



MICROCHIP

PIC16C63A/65B/73B/74B

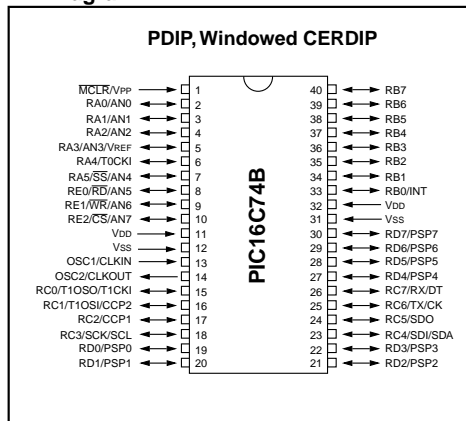
28/40-Pin 8-Bit CMOS Microcontrollers

| Device | Pins | A/D | PSP |
|-----------|------|-----|-----|
| PIC16C63A | 28 | NO | NO |
| PIC16C73B | 28 | YES | NO |
| PIC16C65B | 40 | NO | YES |
| PIC16C74B | 40 | YES | YES |

Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
DC - 200 ns instruction cycle
- 4K x 14 words of Program Memory,
192 x 8 bytes of Data Memory (RAM)
- Interrupt capability (up to 12 internal/external interrupt sources)
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS EPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP)
- Wide operating voltage range: 2.5V to 5.5V
- High Sink/Source Current 25/25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
 - < 2 mA @ 5V, 4 MHz
 - 22.5 µA typical @ 3V, 32 kHz
 - < 1 µA typical standby current

Pin Diagram



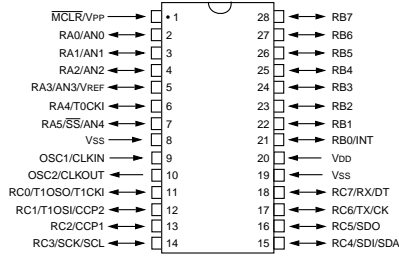
Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
- Capture is 16-bit, max. resolution is 12.5 ns, Compare is 16-bit, max. resolution is 200 ns, PWM maximum resolution is 10-bit
- 8-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with Enhanced SPI™ and I²C™
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI)
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls
- Brown-out detection circuitry for Brown-out Reset (BOR)

PIC16C63A/65B/73B/74B

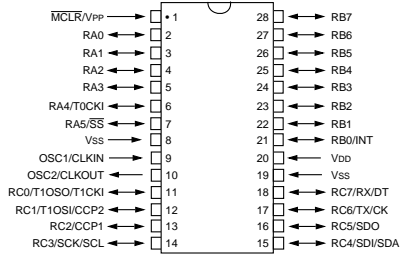
Pin Diagrams

SDIP, SOIC, SSOP, Windowed CERDIP



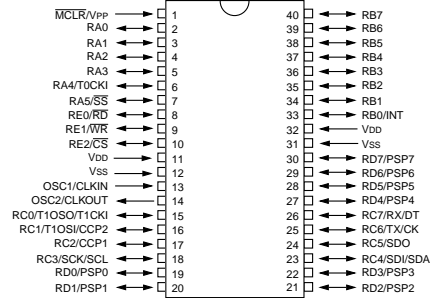
PIC16C73B

SDIP, SOIC, SSOP, Windowed CERDIP



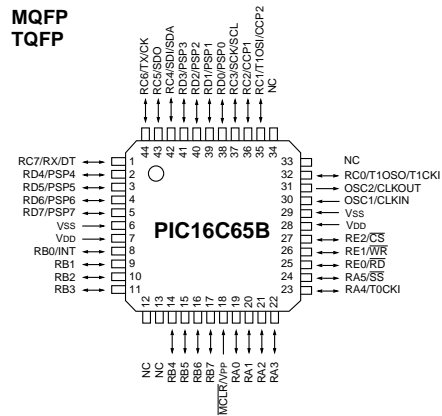
PIC16C63A

PDIP, Windowed CERDIP

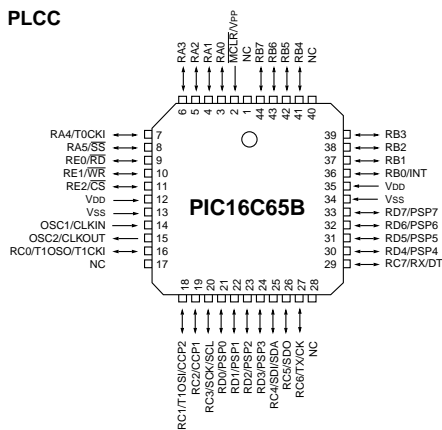


PIC16C65B

MQFP
TQFP

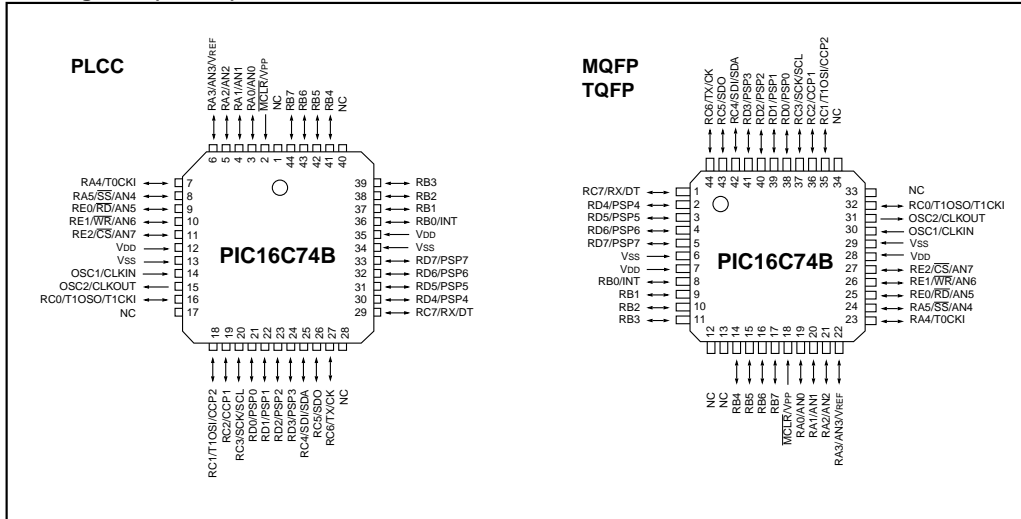


PLCC



PIC16C63A/65B/73B/74B

Pin Diagrams (Cont'd)



| Key Features PICmicro™ Mid-Range Reference Manual (DS33023) | PIC16C63A | PIC16C65B | PIC16C73B | PIC16C74B |
|---|-------------------------|-------------------------|-------------------------|-------------------------|
| Operating Frequency | DC - 20 MHz | DC - 20 MHz | DC - 20 MHz | DC - 20 MHz |
| Resets (and Delays) | POR, BOR (PWRT, OST) | POR, BOR (PWRT, OST) | POR, BOR (PWRT, OST) | POR, BOR (PWRT, OST) |
| Program Memory (14-bit words) | 4K | 4K | 4K | 4K |
| Data Memory (bytes) | 192 | 192 | 192 | 192 |
| Interrupts | 10 | 11 | 11 | 12 |
| I/O Ports | Ports A,B,C | Ports A,B,C,D,E | Ports A,B,C | Ports A,B,C,D,E |
| Timers | 3 | 3 | 3 | 3 |
| Capture/Compare/PWM modules | 2 | 2 | 2 | 2 |
| Serial Communications | SSP, USART | SSP, USART | SSP, USART | SSP, USART |
| Parallel Communications | — | PSP | — | PSP |
| 8-bit Analog-to-Digital Module | — | — | 5 input channels | 8 input channels |
| Instruction Set | 35 Instructions | 35 Instructions | 35 Instructions | 35 Instructions |

PIC16C63A/65B/73B/74B

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An errata sheet may exist for current devices, describing minor operational differences (from the data sheet) and recommended workarounds. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

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We appreciate your assistance in making this a better document.

PIC16C63A/65B/73B/74B

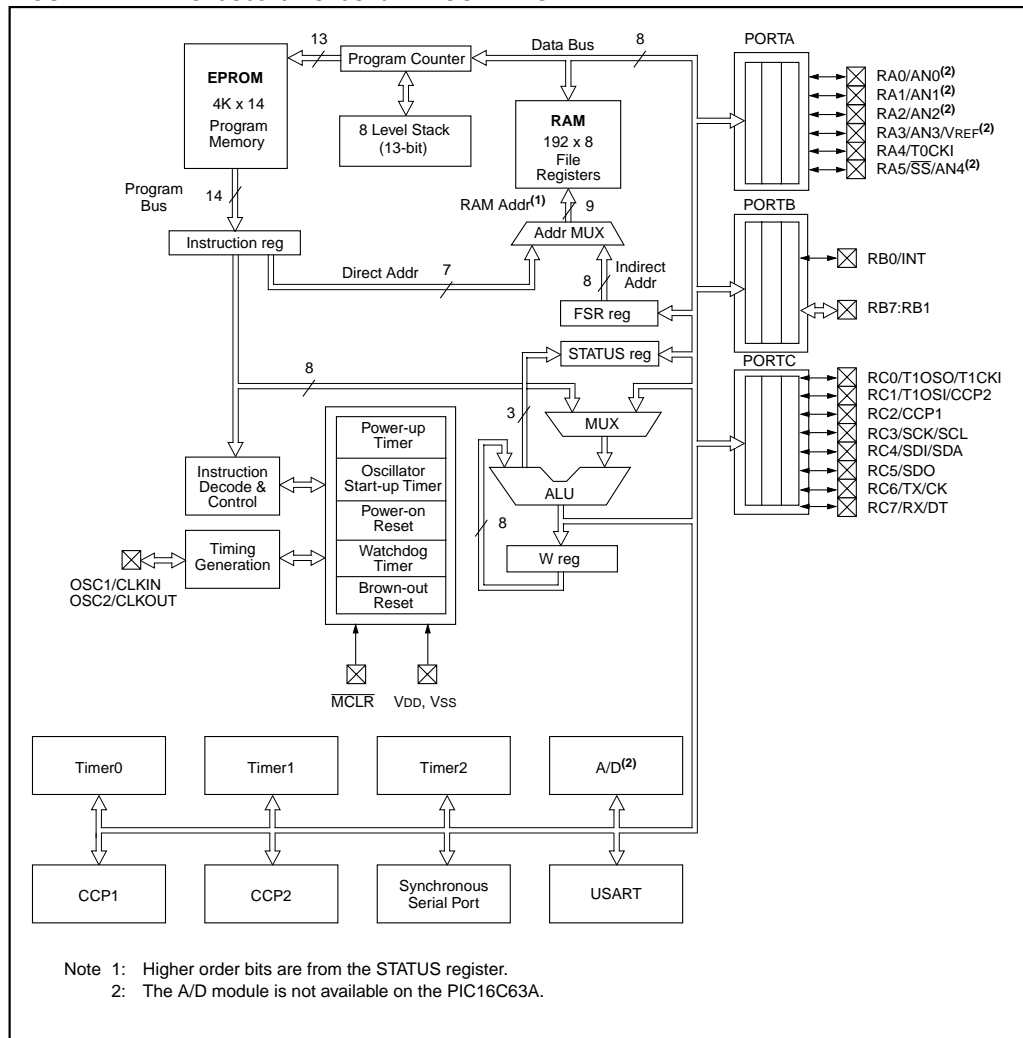
1.0 DEVICE OVERVIEW

This document contains device-specific information. Additional information may be found in the PICmicro™ Mid-Range Reference Manual (DS33023) which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip web site. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

There are four devices (PIC16C63A, PIC16C65B, PIC16C73B, PIC16C74B) covered by this data sheet. These devices come in 28- and 40-pin packages. The 28-pin devices do not have a Parallel Slave Port implemented. The PIC16C6X devices do not have the A/D module implemented.

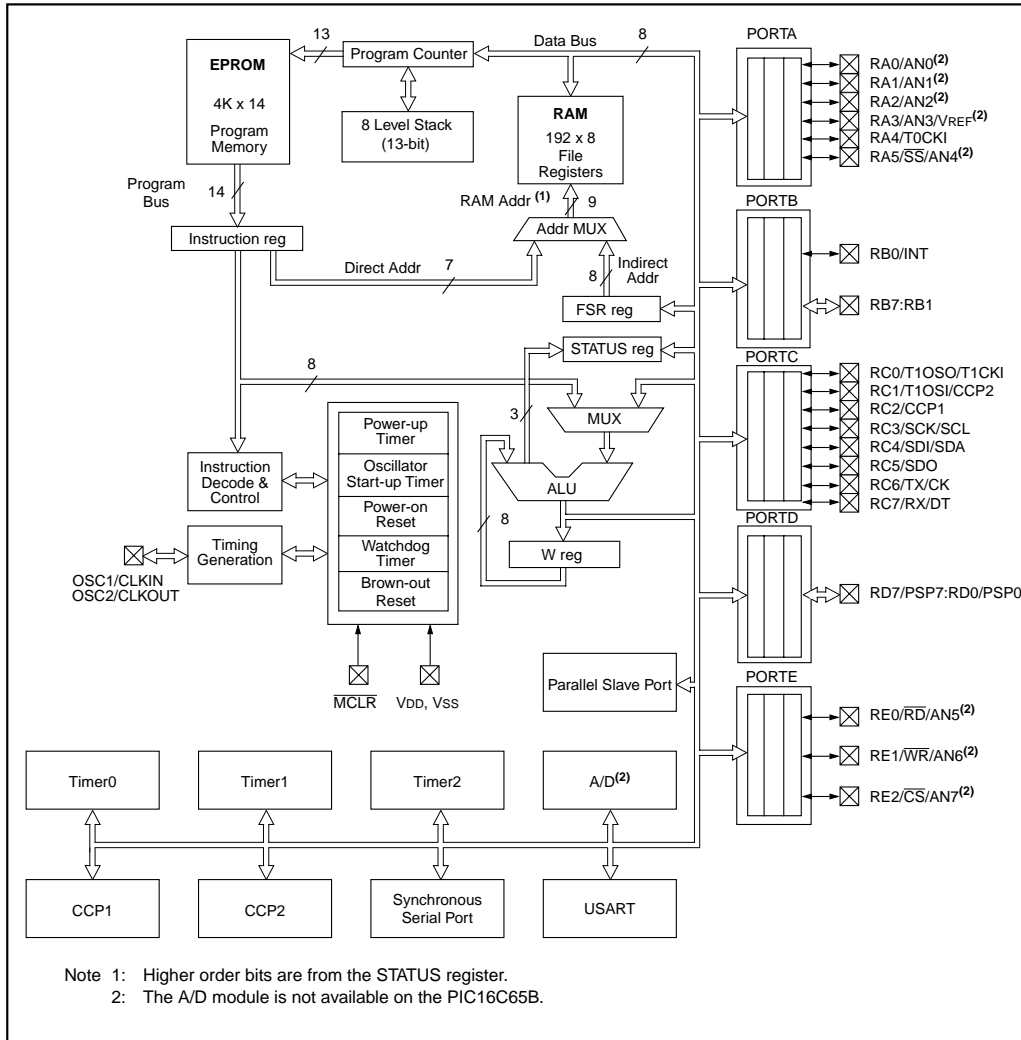
The following two figures are device block diagrams sorted by pin number; 28-pin for Figure 1-1 and 40-pin for Figure 1-2. The 28-pin and 40-pin pinouts are listed in Table 1-1 and Table 1-2 respectively.

FIGURE 1-1: PIC16C63A/PIC16C73B BLOCK DIAGRAM



PIC16C63A/65B/73B/74B

FIGURE 1-2: PIC16C65B/PIC16C74B BLOCK DIAGRAM



PIC16C63A/65B/73B/74B

TABLE 1-1: PIC16C63A/PIC16C73B PINOUT DESCRIPTION

| Pin Name | DIP Pin# | SOIC Pin# | I/O/P Type | Buffer Type | Description |
|-----------------------------|----------|-----------|------------|------------------------|--|
| OSC1/CLKIN | 9 | 9 | I | ST/CMOS ⁽³⁾ | Oscillator crystal input/external clock source input. |
| OSC2/CLKOUT | 10 | 10 | O | — | Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate. |
| MCLR/VPP | 1 | 1 | I/P | ST | Master clear (reset) input or programming voltage input. This pin is an active low reset to the device. |
| RA0/AN0 ⁽⁴⁾ | 2 | 2 | I/O | TTL | PORTA is a bi-directional I/O port. RA0 can also be analog input0 RA1 can also be analog input1 RA2 can also be analog input2 RA3 can also be analog input3 or analog reference voltage RA4 can also be the clock input to the Timer0 module. Output is open drain type. RA5 can also be analog input4 or the slave select for the synchronous serial port. |
| RA1/AN1 ⁽⁴⁾ | 3 | 3 | I/O | TTL | |
| RA2/AN2 ⁽⁴⁾ | 4 | 4 | I/O | TTL | |
| RA3/AN3/VREF ⁽⁴⁾ | 5 | 5 | I/O | TTL | |
| RA4/T0CKI | 6 | 6 | I/O | ST | |
| RA5/SS/AN4 ⁽⁴⁾ | 7 | 7 | I/O | TTL | |
| RB0/INT | 21 | 21 | I/O | TTL/ST ⁽¹⁾ | PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs. RB0 can also be the external interrupt pin. Interrupt on change pin. Interrupt on change pin. Interrupt on change pin. Serial programming clock. Interrupt on change pin. Serial programming data. |
| RB1 | 22 | 22 | I/O | TTL | |
| RB2 | 23 | 23 | I/O | TTL | |
| RB3 | 24 | 24 | I/O | TTL | |
| RB4 | 25 | 25 | I/O | TTL | |
| RB5 | 26 | 26 | I/O | TTL | |
| RB6 | 27 | 27 | I/O | TTL/ST ⁽²⁾ | |
| RB7 | 28 | 28 | I/O | TTL/ST ⁽²⁾ | |
| RC0/T1OSO/T1CKI | 11 | 11 | I/O | ST | PORTC is a bi-directional I/O port. RC0 can also be the Timer1 oscillator output or Timer1 clock input. RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output. RC2 can also be the Capture1 input/Compare1 output/PWM1 output. RC3 can also be the synchronous serial clock input/output for both SPI and I ² C modes. RC4 can also be the SPI Data In (SPI mode) or data I/O (I ² C mode). RC5 can also be the SPI Data Out (SPI mode). RC6 can also be the USART Asynchronous Transmit or Synchronous Clock. RC7 can also be the USART Asynchronous Receive or Synchronous Data. |
| RC1/T1OSI/CCP2 | 12 | 12 | I/O | ST | |
| RC2/CCP1 | 13 | 13 | I/O | ST | |
| RC3/SCK/SCL | 14 | 14 | I/O | ST | |
| RC4/SDI/SDA | 15 | 15 | I/O | ST | |
| RC5/SDO | 16 | 16 | I/O | ST | |
| RC6/TX/CK | 17 | 17 | I/O | ST | |
| RC7/RX/DT | 18 | 18 | I/O | ST | |
| Vss | 8, 19 | 8, 19 | P | — | Ground reference for logic and I/O pins. |
| VDD | 20 | 20 | P | — | Positive supply for logic and I/O pins. |

Legend: I = input O = output I/O = input/output P = power
 — = Not used TTL = TTL input ST = Schmitt Trigger input

- Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
 2: This buffer is a Schmitt Trigger input when used in serial programming mode.
 3: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.
 4: The A/D module is not available on the PIC16C63A.

PIC16C63A/65B/73B/74B

TABLE 1-2: PIC16C65B/PIC16C74B PINOUT DESCRIPTION

| Pin Name | DIP Pin# | PLCC Pin# | QFP Pin# | I/O/P Type | Buffer Type | Description |
|-----------------------------|----------|-----------|----------|------------|------------------------|--|
| OSC1/CLKIN | 13 | 14 | 30 | I | ST/CMOS ⁽⁴⁾ | Oscillator crystal input/external clock source input. |
| OSC2/CLKOUT | 14 | 15 | 31 | O | — | Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate. |
| MCLR/VPP | 1 | 2 | 18 | I/P | ST | Master clear (reset) input or programming voltage input. This pin is an active low reset to the device. |
| RA0/AN0 ⁽⁵⁾ | 2 | 3 | 19 | I/O | TTL | PORTA is a bi-directional I/O port. RA0 can also be analog input0 RA1 can also be analog input1 RA2 can also be analog input2 RA3 can also be analog input3 or analog reference voltage RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type. RA5 can also be analog input4 or the slave select for the synchronous serial port. |
| RA1/AN1 ⁽⁵⁾ | 3 | 4 | 20 | I/O | TTL | |
| RA2/AN2 ⁽⁵⁾ | 4 | 5 | 21 | I/O | TTL | |
| RA3/AN3/VREF ⁽⁵⁾ | 5 | 6 | 22 | I/O | TTL | |
| RA4/T0CKI | 6 | 7 | 23 | I/O | ST | |
| RA5/SS/AN4 ⁽⁵⁾ | 7 | 8 | 24 | I/O | TTL | |
| RB0/INT | 33 | 36 | 8 | I/O | TTL/ST ⁽¹⁾ | PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs. RB0 can also be the external interrupt pin. Interrupt on change pin. Interrupt on change pin. Interrupt on change pin. Serial programming clock. Interrupt on change pin. Serial programming data. |
| RB1 | 34 | 37 | 9 | I/O | TTL | |
| RB2 | 35 | 38 | 10 | I/O | TTL | |
| RB3 | 36 | 39 | 11 | I/O | TTL | |
| RB4 | 37 | 41 | 14 | I/O | TTL | |
| RB5 | 38 | 42 | 15 | I/O | TTL | |
| RB6 | 39 | 43 | 16 | I/O | TTL/ST ⁽²⁾ | |
| RB7 | 40 | 44 | 17 | I/O | TTL/ST ⁽²⁾ | |

Legend: I = input O = output I/O = input/output P = power
 — = Not used TTL = TTL input ST = Schmitt Trigger input

- Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
 2: This buffer is a Schmitt Trigger input when used in serial programming mode.
 3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
 4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.
 5: The A/D module is not available on the PIC16C65B.

PIC16C63A/65B/73B/74B

TABLE 1-2: PIC16C65B/PIC16C74B PINOUT DESCRIPTION (Cont'd)

| Pin Name | DIP Pin# | PLCC Pin# | QFP Pin# | I/O/P Type | Buffer Type | Description |
|--|----------|------------|-------------|------------|-----------------------|--|
| RC0/T1OSO/T1CKI | 15 | 16 | 32 | I/O | ST | PORTC is a bi-directional I/O port. RC0 can also be the Timer1 oscillator output or a Timer1 clock input. |
| RC1/T1OSI/CCP2 | 16 | 18 | 35 | I/O | ST | RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output. |
| RC2/CCP1 | 17 | 19 | 36 | I/O | ST | RC2 can also be the Capture1 input/Compare1 output/PWM1 output. |
| RC3/SCK/SCL | 18 | 20 | 37 | I/O | ST | RC3 can also be the synchronous serial clock input/output for both SPI and I ² C modes. |
| RC4/SDI/SDA | 23 | 25 | 42 | I/O | ST | RC4 can also be the SPI Data In (SPI mode) or data I/O (I ² C mode). |
| RC5/SDO | 24 | 26 | 43 | I/O | ST | RC5 can also be the SPI Data Out (SPI mode). |
| RC6/TX/CK | 25 | 27 | 44 | I/O | ST | RC6 can also be the USART Asynchronous Transmit or Synchronous Clock. |
| RC7/RX/DT | 26 | 29 | 1 | I/O | ST | RC7 can also be the USART Asynchronous Receive or Synchronous Data. |
| RD0/PSP0 | 19 | 21 | 38 | I/O | ST/TTL ⁽³⁾ | PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus. |
| RD1/PSP1 | 20 | 22 | 39 | I/O | ST/TTL ⁽³⁾ | |
| RD2/PSP2 | 21 | 23 | 40 | I/O | ST/TTL ⁽³⁾ | |
| RD3/PSP3 | 22 | 24 | 41 | I/O | ST/TTL ⁽³⁾ | |
| RD4/PSP4 | 27 | 30 | 2 | I/O | ST/TTL ⁽³⁾ | |
| RD5/PSP5 | 28 | 31 | 3 | I/O | ST/TTL ⁽³⁾ | |
| RD6/PSP6 | 29 | 32 | 4 | I/O | ST/TTL ⁽³⁾ | |
| RD7/PSP7 | 30 | 33 | 5 | I/O | ST/TTL ⁽³⁾ | |
| RE0/ \overline{RD} /AN5 ⁽⁵⁾ | 8 | 9 | 25 | I/O | ST/TTL ⁽³⁾ | PORTE is a bi-directional I/O port. RE0 can also be read control for the parallel slave port, or analog input5. |
| RE1/ \overline{WR} /AN6 ⁽⁵⁾ | 9 | 10 | 26 | I/O | ST/TTL ⁽³⁾ | RE1 can also be write control for the parallel slave port, or analog input6. |
| RE2/ \overline{CS} /AN7 ⁽⁵⁾ | 10 | 11 | 27 | I/O | ST/TTL ⁽³⁾ | RE2 can also be select control for the parallel slave port, or analog input7. |
| V _{SS} | 12,31 | 13,34 | 6,29 | P | — | Ground reference for logic and I/O pins. |
| V _{DD} | 11,32 | 12,35 | 7,28 | P | — | Positive supply for logic and I/O pins. |
| NC | — | 1,17,28,40 | 12,13,33,34 | | — | These pins are not internally connected. These pins should be left unconnected. |

Legend: I = input O = output I/O = input/output P = power
 — = Not used TTL = TTL input ST = Schmitt Trigger input

- Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
 2: This buffer is a Schmitt Trigger input when used in serial programming mode.
 3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
 4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.
 5: The A/D module is not available on the PIC16C65B.

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NOTES:

PIC16C63A/65B/73B/74B

2.0 MEMORY ORGANIZATION

There are two memory blocks in each of these PICmicro microcontrollers. Each block (Program Memory and Data Memory) has its own bus so that concurrent access can occur.

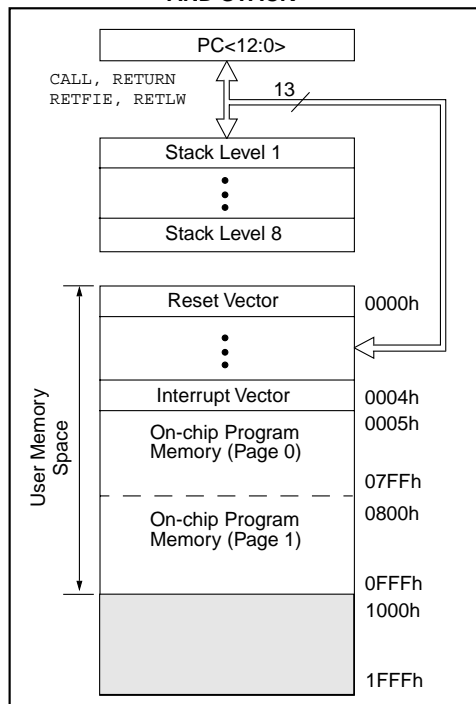
Additional information on device memory may be found in the PICmicro™ Mid-Range Reference Manual (DS33023).

2.1 Program Memory Organization

The PIC16C63A/65B/73B/74B microcontrollers have a 13-bit program counter capable of addressing an 8K x 14 program memory space. Each device has 4K x 14 words of program memory. Accessing a location above the physically implemented address will cause a wrap-around.

The reset vector is at 0000h and the interrupt vector is at 0004h.

FIGURE 2-1: PROGRAM MEMORY MAP AND STACK



2.2 Data Memory Organization

The data memory is partitioned into multiple banks which contain the General Purpose Registers and the Special Function Registers. Bits RP1 and RP0 are the bank select bits.

RP1⁽¹⁾ RP0 (STATUS<6:5>)

- = 00 → Bank0
- = 01 → Bank1
- = 10 → Bank2 (not implemented)
- = 11 → Bank3 (not implemented)

Note 1: Maintain this bit clear to ensure upward compatibility with future products.

Each bank extends up to 7Fh (128 bytes). The lower locations of each bank are reserved for the Special Function Registers. Above the Special Function Registers are General Purpose Registers, implemented as static RAM. All implemented banks contain special function registers. Some "high use" special function registers from one bank may be mirrored in another bank for code reduction and quicker access.

2.2.1 GENERAL PURPOSE REGISTER FILE

The register file can be accessed either directly, or indirectly through the File Select Register FSR (Section 2.5).

PIC16C63A/65B/73B/74B

FIGURE 2-2: REGISTER FILE MAP

| File Address | | | File Address |
|--------------|--------------------------|--------------------------|--------------|
| 00h | INDF ⁽¹⁾ | INDF ⁽¹⁾ | 80h |
| 01h | TMR0 | OPTION_REG | 81h |
| 02h | PCL | PCL | 82h |
| 03h | STATUS | STATUS | 83h |
| 04h | FSR | FSR | 84h |
| 05h | PORTA | TRISA | 85h |
| 06h | PORTB | TRISB | 86h |
| 07h | PORTC | TRISC | 87h |
| 08h | PORTD ⁽²⁾ | TRISD ⁽²⁾ | 88h |
| 09h | PORTE ⁽²⁾ | TRISE ⁽²⁾ | 89h |
| 0Ah | PCLATH | PCLATH | 8Ah |
| 0Bh | INTCON | INTCON | 8Bh |
| 0Ch | PIR1 | PIE1 | 8Ch |
| 0Dh | PIR2 | PIE2 | 8Dh |
| 0Eh | TMR1L | PCON | 8Eh |
| 0Fh | TMR1H | | 8Fh |
| 10h | T1CON | | 90h |
| 11h | TMR2 | | 91h |
| 12h | T2CON | PR2 | 92h |
| 13h | SSPBUF | SSPADD | 93h |
| 14h | SSPCON | SSPSTAT | 94h |
| 15h | CCPR1L | | 95h |
| 16h | CCPR1H | | 96h |
| 17h | CCP1CON | | 97h |
| 18h | RCSTA | TXSTA | 98h |
| 19h | TXREG | SPBRG | 99h |
| 1Ah | RCREG | | 9Ah |
| 1Bh | CCPR2L | | 9Bh |
| 1Ch | CCPR2H | | 9Ch |
| 1Dh | CCP2CON | | 9Dh |
| 1Eh | ADRES ⁽³⁾ | | 9Eh |
| 1Fh | ADCON0 ⁽³⁾ | ADCON1 ⁽³⁾ | 9Fh |
| 20h | | | A0h |
| | General Purpose Register | General Purpose Register | |
| 7Fh | | | FFh |
| | Bank 0 | Bank 1 | |

Unimplemented data memory locations, read as '0'.

Note 1: Not a physical register.
Note 2: These registers are not implemented on the PIC16C63A/73B, read as '0'.
Note 3: These registers are not implemented on the PIC16C63A/65B, read as '0'.

2.2.2 SPECIAL FUNCTION REGISTERS

The Special Function Registers are registers used by the CPU and Peripheral Modules for controlling the desired operation of the device. These registers are implemented as static RAM. A list of these registers is given in Table 2-1.

The special function registers can be classified into two sets; core (CPU) and peripheral. Those registers associated with the core functions are described in detail in this section. Those related to the operation of the peripheral features are described in detail in that peripheral feature section.

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TABLE 2-1 SPECIAL FUNCTION REGISTER SUMMARY

| Addr | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets (5) |
|---------------|-------------------------|--|---------------------|---|--|---------|-----------------|---------|---------|-------------------|-------------------------------|
| Bank 0 | | | | | | | | | | | |
| 00h | INDF ⁽¹⁾ | Addressing this location uses contents of FSR to address data memory (not a physical register) | | | | | | | | 0000 0000 | 0000 0000 |
| 01h | TMR0 | Timer0 module's register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 02h | PCL ⁽¹⁾ | Program Counter's (PC) Least Significant Byte | | | | | | | | 0000 0000 | 0000 0000 |
| 03h | STATUS ⁽¹⁾ | IRP ⁽⁶⁾ | RP1 ⁽⁶⁾ | RP0 | TO | PD | Z | DC | C | rr01 1xxxx | rr0q quuu |
| 04h | FSR ⁽¹⁾ | Indirect data memory address pointer | | | | | | | | xxxx xxxx | uuuu uuuu |
| 05h | PORTA ⁽⁷⁾ | — | — | PORTA Data Latch when written: PORTA pins when read | | | | | | --0x 0000 | --0u 0000 |
| 06h | PORTB ⁽⁸⁾ | PORTB Data Latch when written: PORTB pins when read | | | | | | | | xxxx xxxx | uuuu uuuu |
| 07h | PORTC ⁽⁸⁾ | PORTC Data Latch when written: PORTC pins when read | | | | | | | | xxxx xxxx | uuuu uuuu |
| 08h | PORTD ^(3,8) | PORTD Data Latch when written: PORTD pins when read | | | | | | | | xxxx xxxx | uuuu uuuu |
| 09h | PORTE ^(3,8) | — | — | — | — | — | RE2 | RE1 | RE0 | ---- -xxx | ---- -uuu |
| 0Ah | PCLATH ^(1,2) | — | — | — | Write Buffer for the upper 5 bits of the Program Counter | | | | | --0 0000 | --0 0000 |
| 0Bh | INTCON ⁽¹⁾ | GIE | PEIE | TOIE | INTE | RBIE | TOIF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | PSPIF ⁽³⁾ | ADIF ⁽⁴⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 0Dh | PIR2 | — | — | — | — | — | — | — | CCP2IF | ---- --0 | ---- --0 |
| 0Eh | TMR1L | Holding register for the Least Significant Byte of the 16-bit TMR1 register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 0Fh | TMR1H | Holding register for the Most Significant Byte of the 16-bit TMR1 register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 10h | T1CON | — | — | T1CKPS1 | T1CKPS0 | T1OSCEN | T1SYN \bar{C} | TMR1CS | TMR1ON | --00 0000 | --uu uuuu |
| 11h | TMR2 | Timer2 module's register | | | | | | | | 0000 0000 | 0000 0000 |
| 12h | T2CON | — | TOUTPS3 | TOUTPS2 | TOUTPS1 | TOUTPS0 | TMR2ON | T2CKPS1 | T2CKPS0 | -000 0000 | -000 0000 |
| 13h | SSPBUF | Synchronous Serial Port Receive Buffer/Transmit Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 14h | SSPCON | WCOL | SSPOV | SSPEN | CKP | SSPM3 | SSPM2 | SSPM1 | SSPM0 | 0000 0000 | 0000 0000 |
| 15h | CCPR1L | Capture/Compare/PWM Register1 (LSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 16h | CCPR1H | Capture/Compare/PWM Register1 (MSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 17h | CCP1CON | — | — | CCP1X | CCP1Y | CCP1M3 | CCP1M2 | CCP1M1 | CCP1M0 | --00 0000 | --00 0000 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 19h | TXREG | USART Transmit Data Register | | | | | | | | 0000 0000 | 0000 0000 |
| 1Ah | RCREG | USART Receive Data Register | | | | | | | | 0000 0000 | 0000 0000 |
| 1Bh | CCPR2L | Capture/Compare/PWM Register2 (LSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 1Ch | CCPR2H | Capture/Compare/PWM Register2 (MSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 1Dh | CCP2CON | — | — | CCP2X | CCP2Y | CCP2M3 | CCP2M2 | CCP2M1 | CCP2M0 | --00 0000 | --00 0000 |
| 1Eh | ADRES ⁽⁴⁾ | A/D Result Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 1Fh | ADCON0 ⁽⁴⁾ | ADCS1 | ADCS0 | CHS2 | CHS1 | CHS0 | GO/DONE | — | ADON | 0000 00-0 | 0000 00-0 |

Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', Shaded locations are unimplemented, read as '0'.

- Note 1: These registers can be addressed from either bank.
 2: The upper byte of the program counter is not directly accessible. PCLATH is a holding register for PC<12:8> whose contents are transferred to the upper byte of the program counter.
 3: PORTD and PORTE are not implemented on the PIC16C63A/73B, maintain as '0'.
 4: A/D not implemented on the PIC16C63A/65B, maintain as '0'.
 5: Other (non power-up) resets include: external reset through \overline{MCLR} and the Watchdog Timer Reset.
 6: The IRP and RP1 bits are reserved. Always maintain these bits clear.
 7: On any device reset, these pins are configured as inputs.
 8: This is the value that will be in the port output latch.

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TABLE 2-1 SPECIAL FUNCTION REGISTER SUMMARY (Cont'd)

| Addr | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets (5) |
|---------------|-------------------------|--|---------------------|-------------------------------|--|----------------|---------------------------|--------|--------|-------------------|-------------------------------|
| Bank 1 | | | | | | | | | | | |
| 80h | INDF ⁽¹⁾ | Addressing this location uses contents of FSR to address data memory (not a physical register) | | | | | | | | 0000 0000 | 0000 0000 |
| 81h | OPTION_REG | RBP _U | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 | 1111 1111 | 1111 1111 |
| 82h | PCL ⁽¹⁾ | Program Counter's (PC) Least Significant Byte | | | | | | | | 0000 0000 | 0000 0000 |
| 83h | STATUS ⁽¹⁾ | IRP ⁽⁶⁾ | RP1 ⁽⁶⁾ | RP0 | T _O | P _D | Z | DC | C | rr01 lxxx | rr0q quuu |
| 84h | FSR ⁽¹⁾ | Indirect data memory address pointer | | | | | | | | xxxx xxxx | uuuu uuuu |
| 85h | TRISA | — | — | PORTA Data Direction Register | | | | | | --11 1111 | --11 1111 |
| 86h | TRISB | PORTB Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 87h | TRISC | PORTC Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 88h | TRISD ⁽³⁾ | PORTD Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 89h | TRISE ⁽³⁾ | IBF | OBF | IBOV | PSPMODE | — | PORTE Data Direction Bits | | | 0000 -111 | 0000 -111 |
| 8Ah | PCLATH ^(1,2) | — | — | — | Write Buffer for the upper 5 bits of the Program Counter | | | | | ---0 0000 | ---0 0000 |
| 8Bh | INTCON ⁽¹⁾ | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 8Ch | PIE1 | PSPIE ⁽³⁾ | ADIE ⁽⁴⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 8Dh | PIE2 | — | — | — | — | — | — | — | CCP2IE | ---- -000 | ---- -000 |
| 8Eh | PCON | — | — | — | — | — | — | POR | BOR | ---- -pq | ---- -uu |
| 8Fh | — | Unimplemented | | | | | | | | — | — |
| 90h | — | Unimplemented | | | | | | | | — | — |
| 91h | — | Unimplemented | | | | | | | | — | — |
| 92h | PR2 | Timer2 Period Register | | | | | | | | 1111 1111 | 1111 1111 |
| 93h | SSPADD | Synchronous Serial Port (I ² C mode) Address Register | | | | | | | | 0000 0000 | 0000 0000 |
| 94h | SSPSTAT | SMP | CKE | D/ _A | P | S | R/ _W | UA | BF | 0000 0000 | 0000 0000 |
| 95h | — | Unimplemented | | | | | | | | — | — |
| 96h | — | Unimplemented | | | | | | | | — | — |
| 97h | — | Unimplemented | | | | | | | | — | — |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |
| 9Ah | — | Unimplemented | | | | | | | | — | — |
| 9Bh | — | Unimplemented | | | | | | | | — | — |
| 9Ch | — | Unimplemented | | | | | | | | — | — |
| 9Dh | — | Unimplemented | | | | | | | | — | — |
| 9Eh | — | Unimplemented | | | | | | | | — | — |
| 9Fh | ADCON1 ⁽⁴⁾ | — | — | — | — | — | PCFG2 | PCFG1 | PCFG0 | ---- -000 | ---- -000 |

Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', Shaded locations are unimplemented, read as '0'.

- Note 1: These registers can be addressed from either bank.
- The upper byte of the program counter is not directly accessible. PCLATH is a holding register for PC<12:8> whose contents are transferred to the upper byte of the program counter.
 - PORTD and PORTE are not implemented on the PIC16C63A/73B, maintain as '0'.
 - A/D not implemented on the PIC16C63A/65B, maintain as '0'.
 - Other (non power-up) resets include: external reset through MCLR and the Watchdog Timer Reset.
 - The IRP and RP1 bits are reserved. Always maintain these bits clear.
 - On any device reset, these pins are configured as inputs.
 - This is the value that will be in the port output latch.

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2.2.2.1 STATUS REGISTER

The STATUS register, shown in Figure 2-3, contains the arithmetic status of the ALU, the RESET status and the bank select bits for data memory.

The STATUS register can be the destination for any instruction, as with any other register. If the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the \overline{TO} and \overline{PD} bits are not writable. Therefore, the result of an instruction with the STATUS register as destination may be different than intended.

For example, `CLRF STATUS` will clear the upper-three bits and set the Z bit. This leaves the STATUS register as 000u u1uu (where u = unchanged).

It is recommended, therefore, that only `BCF`, `BSF`, `SWAPF` and `MOVWF` instructions are used to alter the STATUS register because these instructions do not affect the Z, C or DC bits from the STATUS register. For other instructions, not affecting any status bits, see the "Instruction Set Summary."

Note 1: These devices do not use bits IRP and RP1 (STATUS<7:6>). Maintain these bits clear to ensure upward compatibility with future products.

Note 2: The C and DC bits operate as a borrow and digit borrow bit, respectively, in subtraction. See the `SUBLW` and `SUBWF` instructions for examples.

FIGURE 2-3: STATUS REGISTER (ADDRESS 03h, 83h)

| R/W-0 | R/W-0 | R/W-0 | R-1 | R-1 | R/W-x | R/W-x | R/W-x |
|---|-------|-------|-----------------|-----------------|-------|-------|-------|
| IRP | RP1 | RP0 | \overline{TO} | \overline{PD} | Z | DC | C |
| bit7 | | | | | | | bit0 |
| <p>bit 7: IRP: Register Bank Select bit (used for indirect addressing) 1 = Bank 2, 3 (100h - 1FFh) - not implemented, maintain clear 0 = Bank 0, 1 (00h - FFh) - not implemented, maintain clear</p> <p>bit 6-5: RP1:RP0: Register Bank Select bits (used for direct addressing) 11 = Bank 3 (180h - 1FFh) - not implemented, maintain clear 10 = Bank 2 (100h - 17Fh) - not implemented, maintain clear 01 = Bank 1 (80h - FFh) 00 = Bank 0 (00h - 7Fh) Each bank is 128 bytes</p> <p>bit 4: \overline{TO}: Time-out bit 1 = After power-up, <code>CLRWDT</code> instruction, or <code>SLEEP</code> instruction 0 = A WDT time-out occurred</p> <p>bit 3: \overline{PD}: Power-down bit 1 = After power-up or by the <code>CLRWDT</code> instruction 0 = By execution of the <code>SLEEP</code> instruction</p> <p>bit 2: Z: Zero bit 1 = The result of an arithmetic or logic operation is zero 0 = The result of an arithmetic or logic operation is not zero</p> <p>bit 1: DC: Digit carry/borrow bit (<code>ADDWF</code>, <code>ADDLW</code>, <code>SUBLW</code>, <code>SUBWF</code> instructions) (for borrow the polarity is reversed) 1 = A carry-out from the 4th low order bit of the result occurred 0 = No carry-out from the 4th low order bit of the result</p> <p>bit 0: C: Carry/borrow bit (<code>ADDWF</code>, <code>ADDLW</code>, <code>SUBLW</code>, <code>SUBWF</code> instructions) 1 = A carry-out from the most significant bit of the result occurred 0 = No carry-out from the most significant bit of the result occurred Note: For borrow the polarity is reversed. A subtraction is executed by adding the two's complement of the second operand. For rotate (<code>RRF</code>, <code>RLF</code>) instructions, this bit is loaded with either the high or low order bit of the source register.</p> | | | | | | | |

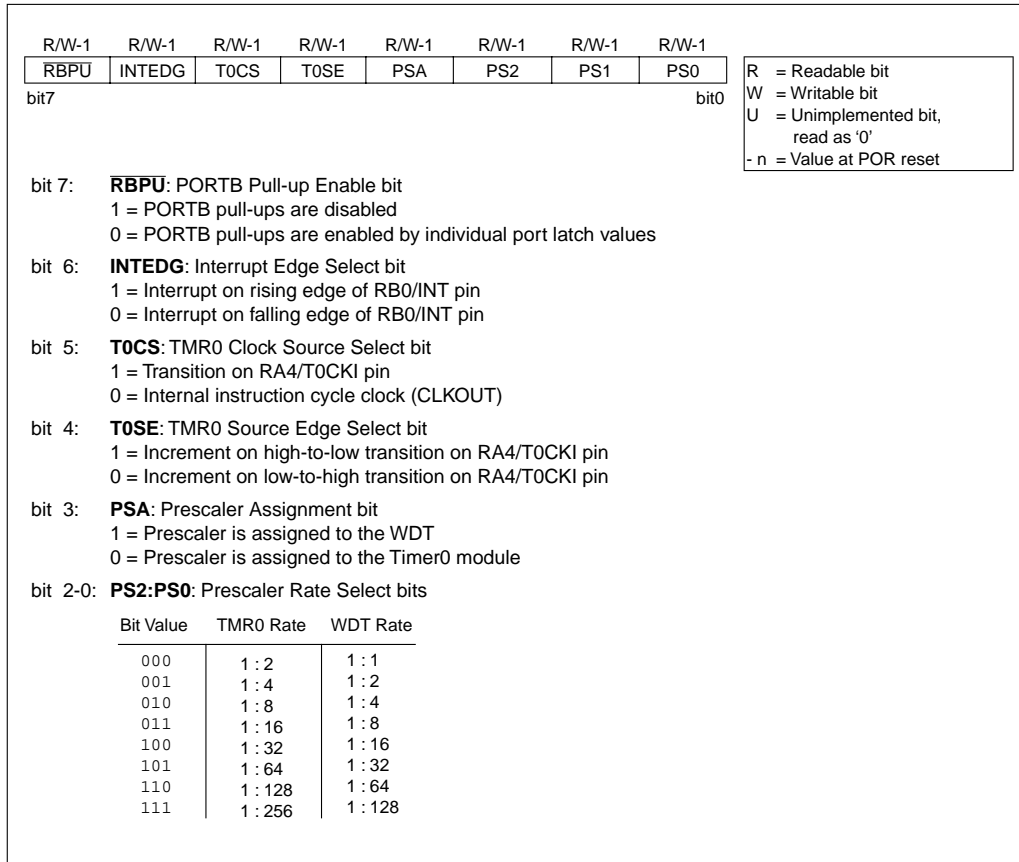
PIC16C63A/65B/73B/74B

2.2.2.2 OPTION_REG REGISTER

The OPTION_REG register is a readable and writable register which contains various control bits to configure the TMR0 prescaler/WDT postscaler (single assignable register known also as the prescaler), the External INT Interrupt, TMR0, and the weak pull-ups on PORTB.

Note: To achieve a 1:1 prescaler assignment for the TMR0 register, assign the prescaler to the Watchdog Timer.

FIGURE 2-4: OPTION_REG REGISTER (ADDRESS 81h)



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2.2.2.3 INTCON REGISTER

The INTCON Register is a readable and writable register which contains various enable and flag bits for the TMR0 register overflow, RB Port change and External RB0/INT pin interrupts.

Note: Interrupt flag bits get set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

FIGURE 2-5: INTCON REGISTER (ADDRESS 0Bh, 8Bh)

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-x |
|--|-------|-------|-------|-------|-------|-------|-------|
| GIE | PEIE | TOIE | INTE | RBIE | TOIF | INTF | RBIF |
| | | | | | | | bit0 |
| bit7 | | | | | | | |
| <p>bit 7: GIE: Global Interrupt Enable bit 1 = Enables all un-masked interrupts 0 = Disables all interrupts</p> <p>bit 6: PEIE: Peripheral Interrupt Enable bit 1 = Enables all un-masked peripheral interrupts 0 = Disables all peripheral interrupts</p> <p>bit 5: TOIE: TMR0 Overflow Interrupt Enable bit 1 = Enables the TMR0 interrupt 0 = Disables the TMR0 interrupt</p> <p>bit 4: IINTE: RB0/INT External Interrupt Enable bit 1 = Enables the RB0/INT external interrupt 0 = Disables the RB0/INT external interrupt</p> <p>bit 3: RBIE: RB Port Change Interrupt Enable bit 1 = Enables the RB port change interrupt 0 = Disables the RB port change interrupt</p> <p>bit 2: TOIF: TMR0 Overflow Interrupt Flag bit 1 = TMR0 register has overflowed (must be cleared in software) 0 = TMR0 register did not overflow</p> <p>bit 1: INTF: RB0/INT External Interrupt Flag bit 1 = The RB0/INT external interrupt occurred (must be cleared in software) 0 = The RB0/INT external interrupt did not occur</p> <p>bit 0: RBIF: RB Port Change Interrupt Flag bit 1 = At least one of the RB7:RB4 pins changed state (must be cleared in software) 0 = None of the RB7:RB4 pins have changed state</p> | | | | | | | |

R = Readable bit
 W = Writable bit
 U = Unimplemented bit, read as '0'
 - n = Value at POR reset

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2.2.2.4 PIE1 REGISTER

This register contains the individual enable bits for the peripheral interrupts.

Note: Bit PEIE (INTCON<6>) must be set to enable any peripheral interrupt.

FIGURE 2-6: PIE1 REGISTER (ADDRESS 8Ch)

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|----------------------|---------------------|-------|-------|-------|--------|--------|--------|
| PSPIE ⁽¹⁾ | ADIE ⁽²⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE |
| bit7 | | | | | | bit0 | |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **PSPIE⁽¹⁾**: Parallel Slave Port Read/Write Interrupt Enable bit
1 = Enables the PSP read/write interrupt
0 = Disables the PSP read/write interrupt

bit 6: **ADIE⁽²⁾**: A/D Converter Interrupt Enable bit
1 = Enables the A/D interrupt
0 = Disables the A/D interrupt

bit 5: **RCIE**: USART Receive Interrupt Enable bit
1 = Enables the USART receive interrupt
0 = Disables the USART receive interrupt

bit 4: **TXIE**: USART Transmit Interrupt Enable bit
1 = Enables the USART transmit interrupt
0 = Disables the USART transmit interrupt

bit 3: **SSPIE**: Synchronous Serial Port Interrupt Enable bit
1 = Enables the SSP interrupt
0 = Disables the SSP interrupt

bit 2: **CCP1IE**: CCP1 Interrupt Enable bit
1 = Enables the CCP1 interrupt
0 = Disables the CCP1 interrupt

bit 1: **TMR2IE**: TMR2 to PR2 Match Interrupt Enable bit
1 = Enables the TMR2 to PR2 match interrupt
0 = Disables the TMR2 to PR2 match interrupt

bit 0: **TMR1IE**: TMR1 Overflow Interrupt Enable bit
1 = Enables the TMR1 overflow interrupt
0 = Disables the TMR1 overflow interrupt

Note 1: PIC16C63A/73B devices do not have a Parallel Slave Port implemented. This bit location is reserved on these devices. Always maintain this bit clear.

Note 2: PIC16C63A/65B devices do not have an A/D module. This bit location is reserved on these devices. Always maintain this bit clear.

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2.2.2.5 PIR1 REGISTER

This register contains the individual flag bits for the peripheral interrupts.

Note: Interrupt flag bits get set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

FIGURE 2-7: PIR1 REGISTER (ADDRESS 0Ch)

| R/W-0 | R/W-0 | R-0 | R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|----------------------|---------------------|------|------|-------|--------|--------|--------|
| PSPIF ⁽¹⁾ | ADIF ⁽²⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF |
| bit7 | | | | bit0 | | | |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **PSPIF⁽¹⁾**: Parallel Slave Port Read/Write Interrupt Flag bit
1 = A read or a write operation has taken place (must be cleared in software)
0 = No read or write has occurred

bit 6: **ADIF⁽²⁾**: A/D Converter Interrupt Flag bit
1 = An A/D conversion completed (must be cleared in software)
0 = The A/D conversion is not complete

bit 5: **RCIF**: USART Receive Interrupt Flag bit
1 = The USART receive buffer is full (cleared by reading RCREG)
0 = The USART receive buffer is empty

bit 4: **TXIF**: USART Transmit Interrupt Flag bit
1 = The USART transmit buffer is empty (cleared by writing to TXREG)
0 = The USART transmit buffer is full

bit 3: **SSPIF**: Synchronous Serial Port Interrupt Flag bit
1 = The transmission/reception is complete (must be cleared in software)
0 = Waiting to transmit/receive

bit 2: **CCP1IF**: CCP1 Interrupt Flag bit
Capture Mode
1 = A TMR1 register capture occurred (must be cleared in software)
0 = No TMR1 register capture occurred
Compare Mode
1 = A TMR1 register compare match occurred (must be cleared in software)
0 = No TMR1 register compare match occurred
PWM Mode
Unused in this mode

bit 1: **TMR2IF**: TMR2 to PR2 Match Interrupt Flag bit
1 = TMR2 to PR2 match occurred (must be cleared in software)
0 = No TMR2 to PR2 match occurred

bit 0: **TMR1IF**: TMR1 Overflow Interrupt Flag bit
1 = TMR1 register overflowed (must be cleared in software)
0 = TMR1 register did not overflow

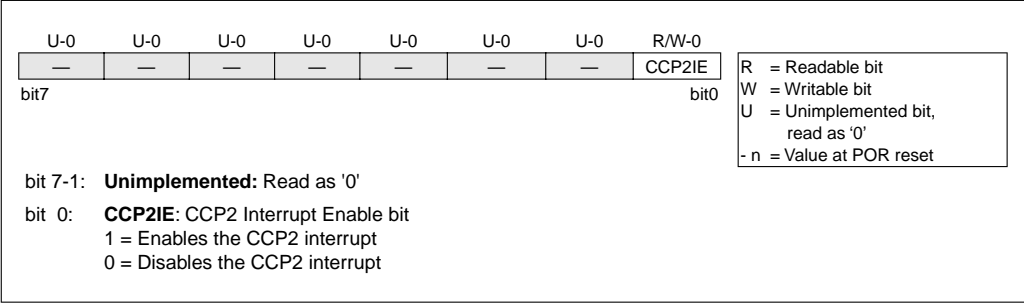
Note 1: PIC16C63A/73B devices do not have a Parallel Slave Port implemented. This bit location is reserved on these devices. Always maintain this bit clear.
2: PIC16C63A/65B devices do not have an A/D module. This bit location is reserved on these devices. Always maintain this bit clear.

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2.2.2.6 PIE2 REGISTER

This register contains the individual enable bit for the CCP2 peripheral interrupt.

FIGURE 2-8: PIE2 REGISTER (ADDRESS 8Dh)



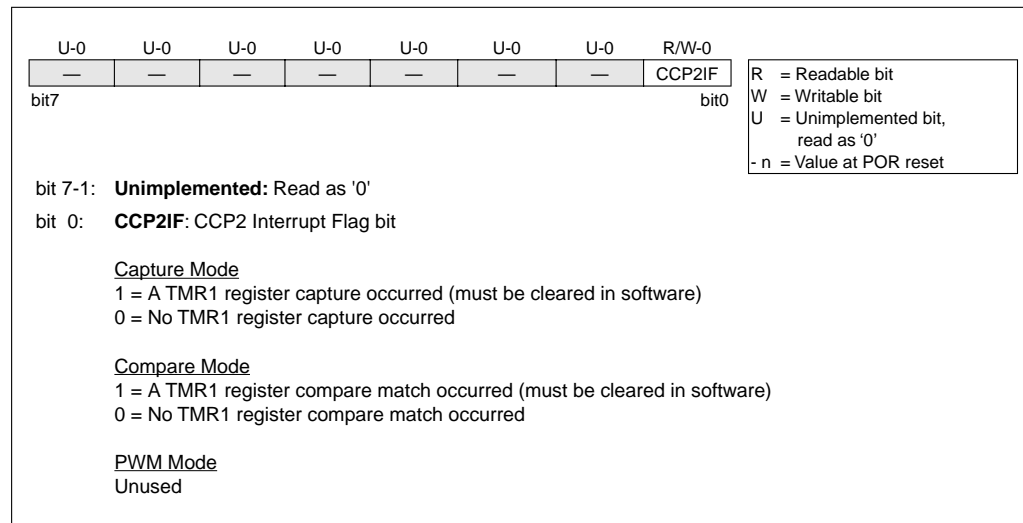
PIC16C63A/65B/73B/74B

2.2.2.7 PIR2 REGISTER

This register contains the CCP2 interrupt flag bit.

Note: Interrupt flag bits get set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

FIGURE 2-9: PIR2 REGISTER (ADDRESS 0Dh)



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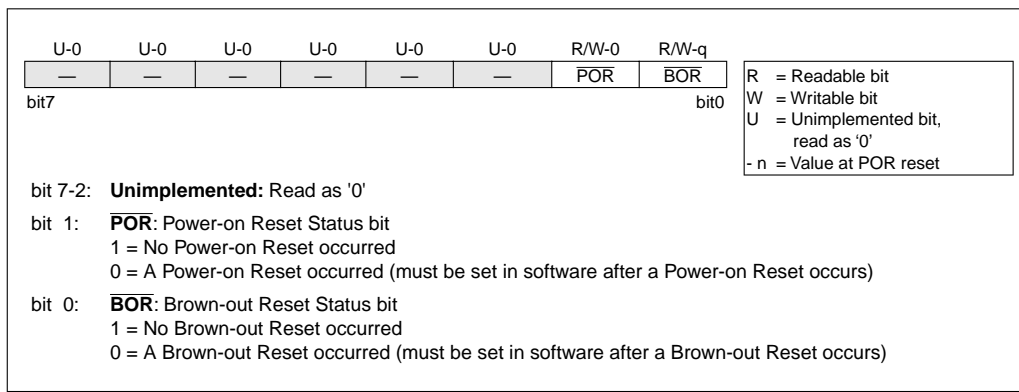
2.2.2.8 PCON REGISTER

The Power Control (PCON) register contains a flag bit to allow differentiation between a Power-on Reset (POR) to an external MCLR Reset or WDT Reset. Those devices with brown-out detection circuitry contain an additional bit to differentiate a Brown-out Reset condition from a Power-on Reset condition.

Note: If the BODEN configuration bit is set, $\overline{\text{BOR}}$ is '1' on Power-on Reset. If the BODEN configuration bit is clear, $\overline{\text{BOR}}$ is unknown on Power-on Reset.

The $\overline{\text{BOR}}$ status bit is a "don't care" and is not necessarily predictable if the brown-out circuit is disabled (the BODEN configuration bit is clear). $\overline{\text{BOR}}$ must then be set by the user and checked on subsequent resets to see if it is clear, indicating a brown-out has occurred.

FIGURE 2-10: PCON REGISTER (ADDRESS 8Eh)



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2.3 PCL and PCLATH

The program counter (PC) specifies the address of the instruction to fetch for execution. The PC is 13 bits wide. The low byte is called the PCL register. This register is readable and writable. The high byte is called the PCH register. This register contains the PC<12:8> bits and is not directly readable or writable. All updates to the PCH register go through the PCLATH register.

2.3.1 STACK

The stack allows a combination of up to 8 program calls and interrupts to occur. The stack contains the return address from this branch in program execution.

Mid-Range devices have an 8 level deep x 13-bit wide hardware stack. The stack space is not part of either program or data space and the stack pointer is not readable or writable. The PC is PUSHed onto the stack when a CALL instruction is executed or an interrupt causes a branch. The stack is POPed in the event of a RETURN, RETLW or a RETFIE instruction execution. PCLATH is not modified when the stack is PUSHed or POPed.

After the stack has been PUSHed eight times, the ninth push overwrites the value that was stored from the first push. The tenth push overwrites the second push (and so on).

2.4 Program Memory Paging

The CALL and GOTO instructions provide 11 bits of address to allow branching within any 2K program memory page. When doing a CALL or GOTO instruction the upper bit of the address is provided by PCLATH<3>. When doing a CALL or GOTO instruction, the user must ensure that the page select bit is programmed so that the desired program memory page is addressed. If a return from a CALL instruction (or interrupt) is executed, the entire 13-bit PC is pushed onto the stack. Therefore, manipulation of the PCLATH<3> bit is not required for the return instructions (which POPs the address from the stack).

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2.5 Indirect Addressing, INDF and FSR Registers

The INDF register is not a physical register. Addressing INDF actually addresses the register whose address is contained in the FSR register (FSR is a *pointer*). This is indirect addressing.

EXAMPLE 2-1: INDIRECT ADDRESSING

- Register file 05 contains the value 10h
- Register file 06 contains the value 0Ah
- Load the value 05 into the FSR register
- A read of the INDF register will return the value of 10h
- Increment the value of the FSR register by one (FSR = 06)
- A read of the INDF register now will return the value of 0Ah.

Reading INDF itself indirectly (FSR = 0) will produce 00h. Writing to the INDF register indirectly results in a no-operation (although STATUS bits may be affected).

A simple program to clear RAM locations 20h-2Fh using indirect addressing is shown in Example 2-2.

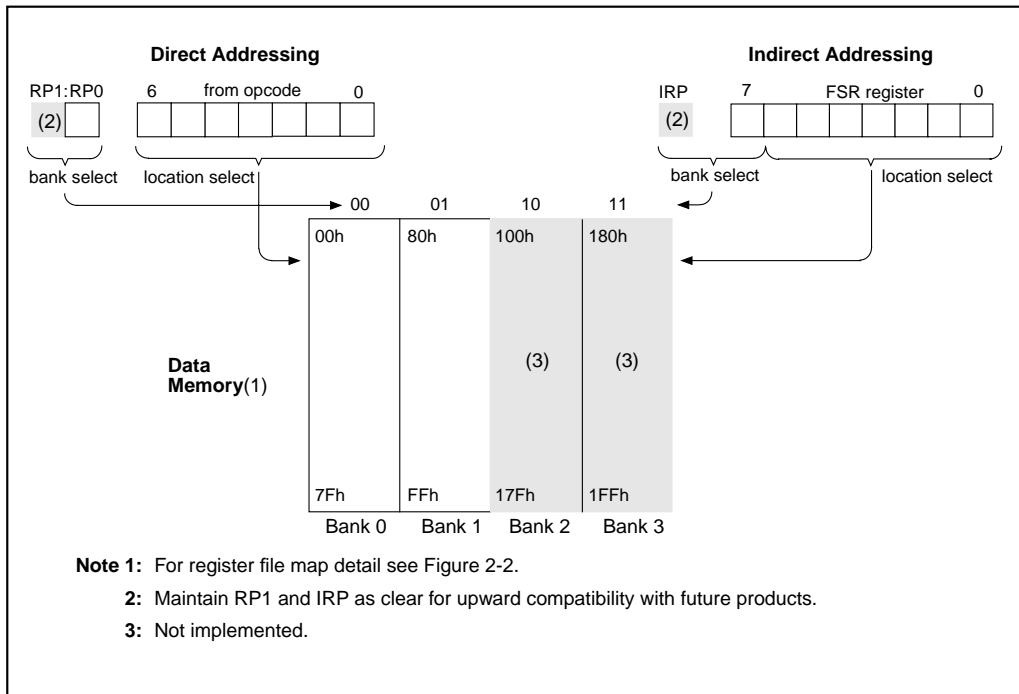
EXAMPLE 2-2: HOW TO CLEAR RAM USING INDIRECT ADDRESSING

```

movlw 0x20 ;initialize pointer
movwf FSR ; to RAM
NEXT   clrf INDF ;clear INDF register
       incf FSR ;inc pointer
       btfss FSR,4 ;all done?
       goto NEXT ;NO, clear next
CONTINUE
       : ;YES, continue
    
```

An effective 9-bit address is obtained by concatenating the 8-bit FSR register and the IRP bit (STATUS<7>), as shown in Figure 2-11. However, IRP is not used in the PIC16C63A/65B/73B/74B.

FIGURE 2-11: DIRECT/INDIRECT ADDRESSING



PIC16C63A/65B/73B/74B

3.0 I/O PORTS

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

Additional information on I/O ports may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

3.1 PORTA and the TRISA Register

PORTA is a 6-bit wide bi-directional port. The corresponding data direction register is TRISA. Setting a TRISA bit (=1) will make the corresponding PORTA pin an input, i.e., put the corresponding output driver in a hi-impedance mode. Clearing a TRISA bit (=0) will make the corresponding PORTA pin an output, i.e., put the contents of the output latch on the selected pin.

Note: On a Power-on Reset, these pins are configured as inputs and read as '0'.

Reading the PORTA register reads the status of the pins, whereas writing to it will write to the port latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read. This value is modified and then written to the port data latch.

Pin RA4 is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. The RA4/T0CKI pin is a Schmitt Trigger input and an open drain output. All other RA port pins have TTL input levels and full CMOS output drivers.

On PIC16C73B/74B devices, other PORTA pins are multiplexed with analog inputs and analog VREF input. The operation of each pin is selected by clearing/setting the control bits in the ADCON1 register (A/D Control Register1).

Note: On a Power-on Reset, these pins are configured as analog inputs and read as '0'.

The TRISA register controls the direction of the RA pins, even when they are being used as analog inputs. The user must ensure the bits in the TRISA register are maintained set when using them as analog inputs.

EXAMPLE 3-1: INITIALIZING PORTA

```
BCF STATUS, RP0 ;
CLRF PORTA      ; Initialize PORTA by
                ; clearing output
                ; data latches

BSF STATUS, RP0 ; Select Bank 1
MOVLW 0xCF      ; Value used to
                ; initialize data
                ; direction

MOVWF TRISA     ; Set RA<3:0> as inputs
                ; RA<5:4> as outputs
                ; TRISA<7:6> are always
                ; read as '0'.
```

FIGURE 3-1: BLOCK DIAGRAM OF RA3:RA0 AND RA5 PINS

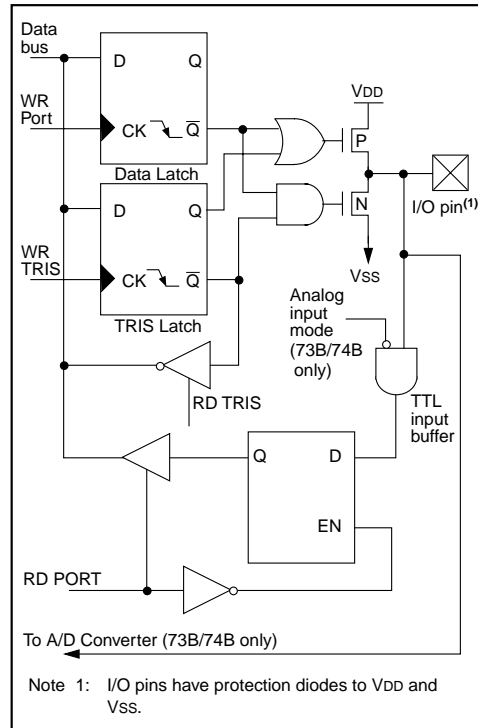
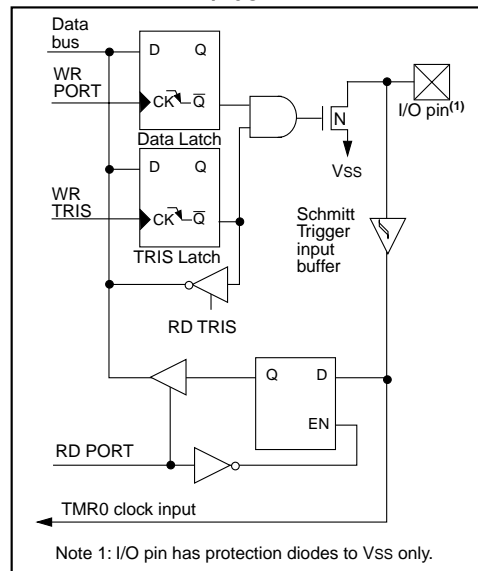


FIGURE 3-2: BLOCK DIAGRAM OF RA4/T0CKI PIN



PIC16C63A/65B/73B/74B

TABLE 3-1: PORTA FUNCTIONS

| Name | Bit# | Buffer | Function |
|--------------|------|--------|---|
| RA0/AN0 | bit0 | TTL | Input/output or analog input ⁽¹⁾ |
| RA1/AN1 | bit1 | TTL | Input/output or analog input ⁽¹⁾ |
| RA2/AN2 | bit2 | TTL | Input/output or analog input ⁽¹⁾ |
| RA3/AN3/VREF | bit3 | TTL | Input/output or analog input ⁽¹⁾ or VREF ⁽¹⁾ |
| RA4/T0CKI | bit4 | ST | Input/output or external clock input for Timer0 Output is open drain type |
| RA5/SS/AN4 | bit5 | TTL | Input/output or slave select input for synchronous serial port or analog input ⁽¹⁾ |

Legend: TTL = TTL input, ST = Schmitt Trigger input

Note 1: On PIC16C73B/74B devices only.

TABLE 3-2: SUMMARY OF REGISTERS ASSOCIATED WITH PORTA

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|-----------------------|-------|-------|-------------------------------|-------|-------|-------|-------|-------|-------------------|---------------------------|
| 05h | PORTA | — | — | RA5 | RA4 | RA3 | RA2 | RA1 | RA0 | --0x 0000 | --0u 0000 |
| 85h | TRISA | — | — | PORTA Data Direction Register | | | | | | --11 1111 | --11 1111 |
| 9Fh | ADCON1 ⁽¹⁾ | — | — | — | — | — | PCFG2 | PCFG1 | PCFG0 | ---- -000 | ---- -000 |

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTA.

Note 1: On PIC16C73B/74B devices only.

PIC16C63A/65B/73B/74B

3.2 PORTB and the TRISB Register

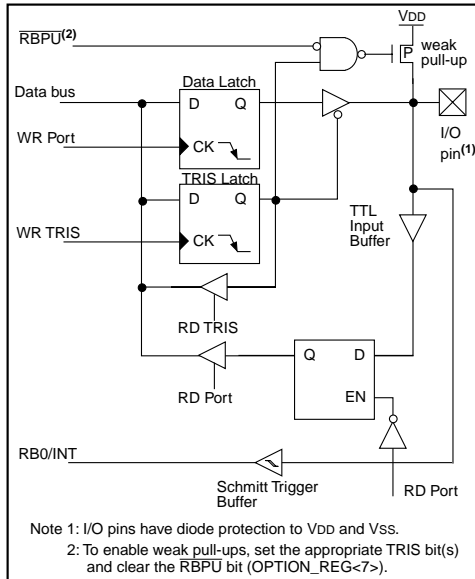
PORTB is an 8-bit wide bi-directional port. The corresponding data direction register is TRISB. Setting a TRISB bit (=1) will make the corresponding PORTB pin an input, i.e., put the corresponding output driver in a hi-impedance mode. Clearing a TRISB bit (=0) will make the corresponding PORTB pin an output, i.e., put the contents of the output latch on the selected pin.

EXAMPLE 3-1: INITIALIZING PORTB

```
BCF STATUS, RP0 ;
CLRFB PORTB ; Initialize PORTB by
; clearing output
; data latches
BSF STATUS, RP0 ; Select Bank 1
MOVLW 0xCF ; Value used to
; initialize data
; direction
MOVWF TRISB ; Set RB<3:0> as inputs
; RB<5:4> as outputs
; RB<7:6> as inputs
```

Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-ups. This is performed by clearing bit $\overline{\text{RBP}}\overline{\text{U}}$ (OPTION_REG<7>). The weak pull-up is automatically turned off when the port pin is configured as an output. The pull-ups are disabled on a Power-on Reset.

FIGURE 3-3: BLOCK DIAGRAM OF RB3:RB0 PINS



Four of PORTB's pins, RB7:RB4, have an interrupt on change feature. Only pins configured as inputs can cause this interrupt to occur (i.e. any RB7:RB4 pin configured as an output is excluded from the interrupt on change comparison). The input pins (of RB7:RB4) are compared with the old value latched on the last read of PORTB. The "mismatch" outputs of RB7:RB4 are OR'ed together to generate the RB Port Change Interrupt with flag bit RBIF (INTCON<0>).

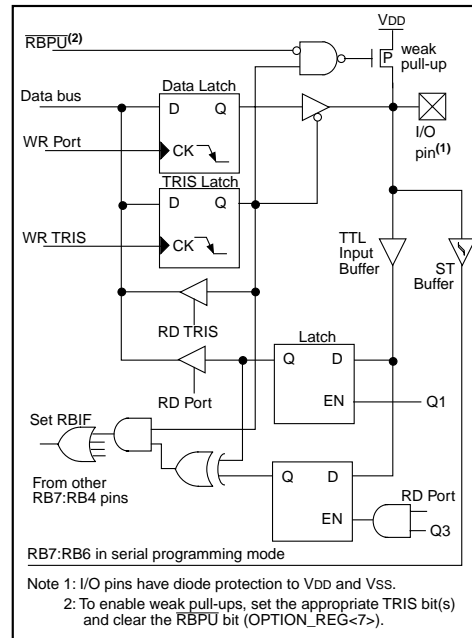
This interrupt can wake the device from SLEEP. The user, in the interrupt service routine, can clear the interrupt in the following manner:

- Any read or write of PORTB. This will end the mismatch condition.
- Clear flag bit RBIF.

A mismatch condition will continue to set flag bit RBIF. Reading PORTB will end the mismatch condition, and allow flag bit RBIF to be cleared.

The interrupt on change feature is recommended for wake-up on key depression operation and operations where PORTB is only used for the interrupt on change feature. Polling of PORTB is not recommended while using the interrupt on change feature.

FIGURE 3-4: BLOCK DIAGRAM OF RB7:RB4 PINS



PIC16C63A/65B/73B/74B

TABLE 3-3: PORTB FUNCTIONS

| Name | Bit# | Buffer | Function |
|---------|------|-----------------------|---|
| RB0/INT | bit0 | TTL/ST ⁽¹⁾ | Input/output pin or external interrupt input. Internal software programmable weak pull-up. |
| RB1 | bit1 | TTL | Input/output pin. Internal software programmable weak pull-up. |
| RB2 | bit2 | TTL | Input/output pin. Internal software programmable weak pull-up. |
| RB3 | bit3 | TTL | Input/output pin. Internal software programmable weak pull-up. |
| RB4 | bit4 | TTL | Input/output pin (with interrupt on change). Internal software programmable weak pull-up. |
| RB5 | bit5 | TTL | Input/output pin (with interrupt on change). Internal software programmable weak pull-up. |
| RB6 | bit6 | TTL/ST ⁽²⁾ | Input/output pin (with interrupt on change). Internal software programmable weak pull-up. Serial programming clock. |
| RB7 | bit7 | TTL/ST ⁽²⁾ | Input/output pin (with interrupt on change). Internal software programmable weak pull-up. Serial programming data. |

Legend: TTL = TTL input, ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.

2: This buffer is a Schmitt Trigger input when used in serial programming mode.

TABLE 3-4: SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|------------|-------------------------------|--------|-------|-------|-------|-------|-------|-------|-------------------|---------------------------|
| 06h | PORTB | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0 | xxxx xxxx | uuuu uuuu |
| 86h | TRISB | PORTB Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 81h | OPTION_REG | RBP _U | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 | 1111 1111 | 1111 1111 |

Legend: x = unknown, u = unchanged. Shaded cells are not used by PORTB.

PIC16C63A/65B/73B/74B

3.3 PORTC and the TRISC Register

PORTC is an 8-bit wide bi-directional port. The corresponding data direction register is TRISC. Setting a TRISC bit (=1) will make the corresponding PORTC pin an input, i.e., put the corresponding output driver in a hi-impedance mode. Clearing a TRISC bit (=0) will make the corresponding PORTC pin an output, i.e., put the contents of the output latch on the selected pin.

PORTC is multiplexed with several peripheral functions (Table 3-5). PORTC pins have Schmitt Trigger input buffers.

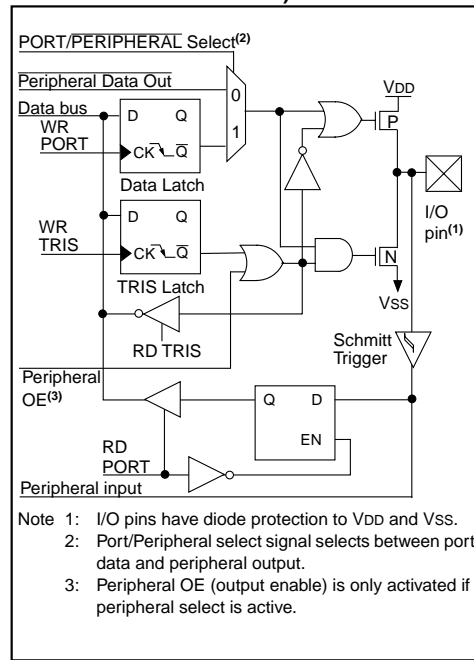
When enabling peripheral functions, care should be taken in defining TRIS bits for each PORTC pin. Some peripherals override the TRIS bit to make a pin an output, while other peripherals override the TRIS bit to make a pin an input. Since the TRIS bit override is in effect while the peripheral is enabled, read-modify-write instructions (BSF, BCF, XORWF) with TRISC as destination should be avoided. The user should refer to the corresponding peripheral section for the correct TRIS bit settings.

EXAMPLE 3-1: INITIALIZING PORTC

```

BCF STATUS, RP0 ; Select Bank 0
CLRf PORTC ; Initialize PORTC by
; clearing output
; data latches
BSF STATUS, RP0 ; Select Bank 1
MOVLW 0xCF ; Value used to
; initialize data
; direction
MOVWF TRISC ; Set RC<3:0> as inputs
; RC<5:4> as outputs
; RC<7:6> as inputs
    
```

FIGURE 3-5: PORTC BLOCK DIAGRAM (PERIPHERAL OUTPUT OVERRIDE)



- Note 1: I/O pins have diode protection to VDD and VSS.
 Note 2: Port/Peripheral select signal selects between port data and peripheral output.
 Note 3: Peripheral OE (output enable) is only activated if peripheral select is active.

PIC16C63A/65B/73B/74B

TABLE 3-5: PORTC FUNCTIONS

| Name | Bit# | Buffer Type | Function |
|-----------------|------|-------------|---|
| RC0/T1OSO/T1CKI | bit0 | ST | Input/output port pin or Timer1 oscillator output/Timer1 clock input |
| RC1/T1OSI | bit1 | ST | Input/output port pin or Timer1 oscillator input |
| RC2/CCP1 | bit2 | ST | Input/output port pin or Capture1 input/Compare1 output/PWM1 output |
| RC3/SCK/SCL | bit3 | ST | RC3 can also be the synchronous serial clock for both SPI and I ² C modes. |
| RC4/SDI/SDA | bit4 | ST | RC4 can also be the SPI Data In (SPI mode) or data I/O (I ² C mode). |
| RC5/SDO | bit5 | ST | Input/output port pin or Synchronous Serial Port data output |
| RC6 | bit6 | ST | Input/output port pin |
| RC7 | bit7 | ST | Input/output port pin |

Legend: ST = Schmitt Trigger input

TABLE 3-6: SUMMARY OF REGISTERS ASSOCIATED WITH PORTC

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|-------|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------------------|---------------------------|
| 07h | PORTC | RC7 | RC6 | RC5 | RC4 | RC3 | RC2 | RC1 | RC0 | xxxx xxxx | uuuu uuuu |
| 87h | TRISC | PORTC Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |

Legend: x = unknown, u = unchanged.

PIC16C63A/65B/73B/74B

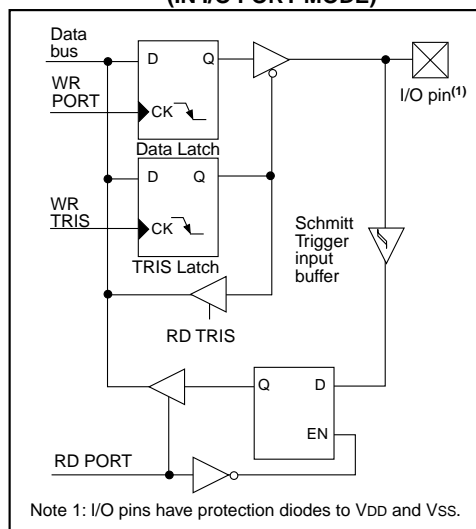
3.4 PORTD and TRISD Registers

This section is applicable to the PIC16C65B/PIC16C74B devices only.

PORTD is an 8-bit port with Schmitt Trigger input buffers. Each pin is individually configurable as an input or output.

PORTD can be configured as an 8-bit wide microprocessor port (parallel slave port) by setting control bit PSPMODE (TRISE<4>). In this mode, the input buffers are TTL.

FIGURE 3-6: PORTD BLOCK DIAGRAM (IN I/O PORT MODE)



PIC16C63A/65B/73B/74B

TABLE 3-7: PORTD FUNCTIONS

| Name | Bit# | Buffer Type | Function |
|----------|------|-----------------------|---|
| RD0/PSP0 | bit0 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit0 |
| RD1/PSP1 | bit1 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit1 |
| RD2/PSP2 | bit2 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit2 |
| RD3/PSP3 | bit3 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit3 |
| RD4/PSP4 | bit4 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit4 |
| RD5/PSP5 | bit5 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit5 |
| RD6/PSP6 | bit6 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit6 |
| RD7/PSP7 | bit7 | ST/TTL ⁽¹⁾ | Input/output port pin or parallel slave port bit7 |

Legend: ST = Schmitt Trigger input TTL = TTL input

Note 1: Input buffers are Schmitt Triggers when in I/O mode and TTL buffer when in Parallel Slave Port Mode.

TABLE 3-8: SUMMARY OF REGISTERS ASSOCIATED WITH PORTD

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|-------|-------------------------------|-------|-------|---------|-------|---------------------------|-------|-------|-------------------|---------------------------|
| 08h | PORTD | RD7 | RD6 | RD5 | RD4 | RD3 | RD2 | RD1 | RD0 | xxxx xxxx | uuuu uuuu |
| 88h | TRISD | PORTD Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 89h | TRISE | IBF | OBF | IBOV | PSPMODE | — | PORTE Data Direction Bits | | | 0000 -111 | 0000 -111 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by PORTD.

PIC16C63A/65B/73B/74B

3.5 PORTE and TRISE Register

This section is applicable to the PIC16C65B/PIC16C74B devices only. The A/D multiplexed functions are available on the PIC16C74B only.

PORTE has three pins RE0/RD/AN5, RE1/WR/AN6 and RE2/CS/AN7, which are individually configurable as inputs or outputs. These pins have Schmitt Trigger input buffers.

I/O PORTE becomes control inputs for the microprocessor port when bit PSPMODE (TRISE<4>) is set. In this mode, the user must make sure that the TRISE<2:0> bits are set (pins are configured as digital inputs). For the PIC16C74B ensure ADCON1 is configured for digital I/O. In this mode, the input buffers are TTL.

Figure 3-8 shows the TRISE register, which also controls the parallel slave port operation.

PORTE pins for the PIC16C74B only are multiplexed with analog inputs. When selected as an analog input, these pins will read as '0's.

TRISE controls the direction of the RE pins, even when they are being used as analog inputs. The user must make sure to keep the pins configured as inputs when using them as analog inputs.

Note: On a Power-on Reset these pins are configured as analog inputs.

FIGURE 3-7: PORTE BLOCK DIAGRAM (IN I/O PORT MODE)

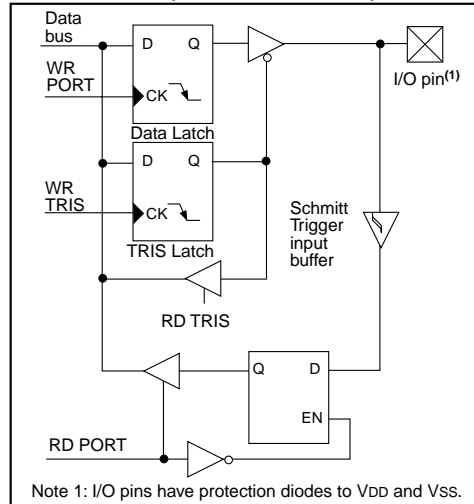


FIGURE 3-8: TRISE REGISTER (ADDRESS 89h)

| R-0 | R-0 | R/W-0 | R/W-0 | U-0 | R/W-1 | R/W-1 | R/W-1 | |
|--|-----|-------|---------|-----|--------|--------|--------|------|
| IBF | OBF | IBOV | PSPMODE | — | TRISE2 | TRISE1 | TRISE0 | |
| bit7 | | | | | | | | bit0 |
| <p>bit 7: IBF: Input Buffer Full Status bit 1 = A word has been received and is waiting to be read by the CPU 0 = No word has been received</p> <p>bit 6: OBF: Output Buffer Full Status bit 1 = The output buffer still holds a previously written word 0 = The output buffer has been read</p> <p>bit 5: IBOV: Input Buffer Overflow Detect bit (in microprocessor mode) 1 = A write occurred when a previously input word has not been read (must be cleared in software) 0 = No overflow occurred</p> <p>bit 4: PSPMODE: Parallel Slave Port Mode Select bit 1 = Parallel slave port mode 0 = General purpose I/O mode</p> <p>bit 3: Unimplemented: Read as '0'</p> <p>bit 2: TRISE2: RE2 Direction Control bit 1 = Input 0 = Output</p> <p>bit 1: TRISE1: RE2 Direction Control bit 1 = Input 0 = Output</p> <p>bit 0: TRISE0: RE2 Direction Control bit 1 = Input 0 = Output</p> | | | | | | | | |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

PIC16C63A/65B/73B/74B

TABLE 3-9: PORTE FUNCTIONS

| Name | Bit# | Buffer Type | Function |
|--|------|-----------------------|---|
| RE0/ \overline{RD} /AN5 ⁽²⁾ | bit0 | ST/TTL ⁽¹⁾ | Input/output port pin or read control input in parallel slave port mode or analog input: RD 1 = Not a read operation 0 = Read operation. Reads PORTD register (if chip selected) |
| RE1/ \overline{WR} /AN6 ⁽²⁾ | bit1 | ST/TTL ⁽¹⁾ | Input/output port pin or write control input in parallel slave port mode or analog input: WR 1 = Not a write operation 0 = Write operation. Writes PORTD register (if chip selected) |
| RE2/ \overline{CS} /AN7 ⁽²⁾ | bit2 | ST/TTL ⁽¹⁾ | Input/output port pin or chip select control input in parallel slave port mode or analog input: \overline{CS} 1 = Device is not selected 0 = Device is selected |

Legend: ST = Schmitt Trigger input TTL = TTL input

Note 1: Input buffers are Schmitt Triggers when in I/O mode and TTL buffers when in Parallel Slave Port Mode.

Note 2: A/D Converter module multiplexing is implemented on the PIC16C74B only.

TABLE 3-10: SUMMARY OF REGISTERS ASSOCIATED WITH PORTE

| Addr | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|------|-----------------------|-------|-------|-------|---------|-------|---------------------------|-------|-------|-------------------|---------------------------|
| 09h | PORTE | — | — | — | — | — | RE2 | RE1 | RE0 | ---- -xxx | ---- -uuu |
| 89h | TRISE | IBF | OBF | IBOV | PSPMODE | — | PORTE Data Direction Bits | | | 0000 -111 | 0000 -111 |
| 9Fh | ADCON1 ⁽¹⁾ | — | — | — | — | — | PCFG2 | PCFG1 | PCFG0 | ---- -000 | ---- -000 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by PORTE.

Note 1: A/D Converter module multiplexing is implemented on the PIC16C74B only.

PIC16C63A/65B/73B/74B

3.6 Parallel Slave Port

The Parallel Slave Port is implemented on the 40-pin devices only (PIC16C65B and PIC16C74B).

PORTD operates as an 8-bit wide Parallel Slave Port, or microprocessor port when control bit PSPMODE (TRISE<4>) is set. In slave mode it is asynchronously readable and writable by the external world through \overline{RD} control input pin RE0/ \overline{RD} and \overline{WR} control input pin RE1/ \overline{WR} .

It can directly interface to an 8-bit microprocessor data bus. The external microprocessor can read or write the PORTD latch as an 8-bit latch. Setting bit PSPMODE enables port pin RE0/ \overline{RD} to be the \overline{RD} input, RE1/ \overline{WR} to be the \overline{WR} input and RE2/ \overline{CS} to be the \overline{CS} (chip select) input. For this functionality, the corresponding data direction bits of the TRISE register (TRISE<2:0>) must be configured as inputs (set). For the PIC16C74B, the A/D port configuration bits PCFG2:PCFG0 (ADCON1<2:0>) must be set, which will configure pins RE2:RE0 as digital I/O.

A write to the PSP occurs when both the \overline{CS} and \overline{WR} lines are first detected low. A read from the PSP occurs when both the \overline{CS} and \overline{RD} lines are first detected low.

FIGURE 3-9: PORTD AND PORTE BLOCK DIAGRAM (PARALLEL SLAVE PORT)

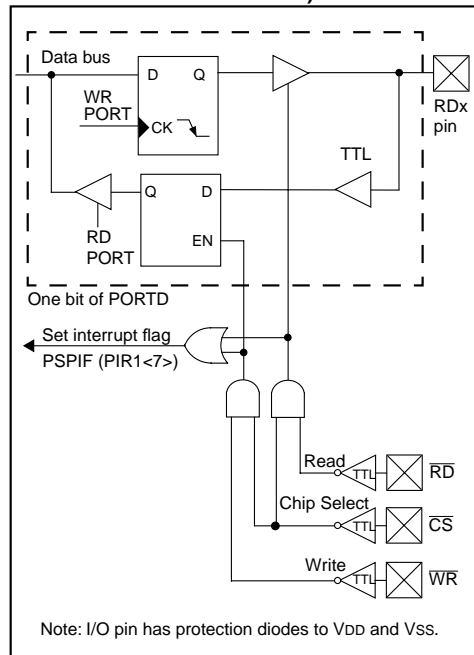
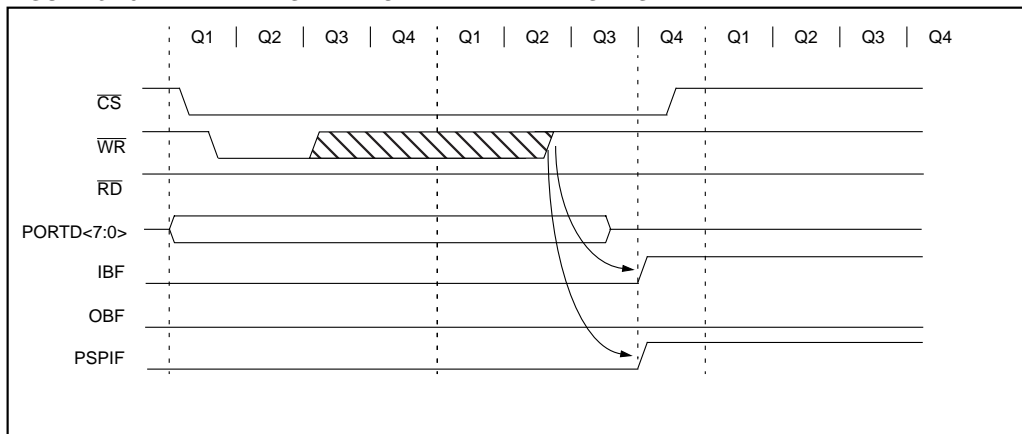


FIGURE 3-10: PARALLEL SLAVE PORT WRITE WAVEFORMS



PIC16C63A/65B/73B/74B

FIGURE 3-11: PARALLEL SLAVE PORT READ WAVEFORMS

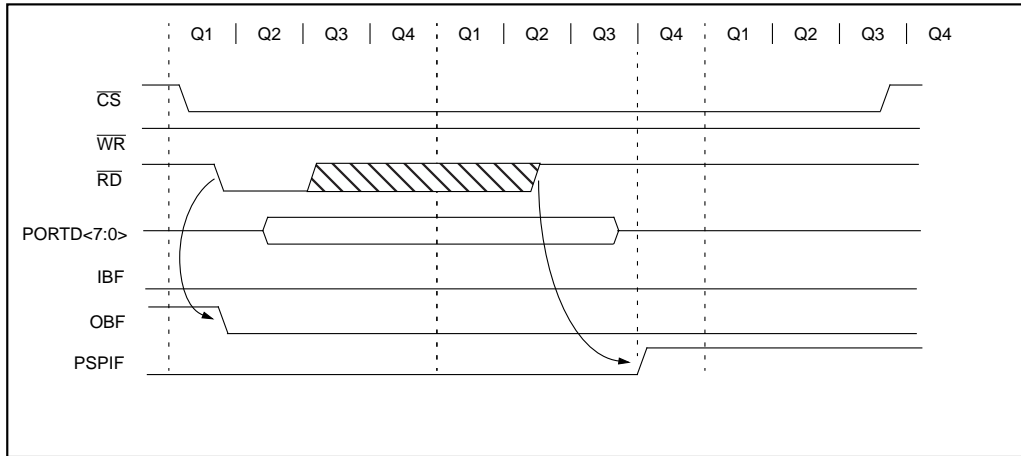


TABLE 3-11: REGISTERS ASSOCIATED WITH PARALLEL SLAVE PORT

| Add. | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|------|-----------------------|---|---------------------|-------|---------|-------|---------------------------|--------|--------|-------------------|---------------------------|
| 08h | PORTD | Port data latch when written: Port pins when read | | | | | | | | xxxx xxxx | uuuu uuuu |
| 09h | PORTE | — | — | — | — | — | RE2 | RE1 | RE0 | ---- -xxx | ---- -uuu |
| 89h | TRISE | IBF | OBF | IBOV | PSPMODE | — | PORTE Data Direction Bits | | | 0000 -111 | 0000 -111 |
| 0Ch | PIR1 | PSPIF | ADIF ⁽¹⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE | ADIE ⁽¹⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 9Fh | ADCON1 ⁽¹⁾ | — | — | — | — | — | PCFG2 | PCFG1 | PCFG0 | ---- -000 | ---- -000 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by the Parallel Slave Port.
 Note 1: On PIC16C74B only.

PIC16C63A/65B/73B/74B

4.0 TIMER0 MODULE

The Timer0 module timer/counter has the following features:

- 8-bit timer/counter
- Readable and writable
- Internal or external clock select
- Edge select for external clock
- 8-bit software programmable prescaler
- Interrupt on overflow from FFh to 00h

Figure 4-1 is a simplified block diagram of the Timer0 module.

Additional information on timer modules is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

4.1 Timer0 Operation

Timer0 can operate as a timer or as a counter.

Timer mode is selected by clearing bit T0CS (OPTION_REG<5>). In timer mode, the Timer0 module will increment every instruction cycle (without prescaler). If the TMR0 register is written, the increment is inhibited for the following two instruction cycles. The user can work around this by writing an adjusted value to the TMR0 register.

Counter mode is selected by setting bit T0CS (OPTION_REG<5>). In counter mode, Timer0 will increment either on every rising or falling edge of pin RA4/T0CKI. The incrementing edge is determined by the Timer0 Source Edge Select bit T0SE (OPTION_REG<4>). Clearing bit T0SE selects the rising edge. Restrictions on the external clock input are discussed below.

When an external clock input is used for Timer0, it must meet certain requirements. The requirements ensure the external clock can be synchronized with the internal phase clock (Tosc). There is a delay in the actual incrementing of Timer0 after synchronization.

Additional information on external clock requirements is available in the PICMicro™ Mid-Range Reference Manual, (DS33023).

4.2 Prescaler

An 8-bit counter is available as a prescaler for the Timer0 module, or as a postscaler for the Watchdog Timer, respectively (Figure 4-2). For simplicity, this counter is being referred to as "prescaler" throughout this data sheet. Note that there is only one prescaler available, which is mutually exclusively shared between the Timer0 module and the Watchdog Timer. Thus, a prescaler assignment for the Timer0 module means that there is no prescaler for the Watchdog Timer and vice-versa.

The prescaler is not readable or writable.

The PSA and PS2:PS0 bits (OPTION_REG<3:0>) determine the prescaler assignment and prescale ratio.

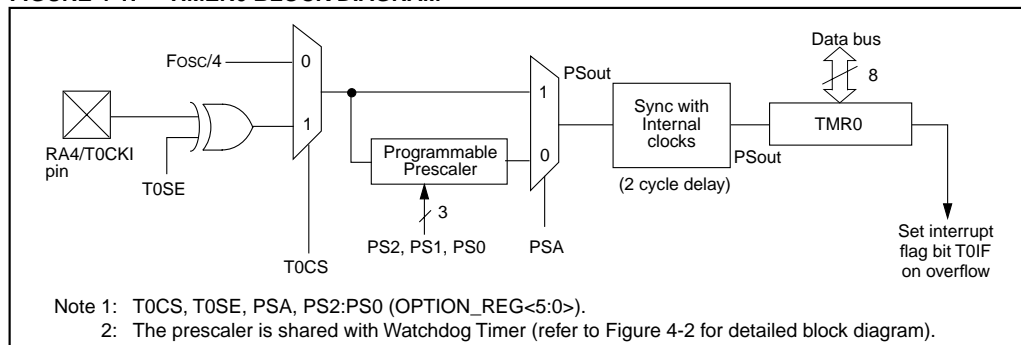
Clearing bit PSA will assign the prescaler to the Timer0 module. When the prescaler is assigned to the Timer0 module, prescale values of 1:2, 1:4, ..., 1:256 are selectable.

Setting bit PSA will assign the prescaler to the Watchdog Timer (WDT). When the prescaler is assigned to the WDT, prescale values of 1:1, 1:2, ..., 1:128 are selectable.

When assigned to the Timer0 module, all instructions writing to the TMR0 register (e.g. CLRF 1, MOVWF 1, BSF 1, x...etc.) will clear the prescaler. When assigned to WDT, a CLRWDT instruction will clear the prescaler along with the WDT.

Note: Writing to TMR0 when the prescaler is assigned to Timer0 will clear the prescaler count, but will not change the prescaler assignment.

FIGURE 4-1: TIMER0 BLOCK DIAGRAM



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4.2.1 SWITCHING PRESCALER ASSIGNMENT

The prescaler assignment is fully under software control, i.e., it can be changed "on the fly" during program execution.

Note: To avoid an unintended device RESET, a specific instruction sequence (shown in the PICmicro™ Mid-Range Reference Manual, (DS33023), must be executed when changing the prescaler assignment from Timer0 to the WDT. This sequence must be followed even if the WDT is disabled.

4.3 Timer0 Interrupt

The TMR0 interrupt is generated when the TMR0 register overflows from FFh to 00h. This overflow sets bit T0IF (INTCON<2>). The interrupt can be masked by clearing bit T0IE (INTCON<5>). Bit T0IF must be cleared in software by the Timer0 module interrupt service routine before re-enabling this interrupt. The TMR0 interrupt cannot awaken the processor from SLEEP since the timer is shut off during SLEEP.

FIGURE 4-2: BLOCK DIAGRAM OF THE TIMER0/WDT PRESCALER

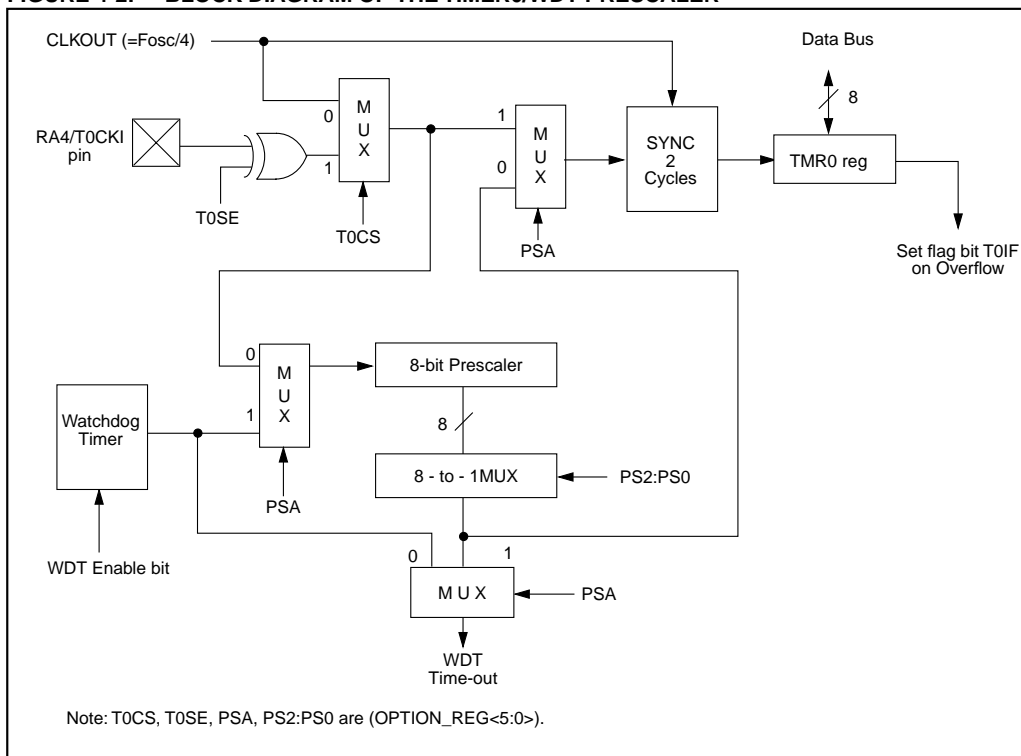


TABLE 4-1: REGISTERS ASSOCIATED WITH TIMER0

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|----------|------------|--------------------------|--------|-------------------------------|-------|-------|-------|-------|-------|-------------------|---------------------------|
| 01h | TMR0 | Timer0 module's register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 0Bh, 8Bh | INTCON | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 81h | OPTION_REG | RBPU | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 | 1111 1111 | 1111 1111 |
| 85h | TRISA | — | — | PORTA Data Direction Register | | | | | | --11 1111 | --11 1111 |

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by Timer0.

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5.0 TIMER1 MODULE

The Timer1 module timer/counter has the following features:

- 16-bit timer/counter (Two 8-bit registers; TMR1H and TMR1L)
- Readable and writable (Both registers)
- Internal or external clock select
- Interrupt on overflow from FFFFh to 0000h
- Reset from CCP module trigger

Timer1 has a control register, shown in Figure 5-1. Timer1 can be enabled/disabled by setting/clearing control bit TMR1ON (T1CON<0>).

Figure 5-2 is a simplified block diagram of the Timer1 module.

Additional information on timer modules is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

5.1 Timer1 Operation

Timer1 can operate in one of these modes:

- As a timer
- As a synchronous counter
- As an asynchronous counter

The operating mode is determined by the clock select bit, TMR1CS (T1CON<1>).

In timer mode, Timer1 increments every instruction cycle. In counter mode, it increments on every rising edge of the external clock input.

When the Timer1 oscillator is enabled (T1OSCEN is set), the RC1/T1OSI and RC0/T1OSO/T1CKI pins become inputs. That is, the TRISC<1:0> value is ignored.

Timer1 also has an internal "reset input". This reset can be generated by the CCP module (Section 7.0).

FIGURE 5-1: T1CON: TIMER1 CONTROL REGISTER (ADDRESS 10h)

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|------|-----|---------|---------|---------|--------|--------|--------|
| — | — | T1CKPS1 | T1CKPS0 | T1OSCEN | T1SYNC | TMR1CS | TMR1ON |
| bit7 | | | | | | | bit0 |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
-n = Value at POR reset

bit 7-6: **Unimplemented:** Read as '0'

bit 5-4: **T1CKPS1:T1CKPS0:** Timer1 Input Clock Prescale Select bits
11 = 1:8 Prescale value
10 = 1:4 Prescale value
01 = 1:2 Prescale value
00 = 1:1 Prescale value

bit 3: **T1OSCEN:** Timer1 Oscillator Enable Control bit
1 = Oscillator is enabled
0 = Oscillator is shut off
Note: The oscillator inverter and feedback resistor are turned off to eliminate power drain

bit 2: **T1SYNC:** Timer1 External Clock Input Synchronization Control bit

TMR1CS = 1
1 = Do not synchronize external clock input
0 = Synchronize external clock input

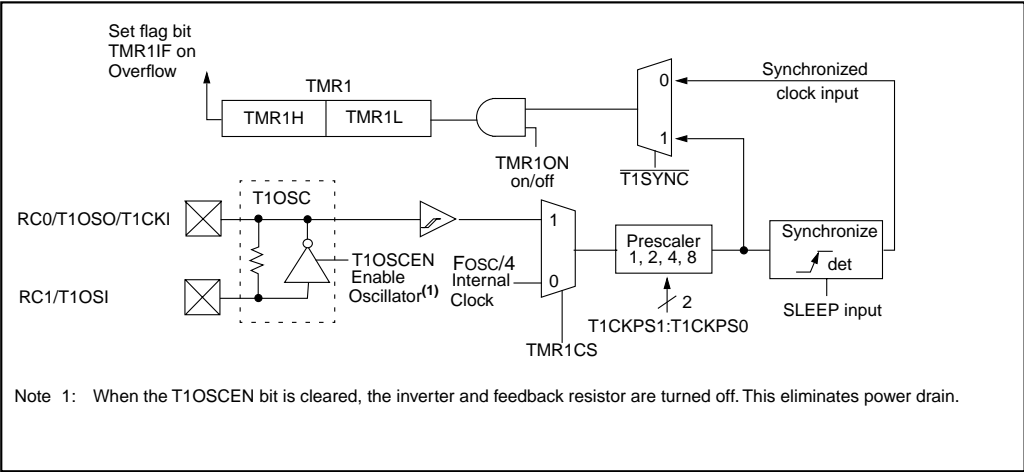
TMR1CS = 0
This bit is ignored. Timer1 uses the internal clock when TMR1CS = 0.

bit 1: **TMR1CS:** Timer1 Clock Source Select bit
1 = External clock from pin RC0/T1OSO/T1CKI (on the rising edge)
0 = Internal clock (Fosc/4)

bit 0: **TMR1ON:** Timer1 On bit
1 = Enables Timer1
0 = Stops Timer1

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FIGURE 5-2: TIMER1 BLOCK DIAGRAM



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5.2 Timer1 Oscillator

A crystal oscillator circuit is built-in between pins T1OSI (input) and T1OSO (amplifier output). It is enabled by setting control bit T1OSCEN (T1CON<3>). The oscillator is a low power oscillator rated up to 200 kHz. It will continue to run during SLEEP. It is primarily intended for a 32 kHz crystal. Table 5-1 shows the capacitor selection for the Timer1 oscillator.

The Timer1 oscillator is identical to the LP oscillator. The user must provide a software time delay to ensure proper oscillator start-up.

TABLE 5-1: CAPACITOR SELECTION FOR THE TIMER1 OSCILLATOR

| Osc Type | Freq | C1 | C2 |
|--|-----------------------|----------|-------|
| LP | 32 kHz | 33 pF | 33 pF |
| | 100 kHz | 15 pF | 15 pF |
| | 200 kHz | 15 pF | 15 pF |
| These values are for design guidance only. | | | |
| Crystals Tested: | | | |
| 32.768 kHz | Epson C-001R32.768K-A | ± 20 PPM | |
| 100 kHz | Epson C-2 100.00 KC-P | ± 20 PPM | |
| 200 kHz | STD XTL 200.000 kHz | ± 20 PPM | |
| Note 1: Higher capacitance increases the stability of the oscillator but also increases the start-up time. 2: Since each resonator/crystal has its own characteristics, the user should consult the resonator/crystal manufacturer for appropriate values of external components. | | | |

TABLE 5-2: REGISTERS ASSOCIATED WITH TIMER1 AS A TIMER/COUNTER

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|--------|---|-------|---------|---------|---------|-----------------|--------|--------|-------------------|---------------------------|
| 0Bh,8Bh | INTCON | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | (1) | ADIF | (1) | (1) | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | (1) | ADIE | (1) | (1) | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 0Eh | TMR1L | Holding register for the Least Significant Byte of the 16-bit TMR1 register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 0Fh | TMR1H | Holding register for the Most Significant Byte of the 16-bit TMR1 register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 10h | T1CON | — | — | T1CKPS1 | T1CKPS0 | T1OSCEN | T1SYN \bar{C} | TMR1CS | TMR1ON | --00 0000 | --uu uuuu |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by the Timer1 module.

Note 1: These bits are reserved, maintain as '0'.

5.3 Timer1 Interrupt

The TMR1 Register pair (TMR1H:TMR1L) increments from 0000h to FFFFh and rolls over to 0000h. The TMR1 Interrupt, if enabled, is generated on overflow which is latched in interrupt flag bit TMR1IF (PIR1<0>). This interrupt can be enabled/disabled by setting/clearing TMR1 interrupt enable bit TMR1IE (PIE1<0>).

5.4 Resetting Timer1 using a CCP Trigger Output

If the CCP module is configured in compare mode to generate a "special event trigger" (CCP1M3:CCP1M0 = 1011), this signal will reset Timer1 and start an A/D conversion (if the A/D module is enabled).

Note: The special event triggers from the CCP1 module will not set interrupt flag bit TMR1IF (PIR1<0>).

Timer1 must be configured for either timer or synchronized counter mode to take advantage of this feature. If Timer1 is running in asynchronous counter mode, this reset operation may not work.

In the event that a write to Timer1 coincides with a special event trigger from CCP1, the write will take precedence.

In this mode of operation, the CCP1H:CCP1L registers pair effectively becomes the period register for Timer1.

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NOTES:

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6.0 TIMER2 MODULE

The Timer2 module timer has the following features:

- 8-bit timer (TMR2 register)
- 8-bit period register (PR2)
- Readable and writable (Both registers)
- Software programmable prescaler (1:1, 1:4, 1:16)
- Software programmable postscaler (1:1 to 1:16)
- Interrupt on TMR2 match of PR2
- SSP module optional use of TMR2 output to generate clock shift

Timer2 has a control register, shown in Figure 6-1. Timer2 can be shut off by clearing control bit TMR2ON (T2CON<2>) to minimize power consumption.

Figure 6-2 is a simplified block diagram of the Timer2 module.

Additional information on timer modules is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

6.1 Timer2 Operation

Timer2 can be used as the PWM time-base for PWM mode of the CCP module.

The TMR2 register is readable and writable, and is cleared on any device reset.

The input clock ($F_{osc}/4$) has a prescale option of 1:1, 1:4 or 1:16, selected by control bits T2CKPS1:T2CKPS0 (T2CON<1:0>).

The match output of TMR2 goes through a 4-bit postscaler (which gives a 1:1 to 1:16 scaling inclusive) to generate a TMR2 interrupt (latched in flag bit TMR2IF, (PIR1<1>)).

The prescaler and postscaler counters are cleared when any of the following occurs:

- a write to the TMR2 register
- a write to the T2CON register
- any device reset (Power-on Reset, \overline{MCLR} reset, Watchdog Timer reset, or Brown-out Reset)

TMR2 is not cleared when T2CON is written.

FIGURE 6-1: T2CON: TIMER2 CONTROL REGISTER (ADDRESS 12h)

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|------|---------|---------|---------|---------|--------|---------|---------|
| — | TOUTPS3 | TOUTPS2 | TOUTPS1 | TOUTPS0 | TMR2ON | T2CKPS1 | T2CKPS0 |
| bit7 | | | | | | | bit0 |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
-n = Value at POR reset

bit 7: **Unimplemented:** Read as '0'

bit 6-3: **TOUTPS3:TOUTPS0:** Timer2 Output Postscale Select bits
0000 = 1:1 Postscale
0001 = 1:2 Postscale
•
•
•
1111 = 1:16 Postscale

bit 2: **TMR2ON:** Timer2 On bit
1 = Timer2 is on
0 = Timer2 is off

bit 1-0: **T2CKPS1:T2CKPS0:** Timer2 Clock Prescale Select bits
00 = Prescaler is 1
01 = Prescaler is 4
1x = Prescaler is 16

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6.2 Timer2 Interrupt

The Timer2 module has an 8-bit period register PR2. Timer2 increments from 00h until it matches PR2 and then resets to 00h on the next increment cycle. PR2 is a readable and writable register. The PR2 register is initialized to FFh upon reset.

6.3 Output of TMR2

The output of TMR2 (before the postscaler) is fed to the Synchronous Serial Port module, which optionally uses it to generate shift clock.

FIGURE 6-2: TIMER2 BLOCK DIAGRAM

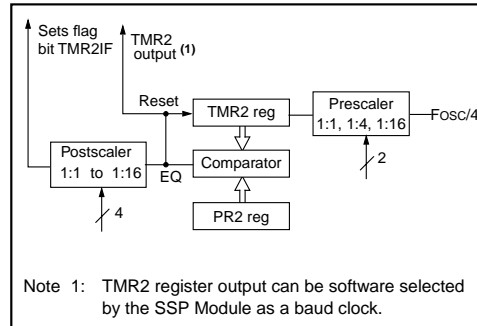


TABLE 6-1: REGISTERS ASSOCIATED WITH TIMER2 AS A TIMER/COUNTER

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on: POR, BOR | Value on all other resets |
|---------|--------|--------------------------|---------|---------|---------|---------|--------|---------|---------|--------------------|---------------------------|
| 0Bh,8Bh | INTCON | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | (1) | ADIF | (1) | (1) | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | (1) | ADIE | (1) | (1) | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 11h | TMR2 | Timer2 module's register | | | | | | | | 0000 0000 | 0000 0000 |
| 12h | T2CON | — | TOUTPS3 | TOUTPS2 | TOUTPS1 | TOUTPS0 | TMR2ON | T2CKPS1 | T2CKPS0 | -000 0000 | -000 0000 |
| 92h | PR2 | Timer2 Period Register | | | | | | | | 1111 1111 | 1111 1111 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by the Timer2 module.

Note 1: These bits are reserved, maintain as '0'.

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7.0 CAPTURE/COMPARE/PWM (CCP) MODULE(S)

Each CCP (Capture/Compare/PWM) module contains a 16-bit register which can operate as a 16-bit capture register, as a 16-bit compare register or as a PWM master/slave Duty Cycle register. Table 7-1 shows the timer resources of the CCP module modes.

The operation of CCP1 is identical to that of CCP2, with the exception of the special trigger. Therefore, operation of a CCP module in the following sections is described with respect to CCP1.

Table 7-2 shows the interaction of the CCP modules.

CCP1 Module

Capture/Compare/PWM Register1 (CCPR1) is comprised of two 8-bit registers: CCPR1L (low byte) and CCPR1H (high byte). The CCP1CON register controls the operation of CCP1. All are readable and writable.

TABLE 7-2: INTERACTION OF TWO CCP MODULES

| CCPx Mode | CCPy Mode | Interaction |
|-----------|-----------|---|
| Capture | Capture | Same TMR1 time-base. |
| Capture | Compare | The compare should be configured for the special event trigger, which clears TMR1. |
| Compare | Compare | The compare(s) should be configured for the special event trigger, which clears TMR1. |
| PWM | PWM | The PWMs will have the same frequency, and update rate (TMR2 interrupt). |
| PWM | Capture | None |
| PWM | Compare | None |

CCP2 Module

Capture/Compare/PWM Register2 (CCPR2) is comprised of two 8-bit registers: CCPR2L (low byte) and CCPR2H (high byte). The CCP2CON register controls the operation of CCP2. All are readable and writable.

Additional information on the CCP module is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

TABLE 7-1: CCP MODE - TIMER RESOURCE

| CCP Mode | Timer Resource |
|----------|----------------|
| Capture | Timer1 |
| Compare | Timer1 |
| PWM | Timer2 |

FIGURE 7-1: CCP1CON REGISTER (ADDRESS 17h) / CCP2CON REGISTER (ADDRESS 1Dh)

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | |
|---|-----|-------|-------|--------|--------|--------|--------|------|
| — | — | CCPxX | CCPxY | CCPxM3 | CCPxM2 | CCPxM1 | CCPxM0 | |
| bit7 | | | | | | | | bit0 |
| <p>bit 7-6: Unimplemented: Read as '0'</p> <p>bit 5-4: CCPxX:CCPxY: PWM Least Significant bits Capture Mode: Unused Compare Mode: Unused PWM Mode: These bits are the two LSBs of the PWM duty cycle. The eight MSBs are found in CCPRxL.</p> <p>bit 3-0: CCPxM3:CCPxM0: CCPx Mode Select bits 0000 = Capture/Compare/PWM off (resets CCPx module) 0100 = Capture mode, every falling edge 0101 = Capture mode, every rising edge 0110 = Capture mode, every 4th rising edge 0111 = Capture mode, every 16th rising edge 1000 = Compare mode, set output on match (CCPxIF bit is set) 1001 = Compare mode, clear output on match (CCPxIF bit is set) 1010 = Compare mode, generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected) 1011 = Compare mode, trigger special event (CCPxIF bit is set; CCP1 resets TMR1; CCP2 resets TMR1 and starts an A/D conversion (if A/D module is enabled)) 11xx = PWM mode</p> | | | | | | | | |

R = Readable bit
 W = Writable bit
 U = Unimplemented bit, read as '0'
 - n = Value at POR reset

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7.1 Capture Mode

In Capture mode, CCPR1H:CCPR1L captures the 16-bit value of the TMR1 register when an event occurs on pin RC2/CCP1. An event is defined as:

- every falling edge
- every rising edge
- every 4th rising edge
- every 16th rising edge

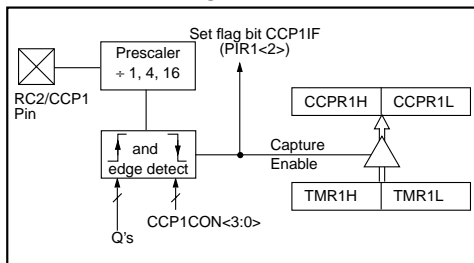
An event is selected by control bits CCP1M3:CCP1M0 (CCP1CON<3:0>). When a capture is made, the interrupt request flag bit CCP1IF (PIR1<2>) is set. It must be cleared in software. If another capture occurs before the value in register CCPR1 is read, the old captured value will be lost.

7.1.1 CCP PIN CONFIGURATION

In Capture mode, the RC2/CCP1 pin should be configured as an input by setting the TRISC<2> bit.

Note: If the RC2/CCP1 is configured as an output, a write to the port can cause a capture condition.

FIGURE 7-2: CAPTURE MODE OPERATION BLOCK DIAGRAM



7.1.2 TIMER1 MODE SELECTION

Timer1 must be running in timer mode or synchronized counter mode for the CCP module to use the capture feature. In asynchronous counter mode, the capture operation may not work.

7.1.3 SOFTWARE INTERRUPT

When the Capture mode is changed, a false capture interrupt may be generated. The user should keep bit CCP1IE (PIE1<2>) clear to avoid false interrupts and should clear the flag bit CCP1IF following any such change in operating mode.

7.1.4 CCP PRESCALER

There are four prescaler settings, specified by bits CCP1M3:CCP1M0. Whenever the CCP module is turned off, or the CCP module is not in capture mode, the prescaler counter is cleared. This means that any reset will clear the prescaler counter.

Switching from one capture prescaler to another may generate an interrupt. Also, the prescaler counter will not be cleared, therefore the first capture may be from a non-zero prescaler. Example 7-1 shows the recommended method for switching between capture prescalers. This example also clears the prescaler counter and will not generate the "false" interrupt.

EXAMPLE 7-1: CHANGING BETWEEN CAPTURE PRESCALERS

```
CLRF  CCP1CON      ;Turn CCP module off
MOVLW NEW_CAPT_PS ;Load the W reg with
                    ; the new prescaler
                    ; mode value and CCP ON
MOVWF  CCP1CON     ;Load CCP1CON with this
                    ; value
```

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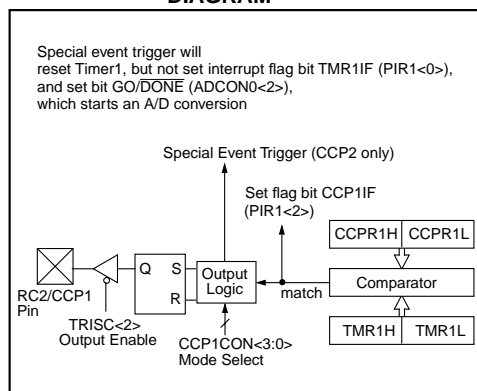
7.2 Compare Mode

In Compare mode, the 16-bit CCPR1 register value is constantly compared against the TMR1 register pair value. When a match occurs, the RC2/CCP1 pin is:

- driven High
- driven Low
- remains Unchanged

The action on the pin is based on the value of control bits CCP1M3:CCP1M0 (CCP1CON<3:0>). At the same time, interrupt flag bit CCP1IF is set.

FIGURE 7-3: COMPARE MODE OPERATION BLOCK DIAGRAM



7.2.1 CCP PIN CONFIGURATION

The user must configure the RC2/CCP1 pin as an output by clearing the TRISC<2> bit.

Note: Clearing the CCP1CON register will force the RC2/CCP1 compare output latch to the default low level. This is not the data latch.

7.2.2 TIMER1 MODE SELECTION

Timer1 must be running in Timer mode or Synchronized Counter mode if the CCP module is using the compare feature. In Asynchronous Counter mode, the compare operation may not work.

7.2.3 SOFTWARE INTERRUPT MODE

When generate software interrupt is chosen the CCP1 pin is not affected. Only a CCP interrupt is generated (if enabled).

7.2.4 SPECIAL EVENT TRIGGER

In this mode, an internal hardware trigger is generated which may be used to initiate an action.

The special event trigger output of CCP1 resets the TMR1 register pair. This allows the CCPR1 register to effectively be a 16-bit programmable period register for Timer1.

The special trigger output of CCP2 resets the TMR1 register pair, and starts an A/D conversion (if the A/D module is enabled).

Note: The special event trigger from the CCP2 module will not set interrupt flag bit TMR1IF (PIR1<0>).

TABLE 7-3: REGISTERS ASSOCIATED WITH CAPTURE, COMPARE, AND TIMER1

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|---------|---|-------|---------|---------|---------|--------|--------|--------|-------------------|---------------------------|
| 0Bh,8Bh | INTCON | GIE | PEIE | TOIE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | (1) | ADIF | (1) | (1) | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | (1) | ADIE | (1) | (1) | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 87h | TRISC | PORTC Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 0Eh | TMR1L | Holding register for the Least Significant Byte of the 16-bit TMR1 register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 0Fh | TMR1H | Holding register for the Most Significant Byte of the 16-bit TMR1 register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 10h | T1CON | — | — | T1CKPS1 | T1CKPS0 | T1OSCEN | T1SYNC | TMR1CS | TMR1ON | --00 0000 | --uu uuuu |
| 15h | CCPR1L | Capture/Compare/PWM register1 (LSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 16h | CCPR1H | Capture/Compare/PWM register1 (MSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 17h | CCP1CON | — | — | CCP1X | CCP1Y | CCP1M3 | CCP1M2 | CCP1M1 | CCP1M0 | --00 0000 | --00 0000 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by Capture and Timer1.

Note 1: These bits/registers are reserved, maintain as '0'.

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7.3 PWM Mode

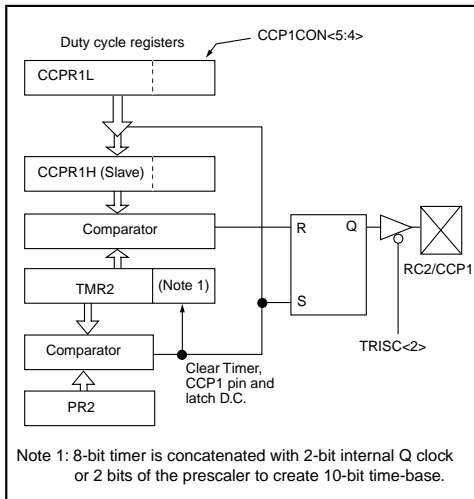
In Pulse Width Modulation (PWM) mode, the CCP1 pin produces up to a 10-bit resolution PWM output. Since the CCP1 pin is multiplexed with the PORTC data latch, the TRISC<2> bit must be cleared to make the CCP1 pin an output.

Note: Clearing the CCP1CON register will force the CCP1 PWM output latch to the default low level. This is not the PORTC I/O data latch.

Figure 7-4 shows a simplified block diagram of the CCP module in PWM mode.

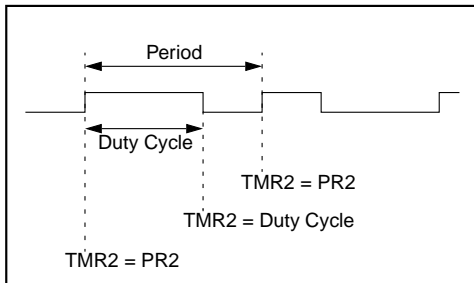
For a step by step procedure on how to set up the CCP module for PWM operation, see Section 7.3.3.

FIGURE 7-4: SIMPLIFIED PWM BLOCK DIAGRAM



A PWM output (Figure 7-5) has a time base (period) and a time that the output stays high (duty cycle). The frequency of the PWM is the inverse of the period (1/period).

FIGURE 7-5: PWM OUTPUT



7.3.1 PWM PERIOD

The PWM period is specified by writing to the PR2 register. The PWM period can be calculated using the following formula:

$$\text{PWM period} = [(PR2) + 1] \cdot 4 \cdot T_{OSC} \cdot (\text{TMR2 prescale value})$$

PWM frequency is defined as $1 / [\text{PWM period}]$.

When TMR2 is equal to PR2, the following three events occur on the next increment cycle:

- TMR2 is cleared
- The CCP1 pin is set (exception: if PWM duty cycle = 0%, the CCP1 pin will not be set)
- The PWM duty cycle is latched from CCPR1L into CCPR1H

Note: The Timer2 postscaler (see Section 6.0) is not used in the determination of the PWM frequency. The postscaler could be used to have a servo update rate at a different frequency than the PWM output.

7.3.2 PWM DUTY CYCLE

The PWM duty cycle is specified by writing to the CCPR1L register and to the CCP1CON<5:4> bits. Up to 10-bit resolution is available: the CCPR1L contains the eight MSBs and the CCP1CON<5:4> contains the two LSBs. This 10-bit value is represented by CCPR1L:CCP1CON<5:4>. The following equation is used to calculate the PWM duty cycle in time:

$$\text{PWM DUTY CYCLE} = (\text{CCPR1L:CCP1CON<5:4>}) \cdot T_{OSC} \cdot (\text{TMR2 PRESCALE VALUE})$$

CCPR1L and CCP1CON<5:4> can be written to at any time, but the duty cycle value is not latched into CCPR1H until after a match between PR2 and TMR2 occurs (i.e., the period is complete). In PWM mode, CCPR1H is a read-only register.

The CCPR1H register and a 2-bit internal latch are used to double buffer the PWM duty cycle. This double buffering is essential for glitchless PWM operation.

When the CCPR1H and 2-bit latch match TMR2 concatenated with an internal 2-bit Q clock or 2 bits of the TMR2 prescaler, the CCP1 pin is cleared.

Maximum PWM resolution (bits) for a given PWM frequency:

$$= \frac{\log\left(\frac{F_{OSC}}{F_{PWM}}\right)}{\log(2)} \text{ bits}$$

Note: If the PWM duty cycle value is longer than the PWM period, the CCP1 pin will not be cleared.

For an example PWM period and duty cycle calculation, see the PICmicro™ Mid-Range Reference Manual (DS33023).

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7.3.3 SET-UP FOR PWM OPERATION

The following steps should be taken when configuring the CCP module for PWM operation:

1. Set the PWM period by writing to the PR2 register.
2. Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON<5:4> bits.
3. Make the CCP1 pin an output by clearing the TRISC<2> bit.
4. Set the TMR2 prescale value and enable Timer2 by writing to T2CON.
5. Configure the CCP1 module for PWM operation.

TABLE 7-4: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS AT 20 MHz

| PWM Frequency | 1.22 kHz | 4.88 kHz | 19.53 kHz | 78.12 kHz | 156.3 kHz | 208.3 kHz |
|----------------------------|----------|----------|-----------|-----------|-----------|-----------|
| Timer Prescaler (1, 4, 16) | 16 | 4 | 1 | 1 | 1 | 1 |
| PR2 Value | 0xFF | 0xFF | 0xFF | 0x3F | 0x1F | 0x17 |
| Maximum Resolution (bits) | 10 | 10 | 10 | 8 | 7 | 5.5 |

TABLE 7-5: REGISTERS ASSOCIATED WITH PWM AND TIMER2

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|---------|-------------------------------------|---------|---------|---------|---------|--------|---------|---------|-------------------|---------------------------|
| 0Bh,8Bh | INTCON | GIE | PEIE | TOIE | INTE | RBIE | TOIF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | (1) | ADIF | (1) | (1) | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | (1) | ADIE | (1) | (1) | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 87h | TRISC | PORTC Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 11h | TMR2 | Timer2 module's register | | | | | | | | 0000 0000 | 0000 0000 |
| 92h | PR2 | Timer2 module's period register | | | | | | | | 1111 1111 | 1111 1111 |
| 12h | T2CON | — | TOUTPS3 | TOUTPS2 | TOUTPS1 | TOUTPS0 | TMR2ON | T2CKPS1 | T2CKPS0 | -000 0000 | -000 0000 |
| 15h | CCPR1L | Capture/Compare/PWM register1 (LSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 16h | CCPR1H | Capture/Compare/PWM register1 (MSB) | | | | | | | | xxxx xxxx | uuuu uuuu |
| 17h | CCP1CON | — | — | CCP1X | CCP1Y | CCP1M3 | CCP1M2 | CCP1M1 | CCP1M0 | --00 0000 | --00 0000 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by PWM and Timer2.

Note 1: These bits/registers are reserved, maintain as '0'.

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NOTES:

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8.0 SYNCHRONOUS SERIAL PORT (SSP) MODULE

8.1 SSP Module Overview

The Synchronous Serial Port (SSP) module is a serial interface useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be Serial EEPROMs, shift registers, display drivers, A/D converters, etc. The SSP module can operate in one of two modes:

- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit (I²C)

For more information on SSP operation (including an I²C Overview), refer to the PICmicro™ Mid-Range Reference Manual (DS33023). Also, refer to Application Note AN578, *“Use of the SSP Module in the I²C Multi-Master Environment.”*

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FIGURE 8-1: SSPSTAT: SYNC SERIAL PORT STATUS REGISTER (ADDRESS 94h)

| R/W-0 | R/W-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|-------|-------|--------------|-----|-----|--------------|-----|------|
| SMP | CKE | D/ \bar{A} | P | S | R/ \bar{W} | UA | BF |
| bit7 | | | | | | | bit0 |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **SMP**: SPI data input sample phase
SPI Master Operation
1 = Input data sampled at end of data output time
0 = Input data sampled at middle of data output time
SPI Slave Mode
SMP must be cleared when SPI is used in slave mode

bit 6: **CKE**: SPI Clock Edge Select
CKP = 0
1 = Data transmitted on rising edge of SCK
0 = Data transmitted on falling edge of SCK
CKP = 1
1 = Data transmitted on falling edge of SCK
0 = Data transmitted on rising edge of SCK

bit 5: **D/ \bar{A}** : Data/Address bit (I²C mode only)
1 = Indicates that the last byte received or transmitted was data
0 = Indicates that the last byte received or transmitted was address

bit 4: **P**: Stop bit (I²C mode only. This bit is cleared when the SSP module is disabled, or when the Start bit is detected last, SSPEN is cleared)
1 = Indicates that a stop bit has been detected last (this bit is '0' on RESET)
0 = Stop bit was not detected last

bit 3: **S**: Start bit (I²C mode only. This bit is cleared when the SSP module is disabled, or when the Stop bit is detected last, SSPEN is cleared)
1 = Indicates that a start bit has been detected last (this bit is '0' on RESET)
0 = Start bit was not detected last

bit 2: **R/ \bar{W}** : Read/Write bit information (I²C mode only)
This bit holds the R/W bit information following the last address match. This bit is only valid from the address match to the next start bit, stop bit, or $\bar{A}CK$ bit.
1 = Read
0 = Write

bit 1: **UA**: Update Address (10-bit I²C mode only)
1 = Indicates that the user needs to update the address in the SSPADD register
0 = Address does not need to be updated

bit 0: **BF**: Buffer Full Status bit
Receive (SPI and I²C modes)
1 = Receive complete, SSPBUF is full
0 = Receive not complete, SSPBUF is empty
Transmit (I²C mode only)
1 = Transmit in progress, SSPBUF is full
0 = Transmit complete, SSPBUF is empty

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FIGURE 8-2: SSPCON: SYNC SERIAL PORT CONTROL REGISTER (ADDRESS 14h)

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|--|-------|-------|-------|-------|-------|-------|-------|
| WCOL | SSPOV | SSPEN | CKP | SSPM3 | SSPM2 | SSPM1 | SSPM0 |
| | | | | | | | bit0 |
| <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-left: auto;"> R = Readable bit W = Writable bit U = Unimplemented bit, read as '0' - n = Value at POR reset </div> | | | | | | | |
| bit 7: WCOL : Write Collision Detect bit 1 = The SSPBUF register is written while it is still transmitting the previous word (must be cleared in software) 0 = No collision | | | | | | | |
| bit 6: SSPOV : Receive Overflow Indicator bit <u>In SPI mode</u> 1 = A new byte is received while the SSPBUF register is still holding the previous data. In case of overflow, the data in SSPSR is lost. Overflow can only occur in slave mode. The user must read the SSPBUF, even if only transmitting data, to avoid setting overflow. In master operation, the overflow bit is not set since each new reception (and transmission) is initiated by writing to the SSPBUF register. 0 = No overflow <u>In I²C mode</u> 1 = A byte is received while the SSPBUF register is still holding the previous byte. SSPOV is a "don't care" in transmit mode. SSPOV must be cleared in software in either mode. 0 = No overflow | | | | | | | |
| bit 5: SSPEN : Synchronous Serial Port Enable bit <u>In SPI mode</u> 1 = Enables serial port and configures SCK, SDO, and SDI as serial port pins 0 = Disables serial port and configures these pins as I/O port pins <u>In I²C mode</u> 1 = Enables the serial port and configures the SDA and SCL pins as serial port pins 0 = Disables serial port and configures these pins as I/O port pins In both modes, when enabled, these pins must be properly configured as input or output. | | | | | | | |
| bit 4: CKP : Clock Polarity Select bit <u>In SPI mode</u> 1 = Idle state for clock is a high level 0 = Idle state for clock is a low level <u>In I²C mode</u> SCK release control 1 = Enable clock 0 = Holds clock low (clock stretch) (Used to ensure data setup time) | | | | | | | |
| bit 3-0: SSPM3:SSPM0 : Synchronous Serial Port Mode Select bits 0000 = SPI master operation, clock = FOSC/4 0001 = SPI master operation, clock = FOSC/16 0010 = SPI master operation, clock = FOSC/64 0011 = SPI master operation, clock = TMR2 output/2 0100 = SPI slave mode, clock = SCK pin. \overline{SS} pin control enabled. 0101 = SPI slave mode, clock = SCK pin. \overline{SS} pin control disabled. \overline{SS} can be used as I/O pin 0110 = I ² C slave mode, 7-bit address 0111 = I ² C slave mode, 10-bit address 1011 = I ² C firmware controlled master operation (slave idle) 1110 = I ² C slave mode, 7-bit address with start and stop bit interrupts enabled 1111 = I ² C slave mode, 10-bit address with start and stop bit interrupts enabled | | | | | | | |

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8.2 SPI Mode

This section contains register definitions and operational characteristics of the SPI module.

Additional information on SPI operation may be found in the PICmicro™ Mid-Range Reference Manual (DS33023).

8.2.1 OPERATION OF SSP MODULE IN SPI MODE

A block diagram of the SSP Module in SPI Mode is shown in Figure 8-3.

The SPI mode allows 8-bits of data to be synchronously transmitted and received simultaneously. To accomplish communication, typically three pins are used:

- Serial Data Out (SDO) RC5/SDO
- Serial Data In (SDI) RC4/SDI/SDA
- Serial Clock (SCK) RC3/SCK/SCL

Additionally a fourth pin may be used when in a slave mode of operation:

- Slave Select (\overline{SS}) RA5/ \overline{SS} /AN4

When initializing the SPI, several options need to be specified. This is done by programming the appropriate control bits in the SSPCON register (SSPCON<5:0>) and SSPSTAT<7:6>. These control bits allow the following to be specified:

- Master Operation (SCK is the clock output)
- Slave Mode (SCK is the clock input)
- Clock Polarity (Idle state of SCK)
- Clock Edge (Output data on rising/falling edge of SCK)
- Clock Rate (master operation only)
- Slave Select Mode (Slave mode only)

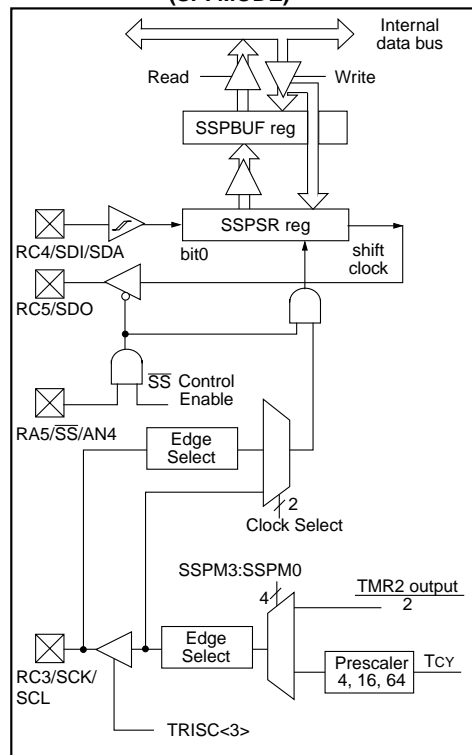
To enable the serial port, SSP Enable bit, SSPEN (SSPCON<5>) must be set. To reset or reconfigure SPI mode, clear bit SSPEN, re-initialize the SSPCON register and then set bit SSPEN. This configures the SDI, SDO, SCK and \overline{SS} pins as serial port pins. For the pins to behave as the serial port function, they must have their data direction bits (in the TRISC register) appropriately programmed. That is:

- SDI must have TRISC<4> set
- SDO must have TRISC<5> cleared
- SCK (master operation) must have TRISC<3> cleared
- SCK (Slave mode) must have TRISC<3> set
- \overline{SS} must have TRISA<5> set

Note: When the SPI is in Slave Mode with \overline{SS} pin control enabled, (SSPCON<3:0> = 0100) the SPI module will reset if the \overline{SS} pin is set to VDD.

Note: If the SPI is used in Slave Mode with CKE = '1', then the \overline{SS} pin control must be enabled.

FIGURE 8-3: SSP BLOCK DIAGRAM (SPI MODE)



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TABLE 8-1: REGISTERS ASSOCIATED WITH SPI OPERATION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on: POR, BOR | Value on all other resets |
|---------|---------|--|-------|-------------------------------|-------|-------|--------|--------|--------|--------------------------|---------------------------------|
| 0Bh,8Bh | INTCON | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | (1) | ADIF | (1) | (1) | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | (1) | ADIE | (1) | (1) | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 87h | TRISC | PORTC Data Direction Register | | | | | | | | 1111 1111 | 1111 1111 |
| 13h | SSPBUF | Synchronous Serial Port Receive Buffer/Transmit Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 14h | SSPCON | WCOL | SSPOV | SSPEN | CKP | SSPM3 | SSPM2 | SSPM1 | SSPM0 | 0000 0000 | 0000 0000 |
| 85h | TRISA | — | — | PORTA Data Direction Register | | | | | | --11 1111 | --11 1111 |
| 94h | SSPSTAT | SMP | CKE | D/Ā | P | S | R/Ī | UA | BF | 0000 0000 | 0000 0000 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used by the SSP in SPI mode.

Note 1: Always maintain these bits clear.

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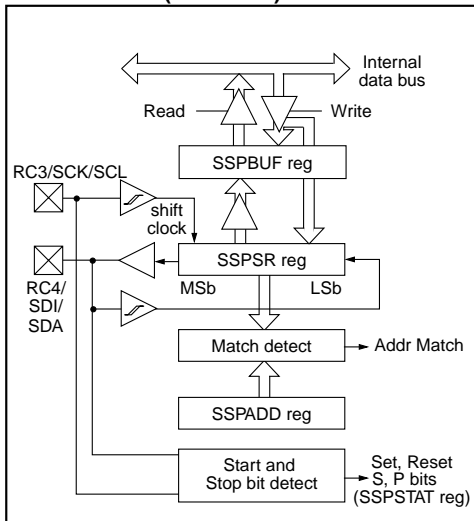
8.3 SSP I²C Operation

The SSP module in I²C mode fully implements all slave functions, except general call support, and provides interrupts on start and stop bits in hardware to facilitate firmware implementations of the master functions. The SSP module implements the standard mode specifications as well as 7-bit and 10-bit addressing.

Two pins are used for data transfer. These are the RC3/SCK/SCL pin, which is the clock (SCL), and the RC4/SDI/SDA pin, which is the data (SDA). The user must configure these pins as inputs or outputs through the TRISC<4:3> bits.

The SSP module functions are enabled by setting SSP Enable bit SSPEN (SSPCON<5>).

FIGURE 8-4: SSP BLOCK DIAGRAM (I²C MODE)



The SSP module has five registers for I²C operation. These are the:

- SSP Control Register (SSPCON)
- SSP Status Register (SSPSTAT)
- Serial Receive/Transmit Buffer (SSPBUF)
- SSP Shift Register (SSPSR) - Not directly accessible
- SSP Address Register (SSPADD)

The SSPCON register allows control of the I²C operation. Four mode selection bits (SSPCON<3:0>) allow one of the following I²C modes to be selected:

- I²C Slave mode (7-bit address)
- I²C Slave mode (10-bit address)
- I²C Slave mode (7-bit address), with start and stop bit interrupts enabled
- I²C Slave mode (10-bit address), with start and stop bit interrupts enabled
- I²C Firmware controlled master operation, slave is idle

Selection of any I²C mode, with the SSPEN bit set, forces the SCL and SDA pins to be open drain, provided these pins are programmed to inputs by setting the appropriate TRISC bits.

Additional information on SSP I²C operation may be found in the PICMicro™ Mid-Range Reference Manual (DS33023).

8.3.1 SLAVE MODE

In slave mode, the SCL and SDA pins must be configured as inputs (TRISC<4:3> set). The SSP module will override the input state with the output data when required (slave-transmitter).

When an address is matched or the data transfer after an address match is received, the hardware automatically will generate the acknowledge (ACK) pulse, and then load the SSPBUF register with the received value currently in the SSPSR register.

There are certain conditions that will cause the SSP module not to give this ACK pulse. These are if either (or both):

- a) The buffer full bit BF (SSPSTAT<0>) was set before the transfer was received.
- b) The overflow bit SSPOV (SSPCON<6>) was set before the transfer was received.

In this case, the SSPSR register value is not loaded into the SSPBUF, but bit SSPIF (PIR1<3>) is set. Table 8-2 shows what happens when a data transfer byte is received, given the status of bits BF and SSPOV. The shaded cells show the condition where user software did not properly clear the overflow condition. Flag bit BF is cleared by reading the SSPBUF register while bit SSPOV is cleared through software.

The SCL clock input must have a minimum high and low for proper operation. The high and low times of the I²C specification as well as the requirement of the SSP module is shown in timing parameter #100 and parameter #101.

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8.3.1.1 ADDRESSING

Once the SSP module has been enabled, it waits for a START condition to occur. Following the START condition, the 8-bits are shifted into the SSPSR register. All incoming bits are sampled with the rising edge of the clock (SCL) line. The value of register SSPSR<7:1> is compared to the value of the SSPADD register. The address is compared on the falling edge of the eighth clock (SCL) pulse. If the addresses match, and the BF and SSPOV bits are clear, the following events occur:

- The SSPSR register value is loaded into the SSPBUF register.
- The buffer full bit, BF is set.
- An \overline{ACK} pulse is generated.
- SSP interrupt flag bit, SSPIF (PIR1<3>) is set (interrupt is generated if enabled) - on the falling edge of the ninth SCL pulse.

In 10-bit address mode, two address bytes need to be received by the slave. The five Most Significant bits (MSBs) of the first address byte specify if this is a 10-bit address. Bit R/\overline{W} (SSPSTAT<2>) must specify a write so the slave device will receive the second address byte. For a 10-bit address the first byte would equal

'1111 0 A9 A8 0', where A9 and A8 are the two MSBs of the address. The sequence of events for 10-bit address is as follows with steps 7- 9 for slave-transmitter:

- Receive first (high) byte of Address (bits SSPIF, BF, and bit UA (SSPSTAT<1>) are set).
- Update the SSPADD register with second (low) byte of Address (clears bit UA and releases the SCL line).
- Read the SSPBUF register (clears bit BF) and clear flag bit SSPIF.
- Receive second (low) byte of Address (bits SSPIF, BF, and UA are set).
- Update the SSPADD register with the first (high) byte of Address. If match releases SCL line, this will clear bit UA.
- Read the SSPBUF register (clears bit BF) and clear flag bit SSPIF.
- Receive repeated START condition.
- Receive first (high) byte of Address (bits SSPIF and BF are set).
- Read the SSPBUF register (clears bit BF) and clear flag bit SSPIF.

TABLE 8-2: DATA TRANSFER RECEIVED BYTE ACTIONS

| Status Bits as Data Transfer is Received | | SSPSR → SSPBUF | Generate \overline{ACK} Pulse | Set bit SSPIF (SSP Interrupt occurs if enabled) |
|--|-------|----------------|---------------------------------|---|
| BF | SSPOV | | | |
| 0 | 0 | Yes | Yes | Yes |
| 1 | 0 | No | No | Yes |
| 1 | 1 | No | No | Yes |
| 0 | 1 | Yes | No | Yes |

Note: Shaded cells show the conditions where the user software did not properly clear the overflow condition.

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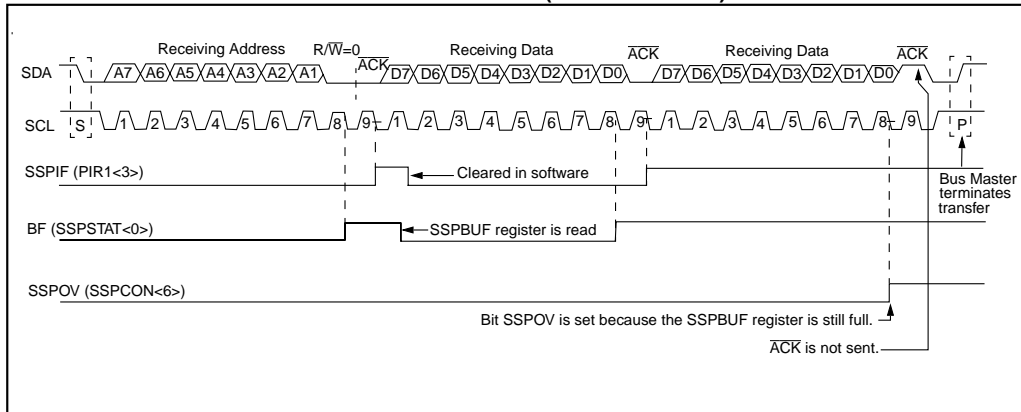
8.3.1.2 RECEPTION

When the R/\overline{W} bit of the address byte is clear and an address match occurs, the R/\overline{W} bit of the SSPSTAT register is cleared. The received address is loaded into the SSPBUF register.

When the address byte overflow condition exists, then no acknowledge (\overline{ACK}) pulse is given. An overflow condition is defined as either bit BF (SSPSTAT<0>) is set or bit SSPOV (SSPCON<6>) is set.

An SSP interrupt is generated for each data transfer byte. Flag bit SSPIF (PIR1<3>) must be cleared in software. The SSPSTAT register is used to determine the status of the byte.

FIGURE 8-5: I²C WAVEFORMS FOR RECEPTION (7-BIT ADDRESS)



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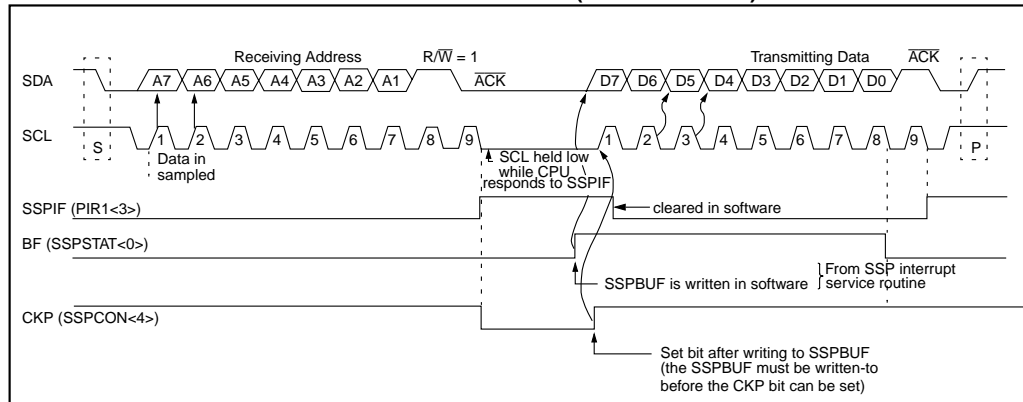
8.3.1.3 TRANSMISSION

When the R/\bar{W} bit of the incoming address byte is set and an address match occurs, the R/\bar{W} bit of the SSPSTAT register is set. The received address is loaded into the SSPBUF register. The \bar{ACK} pulse will be sent on the ninth bit, and pin RC3/SCK/SCL is held low. The transmit data must be loaded into the SSPBUF register, which also loads the SSPSR register. Then pin RC3/SCK/SCL should be enabled by setting bit CKP (SSPCON<4>). The master must monitor the SCL pin prior to asserting another clock pulse. The slave devices may be holding off the master by stretching the clock. The eight data bits are shifted out on the falling edge of the SCL input. This ensures that the SDA signal is valid during the SCL high time (Figure 8-6).

An SSP interrupt is generated for each data transfer byte. Flag bit SSPIF must be cleared in software, and the SSPSTAT register is used to determine the status of the byte. Flag bit SSPIF is set on the falling edge of the ninth clock pulse.

As a slave-transmitter, the \bar{ACK} pulse from the master-receiver is latched on the rising edge of the ninth SCL input pulse. If the SDA line was high (not \bar{ACK}), then the data transfer is complete. When the \bar{ACK} is latched by the slave, the slave logic is reset (resets SSPSTAT register) and the slave then monitors for another occurrence of the START bit. If the SDA line was low (\bar{ACK}), the transmit data must be loaded into the SSPBUF register, which also loads the SSPSR register. Then pin RC3/SCK/SCL should be enabled by setting bit CKP.

FIGURE 8-6: I²C WAVEFORMS FOR TRANSMISSION (7-BIT ADDRESS)



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8.3.2 MASTER OPERATION

Master operation is supported in firmware using interrupt generation on the detection of the START and STOP conditions. The STOP (P) and START (S) bits are cleared from a reset or when the SSP module is disabled. The STOP (P) and START (S) bits will toggle based on the START and STOP conditions. Control of the I²C bus may be taken when the P bit is set, or the bus is idle and both the S and P bits are clear.

In master operation, the SCL and SDA lines are manipulated in firmware by clearing the corresponding TRISC<4:3> bit(s). The output level is always low, irrespective of the value(s) in PORTC<4:3>. So when transmitting data, a '1' data bit must have the TRISC<4> bit set (input) and a '0' data bit must have the TRISC<4> bit cleared (output). The same scenario is true for the SCL line with the TRISC<3> bit.

The following events will cause SSP Interrupt Flag bit, SSPIF, to be set (SSP Interrupt if enabled):

- START condition
- STOP condition
- Data transfer byte transmitted/received

Master operation can be done with either the slave mode idle (SSPM3:SSPM0 = 1011) or with the slave active. When both master operation and slave modes are used, the software needs to differentiate the source(s) of the interrupt.

For more information on master operation, see AN554 - Software Implementation of I²C Bus Master.

8.3.3 MULTI-MASTER OPERATION

In multi-master operation, the interrupt generation on the detection of the START and STOP conditions allows the determination of when the bus is free. The STOP (P) and START (S) bits are cleared from a reset or when the SSP module is disabled. The STOP (P) and START (S) bits will toggle based on the START and STOP conditions. Control of the I²C bus may be taken when bit P (SSPSTAT<4>) is set, or the bus is idle and both the S and P bits clear. When the bus is busy, enabling the SSP Interrupt will generate the interrupt when the STOP condition occurs.

In multi-master operation, the SDA line must be monitored to see if the signal level is the expected output level. This check only needs to be done when a high level is output. If a high level is expected and a low level is present, the device needs to release the SDA and SCL lines (set TRISC<4:3>). There are two stages where this arbitration can be lost, these are:

- Address Transfer
- Data Transfer

When the slave logic is enabled, the slave continues to receive. If arbitration was lost during the address transfer stage, communication to the device may be in progress. If addressed, an \overline{ACK} pulse will be generated. If arbitration was lost during the data transfer stage, the device will need to re-transfer the data at a later time.

For more information on master operation, see AN578 - Use of the SSP Module in the of I²C Multi-Master Environment.

TABLE 8-3: REGISTERS ASSOCIATED WITH I²C OPERATION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|----------|---------|--|-------|-------------------|-------|-------|-------------------|--------|--------|-------------------|---------------------------|
| 0Bh, 8Bh | INTCON | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | (1) | ADIF | (1) | (1) | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | (1) | ADIE | (1) | (1) | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 13h | SSPBUF | Synchronous Serial Port Receive Buffer/Transmit Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 93h | SSPADD | Synchronous Serial Port (I ² C mode) Address Register | | | | | | | | 0000 0000 | 0000 0000 |
| 14h | SSPCON | WCOL | SSPOV | SSPEN | CKP | SSPM3 | SSPM2 | SSPM1 | SSPM0 | 0000 0000 | 0000 0000 |
| 94h | SSPSTAT | SMP | CKE | D/ \overline{A} | P | S | R/ \overline{W} | UA | BF | 0000 0000 | 0000 0000 |
| 87h | TRISC | PORTC Data Direction register | | | | | | | | 1111 1111 | 1111 1111 |

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'.

Shaded cells are not used by SSP module in SPI mode.

Note 1: These bits are unimplemented, read as '0'.

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9.0 UNIVERSAL SYNCHRONOUS ASYNCHRONOUS RECEIVER TRANSMITTER (USART)

The Universal Synchronous Asynchronous Receiver Transmitter (USART) module is one of the two serial I/O modules. (USART is also known as a Serial Communications Interface or SCI). The USART can be configured as a full duplex asynchronous system that can communicate with peripheral devices such as CRT terminals and personal computers, or it can be configured as a half duplex synchronous system that can communicate with peripheral devices such as A/D or D/A integrated circuits, Serial EEPROMs etc.

The USART can be configured in the following modes:

- Asynchronous (full duplex)
- Synchronous - Master (half duplex)
- Synchronous - Slave (half duplex)

Bit SPEN (RCSTA<7>), and bits TRISC<7:6>, have to be set in order to configure pins RC6/TX/CK and RC7/RX/DT as the Universal Synchronous Asynchronous Receiver Transmitter.

FIGURE 9-1: TXSTA: TRANSMIT STATUS AND CONTROL REGISTER (ADDRESS 98h)

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R-1 | R/W-0 |
|---|-------|-------|-------|-----|-------|------|-------|
| CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D |
| | | | | | | | bit0 |
| bit7 | | | | | | | |
| <p>bit 7: CSRC: Clock Source Select bit</p> <p><u>Asynchronous mode</u> Don't care</p> <p><u>Synchronous mode</u> 1 = Master mode (Clock generated internally from BRG) 0 = Slave mode (Clock from external source)</p> <p>bit 6: TX9: 9-bit Transmit Enable bit 1 = Selects 9-bit transmission 0 = Selects 8-bit transmission</p> <p>bit 5: TXEN: Transmit Enable bit 1 = Transmit enabled 0 = Transmit disabled Note: SREN/CREN overrides TXEN in SYNC mode.</p> <p>bit 4: SYNC: USART Mode Select bit 1 = Synchronous mode 0 = Asynchronous mode</p> <p>bit 3: Unimplemented: Read as '0'</p> <p>bit 2: BRGH: High Baud Rate Select bit</p> <p><u>Asynchronous mode</u> 1 = High speed 0 = Low speed</p> <p><u>Synchronous mode</u> Unused in this mode</p> <p>bit 1: TRMT: Transmit Shift Register Status bit 1 = TSR empty 0 = TSR full</p> <p>bit 0: TX9D: 9th bit of transmit data. Can be parity bit.</p> | | | | | | | |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

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FIGURE 9-2: RCSTA: RECEIVE STATUS AND CONTROL REGISTER (ADDRESS 18h)

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R-0 | R-0 | R-x |
|-------|-------|-------|-------|-----|------|------|------|
| SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D |
| bit7 | | | | | | | bit0 |

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **SPEN**: Serial Port Enable bit
1 = Serial port enabled (Configures RC7/RX/DT and RC6/TX/CK pins as serial port pins)
0 = Serial port disabled

bit 6: **RX9**: 9-bit Receive Enable bit
1 = Selects 9-bit reception
0 = Selects 8-bit reception

bit 5: **SREN**: Single Receive Enable bit
Asynchronous mode
Don't care
Synchronous mode - master
1 = Enables single receive
0 = Disables single receive
This bit is cleared after reception is complete.
Synchronous mode - slave
Unused in this mode

bit 4: **CREN**: Continuous Receive Enable bit
Asynchronous mode
1 = Enables continuous receive
0 = Disables continuous receive
Synchronous mode
1 = Enables continuous receive until enable bit CREN is cleared (CREN overrides SREN)
0 = Disables continuous receive

bit 3: **Unimplemented**: Read as '0'

bit 2: **FERR**: Framing Error bit
1 = Framing error (Can be updated by reading RCREG register and receive next valid byte)
0 = No framing error

bit 1: **OERR**: Overrun Error bit
1 = Overrun error (Can be cleared by clearing bit CREN)
0 = No overrun error

bit 0: **RX9D**: 9th bit of received data (Can be parity bit)

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9.1 USART Baud Rate Generator (BRG)

The BRG supports both the Asynchronous and Synchronous modes of the USART. It is a dedicated 8-bit baud rate generator. The SPBRG register controls the period of a free running 8-bit timer. In asynchronous mode bit BRGH (TXSTA<2>) also controls the baud rate. In synchronous mode bit BRGH is ignored. Table 9-1 shows the formula for computation of the baud rate for different USART modes which only apply in master mode (internal clock).

Given the desired baud rate and F_{osc} , the nearest integer value for the SPBRG register can be calculated using the formula in Table 9-1. From this, the error in baud rate can be determined.

Example 9-1 shows the calculation of the baud rate error for the following conditions:

$F_{osc} = 16 \text{ MHz}$
 Desired Baud Rate = 9600
 BRGH = 0
 SYNC = 0

EXAMPLE 9-1: CALCULATING BAUD RATE ERROR

$$\begin{aligned} \text{Desired Baud rate} &= F_{osc} / (64 (X + 1)) \\ 9600 &= 16000000 / (64 (X + 1)) \\ X &= \lfloor 25.042 \rfloor = 25 \\ \text{Calculated Baud Rate} &= 16000000 / (64 (25 + 1)) \\ &= 9615 \\ \text{Error} &= \frac{(\text{Calculated Baud Rate} - \text{Desired Baud Rate})}{\text{Desired Baud Rate}} \\ &= (9615 - 9600) / 9600 \\ &= 0.16\% \end{aligned}$$

It may be advantageous to use the high baud rate (BRGH = 1) even for slower baud clocks. This is because the $F_{osc}/(16(X + 1))$ equation can reduce the baud rate error in some cases.

Writing a new value to the SPBRG register causes the BRG timer to be reset (or cleared). This ensures the BRG does not wait for a timer overflow before outputting the new baud rate.

9.1.1 SAMPLING

The data on the RC7/RX/DT pin is sampled three times by a majority detect circuit to determine if a high or a low level is present at the RX pin.

TABLE 9-1: BAUD RATE FORMULA

| SYNC | BRGH = 0 (Low Speed) | BRGH = 1 (High Speed) |
|------|--|---------------------------------|
| 0 | (Asynchronous) Baud Rate = $F_{osc}/(64(X+1))$ | Baud Rate = $F_{osc}/(16(X+1))$ |
| 1 | (Synchronous) Baud Rate = $F_{osc}/(4(X+1))$ | NA |

X = value in SPBRG (0 to 255)

TABLE 9-2: REGISTERS ASSOCIATED WITH BAUD RATE GENERATOR

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other resets |
|---------|-------|------------------------------|-------|-------|-------|-------|-------|-------|-------|-------------------|---------------------------|
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented read as '0'. Shaded cells are not used by the BRG.

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TABLE 9-3: BAUD RATES FOR SYNCHRONOUS MODE

| BAUD RATE (K) | FOSC = 20 MHz | | | 16 MHz | | | 10 MHz | | | 7.15909 MHz | | |
|---------------|---------------|-------|-----------------------|--------|-------|-----------------------|--------|-------|-----------------------|-------------|-------|-----------------------|
| | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) |
| 0.3 | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 1.2 | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 2.4 | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 9.6 | NA | - | - | NA | - | - | 9.766 | +1.73 | 255 | 9.622 | +0.23 | 185 |
| 19.2 | 19.53 | +1.73 | 255 | 19.23 | +0.16 | 207 | 19.23 | +0.16 | 129 | 19.24 | +0.23 | 92 |
| 76.8 | 76.92 | +0.16 | 64 | 76.92 | +0.16 | 51 | 75.76 | -1.36 | 32 | 77.82 | +1.32 | 22 |
| 96 | 96.15 | +0.16 | 51 | 95.24 | -0.79 | 41 | 96.15 | +0.16 | 25 | 94.20 | -1.88 | 18 |
| 300 | 294.1 | -1.96 | 16 | 307.69 | +2.56 | 12 | 312.5 | +4.17 | 7 | 298.3 | -0.57 | 5 |
| 500 | 500 | 0 | 9 | 500 | 0 | 7 | 500 | 0 | 4 | NA | - | - |
| HIGH | 5000 | - | 0 | 4000 | - | 0 | 2500 | - | 0 | 1789.8 | - | 0 |
| LOW | 19.53 | - | 255 | 15.625 | - | 255 | 9.766 | - | 255 | 6.991 | - | 255 |

| BAUD RATE (K) | FOSC = 5.0688 MHz | | | 4 MHz | | | 3.579545 MHz | | | 1 MHz | | | 32.768 kHz | | |
|---------------|-------------------|-------|-------|--------|-------|-----------------------|--------------|-------|-----------------------|--------|-------|-----------------------|------------|-------|-----------------------|
| | KBAUD | % | SPBRG | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) |
| 0.3 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | 0.303 | +1.14 | 26 |
| 1.2 | NA | - | - | NA | - | - | NA | - | - | 1.202 | +0.16 | 207 | 1.170 | -2.48 | 6 |
| 2.4 | NA | - | - | NA | - | - | NA | - | - | 2.404 | +0.16 | 103 | NA | - | - |
| 9.6 | 9.6 | 0 | 131 | 9.615 | +0.16 | 103 | 9.622 | +0.23 | 92 | 9.615 | +0.16 | 25 | NA | - | - |
| 19.2 | 19.2 | 0 | 65 | 19.231 | +0.16 | 51 | 19.04 | -0.83 | 46 | 19.24 | +0.16 | 12 | NA | - | - |
| 76.8 | 79.2 | +3.13 | 15 | 76.923 | +0.16 | 12 | 74.57 | -2.90 | 11 | 83.34 | +8.51 | 2 | NA | - | - |
| 96 | 97.48 | +1.54 | 12 | 1000 | +4.17 | 9 | 99.43 | +3.57 | 8 | NA | - | - | NA | - | - |
| 300 | 316.8 | +5.60 | 3 | NA | - | - | 298.3 | -0.57 | 2 | NA | - | - | NA | - | - |
| 500 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| HIGH | 1267 | - | 0 | 100 | - | 0 | 894.9 | - | 0 | 250 | - | 0 | 8.192 | - | 0 |
| LOW | 4.950 | - | 255 | 3.906 | - | 255 | 3.496 | - | 255 | 0.9766 | - | 255 | 0.032 | - | 255 |

TABLE 9-4: BAUD RATES FOR ASYNCHRONOUS MODE (BRGH = 0)

| BAUD RATE (K) | FOSC = 20 MHz | | | 16 MHz | | | 10 MHz | | | 7.15909 MHz | | |
|---------------|---------------|-------|-----------------------|--------|-------|-----------------------|--------|-------|-----------------------|-------------|-------|-----------------------|
| | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) |
| 0.3 | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 1.2 | 1.221 | +1.73 | 255 | 1.202 | +0.16 | 207 | 1.202 | +0.16 | 129 | 1.203 | +0.23 | 92 |
| 2.4 | 2.404 | +0.16 | 129 | 2.404 | +0.16 | 103 | 2.404 | +0.16 | 64 | 2.380 | -0.83 | 46 |
| 9.6 | 9.469 | -1.36 | 32 | 9.615 | +0.16 | 25 | 9.766 | +1.73 | 15 | 9.322 | -2.90 | 11 |
| 19.2 | 19.53 | +1.73 | 15 | 19.23 | +0.16 | 12 | 19.53 | +1.73 | 7 | 18.64 | -2.90 | 5 |
| 76.8 | 78.13 | +1.73 | 3 | 83.33 | +8.51 | 2 | 78.13 | +1.73 | 1 | NA | - | - |
| 96 | 104.2 | +8.51 | 2 | NA | - | - | NA | - | - | NA | - | - |
| 300 | 312.5 | +4.17 | 0 | NA | - | - | NA | - | - | NA | - | - |
| 500 | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| HIGH | 312.5 | - | 0 | 250 | - | 0 | 156.3 | - | 0 | 111.9 | - | 0 |
| LOW | 1.221 | - | 255 | 0.977 | - | 255 | 0.6104 | - | 255 | 0.437 | - | 255 |

| BAUD RATE (K) | FOSC = 5.0688 MHz | | | 4 MHz | | | 3.579545 MHz | | | 1 MHz | | | 32.768 kHz | | |
|---------------|-------------------|-------|-------|--------|-------|-----------------------|--------------|-------|-----------------------|--------|-------|-----------------------|------------|--------|-----------------------|
| | KBAUD | % | SPBRG | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) | KBAUD | % | SPBRG value (decimal) |
| 0.3 | 0.31 | +3.13 | 255 | 0.3005 | -0.17 | 207 | 0.301 | +0.23 | 185 | 0.300 | +0.16 | 51 | 0.256 | -14.67 | 1 |
| 1.2 | 1.2 | 0 | 65 | 1.202 | +1.67 | 51 | 1.190 | -0.83 | 46 | 1.202 | +0.16 | 12 | NA | - | - |
| 2.4 | 2.4 | 0 | 32 | 2.404 | +1.67 | 25 | 2.432 | +1.32 | 22 | 2.232 | -6.99 | 6 | NA | - | - |
| 9.6 | 9.9 | +3.13 | 7 | NA | - | - | 9.322 | -2.90 | 5 | NA | - | - | NA | - | - |
| 19.2 | 19.8 | +3.13 | 3 | NA | - | - | 18.64 | -2.90 | 2 | NA | - | - | NA | - | - |
| 76.8 | 79.2 | +3.13 | 0 | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 96 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 300 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 500 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| HIGH | 79.2 | - | 0 | 62.500 | - | 0 | 55.93 | - | 0 | 15.63 | - | 0 | 0.512 | - | 0 |
| LOW | 0.3094 | - | 255 | 3.906 | - | 255 | 0.2185 | - | 255 | 0.0610 | - | 255 | 0.0020 | - | 255 |

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TABLE 9-5: BAUD RATES FOR ASYNCHRONOUS MODE (BRGH = 1)

| BAUD RATE (K) | FOSC = 20 MHz | | | 16 MHz | | | 10 MHz | | | 7.16 MHz | | |
|---------------|---------------|-----------------------|-----|---------|-----------------------|-----|--------|-----------------------|----|----------|-----------------------|----|
| | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | |
| 9.6 | 9.615 | +0.16 | 129 | 9.615 | +0.16 | 103 | 9.615 | +0.16 | 64 | 9.520 | -0.83 | 46 |
| 19.2 | 19.230 | +0.16 | 64 | 19.230 | +0.16 | 51 | 18.939 | -1.36 | 32 | 19.454 | +1.32 | 22 |
| 38.4 | 37.878 | -1.36 | 32 | 38.461 | +0.16 | 25 | 39.062 | +1.7 | 15 | 37.286 | -2.90 | 11 |
| 57.6 | 56.818 | -1.36 | 21 | 58.823 | +2.12 | 16 | 56.818 | -1.36 | 10 | 55.930 | -2.90 | 7 |
| 115.2 | 113.636 | -1.36 | 10 | 111.111 | -3.55 | 8 | 125 | +8.51 | 4 | 111.860 | -2.90 | 3 |
| 250 | 250 | 0 | 4 | 250 | 0 | 3 | NA | - | - | NA | - | - |
| 625 | 625 | 0 | 1 | NA | - | - | 625 | 0 | 0 | NA | - | - |
| 1250 | 1250 | 0 | 0 | NA | - | - | NA | - | - | NA | - | - |

| BAUD RATE (K) | FOSC = 5.068 | | | 4 MHz | | | 3.579 MHz | | | 1 MHz | | | 32.768 kHz | | |
|---------------|--------------|-----------------------|----|--------|-----------------------|-----|-----------|-----------------------|----|--------|-----------------------|---|------------|-----------------------|---|
| | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | | % | SPBRG value (decimal) | |
| 9.6 | 9.6 | 0 | 32 | NA | - | - | 9.727 | +1.32 | 22 | 8.928 | -6.99 | 6 | NA | - | - |
| 19.2 | 18.645 | -2.94 | 16 | 1.202 | +0.17 | 207 | 18.643 | -2.90 | 11 | 20.833 | +8.51 | 2 | NA | - | - |
| 38.4 | 39.6 | +3.12 | 7 | 2.403 | +0.13 | 103 | 37.286 | -2.90 | 5 | 31.25 | -18.61 | 1 | NA | - | - |
| 57.6 | 52.8 | -8.33 | 5 | 9.615 | +0.16 | 25 | 55.930 | -2.90 | 3 | 62.5 | +8.51 | 0 | NA | - | - |
| 115.2 | 105.6 | -8.33 | 2 | 19.231 | +0.16 | 12 | 111.860 | -2.90 | 1 | NA | - | - | NA | - | - |
| 250 | NA | - | - | NA | - | - | 223.721 | -10.51 | 0 | NA | - | - | NA | - | - |
| 625 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - |
| 1250 | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - |

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9.2 USART Asynchronous Mode

In this mode, the USART uses standard non-return-to-zero (NRZ) format (one start bit, eight or nine data bits and one stop bit). The most common data format is 8-bits. An on-chip dedicated 8-bit baud rate generator can be used to derive standard baud rate frequencies from the oscillator. The USART transmits and receives the LSb first. The USART's transmitter and receiver are functionally independent, but use the same data format and baud rate. The baud rate generator produces a clock, either x16 or x64 of the bit shift rate, depending on bit BRGH (TXSTA<2>). Parity is not supported by the hardware, but can be implemented in software (and stored as the ninth data bit). Asynchronous mode is stopped during SLEEP.

Asynchronous mode is selected by clearing bit SYNC (TXSTA<4>).

The USART Asynchronous module consists of the following important elements:

- Baud Rate Generator
- Sampling Circuit
- Asynchronous Transmitter
- Asynchronous Receiver

9.2.1 USART ASYNCHRONOUS TRANSMITTER

The USART transmitter block diagram is shown in Figure 9-3. The heart of the transmitter is the transmit (serial) shift register (TSR). The shift register obtains its data from the read/write transmit buffer, TXREG. The TXREG register is loaded with data in software. The TSR register is not loaded until the STOP bit has been transmitted from the previous load. As soon as the STOP bit is transmitted, the TSR is loaded with new data from the TXREG register (if available). Once the TXREG register transfers the data to the TSR register

(occurs in one Tcy), the TXREG register is empty and flag bit TXIF (PIR1<4>) is set. This interrupt can be enabled/disabled by setting/clearing enable bit TXIE (PIE1<4>). Flag bit TXIF will be set regardless of the state of enable bit TXIE and cannot be cleared in software. It will reset only when new data is loaded into the TXREG register. While flag bit TXIF indicated the status of the TXREG register, another bit TRMT (TXSTA<1>) shows the status of the TSR register. Status bit TRMT is a read only bit which is set when the TSR register is empty. No interrupt logic is tied to this bit, so the user has to poll this bit in order to determine if the TSR register is empty.

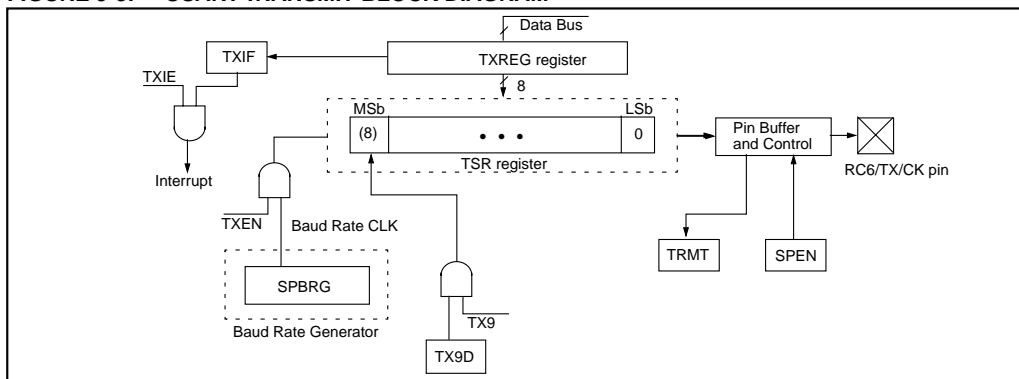
Note 1: The TSR register is not mapped in data memory so it is not available to the user.

Note 2: Flag bit TXIF is set when enable bit TXEN is set.

Steps to follow when setting up an asynchronous transmission:

1. Initialize the SPBRG register for the appropriate baud rate. If a high speed baud rate is desired, set bit BRGH. (Section 9.1)
2. Enable the asynchronous serial port by clearing bit SYNC and setting bit SPEN.
3. If interrupts are desired, then set enable bit TXIE.
4. If 9-bit transmission is desired, then set transmit bit TX9.
5. Enable the transmission by setting bit TXEN, which will also set bit TXIF.
6. If 9-bit transmission is selected, the ninth bit should be loaded in bit TX9D.
7. Load data to the TXREG register (starts transmission).

FIGURE 9-3: USART TRANSMIT BLOCK DIAGRAM



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FIGURE 9-4: ASYNCHRONOUS TRANSMISSION

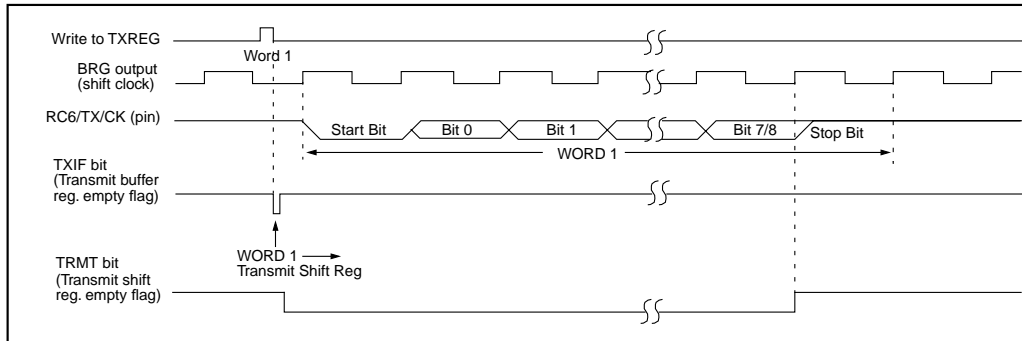


FIGURE 9-5: ASYNCHRONOUS TRANSMISSION (BACK TO BACK)

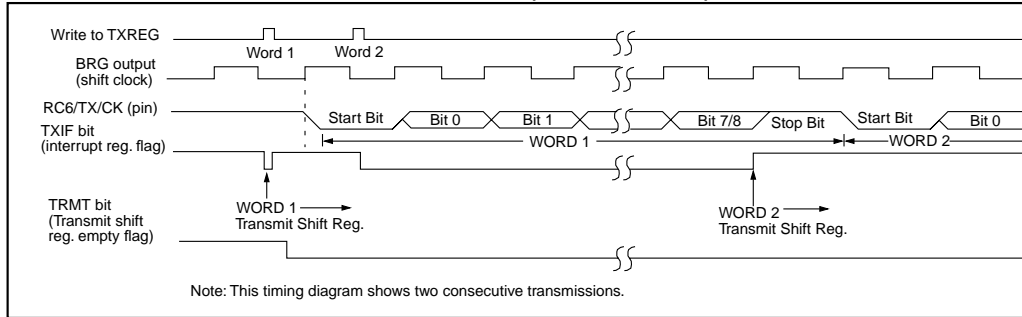


TABLE 9-6: REGISTERS ASSOCIATED WITH ASYNCHRONOUS TRANSMISSION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other Resets |
|---------|-------|------------------------------|----------------------|-------|-------|--------|--------|---------|---------|-------------------|---------------------------|
| 0Ch | PIR1 | PSP1IF ⁽¹⁾ | AD1IF ⁽²⁾ | RC1IF | TX1IF | SSP1IF | CCP1IF | TMR21F | TMR11F | 0000 0000 | 0000 0000 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 19h | TXREG | USART Transmit Register | | | | | | | | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSP1IE ⁽¹⁾ | AD1IE ⁽²⁾ | RC1IE | TX1IE | SSP1IE | CCP1IE | TMR21IE | TMR11IE | 0000 0000 | 0000 0000 |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented locations read as '0'. Shaded cells are not used for Asynchronous Transmission.

Note 1: PORTD and PORTE not implemented on the PIC16C63A/73B, maintain as '0'.

2: A/D not implemented on the PIC16C63A/65B, maintain as '0'.

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9.2.2 USART ASYNCHRONOUS RECEIVER

The receiver block diagram is shown in Figure 9-6. The data is received on the RC7/RX/DT pin and drives the data recovery block. The data recovery block is actually a high speed shifter operating at x16 times the baud rate, whereas the main receive serial shifter operates at the bit rate or at FOSC.

Steps to follow when setting up an Asynchronous Reception:

1. Initialize the SPBRG register for the appropriate baud rate. If a high speed baud rate is desired, set bit BRGH. (Section 9.1).
2. Enable the asynchronous serial port by clearing bit SYNC, and setting bit SPEN.
3. If interrupts are desired, then set enable bit RCIE.
4. If 9-bit reception is desired, then set bit RX9.
5. Enable the reception by setting bit CREN.
6. Flag bit RCIF will be set when reception is complete and an interrupt will be generated if enable bit RCIE was set.
7. Read the RCSTA register to get the ninth bit (if enabled) and determine if any error occurred during reception.
8. Read the 8-bit received data by reading the RCREG register.
9. If any error occurred, clear the error by clearing enable bit CREN.

FIGURE 9-6: USART RECEIVE BLOCK DIAGRAM

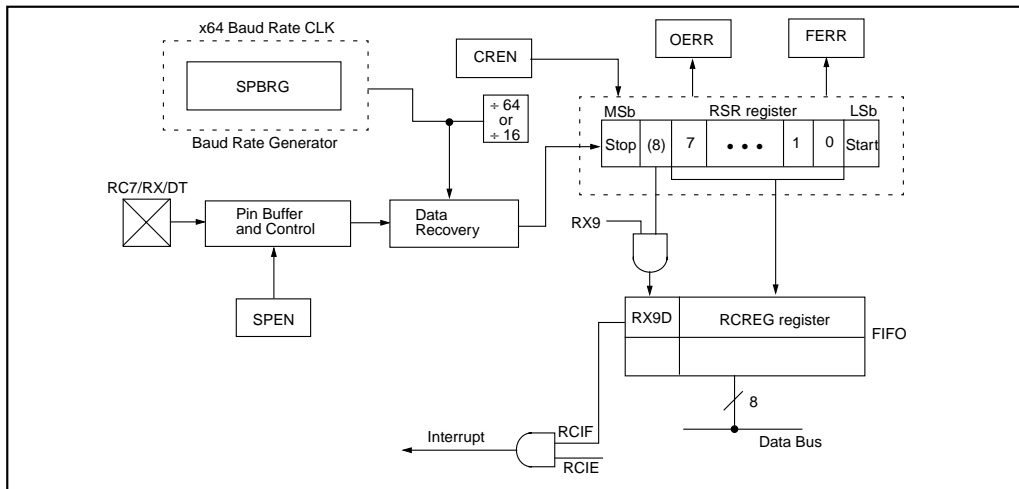
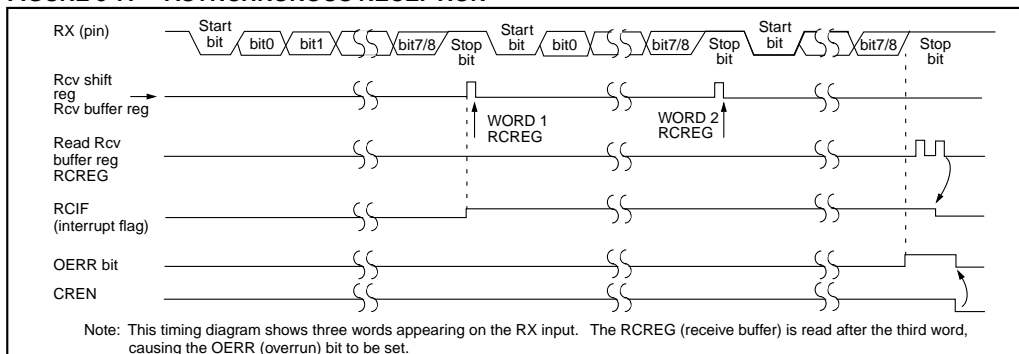


FIGURE 9-7: ASYNCHRONOUS RECEPTION



PIC16C63A/65B/73B/74B

TABLE 9-7: REGISTERS ASSOCIATED WITH ASYNCHRONOUS RECEPTION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other Resets |
|---------|-------|------------------------------|---------------------|-------|-------|-------|--------|--------|--------|-------------------|---------------------------|
| 0Ch | PIR1 | PSPIF ⁽¹⁾ | ADIF ⁽²⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 1Ah | RCREG | USART Receive Register | | | | | | | | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE ⁽¹⁾ | ADIE ⁽²⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented locations read as '0'. Shaded cells are not used for Asynchronous Reception.

Note 1: Bits PSPIE and PSPIF are reserved on the PIC16C63A/73B, always maintain these bits clear.

Note 2: Bits ADIE and ADIF are reserved on the PIC16C63A/65B, always maintain these bits clear.

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9.3 USART Synchronous Master Mode

In Synchronous Master mode, the data is transmitted in a half-duplex manner, i.e. transmission and reception do not occur at the same time. When transmitting data, the reception is inhibited and vice versa. Synchronous mode is entered by setting bit SYNC (TXSTA<4>). In addition, enable bit SPEN (RCSTA<7>) is set in order to configure the RC6/TX/CK and RC7/RX/DT I/O pins to CK (clock) and DT (data) lines respectively. The Master mode indicates that the processor transmits the master clock on the CK line. The Master mode is entered by setting bit CSRC (TXSTA<7>).

9.3.1 USART SYNCHRONOUS MASTER TRANSMISSION

The USART transmitter block diagram is shown in Figure 9-3. The heart of the transmitter is the transmit (serial) shift register (TSR). The shift register obtains its data from the read/write transmit buffer register TXREG. The TXREG register is loaded with data in software. The TSR register is not loaded until the last bit has been transmitted from the previous load. As soon as the last bit is transmitted, the TSR is loaded with new data from the TXREG (if available). Once the TXREG register transfers the data to the TSR register (occurs in one Tcycle), the TXREG is empty and interrupt bit TXIF (PIR1<4>) is set. The interrupt can be

enabled/disabled by setting/clearing enable bit TXIE (PIE1<4>). Flag bit TXIF will be set regardless of the state of enable bit TXIE and cannot be cleared in software. It will reset only when new data is loaded into the TXREG register. While flag bit TXIF indicates the status of the TXREG register, another bit TRMT (TXSTA<1>) shows the status of the TSR register. TRMT is a read only bit which is set when the TSR is empty. No interrupt logic is tied to this bit, so the user has to poll this bit in order to determine if the TSR register is empty. The TSR is not mapped in data memory so it is not available to the user.

Steps to follow when setting up a Synchronous Master Transmission:

1. Initialize the SPBRG register for the appropriate baud rate (Section 9.1).
2. Enable the synchronous master serial port by setting bits SYNC, SPEN, and CSRC.
3. If interrupts are desired, then set enable bit TXIE.
4. If 9-bit transmission is desired, then set bit TX9.
5. Enable the transmission by setting bit TXEN.
6. If 9-bit transmission is selected, the ninth bit should be loaded in bit TX9D.
7. Start transmission by loading data to the TXREG register.

TABLE 9-8: REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER TRANSMISSION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other Resets | |
|---------|-------|------------------------------|---------------------|-------|-------|-------|--------|--------|--------|-------------------|---------------------------|-----------|
| 0Ch | PIR1 | PSPIF ⁽¹⁾ | ADIF ⁽²⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 | |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x | |
| 19h | TXREG | USART Transmit Register | | | | | | | | | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE ⁽¹⁾ | ADIE ⁽²⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 | |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 | |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented, read as '0'. Shaded cells are not used for Synchronous Master Transmission.

Note 1: Bits PSPIE and PSPIF are reserved on the PIC16C63A/73B, always maintain these bits clear.

Note 2: Bits ADIE and ADIF are reserved on the PIC16C63A/65B, always maintain these bits clear.

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FIGURE 9-8: SYNCHRONOUS TRANSMISSION

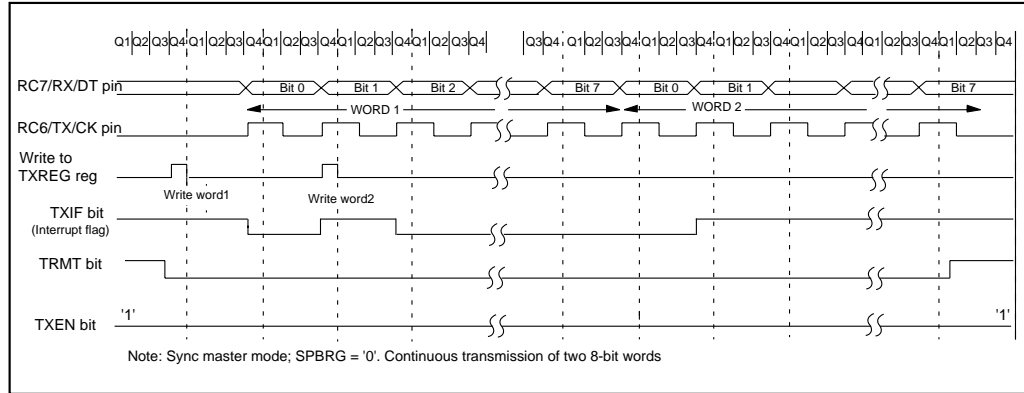
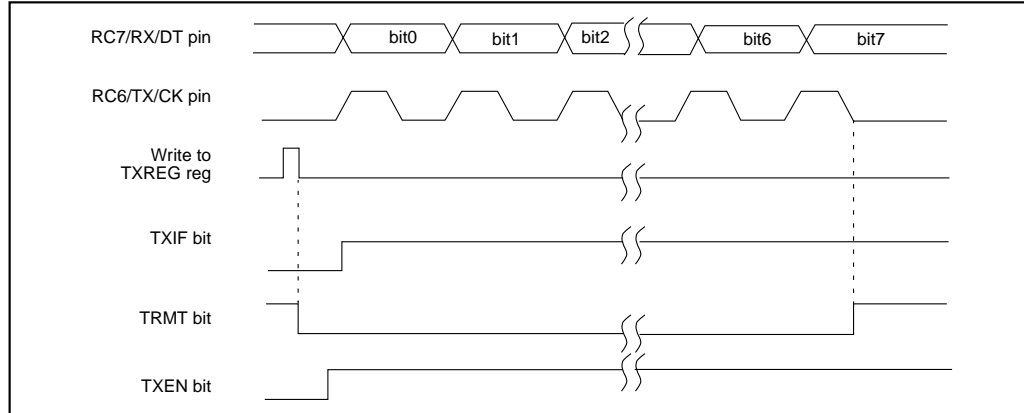


FIGURE 9-9: SYNCHRONOUS TRANSMISSION (THROUGH TXEN)



PIC16C63A/65B/73B/74B

9.3.2 USART SYNCHRONOUS MASTER RECEPTION

Once synchronous mode is selected, reception is enabled by setting either enable bit SREN (RCSTA<5>) or enable bit CREN (RCSTA<4>). Data is sampled on the RC7/RX/DT pin on the falling edge of the clock. If enable bit SREN is set, then only a single word is received. If enable bit CREN is set, the reception is continuous until CREN is cleared. If both bits are set, then CREN takes precedence.

Steps to follow when setting up a Synchronous Master Reception:

1. Initialize the SPBRG register for the appropriate baud rate. (Section 9.1)
2. Enable the synchronous master serial port by setting bits SYNC, SPEN, and CSRC.

3. Ensure bits CREN and SREN are clear.
4. If interrupts are desired, then set enable bit RCIE.
5. If 9-bit reception is desired, then set bit RX9.
6. If a single reception is required, set bit SREN. For continuous reception, set bit CREN.
7. Interrupt flag bit RCIF will be set when reception is complete and an interrupt will be generated if enable bit RCIE was set.
8. Read the RCSTA register to get the ninth bit (if enabled) and determine if any error occurred during reception.
9. Read the 8-bit received data by reading the RCREG register.
10. If any error occurred, clear the error by clearing bit CREN.

TABLE 9-9: REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER RECEPTION

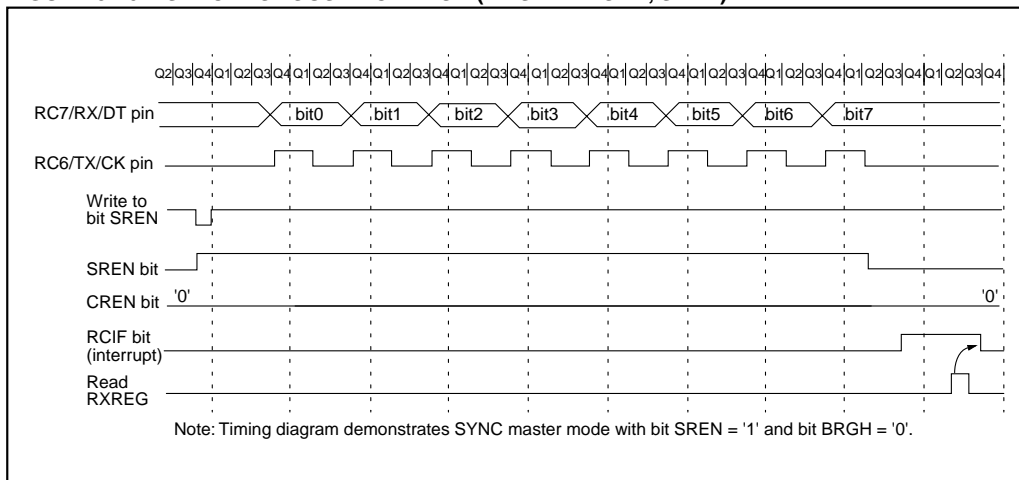
| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on: POR, BOR | Value on all other Resets |
|---------|-------|------------------------------|---------------------|-------|-------|-------|--------|--------|--------|--------------------|---------------------------|
| 0Ch | PIR1 | PSPIF ⁽¹⁾ | ADIF ⁽²⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 1Ah | RCREG | USART Receive Register | | | | | | | | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE ⁽¹⁾ | ADIE ⁽²⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented read as '0'. Shaded cells are not used for Synchronous Master Reception.

Note 1: Bits PSPIE and PSPIF are reserved on the PIC16C63A/73B. Always maintain these bits clear.

Note 2: Bits ADIE and ADIF are reserved on the PIC16C63A/65B. Always maintain these bits clear.

FIGURE 9-10: SYNCHRONOUS RECEPTION (MASTER MODE, SREN)



PIC16C63A/65B/73B/74B

9.4 USART Synchronous Slave Mode

Synchronous slave mode differs from the Master mode in the fact that the shift clock is supplied externally at the RC6/TX/CK pin (instead of being supplied internally in master mode). This allows the device to transfer or receive data while in SLEEP mode. Slave mode is entered by clearing bit CSRC (TXSTA<7>).

9.4.1 USART SYNCHRONOUS SLAVE TRANSMIT

The operation of the synchronous master and slave modes are identical, except in the case of the SLEEP mode.

If two words are written to the TXREG and then the SLEEP instruction is executed, the following will occur:

- a) The first word will immediately transfer to the TSR register and transmit.
- b) The second word will remain in TXREG register.
- c) Flag bit TXIF will not be set.
- d) When the first word has been shifted out of TSR, the TXREG register will transfer the second word to the TSR and flag bit TXIF will now be set.
- e) If enable bit TXIE is set, the interrupt will wake the chip from SLEEP. If the global interrupt is enabled, the program will branch to the interrupt vector (0004h).

Steps to follow when setting up a Synchronous Slave Transmission:

1. Enable the synchronous slave serial port by setting bits SYNC and SPEN and clearing bit CSRC.
2. Clear bits CREN and SREN.
3. If interrupts are desired, then set enable bit TXIE.
4. If 9-bit transmission is desired, then set bit TX9.
5. Enable the transmission by setting enable bit TXEN.
6. If 9-bit transmission is selected, the ninth bit should be loaded in bit TX9D.
7. Start transmission by loading data to the TXREG register.

9.4.2 USART SYNCHRONOUS SLAVE RECEPTION

The operation of the synchronous master and slave modes is identical except in the case of the SLEEP mode and bit SREN, which is a "don't care" in slave mode.

If receive is enabled by setting bit CREN prior to the SLEEP instruction, then a word may be received during SLEEP. On completely receiving the word, the RSR register will transfer the data to the RCREG register and if enable bit RCIE bit is set, the interrupt generated will wake the chip from SLEEP. If the global interrupt is enabled, the program will branch to the interrupt vector (0004h).

Steps to follow when setting up a Synchronous Slave Reception:

1. Enable the synchronous master serial port by setting bits SYNC and SPEN and clearing bit CSRC.
2. If interrupts are desired, then set enable bit RCIE.
3. If 9-bit reception is desired, then set bit RX9.
4. To enable reception, set enable bit CREN.
5. Flag bit RCIF will be set when reception is complete. An interrupt will be generated if enable bit RCIE was set.
6. Read the RCSTA register to get the ninth bit (if enabled) and determine if any error occurred during reception.
7. Read the 8-bit received data by reading the RCREG register.
8. If any error occurred, clear the error by clearing bit CREN.

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TABLE 9-10: REGISTERS ASSOCIATED WITH SYNCHRONOUS SLAVE TRANSMISSION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other Resets |
|---------|-------|------------------------------|---------------------|-------|-------|-------|--------|--------|--------|-------------------|---------------------------|
| 0Ch | PIR1 | PSPIF ⁽¹⁾ | ADIF ⁽²⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 19h | TXREG | USART Transmit Register | | | | | | | | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE ⁽¹⁾ | ADIE ⁽²⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented read as '0'. Shaded cells are not used for Synchronous Slave Transmission.

Note 1: Bits PSPIE and PSPIF are reserved on the PIC16C63A/73B. Always maintain these bits clear.

2: Bits ADIE and ADIF are reserved on the PIC16C63A/65B. Always maintain these bits clear.

TABLE 9-11: REGISTERS ASSOCIATED WITH SYNCHRONOUS SLAVE RECEPTION

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other Resets |
|---------|-------|------------------------------|---------------------|-------|-------|-------|--------|--------|--------|-------------------|---------------------------|
| 0Ch | PIR1 | PSPIF ⁽¹⁾ | ADIF ⁽²⁾ | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 18h | RCSTA | SPEN | RX9 | SREN | CREN | — | FERR | OERR | RX9D | 0000 -00x | 0000 -00x |
| 1Ah | RCREG | USART Receive Register | | | | | | | | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE ⁽¹⁾ | ADIE ⁽²⁾ | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 98h | TXSTA | CSRC | TX9 | TXEN | SYNC | — | BRGH | TRMT | TX9D | 0000 -010 | 0000 -010 |
| 99h | SPBRG | Baud Rate Generator Register | | | | | | | | 0000 0000 | 0000 0000 |

Legend: x = unknown, - = unimplemented read as '0'. Shaded cells are not used for Synchronous Slave Reception.

Note 1: Bits PSPIE and PSPIF are reserved on the PIC16C63A/73B. Always maintain these bits clear.

2: Bits ADIE and ADIF are reserved on the PIC16C63A/65B. Always maintain these bits clear.

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10.0 ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

This section applies to the PIC16C73B and PIC16C74B only. The analog-to-digital (A/D) converter module has five inputs for the PIC16C73B, and eight for the PIC16C74B.

The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number (refer to Application Note AN546 for use of A/D Converter). The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD) or the voltage level on the RA3/AN3/VREF pin.

The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in sleep, the A/D conversion clock must be derived from the A/D's internal RC oscillator.

Additional information on the A/D module is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

The A/D module has three registers. These registers are:

- A/D Result Register (ADRES)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1 (ADCON1)

A device reset forces all registers to their reset state. This forces the A/D module to be turned off and any conversion is aborted.

The ADCON0 register, shown in Figure 10-1, controls the operation of the A/D module. The ADCON1 register, shown in Figure 10-2, configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be a voltage reference) or as digital I/O.

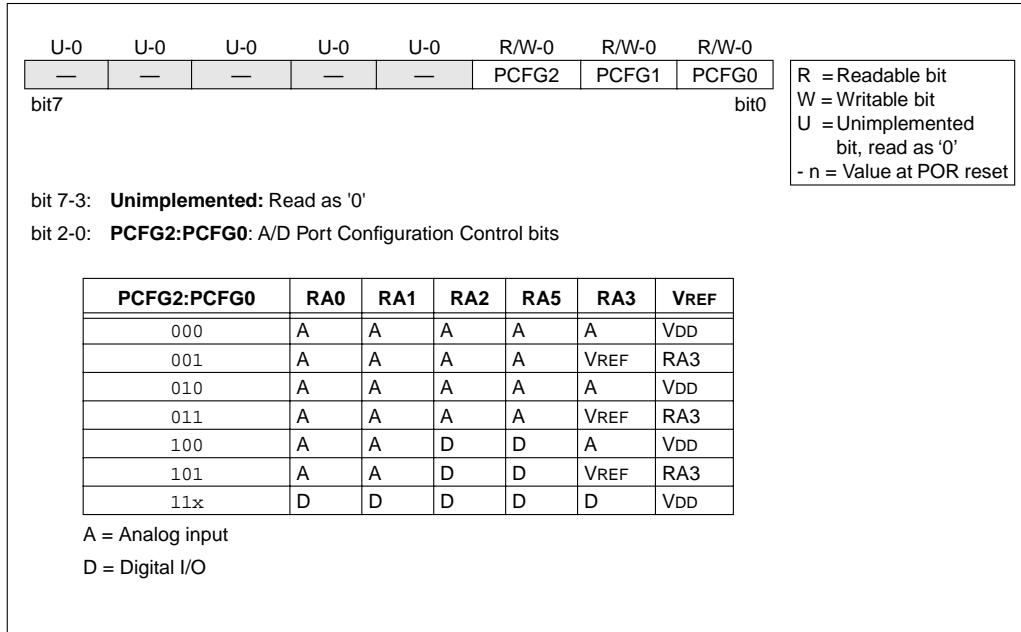
FIGURE 10-1: ADCON0 REGISTER (ADDRESS 1Fh)

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 |
|---|-------|-------|-------|-------|---------|-----|-------|
| ADCS1 | ADCS0 | CHS2 | CHS1 | CHS0 | GO/DONE | — | ADON |
| | | | | | | | bit0 |
| <p>bit 7-6: ADCS1:ADCS0: A/D Conversion Clock Select bits 00 = Fosc/2 01 = Fosc/8 10 = Fosc/32 11 = FRC (clock derived from an internal RC oscillator)</p> <p>bit 5-3: CHS2:CHS0: Analog Channel Select bits 000 = channel 0, (RA0/AN0) 001 = channel 1, (RA1/AN1) 010 = channel 2, (RA2/AN2) 011 = channel 3, (RA3/AN3) 100 = channel 4, (RA5/AN4)</p> <p>bit 2: GO/DONE: A/D Conversion Status bit If ADON = 1 1 = A/D conversion in progress (setting this bit starts the A/D conversion) 0 = A/D conversion not in progress (This bit is automatically cleared by hardware when the A/D conversion is complete)</p> <p>bit 1: Unimplemented: Read as '0'</p> <p>bit 0: ADON: A/D On bit 1 = A/D converter module is operating 0 = A/D converter module is shutoff and consumes no operating current</p> | | | | | | | |

R = Readable bit
 W = Writable bit
 U = Unimplemented bit, read as '0'
 - n = Value at POR reset

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FIGURE 10-2: ADCON1 REGISTER (ADDRESS 9Fh)



PIC16C63A/65B/73B/74B

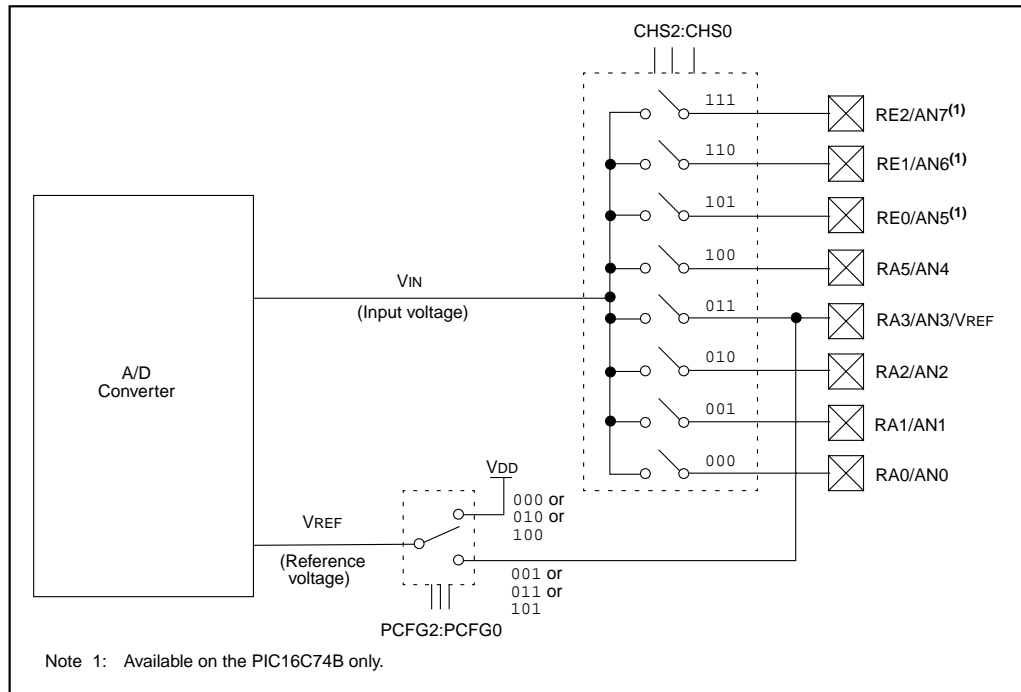
The ADRES register contains the result of the A/D conversion. When the A/D conversion is complete, the result is loaded into the ADRES register, the GO/DONE bit (ADCON0<2>) is cleared, and A/D interrupt flag bit ADIF is set. The block diagram of the A/D module is shown in Figure 10-3.

The value that is in the ADRES register is not modified for a Power-on Reset. The ADRES register will contain unknown data after a Power-on Reset.

After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channels must have their corresponding TRIS bits selected as an input. To determine acquisition time, see Section 10.1. After this acquisition time has elapsed the A/D conversion can be started. The following steps should be followed for doing an A/D conversion:

1. Configure the A/D module:
 - Configure analog pins / voltage reference / and digital I/O (ADCON1)
 - Select A/D input channel (ADCON0)
 - Select A/D conversion clock (ADCON0)
 - Turn on A/D module (ADCON0)
2. Configure A/D interrupt (if desired):
 - Clear ADIF bit
 - Set ADIE bit
 - Set GIE bit
3. Wait the required acquisition time.
4. Start conversion:
 - Set GO/DONE bit (ADCON0)
5. Wait for A/D conversion to complete, by either:
 - Polling for the GO/DONE bit to be cleared
 - OR
 - Waiting for the A/D interrupt
6. Read A/D Result register (ADRES), clear bit ADIF if required.
7. For next conversion, go to step 1 or step 2 as required. The A/D conversion time per bit is defined as TAD. A minimum wait of 2TAD is required before next acquisition starts.

FIGURE 10-3: A/D BLOCK DIAGRAM



PIC16C63A/65B/73B/74B

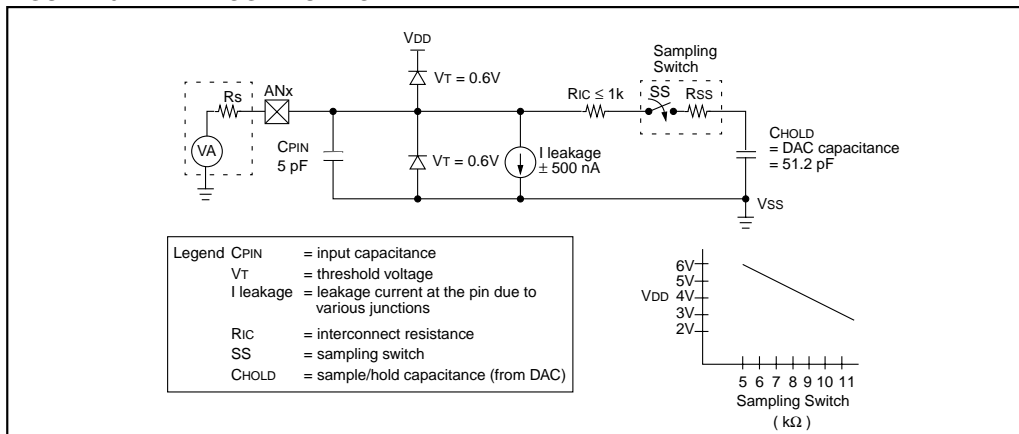
10.1 A/D Acquisition Requirements

For the A/D converter to meet its specified accuracy, the charge holding capacitor (CHOLD) must be allowed to fully charge to the input channel voltage level. The analog input model is shown in Figure 10-4. The source impedance (R_S) and the internal sampling switch (R_{SS}) impedance directly affect the time required to charge the capacitor CHOLD. The sampling switch (R_{SS}) impedance varies over the device voltage (V_{DD}). The source impedance affects the offset voltage at the analog input (due to pin leakage current). **The maximum recommended impedance for analog sources is 10 k Ω .** After the analog input channel is selected (changed) this acquisition must be done before the conversion can be started.

To calculate the minimum acquisition time, T_{ACQ} , see the PICmicro™ Mid-Range Reference Manual, (DS33023). This equation calculates the acquisition time to within 1/2 LSb error (512 steps for the A/D). The 1/2 LSb error is the maximum error allowed for the A/D to meet its specified accuracy.

Note: When the conversion is started, the holding capacitor is disconnected from the input pin.

FIGURE 10-4: ANALOG INPUT MODEL



PIC16C63A/65B/73B/74B

10.2 Selecting the A/D Conversion Clock

The A/D conversion time per bit is defined as T_{AD} . The A/D conversion requires $9.5T_{AD}$ per 8-bit conversion. The source of the A/D conversion clock is software selectable. The four possible options for T_{AD} are:

- $2T_{OSC}$
- $8T_{OSC}$
- $32T_{OSC}$
- Internal RC oscillator

For correct A/D conversions, the A/D conversion clock (T_{AD}) must be selected to ensure a minimum T_{AD} time of $1.6 \mu s$.

Table 10-1 shows the resultant T_{AD} times derived from the device operating frequencies and the A/D clock source selected.

10.3 Configuring Analog Port Pins

The $ADCON1$, $TRISA$, and $TRISE$ registers control the operation of the A/D port pins. The port pins that are desired as analog inputs must have their corresponding TRIS bits set (input). If the TRIS bit is cleared (output), the digital output level (V_{OH} or V_{OL}) will be converted.

The A/D operation is independent of the state of the $CHS2:CHS0$ bits and the TRIS bits.

Note 1: When reading the port register, all pins configured as analog input channels will read as cleared (a low level). Pins configured as digital inputs, will convert an analog input. Analog levels on a digitally configured input will not affect the conversion accuracy.

Note 2: Analog levels on any pin that is defined as a digital input (including the $AN4:AN0$ pins) may cause the input buffer to consume current that is out of the device's specification.

TABLE 10-1: T_{AD} vs. DEVICE OPERATING FREQUENCIES

| AD Clock Source (T_{AD}) | | Device Frequency | | | |
|------------------------------|-------------|--------------------------------|--------------------------------|--------------------------------|------------------------------|
| Operation | ADCS1:ADCS0 | 20 MHz | 5 MHz | 1.25 MHz | 333.33 kHz |
| $2T_{OSC}$ | 00 | 100 ns ⁽²⁾ | 400 ns ⁽²⁾ | 1.6 μs | 6 μs |
| $8T_{OSC}$ | 01 | 400 ns ⁽²⁾ | 1.6 μs | 6.4 μs | 24 μs ⁽³⁾ |
| $32T_{OSC}$ | 10 | 1.6 μs | 6.4 μs | 25.6 μs ⁽³⁾ | 96 μs ⁽³⁾ |
| RC ⁽⁵⁾ | 11 | 2 - 6 μs ^(1,4) | 2 - 6 μs ^(1,4) | 2 - 6 μs ^(1,4) | 2 - 6 μs ⁽¹⁾ |

Legend: Shaded cells are outside of recommended range.

Note 1: The RC source has a typical T_{AD} time of 4 μs .

2: These values violate the minimum required T_{AD} time.

3: For faster conversion times, the selection of another clock source is recommended.

4: When device frequency is greater than 1 MHz, the RC A/D conversion clock source is recommended for sleep operation only.

5: For extended voltage devices (LC), please refer to Electrical Specifications section.

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10.4 A/D Conversions

Note: The GO/DONE bit should **NOT** be set in the same instruction that turns on the A/D.

10.5 Use of the CCP Trigger

An A/D conversion can be started by the “special event trigger” of the CCP2 module. This requires that the CCP2M3:CCP2M0 bits (CCP2CON<3:0>) be programmed as 1011 and that the A/D module is enabled (ADON bit is set). When the trigger occurs, the

GO/DONE bit will be set, starting the A/D conversion, and the Timer1 counter will be reset to zero. Timer1 is reset to automatically repeat the A/D acquisition period with minimal software overhead (moving the ADRES to the desired location). The appropriate analog input channel must be selected and the minimum acquisition done before the “special event trigger” sets the GO/DONE bit (starts a conversion).

If the A/D module is not enabled (ADON is cleared), then the “special event trigger” will be ignored by the A/D module, but will still reset the Timer1 counter.

TABLE 10-2: SUMMARY OF A/D REGISTERS

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on POR, BOR | Value on all other Resets |
|---------|--------|----------------------|-------|-------------------------------|---------|-------|---------------------------|--------|--------|-------------------|---------------------------|
| 0Bh,8Bh | INTCON | GIE | PEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |
| 0Ch | PIR1 | PSPIF ⁽¹⁾ | ADIF | RCIF | TXIF | SSPIF | CCP1IF | TMR2IF | TMR1IF | 0000 0000 | 0000 0000 |
| 8Ch | PIE1 | PSPIE ⁽¹⁾ | ADIE | RCIE | TXIE | SSPIE | CCP1IE | TMR2IE | TMR1IE | 0000 0000 | 0000 0000 |
| 0Dh | PIR2 | — | — | — | — | — | — | — | CCP2IF | ---- --0 | ---- --0 |
| 8Dh | PIE2 | — | — | — | — | — | — | — | CCP2IE | ---- --0 | ---- --0 |
| 1Eh | ADRES | A/D Result Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 1Fh | ADCON0 | ADCS1 | ADCS0 | CHS2 | CHS1 | CHS0 | GO/DONE | — | ADON | 0000 00-0 | 0000 00-0 |
| 9Fh | ADCON1 | — | — | — | — | — | PCFG2 | PCFG1 | PCFG0 | ---- -000 | ---- -000 |
| 05h | PORTA | — | — | RA5 | RA4 | RA3 | RA2 | RA1 | RA0 | --0x 0000 | --0u 0000 |
| 85h | TRISA | — | — | PORTA Data Direction Register | | | | | | --11 1111 | --11 1111 |
| 09h | PORTE | — | — | — | — | — | RE2 | RE1 | RE0 | ---- -xxx | ---- -uuu |
| 89h | TRISE | IBF | OBF | IBOV | PSPMODE | — | PORTE Data Direction Bits | | | 0000 -111 | 0000 -111 |

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are not used for A/D conversion.

Note 1: Bits PSPIE and PSPIF are reserved on the PIC6C73B. Always maintain these bits clear.

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11.0 SPECIAL FEATURES OF THE CPU

The PIC16C63A/65B/73B/74B devices have a host of features intended to maximize system reliability, minimize cost through elimination of external components, provide power saving operating modes and offer code protection. These are:

- OSC Selection
- Reset
 - Power-on Reset (POR)
 - Power-up Timer (PWRT)
 - Oscillator Start-up Timer (OST)
 - Brown-out Reset (BOR)
- Interrupts
- Watchdog Timer (WDT)
- SLEEP
- Code protection
- ID locations
- In-circuit serial programming

These devices have a Watchdog Timer which can be shut off only through configuration bits. It runs off its own RC oscillator for added reliability. There are two timers that offer necessary delays on power-up. One is the Oscillator Start-up Timer (OST), intended to keep the chip in reset until the crystal oscillator is stable. The

other is the Power-up Timer (PWRT), which provides a fixed delay on power-up only, designed to keep the part in reset while the power supply stabilizes. With these two timers on-chip, most applications need no external reset circuitry.

SLEEP mode is designed to offer a very low current power-down mode. The user can wake-up from SLEEP through external reset, Watchdog Timer Wake-up or through an interrupt. Several oscillator options are also made available to allow the part to fit the application. The RC oscillator option saves system cost, while the LP crystal option saves power. A set of configuration bits are used to select various options.

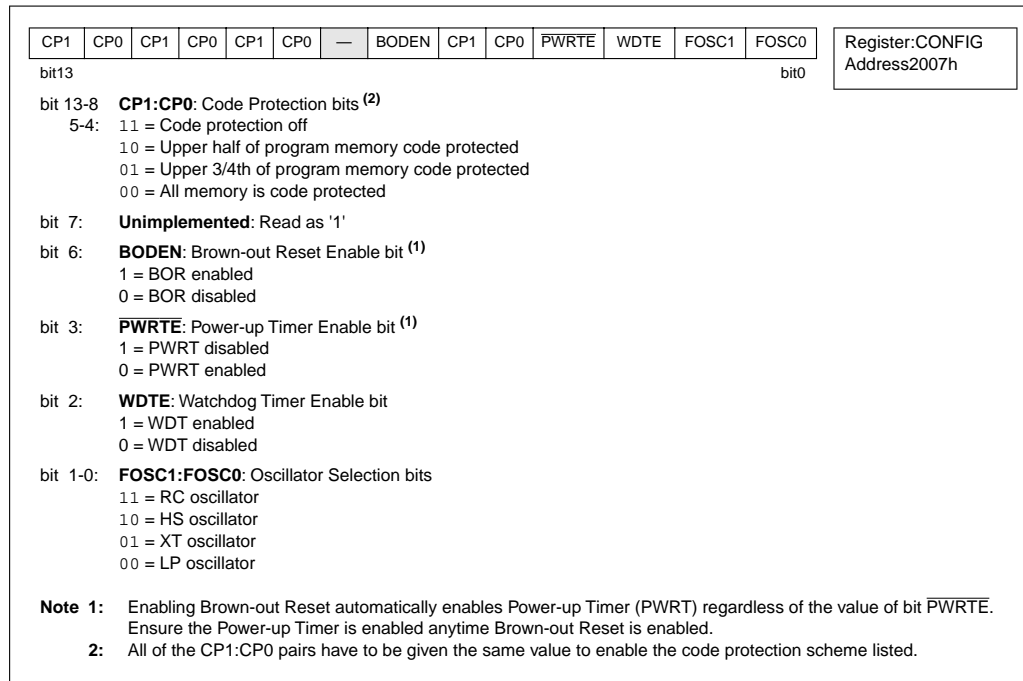
Additional information on special features is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

11.1 Configuration Bits

The configuration bits can be programmed (read as '0') or left unprogrammed (read as '1') to select various device configurations. These bits are mapped in program memory location 2007h.

The user will note that address 2007h is beyond the user program memory space. In fact, it belongs to the special test/configuration memory space (2000h - 3FFFh), which can be accessed only during programming.

FIGURE 11-1: CONFIGURATION WORD



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11.2 Oscillator Configurations

11.2.1 OSCILLATOR TYPES

The PIC16CXXX can be operated in four different oscillator modes. The user can program two configuration bits (FOSC1 and FOSC0) to select one of these four modes:

- LP Low Power Crystal
- XT Crystal/Resonator
- HS High Speed Crystal/Resonator
- RC Resistor/Capacitor

11.2.2 CRYSTAL OSCILLATOR/CERAMIC RESONATORS

In XT, LP or HS modes a crystal or ceramic resonator is connected to the OSC1/CLKIN and OSC2/CLKOUT pins to establish oscillation (Figure 11-2). The PIC16CXXX oscillator design requires the use of a parallel cut crystal. Use of a series cut crystal may give a frequency out of the crystal manufacturers specifications. When in XT, LP or HS modes, the device can have an external clock source to drive the OSC1/CLKIN pin (Figure 11-3).

FIGURE 11-2: CRYSTAL/CERAMIC RESONATOR OPERATION (HS, XT OR LP OSC CONFIGURATION)

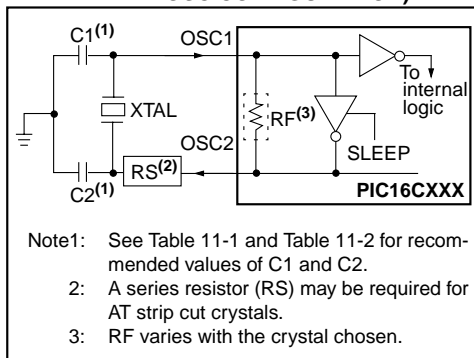


FIGURE 11-3: EXTERNAL CLOCK INPUT OPERATION (HS, XT OR LP OSC CONFIGURATION)

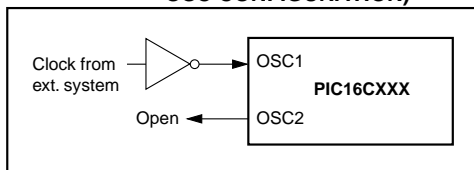


TABLE 11-1: CERAMIC RESONATORS

| Ranges Tested: | | | |
|---|------------------------|-------------|-------------|
| Mode | Freq | OSC1 | OSC2 |
| XT | 455 kHz | 68 - 100 pF | 68 - 100 pF |
| | 2.0 MHz | 15 - 68 pF | 15 - 68 pF |
| | 4.0 MHz | 15 - 68 pF | 15 - 68 pF |
| HS | 8.0 MHz | 10 - 68 pF | 10 - 68 pF |
| | 16.0 MHz | 10 - 22 pF | 10 - 22 pF |
| These values are for design guidance only. See notes at bottom of page. | | | |
| Resonators Used: | | | |
| 455 kHz | Panasonic EFO-A455K04B | ± 0.3% | |
| 2.0 MHz | Murata Erie CSA2.00MG | ± 0.5% | |
| 4.0 MHz | Murata Erie CSA4.00MG | ± 0.5% | |
| 8.0 MHz | Murata Erie CSA8.00MT | ± 0.5% | |
| 16.0 MHz | Murata Erie CSA16.00MX | ± 0.5% | |
| All resonators used did not have built-in capacitors. | | | |

TABLE 11-2: CAPACITOR SELECTION FOR CRYSTAL OSCILLATOR

| Osc Type | Crystal Freq | Cap. Range C1 | Cap. Range C2 |
|---|------------------------|---------------|---------------|
| LP | 32 kHz | 33 pF | 33 pF |
| | 200 kHz | 15 pF | 15 pF |
| XT | 200 kHz | 47-68 pF | 47-68 pF |
| | 1 MHz | 15 pF | 15 pF |
| | 4 MHz | 15 pF | 15 pF |
| HS | 4 MHz | 15 pF | 15 pF |
| | 8 MHz | 15-33 pF | 15-33 pF |
| | 20 MHz | 15-33 pF | 15-33 pF |
| These values are for design guidance only. See notes at bottom of page. | | | |
| Crystals Used | | | |
| 32 kHz | Epson C-001R32.768K-A | ± 20 PPM | |
| 200 kHz | STD XTL 200.000KHz | ± 20 PPM | |
| 1 MHz | ECS ECS-10-13-1 | ± 50 PPM | |
| 4 MHz | ECS ECS-40-20-1 | ± 50 PPM | |
| 8 MHz | EPSON CA-301 8.000M-C | ± 30 PPM | |
| 20 MHz | EPSON CA-301 20.000M-C | ± 30 PPM | |

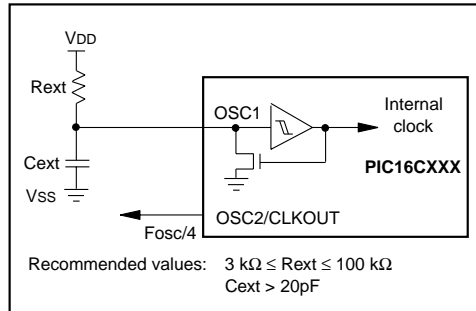
- Note 1: Recommended values of C1 and C2 are identical to the ranges tested (Table 11-1).
 2: Higher capacitance increases the stability of oscillator but also increases the start-up time.
 3: Since each resonator/crystal has its own characteristics, the user should consult the resonator/crystal manufacturer for appropriate values of external components.
 4: Rs may be required in HS mode, as well as XT mode, to avoid overdriving crystals with low drive level specification.

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11.2.3 RC OSCILLATOR

For timing insensitive applications, the "RC" device option offers additional cost savings. The RC oscillator frequency is a function of the supply voltage, the resistor (R_{EXT}) and capacitor (C_{EXT}) values and the operating temperature. In addition to this, the oscillator frequency will vary from unit to unit due to normal process parameter variation. Furthermore, the difference in lead frame capacitance between package types will also affect the oscillation frequency, especially for low C_{EXT} values. The user also needs to take into account variation due to tolerance of external R and C components used. Figure 11-4 shows how the R/C combination is connected to the PIC16CXXX.

FIGURE 11-4: RC OSCILLATOR MODE



11.3 Reset

The PIC16CXXX differentiates between various kinds of reset:

- Power-on Reset (POR)
- $\overline{\text{MCLR}}$ reset during normal operation
- $\overline{\text{MCLR}}$ reset during SLEEP
- WDT Reset (during normal operation)
- WDT Wake-up (during SLEEP)
- Brown-out Reset (BOR)

Some registers are not affected in any reset condition. Their status is unknown on POR and unchanged in any other reset. Most other registers are reset to a "reset state" on Power-on Reset (POR), on the $\overline{\text{MCLR}}$ and WDT Reset, on $\overline{\text{MCLR}}$ reset during SLEEP and Brown-out Reset (BOR). They are not affected by a WDT Wake-up, which is viewed as the resumption of normal operation. The $\overline{\text{TO}}$ and $\overline{\text{PD}}$ bits are set or cleared differently in different reset situations as indicated in Table 11-4. These bits are used in software to determine the nature of the reset. See Table 11-6 for a full description of reset states of all registers.

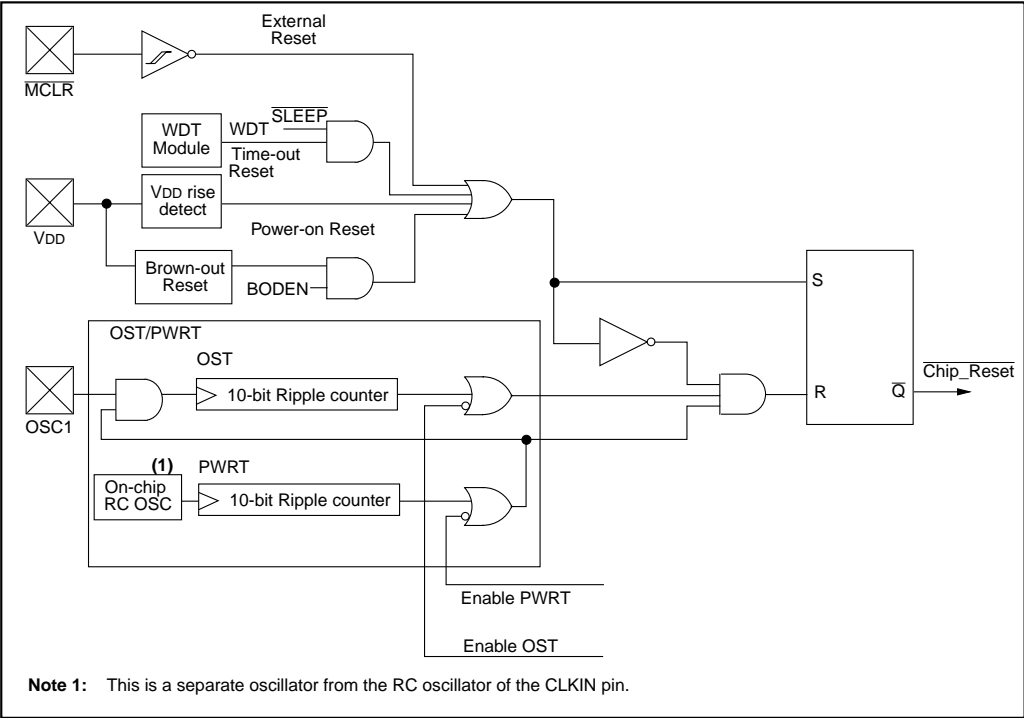
A simplified block diagram of the on-chip reset circuit is shown in Figure 11-5.

The PICmicros have a $\overline{\text{MCLR}}$ noise filter in the $\overline{\text{MCLR}}$ reset path. The filter will detect and ignore small pulses.

It should be noted that a WDT Reset does not drive $\overline{\text{MCLR}}$ pin low.

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FIGURE 11-5: SIMPLIFIED BLOCK DIAGRAM OF ON-CHIP RESET CIRCUIT



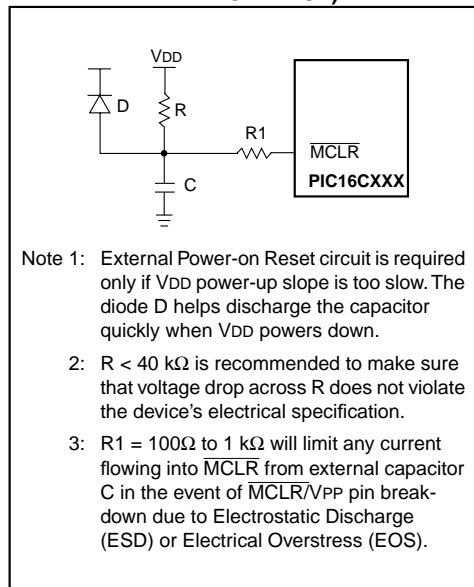
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11.4 Power-On Reset (POR)

A Power-on Reset pulse is generated on-chip when VDD rise is detected (in the range of 1.5V - 2.1V). To take advantage of the POR, just tie the MCLR pin directly (or through a resistor) to VDD. This will eliminate external RC components usually needed to create a Power-on Reset. A maximum rise time for VDD is specified (parameter D004). For a slow rise time, see Figure 11-6.

When the device starts normal operation (exits the reset condition), device operating parameters (voltage, frequency, temperature,...) must be met to ensure operation. If these conditions are not met, the device must be held in reset until the operating conditions are met. Brown-out Reset may be used to meet the start-up conditions.

FIGURE 11-6: EXTERNAL POWER-ON RESET CIRCUIT (FOR SLOW VDD POWER-UP)



11.5 Power-up Timer (PWRT)

The Power-up Timer provides a fixed nominal time-out (parameter #33) on power-up only, from the POR. The Power-up Timer operates on an internal RC oscillator. The chip is kept in reset as long as the PWRT is active. The PWRT's time delay allows VDD to rise to an acceptable level. A configuration bit is provided to enable/disable the PWRT.

The power-up time delay will vary from chip to chip due to VDD, temperature and process variation. See DC parameters for details.

11.6 Oscillator Start-up Timer (OST)

The Oscillator Start-up Timer (OST) provides 1024 oscillator cycle (from OSC1 input) delay after the PWRT delay is over (parameter #32). This ensures that the crystal oscillator or resonator has started and stabilized.

The OST time-out is invoked only for XT, LP and HS modes and only on Power-on Reset or wake-up from SLEEP.

11.7 Brown-Out Reset (BOR)

A configuration bit, BODEN, can disable (if clear/programmed) or enable (if set) the Brown-out Reset circuitry. If VDD falls below parameter D005 for greater than parameter #35, the brown-out situation will reset the chip. A reset may not occur if VDD falls below parameter D005 for less than parameter #35. The chip will remain in Brown-out Reset until VDD rises above BVDD. The Power-up Timer will then be invoked and will keep the chip in RESET an additional time delay (parameter #33). If VDD drops below BVDD while the Power-up Timer is running, the chip will go back into a Brown-out Reset and the Power-up Timer will be initialized. Once VDD rises above BVDD, the Power-up Timer will execute the additional time delay. The Power-up Timer should always be enabled when Brown-out Reset is enabled.

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11.8 Time-out Sequence

On power-up, the time-out sequence is as follows: First PWRT time-out is invoked after the POR time delay has expired. Then OST is activated. The total time-out will vary based on oscillator configuration and the status of the PWRT. For example, in RC mode with the PWRT disabled, there will be no time-out at all. Figure 11-7, Figure 11-8, Figure 11-9 and Figure 11-10 depict time-out sequences on power-up.

Since the time-outs occur from the POR pulse, if $\overline{\text{MCLR}}$ is kept low long enough, the time-outs will expire. Then bringing $\overline{\text{MCLR}}$ high will begin execution immediately (Figure 11-9). This is useful for testing purposes or to synchronize more than one PIC16CXXX device operating in parallel.

Table 11-5 shows the reset conditions for some special function registers, while Table 11-6 shows the reset conditions for all the registers.

TABLE 11-3: TIME-OUT IN VARIOUS SITUATIONS

| Oscillator Configuration | Power-up | | Brown-out | Wake-up from SLEEP |
|--------------------------|------------------|-----------|------------------|--------------------|
| | PWRTE = 0 | PWRTE = 1 | | |
| XT, HS, LP | 72 ms + 1024TOSC | 1024TOSC | 72 ms + 1024TOSC | 1024TOSC |
| RC | 72 ms | — | 72 ms | — |

TABLE 11-4: STATUS BITS AND THEIR SIGNIFICANCE

| POR | BOR | $\overline{\text{TO}}$ | PD | |
|-----|-----|------------------------|----|---|
| 0 | x | 1 | 1 | Power-on Reset |
| 0 | x | 0 | x | Illegal, $\overline{\text{TO}}$ is set on $\overline{\text{POR}}$ |
| 0 | x | x | 0 | Illegal, PD is set on $\overline{\text{POR}}$ |
| 1 | 0 | 1 | 1 | Brown-out Reset |
| 1 | 1 | 0 | 1 | WDT Reset |
| 1 | 1 | 0 | 0 | WDT Wake-up |
| 1 | 1 | u | u | $\overline{\text{MCLR}}$ Reset during normal operation |
| 1 | 1 | 1 | 0 | $\overline{\text{MCLR}}$ Reset during SLEEP or interrupt wake-up from SLEEP |

TABLE 11-5: RESET CONDITION FOR SPECIAL REGISTERS

| Condition | Program Counter | STATUS Register | PCON Register |
|--|-----------------------|-----------------|---------------|
| Power-on Reset | 000h | 0001 1xxx | ---- --0x |
| $\overline{\text{MCLR}}$ Reset during normal operation | 000h | 000u uuuu | ---- --uu |
| $\overline{\text{MCLR}}$ Reset during SLEEP | 000h | 0001 0uuu | ---- --uu |
| WDT Reset | 000h | 0000 1uuu | ---- --uu |
| WDT Wake-up | PC + 1 | uuu0 0uuu | ---- --uu |
| Brown-out Reset | 000h | 0001 1uuu | ---- --u0 |
| Interrupt wake-up from SLEEP | PC + 1 ⁽¹⁾ | uuu1 0uuu | ---- --uu |

Legend: u = unchanged, x = unknown, - = unimplemented bit read as '0'.

Note 1: When the wake-up is due to an interrupt and the GIE bit is set, the PC is loaded with the interrupt vector (0004h).

11.9 Power Control/Status Register (PCON)

The Power Control/Status Register, PCON, has up to two bits, depending upon the device.

Bit0 is Brown-out Reset Status bit, $\overline{\text{BOR}}$. If the BODEN configuration bit is set, $\overline{\text{BOR}}$ is '1' on Power-on Reset. If the BODEN configuration bit is clear, $\overline{\text{BOR}}$ is unknown on Power-on Reset.

The $\overline{\text{BOR}}$ status bit is a "don't care" and is not necessarily predictable if the brown-out circuit is disabled (the BODEN configuration bit is clear). $\overline{\text{BOR}}$ must then be set by the user and checked on subsequent resets to see if it is clear, indicating a brown-out has occurred.

Bit1 is $\overline{\text{POR}}$ (Power-on Reset Status bit). It is cleared on a Power-on Reset and unaffected otherwise. The user must set this bit following a Power-on Reset.

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TABLE 11-6: INITIALIZATION CONDITIONS FOR ALL REGISTERS

| Register | Applicable Devices | | | | Power-on Reset, Brown-out Reset | MCLR Resets WDT Reset | Wake-up via WDT or Interrupt |
|----------------------|--------------------|-----|-----|-----|------------------------------------|--------------------------|---------------------------------|
| | 63A | 65B | 73B | 74B | | | |
| W | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| INDF | 63A | 65B | 73B | 74B | N/A | N/A | N/A |
| TMR0 | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PCL | 63A | 65B | 73B | 74B | 0000h | 0000h | PC + 1 ⁽²⁾ |
| STATUS | 63A | 65B | 73B | 74B | 0001 1xxx | 000q quuu ⁽³⁾ | uuuq quuu ⁽³⁾ |
| FSR | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PORTA ⁽⁴⁾ | 63A | 65B | 73B | 74B | --0x 0000 | --0u 0000 | --uu uuuu |
| PORTB ⁽⁵⁾ | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PORTC ⁽⁵⁾ | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PORTD ⁽⁵⁾ | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PORTE ⁽⁵⁾ | 63A | 65B | 73B | 74B | ---- -xxx | ---- -uuu | ---- -uuu |
| PCLATH | 63A | 65B | 73B | 74B | ---0 0000 | ---0 0000 | ---u uuuu |
| INTCON | 63A | 65B | 73B | 74B | 0000 000x | 0000 000u | uuuu uuuu ⁽¹⁾ |
| PIR1 | 63A | 65B | 73B | 74B | --00 0000 | --00 0000 | --uu uuuu ⁽¹⁾ |
| | 63A | 65B | 73B | 74B | -000 0000 | -000 0000 | -uuu uuuu ⁽¹⁾ |
| | 63A | 65B | 73B | 74B | 0-00 0000 | 0-00 0000 | u-uu uuuu ⁽¹⁾ |
| | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu ⁽¹⁾ |
| PIR2 | 63A | 65B | 73B | 74B | ---- ---0 | ---- ---0 | ---- ---u ⁽¹⁾ |
| TMR1L | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| TMR1H | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| T1CON | 63A | 65B | 73B | 74B | --00 0000 | --uu uuuu | --uu uuuu |
| TMR2 | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| T2CON | 63A | 65B | 73B | 74B | -000 0000 | -000 0000 | -uuu uuuu |
| SSPBUF | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| SSPCON | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| CCPR1L | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| CCPR1H | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| CCP1CON | 63A | 65B | 73B | 74B | --00 0000 | --00 0000 | --uu uuuu |
| RCSTA | 63A | 65B | 73B | 74B | 0000 -00x | 0000 -00x | uuuu -uuu |
| TXREG | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| RCREG | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| CCPR2L | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| CCPR2H | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| CCP2CON | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |

Legend: u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition

Note 1: One or more bits in INTCON, PIR1 and/or PIR2 will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIE bit is set, the PC is loaded with the interrupt vector (0004h).

3: See Table 11-5 for reset value for specific condition.

4: On any device reset, these pins are configured as inputs.

5: This is the value that will be in the port output latch.

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TABLE 11-6: INITIALIZATION CONDITIONS FOR ALL REGISTERS (Cont.'d)

| Register | Applicable Devices | | | | Power-on Reset, Brown-out Reset | MCLR Resets WDT Reset | Wake-up via WDT or Interrupt |
|------------|--------------------|-----|-----|-----|------------------------------------|--------------------------|---------------------------------|
| ADRES | 63A | 65B | 73B | 74B | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| ADCON0 | 63A | 65B | 73B | 74B | 0000 00-0 | 0000 00-0 | uuuu uu-u |
| OPTION_REG | 63A | 65B | 73B | 74B | 1111 1111 | 1111 1111 | uuuu uuuu |
| TRISA | 63A | 65B | 73B | 74B | --11 1111 | --11 1111 | --uu uuuu |
| TRISB | 63A | 65B | 73B | 74B | 1111 1111 | 1111 1111 | uuuu uuuu |
| TRISC | 63A | 65B | 73B | 74B | 1111 1111 | 1111 1111 | uuuu uuuu |
| TRISD | 63A | 65B | 73B | 74B | 1111 1111 | 1111 1111 | uuuu uuuu |
| TRISE | 63A | 65B | 73B | 74B | 0000 -111 | 0000 -111 | uuuu -uuu |
| | 63A | 65B | 73B | 74B | 0000 -000 | 0000 -000 | uuuu -uuu |
| PIE1 | 63A | 65B | 73B | 74B | --00 0000 | --00 0000 | --uu uuuu |
| | 63A | 65B | 73B | 74B | 0-00 0000 | 0-00 0000 | u-uu uuuu |
| | 63A | 65B | 73B | 74B | -000 0000 | -000 0000 | -uuu uuuu |
| | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| PIE2 | 63A | 65B | 73B | 74B | ---- --0 | ---- --0 | ---- --u |
| PCON | 63A | 65B | 73B | 74B | ---- --0q | ---- --uq | ---- --uq |
| PR2 | 63A | 65B | 73B | 74B | 1111 1111 | 1111 1111 | 1111 1111 |
| SSPAD | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| SSPSTAT | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| TXSTA | 63A | 65B | 73B | 74B | 0000 -010 | 0000 -010 | uuuu -uuu |
| SPBRG | 63A | 65B | 73B | 74B | 0000 0000 | 0000 0000 | uuuu uuuu |
| ADCON1 | 63A | 65B | 73B | 74B | ---- -000 | ---- -000 | ---- -uuu |

Legend: u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition

Note 1: One or more bits in INTCON, PIR1 and/or PIR2 will be affected (to cause wake-up).

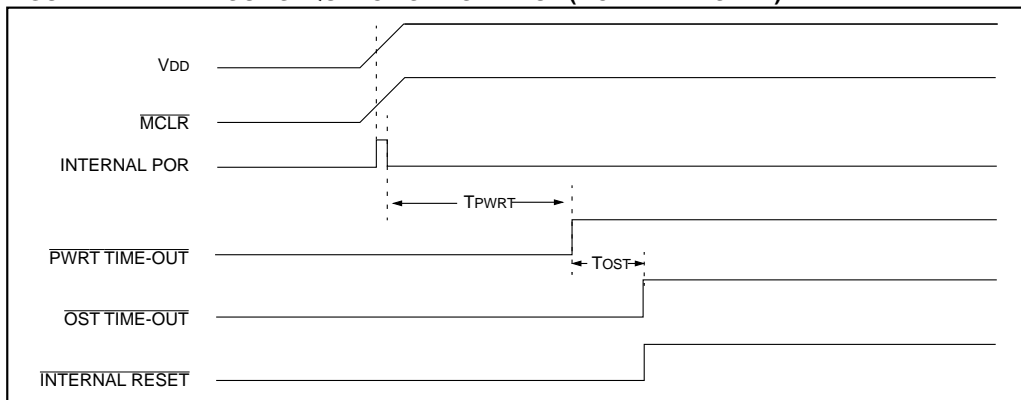
2: When the wake-up is due to an interrupt and the GIE bit is set, the PC is loaded with the interrupt vector (0004h).

3: See Table 11-5 for reset value for specific condition.

4: On any device reset, these pins are configured as inputs.

5: This is the value that will be in the port output latch.

FIGURE 11-7: TIME-OUT SEQUENCE ON POWER-UP (MCLR TIED TO VDD)



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FIGURE 11-8: TIME-OUT SEQUENCE ON POWER-UP ($\overline{\text{MCLR}}$ NOT TIED TO V_{DD}): CASE 1

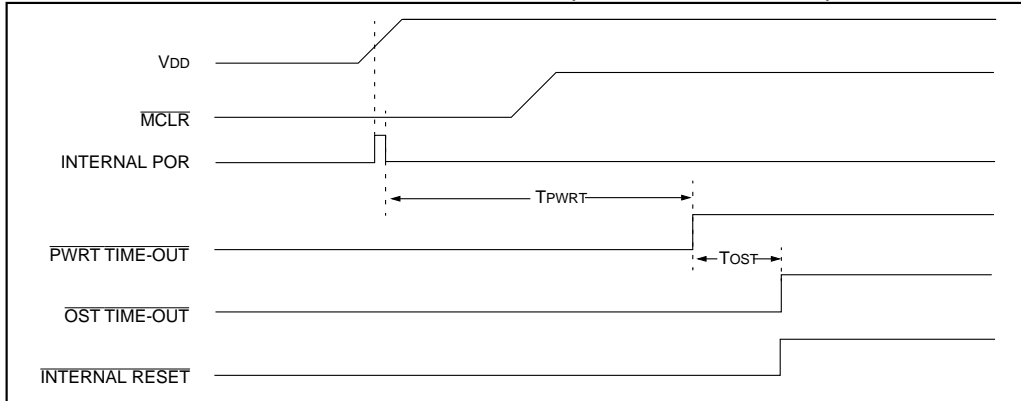


FIGURE 11-9: TIME-OUT SEQUENCE ON POWER-UP ($\overline{\text{MCLR}}$ NOT TIED TO V_{DD}): CASE 2

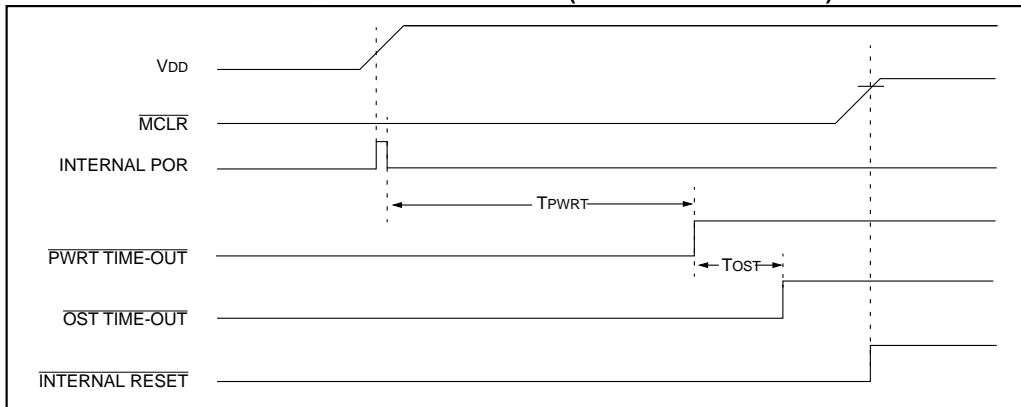
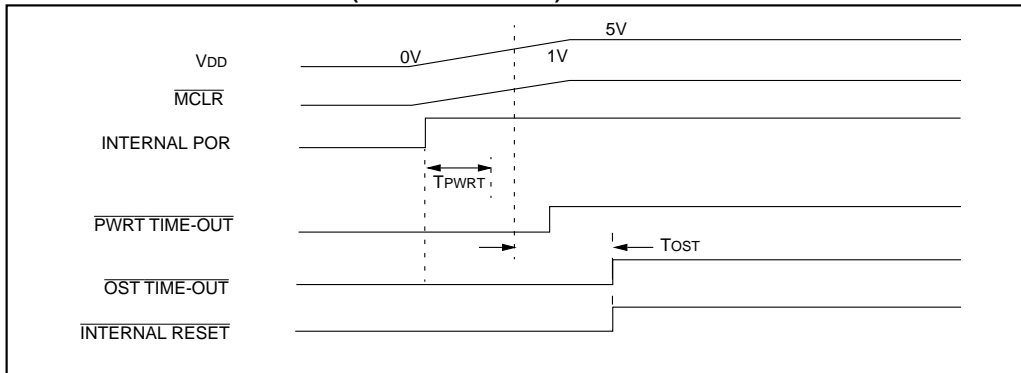


FIGURE 11-10: SLOW RISE TIME ($\overline{\text{MCLR}}$ TIED TO V_{DD})



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11.10 Interrupts

The PIC16CXX family has up to 12 sources of interrupt. The interrupt control register (INTCON) records individual interrupt requests in flag bits. It also has individual and global interrupt enable bits.

Note: Individual interrupt flag bits are set regardless of the status of their corresponding mask bit or the GIE bit.

A global interrupt enable bit, GIE (INTCON<7>) enables (if set) all un-masked interrupts or disables (if cleared) all interrupts. When bit GIE is enabled, and an interrupt's flag bit and mask bit are set, the interrupt will vector immediately. Individual interrupts can be disabled through their corresponding enable bits in various registers. Individual interrupt bits are set regardless of the status of the GIE bit. The GIE bit is cleared on reset.

The "return from interrupt" instruction, RETFIE, exits the interrupt routine as well as sets the GIE bit, which re-enables interrupts.

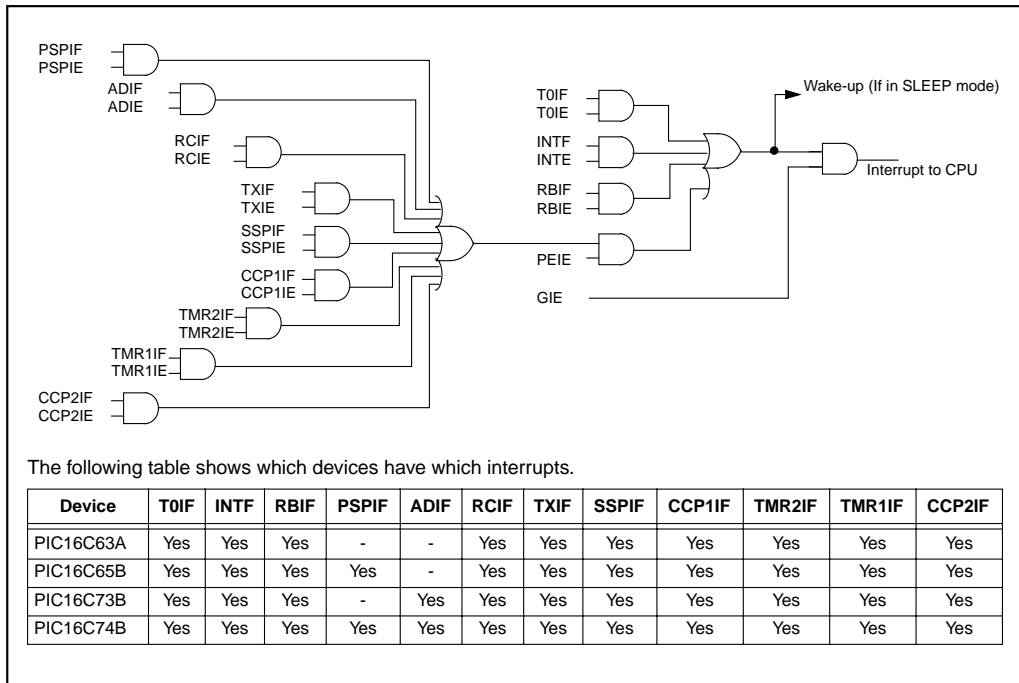
The RB0/INT pin interrupt, the RB port change interrupt and the TMR0 overflow interrupt flags are contained in the INTCON register.

The peripheral interrupt flags are contained in the special function registers PIR1 and PIR2. The corresponding interrupt enable bits are contained in special function registers PIE1 and PIE2, and the peripheral interrupt enable bit is contained in special function register INTCON.

When an interrupt is responded to, the GIE bit is cleared to disable any further interrupt, the return address is pushed onto the stack and the PC is loaded with 0004h. Once in the interrupt service routine, the source(s) of the interrupt can be determined by polling the interrupt flag bits. The interrupt flag bit(s) must be cleared in software before re-enabling interrupts to avoid recursive interrupts.

For external interrupt events, such as the INT pin or PORTB change interrupt, the interrupt latency will be three or four instruction cycles. The exact latency depends when the interrupt event occurs. The latency is the same for one or two cycle instructions. Individual interrupt flag bits are set regardless of the status of their corresponding mask bit or the GIE bit.

FIGURE 11-11: INTERRUPT LOGIC



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11.10.1 INT INTERRUPT

External interrupt on RB0/INT pin is edge triggered; either rising if bit INTEDG (OPTION_REG<6>) is set, or falling, if the INTEDG bit is clear. When a valid edge appears on the RB0/INT pin, flag bit INTF (INTCON<1>) is set. This interrupt can be disabled by clearing enable bit INTE (INTCON<4>). Flag bit INTF must be cleared in software in the interrupt service routine before re-enabling this interrupt. The INT interrupt can wake-up the processor from SLEEP, if bit INTE was set prior to going into SLEEP. The status of global interrupt enable bit GIE decides whether or not the processor branches to the interrupt vector following wake-up. See Section 11.13 for details on SLEEP mode.

11.10.2 TMR0 INTERRUPT

An overflow (FFh → 00h) in the TMR0 register will set flag bit T0IF (INTCON<2>). The interrupt can be enabled/disabled by setting/clearing enable bit TOIE (INTCON<5>). (Section 4.0)

11.10.3 PORTB INTCON CHANGE

An input change on PORTB<7:4> sets flag bit RBIF (INTCON<0>). The interrupt can be enabled/disabled by setting/clearing enable bit RBIE (INTCON<4>). (Section 3.2)

11.11 Context Saving During Interrupts

During an interrupt, only the return PC value is saved on the stack. Typically, users may wish to save key registers during an interrupt, i.e., W register and STATUS register. This will have to be implemented in software.

Example 11-1 stores and restores the W and STATUS registers. The register, W_TEMP, must be defined in each bank and must be defined at the same offset from the bank base address (i.e., if W_TEMP is defined at 0x20 in bank 0. It must also be defined at 0xA0 in bank 1).

The example:

- Stores the W register.
- Stores the STATUS register in bank 0.
- Stores the PCLATH register.
- Executes the interrupt service routine code (User-generated).
- Restores the STATUS register (and bank select bit).
- Restores the W and PCLATH registers.

EXAMPLE 11-1: SAVING STATUS, W, AND PCLATH REGISTERS IN RAM

```
MOVWF    W_TEMP           ;Copy W to TEMP register, could be bank one or zero
SWAPF   STATUS,W          ;Swap status to be saved into W
CLRF    STATUS            ;bank 0, regardless of current bank, Clears IRP,RP1,RP0
MOVWF   STATUS_TEMP       ;Save status to bank zero STATUS_TEMP register
MOVF    PCLATH, W         ;Only required if using pages 1, 2 and/or 3
MOVWF   PCLATH_TEMP      ;Save PCLATH into W
CLRF    PCLATH            ;Page zero, regardless of current page
BCF     STATUS, IRP       ;Return to Bank 0
MOVF    FSR, W           ;Copy FSR to W
MOVWF   FSR_TEMP         ;Copy FSR from W to FSR_TEMP
:
:(ISR)
:
MOVF    PCLATH_TEMP, W   ;Restore PCLATH
MOVWF   PCLATH           ;Move W into PCLATH
SWAPF   STATUS_TEMP,W    ;Swap STATUS_TEMP register into W
; (sets bank to original state)
MOVWF   STATUS           ;Move W into STATUS register
SWAPF   W_TEMP,F        ;Swap W_TEMP
SWAPF   W_TEMP,W        ;Swap W_TEMP into W
```

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11.12 Watchdog Timer (WDT)

The Watchdog Timer is a free running on-chip RC oscillator, which does not require any external components. This RC oscillator is separate from the RC oscillator of the OSC1/CLKIN pin. That means that the WDT will run, even if the clock on the OSC1/CLKIN and OSC2/CLKOUT pins of the device has been stopped, for example, by execution of a `SLEEP` instruction.

During normal operation, a WDT time-out generates a device RESET (Watchdog Timer Reset). If the device is in SLEEP mode, a WDT time-out causes the device to wake-up and continue with normal operation (Watchdog Timer Wake-up). The `T0` bit in the STATUS register will be cleared upon a Watchdog Timer time-out.

The WDT can be permanently disabled by clearing configuration bit `WDTE` (Section 11.1).

WDT time-out period values may be found in the Electrical Specifications section under parameter #31. Values for the WDT prescaler (actually a postscaler, but shared with the Timer0 prescaler) may be assigned using the `OPTION_REG` register.

Note: The `CLRWDT` and `SLEEP` instructions clear the WDT and the postscaler if assigned to the WDT, and prevent it from timing out and generating a device RESET condition.

Note: When a `CLRWDT` instruction is executed and the prescaler is assigned to the WDT, the prescaler count will be cleared, but the prescaler assignment is not changed.

FIGURE 11-12: WATCHDOG TIMER BLOCK DIAGRAM

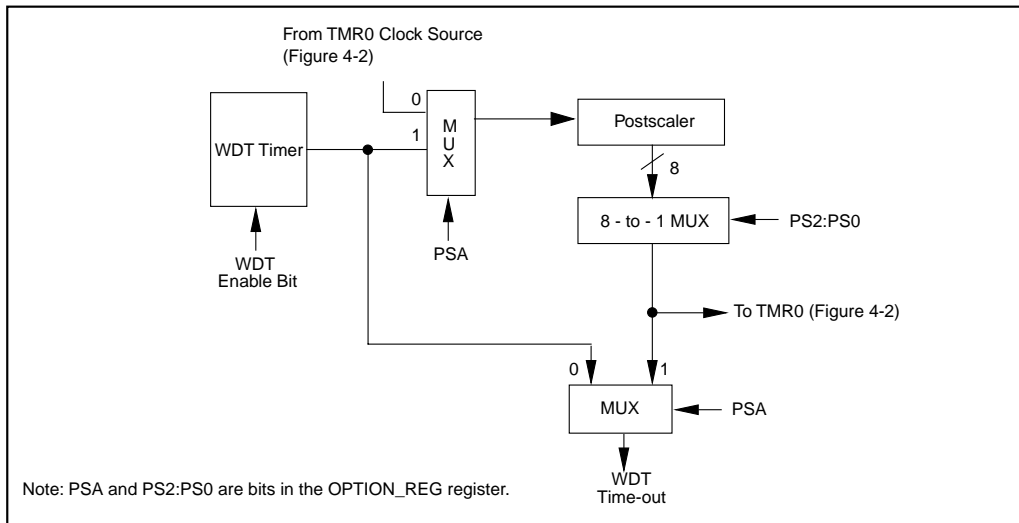


FIGURE 11-13: SUMMARY OF WATCHDOG TIMER REGISTERS

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------|--------------|-------|----------------------|-------|-------|----------------------|-------|-------|-------|
| 2007h | Config. bits | (1) | BODEN ⁽¹⁾ | CP1 | CP0 | PWRTE ⁽¹⁾ | WDTE | FOSC1 | FOSC0 |
| 81h | OPTION_REG | RBPU | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 |

Legend: Shaded cells are not used by the Watchdog Timer.

Note 1: See Figure 11-1 for operation of these bits.

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11.13 Power-down Mode (SLEEP)

Power-down mode is entered by executing a `SLEEP` instruction.

If enabled, the Watchdog Timer will be cleared but keeps running, the \overline{PD} bit (`STATUS<3>`) is cleared, the \overline{TO} (`STATUS<4>`) bit is set, and the oscillator driver is turned off. The I/O ports maintain the status they had, before the `SLEEP` instruction was executed (driving high, low, or hi-impedance).

For lowest current consumption in this mode, place all I/O pins at either V_{DD} or V_{SS} , ensure no external circuitry is drawing current from the I/O pin, power-down the A/D, disable external clocks. Pull all I/O pins, that are hi-impedance inputs, high or low externally to avoid switching currents caused by floating inputs. The `TOCKI` input should also be at V_{DD} or V_{SS} for lowest current consumption. The contribution from on-chip pull-ups on `PORTB` should be considered.

The `MCLR` pin must be at a logic high level (V_{IHMC}).

11.13.1 WAKE-UP FROM SLEEP

The device can wake up from `SLEEP` through one of the following events:

1. External reset input on \overline{MCLR} pin.
2. Watchdog Timer Wake-up (if `WDT` was enabled).
3. Interrupt from `INT` pin, `RB` port change, or some Peripheral Interrupts.

External \overline{MCLR} Reset will cause a device reset. All other events are considered a continuation of program execution and cause a "wake-up". The \overline{TO} and \overline{PD} bits in the `STATUS` register can be used to determine the cause of device reset. The \overline{PD} bit, which is set on power-up, is cleared when `SLEEP` is invoked. The \overline{TO} bit is cleared if a `WDT` time-out occurred (and caused wake-up).

The following peripheral interrupts can wake the device from `SLEEP`:

1. `PSP` read or write.
2. `TMR1` interrupt. `Timer1` must be operating as an asynchronous counter.
3. `CCP` capture mode interrupt.
4. Special event trigger (`Timer1` in asynchronous mode using an external clock).
5. `SSP` (Start/Stop) bit detect interrupt.
6. `SSP` transmit or receive in slave mode (`SPI/I2C`).
7. `USART` `RX` or `TX` (synchronous slave mode).
8. A/D conversion (when A/D clock source is `RC`).

Other peripherals cannot generate interrupts since during `SLEEP`, no on-chip clocks are present.

When the `SLEEP` instruction is being executed, the next instruction (`PC + 1`) is pre-fetched. For the device to wake-up through an interrupt event, the corresponding interrupt enable bit must be set (enabled). Wake-up is regardless of the state of the `GIE` bit. If the `GIE` bit is clear (disabled), the device continues execution at the instruction after the `SLEEP` instruction. If the `GIE` bit is set (enabled), the device executes the instruction after the `SLEEP` instruction and then branches to the interrupt address (0004h). In cases where the execution of the instruction following `SLEEP` is not desirable, the user should have a `NOP` after the `SLEEP` instruction.

11.13.2 WAKE-UP USING INTERRUPTS

When global interrupts are disabled (`GIE` cleared) and any interrupt source has both its interrupt enable bit and interrupt flag bit set, one of the following will occur:

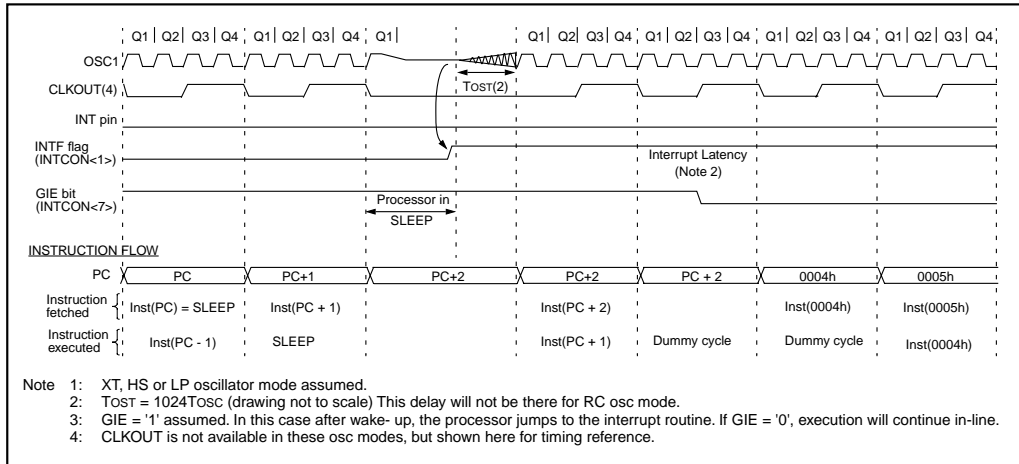
- If the interrupt occurs **before** the execution of a `SLEEP` instruction, the `SLEEP` instruction will complete as a `NOP`. Therefore, the `WDT` and `WDT` postscaler will not be cleared, the \overline{TO} bit will not be set and \overline{PD} bits will not be cleared.
- If the interrupt occurs **during or after** the execution of a `SLEEP` instruction, the device will immediately wake up from sleep. The `SLEEP` instruction will be completely executed before the wake-up. Therefore, the `WDT` and `WDT` postscaler will be cleared, the \overline{TO} bit will be set and the \overline{PD} bit will be cleared.

Even if the flag bits were checked before executing a `SLEEP` instruction, it may be possible for flag bits to become set before the `SLEEP` instruction completes. To determine whether a `SLEEP` instruction executed, test the \overline{PD} bit. If the \overline{PD} bit is set, the `SLEEP` instruction was executed as a `NOP`.

To ensure that the `WDT` is cleared, a `CLRWDT` instruction should be executed before a `SLEEP` instruction.

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FIGURE 11-14: WAKE-UP FROM SLEEP THROUGH INTERRUPT



11.14 Program Verification/Code Protection

If the code protection bit(s) have not been programmed, the on-chip program memory can be read out for verification purposes.

Note: Microchip Technology does not recommend code protecting windowed devices.

11.15 ID Locations

Four memory locations (2000h - 2003h) are designated as ID locations where the user can store checksum or other code-identification numbers. These locations are not accessible during normal execution but are readable and writable during program/verify. It is recommended that only the 4 least significant bits of the ID location are used.

For ROM devices, these values are submitted along with the ROM code.

11.16 In-Circuit Serial Programming

PIC16CXXX microcontrollers can be serially programmed while in the end application circuit. This is simply done with two lines for clock and data, and three other lines for power, ground and the programming voltage. This allows customers to manufacture boards with unprogrammed devices, and then program the microcontroller just before shipping the product. This also allows the most recent firmware or a custom firmware to be programmed.

For complete details of serial programming, please refer to the In-Circuit Serial Programming (ICSP™) Guide, (DS30277B).

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12.0 INSTRUCTION SET SUMMARY

Each PIC16CXXX instruction is a 14-bit word divided into an OPCODE which specifies the instruction type and one or more operands which further specify the operation of the instruction. The PIC16CXX instruction set summary in Table 12-2 lists **byte-oriented**, **bit-oriented**, and **literal and control** operations. Table 12-1 shows the opcode field descriptions.

For **byte-oriented** instructions, 'f' represents a file register designator and 'd' represents a destination designator. The file register designator specifies which file register is to be used by the instruction.

The destination designator specifies where the result of the operation is to be placed. If 'd' is zero, the result is placed in the W register. If 'd' is one, the result is placed in the file register specified in the instruction.

For **bit-oriented** instructions, 'b' represents a bit field designator which selects the number of the bit affected by the operation, while 'f' represents the number of the file in which the bit is located.

For **literal and control** operations, 'k' represents an eight or eleven bit constant or literal value.

TABLE 12-1: OPCODE FIELD DESCRIPTIONS

| Field | Description |
|-------|--|
| f | Register file address (0x00 to 0x7F) |
| w | Working register (accumulator) |
| b | Bit address within an 8-bit file register |
| k | Literal field, constant data or label |
| x | Don't care location (= 0 or 1) The assembler will generate code with x = 0. It is the recommended form of use for compatibility with all Microchip Technology software tools. |
| d | Destination select; d = 0: store result in W, d = 1: store result in file register f. Default is d = 1 |
| PC | Program Counter |
| TO | Time-out bit |
| PD | Power-down bit |

The instruction set is highly orthogonal and is grouped into three basic categories:

- **Byte-oriented** operations
- **Bit-oriented** operations
- **Literal and control** operations

All instructions are executed within one single instruction cycle, unless a conditional test is true or the program counter is changed as a result of an instruction. In this case, the execution takes two instruction cycles with the second cycle executed as a NOP. One instruction cycle consists of four oscillator periods. Thus, for an oscillator frequency of 4 MHz, the normal instruction execution time is 1 μ s. If a conditional test is true or the program counter is changed as a result of an instruction, the instruction execution time is 2 μ s.

Table 12-2 lists the instructions recognized by the MPASM assembler.

Figure 12-1 shows the general formats that the instructions can have.

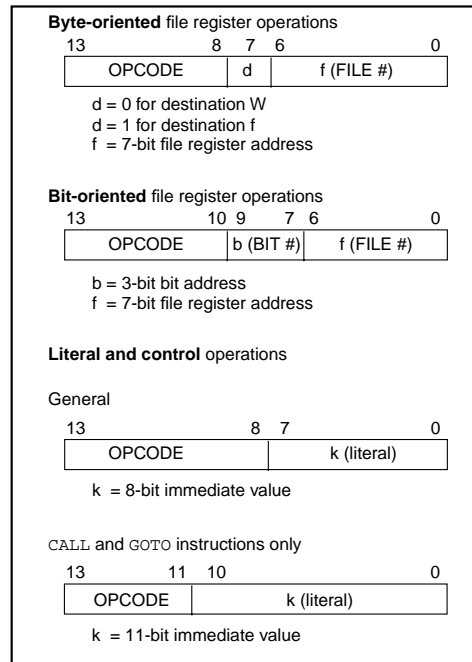
Note: To maintain upward compatibility with future PIC16CXXX products, do not use the **OPTION** and **TRIS** instructions.

All examples use the following format to represent a hexadecimal number:

0xhh

where h signifies a hexadecimal digit.

FIGURE 12-1: GENERAL FORMAT FOR INSTRUCTIONS



A description of each instruction is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

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TABLE 12-2: PIC16CXXX INSTRUCTION SET

| Mnemonic, Operands | Description | Cycles | 14-Bit Opcode | | | Status Affected | Notes | | |
|---|-------------|------------------------------|---------------|-----|------|--------------------|-------|-----------------------------------|-------|
| | | | MSb | LSb | | | | | |
| BYTE-ORIENTED FILE REGISTER OPERATIONS | | | | | | | | | |
| ADDWF | f, d | Add W and f | 1 | 00 | 0111 | dfff | ffff | C,DC,Z | 1,2 |
| ANDWF | f, d | AND W with f | 1 | 00 | 0101 | dfff | ffff | Z | 1,2 |
| CLRF | f | Clear f | 1 | 00 | 0001 | 1fff | ffff | Z | 2 |
| CLRWF | - | Clear W | 1 | 00 | 0001 | 0xxx | xxxx | Z | |
| COMF | f, d | Complement f | 1 | 00 | 1001 | dfff | ffff | Z | 1,2 |
| DECf | f, d | Decrement f | 1 | 00 | 0011 | dfff | ffff | Z | 1,2 |
| DECFSZ | f, d | Decrement f, Skip if 0 | 1(2) | 00 | 1011 | dfff | ffff | | 1,2,3 |
| INCF | f, d | Increment f | 1 | 00 | 1010 | dfff | ffff | Z | 1,2 |
| INCFSZ | f, d | Increment f, Skip if 0 | 1(2) | 00 | 1111 | dfff | ffff | | 1,2,3 |
| IORWF | f, d | Inclusive OR W with f | 1 | 00 | 0100 | dfff | ffff | Z | 1,2 |
| MOVF | f, d | Move f | 1 | 00 | 1000 | dfff | ffff | Z | 1,2 |
| MOVWF | f | Move W to f | 1 | 00 | 0000 | 1fff | ffff | | |
| NOP | - | No Operation | 1 | 00 | 0000 | 0xx0 | 0000 | | |
| RLF | f, d | Rotate Left f through Carry | 1 | 00 | 1101 | dfff | ffff | C | 1,2 |
| RRF | f, d | Rotate Right f through Carry | 1 | 00 | 1100 | dfff | ffff | C | 1,2 |
| SUBWF | f, d | Subtract W from f | 1 | 00 | 0010 | dfff | ffff | C,DC,Z | 1,2 |
| SWAPF | f, d | Swap nibbles in f | 1 | 00 | 1110 | dfff | ffff | | 1,2 |
| XORWF | f, d | Exclusive OR W with f | 1 | 00 | 0110 | dfff | ffff | Z | 1,2 |
| BIT-ORIENTED FILE REGISTER OPERATIONS | | | | | | | | | |
| BCF | f, b | Bit Clear f | 1 | 01 | 00bb | bfff | ffff | | 1,2 |
| BSF | f, b | Bit Set f | 1 | 01 | 01bb | bfff | ffff | | 1,2 |
| BTFSC | f, b | Bit Test f, Skip if Clear | 1(2) | 01 | 10bb | bfff | ffff | | 3 |
| BTFSS | f, b | Bit Test f, Skip if Set | 1(2) | 01 | 11bb | bfff | ffff | | 3 |
| LITERAL AND CONTROL OPERATIONS | | | | | | | | | |
| ADDLW | k | Add literal and W | 1 | 11 | 111x | kkkk | kkkk | C,DC,Z | |
| ANDLW | k | AND literal with W | 1 | 11 | 1001 | kkkk | kkkk | Z | |
| CALL | k | Call subroutine | 2 | 10 | 0kkk | kkkk | kkkk | | |
| CLRWD _T | - | Clear Watchdog Timer | 1 | 00 | 0000 | 0110 | 0100 | \overline{TO} , \overline{PD} | |
| GOTO | k | Go to address | 2 | 10 | 1kkk | kkkk | kkkk | | |
| IORLW | k | Inclusive OR literal with W | 1 | 11 | 1000 | kkkk | kkkk | Z | |
| MOVLW | k | Move literal to W | 1 | 11 | 00xx | kkkk | kkkk | | |
| RETFIE | - | Return from interrupt | 2 | 00 | 0000 | 0000 | 1001 | | |
| RETLW | k | Return with literal in W | 2 | 11 | 01xx | kkkk | kkkk | | |
| RETURN | - | Return from Subroutine | 2 | 00 | 0000 | 0000 | 1000 | | |
| SLEEP | - | Go into standby mode | 1 | 00 | 0000 | 0110 | 0011 | \overline{TO} , \overline{PD} | |
| SUBLW | k | Subtract W from literal | 1 | 11 | 110x | kkkk | kkkk | C,DC,Z | |
| XORLW | k | Exclusive OR literal with W | 1 | 11 | 1010 | kkkk | kkkk | Z | |

Note 1: When an I/O register is modified as a function of itself (e.g., `MOVF PORTB, 1`), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

- If this instruction is executed on the TMR0 register (and, where applicable, d = 1), the prescaler will be cleared if assigned to the Timer0 Module.
- If Program Counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

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13.0 DEVELOPMENT SUPPORT

13.1 Development Tools

The PICmicro™ microcontrollers are supported with a full range of hardware and software development tools:

- PICMASTER®/PICMASTER CE Real-Time In-Circuit Emulator
- ICEPIC™ Low-Cost PIC16C5X and PIC16CXXX In-Circuit Emulator
- PRO MATE® II Universal Programmer
- PICSTART® Plus Entry-Level Prototype Programmer
- PICDEM-1 Low-Cost Demonstration Board
- PICDEM-2 Low-Cost Demonstration Board
- PICDEM-3 Low-Cost Demonstration Board
- MPASM Assembler
- MPLAB™ SIM Software Simulator
- MPLAB-C17 (C Compiler)
- Fuzzy Logic Development System (*fuzzyTECH*®-MP)

13.2 PICMASTER: High Performance Universal In-Circuit Emulator with MPLAB IDE

The PICMASTER Universal In-Circuit Emulator is intended to provide the product development engineer with a complete microcontroller design tool set for all microcontrollers in the PIC14C000, PIC12CXXX, PIC16C5X, PIC16CXXX and PIC17CXX families. PICMASTER is supplied with the MPLAB™ Integrated Development Environment (IDE), which allows editing, "make" and download, and source debugging from a single environment.

Interchangeable target probes allow the system to be easily reconfigured for emulation of different processors. The universal architecture of the PICMASTER allows expansion to support all new Microchip microcontrollers.

The PICMASTER Emulator System has been designed as a real-time emulation system with advanced features that are generally found on more expensive development tools. The PC compatible 386 (and higher) machine platform and Microsoft Windows® 3.x environment were chosen to best make these features available to you, the end user.

A CE compliant version of PICMASTER is available for European Union (EU) countries.

13.3 ICEPIC: Low-Cost PICmicro™ In-Circuit Emulator

ICEPIC is a low-cost in-circuit emulator solution for the Microchip PIC12CXXX, PIC16C5X and PIC16CXXX families of 8-bit OTP microcontrollers.

ICEPIC is designed to operate on PC-compatible machines ranging from 286-AT® through Pentium™ based machines under Windows 3.x environment. ICEPIC features real time, non-intrusive emulation.

13.4 PRO MATE II: Universal Programmer

The PRO MATE II Universal Programmer is a full-featured programmer capable of operating in stand-alone mode as well as PC-hosted mode. PRO MATE II is CE compliant.

The PRO MATE II has programmable VDD and VPP supplies which allows it to verify programmed memory at VDD min and VDD max for maximum reliability. It has an LCD display for displaying error messages, keys to enter commands and a modular detachable socket assembly to support various package types. In stand-alone mode the PRO MATE II can read, verify or program PIC12CXXX, PIC14C000, PIC16C5X, PIC16CXXX and PIC17CXX devices. It can also set configuration and code-protect bits in this mode.

13.5 PICSTART Plus Entry Level Development System

The PICSTART programmer is an easy-to-use, low-cost prototype programmer. It connects to the PC via one of the COM (RS-232) ports. MPLAB Integrated Development Environment software makes using the programmer simple and efficient. PICSTART Plus is not recommended for production programming.

PICSTART Plus supports all PIC12CXXX, PIC14C000, PIC16C5X, PIC16CXXX and PIC17CXX devices with up to 40 pins. Larger pin count devices such as the PIC16C923, PIC16C924 and PIC17C756 may be supported with an adapter socket. PICSTART Plus is CE compliant.

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13.6 PICDEM-1 Low-Cost PICmicro Demonstration Board

The PICDEM-1 is a simple board which demonstrates the capabilities of several of Microchip's microcontrollers. The microcontrollers supported are: PIC16C5X (PIC16C54 to PIC16C58A), PIC16C61, PIC16C62X, PIC16C71, PIC16C8X, PIC17C42, PIC17C43 and PIC17C44. All necessary hardware and software is included to run basic demo programs. The users can program the sample microcontrollers provided with the PICDEM-1 board, on a PRO MATE II or PICSTART-Plus programmer, and easily test firmware. The user can also connect the PICDEM-1 board to the PICMASTER emulator and download the firmware to the emulator for testing. Additional prototype area is available for the user to build some additional hardware and connect it to the microcontroller socket(s). Some of the features include an RS-232 interface, a potentiometer for simulated analog input, push-button switches and eight LEDs connected to PORTB.

13.7 PICDEM-2 Low-Cost PIC16CXXX Demonstration Board

The PICDEM-2 is a simple demonstration board that supports the PIC16C62, PIC16C64, PIC16C65, PIC16C73 and PIC16C74 microcontrollers. All the necessary hardware and software is included to run the basic demonstration programs. The user can program the sample microcontrollers provided with the PICDEM-2 board, on a PRO MATE II programmer or PICSTART-Plus, and easily test firmware. The PICMASTER emulator may also be used with the PICDEM-2 board to test firmware. Additional prototype area has been provided to the user for adding additional hardware and connecting it to the microcontroller socket(s). Some of the features include a RS-232 interface, push-button switches, a potentiometer for simulated analog input, a Serial EEPROM to demonstrate usage of the I²C bus and separate headers for connection to an LCD module and a keypad.

13.8 PICDEM-3 Low-Cost PIC16CXXX Demonstration Board

The PICDEM-3 is a simple demonstration board that supports the PIC16C923 and PIC16C924 in the PLCC package. It will also support future 44-pin PLCC microcontrollers with a LCD Module. All the necessary hardware and software is included to run the basic demonstration programs. The user can program the sample microcontrollers provided with the PICDEM-3 board, on a PRO MATE II programmer or PICSTART Plus with an adapter socket, and easily test firmware. The PICMASTER emulator may also be used with the PICDEM-3 board to test firmware. Additional prototype area has been provided to the user for adding hardware and connecting it to the microcontroller socket(s). Some of the features include

an RS-232 interface, push-button switches, a potentiometer for simulated analog input, a thermistor and separate headers for connection to an external LCD module and a keypad. Also provided on the PICDEM-3 board is an LCD panel, with 4 commons and 12 segments, that is capable of displaying time, temperature and day of the week. The PICDEM-3 provides an additional RS-232 interface and Windows 3.1 software for showing the demultiplexed LCD signals on a PC. A simple serial interface allows the user to construct a hardware demultiplexer for the LCD signals.

13.9 MPLAB™ Integrated Development Environment Software

The MPLAB IDE Software brings an ease of software development previously unseen in the 8-bit microcontroller market. MPLAB is a windows based application which contains:

- A full featured editor
- Three operating modes
 - editor
 - emulator
 - simulator
- A project manager
- Customizable tool bar and key mapping
- A status bar with project information
- Extensive on-line help

MPLAB allows you to:

- Edit your source files (either assembly or 'C')
- One touch assemble (or compile) and download to PICmicro tools (automatically updates all project information)
- Debug using:
 - source files
 - absolute listing file
- Transfer data dynamically via DDE (soon to be replaced by OLE)
- Run up to four emulators on the same PC

The ability to use MPLAB with Microchip's simulator allows a consistent platform and the ability to easily switch from the low cost simulator to the full featured emulator with minimal retraining due to development tools.

13.10 Assembler (MPASM)

The MPASM Universal Macro Assembler is a PC-hosted symbolic assembler. It supports all microcontroller series including the PIC12C5XX, PIC14000, PIC16C5X, PIC16CXXX, and PIC17CXX families.

MPASM offers full featured Macro capabilities, conditional assembly, and several source and listing formats. It generates various object code formats to support Microchip's development tools as well as third party programmers.

MPASM allows full symbolic debugging from PICMASTER, Microchip's Universal Emulator System.

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MPASM has the following features to assist in developing software for specific use applications.

- Provides translation of Assembler source code to object code for all Microchip microcontrollers.
- Macro assembly capability.
- Produces all the files (Object, Listing, Symbol, and special) required for symbolic debug with Microchip's emulator systems.
- Supports Hex (default), Decimal and Octal source and listing formats.

MPASM provides a rich directive language to support programming of the PICmicro. Directives are helpful in making the development of your assemble source code shorter and more maintainable.

13.11 Software Simulator (MPLAB-SIM)

The MPLAB-SIM Software Simulator allows code development in a PC host environment. It allows the user to simulate the PICmicro series microcontrollers on an instruction level. On any given instruction, the user may examine or modify any of the data areas or provide external stimulus to any of the pins. The input/output radix can be set by the user and the execution can be performed in; single step, execute until break, or in a trace mode.

MPLAB-SIM fully supports symbolic debugging using MPLAB-C and MPASM. The Software Simulator offers the low cost flexibility to develop and debug code outside of the laboratory environment making it an excellent multi-project software development tool.

13.12 C Compiler (MPLAB-C17)

The MPLAB-C Code Development System is a complete 'C' compiler and integrated development environment for Microchip's PIC17CXXX family of microcontrollers. The compiler provides powerful integration capabilities and ease of use not found with other compilers.

For easier source level debugging, the compiler provides symbol information that is compatible with the MPLAB IDE memory display.

13.13 Fuzzy Logic Development System (fuzzyTECH-MP)

fuzzyTECH-MP fuzzy logic development tool is available in two versions - a low cost introductory version, MP Explorer, for designers to gain a comprehensive working knowledge of fuzzy logic system design; and a full-featured version, *fuzzyTECH-MP*, Edition for implementing more complex systems.

Both versions include Microchip's *fuzzyLAB™* demonstration board for hands-on experience with fuzzy logic systems implementation.

13.14 MP-DriveWay™ – Application Code Generator

MP-DriveWay is an easy-to-use Windows-based Application Code Generator. With MP-DriveWay you can visually configure all the peripherals in a PICmicro device and, with a click of the mouse, generate all the initialization and many functional code modules in C language. The output is fully compatible with Microchip's MPLAB-C C compiler. The code produced is highly modular and allows easy integration of your own code. MP-DriveWay is intelligent enough to maintain your code through subsequent code generation.

13.15 SEEVAL® Evaluation and Programming System

The SEEVAL SEEPROM Designer's Kit supports all Microchip 2-wire and 3-wire Serial EEPROMs. The kit includes everything necessary to read, write, erase or program special features of any Microchip SEEPROM product including Smart Serials™ and secure serials. The Total Endurance™ Disk is included to aid in trade-off analysis and reliability calculations. The total kit can significantly reduce time-to-market and result in an optimized system.

13.16 KEELoq® Evaluation and Programming Tools

KEELOQ evaluation and programming tools support Microchips HCS Secure Data Products. The HCS evaluation kit includes an LCD display to show changing codes, a decoder to decode transmissions, and a programming interface to program test transmitters.

PIC16C62X(A)

TABLE 13-1 DEVELOPMENT TOOLS FROM MICROCHIP

| | PIC12C5XX | PIC14000 | PIC16C5X | PIC16CXXX | PIC16C6X | PIC16C7XX | PIC16C8X | PIC16C9XX | PIC17C4X | PIC17C7XX | 24CXX | 25CXX | 93CXX | HCSXXX |
|---|-----------|----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------------------|-------|-------|-------|--------|
| EMULATOR PRODUCTS | | | | | | | | | | | | | | |
| PICMASTER [®] / PICMASTER-CE In-Circuit Emulator | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | (PIC17C75X only) ✓ | | | | |
| MPLAB [™] ICE | | | | | | | | | | ✓ | | | | |
| ICEPIC [™] Low-Cost In-Circuit Emulator | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| SOFTWARE PRODUCTS | | | | | | | | | | | | | | |
| MPLAB [™] Integrated Development Environment | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| MPLAB [™] C17 Compiler | | | | | | | | | | ✓ | | | | |
| fuzzyTECH [®] -MP Explorer/Edition Fuzzy Logic Dev. Tool | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| MP-DriveWay [™] Applications Code Generator | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| Total Endurance [™] Software Model | | | | | | | | | | | ✓ | | | |
| PROGRAMMERS | | | | | | | | | | | | | | |
| PICSTART [®] Plus Low-Cost Universal Dev. Kit | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| PRO MATE [®] II Universal Programmer | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| KEELOQ [®] Programmer | | | | | | | | | | | | | | |
| DEMO BOARDS | | | | | | | | | | | | | | |
| SEEVAL [®] Designers Kit | | | | | | | | | | | | ✓ | | |
| PICDEM-1 | | ✓ | | ✓ | | | | | ✓ | | | | | |
| PICDEM-2 | | | | | | ✓ | | | | | | | | |
| PICDEM-3 | | | | | | | | ✓ | | | | | | |

PIC16C63A/65B/73B/74B

14.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings ^(†)

| | |
|--|-----------------------------------|
| Ambient temperature under bias..... | -55°C to +125°C |
| Storage temperature..... | -65°C to +150°C |
| Voltage on any pin with respect to V _{SS} (except V _{DD} , \overline{MCLR} , and RA4)..... | -0.3V to (V _{DD} + 0.3V) |
| Voltage on V _{DD} with respect to V _{SS} | -0.3V to +7.5V |
| Voltage on \overline{MCLR} with respect to V _{SS} (Note 2)..... | 0V to +13.25V |
| Voltage on RA4 with respect to V _{SS} | 0V to +8.5V |
| Total power dissipation (Note 1)..... | 1.0W |
| Maximum current out of V _{SS} pin..... | 300 mA |
| Maximum current into V _{DD} pin..... | 250 mA |
| Input clamp current, I _{IK} (V _I < 0 or V _I > V _{DD})..... | ±20 mA |
| Output clamp current, I _{OK} (V _O < 0 or V _O > V _{DD})..... | ±20 mA |
| Maximum output current sunk by any I/O pin..... | 25 mA |
| Maximum output current sourced by any I/O pin..... | 25 mA |
| Maximum current sunk by PORTA, PORTB, and PORTE (Note 3) (combined)..... | 200 mA |
| Maximum current sourced by PORTA, PORTB, and PORTE (Note 3) (combined)..... | 200 mA |
| Maximum current sunk by PORTC and PORTD (Note 3) (combined)..... | 200 mA |
| Maximum current sourced by PORTC and PORTD (Note 3) (combined)..... | 200 mA |

Note 1: Power dissipation is calculated as follows: $P_{dis} = V_{DD} \times \{I_{DD} - \sum I_{OH}\} + \sum \{(V_{DD} - V_{OH}) \times I_{OH}\} + \sum \{V_{OL} \times I_{OL}\}$

Note 2: Voltage spikes below V_{SS} at the \overline{MCLR}/V_{PP} pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a “low” level to the \overline{MCLR}/V_{PP} pin rather than pulling this pin directly to V_{SS}.

Note 3: PORTD and PORTE not available on the PIC16C63A/73B.

† NOTICE: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

TABLE 14-1: CROSS REFERENCE OF DEVICE SPECS FOR OSCILLATOR MODES AND FREQUENCIES OF OPERATION (COMMERCIAL DEVICES)

| OSC | PIC16C63A-04 PIC16C65B-04 PIC16C73B-04 PIC16C74B-04 | PIC16C63A-20 PIC16C65B-20 PIC16C73B-20 PIC16C74B-20 | PIC16LC63A-04 PIC16LC65B-04 PIC16LC73B-04 PIC16LC74B-04 | Windowed (JW) Devices |
|-----|---|--|---|---|
| RC | V _{DD} : 4.0V to 5.5V I _{DD} : 5 mA max. at 5.5V I _{PD} : 16 μA max. at 4V Freq: 4 MHz max. | V _{DD} : 4.5V to 5.5V I _{DD} : 2.7 mA typ. at 5.5V I _{PD} : 1.5 μA typ. at 4V Freq: 4 MHz max. | V _{DD} : 2.5V to 5.5V I _{DD} : 3.8 mA max. at 3V I _{PD} : 5 μA max. at 3V Freq: 4 MHz max. | V _{DD} : 2.5V to 5.5V I _{DD} : 3.8 mA max. at 3V I _{PD} : 5 μA max. at 3V Freq: 4 MHz max. |
| XT | V _{DD} : 4.0V to 5.5V I _{DD} : 5 mA max. at 5.5V I _{PD} : 16 μA max. at 4V Freq: 4 MHz max. | V _{DD} : 4.5V to 5.5V I _{DD} : 2.7 mA typ. at 5.5V I _{PD} : 1.5 μA typ. at 4V Freq: 4 MHz max. | V _{DD} : 2.5V to 5.5V I _{DD} : 3.8 mA max. at 3V I _{PD} : 5 μA max. at 3V Freq: 4 MHz max. | V _{DD} : 2.5V to 5.5V I _{DD} : 3.8 mA max. at 3V I _{PD} : 5 μA max. at 3V Freq: 4 MHz max. |
| HS | V _{DD} : 4.5V to 5.5V I _{DD} : 13.5 mA typ. at 5.5V I _{PD} : 1.5 μA typ. at 4.5V Freq: 4 MHz max. | V _{DD} : 4.5V to 5.5V I _{DD} : 20 mA max. at 5.5V I _{PD} : 1.5 μA typ. at 4.5V Freq: 20 MHz max. | Not recommended for use in HS mode | V _{DD} : 4.5V to 5.5V I _{DD} : 20 mA max. at 5.5V I _{PD} : 1.5 μA typ. at 4.5V Freq: 20 MHz max. |
| LP | V _{DD} : 4.0V to 5.5V I _{DD} : 52.5 μA typ. at 32 kHz, 4.0V I _{PD} : 0.9 μA typ. at 4.0V Freq: 200 kHz max. | Not recommended for use in LP mode | V _{DD} : 2.5V to 5.5V I _{DD} : 48 μA max. at 32 kHz, 3.0V I _{PD} : 5 μA max. at 3.0V Freq: 200 kHz max. | V _{DD} : 2.5V to 5.5V I _{DD} : 48 μA max. at 32 kHz, 3.0V I _{PD} : 5 μA max. at 3.0V Freq: 200 kHz max. |

The shaded sections indicate oscillator selections which are tested for functionality, but not for MIN/MAX specifications. It is recommended that the user select the device type that ensures the specifications required.

PIC16C63A/65B/73B/74B

14.1 DC Characteristics: PIC16C63A/65B/73B/74B-04 (Commercial, Industrial, Extended) PIC16C6A/65B/73B/74B-20 (Commercial, Industrial, Extended)

| DC CHARACTERISTICS | | Standard Operating Conditions (unless otherwise stated) | | | | | |
|-----------------------|--|---|---------------------|---------------------------|----------------------|--|--|
| | | Operating temperature $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ for commercial $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for extended | | | | | |
| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
| D001 D001A | VDD | Supply Voltage | 4.0 4.5 VBOR* | - - - | 5.5 5.5 5.5 | V V V | XT, RC and LP osc mode HS osc mode BOR enabled (Note 7) |
| D002* | VDR | RAM Data Retention Voltage (Note 1) | - | 1.5 | - | V | |
| D003 | VPOR | VDD Start Voltage to ensure internal Power-on Reset signal | - | VSS | - | V | See section on Power-on Reset for details |
| D004* D004A* | SVDD | VDD Rise Rate to ensure internal Power-on Reset signal | 0.05 TBD | - - | - - | V/ms | PWRT enabled (PWRT bit clear) PWRT disabled (PWRT bit set) See section on Power-on Reset for details |
| D005 | VBOR | Brown-out Reset voltage trip point | 3.65 | - | 4.35 | V | BODEN bit set |
| D010 D013 | IDD | Supply Current (Note 2, 5) | - - | 2.7 10 | 5 20 | mA mA | XT, RC osc modes FOSC = 4 MHz, VDD = 5.5V (Note 4) HS osc mode FOSC = 20 MHz, VDD = 5.5V |
| D020 D021 D021B | IPD | Power-down Current (Note 3, 5) | - - - - | 10.5 1.5 1.5 2.5 | 42 16 19 19 | μA μA μA μA | VDD = 4.0V, WDT enabled, -40°C to +85°C VDD = 4.0V, WDT disabled, 0°C to +70°C VDD = 4.0V, WDT disabled, -40°C to +85°C VDD = 4.0V, WDT disabled, -40°C to +125°C |
| D022* D022A* | ΔIWDT ΔIBOR | Module Differential Current (Note 6) Watchdog Timer Brown-out Reset | - - | 6.0 350 | 20 425 | μA μA | WDTE bit set, VDD = 4.0V BODEN bit set, VDD = 5.0V |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: This is the limit to which VDD can be lowered without losing RAM data.

2: The supply current is mainly a function of the operating voltage and frequency. Other factors such as I/O pin loading and switching rate, oscillator type, internal code execution pattern, and temperature also have an impact on the current consumption.

The test conditions for all IDD measurements in active operation mode are:

OSC1 = external square wave, from rail to rail; all I/O pins in hi-impedance state and tied to VDD and VSS.

MCLR = VDD; WDT enabled/disabled as specified.

3: The power-down current in SLEEP mode does not depend on the oscillator type. Power-down current is measured with the part in SLEEP mode, with all I/O pins in hi-impedance state and tied to VDD and VSS.

4: For RC osc mode, current through Rext is not included. The current through the resistor can be estimated by the formula $I_r = V_{DD}/2R_{ext}$ (mA) with Rext in kOhm.

5: Timer1 oscillator (when enabled) adds approximately 20 μA to the specification. This value is from characterization and is for design guidance only. This is not tested.

6: The Δ current is the additional current consumed when this peripheral is enabled. This current should be added to the base IDD or IPD measurement.

7: When BOR is enabled, the device will operate correctly until the VBOR voltage trip point is reached.

PIC16C63A/65B/73B/74B

14.2 DC Characteristics: PIC16LC63A/65B/73B/74B-04 (Commercial, Industrial)

| DC CHARACTERISTICS | | | | | | | Standard Operating Conditions (unless otherwise stated) | |
|-----------------------|--|--|--------------|-------------------|--------------|---|---|--|
| | | | | | | | Operating temperature $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ for commercial $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for industrial | |
| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions | |
| D001 | VDD | Supply Voltage | 2.5 VBOR* | - | 5.5 5.5 | V | LP, XT, RC osc modes (DC - 4 MHz) BOR enabled (Note 7) | |
| D002* | VDR | RAM Data Retention Voltage (Note 1) | - | 1.5 | - | V | | |
| D003 | VPOR | VDD Start Voltage to ensure internal Power-on Reset signal | - | VSS | - | V | See section on Power-on Reset for details | |
| D004* D004A* | SVDD | VDD Rise Rate to ensure internal Power-on Reset signal | 0.05 TBD | - - | - - | V/ms | PWRT enabled ($\overline{\text{PWRT}}\text{E}$ bit clear) PWRT disabled ($\overline{\text{PWRT}}\text{E}$ bit set) See section on Power-on Reset for details | |
| D005 | VBOR | Brown-out Reset voltage trip point | 3.65 | - | 4.35 | V | BODEN bit set | |
| D010 D010A | IDD | Supply Current (Note 2, 5) | - | 2.0 | 3.8 | mA | XT, RC osc modes FOSC = 4 MHz, VDD = 3.0V (Note 4) | |
| | | | - | 22.5 | 48 | μA | LP osc mode FOSC = 32 kHz, VDD = 3.0V, WDT disabled | |
| D020 D021 D021A | IPD | Power-down Current (Note 3, 5) | - | 7.5 0.9 0.9 | 30 5 5 | μA μA μA | VDD = 3.0V, WDT enabled, -40°C to $+85^{\circ}\text{C}$ VDD = 3.0V, WDT disabled, 0°C to $+70^{\circ}\text{C}$ VDD = 3.0V, WDT disabled, -40°C to $+85^{\circ}\text{C}$ | |
| D022* D022A* | ΔIWDT ΔIBOR | Module Differential Current (Note 6) Watchdog Timer Brown-out Reset | - | 6.0 350 | 20 425 | μA μA | WDTE bit set, VDD = 4.0V BODEN bit set, VDD = 5.0V | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: This is the limit to which VDD can be lowered without losing RAM data.

2: The supply current is mainly a function of the operating voltage and frequency. Other factors such as I/O pin loading and switching rate, oscillator type, internal code execution pattern, and temperature also have an impact on the current consumption.

The test conditions for all IDD measurements in active operation mode are:

OSC1 = external square wave, from rail to rail; all I/O pins tristated, pulled to VDD,

$\overline{\text{MCLR}} = \text{VDD}$; WDT enabled/disabled as specified.

3: The power-down current in SLEEP mode does not depend on the oscillator type. Power-down current is measured with the part in SLEEP mode, with all I/O pins in hi-impedance state and tied to VDD and VSS.

4: For RC osc mode, current through Rext is not included. The current through the resistor can be estimated by the formula $I_r = \text{VDD}/2\text{Rext}$ (mA) with Rext in kOhm.

5: Timer1 oscillator (when enabled) adds approximately $20 \mu\text{A}$ to the specification. This value is from characterization and is for design guidance only. This is not tested.

6: The Δ current is the additional current consumed when this peripheral is enabled. This current should be added to the base IDD or IPD measurement.

7: When BOR is enabled, the device will operate correctly until the VBOR voltage trip point is reached..

PIC16C63A/65B/73B/74B

14.3 DC Characteristics: PIC16C63A/65B/73B/74B-04 (Commercial, Industrial, Extended) PIC16C63A/65B/73B/74B-20 (Commercial, Industrial, Extended) PIC16LC63A/65B/73B/74B-04 (Commercial, Industrial)

| Standard Operating Conditions (unless otherwise stated) | | | | | | | |
|---|----------|---|--|----------------------------|--|---|--|
| DC CHARACTERISTICS | | | | | | | |
| Operating temperature $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ for commercial $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for extended | | | | | | | |
| Operating voltage V_{DD} range as described in DC spec Section 14.1 and Section 14.2 | | | | | | | |
| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
| D030 D030A D031 D032 D033 | V_{IL} | Input Low Voltage I/O ports with TTL buffer with Schmitt Trigger buffer <u>MCLR</u> , OSC1 (in RC mode) OSC1 (in XT, HS and LP modes) | V_{SS} V_{SS} V_{SS} V_{SS} V_{SS} | - - - - - | $0.15V_{DD}$ 0.8V $0.2V_{DD}$ $0.2V_{DD}$ $0.3V_{DD}$ | V V V V V | For entire V_{DD} range $4.5V \leq V_{DD} \leq 5.5V$ Note1 |
| D040 D040A D041 D042 D042A D043 | V_{IH} | Input High Voltage I/O ports with TTL buffer with Schmitt Trigger buffer <u>MCLR</u> OSC1 (XT, HS and LP modes) OSC1 (in RC mode) | 2.0 $0.25V_{DD} + 0.8V$ $0.8V_{DD}$ $0.8V_{DD}$ $0.7V_{DD}$ $0.9V_{DD}$ | - - - - - - | V_{DD} V_{DD} V_{DD} V_{DD} V_{DD} V_{DD} | V V V V V V | $4.5V \leq V_{DD} \leq 5.5V$ For entire V_{DD} range For entire V_{DD} range Note1 |
| D060 D061 D063 | I_{IL} | Input Leakage Current (Notes 2, 3) I/O ports <u>MCLR</u> , RA4/T0CKI OSC1 | - - - | - - - | ± 1 ± 5 ± 5 | μA μA μA | $V_{SS} \leq V_{PIN} \leq V_{DD}$, Pin at hi-impedance $V_{SS} \leq V_{PIN} \leq V_{DD}$ $V_{SS} \leq V_{PIN} \leq V_{DD}$, XT, HS and LP osc modes |
| D070 | IPURB | PORTB weak pull-up current | 50 | 250 | 400 | μA | $V_{DD} = 5V$, $V_{PIN} = V_{SS}$ |
| D080 D083 | V_{OL} | Output Low Voltage I/O ports OSC2/CLKOUT (RC osc mode) | - - - | - - - | 0.6 0.6 0.6 | V V V | $I_{OL} = 8.5\text{ mA}$, $V_{DD} = 4.5V$, -40°C to $+85^{\circ}\text{C}$ $I_{OL} = 7.0\text{ mA}$, $V_{DD} = 4.5V$, -40°C to $+125^{\circ}\text{C}$ $I_{OL} = 1.6\text{ mA}$, $V_{DD} = 4.5V$, -40°C to $+85^{\circ}\text{C}$ $I_{OL} = 1.2\text{ mA}$, $V_{DD} = 4.5V$, -40°C to $+125^{\circ}\text{C}$ |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: In RC oscillator mode, the OSC1/CLKIN pin is a Schmitt Trigger input. It is not recommended that the PICmicro be driven with external clock in RC mode.

2: The leakage current on the MCLR/ V_{PP} pin is strongly dependent on the applied voltage level. The specified levels represent normal operating conditions. Higher leakage current may be measured at different input voltages.

3: Negative current is defined as current sourced by the pin.

PIC16C63A/65B/73B/74B

| DC CHARACTERISTICS | | | | | | | |
|---|-------|--|--------------|------|-----|-------|---|
| Standard Operating Conditions (unless otherwise stated) Operating temperature $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ for commercial $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for extended Operating voltage V_{DD} range as described in DC spec Section 14.1 and Section 14.2 | | | | | | | |
| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
| D090 | VOH | Output High Voltage I/O ports (Note 3) | $V_{DD}-0.7$ | - | - | V | $I_{OH} = -3.0\text{ mA}$, $V_{DD} = 4.5\text{V}$, -40°C to +85°C |
| D092 | | OSC2/CLKOUT (RC osc mode) | $V_{DD}-0.7$ | - | - | V | $I_{OH} = -2.5\text{ mA}$, $V_{DD} = 4.5\text{V}$, -40°C to +125°C |
| D150* | VOD | Open-Drain High Voltage | - | - | 8.5 | V | RA4 pin |
| | | Capacitive Loading Specs on Output Pins | | | | | |
| D100 | COsc2 | OSC2 pin | - | - | 15 | pF | In XT, HS and LP modes when external clock is used to drive OSC1. |
| D101 | CIo | All I/O pins and OSC2 (in RC mode) | - | - | 50 | pF | |
| D102 | Cb | SCL, SDA in I ² C mode | - | - | 400 | pF | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: In RC oscillator mode, the OSC1/CLKIN pin is a Schmitt Trigger input. It is not recommended that the PICmicro be driven with external clock in RC mode.

2: The leakage current on the \overline{MCLR}/V_{PP} pin is strongly dependent on the applied voltage level. The specified levels represent normal operating conditions. Higher leakage current may be measured at different input voltages.

3: Negative current is defined as current sourced by the pin.

PIC16C63A/65B/73B/74B

14.4 AC (Timing) Characteristics

14.4.1 TIMING PARAMETER SYMBOLOGY

The timing parameter symbols have been created following one of the following formats:

- | | | |
|-------------|-----------|--|
| 1. TppS2ppS | 3. Tcc:ST | (I ² C specifications only) |
| 2. TppS | 4. Ts | (I ² C specifications only) |

| | | | |
|----------|-----------|---|------|
| T | | | |
| F | Frequency | T | Time |

Lowercase letters (pp) and their meanings:

| | | | |
|-----------|----------|-----|----------|
| pp | | osc | OSC1 |
| cc | CCP1 | rd | RD |
| ck | CLKOUT | rw | RD or WR |
| cs | CS | sc | SCK |
| di | SDI | ss | SS |
| do | SDO | t0 | T0CKI |
| dt | Data in | t1 | T1CKI |
| io | I/O port | wr | WR |
| mc | MCLR | | |

Uppercase letters and their meanings:

| | | | |
|----------------------------|------------------------|------|--------------|
| S | | P | Period |
| F | Fall | R | Rise |
| H | High | V | Valid |
| I | Invalid (Hi-impedance) | Z | Hi-impedance |
| L | Low | | |
| I²C only | | High | High |
| AA | output access | Low | Low |
| BUF | Bus free | | |

Tcc:ST (I²C specifications only)

| | | | |
|-----------|-----------------|-----|----------------|
| CC | | SU | Setup |
| HD | Hold | | |
| ST | | STO | STOP condition |
| DAT | DATA input hold | | |
| STA | START condition | | |

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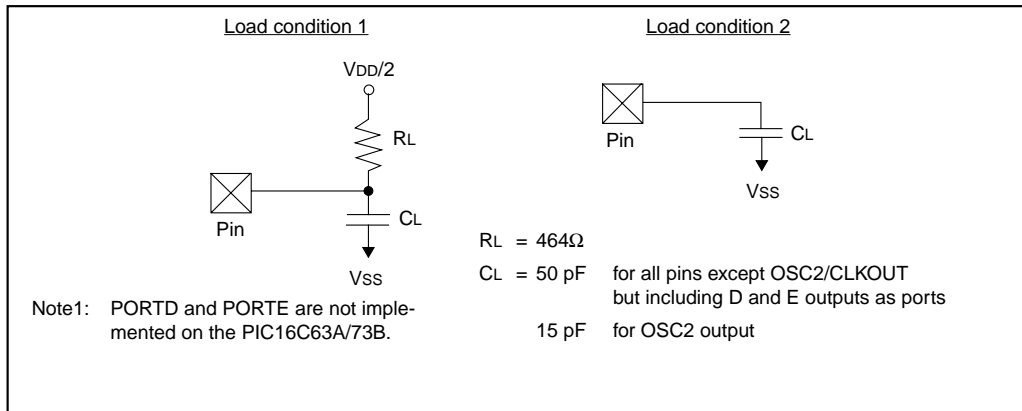
14.4.2 TIMING CONDITIONS

The temperature and voltages specified in Table 14-1 apply to all timing specifications unless otherwise noted. Figure 14-1 specifies the load conditions for the timing specifications.

TABLE 14-1: TEMPERATURE AND VOLTAGE SPECIFICATIONS - AC

| Standard Operating Conditions (unless otherwise stated) | |
|---|--|
| AC CHARACTERISTICS | Operating temperature $0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ for commercial |
| | $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for industrial |
| | $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for extended |
| | Operating voltage V_{DD} range as described in DC spec Section 14.1 and Section 14.2. LC parts operate for commercial/industrial temp's only. |

FIGURE 14-1: LOAD CONDITIONS FOR DEVICE TIMING SPECIFICATIONS



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14.4.3 TIMING DIAGRAMS AND SPECIFICATIONS

FIGURE 14-2: EXTERNAL CLOCK TIMING

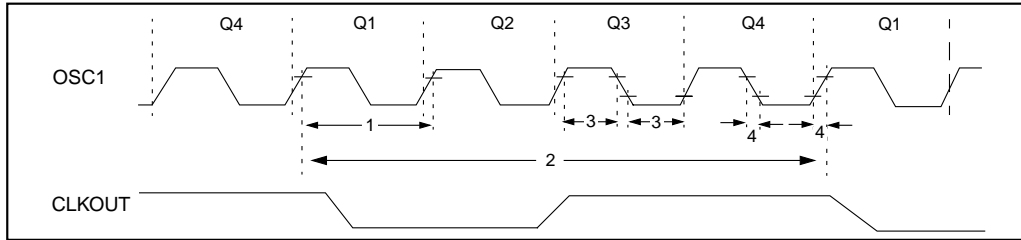


TABLE 14-2: EXTERNAL CLOCK TIMING REQUIREMENTS

| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
|-----------|---------------|---|-----|------|--------|-------|---------------------|
| 1A | Fosc | External CLKIN Frequency (Note 1) | DC | — | 4 | MHz | RC and XT osc modes |
| | | | DC | — | 4 | MHz | HS osc mode (-04) |
| | | | DC | — | 20 | MHz | HS osc mode (-20) |
| | | | DC | — | 200 | kHz | LP osc mode |
| 1 | Tosc | Oscillator Frequency (Note 1) | DC | — | 4 | MHz | RC osc mode |
| | | | 0.1 | — | 4 | MHz | XT osc mode |
| | | | 4 | — | 20 | MHz | HS osc mode |
| | | | 5 | — | 200 | kHz | LP osc mode |
| 2 | Tcy | External CLKIN Period (Note 1) | 250 | — | — | ns | RC and XT osc modes |
| | | | 250 | — | — | ns | HS osc mode (-04) |
| | | | 50 | — | — | ns | HS osc mode (-20) |
| | | | 5 | — | — | µs | LP osc mode |
| 3* | TosL, TosH | Oscillator Period (Note 1) | 250 | — | — | ns | RC osc mode |
| | | | 250 | — | 10,000 | ns | XT osc mode |
| | | | 250 | — | 250 | ns | HS osc mode (-04) |
| | | | 50 | — | 250 | ns | HS osc mode (-20) |
| 4* | TosR, TosF | Oscillator Period (Note 1) | 5 | — | — | µs | LP osc mode |
| | | | 200 | — | DC | ns | Tcy = 4/Fosc |
| | | | 100 | — | — | ns | XT oscillator |
| | | | 2.5 | — | — | µs | LP oscillator |
| 4* | TosR, TosF | External Clock in (OSC1) High or Low Time | 15 | — | — | ns | HS oscillator |
| | | | — | — | 25 | ns | XT oscillator |
| | | | — | — | 50 | ns | LP oscillator |
| 4* | TosR, TosF | External Clock in (OSC1) Rise or Fall Time | — | — | 15 | ns | HS oscillator |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: Instruction cycle period (Tcy) equals four times the input oscillator time-base period. All specified values are based on characterization data for that particular oscillator type under standard operating conditions with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at "min." values with an external clock applied to the OSC1/CLKIN pin.

When an external clock input is used, the "Max." cycle time limit is "DC" (no clock) for all devices.

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FIGURE 14-3: CLKOUT AND I/O TIMING

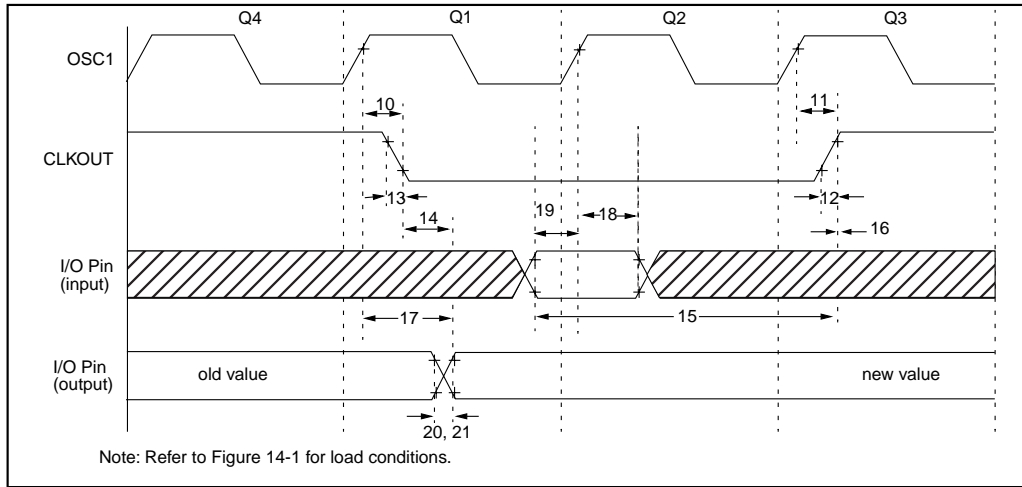


TABLE 14-3: CLKOUT AND I/O TIMING REQUIREMENTS

| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
|-----------|----------|---|-----------------|------|-------------------------|-------|------------|
| 10* | TosH2ckL | OSC1↑ to CLKOUT↓ | — | 75 | 200 | ns | Note 1 |
| 11* | TosH2ckH | OSC1↑ to CLKOUT↑ | — | 75 | 200 | ns | Note 1 |
| 12* | TckR | CLKOUT rise time | — | 35 | 100 | ns | Note 1 |
| 13* | TckF | CLKOUT fall time | — | 35 | 100 | ns | Note 1 |
| 14* | TckL2ioV | CLKOUT ↓ to Port out valid | — | — | 0.5T _{CY} + 20 | ns | Note 1 |
| 15* | TioV2ckH | Port in valid before CLKOUT ↑ | Tosc + 200 | — | — | ns | Note 1 |
| 16* | TckH2ioI | Port in hold after CLKOUT ↑ | 0 | — | — | ns | Note 1 |
| 17* | TosH2ioV | OSC1↑ (Q1 cycle) to Port out valid | — | 50 | 150 | ns | |
| 18* | TosH2ioI | OSC1↑ (Q2 cycle) to Port input invalid (I/O in hold time) | Standard | 100 | — | — | ns |
| 18A* | | | Extended (LC) | 200 | — | — | ns |
| 19* | TioV2osH | Port input valid to OSC1↑ (I/O in setup time) | 0 | — | — | ns | |
| 20* | TioR | Port output rise time | Standard | — | 10 | 40 | ns |
| 20A* | | | Extended (LC) | — | — | 80 | ns |
| 21* | TioF | Port output fall time | Standard | — | 10 | 40 | ns |
| 21A* | | | Extended (LC) | — | — | 80 | ns |
| 22†† | Tinp | INT pin high or low time | T _{CY} | — | — | ns | |
| 23†† | Trbp | RB7:RB4 change INT high or low time | T _{CY} | — | — | ns | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

†† These parameters are asynchronous events not related to any internal clock edge.

Note1: Measurements are taken in RC Mode where CLKOUT output is 4 x T_{osc}.

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FIGURE 14-4: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER TIMING

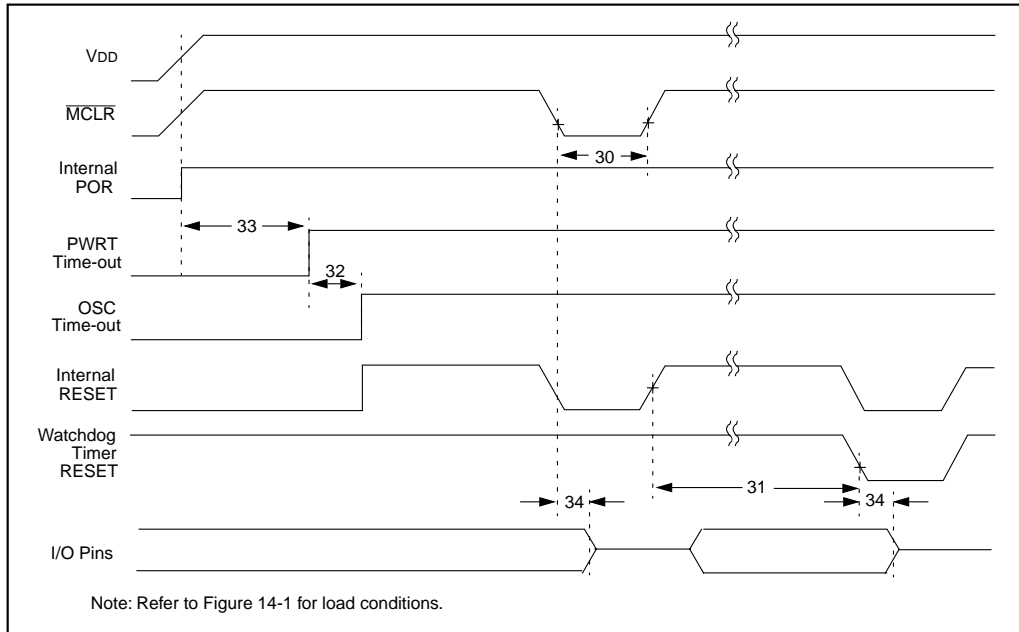


FIGURE 14-5: BROWN-OUT RESET TIMING

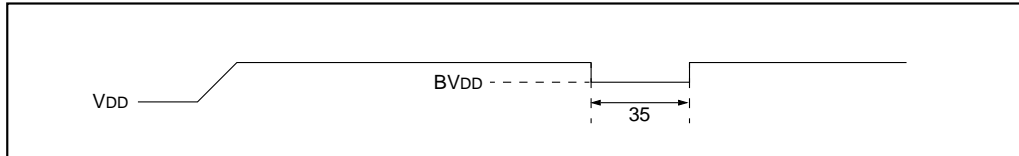


TABLE 14-4: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER, POWER-UP TIMER, AND BROWN-OUT RESET REQUIREMENTS

| Parameter No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
|---------------|-------|---|-----|-----------|-----|-------|---------------------------|
| 30 | Tmcl | MCLR Pulse Width (low) | 2 | — | — | μs | VDD = 5V, -40°C to +125°C |
| 31* | Twdt | Watchdog Timer Time-out Period (No Prescaler) | 7 | 18 | 33 | ms | VDD = 5V, -40°C to +125°C |
| 32 | Tost | Oscillation Start-up Timer Period | — | 1024 TOSC | — | — | TOSC = OSC1 period |
| 33* | Tpwrt | Power-up Timer Period | 28 | 72 | 132 | ms | VDD = 5V, -40°C to +125°C |
| 34 | Tioz | I/O Hi-impedance from MCLR Low or WDT reset | — | — | 2.1 | μs | |
| 35 | TBOR | Brown-out Reset Pulse Width | 100 | — | — | μs | VDD ≤ BVDD (D005) |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

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FIGURE 14-6: TIMER0 AND TIMER1 EXTERNAL CLOCK TIMINGS

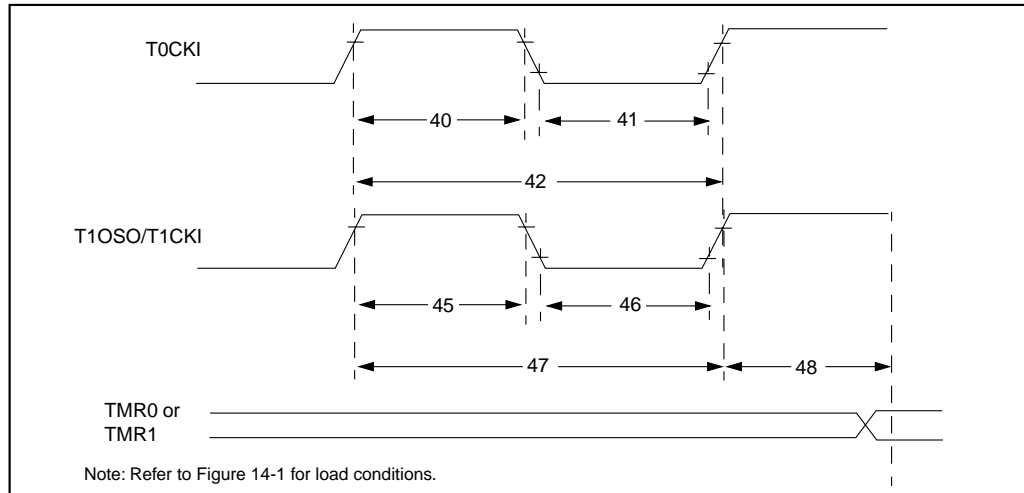


TABLE 14-5: TIMER0 AND TIMER1 EXTERNAL CLOCK REQUIREMENTS

| Param No. | Sym | Characteristic | | Min | Typ† | Max | Units | Conditions | |
|-----------|-----------|---|--------------------------------|--|--|------------|-------|-------------------------------------|---------------------------------|
| 40* | Tt0H | T0CKI High Pulse Width | No Prescaler | $0.5T_{CY} + 20$ | — | — | ns | Must also meet parameter 42 | |
| | | | With Prescaler | 10 | — | — | ns | | |
| 41* | Tt0L | T0CKI Low Pulse Width | No Prescaler | $0.5T_{CY} + 20$ | — | — | ns | Must also meet parameter 42 | |
| | | | With Prescaler | 10 | — | — | ns | | |
| 42* | Tt0P | T0CKI Period | No Prescaler | $T_{CY} + 40$ | — | — | ns | N = prescale value (2, 4, ..., 256) | |
| | | | With Prescaler | Greater of: 20 or $\frac{T_{CY} + 40}{N}$ | — | — | ns | | |
| 45* | Tt1H | T1CKI High Time | Synchronous, Prescaler = 1 | $0.5T_{CY} + 20$ | — | — | ns | Must also meet parameter 47 | |
| | | | Synchronous, Prescaler = 2,4,8 | Standard | 15 | — | — | | ns |
| | | | | Extended (LC) | 25 | — | — | | ns |
| | | | Asynchronous | Standard | 30 | — | — | | ns |
| | | | Extended (LC) | 50 | — | — | ns | | |
| 46* | Tt1L | T1CKI Low Time | Synchronous, Prescaler = 1 | $0.5T_{CY} + 20$ | — | — | ns | Must also meet parameter 47 | |
| | | | Synchronous, Prescaler = 2,4,8 | Standard | 15 | — | — | | ns |
| | | | | Extended (LC) | 25 | — | — | | ns |
| | | | Asynchronous | Standard | 30 | — | — | | ns |
| | | | Extended (LC) | 50 | — | — | ns | | |
| 47* | Tt1P | T1CKI input period | Synchronous | Standard | Greater of: 30 or $\frac{T_{CY} + 40}{N}$ | — | — | ns | N = prescale value (1, 2, 4, 8) |
| | | | | Extended (LC) | Greater of: 50 or $\frac{T_{CY} + 40}{N}$ | | | | N = prescale value (1, 2, 4, 8) |
| | | | Asynchronous | Standard | 60 | — | — | ns | |
| | | | | Extended (LC) | 100 | — | — | ns | |
| | Ft1 | Timer1 oscillator input frequency range (oscillator enabled by setting bit T1OSCEN) | | DC | — | 200 | kHz | | |
| 48 | TCKEZtmr1 | Delay from external clock edge to timer increment | | $2T_{osc}$ | — | $7T_{osc}$ | — | | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

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FIGURE 14-7: CAPTURE/COMPARE/PWM TIMINGS (CCP1 AND CCP2)

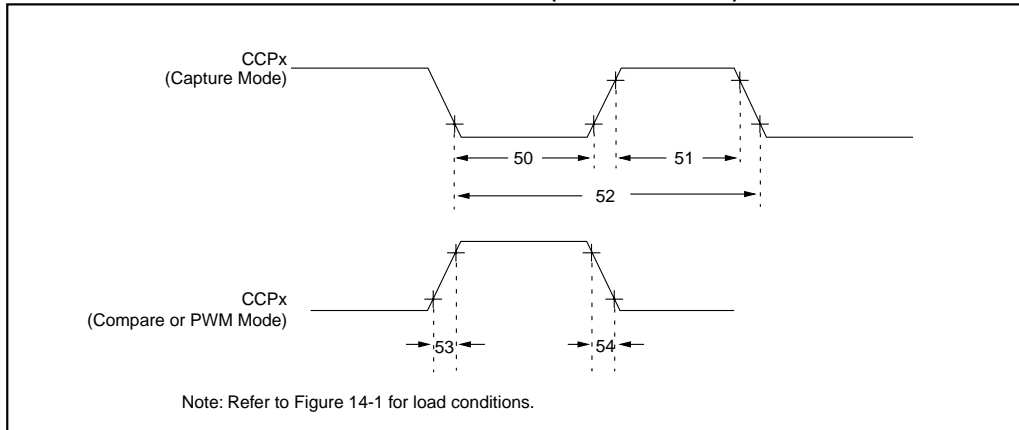


TABLE 14-6: CAPTURE/COMPARE/PWM REQUIREMENTS (CCP1 AND CCP2)

| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions | |
|-----------|------|--------------------------------|--------------------------|------------------|-----|-------|----------------------------------|----|
| 50* | TccL | CCP1 and CCP2 input low time | No Prescaler | $0.5T_{CY} + 20$ | — | — | ns | |
| | | | With Prescaler | Standard | 10 | — | — | ns |
| | | | | Extended (LC) | 20 | — | — | ns |
| 51* | TccH | CCP1 and CCP2 input high time | No Prescaler | $0.5T_{CY} + 20$ | — | — | ns | |
| | | | With Prescaler | Standard | 10 | — | — | ns |
| | | | | Extended (LC) | 20 | — | — | ns |
| 52* | TccP | CCP1 and CCP2 input period | $\frac{3T_{CY} + 40}{N}$ | — | — | ns | N = prescale value (1, 4, or 16) | |
| 53* | TccR | CCP1 and CCP2 output rise time | Standard | — | 10 | 25 | ns | |
| | | | Extended (LC) | — | 25 | 45 | ns | |
| 54* | TccF | CCP1 and CCP2 output fall time | Standard | — | 10 | 25 | ns | |
| | | | Extended (LC) | — | 25 | 45 | ns | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

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FIGURE 14-8: PARALLEL SLAVE PORT TIMING (PIC16C65B/74B)

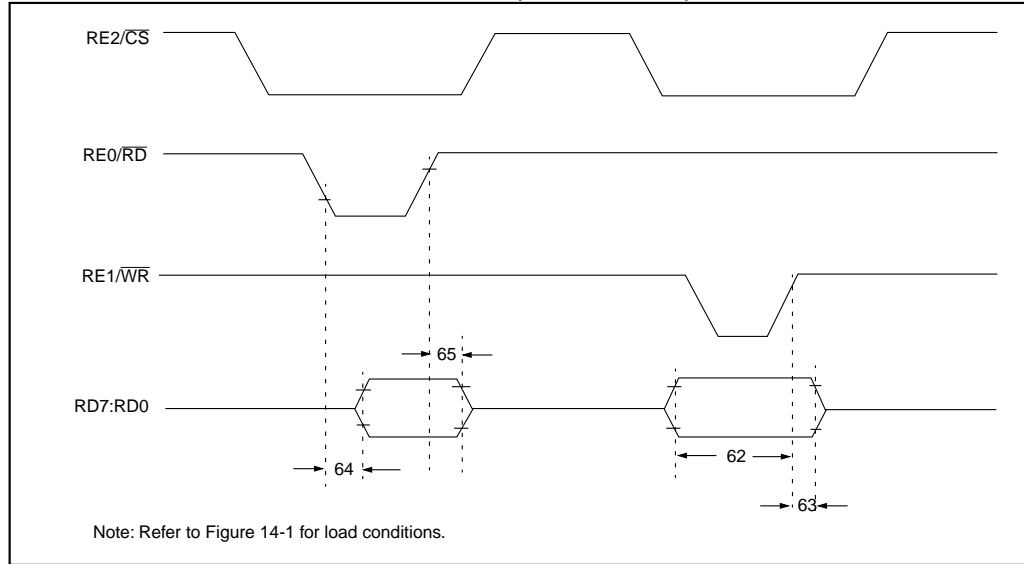


TABLE 14-7: PARALLEL SLAVE PORT REQUIREMENTS (PIC16C65B/74B)

| Parameter No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
|---------------|----------|--|---------------|------|-----|-------|------------|
| 62* | TdtV2wrH | Data in valid before $\overline{WR}\uparrow$ or $\overline{CS}\uparrow$ (setup time) | 20 | — | — | ns | |
| 63* | TwrH2dtI | $\overline{WR}\uparrow$ or $\overline{CS}\uparrow$ to data-in invalid (hold time) | Standard | 20 | — | — | ns |
| | | | Extended (LC) | 35 | — | — | ns |
| 64 | TrdL2dtV | $\overline{RD}\downarrow$ and $\overline{CS}\downarrow$ to data-out valid | — | — | 80 | ns | |
| 65* | TrdH2dtI | $\overline{RD}\uparrow$ or $\overline{CS}\uparrow$ to data-out invalid | 10 | — | 30 | ns | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

PIC16C63A/65B/73B/74B

FIGURE 14-9: EXAMPLE SPI MASTER MODE TIMING (CKE = 0)

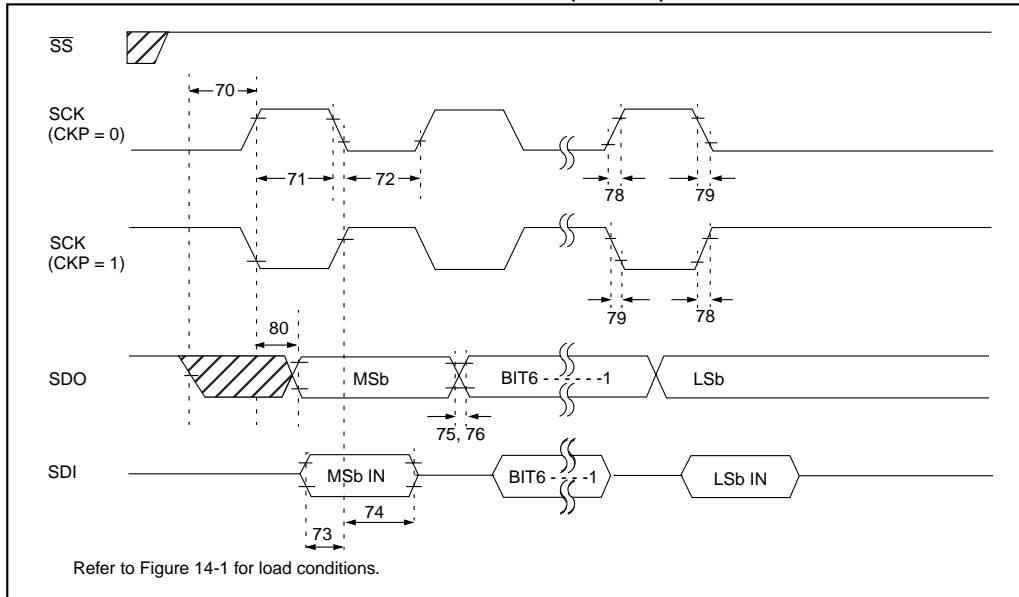


TABLE 14-8: EXAMPLE SPI MODE REQUIREMENTS (MASTER MODE, CKE = 0)

| Param. No. | Symbol | Characteristic | Min | Typ† | Max | Units | Conditions |
|------------|--------------------|---|--------------------------|------|-----|-------|------------|
| 70 | TssL2scH, TssL2scL | SS↓ to SCK↓ or SCK↑ input | T _{CY} | — | — | ns | |
| 71 | Tsch | SCK input high time (slave mode) | 1.25T _{CY} + 30 | — | — | ns | |
| 71A | | Single Byte | 40 | — | — | ns | Note 1 |
| 72 | TscL | SCK input low time (slave mode) | 1.25T _{CY} + 30 | — | — | ns | |
| 72A | | Single Byte | 40 | — | — | ns | Note 1 |
| 73 | TdiV2scH, TdiV2scL | Setup time of SDI data input to SCK edge | 100 | — | — | ns | |
| 73A | Tb2B | Last clock edge of Byte1 to the 1st clock edge of Byte2 | 1.5T _{CY} + 40 | — | — | ns | Note 1 |
| 74 | Tsch2diL, TscL2diL | Hold time of SDI data input to SCK edge | 100 | — | — | ns | |
| 75 | TdoR | SDO data output rise time | — | 10 | 25 | ns | |
| | | Standard | — | 10 | 25 | ns | |
| | | Extended (LC) | — | 20 | 45 | ns | |
| 76 | TdoF | SDO data output fall time | — | 10 | 25 | ns | |
| 78 | TscR | SCK output rise time (master mode) | — | 10 | 25 | ns | |
| | | Standard | — | 10 | 25 | ns | |
| | | Extended (LC) | — | 20 | 45 | ns | |
| 79 | TscF | SCK output fall time (master mode) | — | 10 | 25 | ns | |
| 80 | Tsch2doV, TscL2doV | SDO data output valid after SCK edge | — | — | 50 | ns | |
| | | Standard | — | — | 50 | ns | |
| | | Extended (LC) | — | — | 100 | ns | |

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: Specification 73A is only required if specifications 71A and 72A are used.

PIC16C63A/65B/73B/74B

FIGURE 14-10: EXAMPLE SPI MASTER MODE TIMING (CKE = 1)

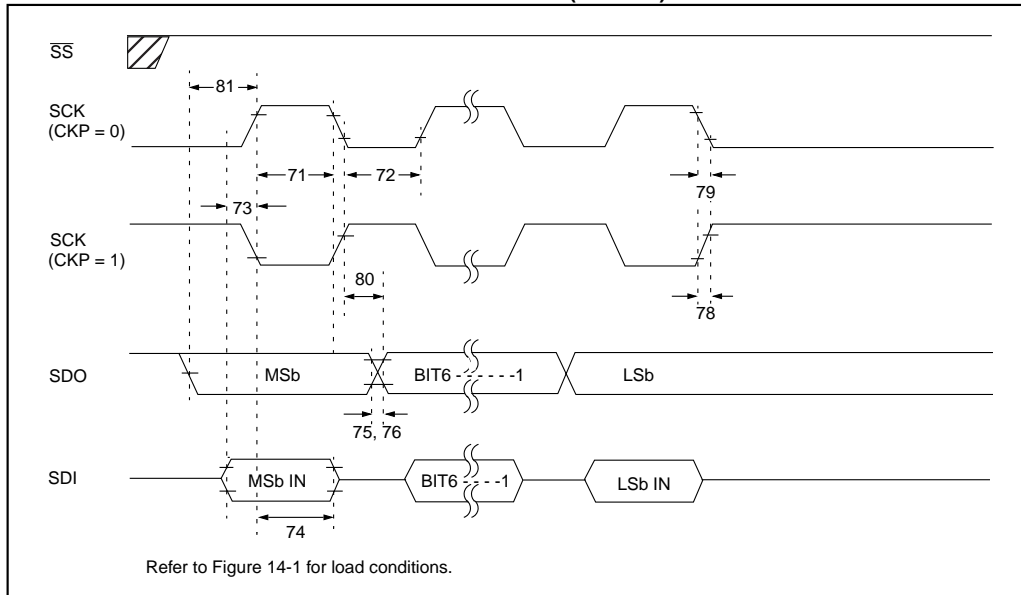


TABLE 14-9: EXAMPLE SPI MODE REQUIREMENTS (MASTER MODE, CKE = 1)

| Param. No. | Symbol | Characteristic | Min | Typ† | Max | Units | Conditions |
|------------|--------------------|---|-------------|------|-----|-------|------------|
| 71 | TscH | SCK input high time (slave mode) | Continuous | — | — | ns | |
| 71A | | Single Byte | 40 | — | — | ns | Note 1 |
| 72 | TscL | SCK input low time (slave mode) | Continuous | — | — | ns | |
| 72A | | Single Byte | 40 | — | — | ns | Note 1 |
| 73 | TdiV2scH, TdiV2scL | Setup time of SDI data input to SCK edge | 100 | — | — | ns | |
| 73A | Tb2B | Last clock edge of Byte1 to the 1st clock edge of Byte2 | 1.5TCY + 40 | — | — | ns | Note 1 |
| 74 | Tsch2diL, TscL2diL | Hold time of SDI data input to SCK edge | 100 | — | — | ns | |
| 75 | TdoR | SDO data output rise time | Standard | 10 | 25 | ns | |
| | | Extended (LC) | | 20 | 45 | ns | |
| 76 | TdoF | SDO data output fall time | — | 10 | 25 | ns | |
| 78 | TscR | SCK output rise time (master mode) | Standard | 10 | 25 | ns | |
| | | Extended (LC) | | 20 | 45 | ns | |
| 79 | TscF | SCK output fall time (master mode) | — | 10 | 25 | ns | |
| 80 | Tsch2doV, TscL2doV | SDO data output valid after SCK edge | Standard | — | 50 | ns | |
| | | Extended (LC) | | — | 100 | ns | |
| 81 | TdoV2scH, TdoV2scL | SDO data output setup to SCK edge | TCY | — | — | ns | |

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: Specification 73A is only required if specifications 71A and 72A are used.

PIC16C63A/65B/73B/74B

FIGURE 14-11: EXAMPLE SPI SLAVE MODE TIMING (CKE = 0)

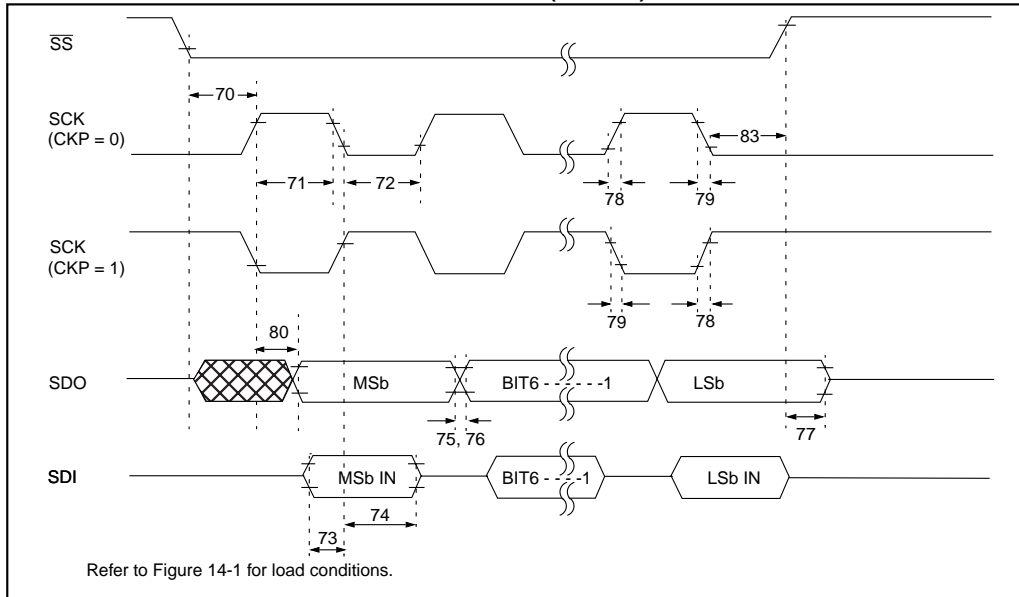


TABLE 14-10: EXAMPLE SPI MODE REQUIREMENTS (SLAVE MODE TIMING (CKE = 0))

| Param. No. | Symbol | Characteristic | Min | Typ† | Max | Units | Conditions |
|------------|--------------------|---|---------------------------|----------|-----------|-------|------------|
| 70 | TssL2sch, TssL2scL | $\overline{SS}\downarrow$ to SCK \downarrow or SCK \uparrow input | T _{CY} | — | — | ns | |
| 71 | Tsch | SCK input high time (slave mode) | Continuous Single Byte | — | — | ns | Note 1 |
| 72 | TscL | SCK input low time (slave mode) | Continuous Single Byte | — | — | ns | Note 1 |
| 73 | TdiV2sch, TdiV2scL | Setup time of SDI data input to SCK edge | 100 | — | — | ns | |
| 73A | Tb2b | Last clock edge of Byte1 to the 1st clock edge of Byte2 | 1.5T _{CY} + 40 | — | — | ns | Note 1 |
| 74 | Tsch2diL, TscL2diL | Hold time of SDI data input to SCK edge | 100 | — | — | ns | |
| 75 | TdoR | SDO data output rise time | Standard Extended (LC) | 10 20 | 25 45 | ns | |
| 76 | TdoF | SDO data output fall time | — | 10 | 25 | ns | |
| 77 | TssH2doZ | $\overline{SS}\uparrow$ to SDO output hi-impedance | 10 | — | 50 | ns | |
| 78 | Tscr | SCK output rise time (master mode) | Standard Extended (LC) | 10 20 | 25 45 | ns | |
| 79 | TscF | SCK output fall time (master mode) | — | 10 | 25 | ns | |
| 80 | Tsch2doV, TscL2doV | SDO data output valid after SCK edge | Standard Extended (LC) | — — | 50 100 | ns | |
| 83 | Tsch2ssH, TscL2ssH | $\overline{SS}\uparrow$ after SCK edge | 1.5T _{CY} + 40 | — | — | ns | |

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: Specification 73A is only required if specifications 71A and 72A are used.

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FIGURE 14-12: EXAMPLE SPI SLAVE MODE TIMING (CKE = 1)

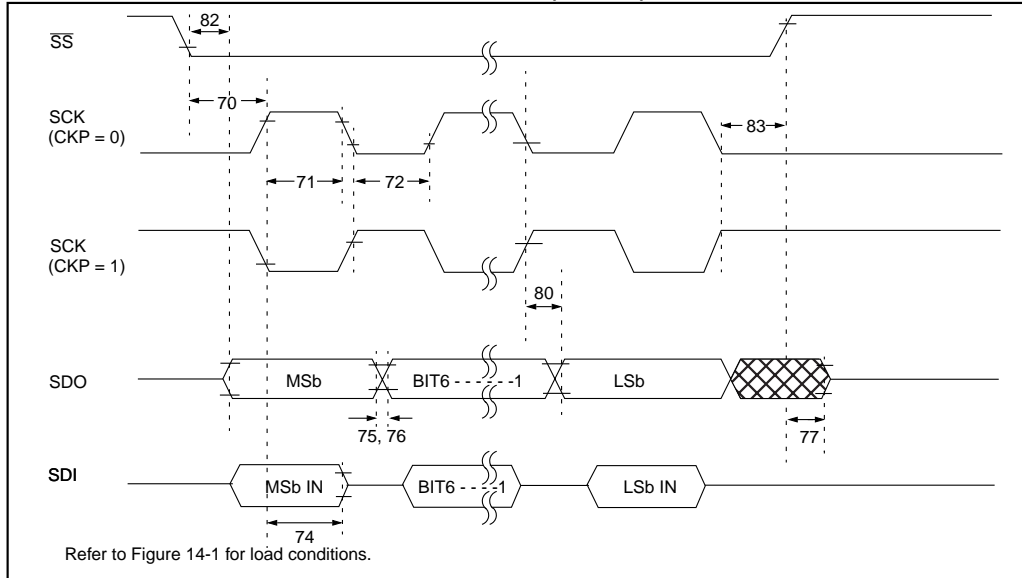


TABLE 14-11: EXAMPLE SPI SLAVE MODE REQUIREMENTS (CKE = 1)

| Param. No. | Symbol | Characteristic | Min | Typ† | Max | Units | Conditions |
|------------|--------------------|---|-------------------------|--------------------------|-----|-------|------------|
| 70 | TssL2scH, TssL2scL | SS↓ to SCK↓ or SCK↑ input | T _{CY} | — | — | ns | |
| 71 | Tsch | SCK input high time (slave mode) | Continuous | 1.25T _{CY} + 30 | — | — | ns |
| 71A | | | Single Byte | 40 | — | — | ns |
| 72 | TscL | SCK input low time (slave mode) | Continuous | 1.25T _{CY} + 30 | — | — | ns |
| 72A | | | Single Byte | 40 | — | — | ns |
| 73A | Tb2b | Last clock edge of Byte1 to the 1st clock edge of Byte2 | 1.5T _{CY} + 40 | — | — | ns | Note 1 |
| 74 | Tsch2diL, TscL2diL | Hold time of SDI data input to SCK edge | 100 | — | — | ns | |
| 75 | TdoR | SDO data output rise time | Standard | — | 10 | 25 | ns |
| 76 | | | Extended (LC) | — | 20 | 45 | ns |
| 76 | TdoF | SDO data output fall time | — | 10 | 25 | ns | |
| 77 | TssH2doZ | SS↑ to SDO output hi-impedance | 10 | — | 50 | ns | |
| 78 | TscR | SCK output rise time (master mode) | Standard | — | 10 | 25 | ns |
| 79 | | | Extended (LC) | — | 20 | 45 | ns |
| 79 | TscF | SCK output fall time (master mode) | — | 10 | 25 | ns | |
| 80 | Tsch2doV, TscL2doV | SDO data output valid after SCK edge | Standard | — | — | 50 | ns |
| 82 | | | Extended (LC) | — | — | 100 | ns |
| 82 | TssL2doV | SDO data output valid after SS↓ edge | Standard | — | — | 50 | ns |
| 83 | | | Extended (LC) | — | — | 100 | ns |
| 83 | Tsch2ssH, TscL2ssH | SS↑ after SCK edge | 1.5T _{CY} + 40 | — | — | ns | |

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: Specification 73A is only required if specifications 71A and 72A are used.

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FIGURE 14-13: I²C BUS START/STOP BITS TIMING

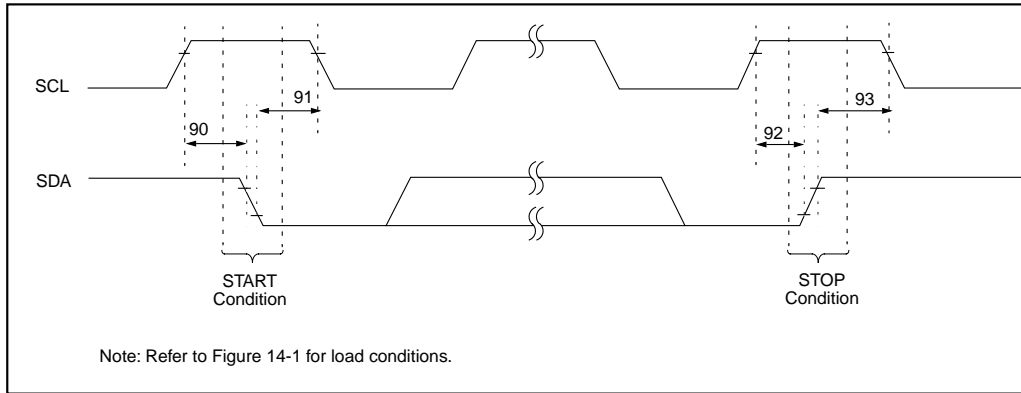


TABLE 14-12: I²C BUS START/STOP BITS REQUIREMENTS

| Parameter No. | Sym | Characteristic | Min | Typ | Max | Units | Conditions | |
|---------------|---------|----------------------------|--------------|------|-----|-------|------------|--|
| 90* | TSU:STA | START condition Setup time | 100 kHz mode | 4700 | — | — | ns | Only relevant for repeated START condition |
| | | 400 kHz mode | 600 | — | — | | | |
| 91* | THD:STA | START condition Hold time | 100 kHz mode | 4000 | — | — | ns | After this period the first clock pulse is generated |
| | | 400 kHz mode | 600 | — | — | | | |
| 92* | TSU:STO | STOP condition Setup time | 100 kHz mode | 4700 | — | — | ns | |
| | | 400 kHz mode | 600 | — | — | | | |
| 93 | THD:STO | STOP condition Hold time | 100 kHz mode | 4000 | — | — | ns | |
| | | 400 kHz mode | 600 | — | — | | | |

* These parameters are characterized but not tested.

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FIGURE 14-14: I²C BUS DATA TIMING

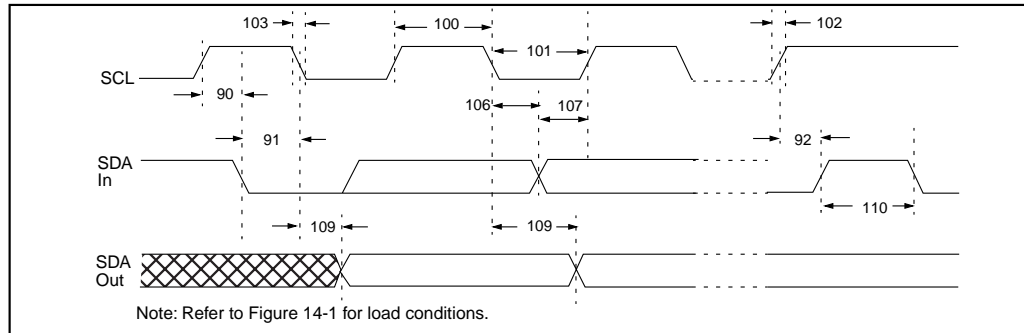


TABLE 14-13: I²C BUS DATA REQUIREMENTS

| Parameter No. | Sym | Characteristic | Min | Max | Units | Conditions | |
|---------------|---------|----------------------------|--------------|------------|-------|------------|---|
| 100* | THIGH | Clock high time | 100 kHz mode | 4.0 | — | μs | Device must operate at a minimum of 1.5 MHz |
| | | | 400 kHz mode | 0.6 | — | μs | Device must operate at a minimum of 10 MHz |
| | | | SSP Module | 1.5TCY | — | | |
| 101* | TLOW | Clock low time | 100 kHz mode | 4.7 | — | μs | Device must operate at a minimum of 1.5 MHz |
| | | | 400 kHz mode | 1.3 | — | μs | Device must operate at a minimum of 10 MHz |
| | | | SSP Module | 1.5TCY | — | | |
| 102* | TR | SDA and SCL rise time | 100 kHz mode | — | 1000 | ns | |
| | | | 400 kHz mode | 20 + 0.1Cb | 300 | ns | Cb is specified to be from 10-400 pF |
| 103* | TF | SDA and SCL fall time | 100 kHz mode | — | 300 | ns | |
| | | | 400 kHz mode | 20 + 0.1Cb | 300 | ns | Cb is specified to be from 10-400 pF |
| 90* | TSU:STA | START condition setup time | 100 kHz mode | 4.7 | — | μs | Only relevant for repeated START condition |
| | | | 400 kHz mode | 0.6 | — | μs | |
| 91* | THD:STA | START condition hold time | 100 kHz mode | 4.0 | — | μs | After this period the first clock pulse is generated |
| | | | 400 kHz mode | 0.6 | — | μs | |
| 106* | THD:DAT | Data input hold time | 100 kHz mode | 0 | — | ns | |
| | | | 400 kHz mode | 0 | 0.9 | μs | |
| 107* | TSU:DAT | Data input setup time | 100 kHz mode | 250 | — | ns | Note 2 |
| | | | 400 kHz mode | 100 | — | ns | |
| 92* | TSU:STO | STOP condition setup time | 100 kHz mode | 4.7 | — | μs | |
| | | | 400 kHz mode | 0.6 | — | μs | |
| 109* | TAA | Output valid from clock | 100 kHz mode | — | 3500 | ns | Note 1 |
| | | | 400 kHz mode | — | — | ns | |
| 110* | TBUF | Bus free time | 100 kHz mode | 4.7 | — | μs | Time the bus must be free before a new transmission can start |
| | | | 400 kHz mode | 1.3 | — | μs | |
| | Cb | Bus capacitive loading | — | 400 | pF | | |

* These parameters are characterized but not tested.

Note1: As a transmitter, the device must provide this internal minimum delay time to bridge the undefined region (min. 300 ns) of the falling edge of SCL to avoid unintended generation of START or STOP conditions.

2: A fast-mode (400 kHz) I²C-bus device can be used in a standard-mode (100 kHz) I²C-bus system, but the requirement Tsu:DAT ≥ 250 ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line Tr max.+tsu:DAT = 1000 + 250 = 1250 ns (according to the standard-mode I²C bus specification) before the SCL line is released.

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FIGURE 14-15: USART SYNCHRONOUS TRANSMISSION (MASTER/SLAVE) TIMING

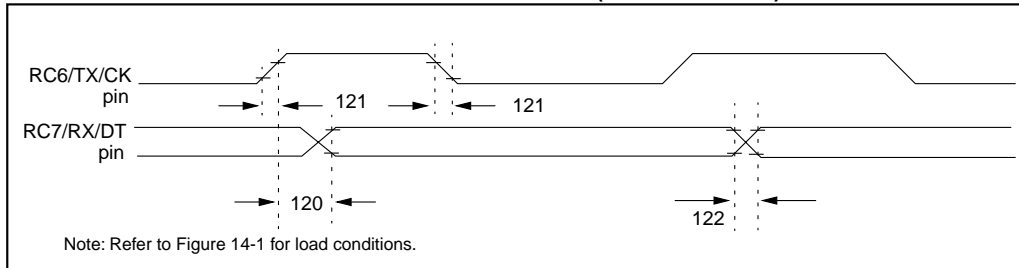


TABLE 14-14: USART SYNCHRONOUS TRANSMISSION REQUIREMENTS

| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions | |
|-----------|----------|---|---------------|------|-----|-------|------------|--|
| 120* | TckH2dtV | SYNC XMIT (MASTER & SLAVE) | — | — | 80 | ns | | |
| | | Clock high to data out valid | — | — | 100 | ns | | |
| 121* | Tckrf | Clock out rise time and fall time (Master Mode) | Standard | — | — | 45 | ns | |
| | | | Extended (LC) | — | — | 50 | ns | |
| 122* | Tdtrf | Data out rise time and fall time | Standard | — | — | 45 | ns | |
| | | | Extended (LC) | — | — | 50 | ns | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

FIGURE 14-16: USART SYNCHRONOUS RECEIVE (MASTER/SLAVE) TIMING

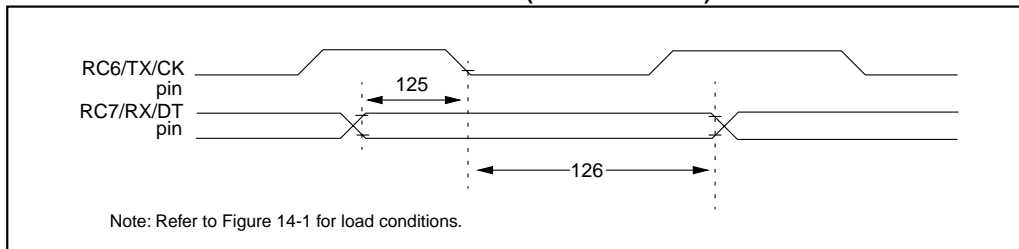


TABLE 14-15: USART SYNCHRONOUS RECEIVE REQUIREMENTS

| Parameter No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
|---------------|----------|--|-----|------|-----|-------|------------|
| 125* | TdtV2ckL | SYNC RCV (MASTER & SLAVE) | — | — | — | ns | |
| | | Data setup before CK ↓ (DT setup time) | 15 | — | — | ns | |
| 126* | TckL2dtl | Data hold after CK ↓ (DT hold time) | 15 | — | — | ns | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

PIC16C63A/65B/73B/74B

TABLE 14-16: A/D CONVERTER CHARACTERISTICS:

PIC16C73B/74B-04 (COMMERCIAL, INDUSTRIAL, EXTENDED)
 PIC16C73B/74B-20 (COMMERCIAL, INDUSTRIAL, EXTENDED)
 PIC16LC73B/74B-04 (COMMERCIAL, INDUSTRIAL)

| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions | |
|-----------|------|--|---------------|------------|------------|-------|--|--|
| A01 | NR | Resolution | — | — | 8-bits | bit | VREF = VDD = 5.12V, VSS ≤ VAIN ≤ VREF | |
| A02 | EABS | Total Absolute error | — | — | < ± 1 | LSb | VREF = VDD = 5.12V, VSS ≤ VAIN ≤ VREF | |
| A03 | EIL | Integral linearity error | — | — | < ± 1 | LSb | VREF = VDD = 5.12V, VSS ≤ VAIN ≤ VREF | |
| A04 | EDL | Differential linearity error | — | — | < ± 1 | LSb | VREF = VDD = 5.12V, VSS ≤ VAIN ≤ VREF | |
| A05 | EFS | Full scale error | — | — | < ± 1 | LSb | VREF = VDD = 5.12V, VSS ≤ VAIN ≤ VREF | |
| A06 | E0FF | Offset error | — | — | < ± 1 | LSb | VREF = VDD = 5.12V, VSS ≤ VAIN ≤ VREF | |
| A10 | — | Monotonicity | — | guaranteed | — | — | VSS ≤ VAIN ≤ VREF | |
| A20 | VREF | Reference voltage | 2.5V | — | VDD + 0.3 | V | | |
| A25 | VAIN | Analog input voltage | VSS - 0.3 | — | VREF + 0.3 | V | | |
| A30 | ZAIN | Recommended impedance of analog voltage source | — | — | 10.0 | kΩ | | |
| A40 | IAD | A/D conversion current (VDD) | Standard | — | 180 | — | μA | Average current consumption when A/D is on. (Note 1) |
| | | | Extended (LC) | — | 90 | — | μA | |
| A50 | IREF | VREF input current (Note 2) | 10 | — | 1000 | μA | During VAIN acquisition. Based on differential of VHOLD to VAIN to charge CHOLD, see Section 10.1. | |
| | | | — | — | 10 | μA | During A/D Conversion cycle | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note1: When A/D is off, it will not consume any current other than minor leakage current. The power-down current spec includes any such leakage from the A/D module.

2: VREF current is from RA3 pin or VDD pin, whichever is selected as reference input.

PIC16C63A/65B/73B/74B

FIGURE 14-17: A/D CONVERSION TIMING

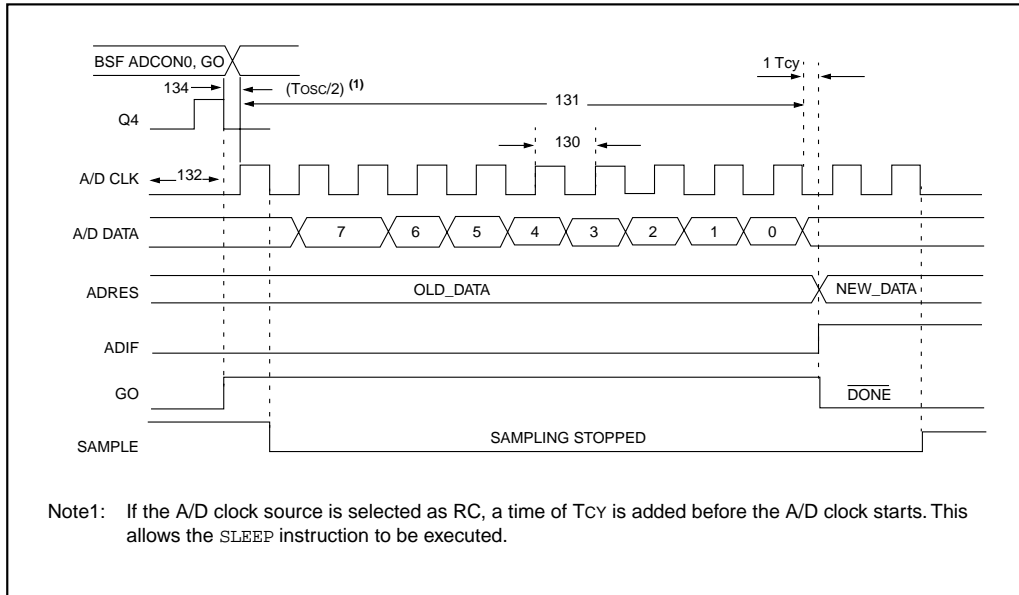


TABLE 14-17: A/D CONVERSION REQUIREMENTS

| Param No. | Sym | Characteristic | | Min | Typ† | Max | Units | Conditions |
|-----------|------|---|---------------|--------|---------------|-----|-------|---|
| 130 | TAD | A/D clock period | Standard | 1.6 | — | — | μs | TOSC based, $V_{REF} \geq 3.0V$ |
| | | | Extended (LC) | 2.0 | — | — | μs | TOSC based, V_{REF} full range |
| | | | Standard | 2.0 | 4.0 | 6.0 | μs | A/D RC Mode |
| | | | Extended (LC) | 3.0 | 6.0 | 9.0 | μs | A/D RC Mode |
| 131 | TCNV | Conversion time (not including S/H time) (Note 1) | | 11 | — | 11 | TAD | |
| 132 | TACQ | Acquisition time | | Note 2 | 20 | — | μs | The minimum time is the amplifier settling time. This may be used if the "new" input voltage has not changed by more than 1 LSB (i.e., 20.0 mV @ 5.12V) from the last sampled voltage (as stated on CHOLD). |
| | | | | 5* | — | — | μs | |
| 134 | TGO | Q4 to A/D clock start | | — | $T_{OSC}/2$ § | — | — | If the A/D clock source is selected as RC, a time of T_{CY} is added before the A/D clock starts. This allows the SLEEP instruction to be executed. |
| 135 | Tswc | Switching from convert → sample time | | 1.5 § | — | — | TAD | |

* These parameters are characterized but not tested.

† Data in "Typ" column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

§ This specification ensured by design.

Note1: ADRES register may be read on the following T_{CY} cycle.

2: See Section 10.1 for min conditions.

PIC16C63A/65B/73B/74B

15.0 DC AND AC CHARACTERISTICS GRAPHS AND TABLES

Graphs and Tables not available at this time.

PIC16C63A/65B/73B/74B

NOTES:

PIC16C63A/65B/73B/74B

16.0 PACKAGING INFORMATION

16.1 Package Marking Information

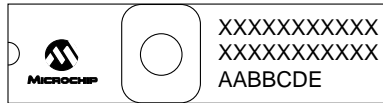
28-Lead PDIP (Skinny DIP)



Example



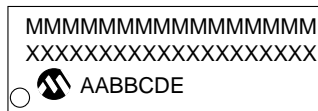
28-Lead CERDIP Windowed



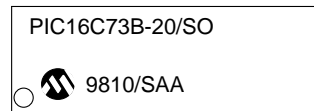
Example



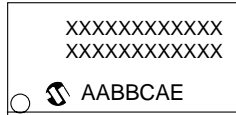
28-Lead SOIC



Example



28-Lead SSOP



Example



| | |
|----------------|---|
| Legend: XX...X | Microchip part number & customer specific information* |
| AA | Year code (last two digits of calendar year) |
| BB | Week code (week of January 1 is week '01') |
| C | Facility code of the plant at which wafer is manufactured C = Chandler, Arizona, U.S.A., S = Tempe, Arizona, U.S.A. - 6" H = Tempe, Arizona, U.S.A. - 8" |
| D | Mask revision number |
| E | Assembly code of the plant or country of origin in which part was assembled |
| Note: | In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer specific information. |

* Standard OTP marking consists of Microchip part number, year code, week code, facility code, mask rev# and assembly code. For OTP marking beyond this, certain price adders apply. Please check with your Microchip Sales Office. For QTP devices, any special marking adders are included in QTP price.

PIC16C63A/65B/73B/74B

Package Marking Information (Cont'd)

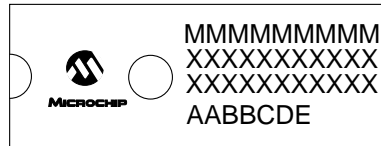
40-Lead PDIP



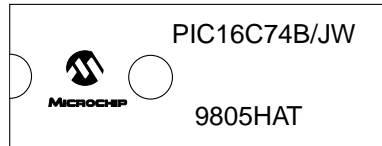
Example



40-Lead CERDIP Windowed



Example



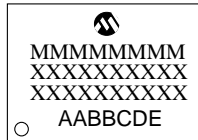
| | |
|----------------|---|
| Legend: XX...X | Microchip part number & customer specific information* |
| AA | Year code (last two digits of calendar year) |
| BB | Week code (week of January 1 is week '01') |
| C | Facility code of the plant at which wafer is manufactured |
| | C = Chandler, Arizona, U.S.A., |
| | S = Tempe, Arizona, U.S.A. - 6" |
| | H = Tempe, Arizona, U.S.A. - 8" |
| D | Mask revision number |
| E | Assembly code of the plant or country of origin in which part was assembled |
| Note: | In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer specific information. |

* Standard OTP marking consists of Microchip part number, year code, week code, facility code, mask rev# and assembly code. For OTP marking beyond this, certain price adders apply. Please check with your Microchip Sales Office. For QTP devices, any special marking adders are included in QTP price.

PIC16C63A/65B/73B/74B

Package Marking Information (Cont'd)

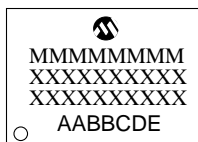
44-Lead TQFP



Example



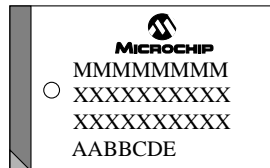
44-Lead MQFP



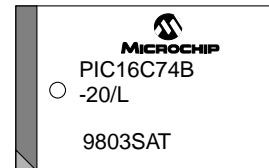
Example



44-Lead PLCC



Example



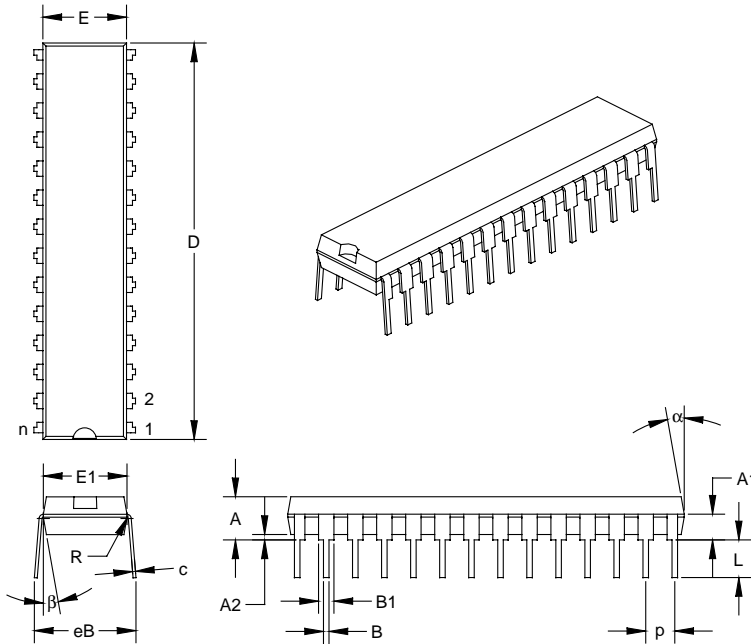
| | |
|----------------|---|
| Legend: XX...X | Microchip part number & customer specific information* |
| AA | Year code (last two digits of calendar year) |
| BB | Week code (week of January 1 is week '01') |
| C | Facility code of the plant at which wafer is manufactured C = Chandler, Arizona, U.S.A., S = Tempe, Arizona, U.S.A. - 6" H = Tempe, Arizona, U.S.A. - 8" |
| D | Mask revision number |
| E | Assembly code of the plant or country of origin in which part was assembled |

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer specific information.

* Standard OTP marking consists of Microchip part number, year code, week code, facility code, mask rev# and assembly code. For OTP marking beyond this, certain price adders apply. Please check with your Microchip Sales Office. For QTP devices, any special marking adders are included in QTP price.

PIC16C63A/65B/73B/74B

16.2 K04-070 28-Lead Skinny Plastic Dual In-line (SP) – 300 mil



| Units | | INCHES* | | | MILLIMETERS | | |
|------------------------------|-------|---------|-------|-------|-------------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Dimension Limits | | | | | | | |
| PCB Row Spacing | | | 0.300 | | | 7.62 | |
| Number of Pins | n | | 28 | | | 28 | |
| Pitch | p | | 0.100 | | | 2.54 | |
| Lower Lead Width | B | 0.016 | 0.019 | 0.022 | 0.41 | 0.48 | 0.56 |
| Upper Lead Width | B1† | 0.040 | 0.053 | 0.065 | 1.02 | 1.33 | 1.65 |
| Shoulder Radius | R | 0.000 | 0.005 | 0.010 | 0.00 | 0.13 | 0.25 |
| Lead Thickness | c | 0.008 | 0.010 | 0.012 | 0.20 | 0.25 | 0.30 |
| Top to Seating Plane | A | 0.140 | 0.150 | 0.160 | 3.56 | 3.81 | 4.06 |
| Top of Lead to Seating Plane | A1 | 0.070 | 0.090 | 0.110 | 1.78 | 2.29 | 2.79 |
| Base to Seating Plane | A2 | 0.015 | 0.020 | 0.025 | 0.38 | 0.51 | 0.64 |
| Tip to Seating Plane | L | 0.125 | 0.130 | 0.135 | 3.18 | 3.30 | 3.43 |
| Package Length | D‡ | 1.345 | 1.365 | 1.385 | 34.16 | 34.67 | 35.18 |
| Molded Package Width | E‡ | 0.280 | 0.288 | 0.295 | 7.11 | 7.30 | 7.49 |
| Radius to Radius Width | E1 | 0.270 | 0.283 | 0.295 | 6.86 | 7.18 | 7.49 |
| Overall Row Spacing | eB | 0.320 | 0.350 | 0.380 | 8.13 | 8.89 | 9.65 |
| Mold Draft Angle Top | alpha | 5 | 10 | 15 | 5 | 10 | 15 |
| Mold Draft Angle Bottom | beta | 5 | 10 | 15 | 5 | 10 | 15 |

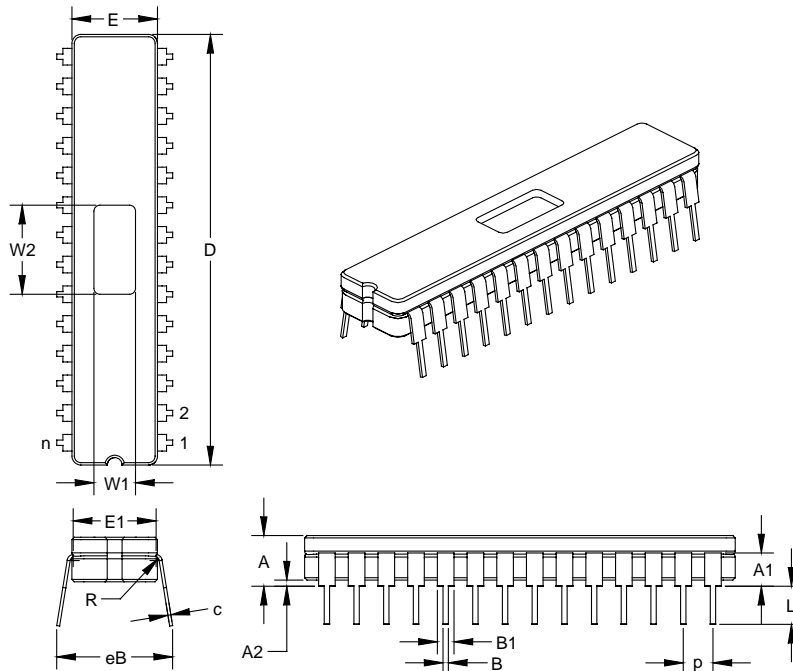
* Controlling Parameter.

† Dimension "B1" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B1."

‡ Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

PIC16C63A/65B/73B/74B

16.3 K04-080 28-Lead Ceramic Dual In-line with Window (JW) – 300 mil

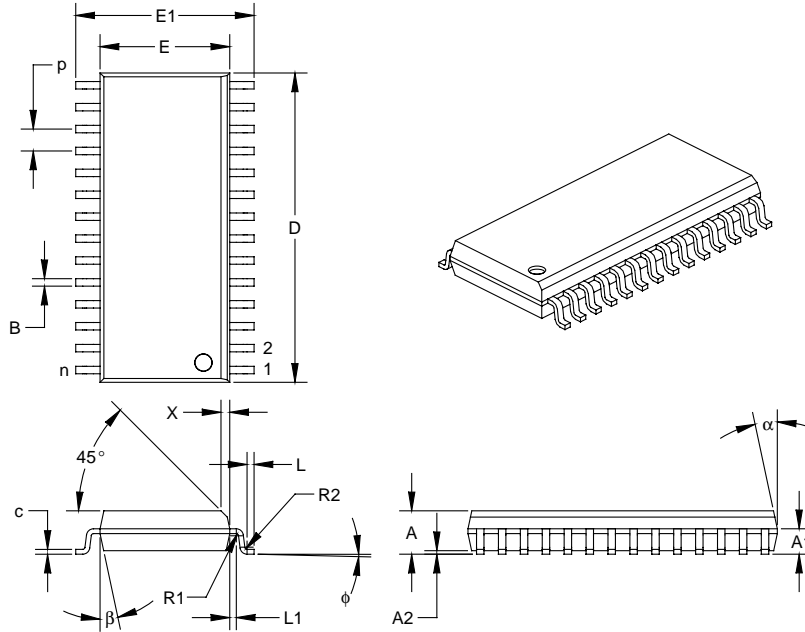


| Units | | INCHES* | | | MILLIMETERS | | |
|------------------------------|----|---------|-------|-------|-------------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Dimension Limits | | | 0.300 | | | 7.62 | |
| PCB Row Spacing | | | | | | | |
| Number of Pins | n | | 28 | | | 28 | |
| Pitch | p | 0.098 | 0.100 | 0.102 | 2.49 | 2.54 | 2.59 |
| Lower Lead Width | B | 0.016 | 0.019 | 0.021 | 0.41 | 0.47 | 0.53 |
| Upper Lead Width | B1 | 0.050 | 0.058 | 0.065 | 1.27 | 1.46 | 1.65 |
| Shoulder Radius | R | 0.010 | 0.013 | 0.015 | 0.25 | 0.32 | 0.38 |
| Lead Thickness | c | 0.008 | 0.010 | 0.012 | 0.20 | 0.25 | 0.30 |
| Top to Seating Plane | A | 0.170 | 0.183 | 0.195 | 4.32 | 4.64 | 4.95 |
| Top of Lead to Seating Plane | A1 | 0.107 | 0.125 | 0.143 | 2.72 | 3.18 | 3.63 |
| Base to Seating Plane | A2 | 0.015 | 0.023 | 0.030 | 0.00 | 0.57 | 0.76 |
| Tip to Seating Plane | L | 0.135 | 0.140 | 0.145 | 3.43 | 3.56 | 3.68 |
| Package Length | D | 1.430 | 1.458 | 1.485 | 36.32 | 37.02 | 37.72 |
| Package Width | E | 0.285 | 0.290 | 0.295 | 7.24 | 7.37 | 7.49 |
| Radius to Radius Width | E1 | 0.255 | 0.270 | 0.285 | 6.48 | 6.86 | 7.24 |
| Overall Row Spacing | eB | 0.345 | 0.385 | 0.425 | 8.76 | 9.78 | 10.80 |
| Window Width | W1 | 0.130 | 0.140 | 0.150 | 0.13 | 0.14 | 0.15 |
| Window Length | W2 | 0.290 | 0.300 | 0.310 | 0.29 | 0.3 | 0.31 |

* Controlling Parameter.

PIC16C63A/65B/73B/74B

16.4 K04-052 28-Lead Plastic Small Outline (SO) – Wide, 300 mil



| Units | Dimension Limits | INCHES* | | | MILLIMETERS | | | |
|-------|-------------------------|----------------|-------|-------|-------------|-------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX | |
| | Pitch | p | 0.050 | | | 1.27 | | |
| | Number of Pins | n | 28 | | | 28 | | |
| | Overall Pack. Height | A | 0.093 | 0.099 | 0.104 | 2.36 | 2.50 | 2.64 |
| | Shoulder Height | A1 | 0.048 | 0.058 | 0.068 | 1.22 | 1.47 | 1.73 |
| | Standoff | A2 | 0.004 | 0.008 | 0.011 | 0.10 | 0.19 | 0.28 |
| | Molded Package Length | D [‡] | 0.700 | 0.706 | 0.712 | 17.78 | 17.93 | 18.08 |
| | Molded Package Width | E [‡] | 0.292 | 0.296 | 0.299 | 7.42 | 7.51 | 7.59 |
| | Outside Dimension | E1 | 0.394 | 0.407 | 0.419 | 10.01 | 10.33 | 10.64 |
| | Chamfer Distance | X | 0.010 | 0.020 | 0.029 | 0.25 | 0.50 | 0.74 |
| | Shoulder Radius | R1 | 0.005 | 0.005 | 0.010 | 0.13 | 0.13 | 0.25 |
| | Gull Wing Radius | R2 | 0.005 | 0.005 | 0.010 | 0.13 | 0.13 | 0.25 |
| | Foot Length | L | 0.011 | 0.016 | 0.021 | 0.28 | 0.41 | 0.53 |
| | Foot Angle | φ | 0 | 4 | 8 | 0 | 4 | 8 |
| | Radius Centerline | L1 | 0.010 | 0.015 | 0.020 | 0.25 | 0.38 | 0.51 |
| | Lead Thickness | c | 0.009 | 0.011 | 0.012 | 0.23 | 0.27 | 0.30 |
| | Lower Lead Width | B [†] | 0.014 | 0.017 | 0.019 | 0.36 | 0.42 | 0.48 |
| | Mold Draft Angle Top | α | 0 | 12 | 15 | 0 | 12 | 15 |
| | Mold Draft Angle Bottom | β | 0 | 12 | 15 | 0 | 12 | 15 |

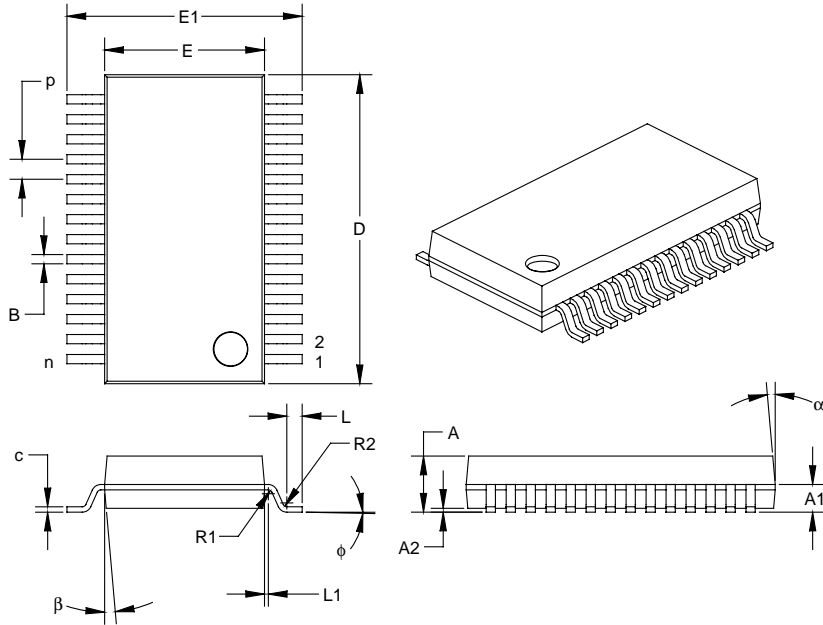
* Controlling Parameter.

† Dimension "B" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B."

‡ Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

PIC16C63A/65B/73B/74B

16.5 K04-073 28-Lead Plastic Shrink Small Outline (SS) – 5.30 mm



| Units | Dimension Limits | INCHES | | | MILLIMETERS* | | | |
|-------|-------------------------|----------------|-------|-------|--------------|-------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX | |
| | Pitch | p | 0.026 | | | 0.65 | | |
| | Number of Pins | n | 28 | | | 28 | | |
| | Overall Pack. Height | A | 0.068 | 0.073 | 0.078 | 1.73 | 1.86 | 1.99 |
| | Shoulder Height | A1 | 0.026 | 0.036 | 0.046 | 0.66 | 0.91 | 1.17 |
| | Standoff | A2 | 0.002 | 0.005 | 0.008 | 0.05 | 0.13 | 0.21 |
| | Molded Package Length | D [‡] | 0.396 | 0.402 | 0.407 | 10.07 | 10.20 | 10.33 |
| | Molded Package Width | E [‡] | 0.205 | 0.208 | 0.212 | 5.20 | 5.29 | 5.38 |
| | Outside Dimension | E1 | 0.301 | 0.306 | 0.311 | 7.65 | 7.78 | 7.90 |
| | Shoulder Radius | R1 | 0.005 | 0.005 | 0.010 | 0.13 | 0.13 | 0.25 |
| | Gull Wing Radius | R2 | 0.005 | 0.005 | 0.010 | 0.13 | 0.13 | 0.25 |
| | Foot Length | L | 0.015 | 0.020 | 0.025 | 0.38 | 0.51 | 0.64 |
| | Foot Angle | phi | 0 | 4 | 8 | 0 | 4 | 8 |
| | Radius Centerline | L1 | 0.000 | 0.005 | 0.010 | 0.00 | 0.13 | 0.25 |
| | Lead Thickness | c | 0.005 | 0.007 | 0.009 | 0.13 | 0.18 | 0.22 |
| | Lower Lead Width | B [†] | 0.010 | 0.012 | 0.015 | 0.25 | 0.32 | 0.38 |
| | Mold Draft Angle Top | alpha | 0 | 5 | 10 | 0 | 5 | 10 |
| | Mold Draft Angle Bottom | beta | 0 | 5 | 10 | 0 | 5 | 10 |

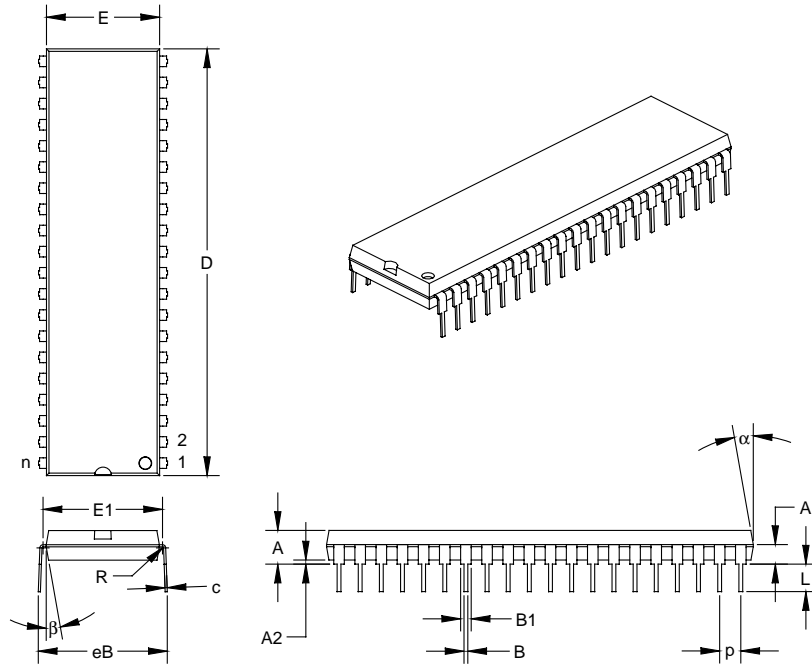
* Controlling Parameter.

† Dimension "B" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B."

‡ Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

PIC16C63A/65B/73B/74B

16.6 K04-016 40-Lead Plastic Dual In-line (P) – 600 mil



| Units | | INCHES* | | | MILLIMETERS | | |
|------------------------------|-----|---------|-------|-------|-------------|-------|-------|
| Dimension Limits | | MIN | NOM | MAX | MIN | NOM | MAX |
| PCB Row Spacing | | | 0.600 | | | 15.24 | |
| Number of Pins | n | | 40 | | | 40 | |
| Pitch | p | | 0.100 | | | 2.54 | |
| Lower Lead Width | B | 0.016 | 0.018 | 0.020 | 0.41 | 0.46 | 0.51 |
| Upper Lead Width | B1† | 0.045 | 0.050 | 0.055 | 1.14 | 1.27 | 1.40 |
| Shoulder Radius | R | 0.000 | 0.005 | 0.010 | 0.00 | 0.13 | 0.25 |
| Lead Thickness | c | 0.009 | 0.010 | 0.011 | 0.23 | 0.25 | 0.28 |
| Top to Seating Plane | A | 0.110 | 0.160 | 0.160 | 2.79 | 4.06 | 4.06 |
| Top of Lead to Seating Plane | A1 | 0.073 | 0.093 | 0.113 | 1.85 | 2.36 | 2.87 |
| Base to Seating Plane | A2 | 0.020 | 0.020 | 0.040 | 0.51 | 0.51 | 1.02 |
| Tip to Seating Plane | L | 0.125 | 0.130 | 0.135 | 3.18 | 3.30 | 3.43 |
| Package Length | D‡ | 2.013 | 2.018 | 2.023 | 51.13 | 51.26 | 51.38 |
| Molded Package Width | E‡ | 0.530 | 0.535 | 0.540 | 13.46 | 13.59 | 13.72 |
| Radius to Radius Width | E1 | 0.545 | 0.565 | 0.585 | 13.84 | 14.35 | 14.86 |
| Overall Row Spacing | eB | 0.630 | 0.610 | 0.670 | 16.00 | 15.49 | 17.02 |
| Mold Draft Angle Top | α | 5 | 10 | 15 | 5 | 10 | 15 |
| Mold Draft Angle Bottom | β | 5 | 10 | 15 | 5 | 10 | 15 |

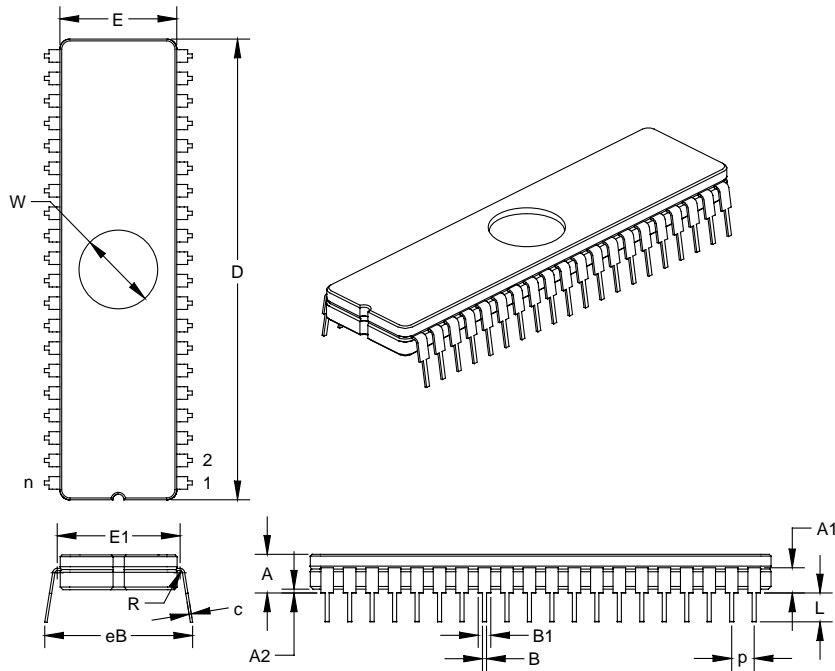
* Controlling Parameter.

† Dimension "B1" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B1."

‡ Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

PIC16C63A/65B/73B/74B

16.7 K04-014 40-Lead Ceramic Dual In-line with Window (JW) – 600 mil

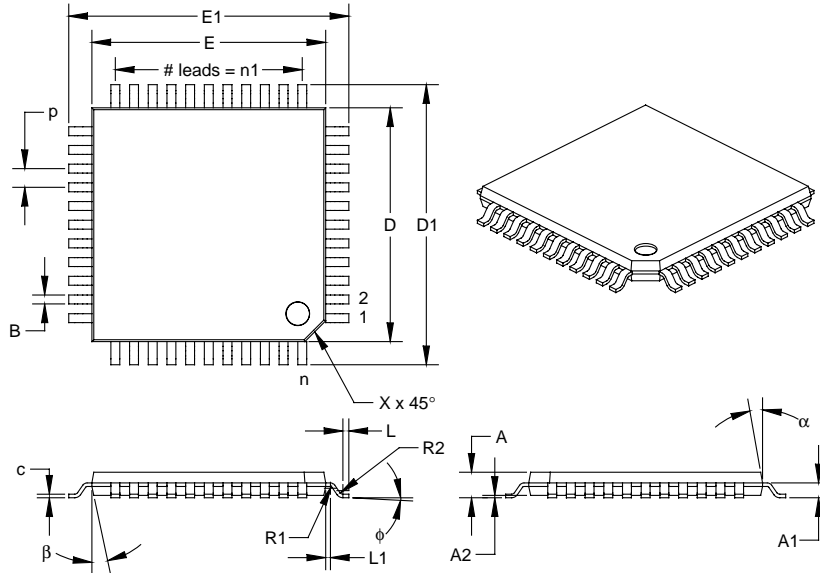


| Units | | INCHES* | | | MILLIMETERS | | |
|------------------------------|----|---------|-------|-------|-------------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Dimension Limits | | | 0.600 | | 15.24 | | |
| PCB Row Spacing | | | | | | | |
| Number of Pins | n | | 40 | | | 40 | |
| Pitch | p | 0.098 | 0.100 | 0.102 | 2.49 | 2.54 | 2.59 |
| Lower Lead Width | B | 0.016 | 0.020 | 0.023 | 0.41 | 0.50 | 0.58 |
| Upper Lead Width | B1 | 0.050 | 0.053 | 0.055 | 1.27 | 1.33 | 1.40 |
| Shoulder Radius | R | 0.000 | 0.005 | 0.010 | 0.00 | 0.13 | 0.25 |
| Lead Thickness | c | 0.008 | 0.011 | 0.014 | 0.20 | 0.28 | 0.36 |
| Top to Seating Plane | A | 0.190 | 0.205 | 0.220 | 4.83 | 5.21 | 5.59 |
| Top of Lead to Seating Plane | A1 | 0.117 | 0.135 | 0.153 | 2.97 | 3.43 | 3.89 |
| Base to Seating Plane | A2 | 0.030 | 0.045 | 0.060 | 0.00 | 1.14 | 1.52 |
| Tip to Seating Plane | L | 0.135 | 0.140 | 0.145 | 3.43 | 3.56 | 3.68 |
| Package Length | D | 2.040 | 2.050 | 2.060 | 51.82 | 52.07 | 52.32 |
| Package Width | E | 0.514 | 0.520 | 0.526 | 13.06 | 13.21 | 13.36 |
| Radius to Radius Width | E1 | 0.560 | 0.580 | 0.600 | 14.22 | 14.73 | 15.24 |
| Overall Row Spacing | eB | 0.610 | 0.660 | 0.710 | 15.49 | 16.76 | 18.03 |
| Window Diameter | W | 0.340 | 0.350 | 0.360 | 8.64 | 8.89 | 9.14 |

* Controlling Parameter.

PIC16C63A/65B/73B/74B

16.8 K04-076 44-Lead Plastic Thin Quad Flatpack (PT) 10x10x1 mm Body, 1.0/0.1 mm Lead Form



| Units | Dimension Limits | INCHES | | | MILLIMETERS* | | |
|-------------------------|------------------|--------|-------|-------|--------------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Pitch | p | | 0.031 | | | 0.80 | |
| Number of Pins | n | | 44 | | | 44 | |
| Pins along Width | n1 | | 11 | | | 11 | |
| Overall Pack. Height | A | 0.039 | 0.043 | 0.047 | 1.00 | 1.10 | 1.20 |
| Shoulder Height | A1 | 0.015 | 0.025 | 0.035 | 0.38 | 0.64 | 0.89 |
| Standoff | A2 | 0.002 | 0.004 | 0.006 | 0.05 | 0.10 | 0.15 |
| Shoulder Radius | R1 | 0.003 | 0.003 | 0.010 | 0.08 | 0.08 | 0.25 |
| Gull Wing Radius | R2 | 0.003 | 0.006 | 0.008 | 0.08 | 0.14 | 0.20 |
| Foot Length | L | 0.005 | 0.010 | 0.015 | 0.13 | 0.25 | 0.38 |
| Foot Angle | ϕ | 0 | 3.5 | 7 | 0 | 3.5 | 7 |
| Radius Centerline | L1 | 0.003 | 0.008 | 0.013 | 0.08 | 0.20 | 0.33 |
| Lead Thickness | c | 0.004 | 0.006 | 0.008 | 0.09 | 0.15 | 0.20 |
| Lower Lead Width | B [†] | 0.012 | 0.015 | 0.018 | 0.30 | 0.38 | 0.45 |
| Outside Tip Length | D1 [‡] | 0.463 | 0.472 | 0.482 | 11.75 | 12.00 | 12.25 |
| Outside Tip Width | E1 [‡] | 0.463 | 0.472 | 0.482 | 11.75 | 12.00 | 12.25 |
| Molded Pack. Length | D [‡] | 0.390 | 0.394 | 0.398 | 9.90 | 10.00 | 10.10 |
| Molded Pack. Width | E [‡] | 0.390 | 0.394 | 0.398 | 9.90 | 10.00 | 10.10 |
| Pin 1 Corner Chamfer | X | 0.025 | 0.035 | 0.045 | 0.64 | 0.89 | 1.14 |
| Mold Draft Angle Top | α | 5 | 10 | 15 | 5 | 10 | 15 |
| Mold Draft Angle Bottom | β | 5 | 12 | 15 | 5 | 12 | 15 |

* Controlling Parameter.

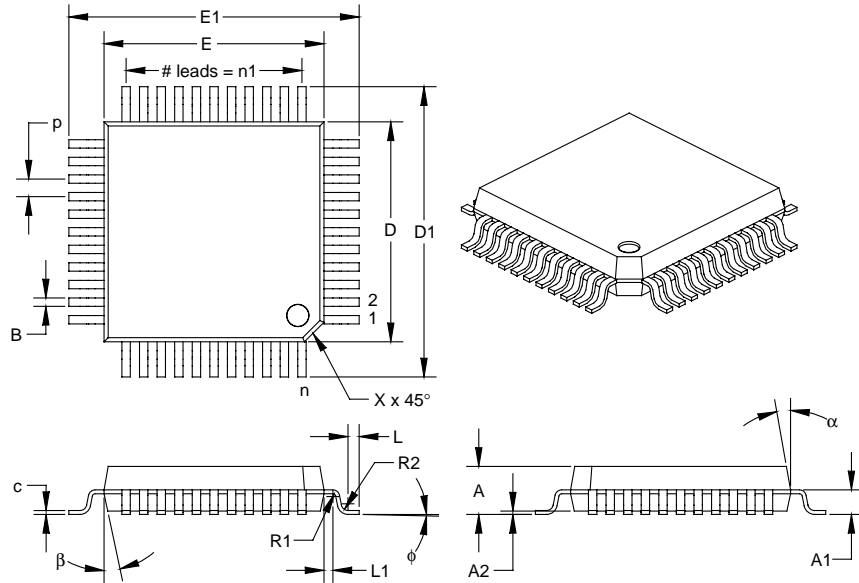
[†] Dimension "B" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B."

[‡] Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

JEDEC equivalent: MS-026 ACB

PIC16C63A/65B/73B/74B

16.9 K04-071 44-Lead Plastic Quad Flatpack (PQ) 10x10x2 mm Body, 1.6/0.15 mm Lead Form



| Units | | INCHES | | | MILLIMETERS* | | |
|-------------------------|----------------|--------|-------|-------|--------------|-------|-------|
| Dimension Limits | | MIN | NOM | MAX | MIN | NOM | MAX |
| Pitch | p | | 0.031 | | | 0.80 | |
| Number of Pins | n | | 44 | | | 44 | |
| Pins along Width | n1 | | 11 | | | 11 | |
| Overall Pack. Height | A | 0.079 | 0.086 | 0.093 | 2.00 | 2.18 | 2.35 |
| Shoulder Height | A1 | 0.032 | 0.044 | 0.056 | 0.81 | 1.11 | 1.41 |
| Standoff | A2 | 0.002 | 0.006 | 0.010 | 0.05 | 0.15 | 0.25 |
| Shoulder Radius | R1 | 0.005 | 0.005 | 0.010 | 0.13 | 0.13 | 0.25 |
| Gull Wing Radius | R2 | 0.005 | 0.012 | 0.015 | 0.13 | 0.30 | 0.38 |
| Foot Length | L | 0.015 | 0.020 | 0.025 | 0.38 | 0.51 | 0.64 |
| Foot Angle | ϕ | 0 | 3.5 | 7 | 0 | 3.5 | 7 |
| Radius Centerline | L1 | 0.011 | 0.016 | 0.021 | 0.28 | 0.41 | 0.53 |
| Lead Thickness | c | 0.005 | 0.007 | 0.009 | 0.13 | 0.18 | 0.23 |
| Lower Lead Width | B [†] | 0.012 | 0.015 | 0.018 | 0.30 | 0.37 | 0.45 |
| Outside Tip Length | D1 | 0.510 | 0.520 | 0.530 | 12.95 | 13.20 | 13.45 |
| Outside Tip Width | E1 | 0.510 | 0.520 | 0.530 | 12.95 | 13.20 | 13.45 |
| Molded Pack. Length | D [‡] | 0.390 | 0.394 | 0.398 | 9.90 | 10.00 | 10.10 |
| Molded Pack. Width | E [‡] | 0.390 | 0.394 | 0.398 | 9.90 | 10.00 | 10.10 |
| Pin 1 Corner Chamfer | X | 0.025 | 0.035 | 0.045 | 0.635 | 0.89 | 1.143 |
| Mold Draft Angle Top | α | 5 | 10 | 15 | 5 | 10 | 15 |
| Mold Draft Angle Bottom | β | 5 | 12 | 15 | 5 | 12 | 15 |

* Controlling Parameter.

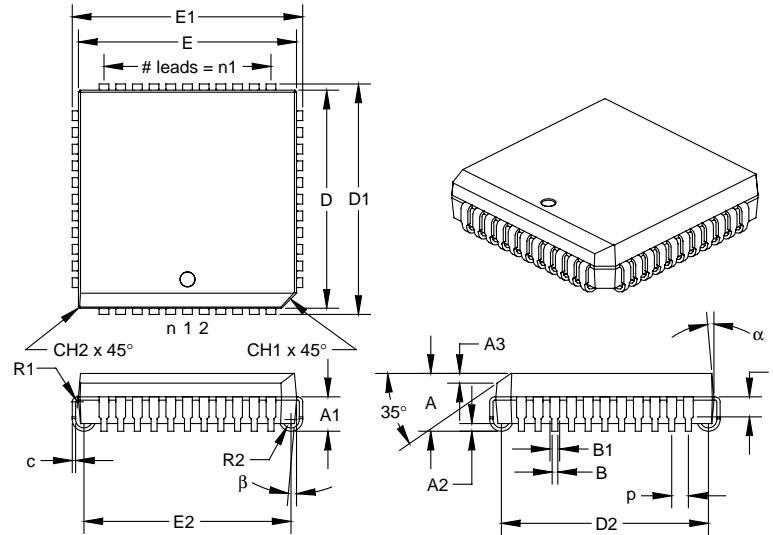
[†] Dimension "B" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B."

[‡] Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

JEDEC equivalent: MS-022 AB

PIC16C63A/65B/73B/74B

16.10 K04-048 44-Lead Plastic Leaded Chip Carrier (L) – Square



| Units | | INCHES* | | | MILLIMETERS | | |
|-------------------------|-----------------|---------|-------|-------|-------------|-------|-------|
| | | MIN | NOM | MAX | MIN | NOM | MAX |
| Dimension Limits | | | | | | | |
| Number of Pins | n | | 44 | | | 44 | |
| Pitch | p | | 0.050 | | | 1.27 | |
| Overall Pack. Height | A | 0.165 | 0.173 | 0.180 | 4.19 | 4.38 | 4.57 |
| Shoulder Height | A1 | 0.095 | 0.103 | 0.110 | 2.41 | 2.60 | 2.79 |
| Standoff | A2 | 0.015 | 0.023 | 0.030 | 0.38 | 0.57 | 0.76 |
| Side 1 Chamfer Dim. | A3 | 0.024 | 0.029 | 0.034 | 0.61 | 0.74 | 0.86 |
| Corner Chamfer (1) | CH1 | 0.040 | 0.045 | 0.050 | 1.02 | 1.14 | 1.27 |
| Corner Chamfer (other) | CH2 | 0.000 | 0.005 | 0.010 | 0.00 | 0.13 | 0.25 |
| Overall Pack. Width | E1 | 0.685 | 0.690 | 0.695 | 17.40 | 17.53 | 17.65 |
| Overall Pack. Length | D1 | 0.685 | 0.690 | 0.695 | 17.40 | 17.53 | 17.65 |
| Molded Pack. Width | E [‡] | 0.650 | 0.653 | 0.656 | 16.51 | 16.59 | 16.66 |
| Molded Pack. Length | D [‡] | 0.650 | 0.653 | 0.656 | 16.51 | 16.59 | 16.66 |
| Footprint Width | E2 | 0.610 | 0.620 | 0.630 | 15.49 | 15.75 | 16.00 |
| Footprint Length | D2 | 0.610 | 0.620 | 0.630 | 15.49 | 15.75 | 16.00 |
| Pins along Width | n1 | | 11 | | | 11 | |
| Lead Thickness | c | 0.008 | 0.010 | 0.012 | 0.20 | 0.25 | 0.30 |
| Upper Lead Width | B1 [†] | 0.026 | 0.029 | 0.032 | 0.66 | 0.74 | 0.81 |
| Lower Lead Width | B | 0.015 | 0.018 | 0.021 | 0.38 | 0.46 | 0.53 |
| Upper Lead Length | L | 0.050 | 0.058 | 0.065 | 1.27 | 1.46 | 1.65 |
| Shoulder Inside Radius | R1 | 0.003 | 0.005 | 0.010 | 0.08 | 0.13 | 0.25 |
| J-Bend Inside Radius | R2 | 0.015 | 0.025 | 0.035 | 0.38 | 0.64 | 0.89 |
| Mold Draft Angle Top | α | 0 | 5 | 10 | 0 | 5 | 10 |
| Mold Draft Angle Bottom | β | 0 | 5 | 10 | 0 | 5 | 10 |

* Controlling Parameter.

[†] Dimension "B1" does not include dam-bar protrusions. Dam-bar protrusions shall not exceed 0.003" (0.076 mm) per side or 0.006" (0.152 mm) more than dimension "B1."

[‡] Dimensions "D" and "E" do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010" (0.254 mm) per side or 0.020" (0.508 mm) more than dimensions "D" or "E."

JEDEC equivalent: MO-047 AC

PIC16C63A/65B/73B/74B

APPENDIX A: REVISION HISTORY

| Version | Date | Revision Description |
|---------|------|--|
| A | 7/98 | This is a new data sheet. However, the devices described in this data sheet are the upgrades to the devices found in the <i>PIC16C6X Data Sheet</i> , DS30234D, and the <i>PIC16C7X Data Sheet</i> , DS30390E. |

APPENDIX B: DEVICE DIFFERENCES

The differences between the devices in this data sheet are listed in Table B-1.

TABLE B-1: DEVICE DIFFERENCES

| Difference | PIC16C63A | PIC16C65B | PIC16C73B | PIC16C74B |
|---------------------|---|--|---|--|
| A/D | no | no | 5 channels, 8 bits | 8 channels, 8 bits |
| Parallel Slave Port | no | yes | no | yes |
| Packages | 28-pin PDIP, 28-pin windowed Cerdip, 28-pin SOIC, 28-pin SSOP | 40-pin PDIP, 40-pin windowed Cerdip, 44-pin TQFP, 44-pin MQFP, 44-pin PLCC | 28-pin PDIP, 28-pin windowed Cerdip, 28-pin SOIC, 28-pin SSOP | 40-pin PDIP, 40-pin windowed Cerdip, 44-pin TQFP, 44-pin MQFP, 44-pin PLCC |

APPENDIX C: CONVERSION CONSIDERATIONS

Considerations for converting from previous versions of devices to the ones listed in this data sheet are listed in Table C-1.

TABLE C-1: CONVERSION CONSIDERATIONS

| Difference | PIC16C63/65A/73A/74A | PIC16C63A/65B/73B/74B |
|---------------|---|-----------------------|
| Voltage Range | 2.5V - 6.0V | 2.5V - 5.5V |
| SSP module | single mode SPI | 4-mode SPI |
| SSP module | Can only transmit one word in SPI mode of enhanced SSP. | N/A |
| CCP module | CCP does not reset TMR1 when in special event trigger mode. | N/A |
| USART module | USART receiver errata in BRGH=1 mode. | N/A |
| Timer1 module | Writing to TMR1L register can cause overflow in TMR1H register. | N/A |

PIC16C63A/65B/73B/74B

APPENDIX D: MIGRATION FROM BASELINE TO MIDRANGE DEVICES

This section discusses how to migrate from a baseline device (i.e., PIC16C5X) to a midrange device (i.e., PIC16CXXX).

The following are the list of modifications over the PIC16C5X microcontroller family:

1. Instruction word length is increased to 14-bits. This allows larger page sizes both in program memory (2K now as opposed to 512 before) and register file (128 bytes now versus 32 bytes before).
2. A PC high latch register (PCLATH) is added to handle program memory paging. Bits PA2, PA1, PA0 are removed from STATUS register.
3. Data memory paging is redefined slightly. STATUS register is modified.
4. Four new instructions have been added: RETURN, RETFIE, ADDLW, and SUBLW. Two instructions TRIS and OPTION are being phased out although they are kept for compatibility with PIC16C5X.
5. OPTION and TRIS registers are made addressable.
6. Interrupt capability is added. Interrupt vector is at 0004h.
7. Stack size is increased to 8 deep.
8. Reset vector is changed to 0000h.
9. Reset of all registers is revisited. Five different reset (and wake-up) types are recognized. Registers are reset differently.
10. Wake up from SLEEP through interrupt is added.
11. Two separate timers, Oscillator Start-up Timer (OST) and Power-up Timer (PWRT) are included for more reliable power-up. These timers are invoked selectively to avoid unnecessary delays on power-up and wake-up.
12. PORTB has weak pull-ups and interrupt on change feature.
13. T0CKI pin is also a port pin (RA4) now.
14. FSR is made a full eight bit register.
15. "In-circuit serial programming" is made possible. The user can program PIC16CXX devices using only five pins: VDD, VSS, MCLR/VPP, RB6 (clock) and RB7 (data in/out).
16. PCON status register is added with a Power-on Reset status bit ($\overline{\text{POR}}$).
17. Code protection scheme is enhanced such that portions of the program memory can be protected, while the remainder is unprotected.
18. Brown-out protection circuitry has been added. Controlled by configuration word bit BODEN. Brown-out reset ensures the device is placed in a reset condition if VDD dips below a fixed set-point.

To convert code written for PIC16C5X to PIC16CXXX, the user should take the following steps:

1. Remove any program memory page select operations (PA2, PA1, PA0 bits) for CALL, GOTO.
2. Revisit any computed jump operations (write to PC or add to PC, etc.) to make sure page bits are set properly under the new scheme.
3. Eliminate any data memory page switching. Redefine data variables to reallocate them.
4. Verify all writes to STATUS, OPTION, and FSR registers since these have changed.
5. Change reset vector to 0000h.

PIC16C63A/65B/73B/74B

APPENDIX E: BIT/REGISTER CROSS-REFERENCE LIST

| | | | |
|---------------|----------------------|-----------------|--------------------|
| ADCS1:ADCS0 |ADCON0<7:6> | T0IE |INTCON<5> |
| ADIE |PIE1<6> | T0IF |INTCON<2> |
| ADIF |PIR1<6> | T0SE |OPTION_REG<4> |
| ADON |ADCON0<0> | T1CKPS1:T1CKPS0 |T1CON<5:4> |
| BF |SSPSTAT<0> | T1OSCCN |T1CON<3> |
| BOR |PCON<0> | T1SYNCR |T1CON<2> |
| BRGH |TXSTA<2> | T2CKPS1:T2CKPS0 |T2CON<1:0> |
| C |STATUS<0> | TMR1CS |T1CON<1> |
| CCP1IE |PIE1<2> | TMR1IE |PIE1<0> |
| CCP1IF |PIR1<2> | TMR1IF |PIR1<0> |
| CCP1M3:CCP1M0 |CCP1CON<3:0> | TMR1ON |T1CON<0> |
| CCP1X:CCP1Y |CCP1CON<5:4> | TMR2IE |PIE1<1> |
| CCP2IE |PIE2<0> | TMR2IF |PIR1<1> |
| CCP2IF |PIR2<0> | TMR2ON |T2CON<2> |
| CCP2M3:CCP2M0 |CCP2CON<3:0> | TÖ |STATUS<4> |
| CCP2X:CCP2Y |CCP2CON<5:4> | TOUTPS3:TOUTPS0 |T2CON<6:3> |
| CHS2:CHS0 |ADCON0<5:3> | TRMT |TXSTA<1> |
| CKE |SSPSTAT<6> | TX9 |TXSTA<6> |
| CKP |SSPCON<4> | TX9D |TXSTA<0> |
| CREN |RCSTA<4> | TXEN |TXSTA<5> |
| CSRC |TXSTA<7> | TXIE |PIE1<4> |
| D/A |SSPSTAT<5> | TXIF |PIR1<4> |
| DC |STATUS<1> | UA |SSPSTAT<1> |
| FERR |RCSTA<2> | WCOL |SSPCON<7> |
| GIE |INTCON<7> | Z |STATUS<2> |
| GO/DONE |ADCON0<2> | | |
| IBF |TRISE<7> | | |
| IBOV |TRISE<5> | | |
| INTE |INTCON<4> | | |
| INTEDG |OPTION_REG<6> | | |
| INTF |INTCON<1> | | |
| IRP |STATUS<7> | | |
| OBF |TRISE<6> | | |
| OERR |RCSTA<1> | | |
| P |SSPSTAT<4> | | |
| PCFG2:PCFG0 |ADCON1<2:0> | | |
| PD |STATUS<3> | | |
| PEIE |INTCON<6> | | |
| POR |PCON<1> | | |
| PS2:PS0 |OPTION_REG<2:0> | | |
| PSA |OPTION_REG<3> | | |
| PSPIE |PIE1<7> | | |
| PSPIF |PIR1<7> | | |
| PSPMODE |TRISE<4> | | |
| R/W |SSPSTAT<2> | | |
| RBIE |INTCON<3> | | |
| RBIF |INTCON<0> | | |
| RBPU |OPTION_REG<7> | | |
| RCIE |PIE1<5> | | |
| RCIF |PIR1<5> | | |
| RP1:RP0 |STATUS<6:5> | | |
| RX9 |RCSTA<6> | | |
| RX9D |RCSTA<0> | | |
| S |SSPSTAT<3> | | |
| SMP |SSPSTAT<7> | | |
| SPEN |RCSTA<7> | | |
| SREN |RCSTA<5> | | |
| SSPEN |SSPCON<5> | | |
| SSPIE |PIE1<3> | | |
| SSPIF |PIR1<3> | | |
| SSPM3:SSPM0 |SSPCON<3:0> | | |
| SSPOV |SSPCON<6> | | |
| SYNC |TXSTA<4> | | |
| T0CS |OPTION_REG<5> | | |

PIC16C63A/65B/73B/74B

NOTES:

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|-------------------|--|-------------------|---------|---------|
| Device | Frequency Range | Temperature Range | Package | Pattern |
| Device | PIC16C6X ⁽¹⁾ , PIC16C6XT ⁽²⁾ ; V _{DD} range 4.0V to 5.5V PIC16LC6X ⁽¹⁾ , PIC16LC6XT ⁽²⁾ ; V _{DD} range 2.5V to 5.5V PIC16C7X ⁽¹⁾ , PIC16C7XT ⁽²⁾ ; V _{DD} range 4.0V to 5.5V PIC16LC7X ⁽¹⁾ , PIC16LC7XT ⁽²⁾ ; V _{DD} range 2.5V to 5.5V | | | |
| Frequency Range | 04 = 4 MHz 20 = 20 MHz | | | |
| Temperature Range | blank = 0°C to 70°C (Commercial) I = -40°C to +85°C (Industrial) E = -40°C to +125°C (Extended) | | | |
| Package | JW = Windowed CERDIP PQ = MQFP (Metric PQFP) PT = TQFP (Thin Quad Flatpack) SO = SOIC SP = Skinny plastic dip P = PDIP L = PLCC SS = SSOP | | | |
| Pattern | QTP, SQTP, Code or Special Requirements (blank otherwise) | | | |

Examples:

a) PIC16C74B -04/P 301 = Commercial temp., PDIP package, 4 MHz, normal V_{DD} limits, QTP pattern #301.

b) PIC16LC63A - 04I/SO = Industrial temp., SOIC package, 200 kHz, Extended V_{DD} limits.

c) PIC16C65B - 20I/P = Industrial temp., PDIP package, 20MHz, normal V_{DD} limits.

Note 1: C = CMOS
LC = Low Power CMOS

2: T = in tape and reel - SOIC, SSOP, PLCC, QFP, TQ and FP packages only.

* JW Devices are UV erasable and can be programmed to any device configuration. JW Devices meet the electrical requirement of each oscillator type (including LC devices).

PIC16C63A/65B/73B/74B

NOTES:

PIC16C63A/65B/73B/74B

NOTES:



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7/7/98



Microchip received ISO 9001 Quality System certification for its worldwide headquarters, design, and wafer fabrication facilities in January, 1997. Our field-programmable PICmicro™ 8-bit MCUs, Serial EEPROMs, related specialty memory products and development systems conform to the stringent quality standards of the International Standard Organization (ISO).

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