



**CY7C65013**  
**CY7C65113**

# USB Hub with Microcontroller

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## 1.0 Features

- USB hub with an integrated microcontroller
- 8-bit USB optimized microcontroller
  - Harvard architecture
  - 6-MHz external clock source
  - 12-MHz internal CPU clock
  - 48-MHz internal hub clock
- Internal memory
  - 256 bytes of RAM
  - 8 KB of PROM
- Integrated Master/Slave I<sup>2</sup>C-compatible Controller (100 kHz) enabled through General-purpose I/O (GPIO) pins
- I/O ports
  - Three GPIO ports (Port 0 to 2) capable of sinking 7 mA per pin (typical)
  - An additional GPIO port (Port 3) capable of sinking 12 mA per pin (typical) for high current requirements: LEDs
  - Higher current drive achievable by connecting multiple GPIO pins together to drive a common output
  - Each GPIO port can be configured as inputs with internal pull-ups or open drain outputs or traditional CMOS outputs
  - Maskable interrupts on all I/O pins
- 12-bit free-running timer with one microsecond clock ticks
- Watchdog timer (WDT)
- Internal Power-on Reset (POR)
- USB Specification compliance
  - Conforms to USB Specification, Version 1.1
  - Conforms to USB HID Specification, Version 1.1
  - Supports one or two device addresses with up to 5 user-configured endpoints
    - Up to two 8-byte control endpoints
    - Up to four 8-byte data endpoints
    - Up to two 32-byte data endpoints
  - Integrated USB transceivers
  - Supports seven (CY7C65013) or four (CY7C65113) downstream USB ports
  - GPIO pins can provide individual power control outputs for each downstream USB port
  - GPIO pins can provide individual port over current inputs for each downstream USB port
- Improved output drivers to reduce electromagnetic interference (EMI)
- Operating voltage from 4.0V to 5.5V DC
- Operating temperature from 0° to 70° C
- CY7C65013 available in 48-pin PDIP (-PC) or 48-pin SSOP (-PVC) packages
- CY7C65113 available in 28-pin SOIC (-SC) or 28-pin PDIP (-PC) packages
- Industry-standard programmer support.

## 2.0 Functional Overview

The CY7C65x13 devices are one-time programmable 8-bit microcontrollers with a built-in 12-Mbps USB hub that supports up to seven downstream ports. The microcontroller instruction set has been optimized specifically for USB operations, although the microcontrollers can be used for a variety of non-USB embedded applications.

### GPIO

#### CY7C65013

The CY7C65013 features 22 GPIO pins to support USB and other applications. The I/O pins are grouped into four ports (P0[7:0], P1[7:4,2:0], P2[7:3], P3[1:0]) where each port can be configured as inputs with internal pull-ups, open drain outputs, or traditional CMOS outputs. Ports 0 to 2 are rated at 7 mA per pin (typical) sink current. Port 3 pins are rated at 12 mA per pin (typical) sink current, which allows these pins to drive LEDs. Multiple GPIO pins can be connected together to drive a single output for more drive current capacity. Additionally, each I/O pin can be used to generate a GPIO interrupt to the microcontroller. All of the GPIO interrupts all share the same "GPIO" interrupt vector.

#### CY7C65113

The CY7C65113 has 11 GPIO pins (P0[7:0], P1[2:0]), both rated at 7 mA per pin (typical) sink current. Multiple GPIO pins can be connected together to drive a single output for more drive current capacity.

### Clock

The microcontroller uses an external 6-MHz crystal and an internal oscillator to provide a reference to an internal phase-locked loop (PLL)-based clock generator. This technology allows the customer application to use an inexpensive 6-MHz fundamental crystal that reduces the clock-related noise emissions (EMI). A PLL clock generator provides the 6-, 12-, and 48-MHz clock signals for distribution within the microcontroller.

### Memory

The CY7C65013 and the CY7C65113 are offered with 8 KB of PROM.

### Power-on Reset, Watchdog, and Free-running Timer

These parts include power-on reset logic, a Watchdog timer, and a 12-bit free-running timer. The POR logic detects when power is applied to the device, resets the logic to a known state, and begins executing instructions at PROM address 0x0000. The Watchdog timer is used to ensure the microcontroller recovers after a period of inactivity. The firmware may become inactive for a variety of reasons, including errors in the code or a hardware failure such as waiting for an interrupt that never occurs.

### I<sup>2</sup>C

The microcontroller can communicate with external electronics through the GPIO pins. An I<sup>2</sup>C-compatible interface accommodates a 100-kHz serial link with an external device.

### Timer

The free-running 12-bit timer clocked at 1 MHz provides two interrupt sources, 128- $\mu$ s and 1.024-ms. The timer can be used to measure the duration of an event under firmware control by reading the timer at the start of the event and after the event is complete. The difference between the two readings indicates the duration of the event in microseconds. The upper four bits of the timer are latched into an internal register when the firmware reads the lower eight bits. A read from the upper four bits actually reads data from the internal register, instead of the timer. This feature eliminates the need for firmware to try to compensate if the upper four bits increment immediately after the lower eight bits are read.

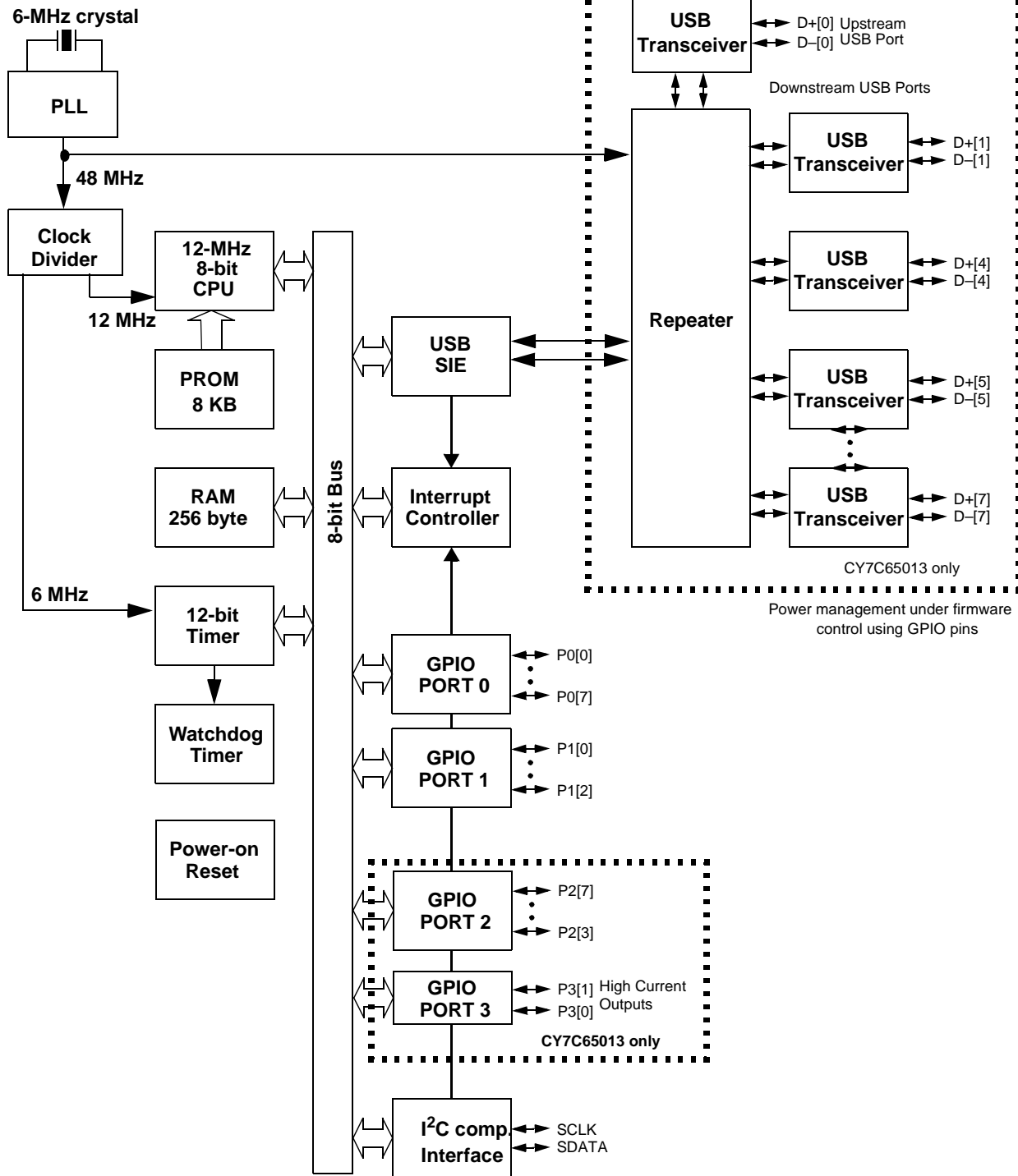
### Interrupts

The microcontroller supports ten maskable interrupts in the vectored interrupt controller. Interrupt sources include the USB Bus Reset interrupt, the 128- $\mu$ s (bit 6) and 1.024-ms (bit 9) outputs from the free-running timer, five USB endpoints, the USB hub, the GPIO ports, and the I<sup>2</sup>C-compatible master mode interface. The timer bits cause an interrupt (if enabled) when the bit toggles from LOW '0' to HIGH '1'. The USB endpoints interrupt after the USB host has written data to the endpoint FIFO or after the USB controller sends a packet to the USB host. The GPIO ports also have a level of masking to select which GPIO inputs can cause a GPIO interrupt. Input transition polarity can be programmed for each GPIO port as part of the port configuration. The interrupt polarity can be rising edge ('0' to '1') or falling edge ('1' to '0').

### USB

The CY7C65013 and CY7C65113 include an integrated USB Serial Interface Engine (SIE) that supports the integrated peripherals and the hub controller function. The hardware supports up to two USB device addresses with one device address for the hub (two endpoints) and a device address for a compound device (three endpoints). The SIE allows the USB host to communicate with the hub and functions integrated into the microcontroller. The CY7C65113 part includes a 1:4 hub repeater with one upstream port and four downstream ports, while the CY7C65013 part includes a 1:7 hub repeater. The USB Hub allows power management control of the downstream ports by using GPIO pins assigned by the user firmware. The user has the option of ganging the downstream ports together with a single pair of power management pins, or providing power management for each port with four (CY7C65113) or seven (CY7C65013) pairs of power management pins.

Logic Block Diagram

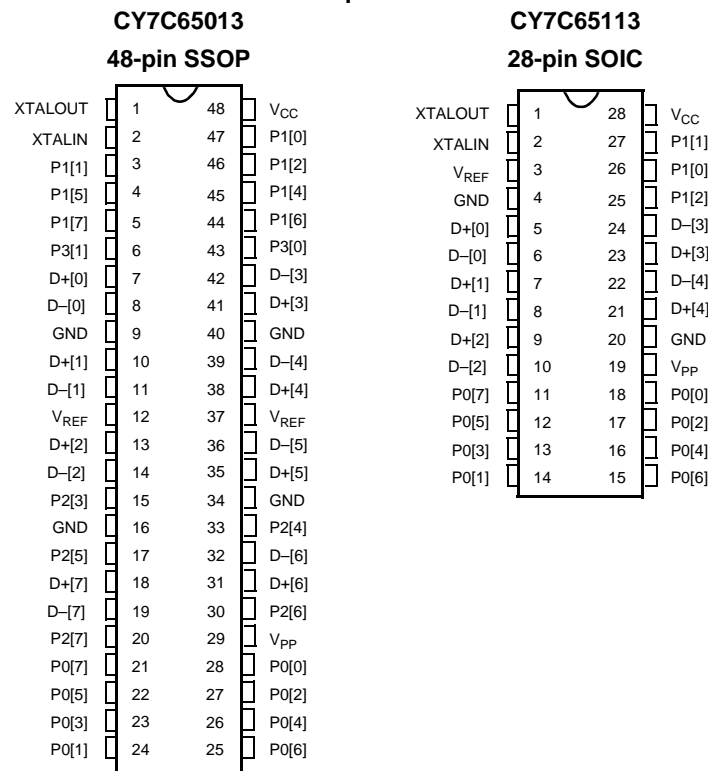


\*I<sup>2</sup>C-compatible interface enabled by firmware through P2[1:0] or P1[1:0]



### 3.0 Pin Configurations

#### Top View



### 4.0 Product Summary Tables

#### 4.1 Pin Assignments

Table 4-1. Pin Assignments

| Name               | I/O | 48-pin                                       | 28-pin                                       | Description                                      |
|--------------------|-----|--|--|--|
| D+[0], D-[0]       | I/O | 7, 8   | 5, 6   | Upstream port, USB differential data.            |
| D+[1], D-[1]       | I/O | 10, 11                                       | 7, 8   | Downstream Port 1, USB differential data.        |
| D+[2], D-[2]       | I/O | 13, 14                                       | 9, 10  | Downstream Port 2, USB differential data.        |
| D+[3], D-[3]       | I/O | 41, 42                                       | 23, 24                                       | Downstream Port 3, USB differential data.        |
| D+[4], D-[4]       | I/O | 38, 39                                       | 21, 22                                       | Downstream Port 4, USB differential data.        |
| D+[5], D-[5]       | I/O | 35, 36                                       |  | Downstream Port 5, USB differential data.        |
| D+[6], D-[6]       | I/O | 31, 32                                       |  | Downstream Port 6, USB differential data.        |
| D+[7], D-[7]       | I/O | 18, 19                                       |  | Downstream Port 7, USB differential data.        |
| P0                 | I/O | P1[7:0]<br>21, 25, 22, 26, 23, 27,<br>24, 28 | P1[7:0]<br>11, 15, 12, 16, 13,<br>17, 14, 18 | GPIO Port 0 capable of sinking 7 mA (typical).   |
| P1                 | I/O | P1[7:4,2:0]<br>5, 44, 4, 45; 46, 3, 47       | P1[2:0]<br>25, 27, 26                        | GPIO Port 1 capable of sinking 7 mA (typical).   |
| P2                 | I/O | P2[7:3]<br>20, 30, 17,33, 15                 |  | GPIO Port 2 capable of sinking 12 mA (typical).  |
| P3                 | I/O | P3[1:0]<br>6, 43                             |  | GPIO Port 3, capable of sinking 12 mA (typical). |
| XTAL <sub>IN</sub> | IN  | 2  | 2  | 6-MHz crystal or external clock input.           |

**Table 4-1. Pin Assignments** (continued)

| Name                | I/O | 48-pin        | 28-pin | Description  |
|---------------------|-----|---------------|--------|--|
| XTAL <sub>OUT</sub> | OUT | 1             | 1      | 6-MHz crystal out.   |
| V <sub>PP</sub>     |     | 29            | 19     | Programming voltage supply, tie to ground during normal operation.                                   |
| V <sub>CC</sub>     |     | 48            | 28     | Voltage supply.  |
| GND                 |     | 9, 16, 34, 40 | 4, 20  | Ground.  |
| V <sub>REF</sub>    | IN  | 12, 37        | 3      | External 3.3V supply voltage for the downstream differential data output buffers and the D+ pull up. |

## 4.2 I/O Register Summary

I/O registers are accessed via the I/O Read (IORD) and I/O Write (IOWR, IOWX) instructions. IORD reads data from the selected port into the accumulator. IOWR performs the reverse; it writes data from the accumulator to the selected port. Indexed I/O Write (IOWX) adds the contents of X to the address in the instruction to form the port address and writes data from the accumulator to the specified port. Specifying address 0 (e.g., IOWX 0h) means the I/O register is selected solely by the contents of X.

All undefined registers are reserved. Do not write to reserved registers as this may cause an undefined operation or increased current consumption during operation. When writing to registers with reserved bits, the reserved bits must be written with '0.'

**Table 4-2. I/O Register Summary**

| Register Name                     | I/O Address | Read/Write | Function                                       | Page |
|-----------------------------------|-------------|------------|--|------|
| Port 0 Data                       | 0x00        | R/W        | GPIO Port 0 Data                               | 18   |
| Port 1 Data                       | 0x01        | R/W        | GPIO Port 1 Data                               | 17   |
| Port 2 Data                       | 0x02        | R/W        | GPIO Port 2 Data                               | 17   |
| Port 3 Data                       | 0x03        | R/W        | GPIO Port 3 Data                               | 19   |
| Port 0 Interrupt Enable           | 0x04        | W          | Interrupt Enable for Pins in Port 0            | 19   |
| Port 1 Interrupt Enable           | 0x05        | W          | Interrupt Enable for Pins in Port 1            | 19   |
| Port 2 Interrupt Enable           | 0x06        | W          | Interrupt Enable for Pins in Port 2            | 19   |
| Port 3 Interrupt Enable           | 0x07        | W          | Interrupt Enable for Pins in Port 3            | 19   |
| GPIO Configuration                | 0x08        | R/W        | GPIO Port Configurations                       | 18   |
| I <sup>2</sup> C Configuration    | 0x09        | R/W        | I <sup>2</sup> C Position Configuration        | 20   |
| USB Device Address A              | 0x10        | R/W        | USB Device Address A                           | 36   |
| EP A0 Counter Register            | 0x11        | R/W        | USB Address A, Endpoint 0 Counter              | 38   |
| EP A0 Mode Register               | 0x12        | R/W        | USB Address A, Endpoint 0 Configuration        | 37   |
| EP A1 Counter Register            | 0x13        | R/W        | USB Address A, Endpoint 1 Counter              | 38   |
| EP A1 Mode Register               | 0x14        | R/W        | USB Address A, Endpoint 1 Configuration        | 38   |
| EP A2 Counter Register            | 0x15        | R/W        | USB Address A, Endpoint 2 Counter              | 38   |
| EP A2 Mode Register               | 0x16        | R/W        | USB Address A, Endpoint 2 Configuration        | 38   |
| USB Status & Control              | 0x1F        | R/W        | USB Upstream Port Traffic Status and Control   | 35   |
| Global Interrupt Enable           | 0x20        | R/W        | Global Interrupt Enable                        | 25   |
| Endpoint Interrupt Enable         | 0x21        | R/W        | USB Endpoint Interrupt Enables                 | 26   |
| Interrupt Vector                  | 0x23        | R          | Pending Interrupt Vector Read/Clear            | 27   |
| Timer (LSB)                       | 0x24        | R          | Lower Eight Bits of Free-running Timer (1 MHz) | 20   |
| Timer (MSB)                       | 0x25        | R          | Upper Four Bits of Free-running Timer          | 20   |
| WDR Clear                         | 0x26        | W          | Watchdog Reset Clear                           | 17   |
| I <sup>2</sup> C Control & Status | 0x28        | R/W        | I <sup>2</sup> C Status and Control            | 21   |
| I <sup>2</sup> C Data             | 0x29        | R/W        | I <sup>2</sup> C Data                          | 23   |

**Table 4-2. I/O Register Summary** (continued)

| Register Name                  | I/O Address | Read/Write | Function   | Page |
|--------------------------------|-------------|------------|--|------|
| Reserved                       | 0x30        |            | Reserved   |      |
| Reserved                       | 0x31        |            | Reserved   |      |
| Reserved                       | 0x32        |            | Reserved   |      |
| Reserved                       | 0x38-0x3F   |            | Reserved   |      |
| USB Device Address B           | 0x40        | R/W        | USB Device Address B (not used in 5-endpoint mode)                                       | 36   |
| EP B0 Counter Register         | 0x41        | R/W        | USB Address B, Endpoint 0 Counter  | 38   |
| EP B0 Mode Register            | 0x42        | R/W        | USB Address B, Endpoint 0 Configuration, or USB Address A, Endpoint 3 in 5-endpoint mode | 37   |
| EP B1 Counter Register         | 0x43        | R/W        | USB Address B, Endpoint 1 Counter  | 38   |
| EP B1 Mode Register            | 0x44        | R/W        | USB Address B, Endpoint 1 Configuration, or USB Address A, Endpoint 4 in 5-endpoint mode | 38   |
| Hub Port Connect Status        | 0x48        | R/W        | Hub Downstream Port Connect Status   | 31   |
| Hub Port Enable                | 0x49        | R/W        | Hub Downstream Ports Enable  | 32   |
| Hub Port Speed                 | 0x4A        | R/W        | Hub Downstream Ports Speed   | 31   |
| Hub Port Control (Ports [4:1]) | 0x4B        | R/W        | Hub Downstream Ports Control (Ports [4:1])   | 33   |
| Hub Port Control (Ports [7:5]) | 0x4C        | R/W        | Hub Downstream Ports Control (Ports [7:5])   | 33   |
| Hub Port Suspend               | 0x4D        | R/W        | Hub Downstream Port Suspend Control  | 34   |
| Hub Port Resume Status         | 0x4E        | R          | Hub Downstream Ports Resume Status   | 35   |
| Hub Ports SE0 Status           | 0x4F        | R          | Hub Downstream Ports SE0 Status  | 33   |
| Hub Ports Data                 | 0x50        | R          | Hub Downstream Ports Differential Data   | 34   |
| Hub Downstream Force Low       | 0x51        | R/W        | Hub Downstream Ports Force LOW (Ports [1:4])   | 33   |
| Hub Downstream Force High      | 0x52        | R/W        | Hub Downstream Ports Force HIGH (Ports [5:7])  | 33   |
| Processor Status & Control     | 0xFF        | R/W        | Microprocessor Status and Control Register   | 24   |

### 4.3 Instruction Set Summary

Refer to the *CYASM Assembler User's Guide* for more details. Note that conditional jump instructions (i.e. JC, JNC, JZ, JNZ) take five cycles if jump is taken, four cycles if no jump.

**Table 4-3. Instruction Set Summary**

| MNEMONIC       | operand | opcode | cycles |
|----------------|---------|--------|--------|
| HALT           |         | 00     | 7      |
| ADD A,expr     | data    | 01     | 4      |
| ADD A,[expr]   | direct  | 02     | 6      |
| ADD A,[X+expr] | index   | 03     | 7      |
| ADC A,expr     | data    | 04     | 4      |
| ADC A,[expr]   | direct  | 05     | 6      |
| ADC A,[X+expr] | index   | 06     | 7      |
| SUB A,expr     | data    | 07     | 4      |
| SUB A,[expr]   | direct  | 08     | 6      |
| SUB A,[X+expr] | index   | 09     | 7      |
| SBB A,expr     | data    | 0A     | 4      |
| SBB A,[expr]   | direct  | 0B     | 6      |
| SBB A,[X+expr] | index   | 0C     | 7      |
| OR A,expr      | data    | 0D     | 4      |

| MNEMONIC     | operand | opcode | cycles |
|--------------|---------|--------|--------|
| NOP          |         | 20     | 4      |
| INC A        | acc     | 21     | 4      |
| INC X        | x       | 22     | 4      |
| INC [expr]   | direct  | 23     | 7      |
| INC [X+expr] | index   | 24     | 8      |
| DEC A        | acc     | 25     | 4      |
| DEC X        | x       | 26     | 4      |
| DEC [expr]   | direct  | 27     | 7      |
| DEC [X+expr] | index   | 28     | 8      |
| IORD expr    | address | 29     | 5      |
| IOWR expr    | address | 2A     | 5      |
| POP A        |         | 2B     | 4      |
| POP X        |         | 2C     | 4      |
| PUSH A       |         | 2D     | 5      |

**Table 4-3. Instruction Set Summary** (continued)

| MNEMONIC       | operand | opcode | cycles   |
|----------------|---------|--------|----------|
| OR A,[expr]    | direct  | 0E     | 6        |
| OR A,[X+expr]  | index   | 0F     | 7        |
| AND A,expr     | data    | 10     | 4        |
| AND A,[expr]   | direct  | 11     | 6        |
| AND A,[X+expr] | index   | 12     | 7        |
| XOR A,expr     | data    | 13     | 4        |
| XOR A,[expr]   | direct  | 14     | 6        |
| XOR A,[X+expr] | index   | 15     | 7        |
| CMP A,expr     | data    | 16     | 5        |
| CMP A,[expr]   | direct  | 17     | 7        |
| CMP A,[X+expr] | index   | 18     | 8        |
| MOV A,expr     | data    | 19     | 4        |
| MOV A,[expr]   | direct  | 1A     | 5        |
| MOV A,[X+expr] | index   | 1B     | 6        |
| MOV X,expr     | data    | 1C     | 4        |
| MOV X,[expr]   | direct  | 1D     | 5        |
| reserved       |         | 1E     |          |
| XPAGE          |         | 1F     | 4        |
| MOV A,X        |         | 40     | 4        |
| MOV X,A        |         | 41     | 4        |
| MOV PSP,A      |         | 60     | 4        |
| CALL           | addr    | 50-5F  | 10       |
| JMP            | addr    | 80-8F  | 5        |
| CALL           | addr    | 90-9F  | 10       |
| JZ             | addr    | A0-AF  | 5 (or 4) |
| JNZ            | addr    | B0-BF  | 5 (or 4) |

| MNEMONIC       | operand | opcode | cycles   |
|----------------|---------|--------|----------|
| PUSH X         |         | 2E     | 5        |
| SWAP A,X       |         | 2F     | 5        |
| SWAP A,DSP     |         | 30     | 5        |
| MOV [expr],A   | direct  | 31     | 5        |
| MOV [X+expr],A | index   | 32     | 6        |
| OR [expr],A    | direct  | 33     | 7        |
| OR [X+expr],A  | index   | 34     | 8        |
| AND [expr],A   | direct  | 35     | 7        |
| AND [X+expr],A | index   | 36     | 8        |
| XOR [expr],A   | direct  | 37     | 7        |
| XOR [X+expr],A | index   | 38     | 8        |
| IOWX [X+expr]  | index   | 39     | 6        |
| CPL            |         | 3A     | 4        |
| ASL            |         | 3B     | 4        |
| ASR            |         | 3C     | 4        |
| RLC            |         | 3D     | 4        |
| RRC            |         | 3E     | 4        |
| RET            |         | 3F     | 8        |
| DI             |         | 70     | 4        |
| EI             |         | 72     | 4        |
| RETI           |         | 73     | 8        |
| JC             | addr    | C0-CF  | 5 (or 4) |
| JNC            | addr    | D0-DF  | 5 (or 4) |
| JACC           | addr    | E0-EF  | 7        |
| INDEX          | addr    | F0-FF  | 14       |
|                |         |        |          |

## 5.0 Programming Model

### 5.1 14-bit Program Counter

The 14-bit Program Counter (PC) allows access to up to 8 KB of PROM available with the CY7C65x13 architecture. The top 32 bytes of the ROM in the 8K part are reserved for testing purposes. The program counter is cleared during reset, such that the first instruction executed after a reset is at address 0x0000h. Typically, this is a jump instruction to a reset handler that initializes the application (see Interrupt Vectors on page 27).

The lower eight bits of the program counter are incremented as instructions are loaded and executed. The upper six bits of the program counter are incremented by executing an XPAGE instruction. As a result, the last instruction executed within a 256-byte "page" of sequential code should be an XPAGE instruction. The assembler directive "XPAGEON" causes the assembler to insert XPAGE instructions automatically. Because instructions can be either one or two bytes long, the assembler may occasionally need to insert a NOP followed by an XPAGE to execute correctly.

The address of the next instruction to be executed, the carry flag, and the zero flag are saved as two bytes on the program stack during an interrupt acknowledge or a CALL instruction. The program counter, carry flag, and zero flag are restored from the program stack during a RETI instruction. Only the program counter is restored during a RET instruction.

The program counter cannot be accessed directly by the firmware. The program stack can be examined by reading SRAM from location 0x00 and up.

## 5.1.1 Program Memory Organization

| Address | Description   |
|---------|---|
| 0x0000  | Program execution begins here after a reset             |
| 0x0002  | USB Bus Reset interrupt vector                          |
| 0x0004  | 128- $\mu$ s timer interrupt vector                     |
| 0x0006  | 1.024-ms timer interrupt vector                         |
| 0x0008  | USB address A endpoint 0 interrupt vector               |
| 0x000A  | USB address A endpoint 1 interrupt vector               |
| 0x000C  | USB address A endpoint 2 interrupt vector               |
| 0x000E  | USB address B endpoint 0 interrupt vector               |
| 0x0010  | USB address B endpoint 1 interrupt vector               |
| 0x0012  | Hub interrupt vector                                    |
| 0x0014  | Reserved  |
| 0x0016  | GPIO interrupt vector                                   |
| 0x0018  | I <sup>2</sup> C interrupt vector                       |
| 0x001A  | <b>Program Memory begins here</b>                       |
| 0x1FDF  | <b>(8 KB -32) PROM ends here (CY7C65013, CY7C65113)</b> |

**Figure 5-1. Program Memory Space with Interrupt Vector Table**

Note that the upper 32 bytes of the 8K PROM are reserved. Therefore, user's program must not overwrite this space.

## 5.2 8-bit Accumulator (A)

The accumulator is the general-purpose register for the microcontroller.

## 5.3 8-bit Temporary Register (X)

The “X” register is available to the firmware for temporary storage of intermediate results. The microcontroller can perform indexed operations based on the value in X. Refer to Section 5.6.3 for additional information.

## 5.4 8-bit Program Stack Pointer (PSP)

During a reset, the Program Stack Pointer (PSP) is set to 0x00 and “grows” upward from this address. The PSP may be set by firmware, using the MOV PSP,A instruction. The PSP supports interrupt service under hardware control and CALL, RET, and RETI instructions under firmware control. The PSP is not readable by the firmware.

During an interrupt acknowledge, interrupts are disabled and the 14-bit program counter, carry flag, and zero flag are written as two bytes of data memory. The first byte is stored in the memory addressed by the PSP, then the PSP is incremented. The second byte is stored in memory addressed by the PSP, and the PSP is incremented again. The overall effect is to store the program counter and flags on the program “stack” and increment the PSP by two.

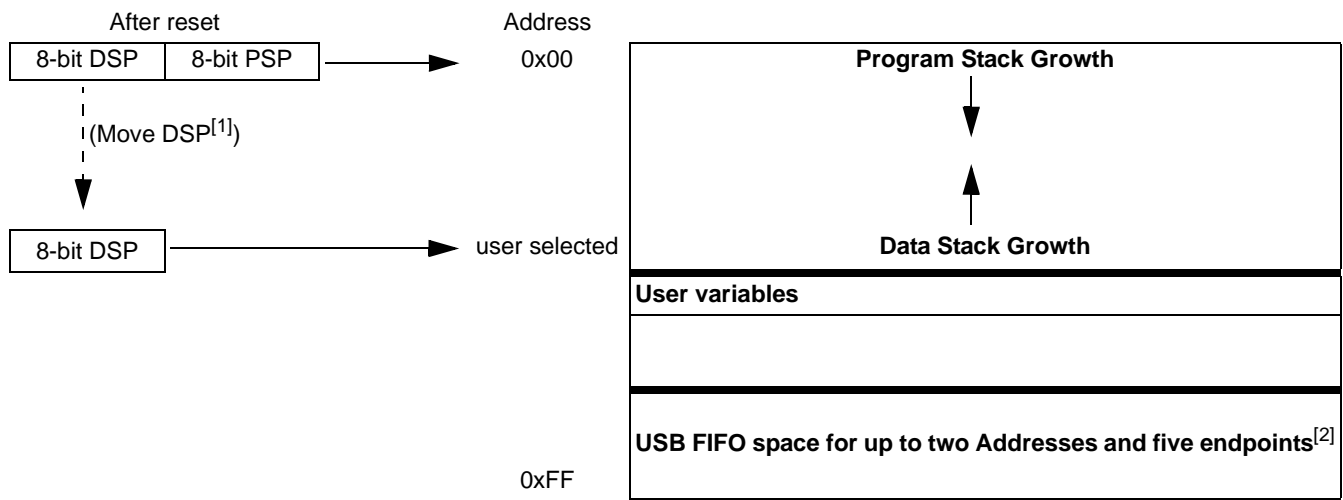
The Return From Interrupt (RETI) instruction decrements the PSP, then restores the second byte from memory addressed by the PSP. The PSP is decremented again and the first byte is restored from memory addressed by the PSP. After the program counter and flags have been restored from stack, the interrupts are enabled. The overall effect is to restore the program counter and flags from the program stack, decrement the PSP by two, and re-enable interrupts.

The Call Subroutine (CALL) instruction stores the program counter and flags on the program stack and increments the PSP by two.

The Return From Subroutine (RET) instruction restores the program counter but not the flags from the program stack and decrements the PSP by two.

### 5.4.1 Data Memory Organization

The CY7C65x13 microcontrollers provide 256 bytes of data RAM. Normally, the SRAM is partitioned into four areas: program stack, user variables, data stack, and USB endpoint FIFOs. The following is one example of where the program stack, data stack, and user variables areas could be located.



**Notes:**

1. Refer to Section 5.5 for a description of DSP.
2. Endpoint sizes are fixed by the Endpoint Size Bit (I/O register 0x1F, Bit 7). See Table 17-1.

## 5.5 8-bit Data Stack Pointer (DSP)

The Data Stack Pointer (DSP) supports PUSH and POP instructions that use the data stack for temporary storage. A PUSH instruction pre-decrements the DSP, then writes data to the memory location addressed by the DSP. A POP instruction reads data from the memory location addressed by the DSP, then post-increments the DSP.

During a reset, the DSP is reset to 0x00. A PUSH instruction when DSP equals 0x00 writes data at the top of the data RAM (address 0xFF). This writes data to the memory area reserved for USB endpoint FIFOs. Therefore, the DSP should be indexed at an appropriate memory location that does not compromise the Program Stack, user-defined memory (variables), or the USB endpoint FIFOs.

For USB applications, the firmware should set the DSP to an appropriate location to avoid a memory conflict with RAM dedicated to USB FIFOs. The memory requirements for the USB endpoints are described in Section 17.2. Example assembly instructions to do this with two device addresses (FIFOs begin at 0xD8) are shown below:

```
MOV A,20h ; Move 20 hex into Accumulator (must be D8h or less)
SWAP A,DSP ; swap accumulator value into DSP register.
```

## 5.6 Address Modes

The CY7C65013 and CY7C65113 microcontrollers support three addressing modes for instructions that require data operands:: data, direct, and indexed.

### 5.6.1 Data (Immediate)

“Data” address mode refers to a data operand that is actually a constant encoded in the instruction. As an example, consider the instruction that loads A with the constant 0xD8:

- MOV A, 0D8h.

This instruction requires two bytes of code where the first byte identifies the “MOV A” instruction with a data operand as the second byte. The second byte of the instruction is the constant “0xD8.” A constant may be referred to by name if a prior “EQU” statement assigns the constant value to the name. For example, the following code is equivalent to the example shown above:

- DSPINIT: EQU 0D8h
- MOV A, DSPINIT.

### 5.6.2 Direct

“Direct” address mode is used when the data operand is a variable stored in SRAM. In that case, the one byte address of the variable is encoded in the instruction. As an example, consider an instruction that loads A with the contents of memory address location 0x10:

- MOV A, [10h].

Normally, variable names are assigned to variable addresses using “EQU” statements to improve the readability of the assembler source code. As an example, the following code is equivalent to the example shown above:

- buttons: EQU 10h
- MOV A, [buttons].

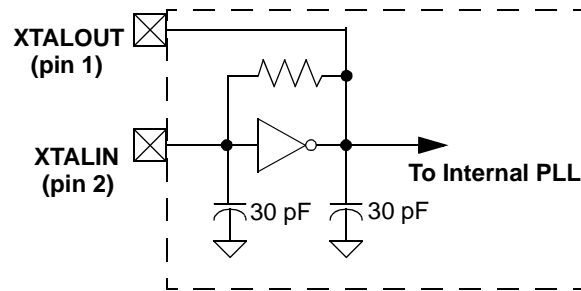
### 5.6.3 Indexed

“Indexed” address mode allows the firmware to manipulate arrays of data stored in SRAM. The address of the data operand is the sum of a constant encoded in the instruction and the contents of the “X” register. Normally, the constant is the “base” address of an array of data and the X register contains an index that indicates which element of the array is actually addressed:

- array: EQU 10h
- MOV X, 3
- MOV A, [X+array].

This would have the effect of loading A with the fourth element of the SRAM “array” that begins at address 0x10. The fourth element would be at address 0x13.

## 6.0 Clocking



**Figure 6-1. Clock Oscillator On-Chip Circuit**

The XTALIN and XTALOUT are the clock pins to the microcontroller. The user can connect an external oscillator or a crystal to these pins. When using an external crystal, keep PCB traces between the chip leads and crystal as short as possible (less than 2 cm). A 6-MHz fundamental frequency parallel resonant crystal can be connected to these pins to provide a reference frequency for the internal PLL. The two internal 30-pF load caps appear in series to the external crystal and would be equivalent to a 15-pF load. Therefore, the crystal must have a required load capacitance of about 15–18 pF. A ceramic resonator does not allow the microcontroller to meet the timing specifications of full speed USB and therefore a ceramic resonator is not recommended with these parts.

An external 6-MHz clock can be applied to the XTALIN pin if the XTALOUT pin is left open. Grounding the XTALOUT pin when driving XTALIN with an oscillator does not work because the internal clock is effectively shorted to ground.

## 7.0 Reset

The CY7C65x13 supports two resets: POR and WDR. Each of these resets causes:

- all registers to be restored to their default states
- the USB device addresses to be set to 0
- all interrupts to be disabled
- the PSP and DSP to be set to memory address 0x00.

The occurrence of a reset is recorded in the Processor Status and Control Register, as described in Section. Bits 4 and 6 are used to record the occurrence of POR and WDR respectively. Firmware can interrogate these bits to determine the cause of a reset.

Program execution starts at ROM address 0x0000 after a reset. Although this looks like interrupt vector 0, there is an important difference. Reset processing does NOT push the program counter, carry flag, and zero flag onto program stack. The firmware reset handler should configure the hardware before the “main” loop of code. Attempting to execute a RET or RETI in the firmware reset handler causes unpredictable execution results.

### 7.1 Power-on Reset

When  $V_{CC}$  is first applied to the chip, the POR signal is asserted and the CY7C65x13 enters a “semi-suspend” state. During the semi-suspend state, which is different from the suspend state defined in the USB specification, the oscillator and all other blocks of the part are functional, except for the CPU. This semi-suspend time ensures that both a valid  $V_{CC}$  level is reached and that the internal PLL has time to stabilize before full operation begins. When the  $V_{CC}$  has risen above approximately 2.5V, and the oscillator is stable, the POR is deasserted and the on-chip timer starts counting. The first 1 ms of suspend time is not interruptible, and the semi-suspend state continues for an additional 95 ms unless the count is bypassed by a USB Bus Reset on the upstream port. The 95 ms provides time for  $V_{CC}$  to stabilize at a valid operating voltage before the chip executes code.

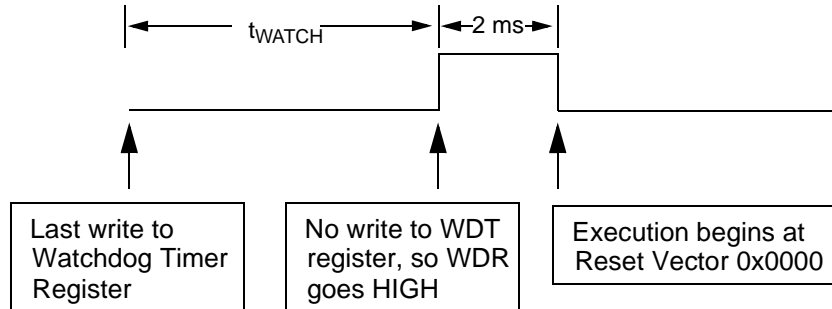
If a USB Bus Reset occurs on the upstream port during the 95 ms semi-suspend time, the semi-suspend state is aborted and program execution begins immediately from address 0x0000. In this case, the Bus Reset interrupt is pending but not serviced until firmware sets the USB Bus Reset Interrupt Enable bit (Bit 0, *Figure 14-1*) and enables interrupts with the EI command.

The POR signal is asserted whenever  $V_{CC}$  drops below approximately 2.5V, and remains asserted until  $V_{CC}$  rises above this level again. Behavior is the same as described above.



## 7.2 Watchdog Reset

The WDR occurs when the internal Watchdog Timer rolls over. Writing any value to the write-only Watchdog Reset Clear Register (Figure 7-1) clears the timer. The timer rolls over and WDR occurs if it is not cleared within  $t_{WATCH}$  of the last clear (see Section 23.0 for the value of  $t_{WATCH}$ ). Bit 6 of the Processor Status and Control Register (Figure 13-1) is set to record this event (the register contents are set to 010X0001 by the WDR). A Watchdog Timer Reset lasts for 2 ms, after which the microcontroller begins execution at ROM address 0x0000.



**Figure 7-1. Watchdog Reset (Address 0x26)**

The USB transmitter is disabled by a Watchdog Reset because the USB Device Address Registers are cleared (see Section 17.1). Otherwise, the USB Controller would respond to all address 0 transactions.

It is possible for the WDR bit of the Processor Status and Control Register (Figure 13-1) to be set following a POR event. If a firmware interrogates the Processor Status and Control Register for a set condition on the WDR bit, the WDR bit should be ignored if the POR bit is set (Bit 3 of the Processor Status and Control Register).

## 8.0 Suspend Mode

The CY7C65x13 can be placed into a low-power state by setting the Suspend bit of the Processor Status and Control register. All logic blocks in the device are turned off except the GPIO interrupt logic and the USB receiver. The clock oscillator and PLL, as well as the free-running and Watchdog timers, are shut down. Only the occurrence of an enabled GPIO interrupt or non-idle bus activity at a USB upstream or downstream port wakes the part out of suspend. The Run bit in the Processor Status and Control Register must be set to resume a part out of suspend.

The clock oscillator restarts immediately after exiting suspend mode. The microcontroller returns to a fully functional state 1 ms after the oscillator is stable. The microcontroller executes the instruction following the I/O write that placed the device into suspend mode before servicing any interrupt requests.

The GPIO interrupt allows the controller to wake-up periodically and poll system components while maintaining a very low average power consumption. To achieve the lowest possible current during suspend mode, all I/O should be held at  $V_{CC}$  or Gnd. **Note:** *This also applies to internal port pins that may not be bonded in a particular package.*

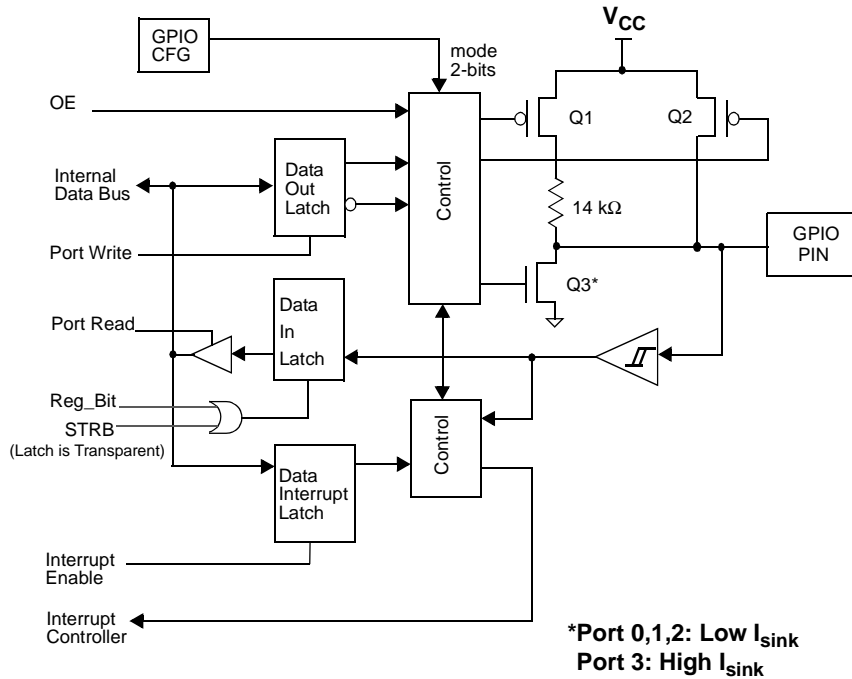
Typical code for entering suspend is shown below:

```

...           ; All GPIO set to low-power state (no floating pins)
...           ; Enable GPIO interrupts if desired for wake-up
mov a, 09h    ; Set suspend and run bits
iowr FFh     ; Write to Status and Control Register – Enter suspend, wait for USB activity (or GPIO Interrupt)
nop          ; This executes before any ISR
...           ; Remaining code for exiting suspend routine.

```

## 9.0 General-purpose I/O Ports



**Figure 9-1. Block Diagram of a GPIO Pin**

There are up to 32 GPIO pins (P0[7:0], P1[7:4,2:0], P2[7:3], and P3[1:0]) for the hardware interface. The number of GPIO pins depends on package type. See Section 3.0 for the port pins availability on different package types. Each port can be configured as inputs with internal pull-ups, open drain outputs, or traditional CMOS outputs. Port 3 offers a higher current drive, with typical current sink capability of 12 mA. The data for each GPIO port is accessible through the data registers. Port data registers are shown in *Figure 9-2* through *Figure 9-5*, and are set to 1 on reset

| Port 0 Data |      |      |      |      |      |      |      | Address 0x00 |
|-------------|------|------|------|------|------|------|------|--------------|
| Bit #       | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0            |
| Bit Name    | P0.7 | P0.6 | P0.5 | P0.4 | P0.3 | P0.2 | P0.1 | P0.0         |
| Read/Write  | R/W  | R/W  | R/W  | R/W  | R/W  | R/W  | R/W  | R/W          |
| Reset       | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1            |

**Figure 9-2. Port 0 Data**

| Port 1 Data |      |      |      |      |          |      |      | Address 0x01 |
|-------------|------|------|------|------|----------|------|------|--------------|
| Bit #       | 7    | 6    | 5    | 4    | 3        | 2    | 1    | 0            |
| Bit Name    | P1.7 | P1.6 | P1.5 | P1.4 | Reserved | P1.2 | P1.1 | P1.0         |
| Read/Write  | R/W  | R/W  | R/W  | R/W  | R/W      | R/W  | R/W  | R/W          |
| Reset       | 1    | 1    | 1    | 1    | 1        | 1    | 1    | 1            |

**Figure 9-3. Port1 Data**

| Port 2 Data |      |      |      |      |      |          |          | Address 0x02 |
|-------------|------|------|------|------|------|----------|----------|--------------|
| Bit #       | 7    | 6    | 5    | 4    | 3    | 2        | 1        | 0            |
| Bit Name    | P2.7 | P2.6 | P2.5 | P2.4 | P2.3 | Reserved | Reserved | Reserved     |
| Read/Write  | R/W  | R/W  | R/W  | R/W  | R/W  | R/W      | R/W      | R/W          |
| Reset       | 1    | 1    | 1    | 1    | 1    | 1        | 1        | 1            |

**Figure 9-4. Port 2 Data**

**Port 3 Data**
**Address 0x03**

| Bit #      | 7        | 6        | 5        | 4        | 3        | 2        | 1    | 0    |
|------------|----------|----------|----------|----------|----------|----------|------|------|
| Bit Name   | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | P3.1 | P3.0 |
| Read/Write | R/W      | R/W      | R/W      | R/W      | R/W      | R/W      | R/W  | R/W  |
| Reset      | 1        | 1        | 1        | 1        | 1        | 1        | 1    | 1    |

**Figure 9-5. Port 3 Data**

Special care should be taken with any unused GPIO data bits. An unused GPIO data bit, either a pin on the chip or a port bit that is not bonded on a particular package, must not be left floating when the device enters the suspend state. If a GPIO data bit is left floating, the leakage current caused by the floating bit may violate the suspend current limitation specified by the USB Specifications. If a '1' is written to the unused data bit and the port is configured with open drain outputs, the unused data bit remains in an indeterminate state. Therefore, if an unused port bit is programmed in open-drain mode, it must be written with a '0.' Notice that the CY7C65113 always requires that P1[7:3], P2[7:0], and P3[7:0] be written with a '0.' When the CY7C65013 is used, the P1[3], P2[2:0], and P3[7:2] should be written with a '0.'

A read from a GPIO port always returns the present state of the voltage at the pin, independent of the settings in the Port Data Registers. During reset, all of the GPIO pins are set to a high-impedance input state. Writing a '0' to a GPIO pin drives the pin LOW. In this state, a '0' is always read on that GPIO pin unless an external source overdrives the internal pull-down device.

**9.1 GPIO Configuration Port**

Every GPIO port can be programmed as inputs with internal pull-ups, outputs LOW or HIGH, or Hi-Z (floating, the pin is not driven internally). In addition, the interrupt polarity for each port can be programmed. The Port Configuration bits (*Figure 9-6*) and the Interrupt Enable bit (*Figure 9-7* through *Figure 9-10*) determine the interrupt polarity of the port pins

**GPIO Configuration**
**Address 0x08**

| Bit #      | 7                      | 6                      | 5                      | 4                      | 3                      | 2                      | 1                      | 0                      |
|------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Bit Name   | Port 3<br>Config Bit 1 | Port 3<br>Config Bit 0 | Port 2<br>Config Bit 1 | Port 2<br>Config Bit 0 | Port 1<br>Config Bit 1 | Port 1<br>Config Bit 0 | Port 0<br>Config Bit 1 | Port 0<br>Config Bit 0 |
| Read/Write | R/W                    | R/W                    | R/W                    | R/W                    | R/W                    | R/W                    | R/W                    | R/W                    |
| Reset      | 0                      | 0                      | 0                      | 0                      | 0                      | 0                      | 0                      | 0                      |

**Figure 9-6. GPIO Configuration Register**

As shown in *Table 9-1* below, a positive polarity on an input pin represents a rising edge interrupt (LOW to HIGH), and a negative polarity on an input pin represents a falling edge interrupt (HIGH to LOW).

The GPIO interrupt is generated when all of the following conditions are met: the Interrupt Enable bit of the associated Port Interrupt Enable Register is enabled, the GPIO Interrupt Enable bit of the Global Interrupt Enable Register (*Figure 14-1*) is enabled, the Interrupt Enable Sense (bit 2, *Figure 13-1*) is set, and the GPIO pin of the port sees an event matching the interrupt polarity.

The driving state of each GPIO pin is determined by the value written to the pin's Data Register (*Figure 9-2* through *Figure 9-5*) and by its associated Port Configuration bits as shown in the GPIO Configuration Register (*Figure 9-6*). These ports are configured on a per-port basis, so all pins in a given port are configured together. The possible port configurations are detailed in *Table 9-1*. As shown in this table below, when a GPIO port is configured with CMOS outputs, interrupts from that port are disabled.

During reset, all of the bits in the GPIO Configuration Register are written with '0' to select Hi-Z mode for all GPIO ports as the default configuration.

**Table 9-1. GPIO Port Output Control Truth Table and Interrupt Polarity**

| Port Config Bit 1 | Port Config Bit 0 | Data Register | Output Drive Strength | Interrupt Enable Bit | Interrupt Polarity |
|-------------------|-------------------|---------------|-----------------------|----------------------|--------------------|
| 1                 | 1                 | 0             | Output LOW            | 0                    | Disabled           |
|                   |                   | 1             | Resistive             | 1                    | – (Falling Edge)   |
| 1                 | 0                 | 0             | Output LOW            | 0                    | Disabled           |
|                   |                   | 1             | Output HIGH           | 1                    | Disabled           |
| 0                 | 1                 | 0             | Output LOW            | 0                    | Disabled           |
|                   |                   | 1             | Hi-Z                  | 1                    | – (Falling Edge)   |
| 0                 | 0                 | 0             | Output LOW            | 0                    | Disabled           |
|                   |                   | 1             | Hi-Z                  | 1                    | + (Rising Edge)    |

Q1, Q2, and Q3 discussed below are the transistors referenced in *Figure 9-2*. The available GPIO drive strength are:

- Output LOW Mode:** The pin's Data Register is set to '0.'  
 Writing '0' to the pin's Data Register puts the pin in output LOW mode, regardless of the contents of the Port Configuration Bits[1:0]. In this mode, Q1 and Q2 are OFF. Q3 is ON. The GPIO pin is driven LOW through Q3.
- Output HIGH Mode:** The pin's Data Register is set to 1 and the Port Configuration Bits[1:0] is set to '10.'  
 In this mode, Q1 and Q3 are OFF. Q2 is ON. The GPIO is pulled up through Q2. The GPIO pin is capable of sourcing... of current.
- Resistive Mode:** The pin's Data Register is set to 1 and the Port Configuration Bits[1:0] is set to '11.'  
 Q2 and Q3 are OFF. Q1 is ON. The GPIO pin is pulled up with an internal 14kΩ resistor. In resistive mode, the pin may serve as an input. Reading the pin's Data Register returns a logic HIGH if the pin is not driven LOW by an external source.
- Hi-Z Mode:** The pin's Data Register is set to 1 and Port Configuration Bits[1:0] is set either '00' or '01.'  
 Q1, Q2, and Q3 are all OFF. The GPIO pin is not driven internally. In this mode, the pin may serve as an input. Reading the Port Data Register returns the actual logic value on the port pins.

## 9.2 GPIO Interrupt Enable Ports

Each GPIO pin can be individually enabled or disabled as an interrupt source. The Port 0–3 Interrupt Enable Registers provide this feature with an Interrupt Enable bit for each GPIO pin.

During a reset, GPIO interrupts are disabled by clearing all of the GPIO Interrupt Enable bits. Writing a '1' to a GPIO Interrupt Enable bit enables GPIO interrupts from the corresponding input pin. All GPIO pins share a common interrupt, as discussed in Section 14.7

**Port 0 Interrupt Enable**
**Address 0x04**

| Bit #      | 7                | 6                | 5                | 4                | 3                | 2                | 1                | 0                |
|------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Bit Name   | P0.7 Intr Enable | P0.6 Intr Enable | P0.5 Intr Enable | P0.4 Intr Enable | P0.3 Intr Enable | P0.2 Intr Enable | P0.1 Intr Enable | P0.0 Intr Enable |
| Read/Write | W                | W                | W                | W                | W                | W                | W                | W                |
| Reset      | 0                | 0                | 0                | 0                | 0                | 0                | 0                | 0                |

**Figure 9-7. Port 0 Interrupt Enable**
**Port 1 Interrupt Enable**
**Address 0x05**

| Bit #      | 7                | 6                | 5                | 4                | 3        | 2                | 1                | 0                |
|------------|------------------|------------------|------------------|------------------|----------|------------------|------------------|------------------|
| Bit Name   | P1.7 Intr Enable | P1.6 Intr Enable | P1.5 Intr Enable | P1.4 Intr Enable | Reserved | P0.2 Intr Enable | P1.1 Intr Enable | P1.0 Intr Enable |
| Read/Write | W                | W                | W                | W                | W        | W                | W                | W                |
| Reset      | 0                | 0                | 0                | 0                | 0        | 0                | 0                | 0                |

**Figure 9-8. Port 1 Interrupt Enable**

**Port 2 Interrupt Enable**
**Address 0x06**

|            |                  |                  |                  |                  |                  |          |          |          |
|------------|------------------|------------------|------------------|------------------|------------------|----------|----------|----------|
| Bit #      | 7                | 6                | 5                | 4                | 3                | 2        | 1        | 0        |
| Bit Name   | P0.7 Intr Enable | P0.6 Intr Enable | P0.5 Intr Enable | P0.4 Intr Enable | P0.3 Intr Enable | Reserved | Reserved | Reserved |
| Read/Write | W                | W                | W                | W                | W                | W        | W        | W        |
| Reset      | 0                | 0                | 0                | 0                | 0                | 0        | 0        | 0        |

**Figure 9-9. Port 2 Interrupt Enable**
**Port 3 Interrupt Enable**
**Address 0x07**

|            |          |          |          |          |          |          |                  |                  |
|------------|----------|----------|----------|----------|----------|----------|------------------|------------------|
| Bit #      | 7        | 6        | 5        | 4        | 3        | 2        | 1                | 0                |
| Bit Name   | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | P3.1 Intr Enable | P0.3 Intr Enable |
| Read/Write | W        | W        | W        | W        | W        | W        | W                | W                |
| Reset      | 0        | 0        | 0        | 0        | 0        | 0        | 0                | 0                |

**Figure 9-10. Port 3 Interrupt Enable**

## 10.0 12-bit Free-Running Timer

The 12-bit timer operates with a 1- $\mu$ s tick, provides two interrupts (128 $\mu$ s and 1.024ms) and allows the firmware to directly time events that are up to 4 ms in duration. The lower eight bits of the timer can be read directly by the firmware. Reading the lower eight bits latches the upper four bits into a temporary register. When the firmware reads the upper four bits of the timer, it is actually reading the count stored in the temporary register. The effect of this is to ensure a stable 12-bit timer value can be read, even when the two reads are separated in time.

**Timer LSB**
**Address 0x24**

|            |             |            |             |             |             |             |             |             |
|------------|-------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Bit #      | 7           | 6          | 5           | 4           | 3           | 2           | 1           | 0           |
| Bit Name   | Timer Bit 7 | TimerBit 6 | Timer Bit 5 | Timer Bit 4 | Timer Bit 3 | Timer Bit 2 | Timer Bit 1 | Timer Bit 0 |
| Read/Write | R           | R          | R           | R           | R           | R           | R           | R           |
| Reset      | 0           | 0          | 0           | 0           | 0           | 0           | 0           | 0           |

**Figure 10-1. Timer LSB Register**

Bit [7:0]: Timer lower eight bits.

|                  |          |          |          |          |              |              |             |                     |
|------------------|----------|----------|----------|----------|--------------|--------------|-------------|---------------------|
| <b>Timer MSB</b> |          |          |          |          |              |              |             | <b>Address 0x25</b> |
| Bit #            | 7        | 6        | 5        | 4        | 3            | 2            | 1           | 0                   |
| Bit Name         | Reserved | Reserved | Reserved | Reserved | Timer Bit 11 | Timer Bit 10 | Timer Bit 9 | Timer Bit 8         |
| Read/Write       | –        | –        | –        | –        | R            | R            | R           | R                   |
| Reset            | 0        | 0        | 0        | 0        | 0            | 0            | 0           | 0                   |

**Figure 10-2. Timer MSB Register**

Bit [3:0]: Timer higher nibble

Bit [7:4]: Reserved.

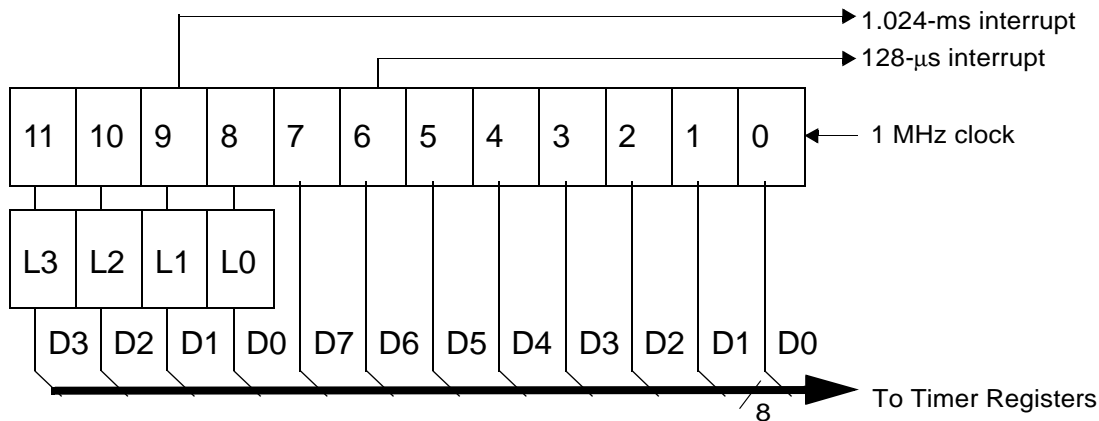


Figure 10-3. Timer Block Diagram

## 11.0 I<sup>2</sup>C Configuration Register

Internal hardware supports communication with external devices through an I<sup>2</sup>C-compatible interface. I<sup>2</sup>C-compatible function is discussed in detail in Section 12.0.<sup>[3]</sup> The I<sup>2</sup>C Position bit (Bit 7, *Figure 11-1*) and I<sup>2</sup>C Port Width bit (Bit 1, *Figure 11-1*) select the locations of the SCL (clock) and SDA (data) pins, either on Port 1 or Port 2 as shown in *Table 11-1*. These bits are cleared on reset. When the GPIO is configured for I<sup>2</sup>C function, the internal pull ups on the pins are disabled. Addition of an external weak pull-up resistors on SCL and SDA is recommended

| I <sup>2</sup> C Configuration |                           |          |          |          |          |          |                             | Address 0x09 |  |
|--------------------------------|---------------------------|----------|----------|----------|----------|----------|-----------------------------|--------------|--|
| Bit #                          | 7                         | 6        | 5        | 4        | 3        | 2        | 1                           | 0            |  |
| Bit Name                       | I <sup>2</sup> C Position | Reserved | Reserved | Reserved | Reserved | Reserved | I <sup>2</sup> C Port Width | Reserved     |  |
| Read/Write                     | R/W                       | R/W      | R/W      | R/W      | R/W      | R/W      | R/W                         | R/W          |  |
| Reset                          | 0                         | 0        | 0        | 0        | 0        | 0        | 0                           | 0            |  |

Figure 11-1. I<sup>2</sup>C Configuration Register

Table 11-1. I<sup>2</sup>C Port Configuration

| I <sup>2</sup> C Position (Bit7, <i>Figure 11-1</i> ) | I <sup>2</sup> C Port Width (Bit1, <i>Figure 11-1</i> ) | I <sup>2</sup> C Position                 |
|---|---|---|
| Don't Care  | 1   | I <sup>2</sup> C on P2[1:0], 0:SCL, 1:SDA |
| 0   | 0   | I <sup>2</sup> C on P1[1:0], 0:SCL, 1:SDA |
| 1   | 0   | I <sup>2</sup> C on P2[1:0], 0:SCL, 1:SDA |

## 12.0 I<sup>2</sup>C-compatible Controller

The I<sup>2</sup>C-compatible block provides a versatile two-wire communication with external devices, supporting master, slave, and multi-master modes of operation. The I<sup>2</sup>C-compatible block functions by handling the low-level signaling in hardware, and issuing interrupts as needed to allow firmware to take appropriate action during transactions. While waiting for firmware response, the hardware keeps the I<sup>2</sup>C-compatible bus idle if necessary.

The I<sup>2</sup>C-compatible block generates an interrupt to the microcontroller at the end of each received or transmitted byte, when a stop bit is detected by the slave when in receive mode, or when arbitration is lost. Details of the interrupt responses are given in Section 14.8.

The I<sup>2</sup>C-compatible interface consists of two registers, an I<sup>2</sup>C Data Register (*Figure 12-1*) and an I<sup>2</sup>C Status and Control Register (*Figure 12-2*). The I<sup>2</sup>C Data Register is implemented as separate read and write registers. Generally, the I<sup>2</sup>C Status and Control Register should only be monitored after the I<sup>2</sup>C interrupt, as all bits are valid at that time. Polling this register at other times could read misleading bit status if a transaction is underway.

**Note:**

- I<sup>2</sup>C-compatible function must be separately enabled, as described in Section 12.0.

The I<sup>2</sup>C clock (SCL) is connected to bit 0 of either GPIO port 1 or GPIO port 2, and the I<sup>2</sup>C SDA data is connected to bit 1 of either GPIO port 1 or GPIO port 2. The port selection is determined by settings in the I<sup>2</sup>C Port Configuration Register (Section 11.0). Once the I<sup>2</sup>C-compatible functionality is enabled by setting the I<sup>2</sup>C Enable bit of the I<sup>2</sup>C Status and Control Register (bit 0, Figure 12-2), the two LSB ([1:0]) of the corresponding GPIO port is placed in Open Drain mode, regardless of the settings of the GPIO Configuration Register. In Open Drain mode, the GPIO pin outputs LOW if the pin's Data Register is '0', and the pin is in Hi-Z mode if the pin's Data Register is '1'. The electrical characteristics of the I<sup>2</sup>C-compatible interface is the same as that of GPIO ports 1 and 2. Note that the I<sub>OL</sub> (max) is 2 mA @ V<sub>OL</sub> = 2.0V for ports 1 and 2.

All control of the I<sup>2</sup>C clock (SCL) and data (SDA) lines is performed by the I<sup>2</sup>C-compatible block.

**I<sup>2</sup>C Data**
**Address 0x29**

| Bit #      | 7                       | 6                       | 5                       | 4                       | 3                       | 2                       | 1                       | 0                       |
|------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Bit Name   | I <sup>2</sup> C Data 7 | I <sup>2</sup> C Data 6 | I <sup>2</sup> C Data 5 | I <sup>2</sup> C Data 4 | I <sup>2</sup> C Data 3 | I <sup>2</sup> C Data 2 | I <sup>2</sup> C Data 1 | I <sup>2</sup> C Data 0 |
| Read/Write | R/W                     | R/W                     | R/W                     | R/W                     | R/W                     | R/W                     | R/W                     | R/W                     |
| Reset      | X                       | X                       | X                       | X                       | X                       | X                       | X                       | X                       |

**Figure 12-1. I<sup>2</sup>C Data Register**

Bits [7..0] : I<sup>2</sup>C Data

Contains the 8-bit data on the I<sup>2</sup>C Bus.

**I<sup>2</sup>C Status and Control**
**Address 0x28**

| Bit #      | 7         | 6             | 5         | 4   | 3    | 2                | 1             | 0                       |
|------------|-----------|---------------|-----------|-----|------|------------------|---------------|-------------------------|
| Bit Name   | MSTR Mode | Continue/Busy | Xmit Mode | ACK | Addr | ARB Lost/Restart | Received Stop | I <sup>2</sup> C Enable |
| Read/Write | R/W       | R/W           | R/W       | R/W | R/W  | R/W              | R/W           | R/W                     |
| Reset      | 0         | 0             | 0         | 0   | 0    | 0                | 0             | 0                       |

**Figure 12-2. I<sup>2</sup>C Status and Control Register**

The I<sup>2</sup>C Status and Control register bits are defined in Table 12-1, with a more detailed description following.

**Table 12-1. I<sup>2</sup>C Status and Control Register Bit Definitions**

| Bit | Name                    | Description  |
|-----|-------------------------|--|
| 0   | I <sup>2</sup> C Enable | When set to '1', the I <sup>2</sup> C-compatible function is enabled. When cleared, I <sup>2</sup> C GPIO pins operate normally.                           |
| 1   | Received Stop           | Reads 1 only in slave receive mode, when I <sup>2</sup> C Stop bit detected (unless firmware did not ACK the last transaction).                            |
| 2   | ARB Lost/Restart        | Reads 1 to indicate master has lost arbitration. Reads 0 otherwise. Write to 1 in master mode to perform a restart sequence (also set Continue bit).       |
| 3   | Addr                    | Reads 1 during first byte after start/restart in slave mode, or if master loses arbitration. Reads 0 otherwise. This bit should always be written as 0.    |
| 4   | ACK                     | In receive mode, write 1 to generate ACK, 0 for no ACK. In transmit mode, reads 1 if ACK was received, 0 if no ACK received.                               |
| 5   | Xmit Mode               | Write to 1 for transmit mode, 0 for receive mode.  |
| 6   | Continue/Busy           | Write 1 to indicate ready for next transaction. Reads 1 when I <sup>2</sup> C-compatible block is busy with a transaction, 0 when transaction is complete. |
| 7   | MSTR Mode               | Write to 1 for master mode, 0 for slave mode. This bit is cleared if master loses arbitration. Clearing from 1 to 0 generates Stop bit.                    |

Bit 7 : MSTR Mode

Setting this bit to 1 causes the I<sup>2</sup>C-compatible block to initiate a master mode transaction by sending a start bit and transmitting the first data byte from the data register (this typically holds the target address and R/W bit). Subsequent bytes are initiated by setting the Continue bit, as described below.

Clearing this bit (set to 0) causes the GPIO pins to operate normally.

In master mode, the I<sup>2</sup>C-compatible block generates the clock (SCK), and drives the data line as required depending on transmit or receive state. The I<sup>2</sup>C-compatible block performs any required arbitration and clock synchronization. IN the event of a loss of arbitration, this MSTR bit is cleared, the ARB Lost bit is set, and an interrupt is generated by the

microcontroller. If the chip is the target of an external master that wins arbitration, then the interrupt is held off until the transaction from the external master is completed.

When MSTR Mode is cleared from 1 to 0 by a firmware write, an I<sup>2</sup>C Stop bit is generated.

**Bit 6 : Continue/Busy**

This bit is written by the firmware to indicate that the firmware is ready for the next byte transaction to begin. In other words, the bit has responded to an interrupt request and has completed the required update or read of the data register. During a read this bit indicates if the hardware is busy and is locking out additional writes to the I<sup>2</sup>C Status and Control register. This locking allows the hardware to complete certain operations that may require an extended period of time. Following an I<sup>2</sup>C interrupt, the I<sup>2</sup>C-compatible block does not return to the Busy state until firmware sets the Continue bit. This allows the firmware to make one control register write without the need to check the Busy bit.

**Bit 5 : Xmit Mode**

This bit is set by firmware to enter transmit mode and perform a data transmit in master or slave mode. Clearing this bit sets the part in receive mode. Firmware generally determines the value of this bit from the R/W bit associated with the I<sup>2</sup>C address packet. The Xmit Mode bit state is ignored when initially writing the MSTR Mode or the Restart bits, as these cases always cause transmit mode for the first byte.

**Bit 4 : ACK**

This bit is set or cleared by firmware during receive operation to indicate if the hardware should generate an ACK signal on the I<sup>2</sup>C-compatible bus. Writing a 1 to this bit generates an ACK (SDA LOW) on the I<sup>2</sup>C-compatible bus at the ACK bit time. During transmits (Xmit Mode = 1), this bit should be cleared.

**Bit 3 : Addr**

This bit is set by the I<sup>2</sup>C-compatible block during the first byte of a slave receive transaction, after an I<sup>2</sup>C start or restart. The Addr bit is cleared when the firmware sets the Continue bit. This bit allows the firmware to recognize when the master has lost arbitration, and in slave mode it allows the firmware to recognize that a start or restart has occurred.

**Bit 2 : ARB Lost/Restart**

This bit is valid as a status bit (ARB Lost) after master mode transactions. In master mode, set this bit (along with the Continue and MSTR Mode bits) to perform an I<sup>2</sup>C restart sequence. The I<sup>2</sup>C target address for the restart must be written to the data register before setting the Continue bit. To prevent false ARB Lost signals, the Restart bit is cleared by hardware during the restart sequence.

**Bit 1 : Receive Stop**

This bit is set when the slave is in receive mode and detects a stop bit on the bus. The Receive Stop bit is not set if the firmware terminates the I<sup>2</sup>C transaction by not acknowledging the previous byte transmitted on the I<sup>2</sup>C-compatible bus, e.g., in receive mode if firmware sets the Continue bit and clears the ACK bit.

**Bit 0 : I<sup>2</sup>C Enable**

Set this bit to override GPIO definition with I<sup>2</sup>C-compatible function on the two I<sup>2</sup>C-compatible pins. When this bit is cleared, these pins are free to function as GPIOs. In I<sup>2</sup>C-compatible mode, the two pins operate in open drain mode, independent of the GPIO configuration setting.

### 13.0 Processor Status and Control Register

| Processor Status and Control |             |                |                         |                |         |                        | Address 0xFF |     |
|------------------------------|-------------|----------------|-------------------------|----------------|---------|------------------------|--------------|-----|
| Bit #                        | 7           | 6              | 5                       | 4              | 3       | 2                      | 1            | 0   |
| Bit Name                     | IRQ Pending | Watchdog Reset | USB Bus Reset Interrupt | Power-on Reset | Suspend | Interrupt Enable Sense | Reserved     | Run |
| Read/Write                   | R           | R/W            | R/W                     | R/W            | R/W     | R                      | R/W          | R/W |
| Reset                        | 0           | 0              | 0                       | 1              | 0       | 0                      | 0            | 1   |

**Figure 13-1. Processor Status and Control Register**

**Bit 0: Run**

This bit is manipulated by the HALT instruction. When Halt is executed, all the bits of the Processor Status and Control Register are cleared to 0. Since the run bit is cleared, the processor stops at the end of the current instruction. The processor remains halted until an appropriate reset occurs (power-on or Watchdog). This bit should normally be written as a '1.'

**Bit 1: Reserved**

Bit 1 is reserved and must be written as a zero.

**Bit 2: Interrupt Enable Sense**



This bit indicates whether interrupts are enabled or disabled. Firmware has no direct control over this bit as writing a zero or one to this bit position has no effect on interrupts. A '0' indicates that interrupts are masked off and a '1' indicates that the interrupts are enabled. This bit is further gated with the bit settings of the Global Interrupt Enable Register (Figure 14-1) and USB End Point Interrupt Enable Register (Figure 14-2). Instructions DI, EI, and RETI manipulate the state of this bit.

**Bit 3: Suspend**

Writing a '1' to the Suspend bit halts the processor and cause the microcontroller to enter the suspend mode that significantly reduces power consumption. A pending, enabled interrupt or USB bus activity causes the device to come out of suspend. After coming out of suspend, the device resumes firmware execution at the instruction following the IOWR which put the part into suspend. An IOWR attempting to put the part into suspend is ignored if USB bus activity is present. See Section 8.0 for more details on suspend mode operation.

**Bit 4: Power-on Reset**

The Power-on Reset is set to '1' during a power-on reset. The firmware can check bits 4 and 6 in the reset handler to determine whether a reset was caused by a power-on condition or a Watchdog timeout. A POR event may be followed by a Watchdog reset before firmware begins executing, as explained below.

**Bit 5: USB Bus Reset Interrupt**

The USB Bus Reset Interrupt bit is set when the USB Bus Reset is detected on receiving a USB Bus Reset signal on the upstream port. The USB Bus Reset signal is a single-ended zero (SE0) that lasts from 12 to 16  $\mu$ s. An SE0 is defined as the condition in which both the D+ line and the D- line are LOW at the same time. .

**Bit 6: Watchdog Reset**

The Watchdog Reset is set during a reset initiated by the Watchdog Timer. This indicates the Watchdog Timer went for more than  $t_{WATCH}$  (8 ms minimum) between Watchdog clears. This can occur with a POR event, as noted below.

**Bit 7: IRQ Pending**

The IRQ pending, when set, indicates that one or more of the interrupts has been recognized as active. An interrupt remains pending until its interrupt enable bit is set (Figure 14-1, Figure 14-2) and interrupts are globally enabled. At that point, the internal interrupt handling sequence clears this bit until another interrupt is detected as pending.

During power-up, the Processor Status and Control Register is set to 00010001, which indicates a POR (bit 4 set) has occurred and no interrupts are pending (bit 7 clear). During the 96-ms suspend at start-up (explained in Section 7.1), a Watchdog Reset also occurs unless this suspend is aborted by an upstream SE0 before 8 ms. If a WDR occurs during the power-up suspend interval, firmware reads 01010001 from the Status and Control Register after power-up. Normally, the POR bit should be cleared so a subsequent WDR can be clearly identified. If an upstream bus reset is received before firmware examines this register, the Bus Reset bit may also be set.

During a Watchdog Reset, the Processor Status and Control Register is set to 01XX0001, which indicates a Watchdog Reset (bit 6 set) has occurred and no interrupts are pending (bit 7 clear). The Watchdog Reset does not effect the state of the POR and the Bus Reset Interrupt bits.

## 14.0 Interrupts

Interrupts are generated by GPIO pins, internal timers, I<sup>2</sup>C-compatible operation, internal USB hub and USB traffic conditions. All interrupts are maskable by the Global Interrupt Enable Register and the USB End Point Interrupt Enable Register. Writing a '1' to a bit position enables the interrupt associated with that bit position.

| Global Interrupt Enable Register |          |                                   |                       |          |                          |                           | Address 0X20                  |                              |
|----------------------------------|----------|-----------------------------------|-----------------------|----------|--------------------------|---------------------------|-------------------------------|------------------------------|
| Bit #                            | 7        | 6                                 | 5                     | 4        | 3                        | 2                         | 1                             | 0                            |
| Bit Name                         | Reserved | I <sup>2</sup> C Interrupt Enable | GPIO Interrupt Enable | Reserved | USB Hub Interrupt Enable | 1.024-ms Interrupt Enable | 128- $\mu$ s Interrupt Enable | USB Bus RST Interrupt Enable |
| Read/Write                       | -        | R/W                               | R/W                   | -        | R/W                      | R/W                       | R/W                           | R/W                          |
| Reset                            | -        | 0                                 | 0                     | X        | 0                        | 0                         | 0                             | 0                            |

**Figure 14-1. Global Interrupt Enable Register**

**Bit 0 : USB Bus RST Interrupt Enable**

1 = Enable Interrupt on a USB Bus Reset; 0 = Disable interrupt on a USB Bus Reset (Refer to section 14.3).

**Bit 1 :128- $\mu$ s Interrupt Enable**

1 = Enable Timer interrupt every 128  $\mu$ s; 0 = Disable Timer Interrupt for every 128  $\mu$ s.

**Bit 2 : 1.024-ms Interrupt Enable**

1 = Enable Timer interrupt every 1.024 ms ; 0 = Disable Timer Interrupt every 1.024 ms.

Bit 3 : USB Hub Interrupt Enable

1 = Enable Interrupt on a Hub status change; 0 = Disable interrupt due to hub status change. (Refer to section 14.6.)

Bit 4 : Reserved .

Bit 5 : GPIO Interrupt Enable

1 = Enable Interrupt on falling/rising edge on any GPIO; 0 = Disable Interrupt on falling/rising edge on any GPIO (Refer to section 14.7, 9.1 and 9.2.).

Bit 6 : I<sup>2</sup>C Interrupt Enable

1 = Enable Interrupt on I2C related activity; 0 = Disable I2C related activity interrupt. (Refer to section 14.8.)

Bit 7 : Reserved.

### USB Endpoint Interrupt Enable

Address 0X21

| Bit #      | 7        | 6        | 5        | 4                     | 3                     | 2                     | 1                     | 0                     |
|------------|----------|----------|----------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Bit Name   | Reserved | Reserved | Reserved | EPB1 Interrupt Enable | EPB0 Interrupt Enable | EPA2 Interrupt Enable | EPA1 Interrupt Enable | EPA0 Interrupt Enable |
| Read/Write | –        | –        | –        | R/W                   | R/W                   | R/W                   | R/W                   | R/W                   |
| Reset      | –        | –        | –        | 0                     | 0                     | 0                     | 0                     | 0                     |

**Figure 14-2. USB Endpoint Interrupt Enable Register**

Bit 0: EPA0 Interrupt Enable

1= Enable Interrupt on data activity through endpoint A0; 0= Disable Interrupt on data activity through endpoint A0

Bit 1: EPA1 Interrupt Enable

1= Enable Interrupt on data activity through endpoint A1; 0= Disable Interrupt on data activity through endpoint A1

Bit 2: EPA2 Interrupt Enable

1= Enable Interrupt on data activity through endpoint A2; 0= Disable Interrupt on data activity through endpoint A2.

Bit 3: EPB0 Interrupt Enable

1= Enable Interrupt on data activity through endpoint B0; 0= Disable Interrupt on data activity through endpoint B0

Bit 4: EPB1 Interrupt Enable

1= Enable Interrupt on data activity through endpoint B1; 0= Disable Interrupt on data activity through endpoint B1

Bit [7..5] : Reserved

During a reset, the contents the Global Interrupt Enable Register and USB End Point Interrupt Enable Register are cleared, effectively, disabling all interrupts

The interrupt controller contains a separate flip-flop for each interrupt. See *Figure 14-3* for the logic block diagram of the interrupt controller. When an interrupt is generated, it is first registered as a pending interrupt. It stays pending until it is serviced or a reset occurs. A pending interrupt only generates an interrupt request if it is enabled by the corresponding bit in the interrupt enable registers. The highest priority interrupt request is serviced following the completion of the currently executing instruction.

When servicing an interrupt, the hardware does the following:

1. Disables all interrupts by clearing the Global Interrupt Enable bit in the CPU (the state of this bit can be read at Bit 2 of the Processor Status and Control Register, *Figure 13-1*).
2. Clears the flip-flop of the current interrupt.
3. Generates an automatic CALL instruction to the ROM address associated with the interrupt being serviced (i.e., the Interrupt Vector, see Section 14.1).

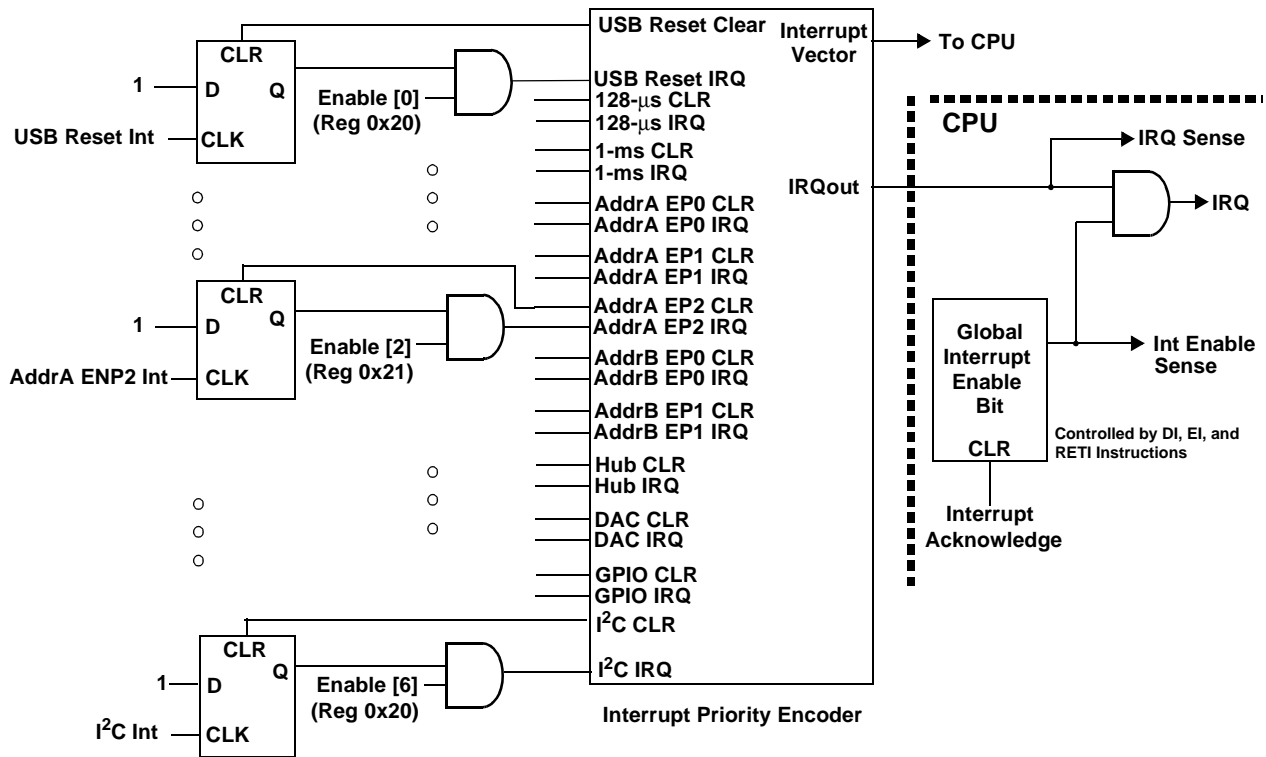
The instruction in the interrupt table is typically a JMP instruction to the address of the Interrupt Service Routine (ISR). The user can reenables interrupts in the interrupt service routine by executing an EI instruction. Interrupts can be nested to a level limited only by the available stack space.

The Program Counter value as well as the Carry and Zero flags (CF, ZF) are stored onto the Program Stack by the automatic CALL instruction generated as part of the interrupt acknowledge process. The user firmware is responsible for ensuring that the processor state is preserved and restored during an interrupt. The PUSH A instruction should typically be used as the first command in the ISR to save the accumulator value and the POP A instruction should be used to restore the accumulator value just before the RETI instruction. The program counter CF and ZF are restored and interrupts are enabled when the RETI instruction is executed.

The DI and EI instructions can be used to disable and enable interrupts, respectively. These instructions affect only the Global Interrupt Enable bit of the CPU. If desired, EI can be used to re-enable interrupts while inside an ISR, instead of waiting for the RETI that exits the ISR. While the global interrupt enable bit is cleared, the presence of a pending interrupt can be detected by examining the IRQ Sense bit (Bit 7 in the Processor Status and Control Register).

### 14.1 Interrupt Vectors

The Interrupt Vectors supported by the USB Controller are listed in *Table 14-1*. The lowest-numbered interrupt (USB Bus Reset interrupt) has the highest priority, and the highest-numbered interrupt (I<sup>2</sup>C interrupt) has the lowest priority.



**Figure 14-3. Interrupt Controller Function Diagram**

Although Reset is not an interrupt, the first instruction executed after a reset is at PROM address 0x0000h—which corresponds to the first entry in the Interrupt Vector Table. Because the JMP instruction is two bytes long, the interrupt vectors occupy two bytes.

**Table 14-1. Interrupt Vector Assignments**

| Interrupt Vector Number | ROM Address | Function                           |
|-------------------------|-------------|------------------------------------|
| Not Applicable          | 0x0000      | Execution after Reset begins here  |
| 1                       | 0x0002      | USB Bus Reset interrupt            |
| 2                       | 0x0004      | 128-µs timer interrupt             |
| 3                       | 0x0006      | 1.024-ms timer interrupt           |
| 4                       | 0x0008      | USB Address A Endpoint 0 interrupt |
| 5                       | 0x000A      | USB Address A Endpoint 1 interrupt |
| 6                       | 0x000C      | USB Address A Endpoint 2 interrupt |
| 7                       | 0x000E      | USB Address B Endpoint 0 interrupt |
| 8                       | 0x0010      | USB Address B Endpoint 1 interrupt |
| 9                       | 0x0012      | USB Hub interrupt                  |
| 10                      | 0x0014      | DAC interrupt                      |
| 11                      | 0x0016      | GPIO interrupt                     |
| 12                      | 0x0018      | I <sup>2</sup> C interrupt         |

## 14.2 Interrupt Latency

Interrupt latency can be calculated from the following equation:

$$\text{Interrupt latency} = (\text{Number of clock cycles remaining in the current instruction}) + (10 \text{ clock cycles for the CALL instruction}) + (5 \text{ clock cycles for the JMP instruction})$$

For example, if a 5-clock cycle instruction such as JC is being executed when an interrupt occurs, the first instruction of the Interrupt Service Routine executes a minimum of 16 clocks (1+10+5) or a maximum of 20 clocks (5+10+5) after the interrupt is issued. For a 12-MHz internal clock (6-MHz crystal), 20 clock periods is  $20/12 \text{ MHz} = 1.667 \mu\text{s}$ .

## 14.3 USB Bus Reset Interrupt

The USB Controller recognizes a USB Reset when a Single Ended Zero (SE0) condition persists on the upstream USB port for 12–16  $\mu\text{s}$ . SE0 is defined as the condition in which both the D+ line and the D– line are LOW. A USB Bus Reset may be recognized for an SE0 as short as 12  $\mu\text{s}$ , but is always recognized for an SE0 longer than 16  $\mu\text{s}$ . When a USB Bus Reset is detected, bit 5 of the Processor Status and Control Register (*Figure 13-1*) is set to record this event. In addition, the controller clears the following registers:

SIE Section: .... USB Device Address Registers (0x10, 0x40)  
Hub Section: ..... Hub Ports Connect Status (0x48)  
..... Hub Ports Enable (0x49)  
..... Hub Ports Speed (0x4A)  
..... Hub Ports Suspend (0x4D)  
..... Hub Ports Resume Status (0x4E)  
..... Hub Ports SE0 Status (0x4F)  
..... Hub Ports Data (0x50)  
..... Hub Downstream Force (0x51).

A USB Bus Reset Interrupt is generated at the end of the USB Bus Reset condition when the SE0 state is deasserted. If the USB reset occurs during the start-up delay following a POR, the delay is aborted as described in Section 7.1.

## 14.4 Timer Interrupt

There are two periodic timer interrupts: the 128- $\mu\text{s}$  interrupt and the 1.024-ms interrupt. The user should disable both timer interrupts before going into the suspend mode to avoid possible conflicts between servicing the timer interrupts first or the suspend request first.

## 14.5 USB Endpoint Interrupts

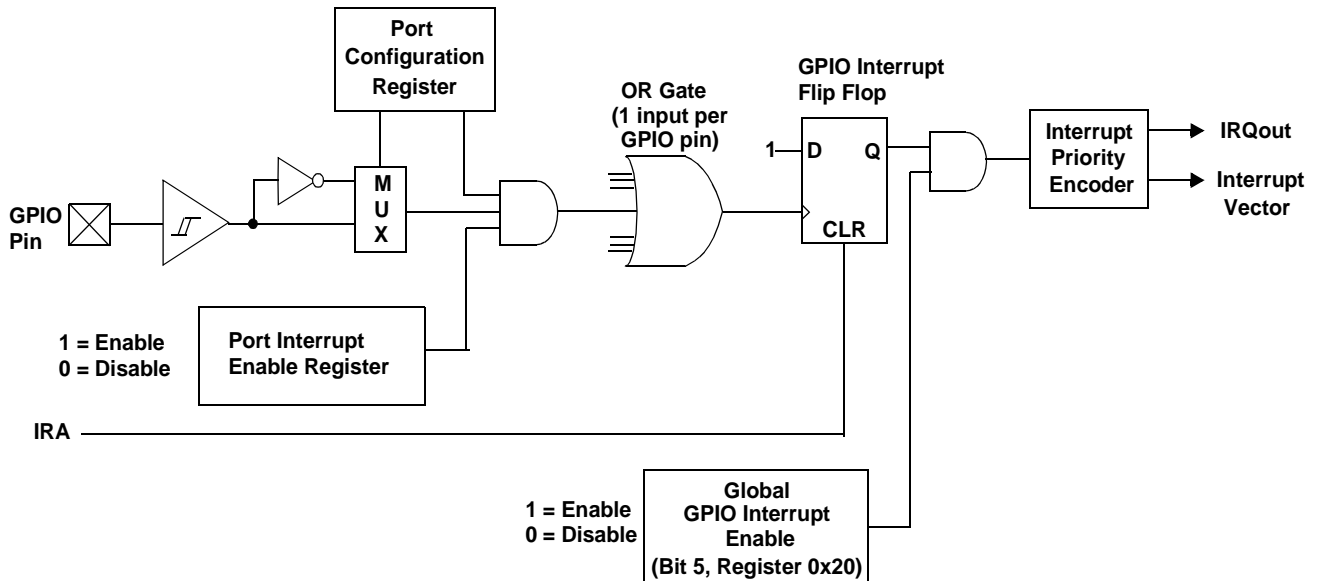
There are five USB endpoint interrupts, one per endpoint. A USB endpoint interrupt is generated after the USB host writes to a USB endpoint FIFO or after the USB controller sends a packet to the USB host. The interrupt is generated on the last packet of the transaction (e.g., on the host's ACK on an IN transfer, or on the device ACK on an OUT transfer). If no ACK is received during an IN transaction, no interrupt is generated.

## 14.6 USB Hub Interrupt

A USB hub interrupt is generated by the hardware after a connect/disconnect change, babble, or a resume event is detected by the USB repeater hardware. The babble and resume events are additionally gated by the corresponding bits of the Hub Port Enable Register (*Figure 16-3*). The connect/disconnect event on a port does not generate an interrupt if the SIE does not drive the port (i.e., the port is being forced).

## 14.7 GPIO Interrupt

Each of the GPIO pins can generate an interrupt, if enabled. The interrupt polarity can be programmed for each GPIO port as part of the GPIO configuration. All of the GPIO pins share a single interrupt vector, which means the firmware needs to read the GPIO ports with enabled interrupts to determine which pin or pins caused an interrupt. A block diagram of the GPIO interrupt logic is shown in *Figure 14-4*.



**Figure 14-4. GPIO Interrupt Structure**

Refer to Sections 9.1 and 9.2 for more information of setting GPIO interrupt polarity and enabling individual GPIO interrupts. If one port pin has triggered an interrupt, no other port pins can cause a GPIO interrupt until that port pin has returned to its inactive (non-trigger) state or its corresponding port interrupt enable bit is cleared. The USB Controller does not assign interrupt priority to different port pins and the Port Interrupt Enable Registers are not cleared during the interrupt acknowledge process.

## 14.8 I<sup>2</sup>C Interrupt

The I<sup>2</sup>C interrupt occurs after various events on the I<sup>2</sup>C-compatible bus to signal the need for firmware interaction. This generally involves reading the I<sup>2</sup>C Status and Control Register (Figure 12-2) to determine the cause of the interrupt, loading/reading the I<sup>2</sup>C Data Register as appropriate, and finally writing the Processor Status and Control Register (Figure 13-1) to initiate the subsequent transaction. The interrupt indicates that status bits are stable and it is safe to read and write the I<sup>2</sup>C registers. Refer to Section 12.0 for details on the I<sup>2</sup>C registers.

When enabled, the I<sup>2</sup>C-compatible state machines generate interrupts on completion of the following conditions. The referenced bits are in the I<sup>2</sup>C Status and Control Register.

1. In **slave receive** mode, after the slave receives a byte of data: The *Addr* bit is set, if this is the first byte since a start or restart signal was sent by the external master. Firmware must read or write the data register as necessary, then set the *ACK*, *Xmit MODE*, and *Continue/Busy* bits appropriately for the next byte.
2. In **slave receive** mode, after a stop bit is detected: The *Received Stop* bit is set, if the stop bit follows a slave receive transaction where the *ACK* bit was cleared to 0, no stop bit detection occurs.
3. In **slave transmit** mode, after the slave transmits a byte of data: The *ACK* bit indicates if the master that requested the byte acknowledged the byte. If more bytes are to be sent, firmware writes the next byte into the Data Register and then sets the *Xmit MODE* and *Continue/Busy* bits as required.
4. In **master transmit** mode, after the master sends a byte of data. Firmware should load the Data Register if necessary, and set the *Xmit MODE*, *MSTR MODE*, and *Continue/Busy* bits appropriately. Clearing the *MSTR MODE* bit issues a stop signal to the I<sup>2</sup>C-compatible bus and return to the idle state.
5. In **master receive** mode, after the master receives a byte of data: Firmware should read the data and set the *ACK* and *Continue/Busy* bits appropriately for the next byte. Clearing the *MSTR MODE* bit at the same time causes the master state machine to issue a stop signal to the I<sup>2</sup>C-compatible bus and leave the I<sup>2</sup>C-compatible hardware in the idle state.
6. When the master loses arbitration: This condition clears the *MSTR MODE* bit and sets the *ARB Lost/Restart* bit immediately and then waits for a stop signal on the I<sup>2</sup>C-compatible bus to generate the interrupt.

The *Continue/Busy* bit is cleared by hardware prior to interrupt conditions 1 to 4. Once the Data Register has been read or written, firmware should configure the other control bits and set the *Continue/Busy* bit for subsequent transactions. Following an interrupt from master mode, firmware should perform only one write to the Status and Control Register that sets the *Continue/Busy* bit, without checking the value of the *Continue/Busy* bit. The *Busy* bit may otherwise be active and I<sup>2</sup>C register contents may be changed by the hardware during the transaction, until the I<sup>2</sup>C interrupt occurs.

## 15.0 USB Overview

The USB hardware includes a USB Hub repeater with one upstream and up to seven downstream ports. The USB Hub repeater interfaces to the microcontroller through a full-speed serial interface engine (SIE). An external series resistor of  $R_{ext}$  must be placed in series with all upstream and downstream USB outputs in order to meet the USB driver requirements of the USB specification. The CY7C65x13 microcontroller can provide the functionality of a compound device consisting of a USB hub and permanently attached functions.

### 15.1 USB Serial Interface Engine (SIE)

The SIE allows the CY7C65x13 microcontroller to communicate with the USB host through the USB repeater portion of the hub. The SIE simplifies the interface between the microcontroller and USB by incorporating hardware that handles the following USB bus activity independently of the microcontroller:

- Bit stuffing/unstuffing
- Checksum generation/checking
- ACK/NAK/STALL
- Token type identification
- Address checking.

Firmware is required to handle the following USB interface tasks:

- Coordinate enumeration by responding to SETUP packets
- Fill and empty the FIFOs
- Suspend/Resume coordination
- Verify and select DATA toggle values.

### 15.2 USB Enumeration

The internal hub and any compound device function are enumerated under firmware control. The hub is enumerated first, followed by any integrated compound function. After the hub is enumerated, the USB host can read hub connection status to determine which (if any) of the downstream ports need to be enumerated. The following is a brief summary of the typical enumeration process of the CY7C65x13 by the USB host. For a detailed description of the enumeration process, refer to the USB specification.

In this description, 'Firmware' refers to embedded firmware in the CY7C65x13 controller.

1. The host computer sends a SETUP packet followed by a DATA packet to USB address 0 requesting the Device descriptor.
2. Firmware decodes the request and retrieves its Device descriptor from the program memory tables.
3. The host computer performs a control read sequence and Firmware responds by sending the Device descriptor over the USB bus, via the on-chip FIFOs.
4. After receiving the descriptor, the host sends a SETUP packet followed by a DATA packet to address 0 assigning a new USB address to the device.
5. Firmware stores the new address in its USB Device Address Register (for example, as Address B) after the no-data control sequence completes.
6. The host sends a request for the Device descriptor using the new USB address.
7. Firmware decodes the request and retrieves the Device descriptor from program memory tables.
8. The host performs a control read sequence and Firmware responds by sending its Device descriptor over the USB bus.
9. The host generates control reads from the device to request the Configuration and Report descriptors.
10. Once the device receives a Set Configuration request, its functions may now be used.
11. Following enumeration as a hub, Firmware can optionally indicate to the host that a compound device exists (for example, the keyboard in a keyboard/hub device).
12. The host carries out the enumeration process with this additional function as though it were attached downstream from the hub.
13. When the host assigns an address to this device, it is stored as the other USB address (for example, Address A).

## 16.0 USB Hub

A USB hub is required to support:

- Connectivity behavior: service connect/disconnect detection
- Bus fault detection and recovery
- Full-/Low-speed device support

These features are mapped onto a hub repeater and a hub controller. The hub controller is supported by the processor integrated into the CY7C65x13 microcontrollers. The hardware in the hub repeater detects whether a USB device is connected to a downstream port. The connection to a downstream port is through a differential signal pair (D+ and D-). Each downstream port provided by the hub requires external  $R_{UDN}$  resistors from each signal line to ground, so that when a downstream port has no device connected, the hub reads a LOW (zero) on both D+ and D-. This condition is used to identify the “no connect” state.

The hub must have a resistor  $R_{UP}$  connected between its upstream D+ line and  $V_{REG}$  to indicate it is a full speed USB device.

The hub generates an EOP at EOF1, in accordance with the USB 1.1 Specification (section 11.2.2, page 234) as well as USB 2.0 specification (section 11.2.5, page 304).

### 16.1 Connecting/Disconnecting a USB Device

A low-speed (1.5 Mbps) USB device has a pull-up resistor on the D- pin. At connect time, the bias resistors set the signal levels on the D+ and D- lines. When a low-speed device is connected to a hub port, the hub sees a LOW on D+ and a HIGH on D-. This causes the hub repeater to set a connect bit in the Hub Ports Connect Status register for the downstream port (see *Figure 16-1*). Then the hub repeater generates a Hub Interrupt to notify the microcontroller that there has been a change in the Hub downstream status. The firmware sets the speed of this port in the Hub Ports Speed Register (see *Figure 16-2*).

A full-speed (12 Mbps) USB device has a pull-up resistor from the D+ pin, so the hub sees a HIGH on D+ and a LOW on D-. In this case, the hub repeater sets a connect bit in the Hub Ports Connect Status register and generates a Hub Interrupt to notify the microcontroller of the change in Hub status. The firmware sets the speed of this port in the Hub Ports Speed Register (see *Figure 16-2*).

Connects are recorded by the time a non-SE0 state lasts for more than 2.5  $\mu$ s on a downstream port.

When a USB device is disconnected from the Hub, the downstream signal pair eventually floats to a single-ended zero state. The hub repeater recognizes a disconnect once the SE0 state on a downstream port lasts from 2.0 to 2.5  $\mu$ s. On a disconnect, the corresponding bit in the Hub Ports Connect Status register is cleared, and the Hub Interrupt is generated

| Hub Ports Connect Status |          |                       |                       |                       |                       |                       |                       | Address 0x48          |
|--------------------------|----------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Bit #                    | 7        | 6                     | 5                     | 4                     | 3                     | 2                     | 1                     | 0                     |
| Bit Name                 | Reserved | Port 7 Connect Status | Port 6 Connect Status | Port 5 Connect Status | Port 4 Connect Status | Port 3 Connect Status | Port 2 Connect Status | Port 1 Connect Status |
| Read/Write               | R/W      | R/W                   | R/W                   | R/W                   | R/W                   | R/W                   | R/W                   | R/W                   |
| Reset                    | 0        | 0                     | 0                     | 0                     | 0                     | 0                     | 0                     | 0                     |

**Figure 16-1. Hub Ports Connect Status**

Bit [0..6] : Port x Connect Status (where x = 1..7).

When set to 1, Port x is connected; When set to 0, Port x is disconnected.

Bit 7 : Reserved.

Set to 0.

The Hub Ports Connect Status register is cleared to zero by reset or USB bus reset, then set to match the hardware configuration by the hub repeater hardware. The Reserved bit [7] should always read as '0' to indicate no connection

| Hub Ports Speed |          |              |              |              |              |              |              | Address 0x4A |
|-----------------|----------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Bit #           | 7        | 6            | 5            | 4            | 3            | 2            | 1            | 0            |
| Bit Name        | Reserved | Port 7 Speed | Port 6 Speed | Port 5 Speed | Port 4 Speed | Port 3 Speed | Port 2 Speed | Port 1 Speed |
| Read/Write      | R/W      | R/W          | R/W          | R/W          | R/W          | R/W          | R/W          | R/W          |
| Reset           | 0        | 0            | 0            | 0            | 0            | 0            | 0            | 0            |

**Figure 16-2. Hub Ports Speed**

Bit [0..6] : Port x Speed (where x = 1..7).

Set to 1 if the device plugged in to Port x is Low Speed; Set to 0 if the device plugged in to Port x is Full Speed.

Bit 7 : Reserved.

Set to 0.

The Hub Ports Speed register is cleared to zero by reset or bus reset. This must be set by the firmware on issuing a port reset. The Reserved bit [7] should always read as '0.'

## 16.2 Enabling/Disabling a USB Device

After a USB device connection has been detected, firmware must update status change bits in the hub status change data structure that is polled periodically by the USB host. The host responds by sending a packet that instructs the hub to reset and enable the downstream port. Firmware then sets the bit in the Hub Ports Enable register (*Figure 16-3*), for the downstream port. The hub repeater hardware responds to an enable bit in the Hub Ports Enable register (*Figure 16-3*) by enabling the downstream port, so that USB traffic can flow to and from that port.

If a port is marked enabled and is not suspended, it receives all USB traffic from the upstream port, and USB traffic from the downstream port is passed to the upstream port (unless babble is detected). Low-speed ports do not receive full-speed traffic from the upstream port.

When firmware writes to the Hub Ports Enable register (*Figure 16-3*) to enable a port, the port is not enabled until the end of any packet currently being transmitted. If there is no USB traffic, the port is enabled immediately.

When a USB device disconnection has been detected, firmware must update status bits in the hub change status data structure that is polled periodically by the USB host. In suspended mode, a connect or disconnect event generates an interrupt (if the hub interrupt is enabled) even if the port is disabled

### Hub Ports Enable Register

Address 0x49

| Bit #      | 7        | 6             | 5             | 4             | 3             | 2             | 1             | 0             |
|------------|----------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Bit Name   | Reserved | Port 7 Enable | Port 6 Enable | Port 5 Enable | Port 4 Enable | Port 3 Enable | Port 2 Enable | Port 1 Enable |
| Read/Write | R/W      | R/W           | R/W           | R/W           | R/W           | R/W           | R/W           | R/W           |
| Reset      | 0        | 0             | 0             | 0             | 0             | 0             | 0             | 0             |

Figure 16-3. Hub Ports Enable Register

Bit [0..6] : Port x Enable (where x = 1..7)

Set to 1 if Port x is enabled; Set to 0 if Port x is disabled

Bit 7 : Reserved.

Set to 0.

The Hub Ports Enable register is cleared to zero by reset or bus reset to disable all downstream ports as the default condition. A port is also disabled by internal hub hardware (enable bit cleared) if babble is detected on that downstream port. Babble is defined as:

- Any non-idle downstream traffic on an enabled downstream port at EOF2.
- Any downstream port with upstream connectivity established at EOF2 (i.e., no EOP received by EOF2).

## 16.3 Hub Downstream Ports Status and Control

Data transfer on hub downstream ports is controlled according to the bit settings of the Hub Downstream Ports Control Register (*Figure 16-4*). Each downstream port is controlled by two bits, as defined in *Table 16-1* below. The Hub Downstream Ports Control Register is cleared upon reset or bus reset, and the reset state is the state for normal USB traffic. Any downstream port being forced must be marked as disabled (*Figure 16-3*) for proper operation of the hub repeater.

Firmware should use this register for driving bus reset and resume signaling to downstream ports. Controlling the port pins through this register uses standard USB edge rate control according to the speed of the port, set in the Hub Port Speed Register.

The downstream USB ports are designed for connection of USB devices, but can also serve as output ports under firmware control. This allows unused USB ports to be used for functions such as driving LEDs or providing additional input signals. Pulling up these pins to voltages above  $V_{REF}$  may cause current flow into the pin.

This register is not reset by USB bus reset. These bits must be cleared before going into suspend.



**Hub Downstream Ports Control Register**
**Address 0x4B**

| Bit #      | 7                    | 6                    | 5                    | 4                    | 3                    | 2                    | 1                    | 0                    |
|------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Bit Name   | Port 4 Control Bit 1 | Port 4 Control Bit 0 | Port 3 Control Bit 1 | Port 3 Control Bit 0 | Port 2 Control Bit 1 | Port 2 Control Bit 0 | Port 1 Control Bit 1 | Port 1 Control Bit 0 |
| Read/Write | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  |
| Reset      | 0                    | 0                    | 0                    | 0                    | 0                    | 0                    | 0                    | 0                    |

**Figure 16-4. Hub Downstream Ports Control Register**
**Table 16-1. Control Bit Definition for Downstream Ports**

| Control Bits |       | Control Action                           |
|--------------|-------|--|
| Bit1         | Bit 0 |  |
| 0            | 0     | Not Forcing (Normal USB Function)        |
| 0            | 1     | Force Differential '1' (D+ HIGH, D- LOW) |
| 1            | 0     | Force Differential '0' (D+ LOW, D- HIGH) |
| 1            | 1     | Force SE0 state                          |

An alternate means of forcing the downstream ports is through the Hub Ports Force Low Register (*Figure 16-5*) and Hub Ports Force High Register (*Figure 16-6*). With these registers the pins of the downstream ports can be individually forced LOW, or left unforced. Unlike the Hub Downstream Ports Control Register, above, the Force Low Register does not produce standard USB edge rate control on the forced pins. However, this register allows downstream port pins to be held LOW in suspend. This register can be used to drive SE0 on all downstream ports when unconfigured, as required in the USB 1.1 specification

**Hub Ports Force Low**
**Address 0x51**

| Bit #      | 7               | 6               | 5               | 4               | 3               | 2               | 1               | 0               |
|------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bit Name   | Force Low D+[4] | Force Low D-[4] | Force Low D+[3] | Force Low D-[3] | Force Low D+[2] | Force Low D-[2] | Force Low D+[1] | Force Low D-[1] |
| Read/Write | R/W             | R/W             | R/W             | R/W             | R/W             | R/W             | R/W             | R/W             |
| Reset      | 0               | 0               | 0               | 0               | 0               | 0               | 0               | 0               |

**Figure 16-5. Hub Ports Force Low Register**
**Hub Ports Force Low**
**Address 0x52**

| Bit #      | 7        | 6        | 5               | 4               | 3               | 2               | 1               | 0               |
|------------|----------|----------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bit Name   | Reserved | Reserved | Force Low D+[7] | Force Low D-[7] | Force Low D+[6] | Force Low D-[6] | Force Low D+[5] | Force Low D-[5] |
| Read/Write | –        | –        | R/W             | R/W             | R/W             | R/W             | R/W             | R/W             |
| Reset      | –        | –        | 0               | 0               | 0               | 0               | 0               | 0               |

**Figure 16-6. Hub Ports Force Low Register**

The data state of downstream ports can be read through the HUB Ports SE0 Status Register (*Figure 16-7*) and the Hub Ports Data Register (*Figure 16-8*). The data read from the Hub Ports Data Register is the differential data only and is independent of the settings of the Hub Ports Speed Register (*Figure 16-2*). When the SE0 condition is sensed on a downstream port, the corresponding bits of the Hub Ports Data Register hold the last differential data state before the SE0. Hub Ports SE0 Status Register and Hub Ports Data Register are cleared upon reset or bus reset

**Hub Ports SE0 Status**
**Address 0x4F**

| Bit #      | 7        | 6                 | 5                 | 4                 | 3                 | 2                 | 1                 | 0                 |
|------------|----------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Bit Name   | Reserved | Port 7 SE0 Status | Port 6 SE0 Status | Port 5 SE0 Status | Port 4 SE0 Status | Port 3 SE0 Status | Port 2 SE0 Status | Port 1 SE0 Status |
| Read/Write | R        | R                 | R                 | R                 | R                 | R                 | R                 | R                 |
| Reset      | 0        | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 |

**Figure 16-7. Hub Ports SE0 Status Register**

Bit [0..6]: Port x SE0 Status (where x = 1..7).

Set to 1 if a SE0 is output on the Port x bus; Set to 0 if a Non-SE0 is output on the Port x bus.

Bit 7: Reserved.

Set to 0

#### Hub Ports Data

ADDRESS 0x50

| Bit #      | 7        | 6                 | 5                 | 4                 | 3                 | 2                 | 1                 | 0                 |
|------------|----------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Bit Name   | Reserved | Port 7 Diff. Data | Port 6 Diff. Data | Port 5 Diff. Data | Port 4 Diff. Data | Port 3 Diff. Data | Port 2 Diff. Data | Port 1 Diff. Data |
| Read/Write | R        | R                 | R                 | R                 | R                 | R                 | R                 | R                 |
| Reset      | 0        | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 |

Figure 16-8. Hub Ports Data Register

Bit [0..6] : Port x Diff Data (where x = 1..7).

Set to 1 if D+ > D- (forced differential 1, if signal is differential, i.e. not a SE0 or SE1). Set to 0 if D- > D+ (forced differential 0, if signal is differential, i.e. not a SE0 or SE1).

Bit 7 : Reserved.

Set to 0.

### 16.4 Downstream Port Suspend and Resume

The Hub Ports Suspend Register (*Figure 16-9*) and Hub Ports Resume Status Register (*Figure 16-10*) indicate the suspend and resume conditions on downstream ports. The suspend register must be set by firmware for any ports that are selectively suspended. Also, this register is only valid for ports that are selectively suspended.

If a port is marked as selectively suspended, normal USB traffic is not sent to that port. Resume traffic is also prevented from going to that port, unless the Resume comes from the selectively suspended port. If a resume condition is detected on the port, hardware reflects a Resume back to the port, sets the Resume bit in the Hub Ports Resume Register, and generates a hub interrupt.

If a disconnect occurs on a port marked as selectively suspended, the suspend bit is cleared.

The Device Remote Wakeup bit (bit 7) of the Hub Ports Suspend Register controls whether or not the resume signal is propagated by the hub after a connect or a disconnect event. If the Device Remote Wakeup bit is set, the hub will automatically propagate the resume signal after a connect or a disconnect event. If the Device Remote Wakeup bit is cleared, the hub will not propagate the resume signal. The setting of the Device Remote Wakeup flag has no impact on the propagation of the resume signal after a downstream remote wakeup event. The hub will automatically propagate the resume signal after a remote wakeup event, regardless of the state of the Device Remote wakeup bit. The state of this bit has no impact on the generation of the hub interrupt.

A resume bit is set automatically when hardware detects a resume condition on a selectively suspended downstream port. The resume condition is a differential '1' for a low-speed device and a differential '0' for a full-speed device.

These registers are cleared on reset or USB bus reset

#### Hub Ports Suspend

Address 0x4D

| Bit #      | 7                    | 6                        | 5                        | 4                        | 3                        | 2                        | 1                        | 0                        |
|------------|----------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Bit Name   | Device Remote Wakeup | Port 7 Selective Suspend | Port 6 Selective Suspend | Port 5 Selective Suspend | Port 4 Selective Suspend | Port 3 Selective Suspend | Port 2 Selective Suspend | Port 1 Selective Suspend |
| Read/Write | R/W                  | R/W                      | R/W                      | R/W                      | R/W                      | R/W                      | R/W                      | R/W                      |
| Reset      | 0                    | 0                        | 0                        | 0                        | 0                        | 0                        | 0                        | 0                        |

Figure 16-9. Hub Ports Suspend Register

Bit [0..6] : Port x Selective Suspend (where x = 1..7).

Set to 1 if Port x is Selectively Suspended; Set to 0 if Port x Do not suspend.

Bit 7 : Device Remote Wakeup.

When set to 1, Enable hardware upstream resume signaling for connect/disconnect events during global resume.

When set to 0, Disable hardware upstream resume signaling for connect/disconnect events during global resume.

**Hub Ports Resume**
**Address 0x4E**

| Bit #      | 7        | 6        | 5        | 4        | 3        | 2        | 1        | 0        |
|------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Bit Name   | Reserved | Resume 7 | Resume 6 | Resume 5 | Resume 4 | Resume 3 | Resume 2 | Resume 1 |
| Read/Write | -        | R        | R        | R        | R        | R        | R        | R        |
| Reset      | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        |

**Figure 16-10. Hub Ports Resume Status Register**

Bit [0..6] : Resume x (where x = 1..7).

When set to 1 Port x requesting to be resumed (set by hardware); default state is 0.

Bit 7 : Reserved.

Set to 0.

Resume from a selectively suspended port, with the hub not in suspend, typically involves the following actions:

1. Hardware detects the Resume, drives a K to the port, and generates the hub interrupt. The corresponding bit in the Resume Status Register (0x4E) reads '1' in this case.
2. Firmware responds to hub interrupt, and reads register 0x4E to determine the source of the Resume.
3. Firmware begins driving K on the port for 10 ms or more through register 0x4B.
4. Firmware clears the Selective Suspend bit for the port (0x4D), which clears the Resume bit (0x4E). This ends the hardware-driven Resume, but the firmware-driven Resume continues. To prevent traffic being fed by the hub repeater to the port during or just after the Resume, firmware should disable this port.
5. Firmware drives a timed SE0 on the port for two low-speed bit times as appropriate. Firmware must disable interrupts during this SE0 so the SE0 pulse isn't inadvertently lengthened, and appear as a bus reset to the downstream device.
6. Firmware drives a J on the port for one low-speed bit time, then it idles the port.
7. Firmware re-enables the port.

Resume when the hub is suspended typically involves these actions:

1. Hardware detects the Resume, drives a K on the upstream (which is then reflected to all downstream enabled ports), and generates the hub interrupt.
2. The part comes out of suspend and the clocks start.
3. Once the clocks are stable, firmware execution resumes. An internal counter ensures that this takes at least 1 ms. Firmware should check for Resume from any selectively suspended ports. If found, the Selective Suspend bit for the port should be cleared; no other action is necessary.
4. The Resume ends when the host stops sending K from upstream. Firmware should check for changes to the Enable and Connect Registers. If a port has become disabled but is still connected, an SE0 has been detected on the port. The port should be treated as having been reset, and should be reported to the host as newly connected.

Firmware can choose to clear the Device Remote Wake-up bit (if set) to implement firmware timed states for port changes. All allowed port changes wake the part. Then, the part can use internal timing to determine whether to take action or return to suspend. If Device Remote Wake-up is set, automatic hardware assertions take place on Resume events.

## 16.5 USB Upstream Port Status and Control

USB status and control is regulated by the USB Status and Control Register, as shown in *Figure 16-11*. All bits in the register are cleared during reset

**USB Status and Control**
**Address 0x1F**

| Bit #      | 7             | 6             | 5           | 4           | 3            | 2                    | 1                    | 0                    |
|------------|---------------|---------------|-------------|-------------|--------------|----------------------|----------------------|----------------------|
| Bit Name   | Endpoint Size | Endpoint Mode | D+ Upstream | D- Upstream | Bus Activity | Control Action Bit 2 | Control Action Bit 1 | Control Action Bit 0 |
| Read/Write | R/W           | R/W           | R           | R           | R/W          | R/W                  | R/W                  | R/W                  |
| Reset      | 0             | 0             | 0           | 0           | 0            | 0                    | 0                    | 0                    |

**Figure 16-11. USB Status and Control Register**

Bits[2..0]: Control Action

Set to control action as per table 16-2. The three control bits allow the upstream port to be driven manually by firmware. For normal USB operation, all of these bits must be cleared. *Table 16-2* shows how the control bits affect the upstream port.

**Table 16-2. Control Bit Definition for Upstream Port**

| Control Bits | Control Action                    |
|--------------|-----------------------------------|
| 000          | Not Forcing (SIE Controls Driver) |
| 001          | Force D+[0] HIGH, D-[0] LOW       |
| 010          | Force D+[0] LOW, D-[0] HIGH       |
| 011          | Force SE0; D+[0] LOW, D-[0] LOW   |
| 100          | Force D+[0] LOW, D-[0] LOW        |
| 101          | Force D+[0] HiZ, D-[0] LOW        |
| 110          | Force D+[0] LOW, D-[0] HiZ        |
| 111          | Force D+[0] HiZ, D-[0] HiZ        |

Bit 3: Bus Activity.

This is a “sticky” bit that indicates if any non-idle USB event has occurred on the upstream USB port. Firmware should check and clear this bit periodically to detect any loss of bus activity. Writing a ‘0’ to the Bus Activity bit clears it, while writing a ‘1’ preserves the current value. In other words, the firmware can clear the Bus Activity bit, but only the SIE can set it.

Bits 4 and 5: D- Upstream and D+ Upstream.

These bits give the state of each upstream port pin individually: 1 = HIGH, 0 = LOW.

Bit 6: Endpoint Mode.

This bit used to configure the number of USB endpoints. See *Section 17.2* for a detailed description.

Bit 7: Endpoint Size.

This bit used to configure the number of USB endpoints. See *Section 17.2* for a detailed description.

The hub generates an EOP at EOF1 in accordance with the USB 1.1 Specification, *Section 11.2.2*.

## 17.0 USB Serial Interface Engine Operation

The CY7C65x13 SIE supports operation as a single device or a compound device. This section describes the two device addresses, the configurable endpoints, and the endpoint function.

### 17.1 USB Device Addresses

The USB Controller provides two USB Device Address Registers: A (addressed at 0x10) and B (addressed at 0x40). Upon reset and under default conditions, Device A has three endpoints and Device B has two endpoints. The USB Device Address Register contents are cleared during a reset, setting the USB device addresses to zero and disabling these addresses. *Figure 17-1* shows the format of the USB Address Registers.

| USB Device Address (Device A, B) | Addresses 0x10(A) and 0x40(B) |                      |                      |                      |                      |                      |                      |                      |
|----------------------------------|-------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Bit #                            | 7                             | 6                    | 5                    | 4                    | 3                    | 2                    | 1                    | 0                    |
| Bit Name                         | Device Address Enable         | Device Address Bit 6 | Device Address Bit 5 | Device Address Bit 4 | Device Address Bit 3 | Device Address Bit 2 | Device Address Bit 1 | Device Address Bit 0 |
| Read/Write                       | R/W                           | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  | R/W                  |
| Reset                            | 0                             | 0                    | 0                    | 0                    | 0                    | 0                    | 0                    | 0                    |

**Figure 17-1. USB Device Address Registers**

Bits[6..0]: Device Address.

Firmware writes this bits during the USB enumeration process to the non-zero address assigned by the USB host.

Bit 7: Device Address Enable.

Must be set by firmware before the SIE can respond to USB traffic to the Device Address.

### 17.2 USB Device Endpoints

The CY7C65x13 controller supports up to two addresses and five endpoints for communication with the host. The configuration of these endpoints, and associated FIFOs, is controlled by bits [7,6] of the USB Status and Control Register (*Figure 16-11*). Bit 7 controls the size of the endpoints and bit 6 controls the number of addresses. These configuration options are detailed in *Table 17-1*. Endpoint FIFOs are part of user RAM (as shown in *Section 5.4.1*).

Table 17-1. Memory Allocation for Endpoints

| USB Status And Control Register (0x1F) Bits [7, 6]           |               |      |  |               |      |                                     |               |      |                                     |               |      |
|--|---------------|------|--|---------------|------|-------------------------------------|---------------|------|-------------------------------------|---------------|------|
| [0,0]  |               |      | [1,0]  |               |      | [0,1]                               |               |      | [1,1]                               |               |      |
| Two USB Addresses:<br>A (3 Endpoints) and<br>B (2 Endpoints) |               |      | Two USB Addresses:<br>A (3 Endpoints) and<br>B (2 Endpoints) |               |      | One USB Address:<br>A (5 Endpoints) |               |      | One USB Address:<br>A (5 Endpoints) |               |      |
| Label  | Start Address | Size | Label  | Start Address | Size | Label                               | Start Address | Size | Label                               | Start Address | Size |
| EPB1   | 0xD8          | 8    | EPB0   | 0xA8          | 8    | EPA4                                | 0xD8          | 8    | EPA3                                | 0xA8          | 8    |
| EPB0   | 0xE0          | 8    | EPB1   | 0xB0          | 8    | EPA3                                | 0xE0          | 8    | EPA4                                | 0xB0          | 8    |
| EPA2   | 0xE8          | 8    | EPA0   | 0xB8          | 8    | EPA2                                | 0xE8          | 8    | EPA0                                | 0xB8          | 8    |
| EPA1   | 0xF0          | 8    | EPA1   | 0xC0          | 32   | EPA1                                | 0xF0          | 8    | EPA1                                | 0xC0          | 32   |
| EPA0   | 0xF8          | 8    | EPA2   | 0xE0          | 32   | EPA0                                | 0xF8          | 8    | EPA2                                | 0xE0          | 32   |

When the SIE writes data to a FIFO, the internal data bus is driven by the SIE; not the CPU. This causes a short delay in the CPU operation. The delay is three clock cycles per byte. For example, an 8-byte data write by the SIE to the FIFO generates a delay of 2  $\mu$ s (3 cycles/byte \* 83.33 ns/cycle \* 8 bytes).

### 17.3 USB Control Endpoint Mode Registers

All USB devices are required to have a control endpoint 0 (EPA0 and EPB0) that is used to initialize and control each USB address. Endpoint 0 provides access to the device configuration information and allows generic USB status and control accesses. Endpoint 0 is bidirectional to both receive and transmit data. The other endpoints are unidirectional, but selectable by the user as IN or OUT endpoints.

The endpoint mode registers are cleared during reset. When USB Status And Control Register Bits [6,7] are set to [0,0] or [1,0], the endpoint zero EPA0 and EPB0 mode registers use the format shown in *Figure 17-2*.

| USB Device Endpoint Zero Mode (A0, B0) | Addresses 0x12(A0) and 0x42(B0) |                              |                               |     |            |            |            |            |
|--|---------------------------------|------------------------------|-------------------------------|-----|------------|------------|------------|------------|
| Bit #                                  | 7                               | 6                            | 5                             | 4   | 3          | 2          | 1          | 0          |
| Bit Name                               | Endpoint 0<br>SETUP<br>Received | Endpoint 0<br>IN<br>Received | Endpoint 0<br>OUT<br>Received | ACK | Mode Bit 3 | Mode Bit 2 | Mode Bit 1 | Mode Bit 0 |
| Read/Write                             | R/W                             | R/W                          | R/W                           | R/W | R/W        | R/W        | R/W        | R/W        |
| Reset                                  | 0                               | 0                            | 0                             | 0   | 0          | 0          | 0          | 0          |

Figure 17-2. USB Device Endpoint Zero Mode Registers

Bits[3..0]: Mode.

These sets the mode which control how the control endpoint responds to traffic.

Bit 4: ACK.

This bit is set whenever the SIE engages in a transaction to the register's endpoint that completes with an ACK packet.

Bit 5: Endpoint 0 OUT Received.

1= Token received is an OUT token. 0= Token received is not an OUT token. This bit is set by the SIE to report the type of token received by the corresponding device address is an OUT token. The bit must be cleared by firmware as part of the USB processing.

Bit 6: Endpoint 0 IN Received.

1= Token received is an IN token. 0= Token received is not an IN token. This bit is set by the SIE to report the type of token received by the corresponding device address is an IN token. The bit must be cleared by firmware as part of the USB processing.

Bit 7: Endpoint 0 SETUP Received.

1 = Token received is a SETUP token. 0= Token received is not a SETUP token. This bit is set ONLY by the SIE to report the type of token received by the corresponding device address is a SETUP token. Any write to this bit by the CPU will clear it (set it to 0). The bit is forced HIGH from the start of the data packet phase of the SETUP transaction until the start of the ACK packet returned by the SIE. The CPU should not clear this bit during this interval, and subsequently, until the CPU first does an IORD to this endpoint 0 mode register. The bit must be cleared by firmware as part of the USB processing.<sup>[4]</sup>

Bits[6:0] of the endpoint 0 mode register are locked from CPU write operations whenever the SIE has updated one of these bits, which the SIE does only at the end of the token phase of a transaction (SETUP... Data... ACK, OUT... Data... ACK, or IN... Data... ACK). The CPU can unlock these bits by doing a subsequent read of this register. Only endpoint 0 mode registers are locked when updated. The locking mechanism does not apply to the mode registers of other endpoints.

Because of these hardware locking features, firmware must perform an IORD after an IOWR to an endpoint 0 register. This verifies that the contents have changed as desired, and that the SIE has not updated these values.

While the SETUP bit is set, the CPU cannot write to the endpoint zero FIFOs. This prevents firmware from overwriting an incoming SETUP transaction before firmware has a chance to read the SETUP data. Refer to *Table 17-1* for the appropriate endpoint zero memory locations.

The Mode bits (bits [3:0]) control how the endpoint responds to USB bus traffic. The mode bit encoding is shown in *Table 18-1*. Additional information on the mode bits can be found in *Table 18-2* and *Table 18-3*.<sup>[5]</sup>

## 17.4 USB Non-control Endpoint Mode Registers

The format of the non-control endpoint mode registers is shown in *Figure 17-3*.

| USB Non-control Device Endpoint Mode |       |          |          |     | Addresses 0x14, 0x16, 0x44 |            |            |            |
|--------------------------------------|-------|----------|----------|-----|----------------------------|------------|------------|------------|
| Bit #                                | 7     | 6        | 5        | 4   | 3                          | 2          | 1          | 0          |
| Bit Name                             | STALL | Reserved | Reserved | ACK | Mode Bit 3                 | Mode Bit 2 | Mode Bit 1 | Mode Bit 0 |
| Read/Write                           | R/W   | R/W      | R/W      | R/W | R/W                        | R/W        | R/W        | R/W        |
| Reset                                | 0     | 0        | 0        | 0   | 0                          | 0          | 0          | 0          |

**Figure 17-3. USB Non-control Device Endpoint Mode Registers**

Bits[3..0] : Mode.

These sets the mode which control how the control endpoint responds to traffic. The mode bit encoding is shown in *Table 18-1*.

Bit 4 : ACK.

This bit is set whenever the SIE engages in a transaction to the register's endpoint that completes with an ACK packet.

Bits[6..5]: Reserved.

Must be written zero during register writes.

Bit 7: STALL.

If this STALL is set, the SIE stalls an OUT packet if the mode bits are set to ACK-IN, and the SIE stalls an IN packet if the mode bits are set to ACK-OUT. For all other modes, the STALL bit must be a LOW.

## 17.5 USB Endpoint Counter Registers

There are five Endpoint Counter registers, with identical formats for both control and non-control endpoints. These registers contain byte count information for USB transactions, as well as bits for data packet status. The format of these registers is shown in *Figure 17-4*.

| USB Endpoint Counter |                 |            |                  |                  | Addresses 0x11, 0x13, 0x15, 0x41, 0x43 |                  |                  |                  |
|----------------------|-----------------|------------|------------------|------------------|--|------------------|------------------|------------------|
| Bit #                | 7               | 6          | 5                | 4                | 3                                      | 2                | 1                | 0                |
| Bit Name             | Data 0/1 Toggle | Data Valid | Byte Count Bit 5 | Byte Count Bit 4 | Byte Count Bit 3                       | Byte Count Bit 2 | Byte Count Bit 1 | Byte Count Bit 0 |
| Read/Write           | R/W             | R/W        | R/W              | R/W              | R/W                                    | R/W              | R/W              | R/W              |
| Reset                | 0               | 0          | 0                | 0                | 0                                      | 0                | 0                | 0                |

**Figure 17-4. USB Endpoint Counter Registers**

Bits[5..0]: Byte Count.

**Notes:**

- In 5-endpoint mode (USB Status And Control Register Bits [7,6] are set to [0,1] or [1,1]), Register 0x42 serves as non-control endpoint 3, and has the format for non-control endpoints shown in *Figure 17-3*.
- The SIE offers an "Ack out – Status in" mode and not an "Ack out – Nak in" mode. Therefore, if following the status stage of a Control Write transfer a USB host were to immediately start the next transfer, the new Setup packet could override the data payload of the data stage of the previous Control Write.

These counter bits indicate the number of data bytes in a transaction. For IN transactions, firmware loads the count with the number of bytes to be transmitted to the host from the endpoint FIFO. Valid values are 0 to 32, inclusive. For OUT or

SETUP transactions, the count is updated by hardware to the number of data bytes received, plus two for the CRC bytes. Valid values are 2 to 34, inclusive.

Bit 6: Data Valid.

This bit is set on receiving a proper CRC when the endpoint FIFO buffer is loaded with data during transactions. This bit is used OUT and SETUP tokens only. If the CRC is not correct, the endpoint interrupt occurs, but Data Valid is cleared to a zero.

Bit 7: Data 0/1 Toggle.

This bit selects the DATA packet's toggle state: 0 for DATA0, 1 for DATA1. For IN transactions, firmware must set this bit to the desired state. For OUT or SETUP transactions, the hardware sets this bit to the state of the received Data Toggle bit.

Whenever the count updates from a SETUP or OUT transaction on endpoint 0, the counter register locks and cannot be written by the CPU. Reading the register unlocks it. This prevents firmware from overwriting a status update on incoming SETUP or OUT transactions before firmware has a chance to read the data. Only endpoint 0 counter register is locked when updated. The locking mechanism does not apply to the count registers of other endpoints.

## 17.6 Endpoint Mode/Count Registers Update and Locking Mechanism

The contents of the endpoint mode and counter registers are updated, based on the packet flow diagram in *Figure 17-5*. Two time points, SETUP and UPDATE, are shown in the same figure. The following activities occur at each time point:

### SETUP:

The SETUP bit of the endpoint 0 mode register is forced HIGH at this time. This bit is forced HIGH by the SIE until the end of the data phase of a control write transfer. The SETUP bit can not be cleared by firmware during this time.

The affected mode and counter registers of endpoint 0 are locked from any CPU writes once they are updated. These registers can be unlocked by a CPU read, only if the read operation occurs after the UPDATE. The firmware needs to perform a register read as a part of the endpoint ISR processing to unlock the effected registers. The locking mechanism on mode and counter registers ensures that the firmware recognizes the changes that the SIE might have made since the previous IO read of that register.

### UPDATE:

1. Endpoint Mode Register – All the bits are updated (except the SETUP bit of the endpoint 0 mode register).
2. Counter Registers – All bits are updated.
3. Interrupt – If an interrupt is to be generated as a result of the transaction, the interrupt flag for the corresponding endpoint is set at this time. For details on what conditions are required to generate an endpoint interrupt, refer to *Table 18-2*.
4. The contents of the updated endpoint 0 mode and counter registers are locked, except the SETUP bit of the endpoint 0 mode register which was locked earlier.

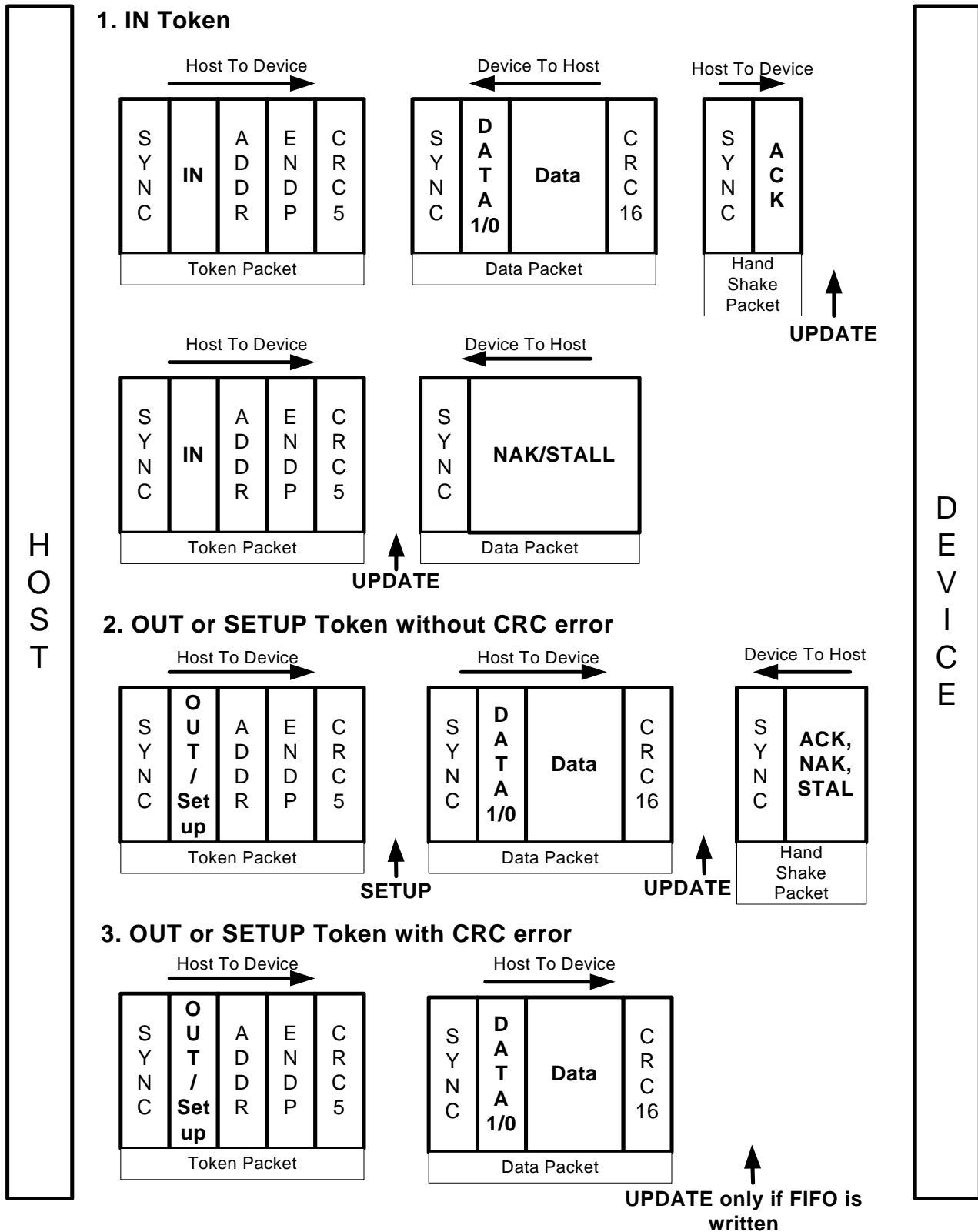


Figure 17-5. Token/Data Packet Flow Diagram



## 18.0 USB Mode Tables

**Table 18-1. USB Register Mode Encoding**

| Moder                            | Mode Bits | SETUP  | IN        | OUT    | Comments  |
|----------------------------------|-----------|--------|-----------|--------|---|
| Disable                          | 0000      | ignore | ignore    | ignore | Ignore all USB traffic to this endpoint   |
| Nak In/Out                       | 0001      | accept | NAK       | NAK    | Forced from Setup on Control endpoint, from modes other than 0000               |
| Status Out Only                  | 0010      | accept | stall     | check  | For Control endpoints   |
| Stall In/Out                     | 0011      | accept | stall     | stall  | For Control endpoints   |
| Ignore In/Out                    | 0100      | accept | ignore    | ignore | For Control endpoints   |
| Isochronous Out                  | 0101      | ignore | ignore    | always | For Isochronous endpoints   |
| Status In Only                   | 0110      | accept | TX 0 BYte | stall  | For Control Endpoints   |
| Isochronous In                   | 0111      | ignore | TX Count  | ignore | For Isochronous endpoints   |
| Nak Out                          | 1000      | ignore | ignore    | NAK    | Is set by SIE on an ACK from mode 1001 (Ack Out)                                |
| Ack Out(STALL <sup>[6]</sup> =0) | 1001      | ignore | ignore    | ACK    | On issuance of an ACK this mode is changed by SIE to 1000 (NAK Out)             |
| Ack Out(STALL <sup>[6]</sup> =1) | 1001      | ignore | ignore    | stall  |   |
| Nak Out - Status In              | 1010      | accept | TX 0 BYte | NAK    | Is set by SIE on an ACK from mode 1011 (Ack Out – Status In)                    |
| Ack Out - Status In              | 1011      | accept | TX 0 BYte | ACK    | On issuance of an ACK this mode is changed by SIE to 1010 (NAK Out – Status In) |
| Nak In                           | 1100      | ignore | NAK       | ignore | Is set by SIE on an ACK from mode 1101 (Ack In)                                 |
| Ack IN(STALL <sup>[6]</sup> =0)  | 1101      | ignore | TX Count  | ignore | On issuance of an ACK this mode is changed by SIE to 1100 (NAK In)              |
| Ack IN(STALL <sup>[6]</sup> =1)  | 1101      | ignore | stall     | ignore |   |
| Nak In - Status Out              | 1110      | accept | NAK       | check  | Is set by SIE on an ACK from mode 1111 (Ack In – Status Out)                    |
| Ack In - Status Out              | 1111      | accept | TX Count  | check  | On issuance of an ACK this mode is changed by SIE to 1110 (NAK In – Status Out) |

### Mode

This lists the mnemonic given to the different modes that can be set in the Endpoint Mode Register by writing to the lower nibble (bits 0..3). The bit settings for different modes are covered in the column marked “Mode Bits”. The Status IN and Status OUT represent the Status stage in the IN or OUT transfer involving the control endpoint.

### Mode Bits

These column lists the encoding for different modes by setting Bits[3..0] of the Endpoint Mode register. This modes represents how the SIE responds to different tokens sent by the host to an endpoint. For instance, if the mode bits are set to “0001” (NAK IN/OUT), the SIE will respond with an

- ACK on receiving a SETUP token from the host.
- NAK on receiving an OUT token from the host.
- NAK on receiving an IN token from the host.

Refer to section 13.0 for more information on the SIE functioning.

### SETUP, IN, and OUT

These columns shows the SIE’s response to the host on receiving a SETUP, IN and OUT token depending on the mode set in the Endpoint Mode Register.

A “Check” on the OUT token column, implies that on receiving an OUT token the SIE checks to see whether the OUT packet is of zero length and has a Data Toggle (DTOG) set to ‘1.’ If the DTOG bit is set and the received OUT Packet has zero length, the OUT is ACKed to complete the transaction. If either of this condition is not met the SIE will respond with a STALL or just ignore the transaction.

A “TX Count” entry in the IN column implies that the SIE transmit the number of bytes specified in the Byte Count (bits 3..0 of the Endpoint Count Register) to the host in response to the IN token received.

### Note:

6. STALL bit is bit 7 of the USB Non-control Device Endpoint Mode registers. For more information, refer to Section 17.4.

A “TX0 Byte” entry in the IN column implies that the SIE transmit a zero length byte packet in response to the IN token received from the host.

An “Ignore” in any of the columns means that the device will not send any handshake tokens (no ACK) to the host.

An “Accept” in any of the columns means that the device will respond with an ACK to a valid SETUP transaction to the host.

### Comments

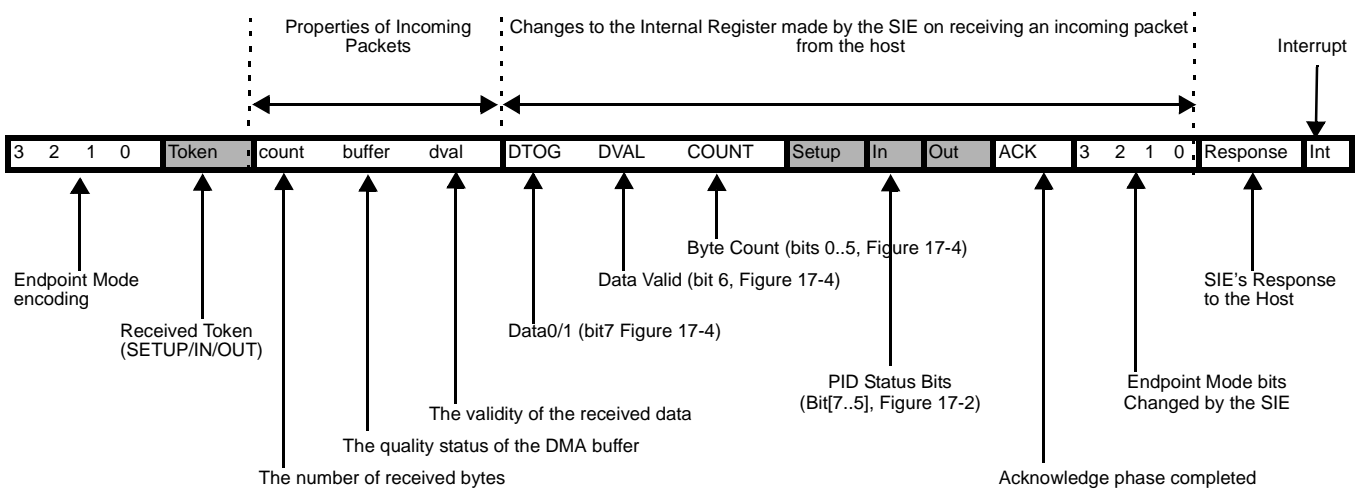
Some Mode Bits are automatically changed by the SIE in response to certain USB transactions. For example, if the Mode Bits [3:0] are set to '1111' which is ACK IN-Status OUT mode as shown in *Table 18-1*, the SIE will change the endpoint Mode Bits [3:0] to NAK IN-Status OUT mode (1110) after ACK'ing a valid status stage OUT token. The firmware needs to update the mode for the SIE to respond appropriately. See *Table 18-1* for more details on what modes will be changed by the SIE. A disabled endpoint will remain disabled until changed by firmware, and all endpoints reset to the disabled mode (0000). Firmware normally enables the endpoint mode after a SetConfiguration request.

Any SETUP packet to an enabled endpoint with mode set to accept SETUPS will be changed by the SIE to 0001 (NAKING INs and OUTs). Any mode set to accept a SETUP will send an ACK handshake to a valid SETUP token.

The control endpoint has three status bits for identifying the token type received (SETUP, IN, or OUT), but the endpoint must be placed in the correct mode to function as such. Non-control endpoints should not be placed into modes that accept SETUPS.

Note that most modes that control transactions involving an ending ACK, are changed by the SIE to a corresponding mode which NAKs subsequent packets following the ACK. Exceptions are modes 1010 and 1110

**Table 18-2. Decode table for *Table 18-3: “Details of Modes for Differing Traffic Conditions”***



**Legend:**

|  |                               |
|--|-------------------------------|
| TX : transmit                                    | UC : unchanged                |
| RX : receive                                     | TX0 :Transmit 0 length packet |
| [shaded box] available for Control endpoint only |                               |
| x: don't care                                    |                               |

The response of the SIE can be summarized as follows:

1. The SIE will only respond to valid transactions, and will ignore non-valid ones.
2. The SIE will generate an interrupt when a valid transaction is completed or when the FIFO is corrupted. FIFO corruption occurs during an OUT or SETUP transaction to a valid internal address, that ends with a non-valid CRC.
3. An incoming Data packet is valid if the count is  $\leq$  Endpoint Size + 2 (includes CRC) and passes all error checking;
4. An IN will be ignored by an OUT configured endpoint and visa versa.
5. The IN and OUT PID status is updated at the end of a transaction.
6. The SETUP PID status is updated at the beginning of the Data packet phase.

7. The entire Endpoint 0 mode register and the Count register are locked to CPU writes at the end of any transaction to that endpoint in which an ACK is transferred. These registers are only unlocked by a CPU read of the register, which should be done by the firmware only after the transaction is complete. This represents about a 1- $\mu$ s window in which the CPU is locked from register writes to these USB registers. Normally the firmware should perform a register read at the beginning of the Endpoint ISRs to unlock and get the mode register information. The interlock on the Mode and Count registers ensures that the firmware recognizes the changes that the SIE might have made during the previous transaction. Note that the setup bit of the mode register is NOT locked. This means that before writing to the mode register, firmware must first read the register to make sure that the setup bit is not set (which indicates a setup was received, while processing the current USB request). This read will of course unlock the register. So care must be taken not to overwrite the register elsewhere

**Table 18-3. Details of Modes for Differing Traffic Conditions** (see Table 18-2 for the decode legend)

| SETUP (if accepting SETUPS)    |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
|--------------------------------|-------|-------|--------|---------|---|---------|---------|---------|---------|---------|-----|-----------|----|----|----------|----------|--------|--------|------------|-------|-----|
| Properties of Incoming Packet  |       |       |        |         | Changes made by SIE to Internal Registers and Mode Bits |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| Mode Bits                      | token | count | buffer | dval    | DTOG  | DVAL    | COUNT   | Setup   | In      | Out     | ACK | Mode Bits |    |    | Response | Intr     |        |        |            |       |     |
| See Table 18-1                 | Setup | <= 10 | data   | valid   | updates   | 1       | updates | 1       | UC      | UC      | 1   | 0         | 0  | 0  | 1        | ACK      | yes    |        |            |       |     |
| See Table 18-1                 | Setup | > 10  | junk   | x       | updates   | updates | updates | 1       | UC      | UC      | UC  | NoChange  |    |    | ignore   | yes      |        |        |            |       |     |
| See Table 18-1                 | Setup | x     | junk   | invalid | updates   | 0       | updates | 1       | UC      | UC      | UC  | NoChange  |    |    | ignore   | yes      |        |        |            |       |     |
| Properties of Incoming Packet  |       |       |        |         | Changes made by SIE to Internal Registers and Mode Bits |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| Mode Bits                      | token | count | buffer | dval    | DTOG  | DVAL    | COUNT   | Setup   | In      | Out     | ACK | Mode Bits |    |    | Response | Intr     |        |        |            |       |     |
| DISABLED                       |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 0                              | 0     | 0     | 0      | x       | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange | ignore | no     |            |       |     |
| Nak In/Out                     |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 0                              | 0     | 0     | 1      | Out     | x   | UC      | x       | UC      | UC      | UC      | UC  | 1         | 1  | UC | UC       | NoChange | NAK    | yes    |            |       |     |
| 0                              | 0     | 0     | 1      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | 1         | UC | UC | UC       | NoChange | NAK    | yes    |            |       |     |
| Ignore In/Out                  |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 0                              | 1     | 0     | 0      | Out     | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange | ignore | no     |            |       |     |
| 0                              | 1     | 0     | 0      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange | ignore | no     |            |       |     |
| Stall In/Out                   |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 0                              | 0     | 1     | 1      | Out     | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | 1  | UC | UC       | NoChange | Stall  | yes    |            |       |     |
| 0                              | 0     | 1     | 1      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | 1  | UC | UC       | NoChange | Stall  | yes    |            |       |     |
| CONTROL WRITE                  |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| Properties of Incoming Packet  |       |       |        |         | Changes made by SIE to Internal Registers and Mode Bits |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| Mode Bits                      | token | count | buffer | dval    | DTOG  | DVAL    | COUNT   | Setup   | In      | Out     | ACK | Mode Bits |    |    | Response | Intr     |        |        |            |       |     |
| Normal Out/premature status In |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 1                              | 0     | 1     | 1      | Out     | <= 10   | data    | valid   | updates | 1       | updates | UC  | UC        | 1  | 1  | 1        | 0        | 1      | 0      | ACK        | yes   |     |
| 1                              | 0     | 1     | 1      | Out     | > 10  | junk    | x       | updates | updates | updates | UC  | UC        | 1  | UC | NoChange |          |        | ignore | yes        |       |     |
| 1                              | 0     | 1     | 1      | Out     | x   | junk    | invalid | updates | 0       | updates | UC  | UC        | 1  | UC | NoChange |          |        | ignore | yes        |       |     |
| 1                              | 0     | 1     | 1      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | 1         | UC | 1  | NoChange |          |        | TX 0   | yes        |       |     |
| NAK Out/premature status In    |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 1                              | 0     | 1     | 0      | Out     | <= 10   | UC      | valid   | UC      | UC      | UC      | UC  | UC        | UC | 1  | UC       | NoChange |        |        | NAK        | yes   |     |
| 1                              | 0     | 1     | 0      | Out     | > 10  | UC      | x       | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange |        |        | ignore     | no    |     |
| 1                              | 0     | 1     | 0      | Out     | x   | UC      | invalid | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange |        |        | ignore     | no    |     |
| 1                              | 0     | 1     | 0      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | 1  | UC | 1        | NoChange |        |        | TX 0       | yes   |     |
| Status In/extra Out            |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 0                              | 1     | 1     | 0      | Out     | <= 10   | UC      | valid   | UC      | UC      | UC      | UC  | UC        | UC | 1  | UC       | 0        | 0      | 1      | 1          | Stall | yes |
| 0                              | 1     | 1     | 0      | Out     | > 10  | UC      | x       | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange |        |        | ignore     | no    |     |
| 0                              | 1     | 1     | 0      | Out     | x   | UC      | invalid | UC      | UC      | UC      | UC  | UC        | UC | UC | UC       | NoChange |        |        | ignore     | no    |     |
| 0                              | 1     | 1     | 0      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | 1  | UC | 1        | NoChange |        |        | TX 0       | yes   |     |
| CONTROL READ                   |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| Properties of Incoming Packet  |       |       |        |         | Changes made by SIE to Internal Registers and Mode Bits |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| Mode Bits                      | token | count | buffer | dval    | DTOG  | DVAL    | COUNT   | Setup   | In      | Out     | ACK | Mode Bits |    |    | Response | Intr     |        |        |            |       |     |
| Normal In/premature status Out |       |       |        |         |   |         |         |         |         |         |     |           |    |    |          |          |        |        |            |       |     |
| 1                              | 1     | 1     | 1      | Out     | 2   | UC      | valid   | 1       | 1       | updates | UC  | UC        | 1  | 1  | NoChange |          |        | ACK    | yes        |       |     |
| 1                              | 1     | 1     | 1      | Out     | 2   | UC      | valid   | 0       | 1       | updates | UC  | UC        | 1  | UC | 0        | 0        | 1      | 1      | Stall      | yes   |     |
| 1                              | 1     | 1     | 1      | Out     | !=2   | UC      | valid   | updates | 1       | updates | UC  | UC        | 1  | UC | 0        | 0        | 1      | 1      | Stall      | yes   |     |
| 1                              | 1     | 1     | 1      | Out     | > 10  | UC      | x       | UC      | UC      | UC      | UC  | UC        | UC | UC | NoChange |          |        | ignore | no         |       |     |
| 1                              | 1     | 1     | 1      | Out     | x   | UC      | invalid | UC      | UC      | UC      | UC  | UC        | UC | UC | NoChange |          |        | ignore | no         |       |     |
| 1                              | 1     | 1     | 1      | In      | x   | UC      | x       | UC      | UC      | UC      | UC  | UC        | 1  | UC | 1        | 1        | 1      | 0      | ACK (back) | yes   |     |



Table 18-3. Details of Modes for Differing Traffic Conditions (see Table 18-2 for the decode legend) (continued)

| Nak In/premature status Out   |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
|-------------------------------|-------|-------|--------|------|-------|---------|---------|---------|---|---------|-----|-----------|----------|------|----------|--------|-----|---|----------------------------|-----|
| 1                             | 1     | 1     | 0      | Out  | 2     | UC      | valid   | 1       | 1   | updates | UC  | UC        | 1        | 1    | NoChange | ACK    | yes |   |                            |     |
| 1                             | 1     | 1     | 0      | Out  | 2     | UC      | valid   | 0       | 1   | updates | UC  | UC        | 1        | UC   | 0        | 0      | 1   | 1 | Stall                      | yes |
| 1                             | 1     | 1     | 0      | Out  | !=2   | UC      | valid   | updates | 1   | updates | UC  | UC        | 1        | UC   | 0        | 0      | 1   | 1 | Stall                      | yes |
| 1                             | 1     | 1     | 0      | Out  | > 10  | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 1                             | 1     | 1     | 0      | Out  | x     | UC      | invalid | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 1                             | 1     | 1     | 0      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | 1         | UC       | UC   | NoChange | NAK    | yes |   |                            |     |
| Status Out/extra In           |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 0                             | 0     | 1     | 0      | Out  | 2     | UC      | valid   | 1       | 1   | updates | UC  | UC        | 1        | 1    | NoChange | ACK    | yes |   |                            |     |
| 0                             | 0     | 1     | 0      | Out  | 2     | UC      | valid   | 0       | 1   | updates | UC  | UC        | 1        | UC   | 0        | 0      | 1   | 1 | Stall                      | yes |
| 0                             | 0     | 1     | 0      | Out  | !=2   | UC      | valid   | updates | 1   | updates | UC  | UC        | 1        | UC   | 0        | 0      | 1   | 1 | Stall                      | yes |
| 0                             | 0     | 1     | 0      | Out  | > 10  | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 0                             | 0     | 1     | 0      | Out  | x     | UC      | invalid | UC      | UC  | UC      | UC  | 1         | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 0                             | 0     | 1     | 0      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | 1         | UC       | UC   | 0        | 0      | 1   | 1 | Stall                      | yes |
| OUT ENDPOINT                  |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| Properties of Incoming Packet |       |       |        |      |       |         |         |         | Changes made by SIE to Internal Registers and Mode Bits |         |     |           |          |      |          |        |     |   |                            |     |
| Mode Bits                     | token | count | buffer | dval | DTOG  | DVAL    | COUNT   | Setup   | In  | Out     | ACK | Mode Bits | Response | Intr |          |        |     |   |                            |     |
| Normal Out/erroneous In       |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 1                             | 0     | 0     | 1      | Out  | <= 10 | data    | valid   | updates | 1   | updates | UC  | UC        | 1        | 1    | 1        | 0      | 0   | 0 | ACK                        | yes |
| 1                             | 0     | 0     | 1      | Out  | > 10  | junk    | x       | updates | updates   | updates | UC  | UC        | 1        | UC   | NoChange | ignore | yes |   |                            |     |
| 1                             | 0     | 0     | 1      | Out  | x     | junk    | invalid | updates | 0   | updates | UC  | UC        | 1        | UC   | NoChange | ignore | yes |   |                            |     |
| 1                             | 0     | 0     | 1      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
|                               |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   | (STALL <sup>[6]</sup> = 0) |     |
| 1                             | 0     | 0     | 1      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | Stall  | no  |   |                            |     |
|                               |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   | (STALL <sup>[6]</sup> = 1) |     |
| NAK Out/erroneous In          |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 1                             | 0     | 0     | 0      | Out  | <= 10 | UC      | valid   | UC      | UC  | UC      | UC  | UC        | 1        | UC   | NoChange | NAK    | yes |   |                            |     |
| 1                             | 0     | 0     | 0      | Out  | > 10  | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 1                             | 0     | 0     | 0      | Out  | x     | UC      | invalid | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 1                             | 0     | 0     | 0      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| Isochronous endpoint (Out)    |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 0                             | 1     | 0     | 1      | Out  | x     | updates | updates | updates | updates   | updates | UC  | UC        | 1        | 1    | NoChange | RX     | yes |   |                            |     |
| 0                             | 1     | 0     | 1      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| IN ENDPOINT                   |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| Properties of Incoming Packet |       |       |        |      |       |         |         |         | Changes made by SIE to Internal Registers and Mode Bits |         |     |           |          |      |          |        |     |   |                            |     |
| Mode Bits                     | token | count | buffer | dval | DTOG  | DVAL    | COUNT   | Setup   | In  | Out     | ACK | Mode Bits | Response | Intr |          |        |     |   |                            |     |
| Normal In/erroneous Out       |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 1                             | 1     | 0     | 1      | Out  | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
|                               |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   | (STALL <sup>[6]</sup> = 0) |     |
| 1                             | 1     | 0     | 1      | Out  | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | stall  | no  |   |                            |     |
|                               |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   | (STALL <sup>[6]</sup> = 1) |     |
| 1                             | 1     | 0     | 1      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | 1         | UC       | 1    | 1        | 1      | 0   | 0 | ACK (back)                 | yes |
| NAK In/erroneous Out          |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 1                             | 1     | 0     | 0      | Out  | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 1                             | 1     | 0     | 0      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | 1         | UC       | UC   | NoChange | NAK    | yes |   |                            |     |
| Isochronous endpoint (In)     |       |       |        |      |       |         |         |         |   |         |     |           |          |      |          |        |     |   |                            |     |
| 0                             | 1     | 1     | 1      | Out  | x     | UC      | x       | UC      | UC  | UC      | UC  | UC        | UC       | UC   | NoChange | ignore | no  |   |                            |     |
| 0                             | 1     | 1     | 1      | In   | x     | UC      | x       | UC      | UC  | UC      | UC  | 1         | UC       | UC   | NoChange | TX     | yes |   |                            |     |



19.0 Register Summary

|  | Address                              | Register Name                       | Bit 7                     | Bit 6                    | Bit 5                             | Bit 4                   | Bit 3                   | Bit 2                    | Bit 1                       | Bit 0                   | Read/Write/Both-[7]            | Default/Reset |          |
|--|--------------------------------------|-------------------------------------|---------------------------|--------------------------|-----------------------------------|-------------------------|-------------------------|--------------------------|-----------------------------|-------------------------|--------------------------------|---------------|----------|
| GPIO CONFIGURATION PORTS 0, 1, 2 AND 3 | 0x00                                 | Port 0 Data                         | P0.7                      | P0.6                     | P0.5                              | P0.4                    | P0.3                    | P0.2                     | P0.1                        | P0.0                    | BBBBBBBB                       | 11111111      |          |
|  | 0x01                                 | Port 1 Data                         | P1.7                      | P1.6                     | P1.5                              | P1.4                    | P1.3                    | P1.2                     | P1.1                        | P1.0                    | BBBBBBBB                       | 11111111      |          |
|  | 0x02                                 | Port 2 Data                         | P2.7                      | P2.6                     | P2.5                              | P2.4                    | P2.3                    | P2.2                     | P2.1                        | P2.0                    | BBBBBBBB                       | 11111111      |          |
|  | 0x03                                 | Port 3 Data                         | P3.7                      | P3.6                     | P3.5                              | P3.4                    | P3.3                    | P3.2                     | P3.1                        | P3.0                    | BBBBBBBB                       | 11111111      |          |
|  | 0x04                                 | Port 0 Interrupt Enable             | P0.7 Intr Enable          | P0.6 Intr Enable         | P0.5 Intr Enable                  | P0.4 Intr Enable        | P0.3 Intr Enable        | P0.2 Intr Enable         | P0.1 Intr Enable            | P0.0 Intr Enable        | wwwwwwww                       | 00000000      |          |
|  | 0x05                                 | Port 1 Interrupt Enable             | P1.7 Intr Enable          | P1.6 Intr Enable         | P1.5 Intr Enable                  | P1.4 Intr Enable        | Reserved                | P1.2 Intr Enable         | P1.1 Intr Enable            | P1.0 Intr Enable        | wwwwwwww                       | 00000000      |          |
|  | 0x06                                 | Port 2 Interrupt Enable             | P2.7 Intr Enable          | P2.6 Intr Enable         | P2.5 Intr Enable                  | P2.4 Intr Enable        | P2.3 Intr Enable        | Reserved                 | Reserved                    | Reserved                | wwwwwwww                       | 00000000      |          |
|  | 0x07                                 | Port 3 Interrupt Enable             | Reserved                  | Reserved                 | Reserved                          | Reserved                | Reserved                | Reserved                 | P3.1 Intr Enable            | P3.0 Intr Enable        | wwwwwwww                       | 00000000      |          |
|  | 0x08                                 | GPIO Configuration                  | Port 3 Config Bit 1       | Port 3 Config Bit 0      | Port 2 Config Bit 1               | Port 2 Config Bit 0     | Port 1 Config Bit 1     | Port 1 Config Bit 0      | Port 0 Config Bit 1         | Port 0 Config Bit 0     | BBBBBBBB                       | 00000000      |          |
| HAPI I <sup>2</sup> C                  | 0x09                                 | HAPI/I <sup>2</sup> C Configuration | I <sup>2</sup> C Position | Reserved                 | Reserved                          | Reserved                | Reserved                | Reserved                 | I <sup>2</sup> C Port Width | Reserved                | BBBBBBBB                       | 00000000      |          |
|  | ENDPOINT A0, A1 AND A2 CONFIGURATION | 0x10                                | USB Device Address A      | Device Address A Enable  | Device Address A Bit 6            | Device Address A Bit 5  | Device Address A Bit 4  | Device Address A Bit 3   | Device Address A Bit 2      | Device Address A Bit 1  | Device Address A Bit 0         | BBBBBBBB      | 00000000 |
|  |                                      | 0x11                                | EP A0 Counter Register    | Data 0/1 Toggle          | Data Valid                        | Byte Count Bit 5        | Byte Count Bit 4        | Byte Count Bit 3         | Byte Count Bit 2            | Byte Count Bit 1        | Byte Count Bit 0               | BBBBBBBB      | 00000000 |
|  |                                      | 0x12                                | EP A0 Mode Register       | Endpoint0 SETUP Received | Endpoint0 IN Received             | Endpoint0 OUT Received  | ACK                     | Mode Bit 3               | Mode Bit 2                  | Mode Bit 1              | Mode Bit 0                     | BBBBBBBB      | 00000000 |
|  |                                      | 0x13                                | EP A1 Counter Register    | Data 0/1 Toggle          | Data Valid                        | Byte Count Bit 5        | Byte Count Bit 4        | Byte Count Bit 3         | Byte Count Bit 2            | Byte Count Bit 1        | Byte Count Bit 0               | BBBBBBBB      | 00000000 |
|  |                                      | 0x14                                | EP A1 Mode Register       | STALL                    | -                                 | -                       | ACK                     | Mode Bit 3               | Mode Bit 2                  | Mode Bit 1              | Mode Bit 0                     | BBBBBBBB      | 00000000 |
|  |                                      | 0x15                                | EP A2 Counter Register    | Data 0/1 Toggle          | Data Valid                        | Byte Count Bit 5        | Byte Count Bit 4        | Byte Count Bit 3         | Byte Count Bit 2            | Byte Count Bit 1        | Byte Count Bit 0               | BBBBBBBB      | 00000000 |
|  |                                      | 0x16                                | EP A2 Mode Register       | STALL                    | -                                 | -                       | ACK                     | Mode Bit 3               | Mode Bit 2                  | Mode Bit 1              | Mode Bit 0                     | BBBBBBBB      | 00000000 |
| USB-CS                                 | 0x1F                                 | USB Status and Control              | Endpoint Size             | Endpoint Mode            | D+ Upstream                       | D- Upstream             | Bus Activity            | Control Bit 2            | Control Bit 1               | Control Bit 0           | BBRRBBBB                       | -0x0000       |          |
|  | INTERRUPT                            | 0x20                                | Global Interrupt Enable   | Reserved                 | I <sup>2</sup> C Interrupt Enable | GPIO Interrupt Enable   | Reserved                | USB Hub Interrupt Enable | 1.024-ms Interrupt Enable   | 128-μs Interrupt Enable | USB Bus RESET Interrupt Enable | -BBBBBBB      | -0000000 |
| 0x21                                   |                                      | Endpoint Interrupt Enable           | Reserved                  | Reserved                 | Reserved                          | EPB1 Interrupt Enable   | EPB0 Interrupt Enable   | EPA2 Interrupt Enable    | EPA1 Interrupt Enable       | EPA0 Interrupt Enable   | ---BBBBB                       | ---00000      |          |
| TIMER                                  | 0x24                                 | Timer (LSB)                         | Timer Bit 7               | Timer Bit 6              | Timer Bit 5                       | Timer Bit 4             | Timer Bit 3             | Timer Bit 2              | Timer Bit 1                 | Timer Bit 0             | RRRRRRRR                       | 00000000      |          |
|  | 0x25                                 | Timer (MSB)                         | Reserved                  | Reserved                 | Reserved                          | Reserved                | Timer Bit 11            | Timer Bit 10             | Time Bit 9                  | Timer Bit 8             | ----rrrr                       | ----0000      |          |
| I <sup>2</sup> C                       | 0x28                                 | I <sup>2</sup> C Control and Status | MSTR Mode                 | Continue/Busy            | Xmit Mode                         | ACK                     | Addr                    | ARB Lost/Restart         | Received Stop               | I <sup>2</sup> C Enable | BBBBBBBB                       | 00000000      |          |
|  | 0x29                                 | I <sup>2</sup> C Data               | I <sup>2</sup> C Data 7   | I <sup>2</sup> C Data 6  | I <sup>2</sup> C Data 5           | I <sup>2</sup> C Data 4 | I <sup>2</sup> C Data 3 | I <sup>2</sup> C Data 2  | I <sup>2</sup> C Data 1     | I <sup>2</sup> C Data 0 | BBBBBBBB                       | xxxxxxxx      |          |
| ENDPOINT B0, B1 CONFIGURATION          | 0x40                                 | USB Device Address B                | Device Address B Enable   | Device Address B Bit 6   | Device Address B Bit 5            | Device Address B Bit 4  | Device Address B Bit 3  | Device Address B Bit 2   | Device Address B Bit 1      | Device Address B Bit 0  | BBBBBBBB                       | 00000000      |          |
|  | 0x41                                 | EP B0 Counter Register              | Data 0/1 Toggle           | Data Valid               | Byte Count Bit 5                  | Byte Count Bit 4        | Byte Count Bit 3        | Byte Count Bit 2         | Byte Count Bit 1            | Byte Count Bit 0        | BBBBBBBB                       | 00000000      |          |
|  | 0x42                                 | EP B0 Mode Register                 | Endpoint 0 SETUP Received | Endpoint 0 IN Received   | Endpoint 0 OUT Received           | ACK                     | Mode Bit 3              | Mode Bit 2               | Mode Bit 1                  | Mode Bit 0              | BBBBBBBB                       | 00000000      |          |
|  | 0x43                                 | EP B1 Counter Register              | Data 0/1 Toggle           | Data Valid               | Byte Count Bit 5                  | Byte Count Bit 4        | Byte Count Bit 3        | Byte Count Bit 2         | Byte Count Bit 1            | Byte Count Bit 0        | BBBBBBBB                       | 00000000      |          |
|  | 0x44                                 | EP B1 Mode Register                 | STALL                     | -                        | -                                 | ACK                     | Mode Bit 3              | Mode Bit 2               | Mode Bit 1                  | Mode Bit 0              | BBBBBBBB                       | 00000000      |          |

Note:

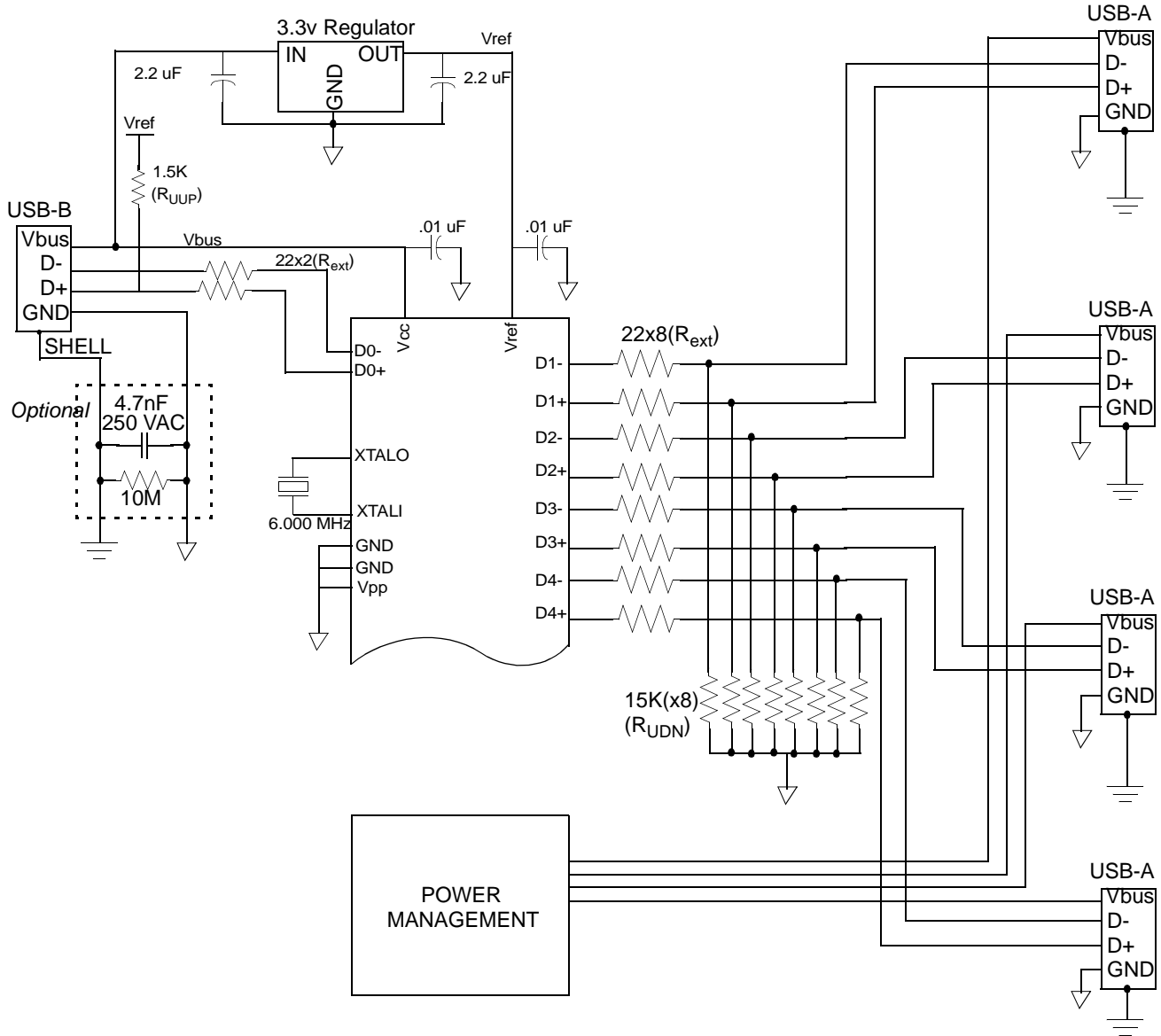
7. B: Read and Write; W: Write; R: Read.



19.0 Register Summary (continued)

|  | Address | Register Name                  | Bit 7                | Bit 6                    | Bit 5                    | Bit 4                    | Bit 3                    | Bit 2                    | Bit 1                    | Bit 0                    | Read/Write/Both/[7] | Default/Reset |
|--|---------|--------------------------------|----------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------|---------------|
| HUB PORT CONTROL, STATUS, SUSPEND RESUME, SE0, FORCE LOW | 0x48    | Hub Port Connect Status        | Reserved             | Port 7 Connect Status    | Port 6 Connect Status    | Port 5 Connect Status    | Port 4 Connect Status    | Port 3 Connect Status    | Port 2 Connect Status    | Port 1 Connect Status    | BBBBBBBB            | 00000000      |
|  | 0x49    | Hub Port Enable                | Reserved             | Port 7 Enable            | Port 6 Enable            | Port 5 Enable            | Port 4 Enable            | Port 3 Enable            | Port 2 Enable            | Port 1 Enable            | BBBBBBBB            | 00000000      |
|  | 0x4A    | Hub Port Speed                 | Reserved             | Port 7 Speed             | Port 6 Speed             | Port 5 Speed             | Port 4 Speed             | Port 3 Speed             | Port 2 Speed             | Port 1 Speed             | BBBBBBBB            | 00000000      |
|  | 0x4B    | Hub Port Control (Ports 4:1)   | Port 4 Control Bit 1 | Port 4 Control Bit 0     | Port 3 Control Bit 1     | Port 3 Control Bit 0     | Port 2 Control Bit 1     | Port 2 Control Bit 0     | Port 1 Control Bit 1     | Port 1 Control Bit 0     | BBBBBBBB            | 00000000      |
|  | 0x4C    | Hub Port Control (Ports 7:5)   | Reserved             | Reserved                 | Port 7 Control Bit 1     | Port 7 Control Bit 0     | Port 6 Control Bit 1     | Port 6 Control Bit 0     | Port 5 Control Bit 1     | Port 5 Control Bit 0     | --BBBBBB            | --000000      |
|  | 0x4D    | Hub Port Suspend               | Device Remote Wakeup | Port 7 Selective Suspend | Port 6 Selective Suspend | Port 5 Selective Suspend | Port 4 Selective Suspend | Port 3 Selective Suspend | Port 2 Selective Suspend | Port 1 Selective Suspend | BBBBBBBB            | 00000000      |
|  | 0x4E    | Hub Port Resume Status         | Reserved             | Resume 7                 | Resume 6                 | Resume 5                 | Resume 4                 | Resume 3                 | Resume 2                 | Resume 1                 | -RRRRRRR            | 00000000      |
|  | 0x4F    | Hub Port SE0 Status            | Reserved             | Port 7 SE0 Status        | Port 6 SE0 Status        | Port 5 SE0 Status        | Port 4 SE0 Status        | Port 3 SE0 Status        | Port 2 SE0 Status        | Port 1 SE0 Status        | RRRRRRRR            | 00000000      |
|  | 0x50    | Hub Ports Data                 | Reserved             | Port 7 Diff. Data        | Port 6 Diff. Data        | Port 5 Diff. Data        | Port 4 Diff. Data        | Port 3 Diff. Data        | Port 2 Diff. Data        | Port 1 Diff. Data        | RRRRRRRR            | 00000000      |
|  | 0x51    | Hub Port Force Low (Ports 4:1) | Force Low D+[4]      | Force Low D-[4]          | Force Low D+[3]          | Force Low D-[3]          | Force Low D+[2]          | Force Low D-[2]          | Force Low D+[1]          | Force Low D-[1]          | BBBBBBBB            | 00000000      |
|  | 0x52    | Hub Port Force Low (Ports 7:5) | Reserved             | Reserved                 | Force Low D+[7]          | Force Low D-[7]          | Force Low D+[6]          | Force Low D-[6]          | Force Low D+[5]          | Force Low D-[5]          | --BBBBBB            | 00000000      |
|  |         |                                |                      |                          |                          |                          |                          |                          |                          |                          |                     |               |
|  | 0xFF    | Process Status & Control       | IRQ Pending          | Watchdog Reset           | USB Bus Reset Interrupt  | Power-on Reset           | Suspend                  | Interrupt Enable Sense   | Reserved                 | Run                      | RBBBBRBB            | 00010001      |

## 20.0 Sample Schematic



## 21.0 Absolute Maximum Ratings

|   |                                  |
|---|----------------------------------|
| Storage Temperature .....   | -65°C to +150°C                  |
| Ambient Temperature with Power Applied .....                        | 0°C to +70°C                     |
| Supply voltage on V <sub>CC</sub> relative to V <sub>SS</sub> ..... | -0.5V to +7.0V                   |
| DC Input Voltage .....  | -0.5V to +V <sub>CC</sub> + 0.5V |
| DC Voltage applied to Outputs in High Z State .....                 | -0.5V to +V <sub>CC</sub> + 0.5V |
| Power Dissipation .....   | 500 mW                           |
| Static Discharge Voltage .....                                      | > 2000V                          |
| Latch-up Current .....  | > 200 mA                         |
| Max Output Sink Current into Port 0, 1, 2, 3 .....                  | 60 mA                            |
| Max Output Sink Current into DAC[7:2] Pins .....                    | 10 mA                            |
| Max Output Source Current from Port 1, 2, 3, 4, 5, 6, 7 .....       | 30 mA                            |

## 22.0 Electrical Characteristics

$f_{OSC} = 6 \text{ MHz}$ ; Operating Temperature = 0 to 70°C,  $V_{CC} = 4.0\text{V to }5.25\text{V}$

| Parameter                           | Description                                 | Conditions   | Min.  | Max.       | Unit          |
|-------------------------------------|---|--|-------|------------|---------------|
| <b>General</b>                      |   |  |       |            |               |
| $V_{REF}$                           | Reference Voltage                           | 3.3V $\pm 5\%$                                     | 3.15  | 3.45       | V             |
| $V_{pp}$                            | Programming Voltage (disabled)              |  | -0.4  | 0.4        | V             |
| $I_{CC}$                            | $V_{CC}$ Operating Current                  | No GPIO source current                             |       | 50         | mA            |
| $I_{SB1}$                           | Supply Current—Suspend Mode                 |  |       | 50         | $\mu\text{A}$ |
| $I_{ref}$                           | $V_{REF}$ Operating Current                 | No USB Traffic <sup>[8]</sup>                      |       | 10         | mA            |
| $I_{il}$                            | Input Leakage Current                       | Any pin  |       | 1          | $\mu\text{A}$ |
| <b>USB Interface</b>                |   |  |       |            |               |
| $V_{di}$                            | Differential Input Sensitivity              | (D+)–(D–)  | 0.2   |            | V             |
| $V_{cm}$                            | Differential Input Common Mode Range        |  | 0.8   | 2.5        | V             |
| $V_{se}$                            | Single Ended Receiver Threshold             |  | 0.8   | 2.0        | V             |
| $C_{in}$                            | Transceiver Capacitance                     |  |       | 20         | pF            |
| $I_{lo}$                            | Hi-Z State Data Line Leakage                | $0\text{V} < V_{in} < 3.3\text{V}$                 | -10   | 10         | $\mu\text{A}$ |
| $R_{ext}$                           | External USB Series Resistor                | In series with each USB pin                        | 19    | 21         | $\Omega$      |
| $R_{UUP}$                           | External Upstream USB Pull-up Resistor      | 1.5 k $\Omega$ $\pm 5\%$ , D+ to $V_{REG}$         | 1.425 | 1.575      | k $\Omega$    |
| $R_{UDN}$                           | External Downstream Pull-down Resistors     | 15 k $\Omega$ $\pm 5\%$ , downstream USB pins      | 14.25 | 15.75      | k $\Omega$    |
| <b>Power-on Reset</b>               |   |  |       |            |               |
| $t_{vccs}$                          | $V_{CC}$ Ramp Rate                          | Linear ramp 0V to $V_{CC}$ <sup>[9]</sup>          | 0     | 100        | ms            |
| <b>USB Upstream/Downstream Port</b> |   |  |       |            |               |
| $V_{UOH}$                           | Static Output High                          | 15 k $\Omega$ $\pm 5\%$ to Gnd                     | 2.8   | 3.6        | V             |
| $V_{UOL}$                           | Static Output Low                           | 1.5 k $\Omega$ $\pm 5\%$ to $V_{REF}$              |       | 0.3        | V             |
| $Z_O$                               | USB Driver Output Impedance                 | Including $R_{ext}$ Resistor                       | 28    | 44         | $\Omega$      |
| <b>General Purpose I/O (GPIO)</b>   |   |  |       |            |               |
| $R_{up}$                            | Pull-up Resistance (typical 14 k $\Omega$ ) |  | 8.0   | 24.0       | k $\Omega$    |
| $V_{ITH}$                           | Input Threshold Voltage                     | All ports, low-to-high edge                        | 20%   | 40%        | $V_{CC}$      |
| $V_H$                               | Input Hysteresis Voltage                    | All ports, high-to-low edge                        | 2%    | 8%         | $V_{CC}$      |
| $V_{OL}$                            | Port 0,1,2,3 Output Low Voltage             | $I_{OL} = 3 \text{ mA}$<br>$I_{OL} = 8 \text{ mA}$ |       | 0.4<br>2.0 | V<br>V        |
| $V_{OH}$                            | Output High Voltage                         | $I_{OH} = 1.9 \text{ mA}$ (all ports 0,1,2,3)      | 2.4   |            | V             |

## 23.0 Switching Characteristics ( $f_{OSC} = 6.0 \text{ MHz}$ )

| Parameter                                      | Description                            | Min.           | Max.   | Unit |
|--|--|----------------|--------|------|
| <b>Clock Source</b>                            |  |                |        |      |
| $f_{OSC}$                                      | Clock Rate                             | 6 $\pm 0.25\%$ |        | MHz  |
| $t_{cyc}$                                      | Clock Period                           | 166.25         | 167.08 | ns   |
| $t_{CH}$                                       | Clock HIGH time                        | 0.45 $t_{CYC}$ |        | ns   |
| $t_{CL}$                                       | Clock LOW time                         | 0.45 $t_{CYC}$ |        | ns   |
| <b>USB Full-speed Signaling<sup>[10]</sup></b> |  |                |        |      |
| $t_{rfs}$                                      | Transition Rise Time                   | 4              | 20     | ns   |
| $t_{ffs}$                                      | Transition Fall Time                   | 4              | 20     | ns   |
| $t_{rfmfs}$                                    | Rise/Fall Time Matching; ( $t_r/t_f$ ) | 90             | 111    | %    |

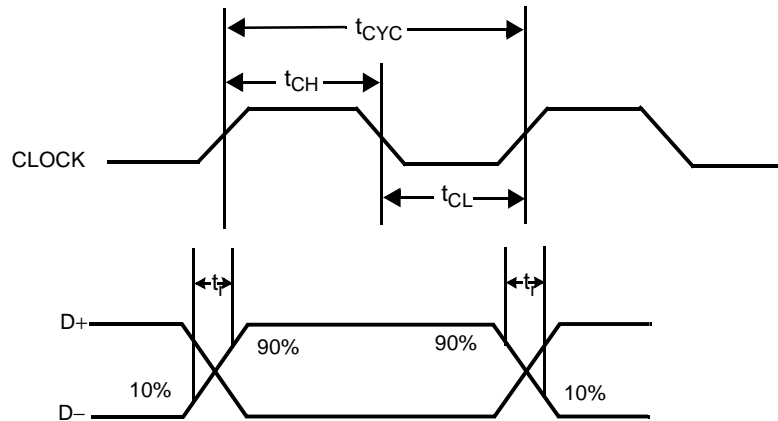
**Notes:**

8. Add 18 mA per driven USB cable (upstream or downstream). This is based on transitions every 2 full-speed bit times on average.
9. Power-on Reset occurs whenever the voltage on  $V_{CC}$  is below approximately 2.5V.
10. Per Table 7-6 of revision 1.1 of USB specification.

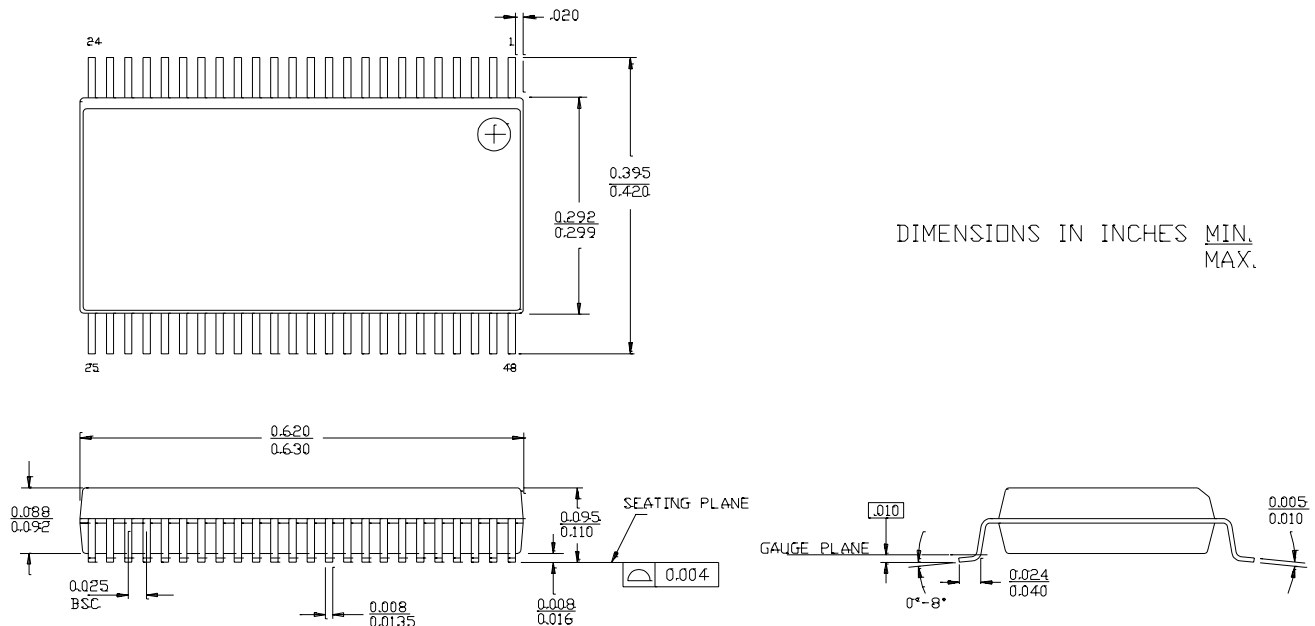


**23.0 Switching Characteristics** ( $f_{OSC} = 6.0 \text{ MHz}$ ) (continued)

|                      |                       |                |        |      |
|----------------------|-----------------------|----------------|--------|------|
| $t_{dratefs}$        | Full Speed Data Rate  | 12 $\pm$ 0.25% |        | Mb/s |
| <b>Timer Signals</b> |                       |                |        |      |
| $t_{watch}$          | Watchdog Timer Period | 8.192          | 14.336 | ms   |


**24.0 Ordering Information**

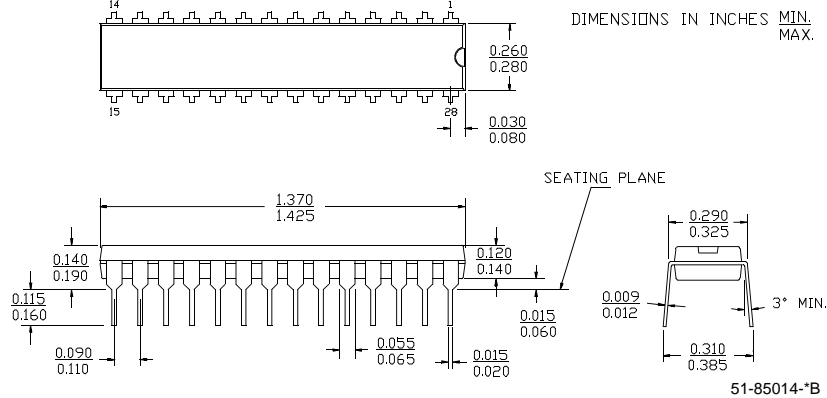
| Ordering Code | PROM Size | Package Name | Package Type          | Operating Range |
|---------------|-----------|--------------|-----------------------|-----------------|
| CY7C65013-PVC | 8 KB      | O48          | 48-pin (300-Mil) SSOP | Commercial      |
| CY7C65113-SC  | 8 KB      | S21          | 28-pin SOIC           | Commercial      |
| CY7C65013-PC  | 8 KB      | P25          | 48-pin (600 Mil) PDIP | Commercial      |
| CY7C65113-PC  | 8 KB      | P21          | 28-pin (300-Mil) PDIP | Commercial      |

**25.0 Package Diagrams**
**48-lead Shrunken Small Outline Package O48**


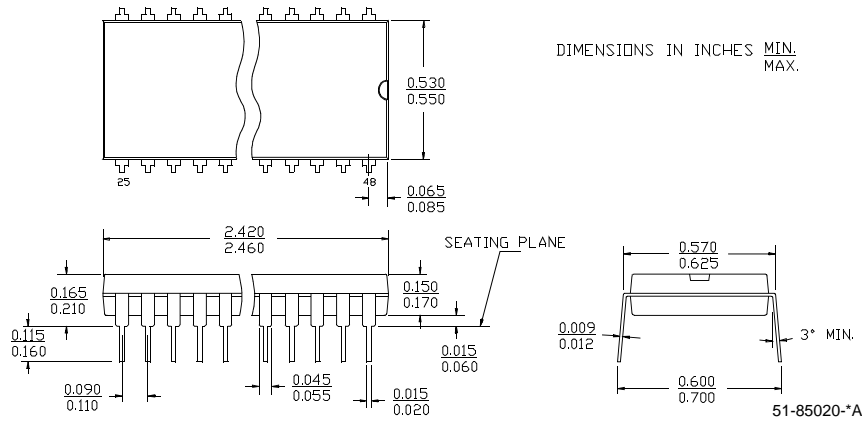
51-85061-°C

**25.0 Package Diagrams (continued)**

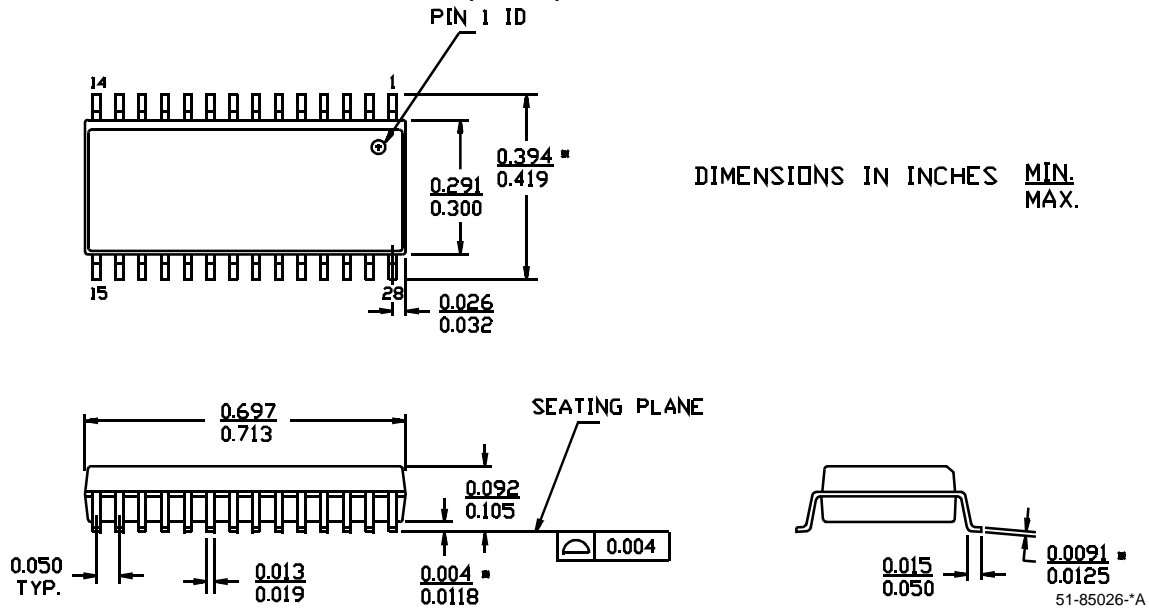
**28-lead (300-Mil) Molded DIP P21**



**48-lead (600-Mil) Molded DIP P25**



**28-lead (300-Mil) Molded SOIC S21**



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**Document History Page**

| Document Title: CY7C65013/CY7C65113 USB Hub with Microcontroller |         |            |                 |   |
|--|---------|------------|-----------------|---|
| Document Number: 38-08002  |         |            |                 |   |
| REV.   | ECN NO. | Issue Date | Orig. of Change | Description of Change   |
| **   | 109965  | 02/22/02   | SZV             | Change from Spec number: 38-00590 to 38-08002   |
| *A   | 120372  | 12/17/02   | MON             | Added register bit definitions.<br>Added default bit state of each register.<br>Corrected the Schematic (location of the pull-up on D+).<br>Corrected the Logical Diagram (removed the extra GPIO Port 1).<br>Added register summary.<br>Modified <i>Figure 17-5</i> , more labeling.<br>Removed information on the availability of the part in PDIP package.<br>Modified <i>Table 18-1</i> and provided more explanation regarding locking/unlocking mechanism of the mode register.<br>Removed any information regarding the speed detect bit in Hub Port Speed register being set by hardware. |
| *B   | 124522  | 03/13/03   | MON             | Fixed the figure on page 42 regarding the update of mode registers. The arrows in the figure were misplaced and the figure was unreadable. This is an important figure for understanding mode register functioning.   |