</i>-type material	Semiconductor material with introduced impurities (<i>doping</i>) causing it to have an excess of negatively charged carriers.
nonmaskable interrupt	An interrupt that cannot be disabled (masked). The firmware trap (TRAP) is the 8x930's only nonmaskable interrupt.
<i>npn</i> transistor	A transistor consisting of one part <i>p</i> -type material and two parts <i>n</i> -type material.
NRZI	Non Return to Zero Invert. A method of encoding serial data in which ones and zeroes are represented by opposite and alternating high and low voltages where there is no return to zero (reference) voltage between encoded bits. Eliminates the need for clock pulses.
OTPROM	One-time-programmable read-only memory, a version of EPROM.
<i>p</i>-channel FET	A field-effect transistor with a <i>p</i> -type conducting path.
<i>p</i>-type material	Semiconductor material with introduced impurities (<i>doping</i>) causing it to have an excess of positively charged carriers.
PC	Program counter.
phase-locked loop	A circuit that acts as a phase detector to keep an oscillator in phase with an incoming frequency.
PID	Packet ID. A field in a USB packet that identifies the type of packet and hence its format.
PLL	See <i>phase-locked loop</i> .
program memory	A part of memory where instructions can be stored for fetching and execution.
powerdown mode	The power conservation mode that freezes both the core clocks and the peripheral clocks.
PWM	Pulse-width modulated (outputs).

rel	A signed (two's complement) 8-bit, relative destination address. The destination is -128 to +127 bytes relative to the first byte of the next instruction.
reserved bits	Register bits that are not used in this device but may be used in future implementations. Avoid any firmware dependence on these bits. In the 8x930, the value read from a reserved bit is indeterminate; do not write a "1" to a reserved bit.
resume	Once a device is in the suspend state, its operation can be resumed by receiving non-idle signaling on the bus. See also <i>suspend</i> .
RT	Real-time
root hub	A USB hub directly attached to the host controller. This hub is attached to the host; tier 0.
root port	The upstream port on a hub.
SE0	Single-ended zero. This is a reference to the USB reset signal which is defined as both D_{P0} and D_{M0} below their threshold voltage.
SIE	Serial Bus Interface Engine. Handles the communications protocol of the USB.
set	The term <i>set</i> refers to the value of a bit or the act of giving it a value. If a bit is <i>set</i> , its value is "1"; <i>setting</i> a bit gives it a "1" value.
SFR	A special function register that resides in its associated on-chip peripheral or in the 8x930 core.
sign extension	A method for converting data to a larger format by filling the extra bit positions with the value of the sign. This conversion preserves the positive or negative value of signed integers.
sink current	Current flowing into a device to ground. Always a positive value.
SOF	Start of Frame. The SOF is the first transaction in each frame. SOF allows endpoints to identify the start of frame and synchronize internal endpoint clocks to the host.
source-code compatibility	The ability of an 8x930 to execute re-compiled source code written for an MCS 51 microcontroller.

source current	Current flowing out of a device from V_{CC} . Always a negative value.
source mode	An operating mode that is selected by a configuration bit. In source mode, an 8x930 can execute re-compiled source code written for an MCS 51 microcontroller. In source mode, the 8x930 cannot execute unmodified binary code written for an MCS 51 microcontroller. See binary mode.
SP	Stack pointer.
SPX	Extended stack pointer.
state time (or state)	The basic time unit of the device; the combined period of the two internal timing signals, PH1 and PH2. (The internal clock generator produces PH1 and PH2 by halving the frequency of the signal on XTAL1.) With a 16 MHz crystal, one <i>state time</i> equals 125 ns. Because the device can operate at many frequencies, this manual defines time requirements in terms of <i>state times</i> rather than in specific units of time.
suspend	A low current mode used when the USB bus is idle. The 8x930 enters suspend when there is a constant idle state on the bus lines for more than 3.0 msec. When a device is in suspend state, it draws less than 500 μ A from the bus. See also <i>resume</i> .
token packet	A type of packet that identifies what transaction is to be performed on the bus.
UART	Universal asynchronous receiver and transmitter. A part of the serial I/O port.
USB	Universal Serial Bus. An industry-standard extension to the PC architecture with a focus on Computer Telephony Integration (CTI), consumer, and productivity applications.
WDT	Watchdog timer, an internal timer that resets the device if the firmware fails to operate properly.
word	A 16-bit unit of data. In memory, a word comprises two contiguous bytes.

wraparound

The result of interpreting an address whose hexadecimal expression uses more bits than the number of available address lines. Wraparound ignores the upper address bits and directs access to the value expressed by the lower bits.





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