# PIC16F84A

## 18-pin *Enhanced* FLASH/EEPROM 8-Bit Microcontroller

### High Performance RISC CPU Features:

- Only 35 single word instructions to learn
- All instructions single-cycle except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- 1024 words of program memory
- 68 bytes of Data RAM
- 64 bytes of Data EEPROM
- 14-bit wide instruction words
- 8-bit wide data bytes
- 15 Special Function Hardware registers
- Eight-level deep hardware stack
- Direct, indirect and relative addressing modes
- Four interrupt sources:
  - External RB0/INT pin
  - TMR0 timer overflow
  - PORTB<7:4> interrupt-on-change
  - Data EEPROM write complete

### Peripheral Features:

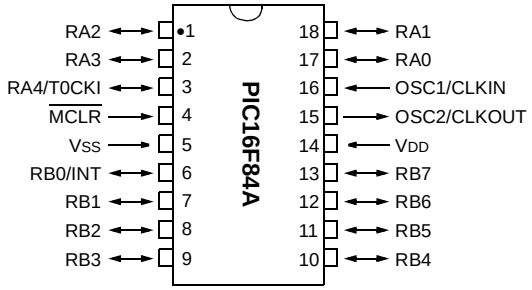
- 13 I/O pins with individual direction control
- High current sink/source for direct LED drive
  - 25 mA sink max. per pin
  - 25 mA source max. per pin
- TMR0: 8-bit timer/counter with 8-bit programmable prescaler

### Special Microcontroller Features:

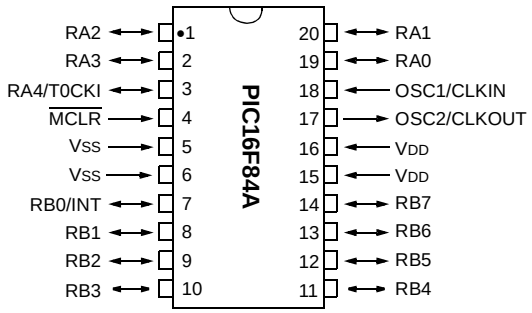
- 10,000 erase/write cycles *Enhanced* FLASH Program memory typical
- 10,000,000 typical erase/write cycles EEPROM Data memory typical
- EEPROM Data Retention > 40 years
- In-Circuit Serial Programming™ (ICSP™) - via two pins
- Power-on Reset (POR), Power-up Timer (PWRT), Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own On-Chip RC Oscillator for reliable operation
- Code protection
- Power saving SLEEP mode
- Selectable oscillator options

### Pin Diagrams

**PDIP, SOIC**




**SSOP**




### CMOS Enhanced FLASH/EEPROM Technology:

- Low power, high speed technology
- Fully static design
- Wide operating voltage range:
  - Commercial: 2.0V to 5.5V
  - Industrial: 2.0V to 5.5V
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 15 μA typical @ 2V, 32 kHz
  - < 0.5 μA typical standby current @ 2V

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## 1.0 DEVICE OVERVIEW

This document contains device specific information for the operation of the PIC16F84A device. Additional information may be found in the PIC® Mid-Range Reference Manual, (DS33023), which may be downloaded from the Microchip website. 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.

The PIC16F84A belongs to the mid-range family of the PIC® microcontroller devices. A block diagram of the device is shown in Figure 1-1.

The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data EEPROM is 64 bytes.

There are also 13 I/O pins that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions. These functions include:

- External interrupt
- Change on PORTB interrupt
- Timer0 clock input

Table 1-1 details the pinout of the device with descriptions and details for each pin.

**FIGURE 1-1: PIC16F84A BLOCK DIAGRAM**

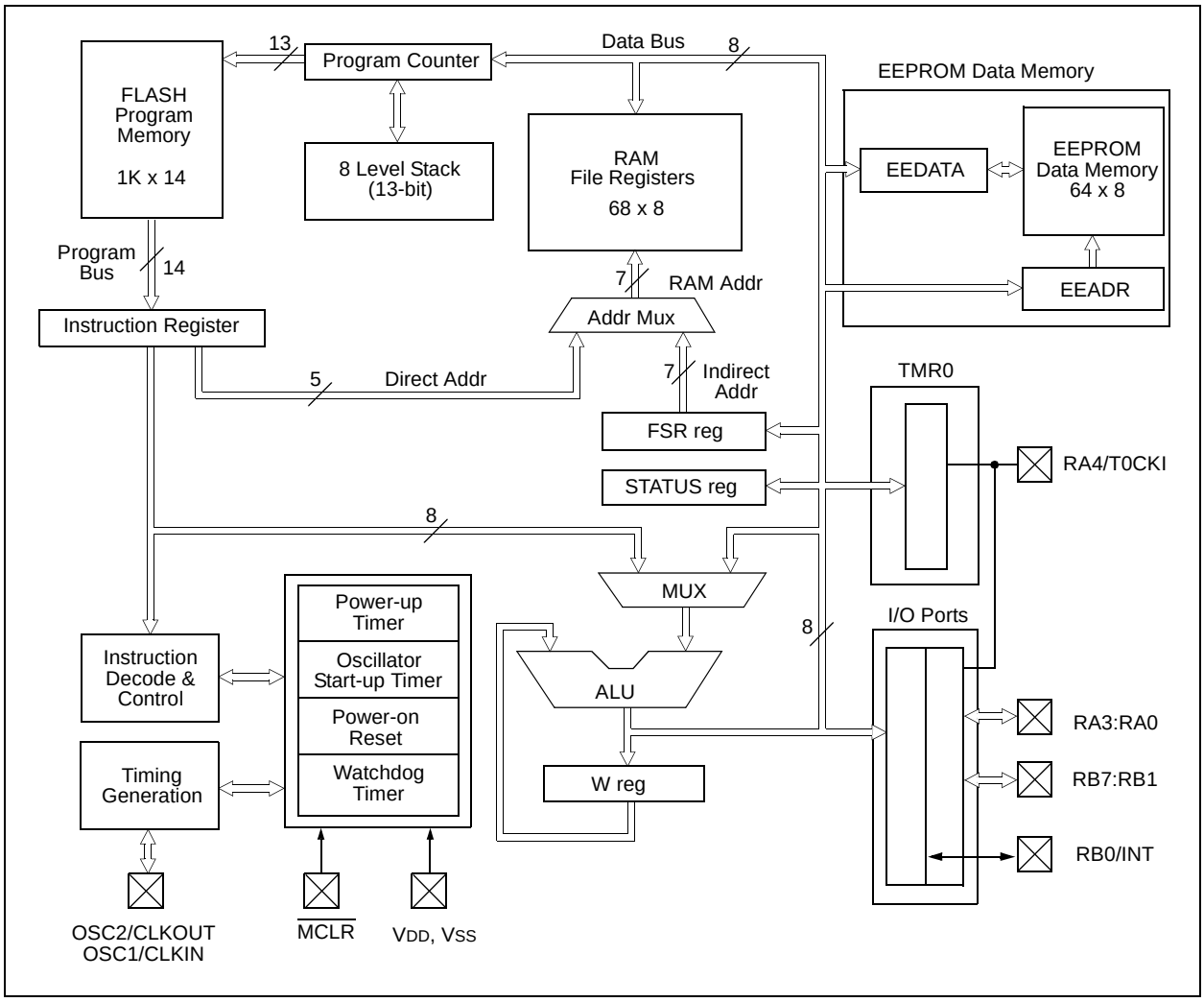

**TABLE 1-1: PIC16F84A PINOUT DESCRIPTION**

| Pin Name | PDIP No. | SOIC No. | SSOP No. | I/O/P Type | Buffer Type | Description |
|---|---|---|---|---|---|---|
| OSC1/CLKIN | 16 | 16 | 18 | I | ST/CMOS(3) | Oscillator crystal input/external clock source input. |
| OSC2/CLKOUT | 15 | 15 | 19 | 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. |
| $\overline{MCLR}$ | 4 | 4 | 4 | I/P | ST | Master Clear (Reset) input/programming voltage input. This pin is an active low RESET to the device. |
| | | | | | | PORTA is a bi-directional I/O port. |
| RA0 | 17 | 17 | 19 | I/O | TTL | |
| RA1 | 18 | 18 | 20 | I/O | TTL | |
| RA2 | 1 | 1 | 1 | I/O | TTL | |
| RA3 | 2 | 2 | 2 | I/O | TTL | |
| RA4/T0CKI | 3 | 3 | 3 | I/O | ST | Can also be selected to be the clock input to the TMR0 timer/counter. Output is open drain type. |
| | | | | | | PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs. |
| RB0/INT | 6 | 6 | 7 | I/O | TTL/ST(1) | RB0/INT can also be selected as an external interrupt pin. |
| RB1 | 7 | 7 | 8 | I/O | TTL | |
| RB2 | 8 | 8 | 9 | I/O | TTL | |
| RB3 | 9 | 9 | 10 | I/O | TTL | |
| RB4 | 10 | 10 | 11 | I/O | TTL | Interrupt-on-change pin. |
| RB5 | 11 | 11 | 12 | I/O | TTL | Interrupt-on-change pin. |
| RB6 | 12 | 12 | 13 | I/O | TTL/ST(2) | Interrupt-on-change pin. Serial programming clock. |
| RB7 | 13 | 13 | 14 | I/O | TTL/ST(2) | Interrupt-on-change pin. Serial programming data. |
| VSS | 5 | 5 | 5,6 | P | — | Ground reference for logic and I/O pins. |
| VDD | 14 | 14 | 15,16 | 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.


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## 2.0 MEMORY ORGANIZATION

There are two memory blocks in the PIC16F84A. These are the program memory and the data memory. Each block has its own bus, so that access to each block can occur during the same oscillator cycle.

The data memory can further be broken down into the general purpose RAM and the Special Function Registers (SFRs). The operation of the SFRs that control the “core” are described here. The SFRs used to control the peripheral modules are described in the section discussing each individual peripheral module.

The data memory area also contains the data EEPROM memory. This memory is not directly mapped into the data memory, but is indirectly mapped. That is, an indirect address pointer specifies the address of the data EEPROM memory to read/write. The 64 bytes of data EEPROM memory have the address range 0h-3Fh. More details on the EEPROM memory can be found in Section 3.0.

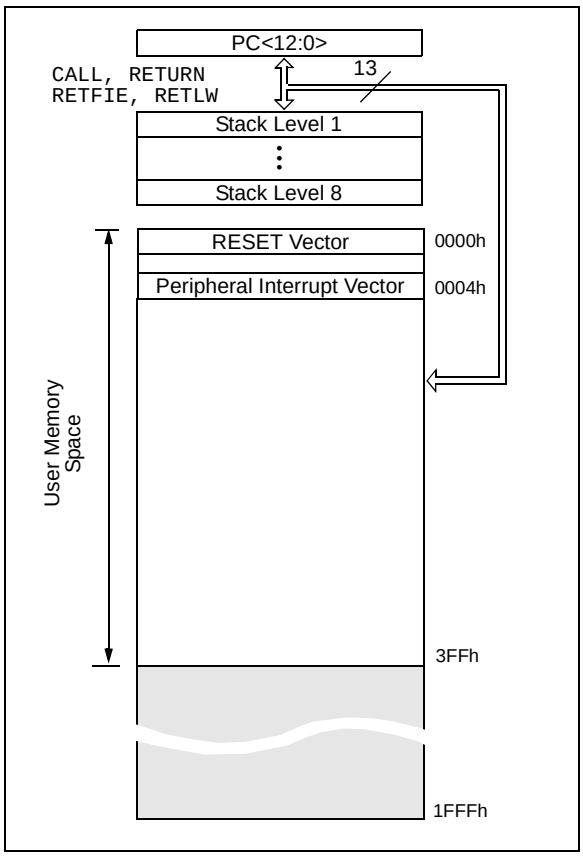
Additional information on device memory may be found in the PIC® Mid-Range Reference Manual, (DS33023).

### 2.1 Program Memory Organization

The PIC16FXX has a 13-bit program counter capable of addressing an 8K x 14 program memory space. For the PIC16F84A, the first 1K x 14 (0000h-03FFh) are physically implemented (Figure 2-1). Accessing a location above the physically implemented address will cause a wraparound. For example, for locations 20h, 420h, 820h, C20h, 1020h, 1420h, 1820h, and 1C20h, the instruction will be the same.

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

**FIGURE 2-1: PROGRAM MEMORY MAP AND STACK - PIC16F84A**



## 2.2 Data Memory Organization

The data memory is partitioned into two areas. The first is the Special Function Registers (SFR) area, while the second is the General Purpose Registers (GPR) area. The SFRs control the operation of the device.

Portions of data memory are banked. This is for both the SFR area and the GPR area. The GPR area is banked to allow greater than 116 bytes of general purpose RAM. The banked areas of the SFR are for the registers that control the peripheral functions. Banking requires the use of control bits for bank selection. These control bits are located in the STATUS Register. Figure 2-2 shows the data memory map organization.

Instructions `MOVWF` and `MOVF` can move values from the W register to any location in the register file ("F"), and vice-versa.

The entire data memory can be accessed either directly using the absolute address of each register file or indirectly through the File Select Register (FSR) (Section 2.5). Indirect addressing uses the present value of the RP0 bit for access into the banked areas of data memory.

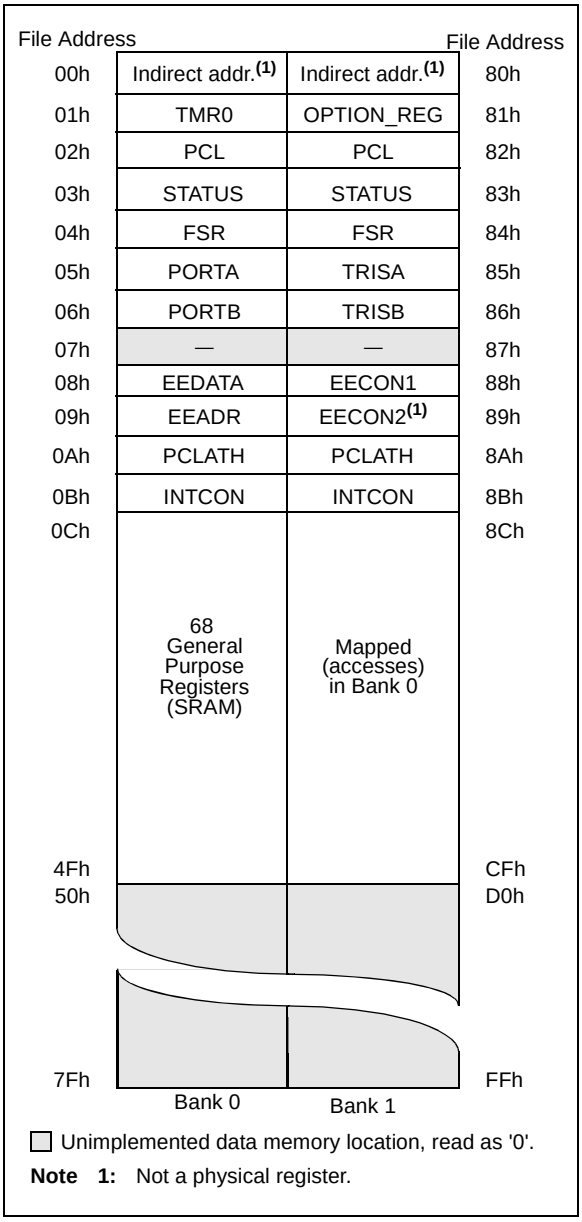
Data memory is partitioned into two banks which contain the general purpose registers and the special function registers. Bank 0 is selected by clearing the RP0 bit (STATUS<5>). Setting the RP0 bit selects Bank 1. Each Bank extends up to 7Fh (128 bytes). The first twelve locations of each Bank are reserved for the Special Function Registers. The remainder are General Purpose Registers, implemented as static RAM.

### 2.2.1 GENERAL PURPOSE REGISTER FILE

Each General Purpose Register (GPR) is 8-bits wide and is accessed either directly or indirectly through the FSR (Section 2.5).

The GPR addresses in Bank 1 are mapped to addresses in Bank 0. As an example, addressing location 0Ch or 8Ch will access the same GPR.

**FIGURE 2-2: REGISTER FILE MAP - PIC16F84A**





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## 2.3 Special Function Registers

The Special Function Registers (Figure 2-2 and Table 2-1) are used by the CPU and Peripheral functions to control the device operation. These registers are static RAM.

The special function registers can be classified into two sets, core and peripheral. Those associated with the core functions are described in this section. Those related to the operation of the peripheral features are described in the section for that specific feature.

**TABLE 2-1: SPECIAL FUNCTION REGISTER FILE SUMMARY**

| Addr | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on Power-on RESET | Details on page |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bank 0** | | | | | | | | | | | |
| 00h | INDF | Uses contents of FSR to address Data Memory (not a physical register) | | | | | | | | ---- ---- | 11 |
| 01h | TMR0 | 8-bit Real-Time Clock/Counter | | | | | | | | xxxx xxxx | 20 |
| 02h | PCL | Low Order 8 bits of the Program Counter (PC) | | | | | | | | 0000 0000 | 11 |
| 03h | STATUS(2) | IRP | RP1 | RP0 | $\overline{TO}$ | $\overline{PD}$ | Z | DC | C | 0001 1xxx | 8 |
| 04h | FSR | Indirect Data Memory Address Pointer 0 | | | | | | | | xxxx xxxx | 11 |
| 05h | PORTA(4) | — | — | — | RA4/T0CKI | RA3 | RA2 | RA1 | RA0 | ---x xxxx | 16 |
| 06h | PORTB(5) | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0/INT | xxxx xxxx | 18 |
| 07h | — | Unimplemented location, read as '0' | | | | | | | | — | — |
| 08h | EEDATA | EEPROM Data Register | | | | | | | | xxxx xxxx | 13,14 |
| 09h | EEADR | EEPROM Address Register | | | | | | | | xxxx xxxx | 13,14 |
| 0Ah | PCLATH | — | — | — | Write Buffer for upper 5 bits of the PC(1) | | | | | ---0 0000 | 11 |
| 0Bh | INTCON | GIE | EEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 10 |
| **Bank 1** | | | | | | | | | | | |
| 80h | INDF | Uses Contents of FSR to address Data Memory (not a physical register) | | | | | | | | ---- ---- | 11 |
| 81h | OPTION_REG | RBPU | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 | 1111 1111 | 9 |
| 82h | PCL | Low order 8 bits of Program Counter (PC) | | | | | | | | 0000 0000 | 11 |
| 83h | STATUS (2) | IRP | RP1 | RP0 | $\overline{TO}$ | $\overline{PD}$ | Z | DC | C | 0001 1xxx | 8 |
| 84h | FSR | Indirect data memory address pointer 0 | | | | | | | | xxxx xxxx | 11 |
| 85h | TRISA | — | — | — | PORTA Data Direction Register | | | | | ---1 1111 | 16 |
| 86h | TRISB | PORTB Data Direction Register | | | | | | | | 1111 1111 | 18 |
| 87h | — | Unimplemented location, read as '0' | | | | | | | | — | — |
| 88h | EECON1 | — | — | — | EEIF | WRERR | WREN | WR | RD | ---0 x000 | 13 |
| 89h | EECON2 | EEPROM Control Register 2 (not a physical register) | | | | | | | | ---- ---- | 14 |
| 0Ah | PCLATH | — | — | — | Write buffer for upper 5 bits of the PC(1) | | | | | ---0 0000 | 11 |
| 0Bh | INTCON | GIE | EEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 10 |

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

**Note 1:** The upper byte of the program counter is not directly accessible. PCLATH is a slave register for PC<12:8>. The contents of PCLATH can be transferred to the upper byte of the program counter, but the contents of PC<12:8> are never transferred to PCLATH.

**2:** The $\overline{TO}$ and $\overline{PD}$ status bits in the STATUS register are not affected by a $\overline{MCLR}$ Reset.

**3:** Other (non power-up) RESETS include: external RESET through $\overline{MCLR}$ and the Watchdog Timer Reset.

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

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

### 2.3.1 STATUS REGISTER

The STATUS register contains the arithmetic status of the ALU, the RESET status and the bank select bit for data memory.

As with any register, the STATUS register can be the destination for any instruction. 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 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).

Only the BCF, BSF, SWAPF and MOVWF instructions should be used to alter the STATUS register (Table 7-2), because these instructions do not affect any status bit.

**Note 1:** The IRP and RP1 bits (STATUS<7:6>) are not used by the PIC16F84A and should be programmed as cleared. Use of these bits as general purpose R/W bits is NOT recommended, since this may affect upward compatibility with future products.

**2:** The C and DC bits operate as a $\overline{borrow}$ and digit borrow out bit, respectively, in subtraction. See the SUBLW and SUBWF instructions for examples.

**3:** When 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. The specified bit(s) will be updated according to device logic

**REGISTER 2-1: 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 |
| bit 7 | | | | | | | bit 0 |

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

bit 5 **RP0**: Register Bank Select bits (used for direct addressing)
01 = Bank 1 (80h - FFh)
00 = Bank 0 (00h - 7Fh)

bit 4 $\overline{\textbf{TO}}$: Time-out bit
1 = After power-up, CLRWDT instruction, or SLEEP instruction
0 = A WDT time-out occurred

bit 3 $\overline{\textbf{PD}}$: Power-down bit
1 = After power-up or by the CLRWDT instruction
0 = By execution of the SLEEP instruction

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

bit 1 **DC**: Digit carry/$\overline{borrow}$ bit (ADDWF, ADDLW, SUBLW, SUBWF instructions) (for $\overline{borrow}$, 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

bit 0 **C**: Carry/$\overline{borrow}$ bit (ADDWF, ADDLW, SUBLW, SUBWF instructions) (for $\overline{borrow}$, the polarity is reversed)
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:** A subtraction is executed by adding the two's complement of the second operand. For rotate (RRF, RLF) instructions, this bit is loaded with either the high or low order bit of the source register.

| Legend: | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |


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### 2.3.2 OPTION REGISTER

The OPTION register is a readable and writable register which contains various control bits to configure the TMR0/WDT prescaler, the external INT interrupt, TMR0, and the weak pull-ups on PORTB.

| **Note:** | When the prescaler is assigned to the WDT (PSA = '1'), TMR0 has a 1:1 prescaler assignment. |
|---|---|

**REGISTER 2-2: OPTION REGISTER (ADDRESS 81h)**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| RBPU | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 |
| bit 7 | | | | | | | bit 0 |

bit 7 **$\overline{\text{RBPU}}$:** PORTB Pull-up Enable bit
1 = PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled by individual port latch values

bit 6 **INTEDG**: Interrupt Edge Select bit
1 = Interrupt on rising edge of RB0/INT pin
0 = Interrupt on falling edge of RB0/INT pin

bit 5 **T0CS**: TMR0 Clock Source Select bit
1 = Transition on RA4/T0CKI pin
0 = Internal instruction cycle clock (CLKOUT)

bit 4 **T0SE**: TMR0 Source Edge Select bit
1 = Increment on high-to-low transition on RA4/T0CKI pin
0 = Increment on low-to-high transition on RA4/T0CKI pin

bit 3 **PSA**: Prescaler Assignment bit
1 = Prescaler is assigned to the WDT
0 = Prescaler is assigned to the Timer0 module

bit 2-0 **PS2:PS0**: Prescaler Rate Select bits

| Bit Value | TMR0 Rate | WDT Rate |
|---|---|---|
| 000 | 1 : 2 | 1 : 1 |
| 001 | 1 : 4 | 1 : 2 |
| 010 | 1 : 8 | 1 : 4 |
| 011 | 1 : 16 | 1 : 8 |
| 100 | 1 : 32 | 1 : 16 |
| 101 | 1 : 64 | 1 : 32 |
| 110 | 1 : 128 | 1 : 64 |
| 111 | 1 : 256 | 1 : 128 |

| Legend: | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

### 2.3.3 INTCON REGISTER

The INTCON register is a readable and writable register that contains the various enable bits for all interrupt sources.

| **Note:** | Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). |
|---|---|

**REGISTER 2-3: 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 | EEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF |
| bit 7 | | | | | | | bit 0 |

bit 7 **GIE:** Global Interrupt Enable bit
1 = Enables all unmasked interrupts
0 = Disables all interrupts

bit 6 **EEIE**: EE Write Complete Interrupt Enable bit
1 = Enables the EE Write Complete interrupts
0 = Disables the EE Write Complete interrupt

bit 5 **T0IE**: TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt

bit 4 **INTE**: RB0/INT External Interrupt Enable bit
1 = Enables the RB0/INT external interrupt
0 = Disables the RB0/INT external interrupt

bit 3 **RBIE**: RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2 **T0IF**: TMR0 Overflow Interrupt Flag bit
1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow

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

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

| Legend: | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| - n = Value at POR | ’1’ = Bit is set | ’0’ = Bit is cleared | x = Bit is unknown |


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## 2.4 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. If the program counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP. All updates to the PCH register go through the PCLATH register.

### 2.4.1 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).

## 2.5 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).

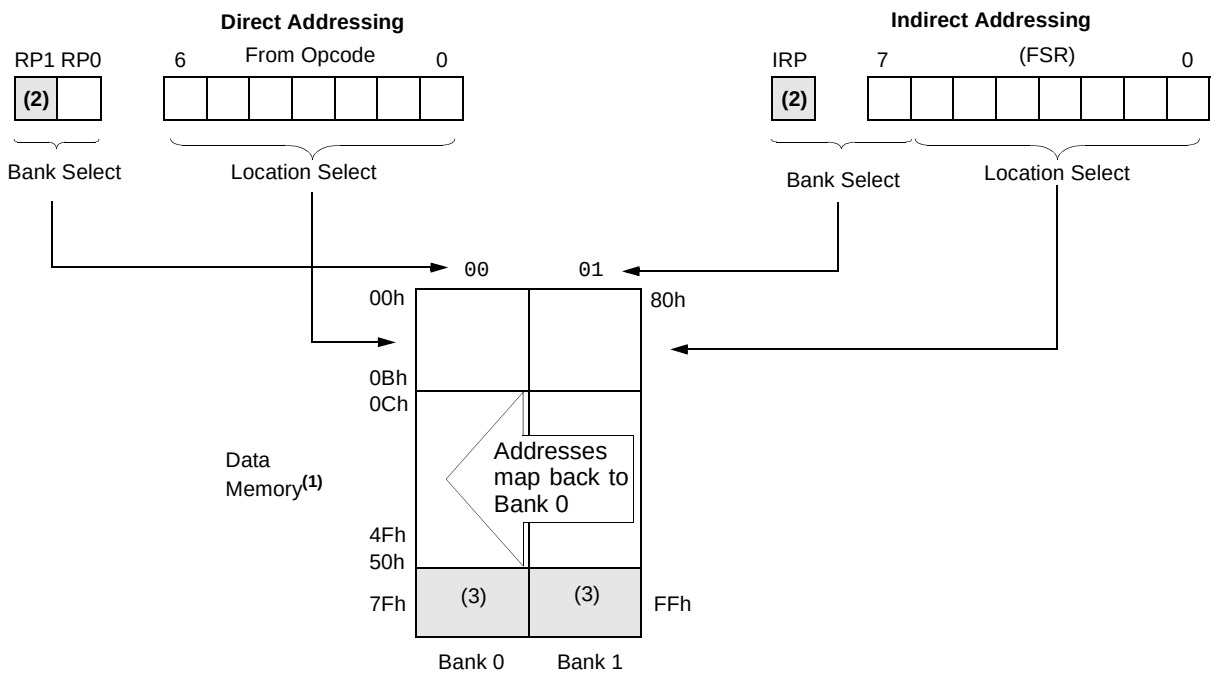
A simple program to clear RAM locations 20h-2Fh using indirect addressing is shown in Example 2-2.

**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 2-3. However, IRP is not used in the PIC16F84A.

**FIGURE 2-3: DIRECT/INDIRECT ADDRESSING**




**Note 1:** For memory map detail, see Figure 2-2.

**2:** Maintain as clear for upward compatibility with future products.

**3:** Not implemented.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## 3.0 DATA EEPROM MEMORY

The EEPROM data memory is readable and writable during normal operation (full VDD range). This memory is not directly mapped in the register file space. Instead it is indirectly addressed through the Special Function Registers. There are four SFRs used to read and write this memory. These registers are:

- EECON1
- EECON2 (not a physically implemented register)
- EEDATA
- EEADR

EEDATA holds the 8-bit data for read/write, and EEADR holds the address of the EEPROM location being accessed. PIC16F84A devices have 64 bytes of data EEPROM with an address range from 0h to 3Fh.

The EEPROM data memory allows byte read and write. A byte write automatically erases the location and writes the new data (erase before write). The EEPROM data memory is rated for high erase/write cycles. The write time is controlled by an on-chip timer. The write-time will vary with voltage and temperature as well as from chip to chip. Please refer to AC specifications for exact limits.

When the device is code protected, the CPU may continue to read and write the data EEPROM memory. The device programmer can no longer access this memory.

Additional information on the Data EEPROM is available in the PIC® Mid-Range Reference Manual (DS33023).

**REGISTER 3-1: EECON1 REGISTER (ADDRESS 88h)**

| U-0 | U-0 | U-0 | R/W-0 | R/W-x | R/W-0 | R/S-0 | R/S-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | EEIF | WRERR | WREN | WR | RD |
| bit 7 | | | | | | | bit 0 |

bit 7-5 **Unimplemented:** Read as '0'

bit 4 **EEIF:** EEPROM Write Operation Interrupt Flag bit
1 = The write operation completed (must be cleared in software)
0 = The write operation is not complete or has not been started

bit 3 **WRERR:** EEPROM Error Flag bit
1 = A write operation is prematurely terminated
(any MCLR Reset or any WDT Reset during normal operation)
0 = The write operation completed

bit 2 **WREN:** EEPROM Write Enable bit
1 = Allows write cycles
0 = Inhibits write to the EEPROM

bit 1 **WR:** Write Control bit
1 = Initiates a write cycle. The bit is cleared by hardware once write is complete. The WR bit can only be set (not cleared) in software.
0 = Write cycle to the EEPROM is complete

bit 0 **RD:** Read Control bit
1 = Initiates an EEPROM read RD is cleared in hardware. The RD bit can only be set (not cleared) in software.
0 = Does not initiate an EEPROM read

| Legend: | | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| - n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

## 3.1 Reading the EEPROM Data Memory

To read a data memory location, the user must write the address to the EEADR register and then set control bit RD (EECON1<0>). The data is available, in the very next cycle, in the EEDATA register; therefore, it can be read in the next instruction. EEDATA will hold this value until another read or until it is written to by the user (during a write operation).

**EXAMPLE 3-1: DATA EEPROM READ**

```
BCF     STATUS, RP0  ; Bank 0
MOVLW   CONFIG_ADDR  ;
MOVWF   EEADR        ; Address to read
BSF     STATUS, RP0  ; Bank 1
BSF     EECON1, RD   ; EE Read
BCF     STATUS, RP0  ; Bank 0
MOVF    EEDATA, W    ; W = EEDATA
```

## 3.2 Writing to the EEPROM Data Memory

To write an EEPROM data location, the user must first write the address to the EEADR register and the data to the EEDATA register. Then the user must follow a specific sequence to initiate the write for each byte.

**EXAMPLE 3-2: DATA EEPROM WRITE**

```
        BSF     STATUS, RP0  ; Bank 1
        BCF     INTCON, GIE  ; Disable INTs.
        BSF     EECON1, WREN ; Enable Write
        MOVLW   55h          ;
Required
Sequence
        MOVWF   EECON2       ; Write 55h
        MOVLW   AAh          ;
        MOVWF   EECON2       ; Write AAh
        BSF     EECON1,WR    ; Set WR bit
                             ;   begin write
        BSF     INTCON, GIE  ; Enable INTs.
```

The write will not initiate if the above sequence is not exactly followed (write 55h to EECON2, write AAh to EECON2, then set WR bit) for each byte. We strongly recommend that interrupts be disabled during this code segment.

Additionally, the WREN bit in EECON1 must be set to enable write. This mechanism prevents accidental writes to data EEPROM due to errant (unexpected) code execution (i.e., lost programs). The user should keep the WREN bit clear at all times, except when updating EEPROM. The WREN bit is not cleared by hardware.

After a write sequence has been initiated, clearing the WREN bit will not affect this write cycle. The WR bit will be inhibited from being set unless the WREN bit is set.

At the completion of the write cycle, the WR bit is cleared in hardware and the EE Write Complete Interrupt Flag bit (EEIF) is set. The user can either enable this interrupt or poll this bit. EEIF must be cleared by software.

## 3.3 Write Verify

Depending on the application, good programming practice may dictate that the value written to the Data EEPROM should be verified (Example 3-3) to the desired value to be written. This should be used in applications where an EEPROM bit will be stressed near the specification limit.

Generally, the EEPROM write failure will be a bit which was written as a '0', but reads back as a '1' (due to leakage off the bit).

**EXAMPLE 3-3: WRITE VERIFY**

```
      BCF   STATUS,RP0 ; Bank 0
      :                ; Any code
      :                ; can go here
      MOVF  EEDATA,W   ; Must be in Bank 0
      BSF   STATUS,RP0 ; Bank 1
READ
      BSF   EECON1, RD ; YES, Read the
                       ; value written
      BCF   STATUS, RP0 ; Bank 0
                       ;
                       ; Is the value written
                       ; (in W reg) and
                       ; read (in EEDATA)
                       ; the same?
                       ;
      SUBWF EEDATA, W  ;
      BTFSS STATUS, Z  ; Is difference 0?
      GOTO  WRITE_ERR  ; NO, Write error
```

**TABLE 3-1: REGISTERS/BITS ASSOCIATED WITH DATA EEPROM**

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on Power-on Reset | Value on all other RESETS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 08h | EEDATA | EEPROM Data Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 09h | EEADR | EEPROM Address Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 88h | EECON1 | — | — | — | EEIF | WRERR | WREN | WR | RD | ---0 x000 | ---0 q000 |
| 89h | EECON2 | EEPROM Control Register 2 | | | | | | | | ---- ---- | ---- ---- |

Legend: x = unknown, u = unchanged, - = unimplemented, read as '0', q = value depends upon condition.
Shaded cells are not used by data EEPROM.


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## 4.0 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 PIC® Mid-Range Reference Manual (DS33023).

### 4.1 PORTA and TRISA Registers

PORTA is a 5-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'. |
|---|---|

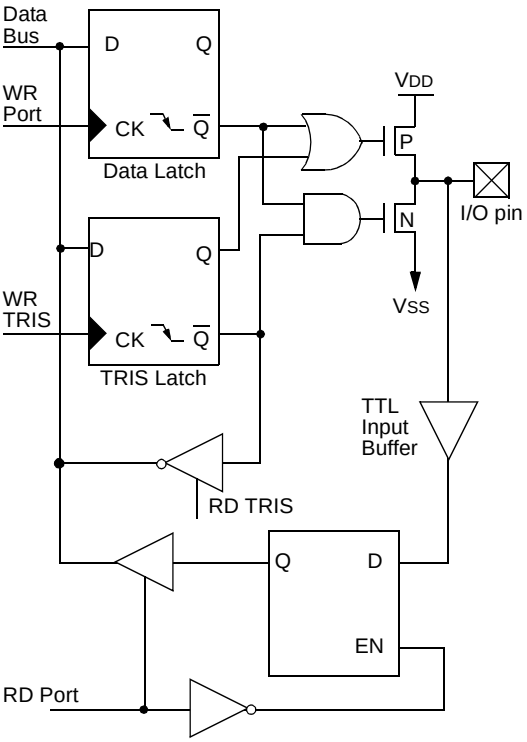
Reading the PORTA register reads the status of the pins, whereas writing to it will write to the port latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read. This value is modified and then written to the port data latch.

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.

**EXAMPLE 4-1: INITIALIZING PORTA**

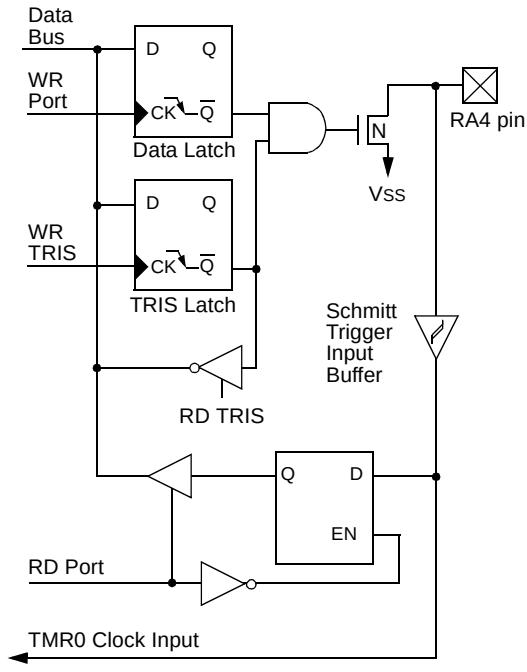
```
BCF     STATUS, RP0 ;
CLRF    PORTA       ; Initialize PORTA by
                    ; clearing output
                    ; data latches
BSF     STATUS, RP0 ; Select Bank 1
MOVLW   0x0F        ; Value used to
                    ; initialize data
                    ; direction
MOVWF   TRISA       ; Set RA<3:0> as inputs
                    ; RA4 as output
                    ; TRISA<7:5> are always
                    ; read as '0'.
```

**FIGURE 4-1: BLOCK DIAGRAM OF PINS RA3:RA0**




**Note:** I/O pins have protection diodes to VDD and VSS.

**FIGURE 4-2: BLOCK DIAGRAM OF PIN RA4**




**Note:** I/O pins have protection diodes to VDD and VSS.

**TABLE 4-1: PORTA FUNCTIONS**

| Name | Bit0 | Buffer Type | Function |
|---|---|---|---|
| RA0 | bit0 | TTL | Input/output |
| RA1 | bit1 | TTL | Input/output |
| RA2 | bit2 | TTL | Input/output |
| RA3 | bit3 | TTL | Input/output |
| RA4/T0CKI | bit4 | ST | Input/output or external clock input for TMR0.<br>Output is open drain type. |

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

**TABLE 4-2: 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 Power-on Reset | Value on all other RESETS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 05h | PORTA | — | — | — | RA4/T0CKI | RA3 | RA2 | RA1 | RA0 | ---x xxxx | ---u uuuu |
| 85h | TRISA | — | — | — | TRISA4 | TRISA3 | TRISA2 | TRISA1 | TRISA0 | ---1 1111 | ---1 1111 |

Legend: x = unknown, u = unchanged, - = unimplemented, read as '0'. Shaded cells are unimplemented, read as '0'.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## 4.2 PORTB and TRISB Registers

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 4-2: INITIALIZING PORTB**

```
BCF     STATUS, RP0 ;
CLRF    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 $\overline{\text{RBPU}}$ (OPTION<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.

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:

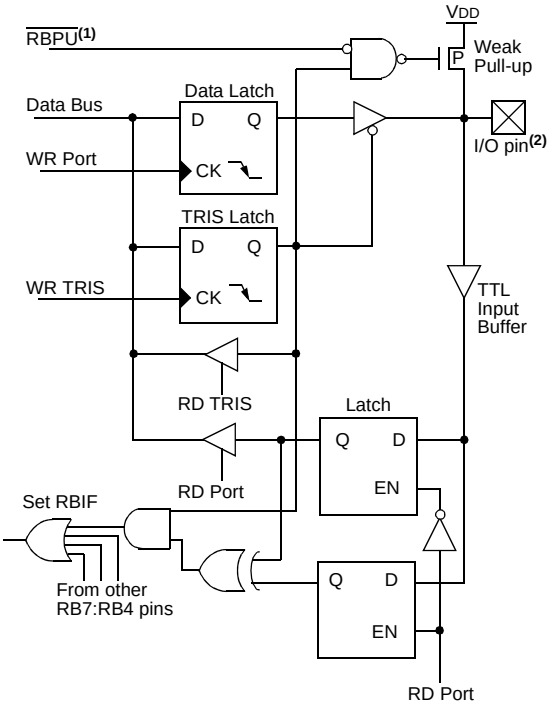
a) Any read or write of PORTB. This will end the mismatch condition.

b) 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.

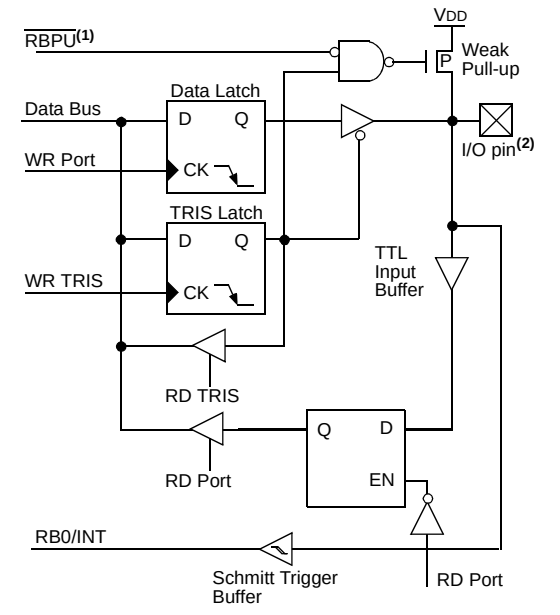
**FIGURE 4-3: BLOCK DIAGRAM OF PINS RB7:RB4**




**Note 1:** TRISB = '1' enables weak pull-up (if $\overline{\text{RBPU}}$ = '0' in the OPTION_REG register).

**2:** I/O pins have diode protection to VDD and VSS.

**FIGURE 4-4: BLOCK DIAGRAM OF PINS RB3:RB0**




**Note 1:** TRISB = '1' enables weak pull-up (if $\overline{\text{RBPU}}$ = '0' in the OPTION_REG register).

**2:** I/O pins have diode protection to VDD and VSS.

**TABLE 4-3: PORTB FUNCTIONS**

| Name | Bit | Buffer Type | I/O Consistency Function |
|---|---|---|---|
| RB0/INT | bit0 | TTL/ST(1) | Input/output pin or external interrupt input.<br>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).<br>Internal software programmable weak pull-up. |
| RB5 | bit5 | TTL | Input/output pin (with interrupt-on-change).<br>Internal software programmable weak pull-up. |
| RB6 | bit6 | TTL/ST(2) | Input/output pin (with interrupt-on-change).<br>Internal software programmable weak pull-up. Serial programming clock. |
| RB7 | bit7 | TTL/ST(2) | Input/output pin (with interrupt-on-change).<br>Internal software programmable weak pull-up. Serial programming data. |

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

**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 4-4: 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 Power-on Reset | Value on all other RESETS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 06h | PORTB | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0/INT | xxxx xxxx | uuuu uuuu |
| 86h | TRISB | TRISB7 | TRISB6 | TRISB5 | TRISB4 | TRISB3 | TRISB2 | TRISB1 | TRISB0 | 1111 1111 | 1111 1111 |
| 81h | OPTION_REG | RBPU | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 | 1111 1111 | 1111 1111 |
| 0Bh,8Bh | INTCON | GIE | EEIE | T0IE | INTE | RBIE | T0IF | INTF | RBIF | 0000 000x | 0000 000u |

Legend: x = unknown, u = unchanged. Shaded cells are not used by PORTB.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## 5.0 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 5-1 is a simplified block diagram of the Timer0 module.

Additional information on timer modules is available in the PIC® Mid-Range Reference Manual (DS33023).

### 5.1 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). Also, there is a delay in the actual incrementing of Timer0 after synchronization.

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

### 5.2 Prescaler

An 8-bit counter is available as a prescaler for the Timer0 module, or as a postscaler for the Watchdog Timer, respectively (Figure 5-2). 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.

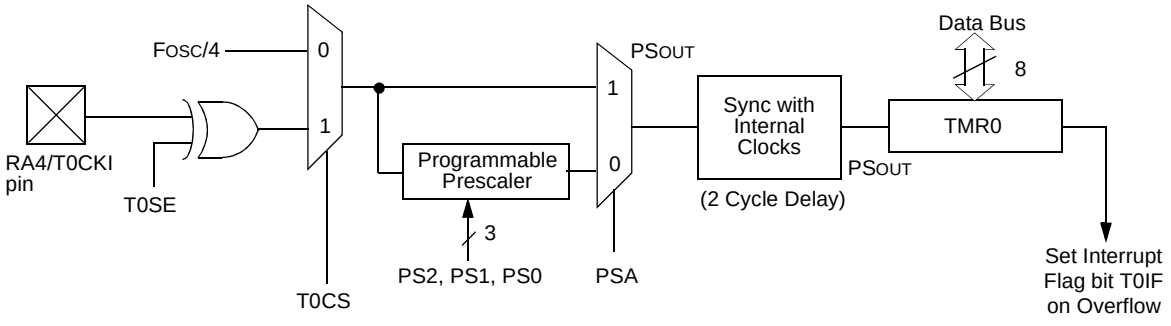
Clearing bit PSA will assign the prescaler to the Timer0 module. When the prescaler is assigned to the Timer0 module, prescale values of 1:2, 1:4, ..., 1:256 are selectable.

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,` 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 5-1: TIMER0 BLOCK DIAGRAM**




**Note 1:** T0CS, T0SE, PSA, PS2:PS0 (OPTION_REG<5:0>).
**2:** The prescaler is shared with Watchdog Timer (refer to Figure 5-2 for detailed block diagram).

### 5.2.1 SWITCHING PRESCALER ASSIGNMENT

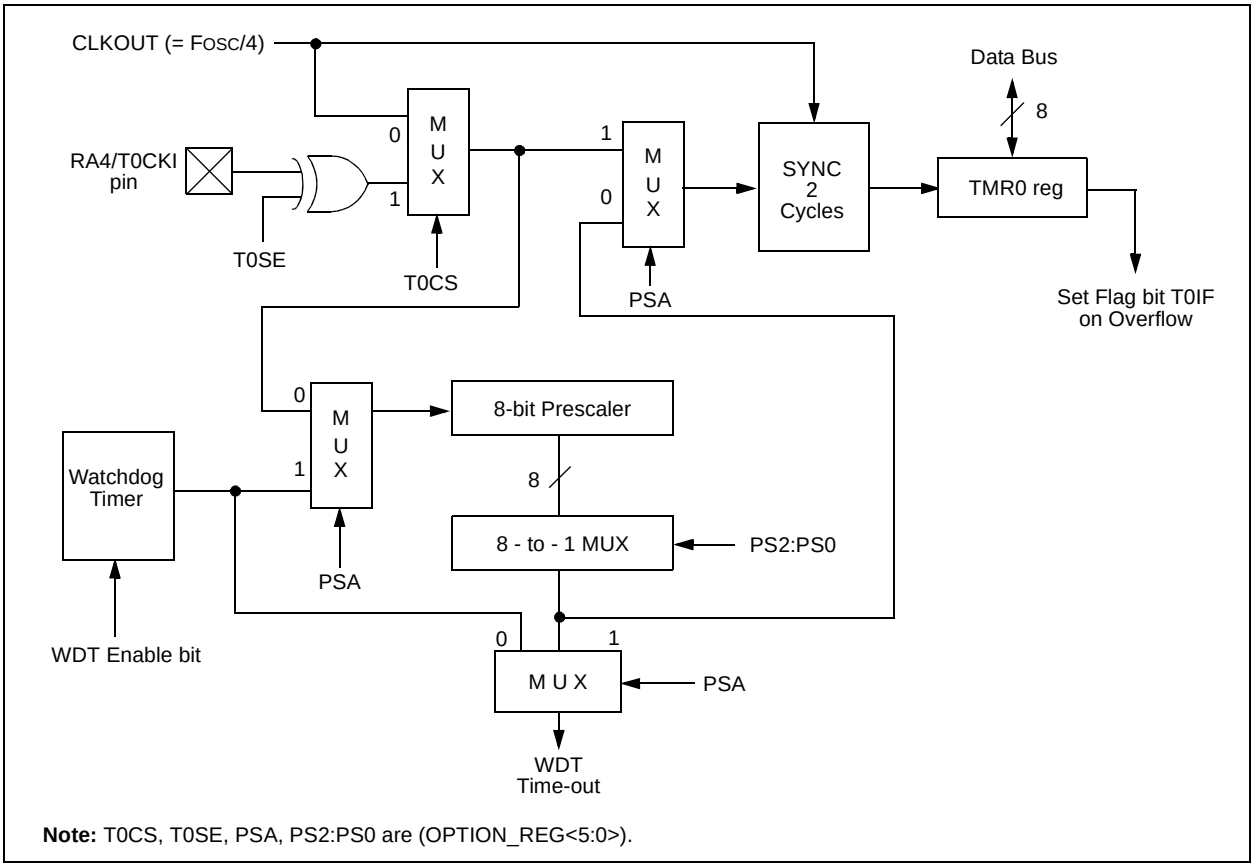
The prescaler assignment is fully under software control (i.e., it can be changed “on the fly” during program execution).

| | |
|---|---|
| **Note:** | To avoid an unintended device RESET, a specific instruction sequence (shown in the PIC® 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. |

## 5.3 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 5-2: BLOCK DIAGRAM OF THE TIMER0/WDT PRESCALER**




**Note:** T0CS, T0SE, PSA, PS2:PS0 are (OPTION_REG<5:0>).

**TABLE 5-1: 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 Register | | | | | | | | xxxx xxxx | uuuu uuuu |
| 0Bh,8Bh | INTCON | GIE | EEIE | 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 | | | | | ---1 1111 | ---1 1111 |

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by Timer0.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## 6.0 SPECIAL FEATURES OF THE CPU

What sets a microcontroller apart from other processors are special circuits to deal with the needs of real time applications. The PIC16F84A has a host of such features intended to maximize system reliability, minimize cost through elimination of external components, provide power saving operating modes and offer code protection. These features are:

- OSC Selection
- RESET
  - Power-on Reset (POR)
  - Power-up Timer (PWRT)
  - Oscillator Start-up Timer (OST)
- Interrupts
- Watchdog Timer (WDT)
- SLEEP
- Code Protection
- ID Locations
- In-Circuit Serial Programming™ (ICSP™)

The PIC16F84A has 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 of 72 ms (nominal) on power-up only. This design keeps the device in RESET while the power supply stabilizes. With these two timers on-chip, most applications need no external RESET circuitry.

SLEEP mode offers a very low current power-down mode. The user can wake-up from SLEEP through external RESET, Watchdog Timer Time-out or through an interrupt. Several oscillator options are provided 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 the various options.

Additional information on special features is available in the PIC® Mid-Range Reference Manual (DS33023).

### 6.1 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.

Address 2007h is beyond the user program memory space and it belongs to the special test/configuration memory space (2000h - 3FFFh). This space can only be accessed during programming.

**REGISTER 6-1: PIC16F84A CONFIGURATION WORD**

| R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u | R/P-u |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CP | CP | CP | CP | CP | CP | CP | CP | CP | CP | $\overline{\text{PWRTE}}$ | WDTE | F0SC1 | F0SC0 |
| bit13 | | | | | | | | | | | | | bit0 |

bit 13-4 **CP:** Code Protection bit
1 = Code protection disabled
0 = All program memory is code protected

bit 3 **$\overline{\text{PWRTE}}$**: Power-up Timer Enable bit
1 = Power-up Timer is disabled
0 = Power-up Timer is enabled

bit 2 **WDTE**: Watchdog Timer Enable bit
1 = WDT enabled
0 = WDT disabled

bit 1-0 **FOSC1:FOSC0**: Oscillator Selection bits
11 = RC oscillator
10 = HS oscillator
01 = XT oscillator
00 = LP oscillator

## 6.2 Oscillator Configurations

### 6.2.1 OSCILLATOR TYPES

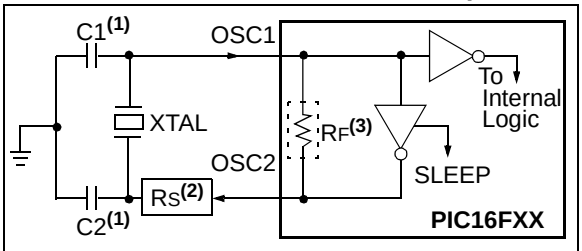
The PIC16F84A can be operated in four different oscillator modes. The user can program two configuration bits (FOSC1 and FOSC0) to select one of these four modes:

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

### 6.2.2 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 6-1).

**FIGURE 6-1: CRYSTAL/CERAMIC RESONATOR OPERATION (HS, XT OR LP OSC CONFIGURATION)**




**Note 1:** See Table 6-1 for recommended values of C1 and C2.

**2:** A series resistor (RS) may be required for AT strip cut crystals.

The PIC16F84A 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 6-2).

**FIGURE 6-2: EXTERNAL CLOCK INPUT OPERATION (HS, XT OR LP OSC CONFIGURATION)**

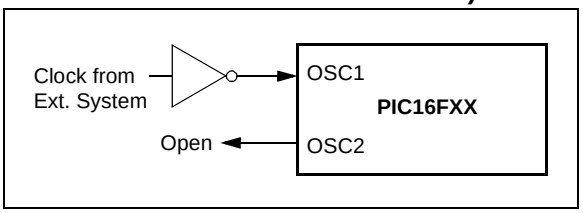



**TABLE 6-1: CAPACITOR SELECTION FOR CERAMIC RESONATORS**

| Ranges Tested: | | | |
|---|---|---|---|
| **Mode** | **Freq** | **OSC1/C1** | **OSC2/C2** |
| XT | 455 kHz | 47 - 100 pF | 47 - 100 pF |
| | 2.0 MHz | 15 - 33 pF | 15 - 33 pF |
| | 4.0 MHz | 15 - 33 pF | 15 - 33 pF |
| HS | 8.0 MHz | 15 - 33 pF | 15 - 33 pF |
| | 10.0 MHz | 15 - 33 pF | 15 - 33 pF |

**Note:** Recommended values of C1 and C2 are identical to the ranges tested in this table. Higher capacitance increases the stability of the oscillator, but also increases the start-up time. These values are for design guidance only. Since each resonator has its own characteristics, the user should consult the resonator manufacturer for the appropriate values of external components.

**Note:** When using resonators with frequencies above 3.5 MHz, the use of HS mode rather than XT mode, is recommended. HS mode may be used at any VDD for which the controller is rated.


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**TABLE 6-2: CAPACITOR SELECTION FOR CRYSTAL OSCILLATOR**

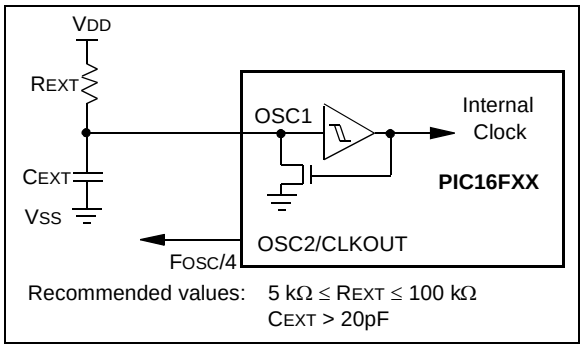
| Mode | Freq | OSC1/C1 | OSC2/C2 |
|---|---|---|---|
| LP | 32 kHz | 68 - 100 pF | 68 - 100 pF |
| | 200 kHz | 15 - 33 pF | 15 - 33 pF |
| XT | 100 kHz | 100 - 150 pF | 100 - 150 pF |
| | 2 MHz | 15 - 33 pF | 15 - 33 pF |
| | 4 MHz | 15 - 33 pF | 15 - 33 pF |
| HS | 4 MHz | 15 - 33 pF | 15 - 33 pF |
| | 20 MHz | 15 - 33 pF | 15 - 33 pF |

**Note:** Higher capacitance increases the stability of the oscillator, but also increases the start-up time. These values are for design guidance only. Rs may be required in HS mode, as well as XT mode, to avoid overdriving crystals with low drive level specification. Since each crystal has its own characteristics, the user should consult the crystal manufacturer for appropriate values of external components.
For $V_{DD}$ > 4.5V, C1 = C2 ≈ 30 pF is recommended.

### 6.2.3 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 ($R_{EXT}$) values, 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 also affects the oscillation frequency, especially for low $C_{EXT}$ values. The user needs to take into account variation, due to tolerance of the external R and C components. Figure 6-3 shows how an R/C combination is connected to the PIC16F84A.

**FIGURE 6-3: RC OSCILLATOR MODE**



## 6.3 RESET

The PIC16F84A differentiates between various kinds of RESET:

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

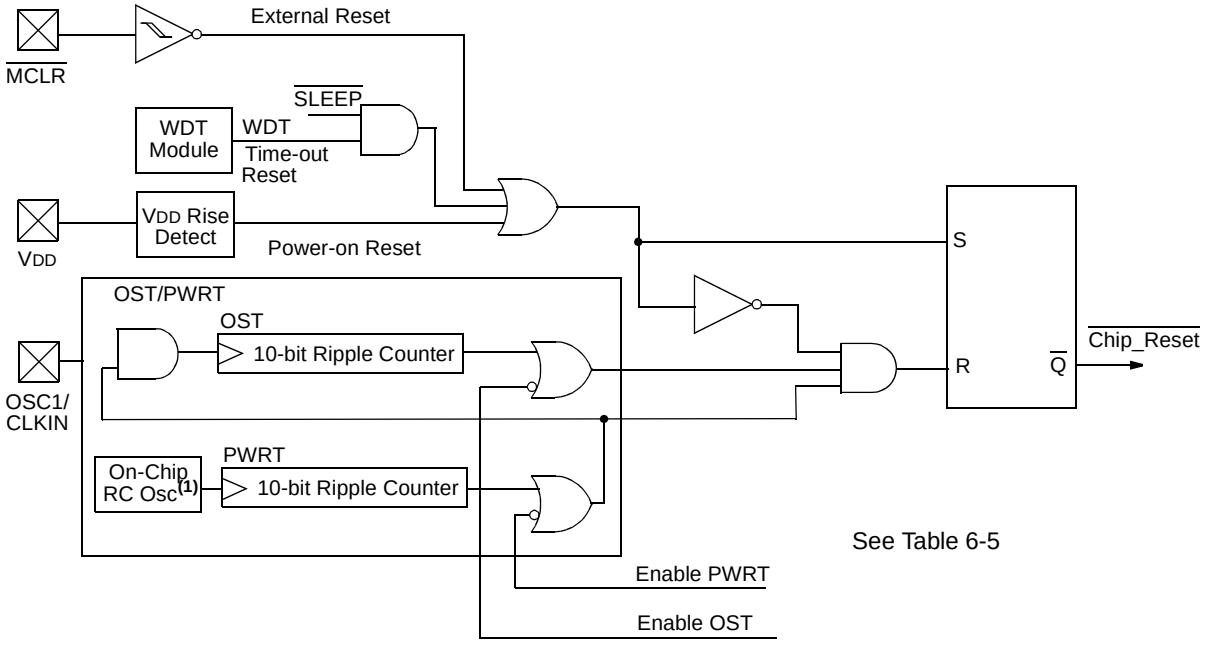
Figure 6-4 shows a simplified block diagram of the On-Chip RESET Circuit. The $\overline{MCLR}$ Reset path has a noise filter to ignore small pulses. The electrical specifications state the pulse width requirements for the $\overline{MCLR}$ pin.

Some registers are not affected in any RESET condition; their status is unknown on a POR and unchanged in any other RESET. Most other registers are reset to a "RESET state" on POR, $\overline{MCLR}$ or WDT Reset during normal operation and on $\overline{MCLR}$ during SLEEP. They are not affected by a WDT Reset during SLEEP, since this RESET is viewed as the resumption of normal operation.

Table 6-3 gives a description of RESET conditions for the program counter (PC) and the STATUS register. Table 6-4 gives a full description of RESET states for all registers.

The $\overline{TO}$ and $\overline{PD}$ bits are set or cleared differently in different RESET situations (Section 6.7). These bits are used in software to determine the nature of the RESET.

**FIGURE 6-4: SIMPLIFIED BLOCK DIAGRAM OF ON-CHIP RESET CIRCUIT**




**Note 1:** This is a separate oscillator from the RC oscillator of the CLKIN pin.
**2:** See Table 6-5.

**TABLE 6-3: RESET CONDITION FOR PROGRAM COUNTER AND THE STATUS REGISTER**

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

Legend: u = unchanged, x = unknown
**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).


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**TABLE 6-4: RESET CONDITIONS FOR ALL REGISTERS**

| Register | Address | Power-on Reset | $\overline{\text{MCLR}}$ during:<br>– normal operation<br>– SLEEP<br>WDT Reset during normal operation | Wake-up from SLEEP:<br>– through interrupt<br>– through WDT Time-out |
|---|---|---|---|---|
| W | — | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| INDF | 00h | ---- ---- | ---- ---- | ---- ---- |
| TMR0 | 01h | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PCL | 02h | 0000 0000 | 0000 0000 | PC + 1(2) |
| STATUS | 03h | 0001 1xxx | 000q quuu(3) | uuuq quuu(3) |
| FSR | 04h | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PORTA(4) | 05h | ---x xxxx | ---u uuuu | ---u uuuu |
| PORTB(5) | 06h | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| EEDATA | 08h | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| EEADR | 09h | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| PCLATH | 0Ah | ---0 0000 | ---0 0000 | ---u uuuu |
| INTCON | 0Bh | 0000 000x | 0000 000u | uuuu uuuu(1) |
| INDF | 80h | ---- ---- | ---- ---- | ---- ---- |
| OPTION_REG | 81h | 1111 1111 | 1111 1111 | uuuu uuuu |
| PCL | 82h | 0000 0000 | 0000 0000 | PC + 1(2) |
| STATUS | 83h | 0001 1xxx | 000q quuu(3) | uuuq quuu(3) |
| FSR | 84h | xxxx xxxx | uuuu uuuu | uuuu uuuu |
| TRISA | 85h | ---1 1111 | ---1 1111 | ---u uuuu |
| TRISB | 86h | 1111 1111 | 1111 1111 | uuuu uuuu |
| EECON1 | 88h | ---0 x000 | ---0 q000 | ---0 uuuu |
| EECON2 | 89h | ---- ---- | ---- ---- | ---- ---- |
| PCLATH | 8Ah | ---0 0000 | ---0 0000 | ---u uuuu |
| INTCON | 8Bh | 0000 000x | 0000 000u | uuuu uuuu(1) |

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

**Note 1:** One or more bits in INTCON 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:** Table 6-3 lists the RESET value for each 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.

## 6.4 Power-on Reset (POR)

A Power-on Reset pulse is generated on-chip when VDD rise is detected (in the range of 1.2V - 1.7V). 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 Power-on Reset. A minimum rise time for VDD must be met for this to operate properly. See Electrical Specifications for details.

When the device starts normal operation (exits the RESET condition), device operating parameters (voltage, frequency, temperature, etc.) 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.

For additional information, refer to Application Note AN607, "*Power-up Trouble Shooting*."

The POR circuit does not produce an internal RESET when VDD declines.

## 6.5 Power-up Timer (PWRT)

The Power-up Timer (PWRT) provides a fixed 72 ms nominal time-out (TPWRT) from POR (Figures 6-6 through 6-9). 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 delay allows the VDD to rise to an acceptable level (possible exception shown in Figure 6-9).

A configuration bit, PWRTE, can enable/disable the PWRT. See Register 6-1 for the operation of the PWRTE bit for a particular device.

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

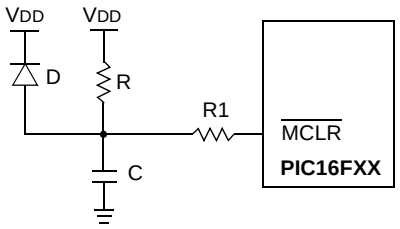
## 6.6 Oscillator Start-up Timer (OST)

The Oscillator Start-up Timer (OST) provides a 1024 oscillator cycle delay (from OSC1 input) after the PWRT delay ends (Figure 6-6, Figure 6-7, Figure 6-8 and Figure 6-9). This ensures the crystal oscillator or resonator has started and stabilized.

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

When VDD rises very slowly, it is possible that the TPWRT time-out and TOST time-out will expire before VDD has reached its final value. In this case (Figure 6-9), an external Power-on Reset circuit may be necessary (Figure 6-5).

**FIGURE 6-5: EXTERNAL POWER-ON RESET CIRCUIT (FOR SLOW VDD POWER-UP)**




**Note 1:** External Power-on Reset circuit is required only if VDD power-up rate is too slow. The diode D helps discharge the capacitor quickly when VDD powers down.

**2:** R < 40 kΩ is recommended to make sure that voltage drop across R does not exceed 0.2V (max leakage current spec on MCLR pin is 5 μA). A larger voltage drop will degrade VIH level on the MCLR pin.

**3:** R1 = 100Ω to 1 kΩ will limit any current flowing into MCLR from external capacitor C, in the event of a MCLR pin breakdown due to ESD or EOS.


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**FIGURE 6-6: TIME-OUT SEQUENCE ON POWER-UP ($\overline{MCLR}$ NOT TIED TO $V_{DD}$): CASE 1**

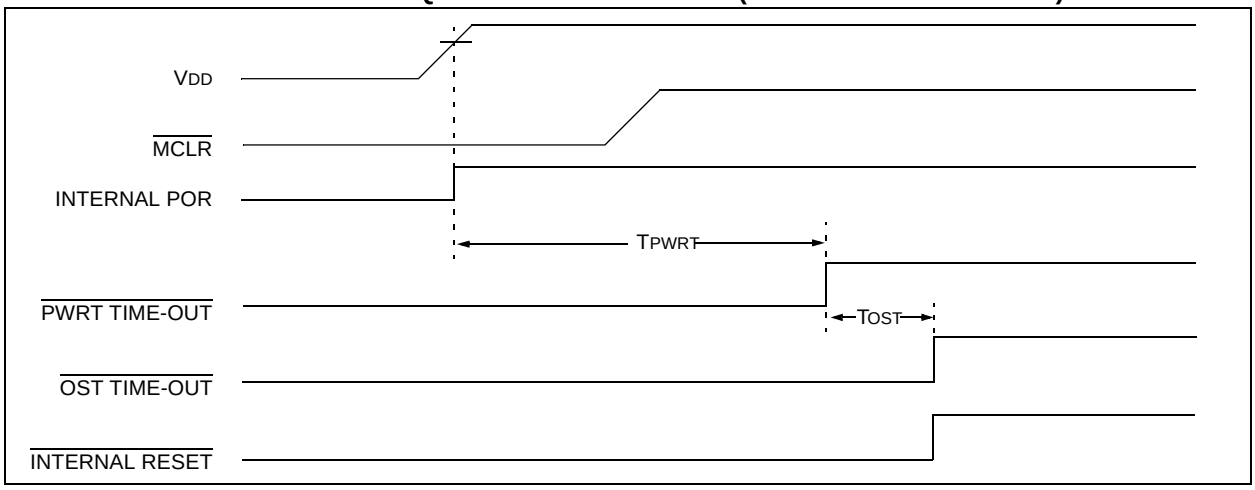



**FIGURE 6-7: TIME-OUT SEQUENCE ON POWER-UP ($\overline{MCLR}$ NOT TIED TO $V_{DD}$): CASE 2**

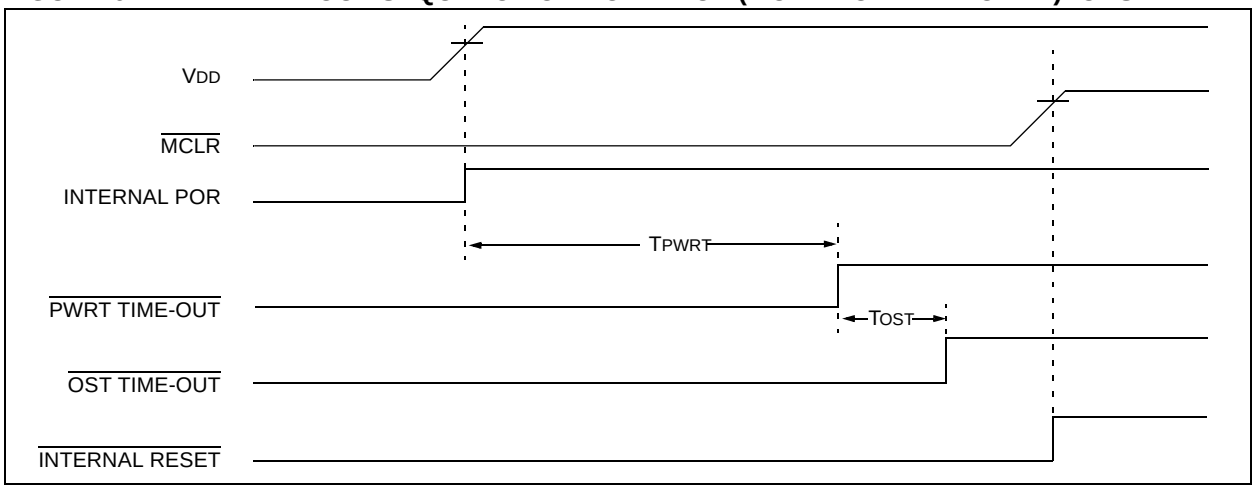



**FIGURE 6-8: TIME-OUT SEQUENCE ON POWER-UP ($\overline{MCLR}$ TIED TO $V_{DD}$): FAST $V_{DD}$ RISE TIME**

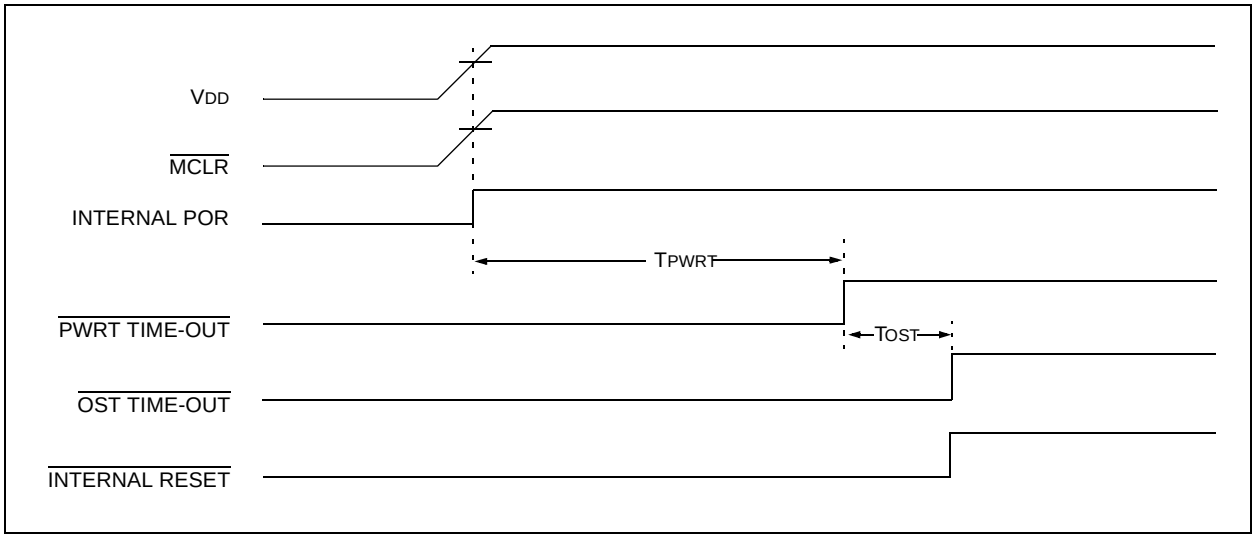
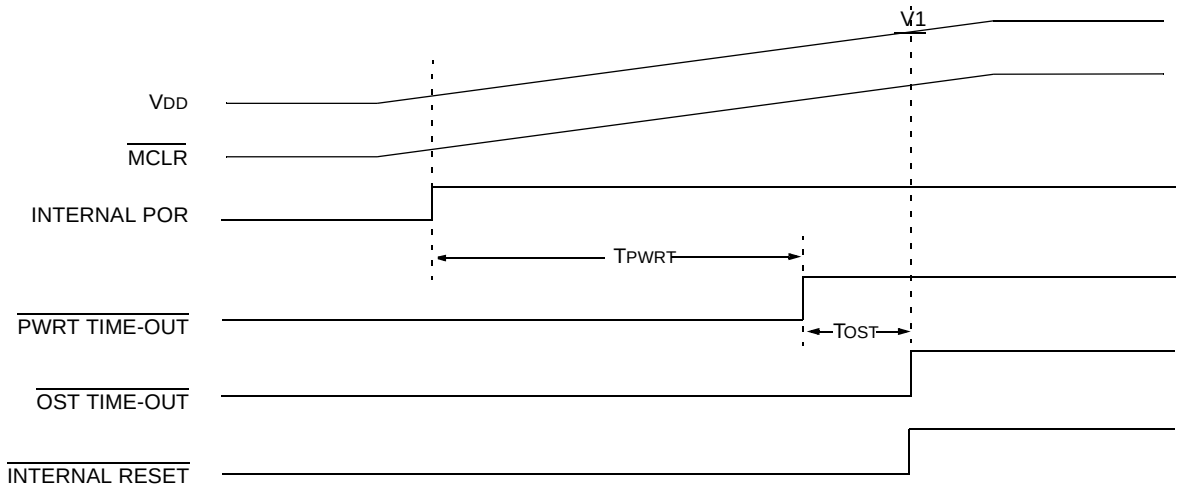


**FIGURE 6-9: TIME-OUT SEQUENCE ON POWER-UP ($\overline{MCLR}$ TIED TO $V_{DD}$): SLOW $V_{DD}$ RISE TIME**




When $V_{DD}$ rises very slowly, it is possible that the $T_{PWRT}$ time-out and $T_{OST}$ time-out will expire before $V_{DD}$ has reached its final value. In this example, the chip will reset properly if, and only if, V1 ≥ $V_{DD}$ min.

## 6.7 Time-out Sequence and Power-down Status Bits ($\overline{TO}$/$\overline{PD}$)

On power-up (Figures 6-6 through 6-9), the time-out sequence is as follows:

1. PWRT time-out is invoked after a POR has expired.
2. Then, the OST is activated.

The total time-out will vary based on oscillator configuration and PWRTE configuration bit status. For example, in RC mode with the PWRT disabled, there will be no time-out at all.

**TABLE 6-5: TIME-OUT IN VARIOUS SITUATIONS**

| Oscillator Configuration | Power-up | | Wake-up from SLEEP |
|---|---|---|---|
| | PWRT Enabled | PWRT Disabled | |
| XT, HS, LP | 72 ms + 1024TOSC | 1024TOSC | 1024TOSC |
| RC | 72 ms | — | — |

Since the time-outs occur from the POR pulse, if $\overline{MCLR}$ is kept low long enough, the time-outs will expire. Then bringing $\overline{MCLR}$ high, execution will begin immediately (Figure 6-6). This is useful for testing purposes or to synchronize more than one PIC16F84A device when operating in parallel.

Table 6-6 shows the significance of the $\overline{TO}$ and $\overline{PD}$ bits. Table 6-3 lists the RESET conditions for some special registers, while Table 6-4 lists the RESET conditions for all the registers.

**TABLE 6-6: STATUS BITS AND THEIR SIGNIFICANCE**

| $\overline{TO}$ | $\overline{PD}$ | Condition |
|---|---|---|
| 1 | 1 | Power-on Reset |
| 0 | x | Illegal, $\overline{TO}$ is set on $\overline{POR}$ |
| x | 0 | Illegal, $\overline{PD}$ is set on $\overline{POR}$ |
| 0 | 1 | WDT Reset (during normal operation) |
| 0 | 0 | WDT Wake-up |
| 1 | 1 | $\overline{MCLR}$ during normal operation |
| 1 | 0 | $\overline{MCLR}$ during SLEEP or interrupt wake-up from SLEEP |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## 6.8 Interrupts

The PIC16F84A has 4 sources of interrupt:

- External interrupt RB0/INT pin
- TMR0 overflow interrupt
- PORTB change interrupts (pins RB7:RB4)
- Data EEPROM write complete interrupt

The interrupt control register (INTCON) records individual interrupt requests in flag bits. It also contains the individual and global interrupt enable bits.

The global interrupt enable bit, GIE (INTCON<7>), enables (if set) all unmasked interrupts or disables (if cleared) all interrupts. Individual interrupts can be disabled through their corresponding enable bits in INTCON register. Bit GIE is cleared on RESET.

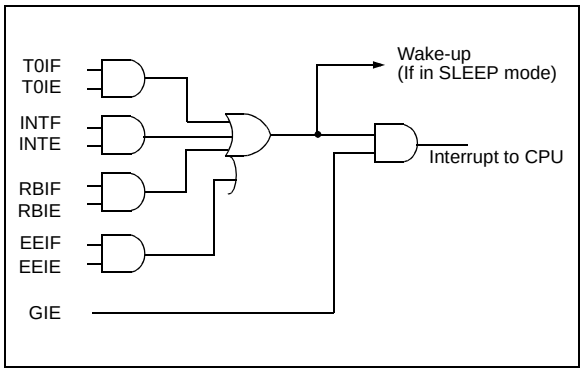
The "return from interrupt" instruction, `RETFIE`, exits interrupt routine as well as sets the GIE bit, which re-enables interrupts.

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

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. For external interrupt events, such as the RB0/INT pin or PORTB change interrupt, the interrupt latency will be three to four instruction cycles. The exact latency depends when the interrupt event occurs. The latency is the same for both one and two cycle instructions. 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 infinite interrupt requests.

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

**FIGURE 6-10: INTERRUPT LOGIC**




### 6.8.1 INT INTERRUPT

External interrupt on RB0/INT pin is edge triggered: either rising if INTEDG bit (OPTION_REG<6>) is set, or falling if INTEDG bit is clear. When a valid edge appears on the RB0/INT pin, the INTF bit (INTCON<1>) is set. This interrupt can be disabled by clearing control bit INTE (INTCON<4>). Flag bit INTF must be cleared in software via the Interrupt Service Routine before re-enabling this interrupt. The INT interrupt can wake the processor from SLEEP (Section 6.11) only if the INTE bit was set prior to going into SLEEP. The status of the GIE bit decides whether the processor branches to the interrupt vector following wake-up.

### 6.8.2 TMR0 INTERRUPT

An overflow (FFh $\rightarrow$ 00h) in TMR0 will set flag bit T0IF (INTCON<2>). The interrupt can be enabled/disabled by setting/clearing enable bit T0IE (INTCON<5>) (Section 5.0).

### 6.8.3 PORTB INTERRUPT

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<3>) (Section 4.2).

| **Note:** | For a change on the I/O pin to be recognized, the pulse width must be at least TCY wide. |
|---|---|

### 6.8.4 DATA EEPROM INTERRUPT

At the completion of a data EEPROM write cycle, flag bit EEIF (EECON1<4>) will be set. The interrupt can be enabled/disabled by setting/clearing enable bit EEIE (INTCON<6>) (Section 3.0).

## 6.9 Context Saving During Interrupts

During an interrupt, only the return PC value is saved on the stack. Typically, users wish to save key register values during an interrupt (e.g., W register and STATUS register). This is implemented in software.

The code in Example 6-1 stores and restores the STATUS and W register's values. The user defined registers, W_TEMP and STATUS_TEMP are the temporary storage locations for the W and STATUS registers values.

Example 6-1 does the following:

a) Stores the W register.
b) Stores the STATUS register in STATUS_TEMP.
c) Executes the Interrupt Service Routine code.
d) Restores the STATUS (and bank select bit) register.
e) Restores the W register.

**EXAMPLE 6-1: SAVING STATUS AND W REGISTERS IN RAM**

```
PUSH    MOVWF   W_TEMP              ; Copy W to TEMP register,
        SWAPF   STATUS,     W       ; Swap status to be saved into W
        MOVWF   STATUS_TEMP         ; Save status to STATUS_TEMP register
ISR     :                           :
        :                           ; Interrupt Service Routine
        :                           ; should configure Bank as required
        :                           ;
POP     SWAPF   STATUS_TEMP,W       ; Swap nibbles in STATUS_TEMP register
                                    ; and place result into W
        MOVWF   STATUS              ; Move W into STATUS register
                                    ; (sets bank to original state)
        SWAPF   W_TEMP,     F       ; Swap nibbles in W_TEMP and place result in W_TEMP
        SWAPF   W_TEMP,     W       ; Swap nibbles in W_TEMP and place result into W
```

## 6.10 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. If the device is in SLEEP mode, a WDT wake-up causes the device to wake-up and continue with normal operation. The WDT can be permanently disabled by programming configuration bit WDTE as a '0' (Section 6.1).

### 6.10.1 WDT PERIOD

The WDT has a nominal time-out period of 18 ms, (with no prescaler). The time-out periods vary with temperature, $V_{DD}$ and process variations from part to part (see DC specs). If longer time-out periods are desired, a prescaler with a division ratio of up to 1:128 can be assigned to the WDT under software control by writing to the OPTION_REG register. Thus, time-out periods up to 2.3 seconds can be realized.

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.

The $\overline{TO}$ bit in the STATUS register will be cleared upon a WDT time-out.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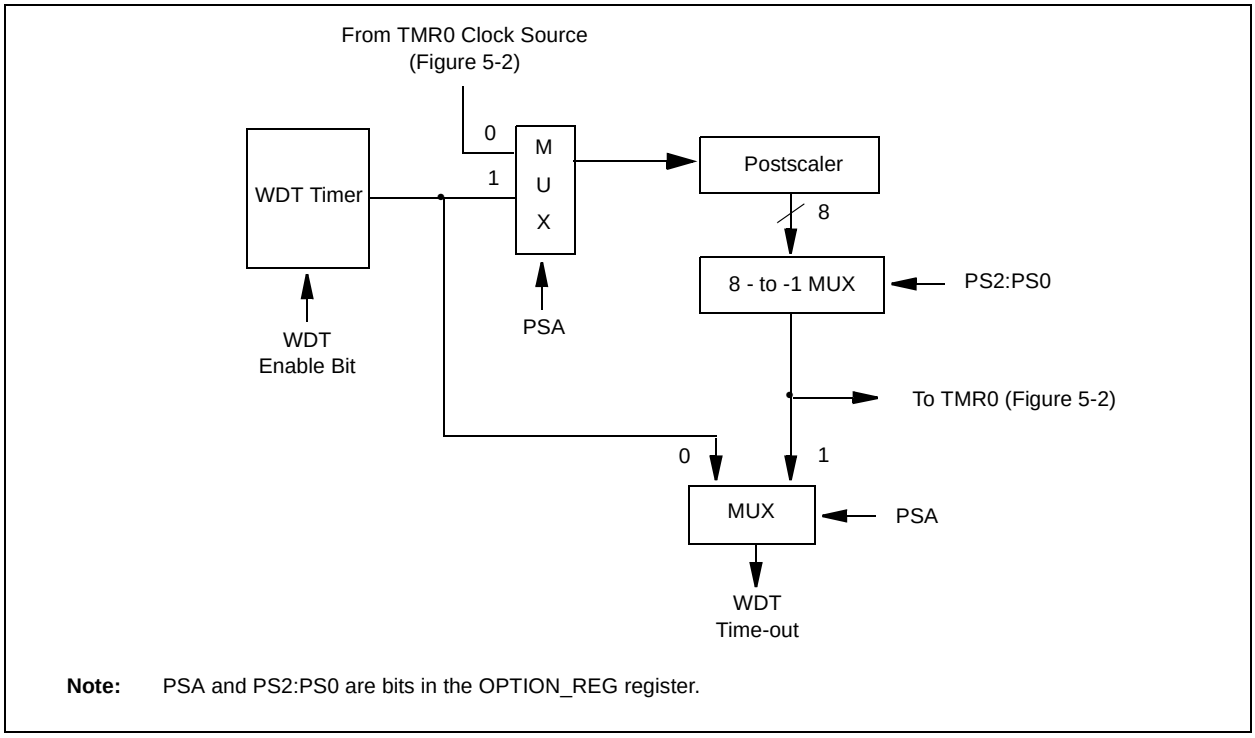
### 6.10.2 WDT PROGRAMMING CONSIDERATIONS

It should also be taken into account that under worst case conditions ($V_{DD}$ = Min., Temperature = Max., Max. WDT Prescaler), it may take several seconds before a WDT time-out occurs.

**FIGURE 6-11: WATCHDOG TIMER BLOCK DIAGRAM**




**Note:** PSA and PS2:PS0 are bits in the OPTION_REG register.

**TABLE 6-7: SUMMARY OF REGISTERS ASSOCIATED WITH THE WATCHDOG TIMER**

| Addr | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Value on Power-on Reset | Value on all other RESETS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007h | Config. bits | (2) | (2) | (2) | (2) | $\overline{\text{PWRTE}}$(1) | WDTE | FOSC1 | FOSC0 | (2) | |
| 81h | OPTION_REG | RBPU | INTEDG | T0CS | T0SE | PSA | PS2 | PS1 | PS0 | 1111 1111 | 1111 1111 |

Legend: x = unknown. Shaded cells are not used by the WDT.

**Note 1:** See Register 6-1 for operation of the $\overline{\text{PWRTE}}$ bit.

**2:** See Register 6-1 and Section 6.12 for operation of the code and data protection bits.

## 6.11 Power-down Mode (SLEEP)

A device may be powered down (SLEEP) and later powered up (wake-up from SLEEP).

### 6.11.1 SLEEP

The Power-down mode is entered by executing the SLEEP instruction.

If enabled, the Watchdog Timer is cleared (but keeps running), the $\overline{PD}$ bit (STATUS<3>) is cleared, the $\overline{TO}$ bit (STATUS<4>) 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 the lowest current consumption in SLEEP mode, place all I/O pins at either $V_{DD}$ or $V_{SS}$, with no external circuitry drawing current from the I/O pins, and disable external clocks. I/O pins that are hi-impedance inputs should be pulled high or low externally to avoid switching currents caused by floating inputs. The T0CKI input should also be at $V_{DD}$ or $V_{SS}$. The contribution from on-chip pull-ups on PORTB should be considered.

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

It should be noted that a RESET generated by a WDT time-out does not drive the $\overline{MCLR}$ pin low.

### 6.11.2 WAKE-UP FROM SLEEP

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

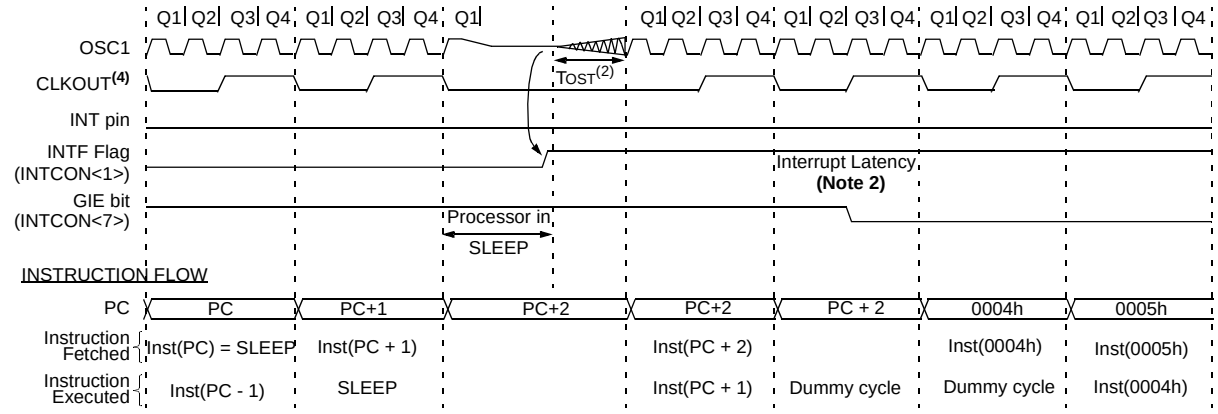
1. External RESET input on $\overline{MCLR}$ pin.
2. WDT wake-up (if WDT was enabled).
3. Interrupt from RB0/INT pin, RB port change, or data EEPROM write complete.

Peripherals cannot generate interrupts during SLEEP, since no on-chip Q clocks are present.

The first event ($\overline{MCLR}$ Reset) will cause a device RESET. The two latter events are considered a continuation of program execution. The $\overline{TO}$ and $\overline{PD}$ bits can be used to determine the cause of a 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).

While 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 occurs 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.

**FIGURE 6-12: WAKE-UP FROM SLEEP THROUGH INTERRUPT**




**Note 1:** XT, HS, or LP oscillator mode assumed.
**2:** $T_{OST}$ = 1024$T_{OSC}$ (drawing not to scale). This delay will not be there for RC osc mode.
**3:** GIE = '1' assumed. In this case after wake-up, the processor jumps to the interrupt routine. If GIE = '0', execution will continue in-line.
**4:** CLKOUT is not available in these osc modes, but shown here for timing reference.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### 6.11.3 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.

## 6.12 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.

## 6.13 ID Locations

Four memory locations (2000h - 2004h) are designated as ID locations to store checksum or other code identification numbers. These locations are not accessible during normal execution but are readable and writable only during program/verify. Only the four Least Significant bits of ID location are usable.

## 6.14 In-Circuit Serial Programming

PIC16F84A 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. Customers can manufacture boards with unprogrammed devices, and then program the microcontroller just before shipping the product, allowing the most recent firmware or custom firmware to be programmed.

For complete details of Serial Programming, please refer to the In-Circuit Serial Programming™ (ICSP™) Guide, (DS30277).

**NOTES:**


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## 7.0 INSTRUCTION SET SUMMARY

Each PIC16CXX 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 7-2 lists **byte-oriented**, **bit-oriented**, and **literal and control** operations. Table 7-1 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 address 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 7-1: 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)<br>The assembler will generate code with x = 0.<br>It is the recommended form of use for compatibility with all Microchip software tools. |
| d | Destination select; d = 0: store result in W,<br>d = 1: store result in file register f.<br>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 μs. If a conditional test is true or the program counter is changed as a result of an instruction, the instruction execution time is 2 μs.

Table 7-2 lists the instructions recognized by the MPASM™ Assembler.

Figure 7-1 shows the general formats that the instructions can have.

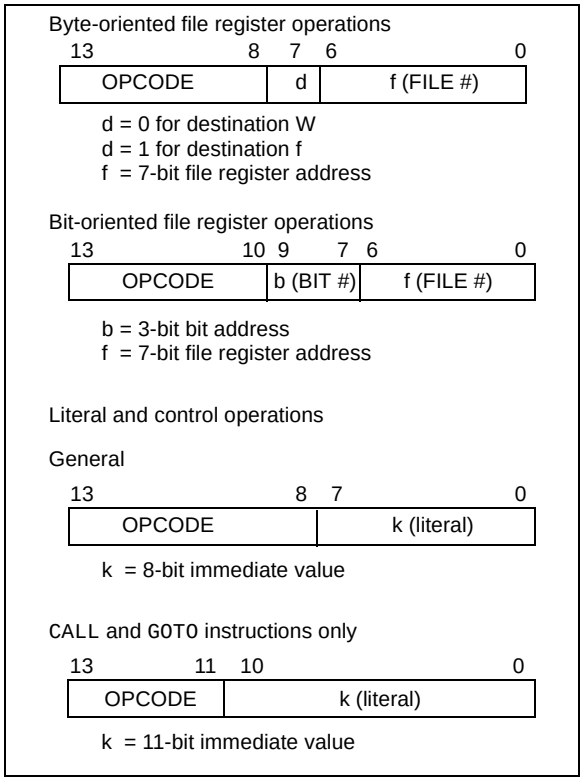
| **Note:** | To maintain upward compatibility with future PIC16CXX products, do not use the OPTION and TRIS instructions. |
|---|---|

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

0xhh

where h signifies a hexadecimal digit.

**FIGURE 7-1: GENERAL FORMAT FOR INSTRUCTIONS**




A description of each instruction is available in the PIC® Mid-Range Reference Manual (DS33023).

**TABLE 7-2: PIC16CXXX INSTRUCTION SET**

| Mnemonic, Operands | | Description | Cycles | 14-Bit Opcode MSb LSb | Status Affected | Notes |
|---|---|---|---|---|---|---|
| **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 lfff ffff | Z | 2 |
| CLRW | - | 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 lfff 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 | | |
| CLRWDT | - | 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'.

**2:** 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.

**3:** 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`.

**Note:** Additional information on the mid-range instruction set is available in the PIC® Mid-Range MCU Family Reference Manual (DS33023).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## 7.1 Instruction Descriptions

| ADDLW | Add Literal and W |
|---|---|
| Syntax: | [*label*] ADDLW k |
| Operands: | $0 \le k \le 255$ |
| Operation: | (W) + k → (W) |
| Status Affected: | C, DC, Z |
| Description: | The contents of the W register are added to the eight-bit literal 'k' and the result is placed in the W register. |

| ADDWF | Add W and f |
|---|---|
| Syntax: | [*label*] ADDWF f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (W) + (f) → (destination) |
| Status Affected: | C, DC, Z |
| Description: | Add the contents of the W register with register 'f'. If 'd' is 0, the result is stored in the W register. If 'd' is 1, the result is stored back in register 'f'. |

| ANDLW | AND Literal with W |
|---|---|
| Syntax: | [*label*] ANDLW k |
| Operands: | $0 \le k \le 255$ |
| Operation: | (W) .AND. (k) → (W) |
| Status Affected: | Z |
| Description: | The contents of W register are AND'ed with the eight-bit literal 'k'. The result is placed in the W register. |

| ANDWF | AND W with f |
|---|---|
| Syntax: | [*label*] ANDWF f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (W) .AND. (f) → (destination) |
| Status Affected: | Z |
| Description: | AND the W register with register 'f'. If 'd' is 0, the result is stored in the W register. If 'd' is 1, the result is stored back in register 'f'. |

| BCF | Bit Clear f |
|---|---|
| Syntax: | [*label*] BCF f,b |
| Operands: | $0 \le f \le 127$<br>$0 \le b \le 7$ |
| Operation: | 0 → (f<b>) |
| Status Affected: | None |
| Description: | Bit 'b' in register 'f' is cleared. |

| BSF | Bit Set f |
|---|---|
| Syntax: | [*label*] BSF f,b |
| Operands: | $0 \le f \le 127$<br>$0 \le b \le 7$ |
| Operation: | 1 → (f<b>) |
| Status Affected: | None |
| Description: | Bit 'b' in register 'f' is set. |

| BTFSS | Bit Test f, Skip if Set |
|---|---|
| Syntax: | [*label*] BTFSS f,b |
| Operands: | $0 \le f \le 127$<br>$0 \le b < 7$ |
| Operation: | skip if (f<b>) = 1 |
| Status Affected: | None |
| Description: | If bit 'b' in register 'f' is '0', the next instruction is executed.<br>If bit 'b' is '1', then the next instruction is discarded and a NOP is executed instead, making this a 2TCY instruction. |

**BTFSC** **Bit Test, Skip if Clear**

Syntax: [*label*] BTFSC f,b

Operands: $0 \le f \le 127$
$0 \le b \le 7$

Operation: skip if (f<b>) = 0

Status Affected: None

Description: If bit 'b' in register 'f' is '1', the next instruction is executed.
If bit 'b' in register 'f' is '0', the next instruction is discarded, and a NOP is executed instead, making this a 2TCY instruction.

**CALL** **Call Subroutine**

Syntax: [ *label* ] CALL k

Operands: $0 \le k \le 2047$

Operation: (PC)+ 1→ TOS,
k → PC<10:0>,
(PCLATH<4:3>) → PC<12:11>

Status Affected: None

Description: Call Subroutine. First, return address (PC+1) is pushed onto the stack. The eleven-bit immediate address is loaded into PC bits <10:0>. The upper bits of the PC are loaded from PCLATH. CALL is a two-cycle instruction.

**CLRF** **Clear f**

Syntax: [*label*] CLRF f

Operands: $0 \le f \le 127$

Operation: 00h → (f)
1 → Z

Status Affected: Z

Description: The contents of register 'f' are cleared and the Z bit is set.

**CLRW** **Clear W**

Syntax: [ *label* ] CLRW

Operands: None

Operation: 00h → (W)
1 → Z

Status Affected: Z

Description: W register is cleared. Zero bit (Z) is set.

**CLRWDT** **Clear Watchdog Timer**

Syntax: [ *label* ] CLRWDT

Operands: None

Operation: 00h → WDT
0 → WDT prescaler,
1 → $\overline{TO}$
1 → $\overline{PD}$

Status Affected: $\overline{TO}$, $\overline{PD}$

Description: CLRWDT instruction resets the Watchdog Timer. It also resets the prescaler of the WDT. Status bits $\overline{TO}$ and $\overline{PD}$ are set.

**COMF** **Complement f**

Syntax: [ *label* ] COMF f,d

Operands: $0 \le f \le 127$
$d \in [0,1]$

Operation: $(\bar{f}) \rightarrow$ (destination)

Status Affected: Z

Description: The contents of register 'f' are complemented. If 'd' is 0, the result is stored in W. If 'd' is 1, the result is stored back in register 'f'.

**DECF** **Decrement f**

Syntax: [*label*] DECF f,d

Operands: $0 \le f \le 127$
$d \in [0,1]$

Operation: (f) - 1 → (destination)

Status Affected: Z

Description: Decrement register 'f'. If 'd' is 0, the result is stored in the W register. If 'd' is 1, the result is stored back in register 'f'.


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**DECFSZ** **Decrement f, Skip if 0**

| | |
|---|---|
| Syntax: | [ *label* ] DECFSZ f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (f) - 1 → (destination);<br>skip if result = 0 |
| Status Affected: | None |
| Description: | The contents of register 'f' are decremented. If 'd' is 0, the result is placed in the W register. If 'd' is 1, the result is placed back in register 'f'.<br>If the result is 1, the next instruction is executed. If the result is 0, then a NOP is executed instead, making it a 2TCY instruction. |

**GOTO** **Unconditional Branch**

| | |
|---|---|
| Syntax: | [ *label* ] GOTO k |
| Operands: | $0 \le k \le 2047$ |
| Operation: | k → PC<10:0><br>PCLATH<4:3> → PC<12:11> |
| Status Affected: | None |
| Description: | GOTO is an unconditional branch. The eleven-bit immediate value is loaded into PC bits <10:0>. The upper bits of PC are loaded from PCLATH<4:3>. GOTO is a two-cycle instruction. |

**INCF** **Increment f**

| | |
|---|---|
| Syntax: | [ *label* ] INCF f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (f) + 1 → (destination) |
| Status Affected: | Z |
| Description: | The contents of register 'f' are incremented. If 'd' is 0, the result is placed in the W register. If 'd' is 1, the result is placed back in register 'f'. |

**INCFSZ** **Increment f, Skip if 0**

| | |
|---|---|
| Syntax: | [ *label* ] INCFSZ f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (f) + 1 → (destination),<br>skip if result = 0 |
| Status Affected: | None |
| Description: | The contents of register 'f' are incremented. If 'd' is 0, the result is placed in the W register. If 'd' is 1, the result is placed back in register 'f'.<br>If the result is 1, the next instruction is executed. If the result is 0, a NOP is executed instead, making it a 2TCY instruction. |

**IORLW** **Inclusive OR Literal with W**

| | |
|---|---|
| Syntax: | [ *label* ] IORLW k |
| Operands: | $0 \le k \le 255$ |
| Operation: | (W) .OR. k → (W) |
| Status Affected: | Z |
| Description: | The contents of the W register are OR'ed with the eight-bit literal 'k'. The result is placed in the W register. |

**IORWF** **Inclusive OR W with f**

| | |
|---|---|
| Syntax: | [ *label* ] IORWF f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (W) .OR. (f) → (destination) |
| Status Affected: | Z |
| Description: | Inclusive OR the W register with register 'f'. If 'd' is 0, the result is placed in the W register. If 'd' is 1, the result is placed back in register 'f'. |

| MOVF | Move f |
|---|---|
| Syntax: | [ *label* ] MOVF f,d |
| Operands: | $0 \le f \le 127$<br>$d \in [0,1]$ |
| Operation: | (f) → (destination) |
| Status Affected: | Z |
| Description: | The contents of register f are moved to a destination dependant upon the status of d. If d = 0, destination is W register. If d = 1, the destination is file register f itself. d = 1 is useful to test a file register, since status flag Z is affected. |

| MOVLW | Move Literal to W |
|---|---|
| Syntax: | [ *label* ] MOVLW k |
| Operands: | $0 \le k \le 255$ |
| Operation: | k → (W) |
| Status Affected: | None |
| Description: | The eight-bit literal 'k' is loaded into W register. The don't cares will assemble as 0's. |

| MOVWF | Move W to f |
|---|---|
| Syntax: | [ *label* ] MOVWF f |
| Operands: | $0 \le f \le 127$ |
| Operation: | (W) → (f) |
| Status Affected: | None |
| Description: | Move data from W register to register 'f'. |

| NOP | No Operation |
|---|---|
| Syntax: | [ *label* ] NOP |
| Operands: | None |
| Operation: | No operation |
| Status Affected: | None |
| Description: | No operation. |

| RETFIE | Return from Interrupt |
|---|---|
| Syntax: | [ *label* ] RETFIE |
| Operands: | None |
| Operation: | TOS → PC,<br>1 → GIE |
| Status Affected: | None |

| RETLW | Return with Literal in W |
|---|---|
| Syntax: | [ *label* ] RETLW k |
| Operands: | $0 \le k \le 255$ |
| Operation: | k → (W);<br>TOS → PC |
| Status Affected: | None |
| Description: | The W register is loaded with the eight-bit literal 'k'. The program counter is loaded from the top of the stack (the return address). This is a two-cycle instruction. |

| RETURN | Return from Subroutine |
|---|---|
| Syntax: | [ *label* ] RETURN |
| Operands: | None |
| Operation: | TOS → PC |
| Status Affected: | None |
| Description: | Return from subroutine. The stack is POPed and the top of the stack (TOS) is loaded into the program counter. This is a two-cycle instruction. |


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**RLF** **Rotate Left f through Carry**

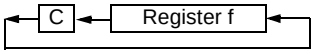
Syntax: [ *label* ] RLF f,d

Operands: $0 \le f \le 127$
$d \in [0,1]$

Operation: See description below

Status Affected: C

Description: The contents of register 'f' are rotated one bit to the left through the Carry Flag. If 'd' is 0, the result is placed in the W register. If 'd' is 1, the result is stored back in register 'f'.




**RRF** **Rotate Right f through Carry**

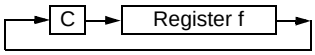
Syntax: [ *label* ] RRF f,d

Operands: $0 \le f \le 127$
$d \in [0,1]$

Operation: See description below

Status Affected: C

Description: The contents of register 'f' are rotated one bit to the right through the Carry Flag. If 'd' is 0, the result is placed in the W register. If 'd' is 1, the result is placed back in register 'f'.




**SLEEP**

Syntax: [ *label* ] SLEEP

Operands: None

Operation: 00h → WDT,
0 → WDT prescaler,
1 → $\overline{TO}$,
0 → $\overline{PD}$

Status Affected: $\overline{TO}$, $\overline{PD}$

Description: The power-down status bit, $\overline{PD}$ is cleared. Time-out status bit, $\overline{TO}$ is set. Watchdog Timer and its prescaler are cleared.
The processor is put into SLEEP mode with the oscillator stopped.

**SUBLW** **Subtract W from Literal**

Syntax: [ *label* ] SUBLW k

Operands: $0 \le k \le 255$

Operation: k - (W) → (W)

Status Affected: C, DC, Z

Description: The W register is subtracted (2's complement method) from the eight-bit literal 'k'. The result is placed in the W register.

**SUBWF** **Subtract W from f**

Syntax: [ *label* ] SUBWF f,d

Operands: $0 \le f \le 127$
$d \in [0,1]$

Operation: (f) - (W) → (destination)

Status Affected: C, DC, Z

Description: Subtract (2's complement method) W register from register 'f'. If 'd' is 0, the result is stored in the W register. If 'd' is 1, the result is stored back in register 'f'.

**SWAPF** **Swap Nibbles in f**

Syntax: [ *label* ] SWAPF f,d

Operands: $0 \le f \le 127$
$d \in [0,1]$

Operation: (f<3:0>) → (destination<7:4>),
(f<7:4>) → (destination<3:0>)

Status Affected: None

Description: The upper and lower nibbles of register 'f' are exchanged. If 'd' is 0, the result is placed in W register. If 'd' is 1, the result is placed in register 'f'.

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| XORLW | Exclusive OR Literal with W |
|---|---|
| Syntax: | [*label*] XORLW k |
| Operands: | $0 \leq k \leq 255$ |
| Operation: | (W) .XOR. k $\rightarrow$ (W) |
| Status Affected: | Z |
| Description: | The contents of the W register are XOR'ed with the eight-bit literal 'k'. The result is placed in the W register. |

| XORWF | Exclusive OR W with f |
|---|---|
| Syntax: | [*label*] XORWF f,d |
| Operands: | $0 \leq f \leq 127$<br>$d \in [0,1]$ |
| Operation: | (W) .XOR. (f) $\rightarrow$ (destination) |
| Status Affected: | Z |
| Description: | Exclusive OR the contents of the W register with register 'f'. If 'd' is 0, the result is stored in the W register. If 'd' is 1, the result is stored back in register 'f'. |


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## 8.0 DEVELOPMENT SUPPORT

The PIC® microcontrollers and dsPIC® digital signal controllers are supported with a full range of software and hardware development tools:

- Integrated Development Environment
  - MPLAB® IDE Software
- Compilers/Assemblers/Linkers
  - MPLAB C Compiler for Various Device Families
  - HI-TECH C® for Various Device Families
  - MPASM™ Assembler
  - MPLINK™ Object Linker/ MPLIB™ Object Librarian
  - MPLAB Assembler/Linker/Librarian for Various Device Families
- Simulators
  - MPLAB SIM Software Simulator
- Emulators
  - MPLAB REAL ICE™ In-Circuit Emulator
- In-Circuit Debuggers
  - MPLAB ICD 3
  - PICkit™ 3 Debug Express
- Device Programmers
  - PICkit™ 2 Programmer
  - MPLAB PM3 Device Programmer
- Low-Cost Demonstration/Development Boards, Evaluation Kits, and Starter Kits

### 8.1 MPLAB Integrated Development Environment Software

The MPLAB IDE software brings an ease of software development previously unseen in the 8/16/32-bit microcontroller market. The MPLAB IDE is a Windows® operating system-based application that contains:

- A single graphical interface to all debugging tools
  - Simulator
  - Programmer (sold separately)
  - In-Circuit Emulator (sold separately)
  - In-Circuit Debugger (sold separately)
- A full-featured editor with color-coded context
- A multiple project manager
- Customizable data windows with direct edit of contents
- High-level source code debugging
- Mouse over variable inspection
- Drag and drop variables from source to watch windows
- Extensive on-line help
- Integration of select third party tools, such as IAR C Compilers

The MPLAB IDE allows you to:

- Edit your source files (either C or assembly)
- One-touch compile or assemble, and download to emulator and simulator tools (automatically updates all project information)
- Debug using:
  - Source files (C or assembly)
  - Mixed C and assembly
  - Machine code

MPLAB IDE supports multiple debugging tools in a single development paradigm, from the cost-effective simulators, through low-cost in-circuit debuggers, to full-featured emulators. This eliminates the learning curve when upgrading to tools with increased flexibility and power.

## 8.2 MPLAB C Compilers for Various Device Families

The MPLAB C Compiler code development systems are complete ANSI C compilers for Microchip's PIC18, PIC24 and PIC32 families of microcontrollers and the dsPIC30 and dsPIC33 families of digital signal controllers. These compilers provide powerful integration capabilities, superior code optimization and ease of use.

For easy source level debugging, the compilers provide symbol information that is optimized to the MPLAB IDE debugger.

## 8.3 HI-TECH C for Various Device Families

The HI-TECH C Compiler code development systems are complete ANSI C compilers for Microchip's PIC family of microcontrollers and the dsPIC family of digital signal controllers. These compilers provide powerful integration capabilities, omniscient code generation and ease of use.

For easy source level debugging, the compilers provide symbol information that is optimized to the MPLAB IDE debugger.

The compilers include a macro assembler, linker, preprocessor, and one-step driver, and can run on multiple platforms.

## 8.4 MPASM Assembler

The MPASM Assembler is a full-featured, universal macro assembler for PIC10/12/16/18 MCUs.

The MPASM Assembler generates relocatable object files for the MPLINK Object Linker, Intel® standard HEX files, MAP files to detail memory usage and symbol reference, absolute LST files that contain source lines and generated machine code and COFF files for debugging.

The MPASM Assembler features include:

- Integration into MPLAB IDE projects
- User-defined macros to streamline assembly code
- Conditional assembly for multi-purpose source files
- Directives that allow complete control over the assembly process

## 8.5 MPLINK Object Linker/ MPLIB Object Librarian

The MPLINK Object Linker combines relocatable objects created by the MPASM Assembler and the MPLAB C18 C Compiler. It can link relocatable objects from precompiled libraries, using directives from a linker script.

The MPLIB Object Librarian manages the creation and modification of library files of precompiled code. When a routine from a library is called from a source file, only the modules that contain that routine will be linked in with the application. This allows large libraries to be used efficiently in many different applications.

The object linker/library features include:

- Efficient linking of single libraries instead of many smaller files
- Enhanced code maintainability by grouping related modules together
- Flexible creation of libraries with easy module listing, replacement, deletion and extraction

## 8.6 MPLAB Assembler, Linker and Librarian for Various Device Families

MPLAB Assembler produces relocatable machine code from symbolic assembly language for PIC24, PIC32 and dsPIC devices. MPLAB C Compiler uses the assembler to produce its object file. The assembler generates relocatable object files that can then be archived or linked with other relocatable object files and archives to create an executable file. Notable features of the assembler include:

- Support for the entire device instruction set
- Support for fixed-point and floating-point data
- Command line interface
- Rich directive set
- Flexible macro language
- MPLAB IDE compatibility


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## 8.7 MPLAB SIM Software Simulator

The MPLAB SIM Software Simulator allows code development in a PC-hosted environment by simulating the PIC MCUs and dsPIC® DSCs on an instruction level. On any given instruction, the data areas can be examined or modified and stimuli can be applied from a comprehensive stimulus controller. Registers can be logged to files for further run-time analysis. The trace buffer and logic analyzer display extend the power of the simulator to record and track program execution, actions on I/O, most peripherals and internal registers.

The MPLAB SIM Software Simulator fully supports symbolic debugging using the MPLAB C Compilers, and the MPASM and MPLAB Assemblers. The software simulator offers the flexibility to develop and debug code outside of the hardware laboratory environment, making it an excellent, economical software development tool.

## 8.8 MPLAB REAL ICE In-Circuit Emulator System

MPLAB REAL ICE In-Circuit Emulator System is Microchip's next generation high-speed emulator for Microchip Flash DSC and MCU devices. It debugs and programs PIC® Flash MCUs and dsPIC® Flash DSCs with the easy-to-use, powerful graphical user interface of the MPLAB Integrated Development Environment (IDE), included with each kit.

The emulator is connected to the design engineer's PC using a high-speed USB 2.0 interface and is connected to the target with either a connector compatible with in-circuit debugger systems (RJ11) or with the new high-speed, noise tolerant, Low-Voltage Differential Signal (LVDS) interconnection (CAT5).

The emulator is field upgradable through future firmware downloads in MPLAB IDE. In upcoming releases of MPLAB IDE, new devices will be supported, and new features will be added. MPLAB REAL ICE offers significant advantages over competitive emulators including low-cost, full-speed emulation, run-time variable watches, trace analysis, complex breakpoints, a ruggedized probe interface and long (up to three meters) interconnection cables.

## 8.9 MPLAB ICD 3 In-Circuit Debugger System

MPLAB ICD 3 In-Circuit Debugger System is Microchip's most cost effective high-speed hardware debugger/programmer for Microchip Flash Digital Signal Controller (DSC) and microcontroller (MCU) devices. It debugs and programs PIC® Flash microcontrollers and dsPIC® DSCs with the powerful, yet easy-to-use graphical user interface of MPLAB Integrated Development Environment (IDE).

The MPLAB ICD 3 In-Circuit Debugger probe is connected to the design engineer's PC using a high-speed USB 2.0 interface and is connected to the target with a connector compatible with the MPLAB ICD 2 or MPLAB REAL ICE systems (RJ-11). MPLAB ICD 3 supports all MPLAB ICD 2 headers.

## 8.10 PICkit 3 In-Circuit Debugger/ Programmer and PICkit 3 Debug Express

The MPLAB PICkit 3 allows debugging and programming of PIC® and dsPIC® Flash microcontrollers at a most affordable price point using the powerful graphical user interface of the MPLAB Integrated Development Environment (IDE). The MPLAB PICkit 3 is connected to the design engineer's PC using a full speed USB interface and can be connected to the target via an Microchip debug (RJ-11) connector (compatible with MPLAB ICD 3 and MPLAB REAL ICE). The connector uses two device I/O pins and the reset line to implement in-circuit debugging and In-Circuit Serial Programming™.

The PICkit 3 Debug Express include the PICkit 3, demo board and microcontroller, hookup cables and CDROM with user's guide, lessons, tutorial, compiler and MPLAB IDE software.

## 8.11 PICkit 2 Development Programmer/Debugger and PICkit 2 Debug Express

The PICkit™ 2 Development Programmer/Debugger is a low-cost development tool with an easy to use interface for programming and debugging Microchip's Flash families of microcontrollers. The full featured Windows® programming interface supports baseline (PIC10F, PIC12F5xx, PIC16F5xx), midrange (PIC12F6xx, PIC16F), PIC18F, PIC24, dsPIC30, dsPIC33, and PIC32 families of 8-bit, 16-bit, and 32-bit microcontrollers, and many Microchip Serial EEPROM products. With Microchip's powerful MPLAB Integrated Development Environment (IDE) the PICkit™ 2 enables in-circuit debugging on most PIC® microcontrollers. In-Circuit-Debugging runs, halts and single steps the program while the PIC microcontroller is embedded in the application. When halted at a breakpoint, the file registers can be examined and modified.

The PICkit 2 Debug Express include the PICkit 2, demo board and microcontroller, hookup cables and CDROM with user's guide, lessons, tutorial, compiler and MPLAB IDE software.

## 8.12 MPLAB PM3 Device Programmer

The MPLAB PM3 Device Programmer is a universal, CE compliant device programmer with programmable voltage verification at $V_{DDMIN}$ and $V_{DDMAX}$ for maximum reliability. It features a large LCD display (128 x 64) for menus and error messages and a modular, detachable socket assembly to support various package types. The ICSP™ cable assembly is included as a standard item. In Stand-Alone mode, the MPLAB PM3 Device Programmer can read, verify and program PIC devices without a PC connection. It can also set code protection in this mode. The MPLAB PM3 connects to the host PC via an RS-232 or USB cable. The MPLAB PM3 has high-speed communications and optimized algorithms for quick programming of large memory devices and incorporates an MMC card for file storage and data applications.

## 8.13 Demonstration/Development Boards, Evaluation Kits, and Starter Kits

A wide variety of demonstration, development and evaluation boards for various PIC MCUs and dsPIC DSCs allows quick application development on fully functional systems. Most boards include prototyping areas for adding custom circuitry and provide application firmware and source code for examination and modification.

The boards support a variety of features, including LEDs, temperature sensors, switches, speakers, RS-232 interfaces, LCD displays, potentiometers and additional EEPROM memory.

The demonstration and development boards can be used in teaching environments, for prototyping custom circuits and for learning about various microcontroller applications.

In addition to the PICDEM™ and dsPICDEM™ demonstration/development board series of circuits, Microchip has a line of evaluation kits and demonstration software for analog filter design, KEELOQ® security ICs, CAN, IrDA®, PowerSmart battery management, SEEVAL® evaluation system, Sigma-Delta ADC, flow rate sensing, plus many more.

Also available are starter kits that contain everything needed to experience the specified device. This usually includes a single application and debug capability, all on one board.

Check the Microchip web page (www.microchip.com) for the complete list of demonstration, development and evaluation kits.


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## 9.0 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 $V_{SS}$ ..... -0.3 to +7.5V

Voltage on $\overline{MCLR}$ with respect to $V_{SS}$ **(1)** ..... -0.3 to +14V

Voltage on RA4 with respect to $V_{SS}$ ..... -0.3 to +8.5V

Total power dissipation **(2)** ..... 800 mW

Maximum current out of $V_{SS}$ pin ..... 150 mA

Maximum current into $V_{DD}$ pin ..... 100 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 ..... 80 mA

Maximum current sourced by PORTA ..... 50 mA

Maximum current sunk by PORTB ..... 150 mA

Maximum current sourced by PORTB ..... 100 mA

**Note 1:** Voltage spikes below $V_{SS}$ at the $\overline{MCLR}$ 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 $\overline{MCLR}$ pin rather than pulling this pin directly to $V_{SS}$.

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

† 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.

**FIGURE 9-1: PIC16F84A-20 VOLTAGE-FREQUENCY GRAPH**

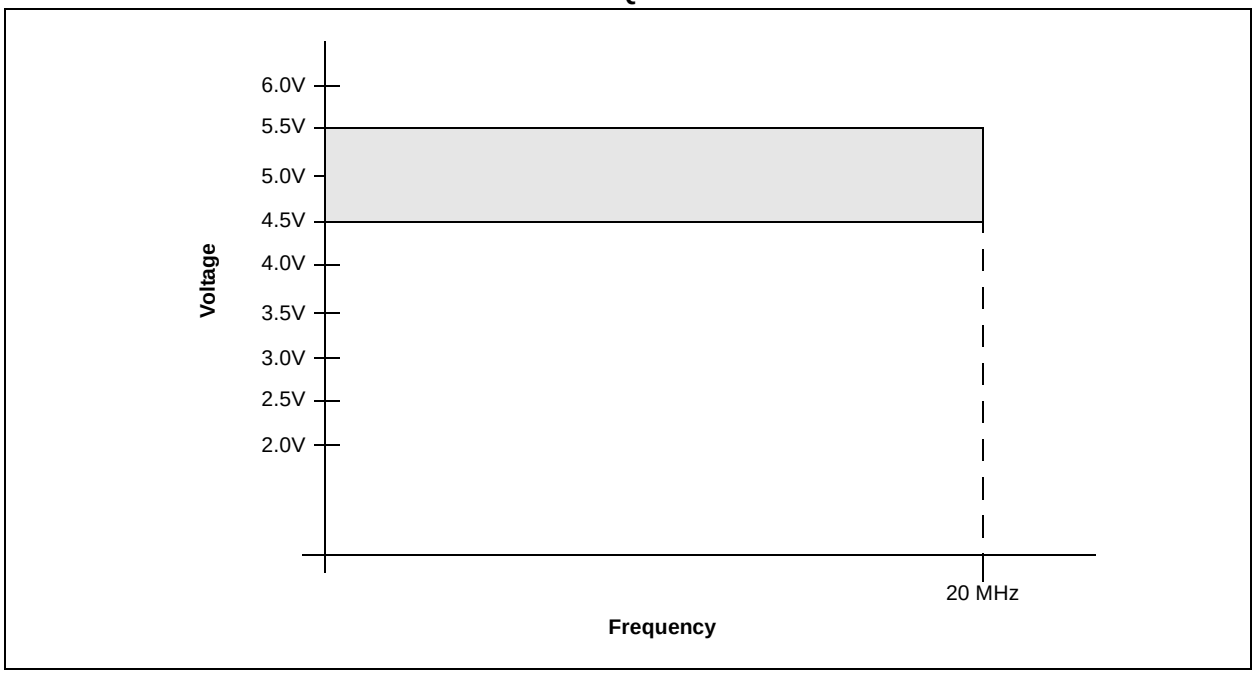
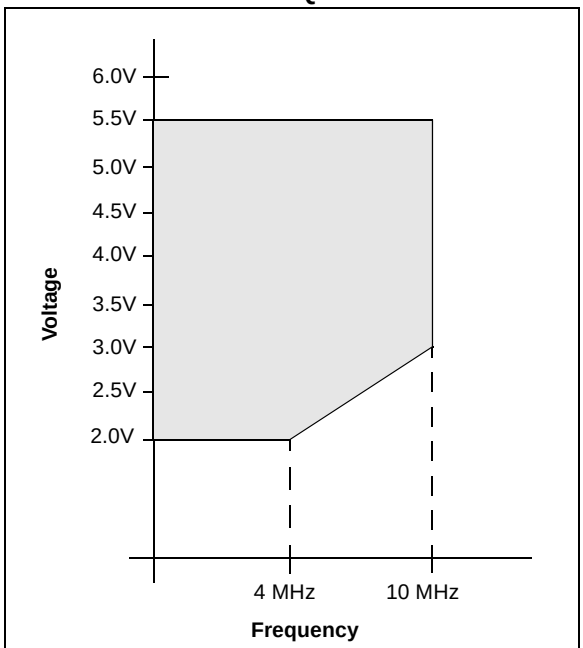



**FIGURE 9-2: PIC16LF84A-04 VOLTAGE-FREQUENCY GRAPH**

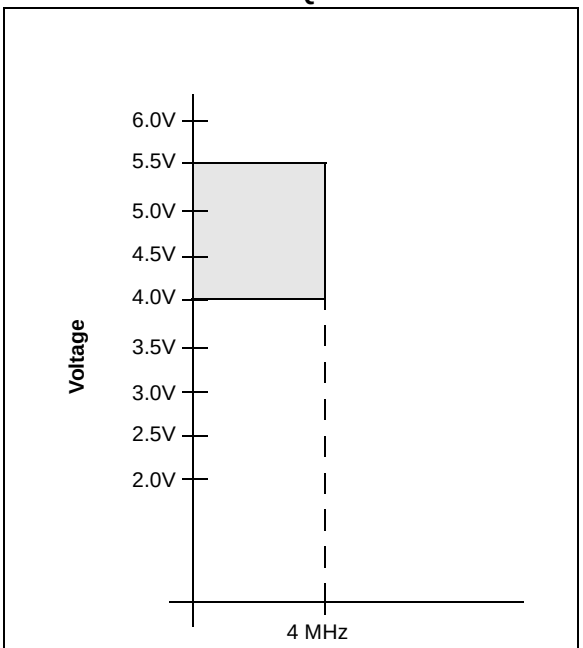



FMAX = (6.0 MHz/V) (VDDAPPMIN - 2.0V) + 4 MHz

**Note 1:** VDDAPPMIN is the minimum voltage of the PIC® device in the application.

**2:** FMAX has a maximum frequency of 10 MHz.

**FIGURE 9-3: PIC16F84A-04 VOLTAGE-FREQUENCY GRAPH**





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## 9.1 DC Characteristics

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PIC16LF84A-04** (Commercial, Industrial) | | | **Standard Operating Conditions (unless otherwise stated)** Operating temperature 0°C ≤ TA ≤ +70°C (commercial) -40°C ≤ TA ≤ +85°C (industrial) -40°C ≤ TA ≤ +125°C (extended) | | | | |
| **PIC16F84A-04** (Commercial, Industrial, Extended) **PIC16F84A-20** (Commercial, Industrial, Extended) | | | **Standard Operating Conditions (unless otherwise stated)** Operating temperature 0°C ≤ TA ≤ +70°C (commercial) -40°C ≤ TA ≤ +85°C (industrial) -40°C ≤ TA ≤ +125°C (extended) | | | | |
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Typ†** | **Max** | **Units** | **Conditions** |
| | VDD | **Supply Voltage** | | | | | |
| D001 | | 16LF84A | 2.0 | — | 5.5 | V | XT, RC, and LP osc configuration |
| D001 | | 16F84A | 4.0 | — | 5.5 | V | XT, RC and LP osc configuration |
| D001A | | | 4.5 | — | 5.5 | V | HS osc configuration |
| D002 | VDR | **RAM Data Retention Voltage (Note 1)** | 1.5 | — | — | V | Device in SLEEP mode |
| D003 | VPOR | **VDD Start Voltage** to ensure internal Power-on Reset signal | — | Vss | — | V | See section on Power-on Reset for details |
| D004 | SVDD | **VDD Rise Rate** to ensure internal Power-on Reset signal | 0.05 | — | — | V/ms | |
| | IDD | **Supply Current (Note 2)** | | | | | |
| D010 | | 16LF84A | — | 1 | 4 | mA | RC and XT osc configuration **(Note 4)** FOSC = 2.0 MHz, VDD = 5.5V |
| D010 | | 16F84A | — | 1.8 | 4.5 | mA | RC and XT osc configuration **(Note 4)** FOSC = 4.0 MHz, VDD = 5.5V |
| D010A | | | — | 3 | 10 | mA | RC and XT osc configuration **(Note 4)** FOSC = 4.0 MHz, VDD = 5.5V (During FLASH programming) |
| D013 | | | — | 10 | 20 | mA | HS osc configuration (PIC16F84A-20) FOSC = 20 MHz, VDD = 5.5V |
| D014 | | 16LF84A | — | 15 | 45 | µA | LP osc configuration FOSC = 32 kHz, VDD = 2.0V, WDT disabled |

Legend: Rows with standard voltage device data only are shaded for improved readability.

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

NR Not rated for operation.

**Note 1:** 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 tri-stated, pulled to VDD,
T0CKI = VDD, $\overline{MCLR}$ = 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 configuration, current through REXT is not included. The current through the resistor can be estimated by the formula IR = VDD/2REXT (mA) with REXT in kOhm.

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

## 9.1 DC Characteristics (Continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **PIC16LF84A-04**<br>(Commercial, Industrial) | | | **Standard Operating Conditions (unless otherwise stated)**<br>Operating temperature 0°C ≤ TA ≤ +70°C (commercial)<br>-40°C ≤ TA ≤ +85°C (industrial)<br>-40°C ≤ TA ≤ +125°C (extended) | | | | |
| **PIC16F84A-04**<br>(Commercial, Industrial, Extended)<br>**PIC16F84A-20**<br>(Commercial, Industrial, Extended) | | | **Standard Operating Conditions (unless otherwise stated)**<br>Operating temperature 0°C ≤ TA ≤ +70°C (commercial)<br>-40°C ≤ TA ≤ +85°C (industrial)<br>-40°C ≤ TA ≤ +125°C (extended) | | | | |
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Typ†** | **Max** | **Units** | **Conditions** |
| | IPD | **Power-down Current (Note 3)** | | | | | |
| D020 | | 16LF84A | | | | | |
| D020 | | 16F84A-20<br>16F84A-04 | | | | | |
| D021A | | 16LF84A | — | 0.4 | 1.0 | µA | VDD = 2.0V, WDT disabled, industrial |
| D021A | | 16F84A-20 | — | 1.5 | 3.5 | µA | VDD = 4.5V, WDT disabled, industrial |
| | | 16F84A-04 | — | 1.0 | 3.0 | µA | VDD = 4.0V, WDT disabled, industrial |
| D021B | | 16F84A-20 | — | 1.5 | 5.5 | µA | VDD = 4.5V, WDT disabled, extended |
| | | 16F84A-04 | — | 1.0 | 5.0 | µA | VDD = 4.0V, WDT disabled, extended |
| | | **Module Differential Current (Note 5)** | | | | | |
| D022 | ΔIWDT | Watchdog Timer | — | .20 | 16 | µA | VDD = 2.0V, Industrial, Commercial |
| | | | — | 3.5 | 20 | µA | VDD = 4.0V, Commercial |
| | | | — | 3.5 | 28 | µA | VDD = 4.0V, Industrial, Extended |
| | | | — | 4.8 | 25 | µA | VDD = 4.5V, Commercial |
| | | | — | 4.8 | 30 | µA | VDD = 4.5V, Industrial, Extended |

Legend: Rows with standard voltage device data only are shaded for improved readability.

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

NR Not rated for operation.

**Note 1:** 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 tri-stated, pulled to VDD,

T0CKI = VDD, $\overline{MCLR}$ = 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 configuration, current through REXT is not included. The current through the resistor can be estimated by the formula IR = VDD/2REXT (mA) with REXT in kOhm.

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


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## 9.2 DC Characteristics: PIC16F84A-04 (Commercial, Industrial) PIC16F84A-20 (Commercial, Industrial) PIC16LF84A-04 (Commercial, Industrial)

| DC Characteristics<br>All Pins Except Power Supply Pins | | | Standard Operating Conditions (unless otherwise stated)<br>Operating temperature 0°C ≤ TA ≤ +70°C (commercial)<br>-40°C ≤ TA ≤ +85°C (industrial)<br>Operating voltage VDD range as described in DC specifications (Section 9.1) | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Typ†** | **Max** | **Units** | **Conditions** |
| | VIL | **Input Low Voltage** | | | | | |
| | | I/O ports: | | | | | |
| D030 | | with TTL buffer | VSS | — | 0.8 | V | 4.5V ≤ VDD ≤ 5.5V **(Note 4)** |
| D030A | | | VSS | — | 0.16VDD | V | Entire range **(Note 4)** |
| D031 | | with Schmitt Trigger buffer | VSS | — | 0.2VDD | V | Entire range |
| D032 | | $\overline{MCLR}$, RA4/T0CKI | VSS | — | 0.2VDD | V | |
| D033 | | OSC1 (XT, HS and LP modes) | VSS | — | 0.3VDD | V | **(Note 1)** |
| D034 | | OSC1 (RC mode) | VSS | — | 0.1VDD | V | |
| | VIH | **Input High Voltage** | | | | | |
| | | I/O ports: | | — | | | |
| D040 | | with TTL buffer | 2.0 | — | VDD | V | 4.5V ≤ VDD ≤ 5.5V **(Note 4)** |
| D040A | | | 0.25VDD+0.8 | — | VDD | V | Entire range **(Note 4)** |
| D041 | | with Schmitt Trigger buffer | 0.8 VDD | — | VDD | | Entire range |
| D042 | | $\overline{MCLR}$, | 0.8 VDD | — | VDD | V | |
| D042A | | RA4/T0CKI | 0.8 VDD | — | 8.5 | V | |
| D043 | | OSC1 (XT, HS and LP modes) | 0.8 VDD | — | VDD | V | **(Note 1)** |
| D043A | | OSC1 (RC mode) | 0.9 VDD | | VDD | V | |
| D050 | VHYS | **Hysteresis of Schmitt Trigger Inputs** | — | 0.1 | — | V | |
| D070 | IPURB | **PORTB Weak Pull-up Current** | 50 | 250 | 400 | µA | VDD = 5.0V, VPIN = VSS |
| | IIL | **Input Leakage Current (Notes 2, 3)** | | | | | |
| D060 | | I/O ports | — | — | ±1 | µA | Vss ≤ VPIN ≤ VDD, Pin at hi-impedance |
| D061 | | $\overline{MCLR}$, RA4/T0CKI | — | — | ±5 | µA | Vss ≤ VPIN ≤ VDD |
| D063 | | OSC1 | — | — | ±5 | µA | Vss ≤ VPIN ≤ VDD, XT, HS and LP osc configuration |

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

**Note 1:** In RC oscillator configuration, the OSC1 pin is a Schmitt Trigger input. Do not drive the PIC16F84A with an external clock while the device is in RC mode, or chip damage may result.

**2:** The leakage current on the $\overline{MCLR}$ 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 coming out of the pin.

**4:** The user may choose the better of the two specs.

## 9.2 DC Characteristics: PIC16F84A-04 (Commercial, Industrial) PIC16F84A-20 (Commercial, Industrial) PIC16LF84A-04 (Commercial, Industrial) (Continued)

| DC Characteristics<br>All Pins Except Power Supply Pins | | | Standard Operating Conditions (unless otherwise stated)<br>Operating temperature 0°C ≤ TA ≤ +70°C (commercial)<br>-40°C ≤ TA ≤ +85°C (industrial)<br>Operating voltage VDD range as described in DC specifications (Section 9.1) | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Typ†** | **Max** | **Units** | **Conditions** |
| | VOL | **Output Low Voltage** | | | | | |
| D080 | | I/O ports | — | — | 0.6 | V | IOL = 8.5 mA, VDD = 4.5V |
| D083 | | OSC2/CLKOUT | — | — | 0.6 | V | IOL = 1.6 mA, VDD = 4.5V, (RC mode only) |
| | VOH | **Output High Voltage** | | | | | |
| D090 | | I/O ports **(Note 3)** | VDD-0.7 | — | — | V | IOH = -3.0 mA, VDD = 4.5V |
| D092 | | OSC2/CLKOUT **(Note 3)** | VDD-0.7 | — | — | V | IOH = -1.3 mA, VDD = 4.5V (RC mode only) |
| | VOD | **Open Drain High Voltage** | | | | | |
| D150 | | RA4 pin | — | — | 8.5 | V | |
| | | **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 (RC mode) | — | — | 50 | pF | |
| | | **Data EEPROM Memory** | | | | | |
| D120 | ED | Endurance | 1M | 10M | — | E/W | 25°C at 5V |
| D121 | VDRW | VDD for read/write | VMIN | — | 5.5 | V | VMIN = Minimum operating voltage |
| D122 | TDEW | Erase/Write cycle time | — | 4 | 8 | ms | |
| | | **Program FLASH Memory** | | | | | |
| D130 | EP | Endurance | 1000 | 10K | — | E/W | |
| D131 | VPR | VDD for read | VMIN | — | 5.5 | V | VMIN = Minimum operating voltage |
| D132 | VPEW | VDD for erase/write | 4.5 | — | 5.5 | V | |
| D133 | TPEW | Erase/Write cycle time | — | 4 | 8 | ms | |

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

**Note 1:** In RC oscillator configuration, the OSC1 pin is a Schmitt Trigger input. Do not drive the PIC16F84A with an external clock while the device is in RC mode, or chip damage may result.

**2:** The leakage current on the $\overline{MCLR}$ 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 coming out of the pin.

**4:** The user may choose the better of the two specs.


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## 9.3 AC (Timing) Characteristics

### 9.3.1 TIMING PARAMETER SYMBOLOGY

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

1. TppS2ppS
2. TppS

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

Lowercase letters (pp) and their meanings:

| | | | |
|---|---|---|---|
| pp | | | |
| 2 | to | os, osc | OSC1 |
| ck | CLKOUT | ost | oscillator start-up timer |
| cy | cycle time | pwrt | power-up timer |
| io | I/O port | rbt | RBx pins |
| inp | INT pin | t0 | T0CKI |
| mp | $\overline{\text{MCLR}}$ | wdt | watchdog timer |

Uppercase letters and their meanings:

| | | | |
|---|---|---|---|
| S | | | |
| F | Fall | P | Period |
| H | High | R | Rise |
| I | Invalid (high impedance) | V | Valid |
| L | Low | Z | High Impedance |

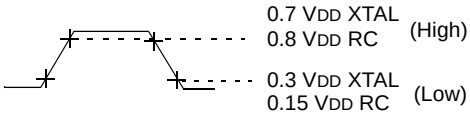
### 9.3.2 TIMING CONDITIONS

The temperature and voltages specified in Table 9-1 apply to all timing specifications unless otherwise noted. All timings are measured between high and low measurement points as indicated in Figure 9-4. Figure 9-5 specifies the load conditions for the timing specifications.

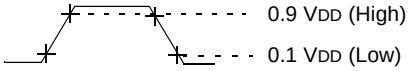
**TABLE 9-1: TEMPERATURE AND VOLTAGE SPECIFICATIONS - AC**

| | |
|---|---|
| **AC CHARACTERISTICS** | **Standard Operating Conditions (unless otherwise stated)**<br>Operating temperature 0°C ≤ TA ≤ +70°C for commercial<br>-40°C ≤ TA ≤ +85°C for industrial<br>Operating voltage VDD range as described in DC specifications (Section 9.1) |

**FIGURE 9-4: PARAMETER MEASUREMENT INFORMATION**



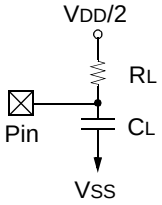

OSC1 Measurement Points



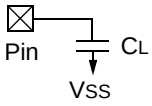

I/O Port Measurement Points

**FIGURE 9-5: LOAD CONDITIONS**

Load Condition 1




Load Condition 2




RL = 464Ω

CL = 50 pF for all pins except OSC2

15 pF for OSC2 output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### 9.3.3 TIMING DIAGRAMS AND SPECIFICATIONS

**FIGURE 9-6: EXTERNAL CLOCK TIMING**

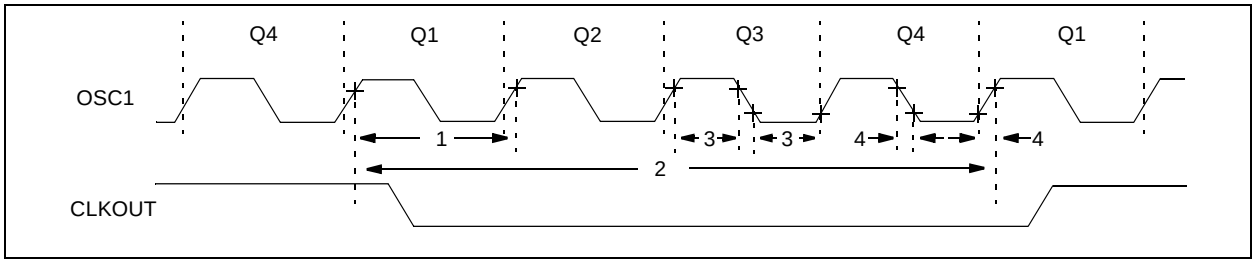


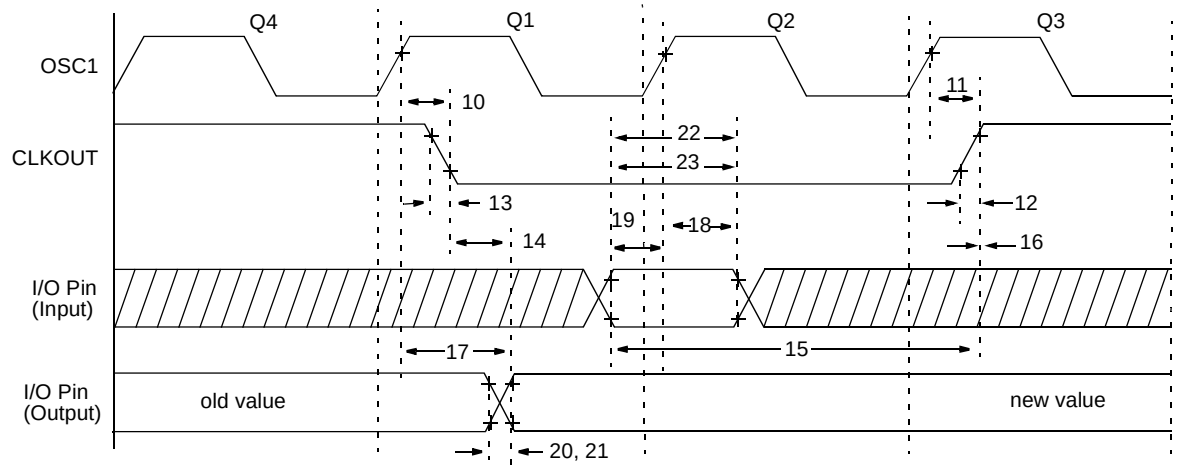

**TABLE 9-2: EXTERNAL CLOCK TIMING REQUIREMENTS**

| Param No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions | |
|---|---|---|---|---|---|---|---|---|
| | FOSC | **External CLKIN Frequency(1)** | DC | — | 2 | MHz | XT, RC osc | (-04, LF) |
| | | | DC | — | 4 | MHz | XT, RC osc | (-04) |
| | | | DC | — | 20 | MHz | HS osc | (-20) |
| | | | DC | — | 200 | kHz | LP osc | (-04, LF) |
| | | **Oscillator Frequency(1)** | DC | — | 2 | MHz | RC osc | (-04, LF) |
| | | | DC | — | 4 | MHz | RC osc | (-04) |
| | | | 0.1 | — | 2 | MHz | XT osc | (-04, LF) |
| | | | 0.1 | — | 4 | MHz | XT osc | (-04) |
| | | | 1.0 | — | 20 | MHz | HS osc | (-20) |
| | | | DC | — | 200 | kHz | LP osc | (-04, LF) |
| 1 | TOSC | **External CLKIN Period(1)** | 500 | — | — | ns | XT, RC osc | (-04, LF) |
| | | | 250 | — | — | ns | XT, RC osc | (-04) |
| | | | 50 | — | — | ns | HS osc | (-20) |
| | | | 5.0 | — | — | µs | LP osc | (-04, LF) |
| | | **Oscillator Period(1)** | 500 | — | — | ns | RC osc | (-04, LF) |
| | | | 250 | — | — | ns | RC osc | (-04) |
| | | | 500 | — | 10,000 | ns | XT osc | (-04, LF) |
| | | | 250 | — | 10,000 | ns | XT osc | (-04) |
| | | | 50 | — | 1,000 | ns | HS osc | (-20) |
| | | | 5.0 | — | — | µs | LP osc | (-04, LF) |
| 2 | TCY | **Instruction Cycle Time(1)** | 0.2 | 4/FOSC | DC | µs | | |
| 3 | TosL, TosH | **Clock in (OSC1) High or Low Time** | 60 | — | — | ns | XT osc | (-04, LF) |
| | | | 50 | — | — | ns | XT osc | (-04) |
| | | | 2.0 | — | — | µs | LP osc | (-04, LF) |
| | | | 17.5 | — | — | ns | HS osc | (-20) |
| 4 | TosR, TosF | **Clock in (OSC1) Rise or Fall Time** | 25 | — | — | ns | XT osc | (-04) |
| | | | 50 | — | — | ns | LP osc | (-04, LF) |
| | | | 7.5 | — | — | ns | HS osc | (-20) |

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

**Note 1:** 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 pin.
When an external clock input is used, the "Max." cycle time limit is "DC" (no clock) for all devices.

**FIGURE 9-7: CLKOUT AND I/O TIMING**




**Note:** All tests must be done with specified capacitive loads (Figure 9-5) 50 pF on I/O pins and CLKOUT.

**TABLE 9-3: CLKOUT AND I/O TIMING REQUIREMENTS**

| Param No. | Sym | Characteristic | | Min | Typ† | Max | Units | Conditions |
|---|---|---|---|---|---|---|---|---|
| 10 | TosH2ckL | OSC1↑ to CLKOUT↓ | Standard | — | 15 | 30 | ns | **(Note 1)** |
| 10A | | | Extended (LF) | — | 15 | 120 | ns | **(Note 1)** |
| 11 | TosH2ckH | OSC1↑ to CLKOUT↑ | Standard | — | 15 | 30 | ns | **(Note 1)** |
| 11A | | | Extended (LF) | — | 15 | 120 | ns | **(Note 1)** |
| 12 | TckR | CLKOUT rise time | Standard | — | 15 | 30 | ns | **(Note 1)** |
| 12A | | | Extended (LF) | — | 15 | 100 | ns | **(Note 1)** |
| 13 | TckF | CLKOUT fall time | Standard | — | 15 | 30 | ns | **(Note 1)** |
| 13A | | | Extended (LF) | — | 15 | 100 | ns | **(Note 1)** |
| 14 | TckL2ioV | CLKOUT ↓ to Port out valid | | — | — | 0.5TCY +20 | ns | **(Note 1)** |
| 15 | TioV2ckH | Port in valid before CLKOUT ↑ | Standard | 0.30TCY + 30 | — | — | ns | **(Note 1)** |
| | | | Extended (LF) | 0.30TCY + 80 | — | — | ns | **(Note 1)** |
| 16 | TckH2ioI | Port in hold after CLKOUT ↑ | | 0 | — | — | ns | **(Note 1)** |
| 17 | TosH2ioV | OSC1↑ (Q1 cycle) to Port out valid | Standard | — | — | 125 | ns | |
| | | | Extended (LF) | — | — | 250 | ns | |
| 18 | TosH2ioI | OSC1↑ (Q2 cycle) to Port input invalid (I/O in hold time) | Standard | 10 | — | — | ns | |
| | | | Extended (LF) | 10 | — | — | ns | |
| 19 | TioV2osH | Port input valid to OSC1↑ (I/O in setup time) | Standard | -75 | — | — | ns | |
| | | | Extended (LF) | -175 | — | — | ns | |
| 20 | TioR | Port output rise time | Standard | — | 10 | 35 | ns | |
| 20A | | | Extended (LF) | — | 10 | 70 | ns | |
| 21 | TioF | Port output fall time | Standard | — | 10 | 35 | ns | |
| 21A | | | Extended (LF) | — | 10 | 70 | ns | |
| 22 | TINP | INT pin high or low time | Standard | 20 | — | — | ns | |
| 22A | | | Extended (LF) | 55 | — | — | ns | |
| 23 | TRBP | RB7:RB4 change INT high or low time | Standard | TOSC§ | — | — | ns | |
| 23A | | | Extended (LF) | TOSC§ | — | — | ns | |

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.
§ By design.
**Note 1:** Measurements are taken in RC mode where CLKOUT output is 4 x TOSC.


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**FIGURE 9-8: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER TIMING**

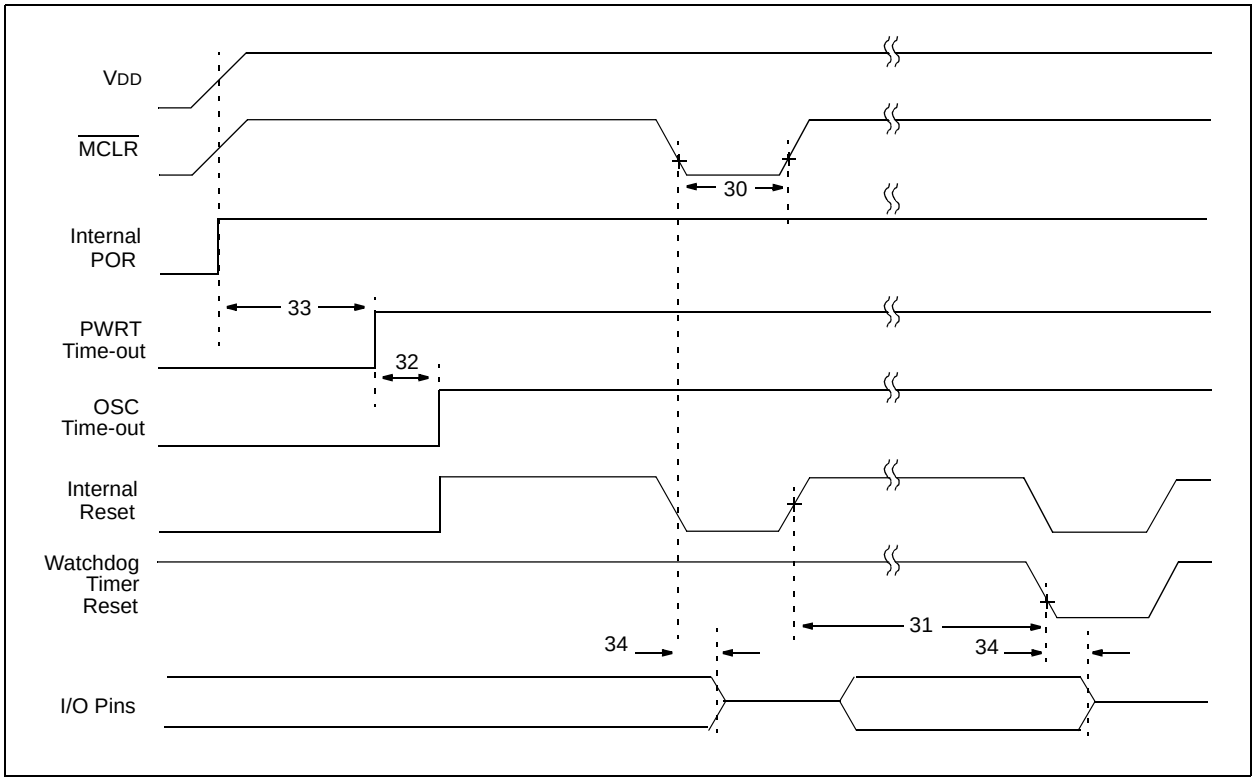


**TABLE 9-4: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER REQUIREMENTS**

| Parameter No. | Sym | Characteristic | Min | Typ† | Max | Units | Conditions |
|---|---|---|---|---|---|---|---|
| 30 | TmcL | $\overline{MCLR}$ Pulse Width (low) | 2 | — | — | μs | VDD = 5.0V |
| 31 | TWDT | Watchdog Timer Time-out Period (No Prescaler) | 7 | 18 | 33 | ms | VDD = 5.0V |
| 32 | TOST | Oscillation Start-up Timer Period | | 1024TOSC | | ms | TOSC = OSC1 period |
| 33 | TPWRT | Power-up Timer Period | 28 | 72 | 132 | ms | VDD = 5.0V |
| 34 | TIOZ | I/O hi-impedance from $\overline{MCLR}$ Low or RESET | — | — | 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.

**FIGURE 9-9: TIMER0 CLOCK TIMINGS**

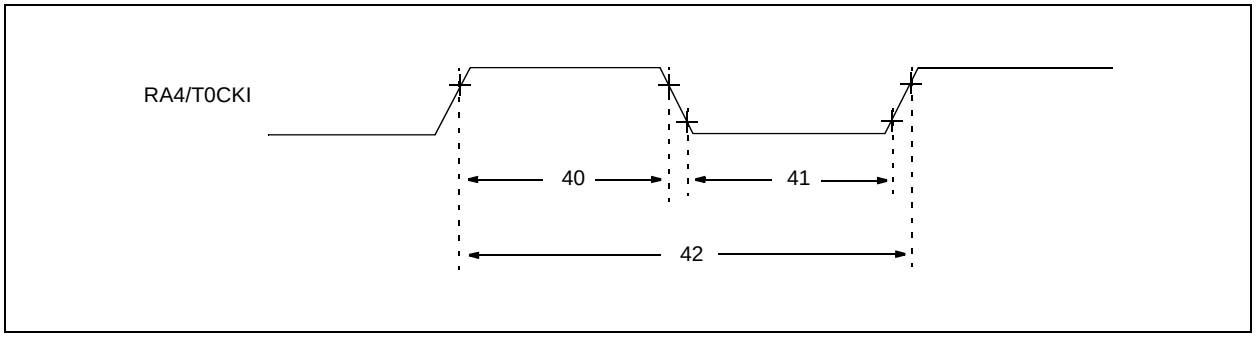


**TABLE 9-5: TIMER0 CLOCK REQUIREMENTS**

| Parameter No. | Sym | Characteristic | | Min | Typ† | Max | Units | Conditions |
|---|---|---|---|---|---|---|---|---|
| 40 | Tt0H | T0CKI High Pulse Width | No Prescaler | 0.5TCY + 20 | — | — | ns | |
| | | | With Prescaler | 50 | — | — | ns | 2.0V ≤ VDD ≤ 3.0V |
| | | | | 30 | — | — | ns | 3.0V ≤ VDD ≤ 6.0V |
| 41 | Tt0L | T0CKI Low Pulse Width | No Prescaler | 0.5TCY + 20 | — | — | ns | |
| | | | With Prescaler | 50 | — | — | ns | 2.0V ≤ VDD ≤ 3.0V |
| | | | | 20 | — | — | ns | 3.0V ≤ VDD ≤ 6.0V |
| 42 | Tt0P | T0CKI Period | | $\frac{T_{CY} + 40}{N}$ | — | — | ns | N = prescale value (2, 4, ..., 256) |

† Data in "Typ" column is at 5.0V, 25°C, unless otherwise stated. These parameters are for design guidance only and are not tested.


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## 10.0 DC/AC CHARACTERISTIC GRAPHS

The graphs provided in this section are for **design guidance** and are **not tested**.

In some graphs, the data presented are **outside specified operating range** (i.e., outside specified $V_{DD}$ range). This is for **information only** and devices are ensured to operate properly only within the specified range.

The data presented in this section is a **statistical summary** of data collected on units from different lots over a period of time and matrix samples. 'Typical' represents the mean of the distribution at 25°C. 'Max' or 'Min' represents (mean + 3σ) or (mean - 3σ), respectively, where σ is a standard deviation over the whole temperature range.

**FIGURE 10-1: TYPICAL IDD vs. FOSC OVER VDD (HS MODE, 25°C)**

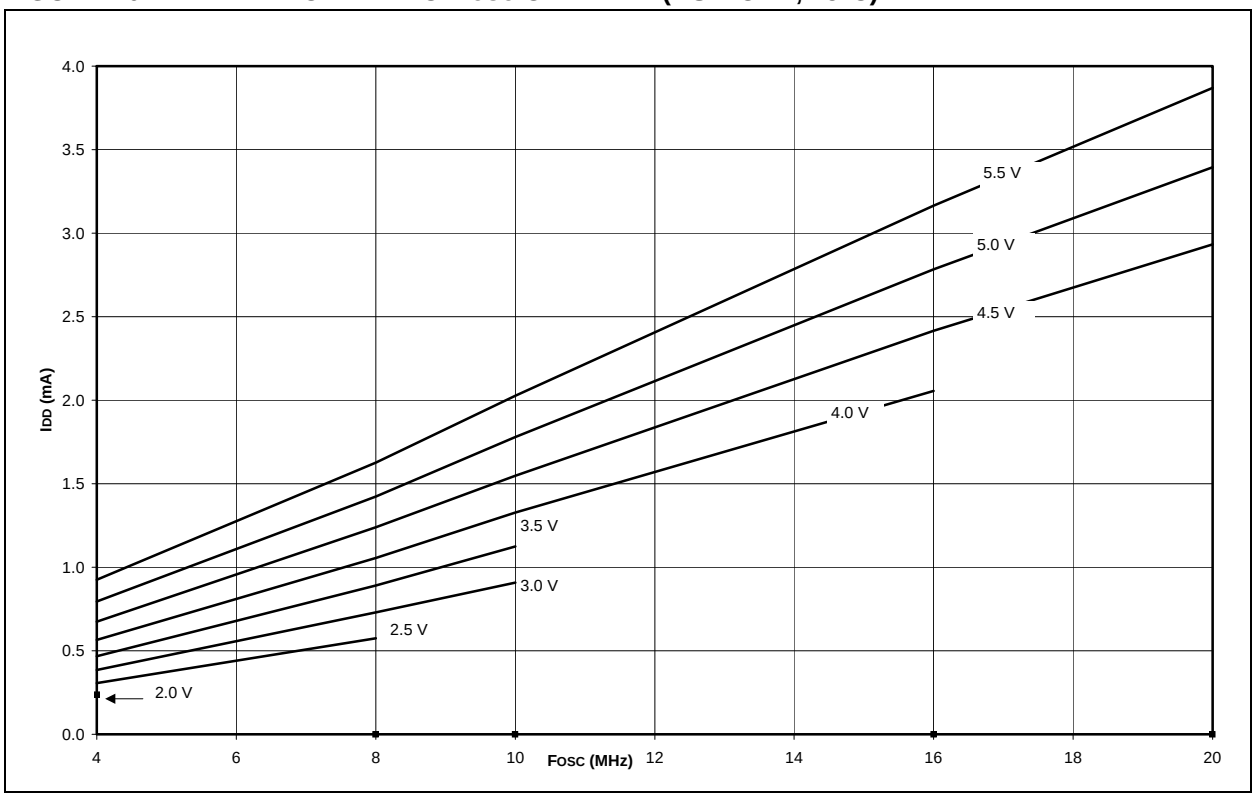


**FIGURE 10-2: MAXIMUM IDD vs. FOSC OVER VDD (HS MODE, -40° TO +125°C)**

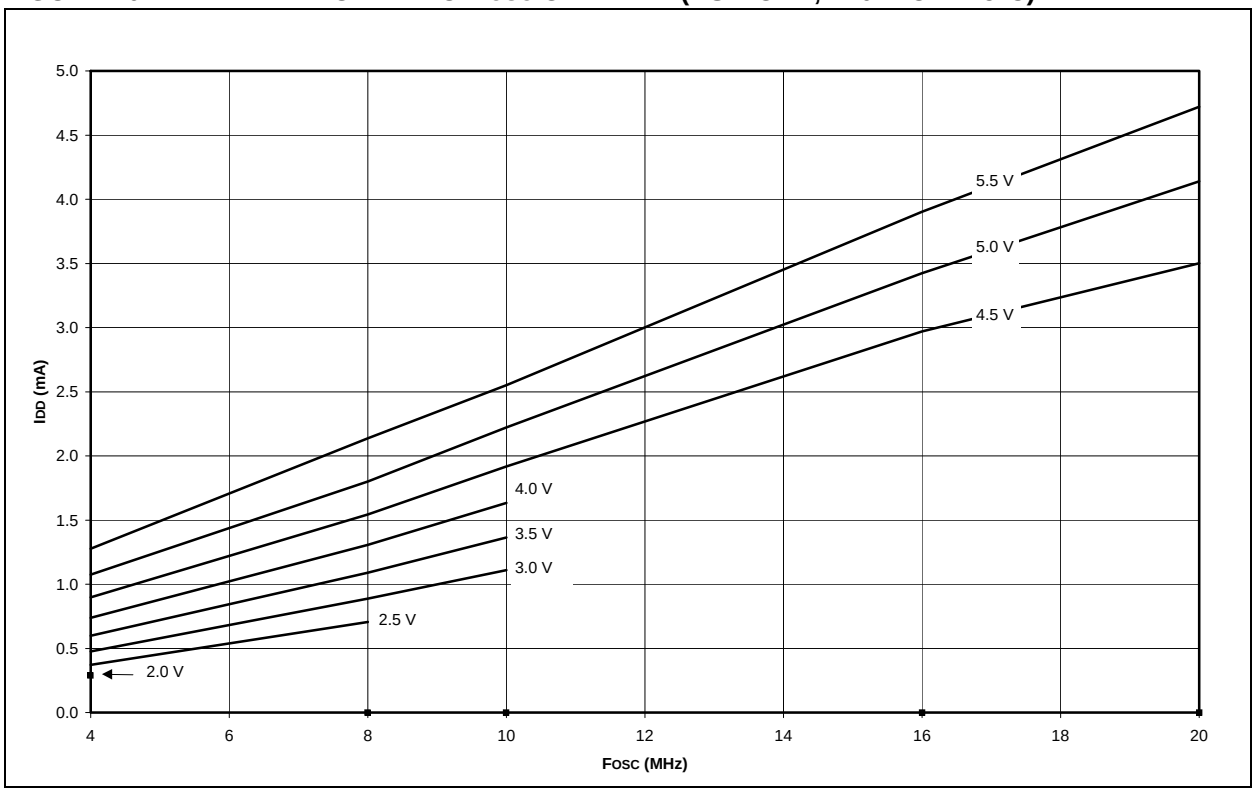



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**FIGURE 10-3: TYPICAL IDD vs. FOSC OVER VDD (XT MODE, 25°C)**

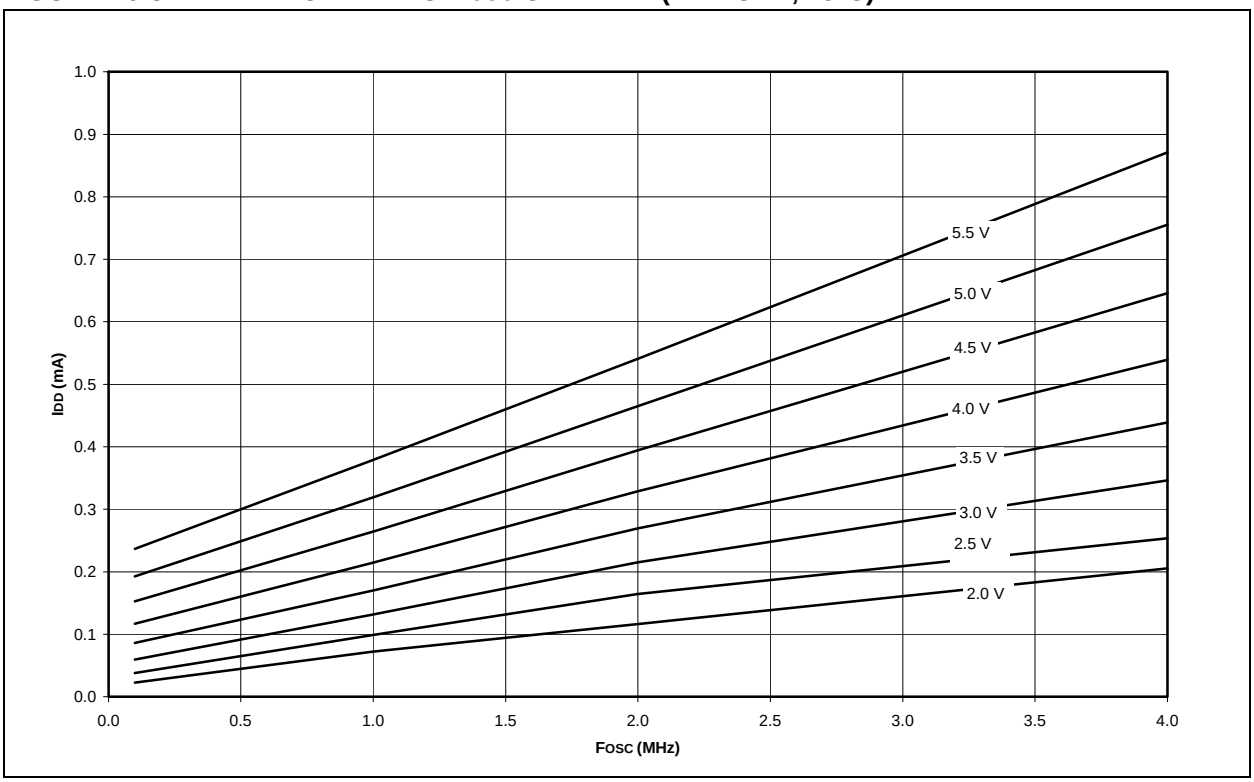


**FIGURE 10-4: MAXIMUM IDD vs. FOSC OVER VDD (XT MODE, -40° TO +125°C)**

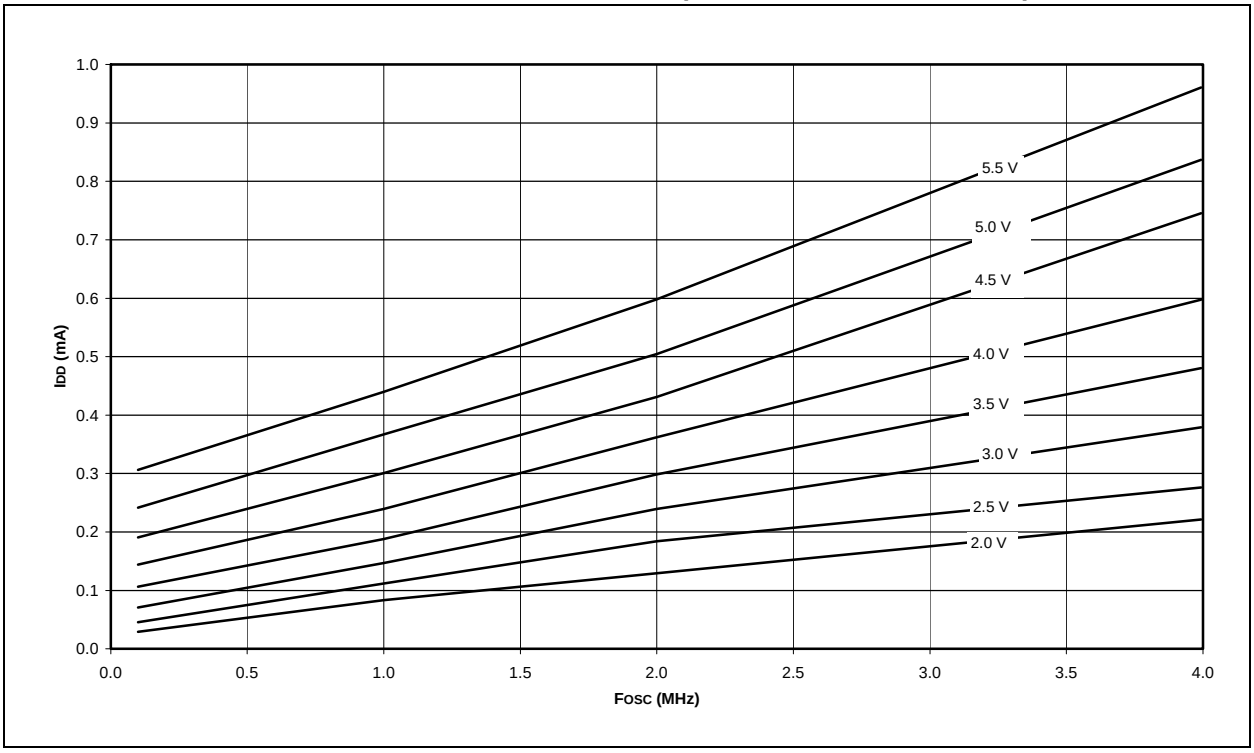

**FIGURE 10-5: TYPICAL IDD vs. FOSC OVER VDD (LP MODE, 25°C)**

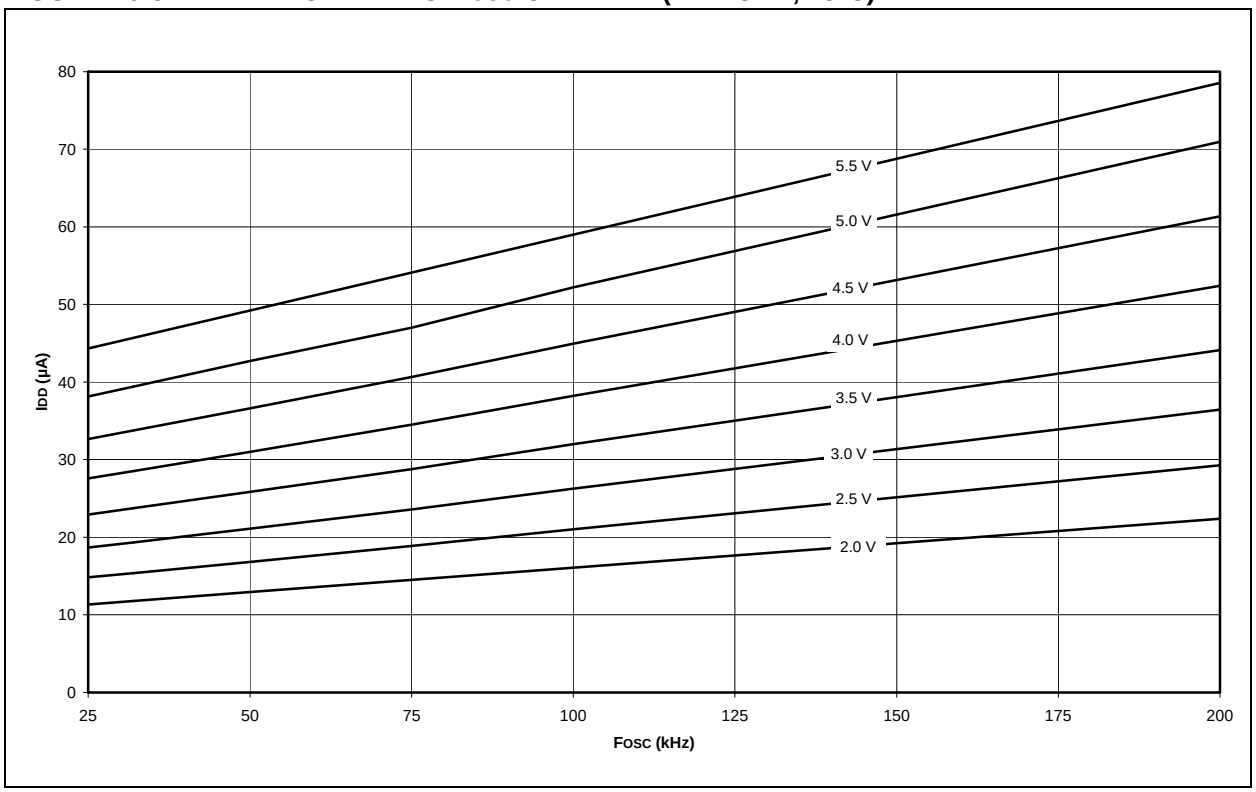


**FIGURE 10-6: MAXIMUM IDD vs. FOSC OVER VDD (LP MODE, -40° TO +125°C)**

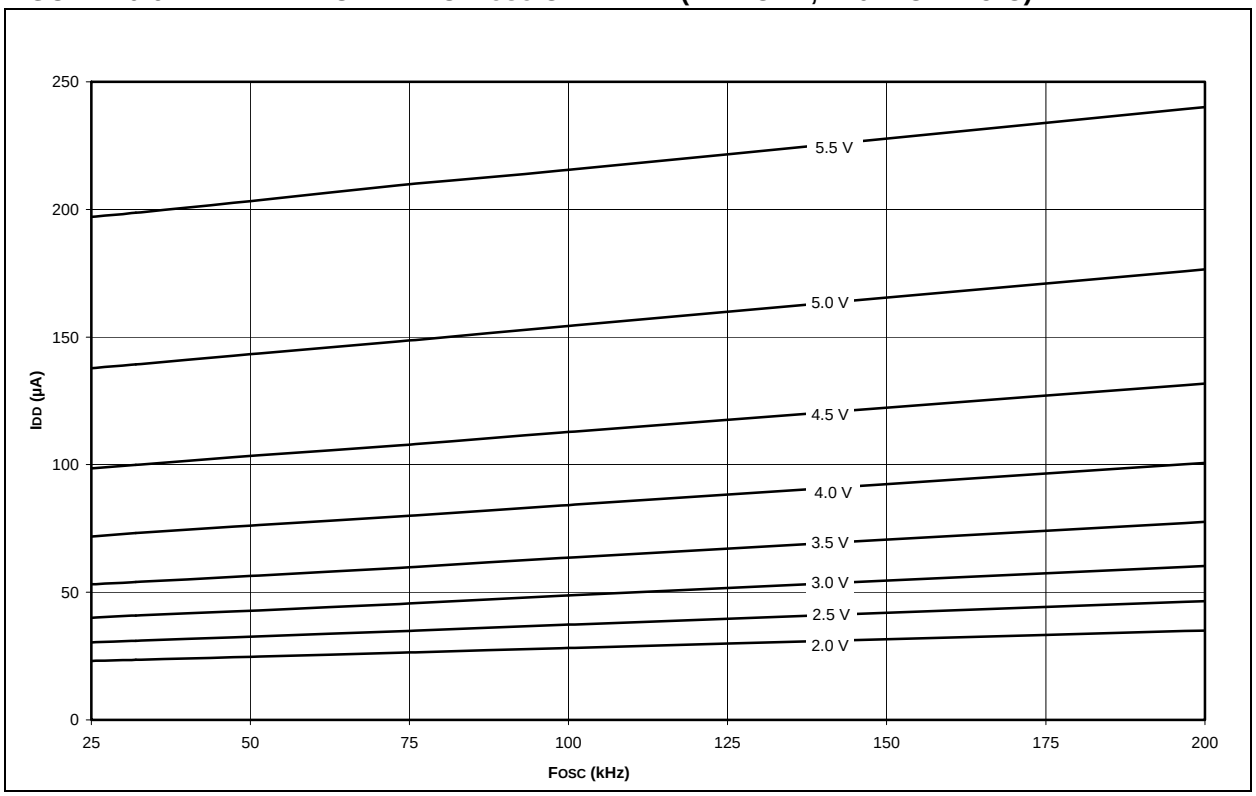



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**FIGURE 10-7: AVERAGE FOSC vs. VDD FOR R (RC MODE, C = 22 pF, 25°C)**

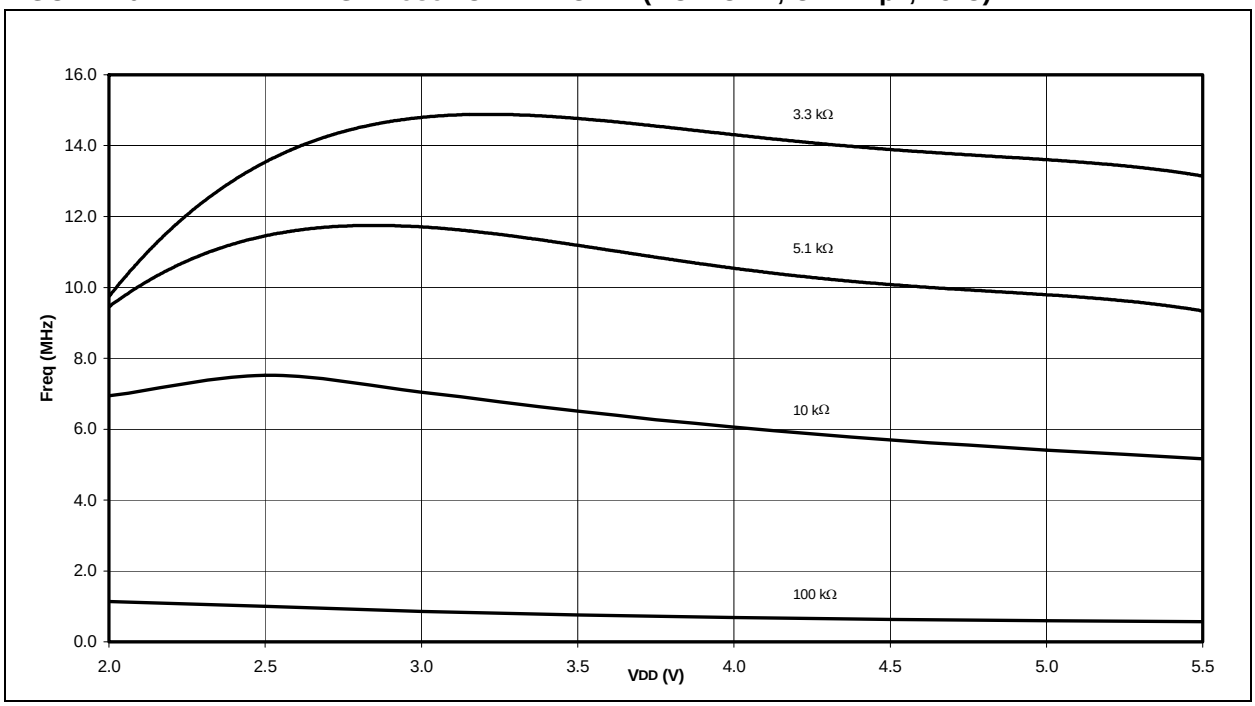


**FIGURE 10-8: AVERAGE FOSC vs. VDD FOR R (RC MODE, C = 100 pF, 25°C)**

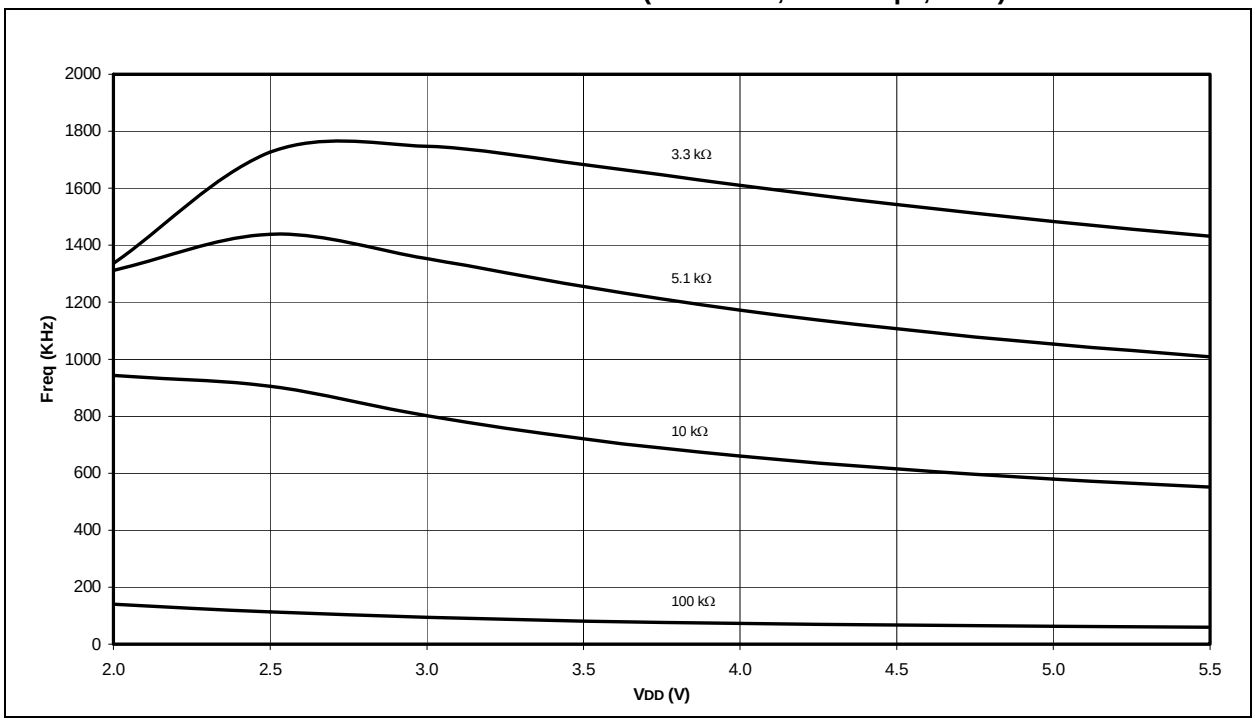

**FIGURE 10-9: AVERAGE FOSC vs. VDD FOR R (RC MODE, C = 300 pF, 25°C)**

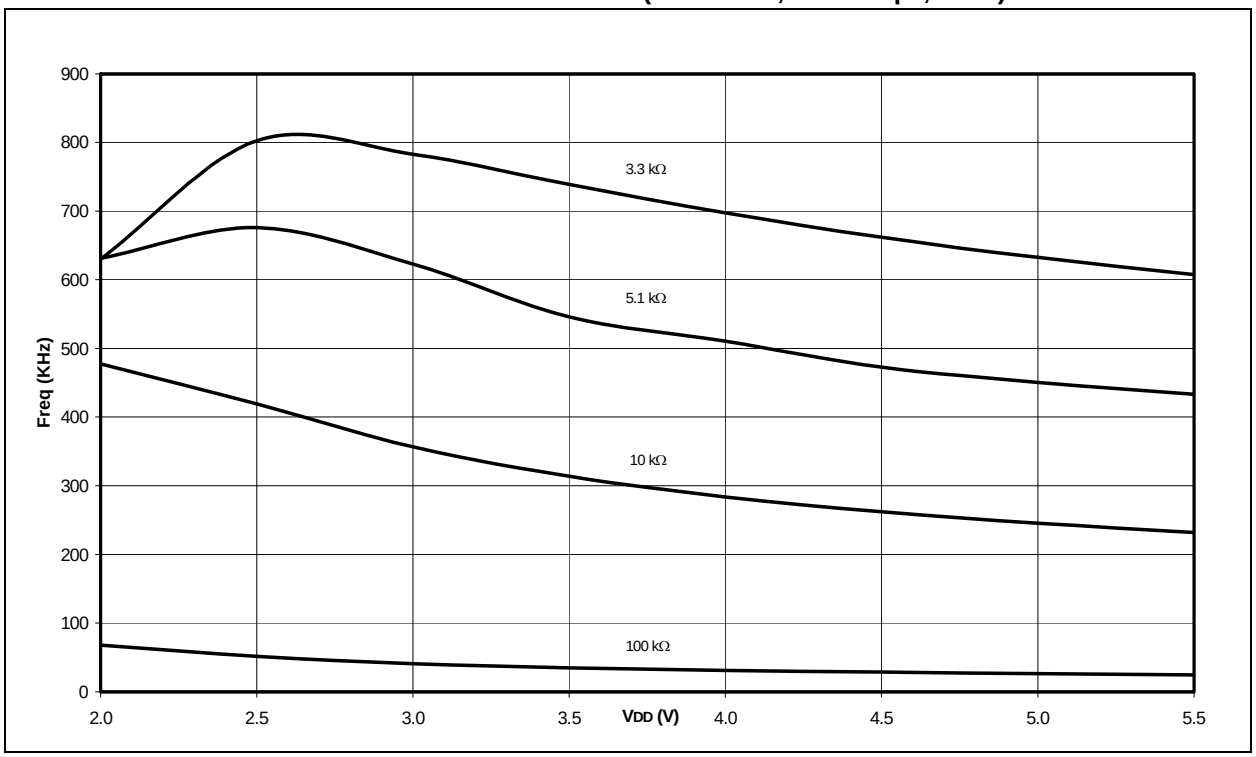


**FIGURE 10-10: IPD vs. VDD (SLEEP MODE, ALL PERIPHERALS DISABLED)**

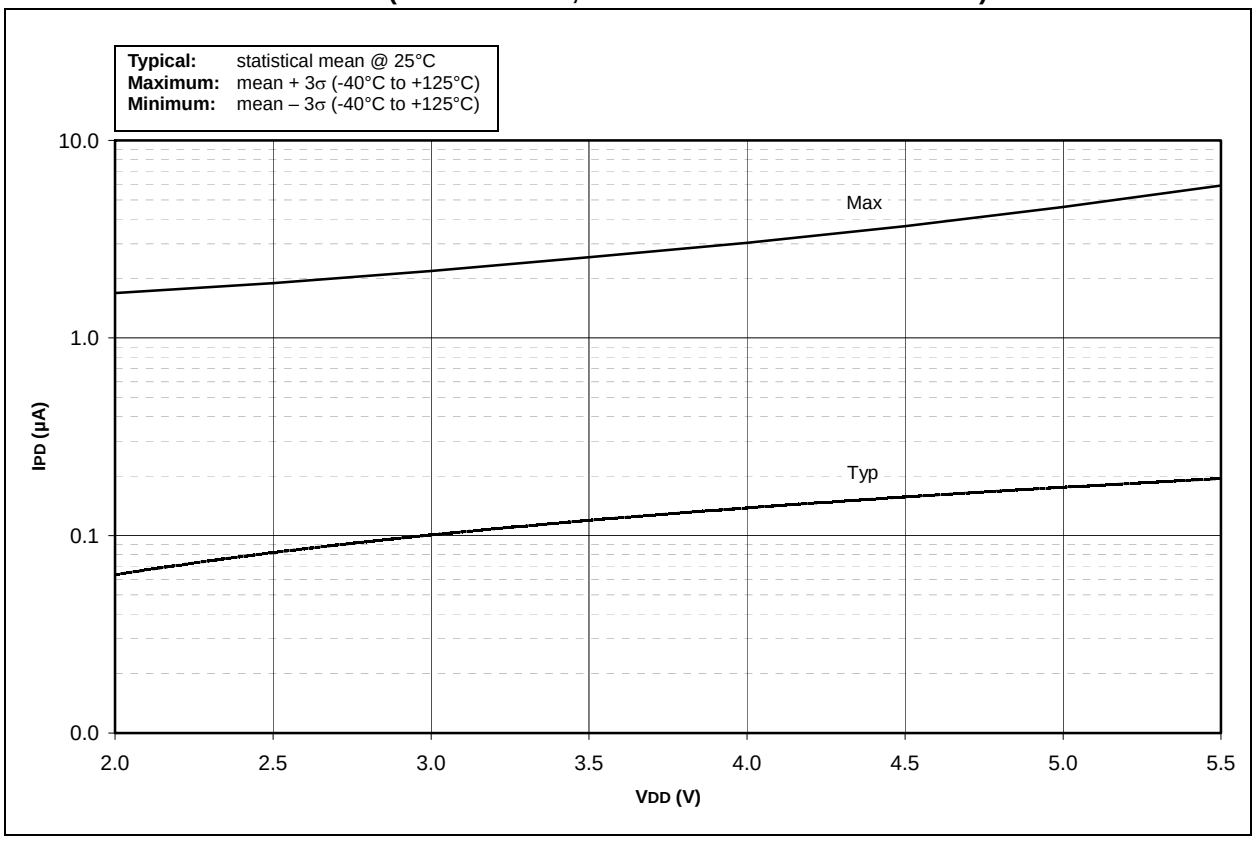



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**FIGURE 10-11: IPD vs. VDD (WDT MODE)**

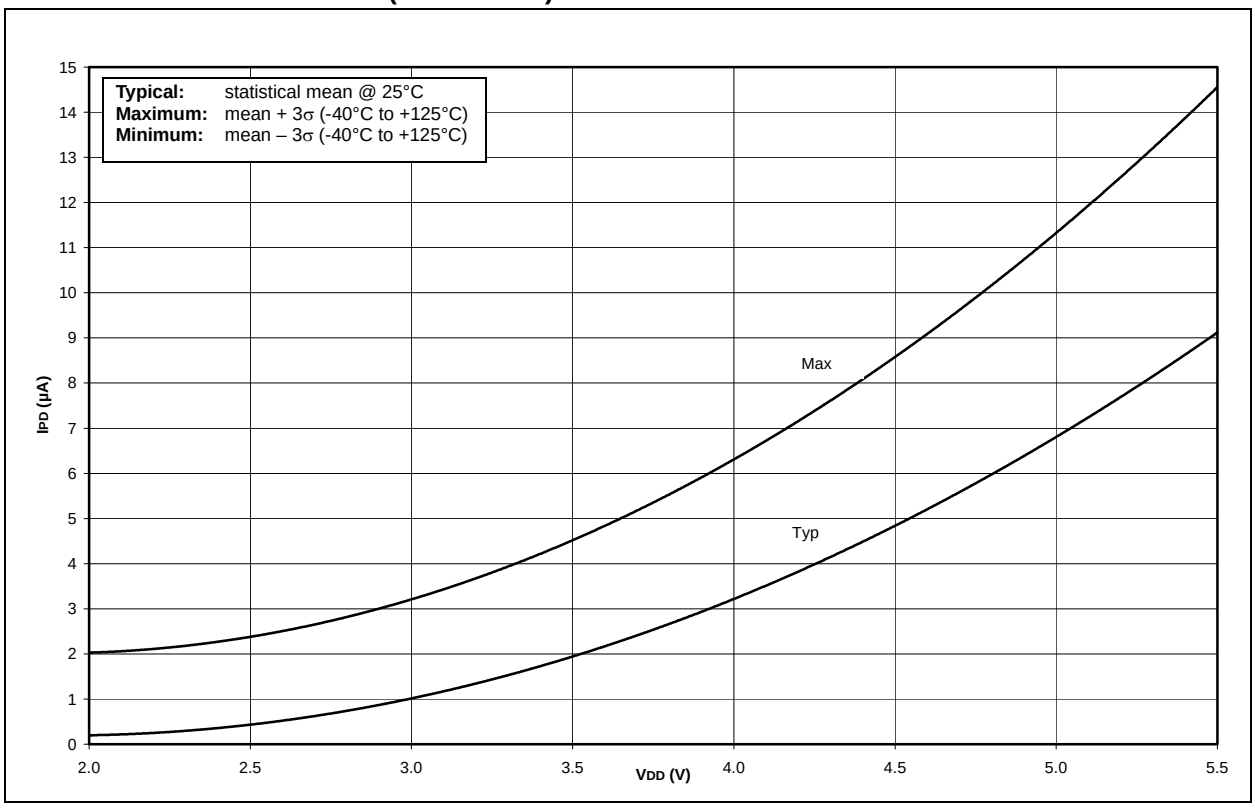


**FIGURE 10-12: TYPICAL, MINIMUM, AND MAXIMUM WDT PERIOD vs. VDD OVER TEMP**

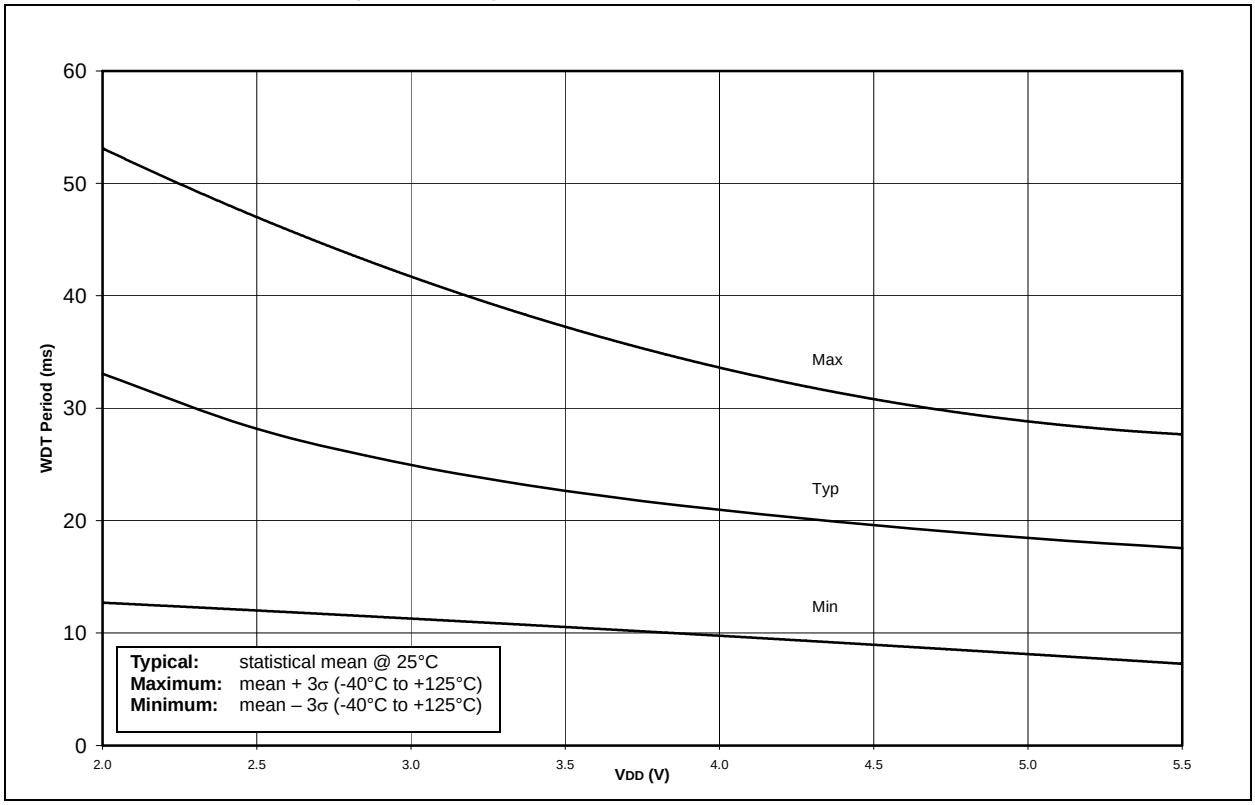

**FIGURE 10-13: TYPICAL, MINIMUM AND MAXIMUM VOH vs. IOH (VDD = 5V, -40°C TO +125°C)**

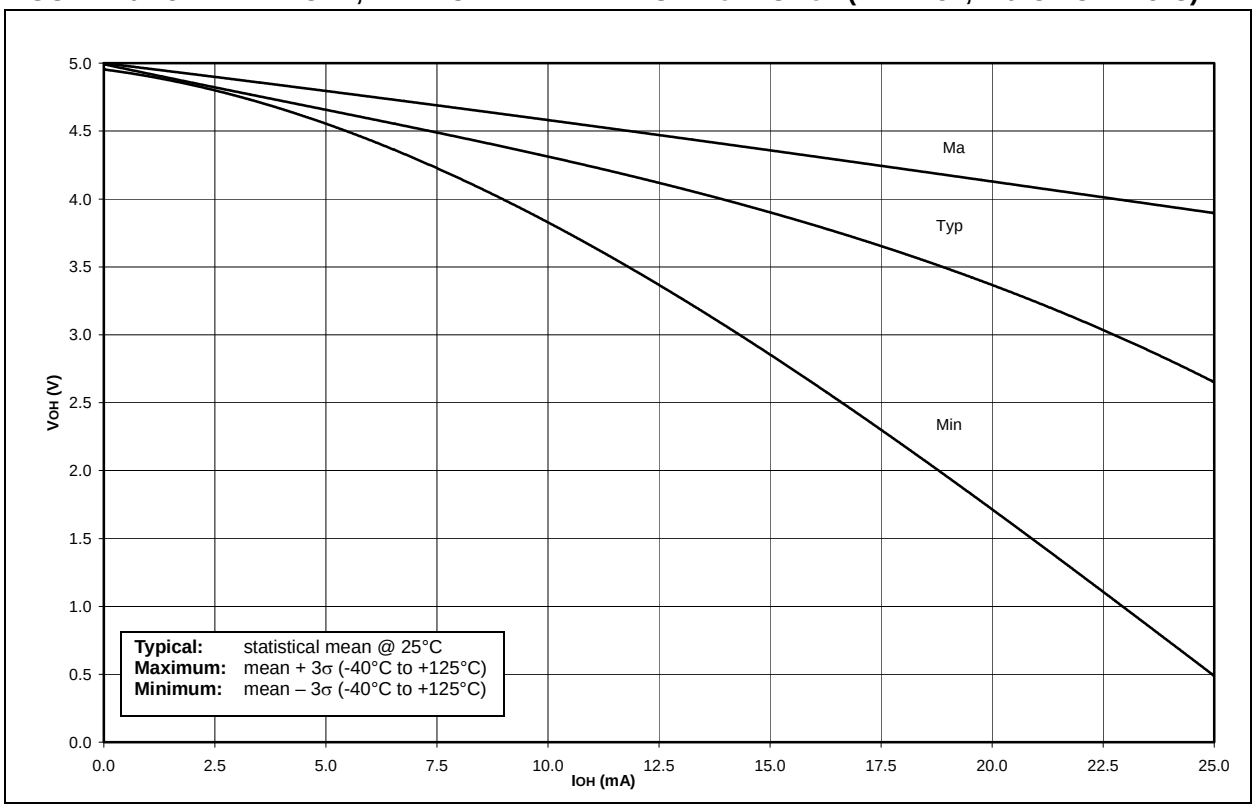


**FIGURE 10-14: TYPICAL, MINIMUM AND MAXIMUM VOH vs. IOH (VDD = 3V, -40°C TO +125°C)**

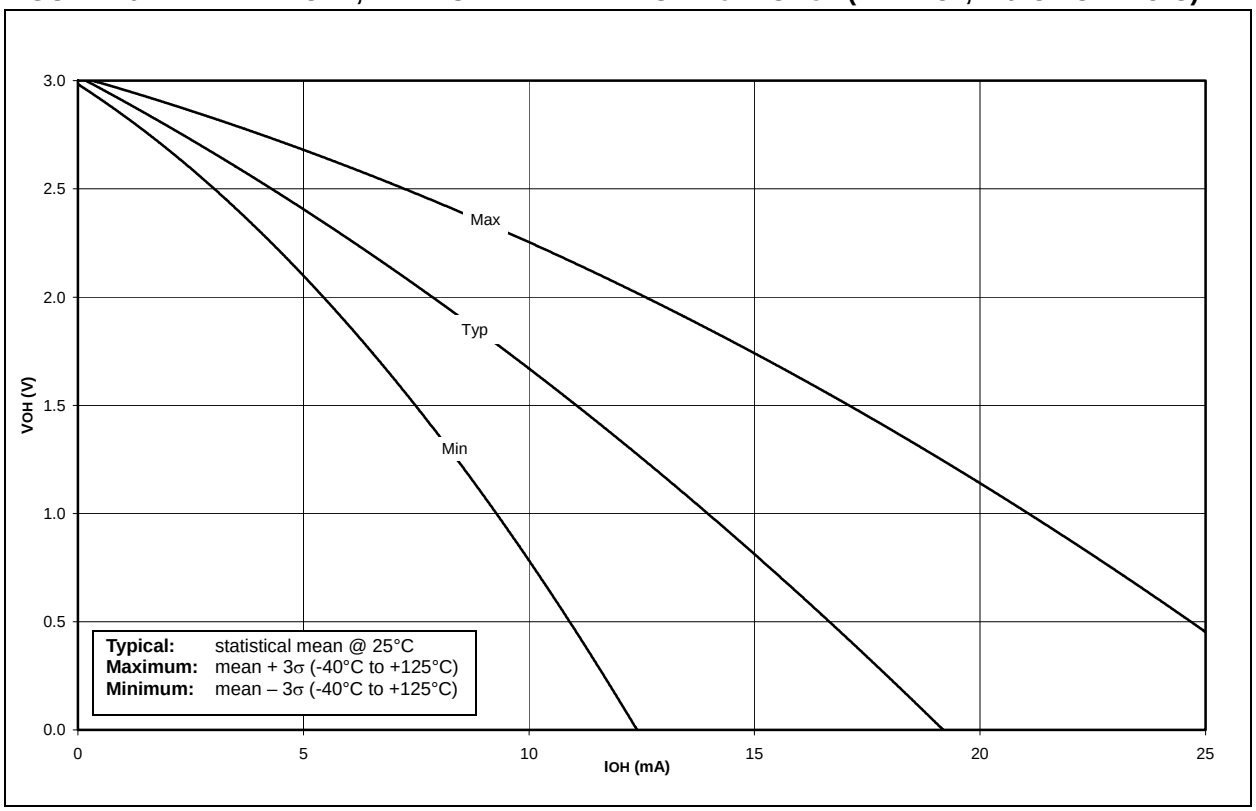



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**FIGURE 10-15: TYPICAL, MINIMUM AND MAXIMUM $V_{OL}$ vs. $I_{OL}$ ($V_{DD}$ = 5V, -40°C TO +125°C)**

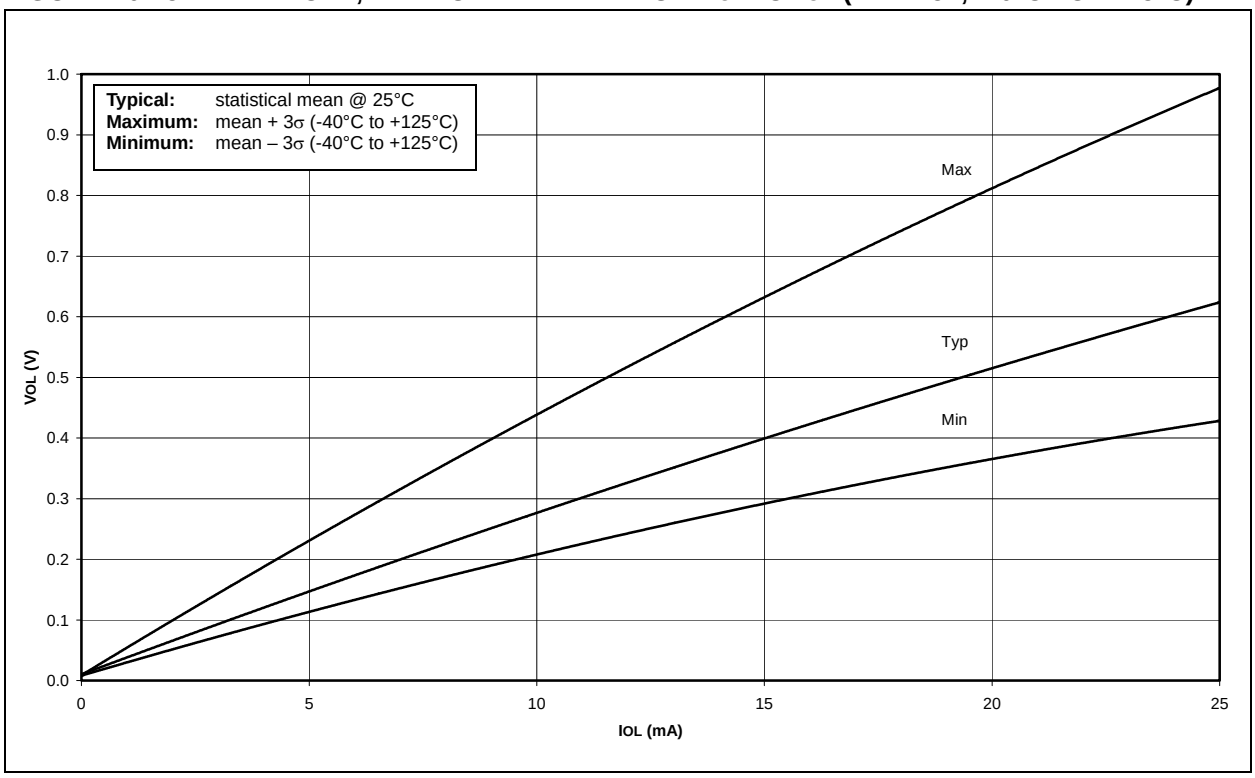



**FIGURE 10-16: TYPICAL, MINIMUM AND MAXIMUM $V_{OL}$ vs. $I_{OL}$ ($V_{DD}$ = 3V, -40°C TO +125°C)**

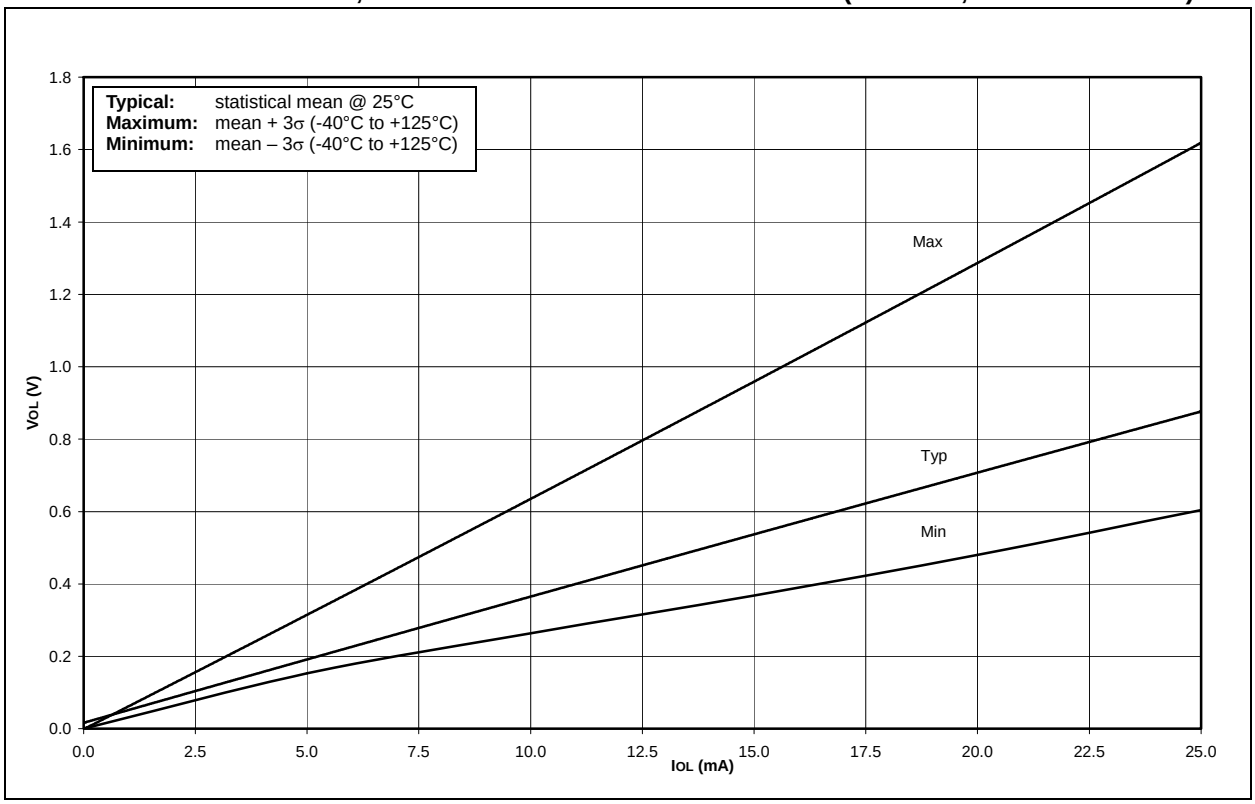


**FIGURE 10-17: MINIMUM AND MAXIMUM VIN vs. VDD, (TTL INPUT, -40°C TO +125°C)**

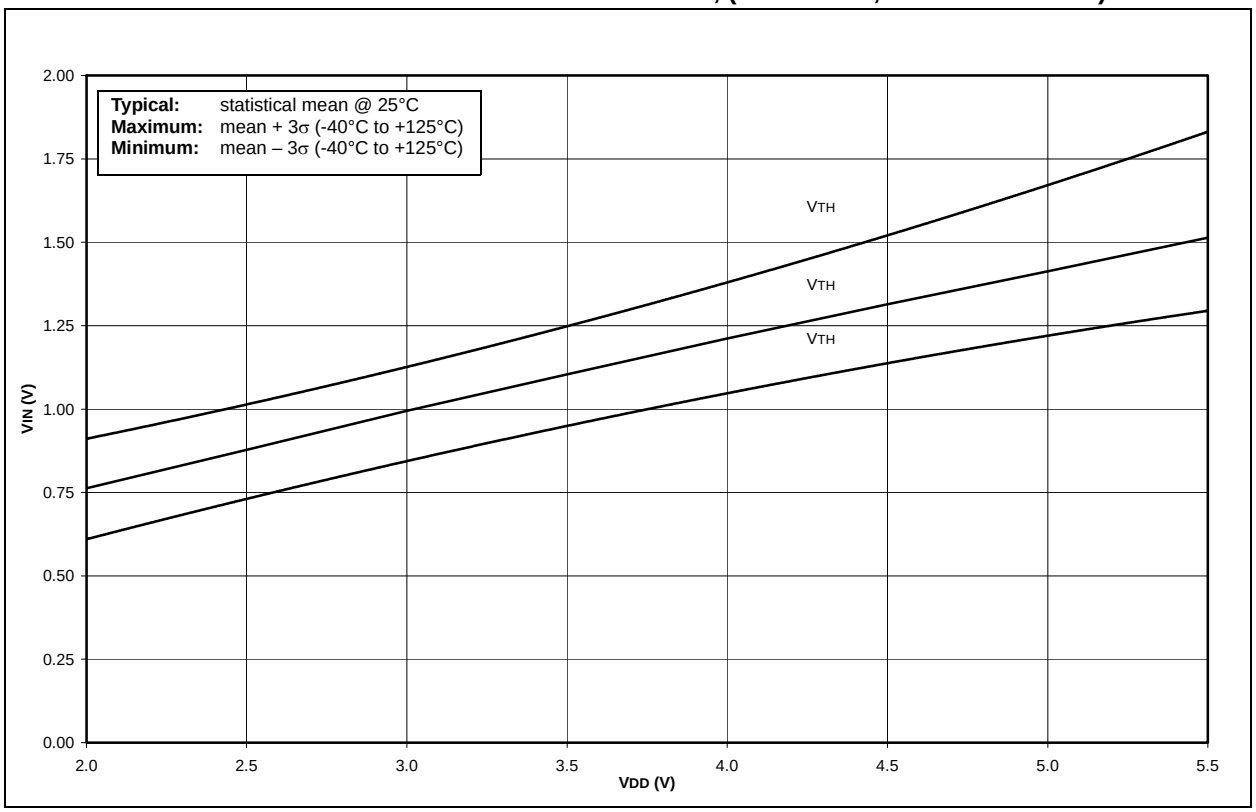
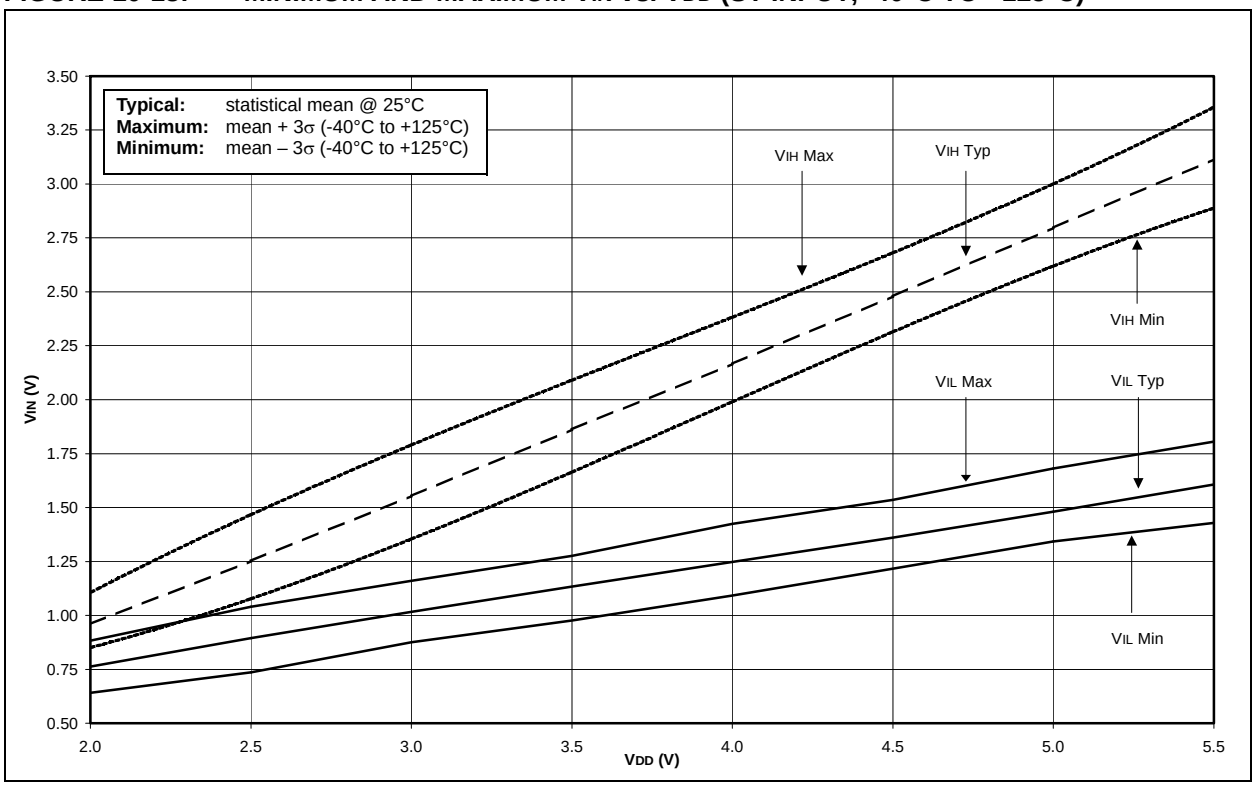



**FIGURE 10-18: MINIMUM AND MAXIMUM VIN vs. VDD (ST INPUT, -40°C TO +125°C)**





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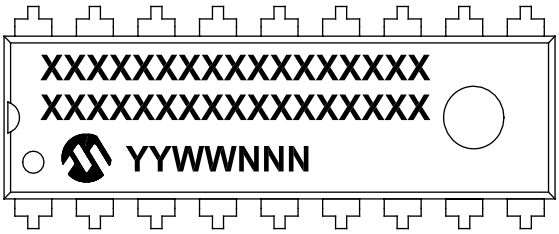
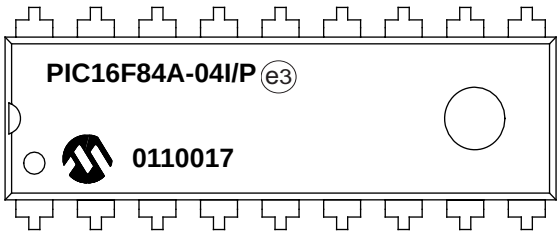
## 11.0 PACKAGING INFORMATION

### 11.1 Package Marking Information

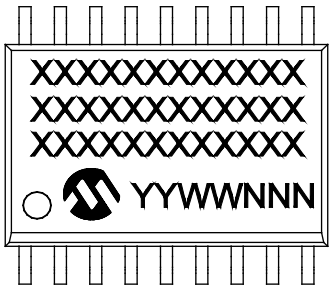
18-Lead PDIP (300 mil)



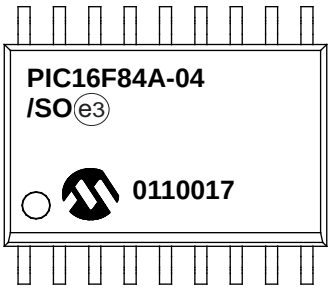

Example



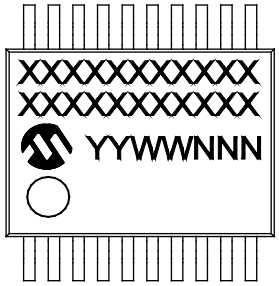

18-Lead SOIC (7.50 mm)



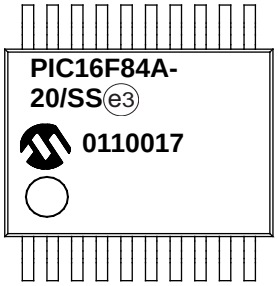

Example




20-Lead SSOP (5.30 mm)




Example

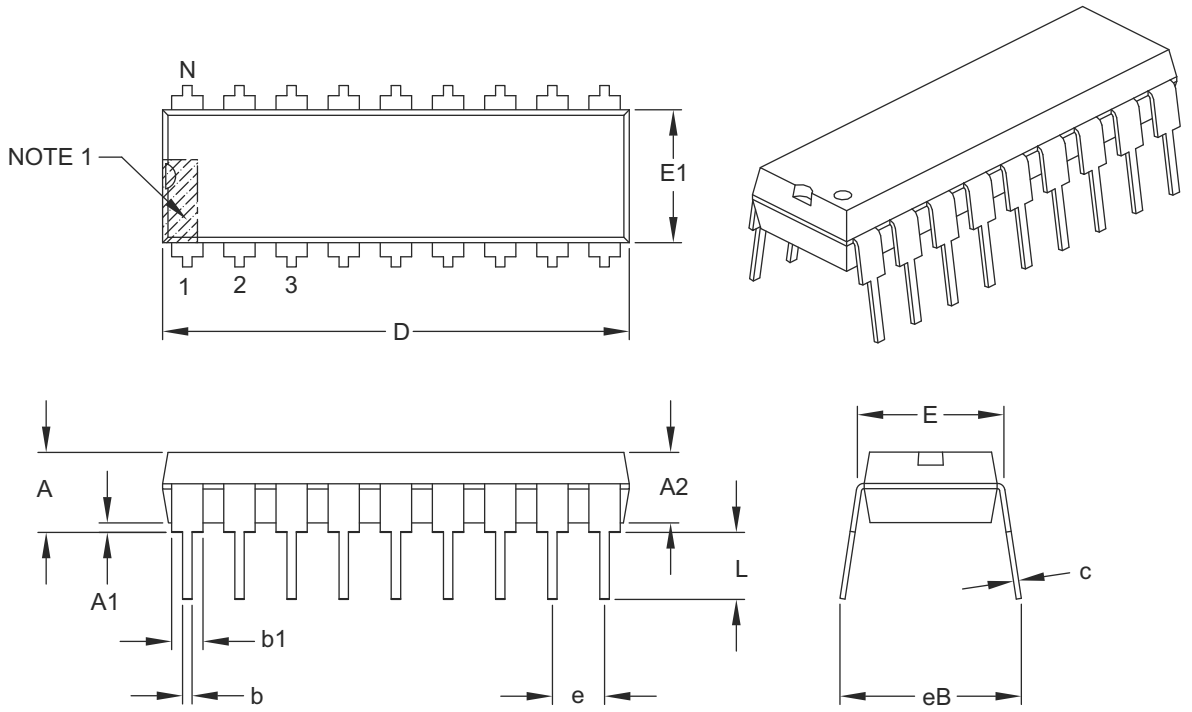



| | | |
|---|---|---|
| **Legend:** | XX...X | Customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week ‘01’) |
| | NNN | Alphanumeric traceability code |
| | (e3) | Pb-free JEDEC designator for Matte Tin (Sn) |
| | * | This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package. |

**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.

### 18-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




| Units | | INCHES | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | | 18 | |
| Pitch | e | | .100 BSC | |
| Top to Seating Plane | A | – | – | .210 |
| Molded Package Thickness | A2 | .115 | .130 | .195 |
| Base to Seating Plane | A1 | .015 | – | – |
| Shoulder to Shoulder Width | E | .300 | .310 | .325 |
| Molded Package Width | E1 | .240 | .250 | .280 |
| Overall Length | D | .880 | .900 | .920 |
| Tip to Seating Plane | L | .115 | .130 | .150 |
| Lead Thickness | c | .008 | .010 | .014 |
| Upper Lead Width | b1 | .045 | .060 | .070 |
| Lower Lead Width | b | .014 | .018 | .022 |
| Overall Row Spacing § | eB | – | – | .430 |

**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-007B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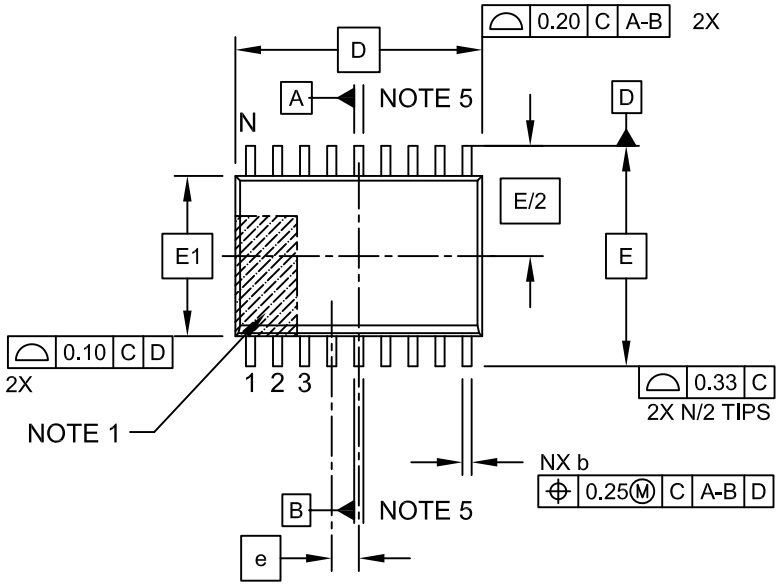
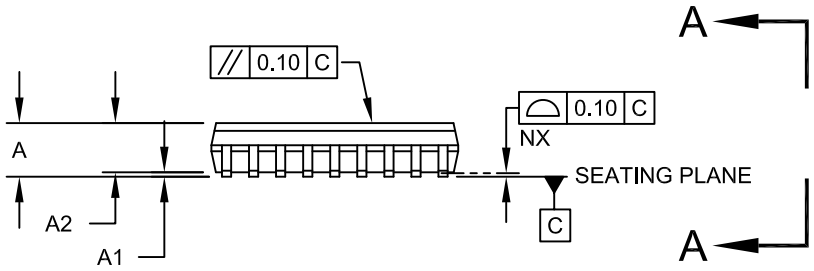
### 18-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

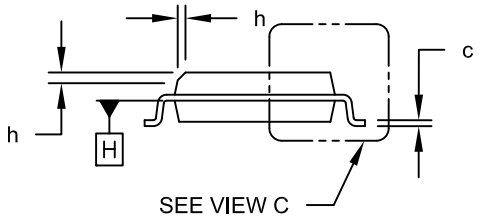
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




**TOP VIEW**




**SIDE VIEW**

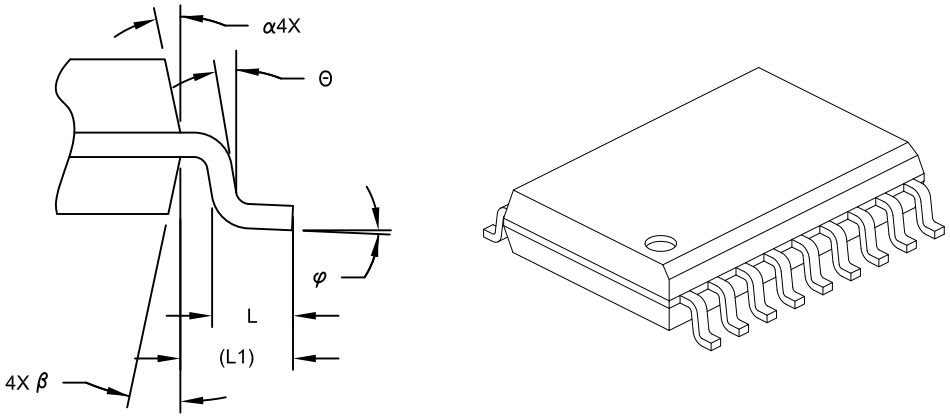



**VIEW A-A**

Microchip Technology Drawing C04-051C Sheet 1 of 2

## 18-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




**VIEW C**

| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | | 18 | |
| Pitch | e | | 1.27 BSC | |
| Overall Height | A | - | - | 2.65 |
| Molded Package Thickness | A2 | 2.05 | - | - |
| Standoff § | A1 | 0.10 | - | 0.30 |
| Overall Width | E | | 10.30 BSC | |
| Molded Package Width | E1 | | 7.50 BSC | |
| Overall Length | D | | 11.55 BSC | |
| Chamfer (Optional) | h | 0.25 | - | 0.75 |
| Foot Length | L | 0.40 | - | 1.27 |
| Footprint | L1 | | 1.40 REF | |
| Lead Angle | Θ | 0° | - | - |
| Foot Angle | φ | 0° | - | 8° |
| Lead Thickness | c | 0.20 | - | 0.33 |
| Lead Width | b | 0.31 | - | 0.51 |
| Mold Draft Angle Top | α | 5° | - | 15° |
| Mold Draft Angle Bottom | β | 5° | - | 15° |

**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic
3. Dimension D does not include mold flash, protrusions or gate burrs, which shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion, which shall not exceed 0.25 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.
5. Datums A & B to be determined at Datum H.

Microchip Technology Drawing No. C04-051C Sheet 2 of 2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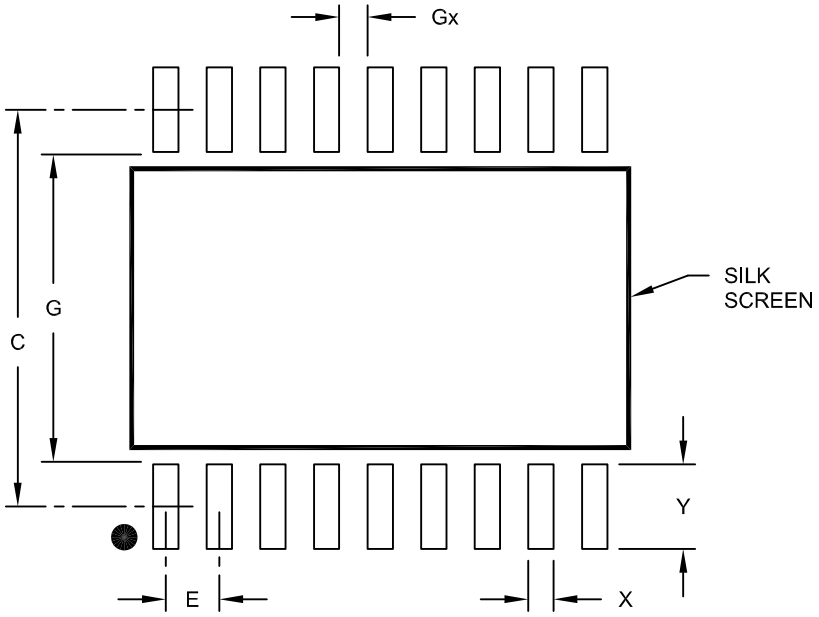
18-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | | 1.27 BSC | |
| Contact Pad Spacing | C | | 9.40 | |
| Contact Pad Width | X | | | 0.60 |
| Contact Pad Length | Y | | | 2.00 |
| Distance Between Pads | Gx | 0.67 | | |
| Distance Between Pads | G | 7.40 | | |

Notes:

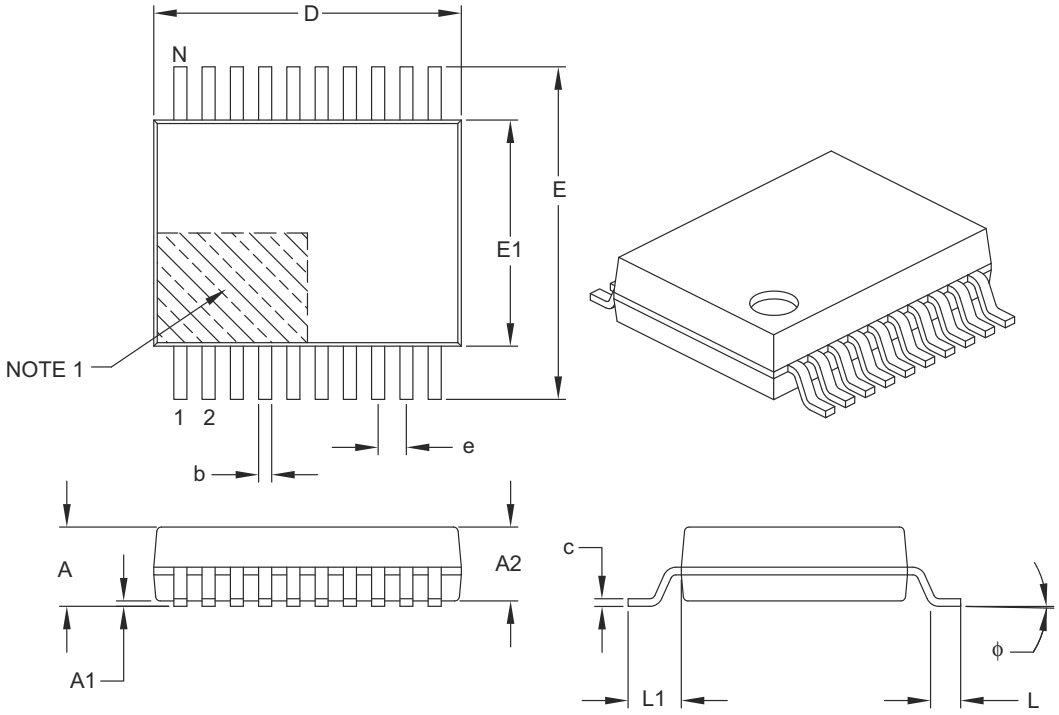
1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2051A

## 20-Lead Plastic Shrink Small Outline (SS) – 5.30 mm Body [SSOP]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | | 20 | |
| Pitch | e | | 0.65 BSC | |
| Overall Height | A | – | – | 2.00 |
| Molded Package Thickness | A2 | 1.65 | 1.75 | 1.85 |
| Standoff | A1 | 0.05 | – | – |
| Overall Width | E | 7.40 | 7.80 | 8.20 |
| Molded Package Width | E1 | 5.00 | 5.30 | 5.60 |
| Overall Length | D | 6.90 | 7.20 | 7.50 |
| Foot Length | L | 0.55 | 0.75 | 0.95 |
| Footprint | L1 | | 1.25 REF | |
| Lead Thickness | c | 0.09 | – | 0.25 |
| Foot Angle | ϕ | 0° | 4° | 8° |
| Lead Width | b | 0.22 | – | 0.38 |

**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.20 mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-072B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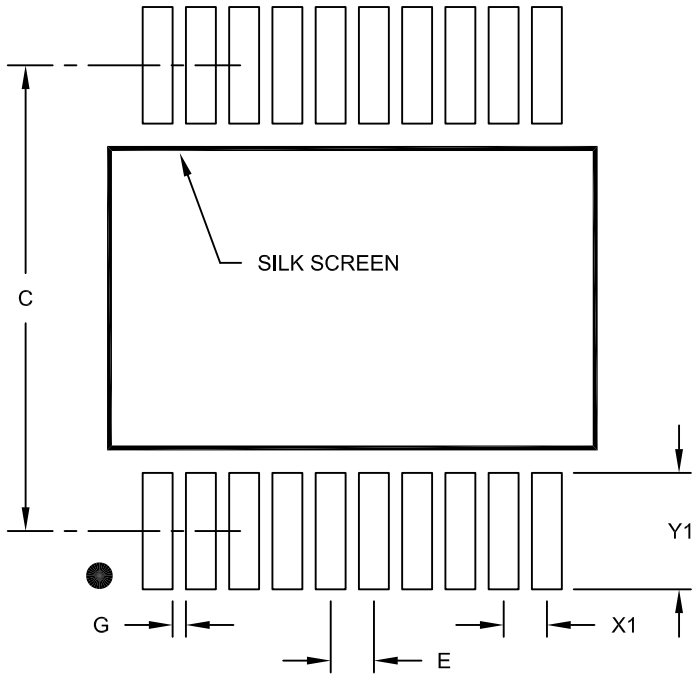
20-Lead Plastic Shrink Small Outline (SS) - 5.30 mm Body [SSOP]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | | 0.65 BSC | |
| Contact Pad Spacing | C | | 7.20 | |
| Contact Pad Width (X20) | X1 | | | 0.45 |
| Contact Pad Length (X20) | Y1 | | | 1.75 |
| Distance Between Pads | G | 0.20 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2072A

**NOTES:**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## APPENDIX A: REVISION HISTORY

| Version | Date | Revision Description |
|---|---|---|
| A | 9/1998 | This is a new data sheet. However, the devices described in this data sheet are the upgrades to the devices found in the *PIC16F8X Data Sheet*, DS30430. |
| B | 05/2001 | Added DC and AC Characteristics Graphs and Tables to Section 10. |
| C | 11/2011 | Updated the “Packaging Information” section. |

## APPENDIX B: CONVERSION CONSIDERATIONS

Considerations for converting from one PIC16X8X device to another are listed in Table 1.

**TABLE 1: CONVERSION CONSIDERATIONS - PIC16C84, PIC16F83/F84, PIC16CR83/CR84, PIC16F84A**

| Difference | PIC16C84 | PIC16F83/F84 | PIC16CR83/ CR84 | PIC16F84A |
|---|---|---|---|---|
| Program Memory Size | 1K x 14 | 512 x 14 / 1K x 14 | 512 x 14 / 1K x 14 | 1K x 14 |
| Data Memory Size | 36 x 8 | 36 x 8 / 68 x 8 | 36 x 8 / 68 x 8 | 68 x 8 |
| Voltage Range | 2.0V - 6.0V<br>(-40°C to +85°C) | 2.0V - 6.0V<br>(-40°C to +85°C) | 2.0V - 6.0V<br>(-40°C to +85°C) | 2.0V - 5.5V<br>(-40°C to +125°C) |
| Maximum Operating Frequency | 10 MHz | 10 MHz | 10 MHz | 20 MHz |
| Supply Current ($I_{DD}$). See parameter # D014 in the electrical specs for more detail. | $I_{DD}$ (typ) = 60 μA<br>$I_{DD}$ (max) = 400 μA<br>(LP osc, $F_{OSC}$ = 32 kHz, $V_{DD}$ = 2.0V, WDT disabled) | $I_{DD}$ (typ) = 15 μA<br>$I_{DD}$ (max) = 45 μA<br>(LP osc, $F_{OSC}$ = 32 kHz, $V_{DD}$ = 2.0V, WDT disabled) | $I_{DD}$ (typ) = 15 μA<br>$I_{DD}$ (max) = 45 μA<br>(LP osc, $F_{OSC}$ = 32 kHz, $V_{DD}$ = 2.0V, WDT disabled) | $I_{DD}$ (typ) = 15 μA<br>$I_{DD}$ (max) = 45 μA<br>(LP osc, $F_{OSC}$ = 32 kHz, $V_{DD}$ = 2.0V, WDT disabled) |
| Power-down Current ($I_{PD}$). See parameters # D020, D021, and D021A in the electrical specs for more detail. | $I_{PD}$ (typ) = 26 μA<br>$I_{PD}$ (max) = 100 μA<br>($V_{DD}$ = 2.0V, WDT disabled, industrial) | $I_{PD}$ (typ) = 0.4 μA<br>$I_{PD}$ (max) = 9 μA<br>($V_{DD}$ = 2.0V, WDT disabled, industrial) | $I_{PD}$ (typ) = 0.4 μA<br>$I_{PD}$ (max) = 6 μA<br>($V_{DD}$ = 2.0V, WDT disabled, industrial) | $I_{PD}$ (typ) = 0.4 μA<br>$I_{PD}$ (max) = 1 μA<br>($V_{DD}$ = 2.0V, WDT disabled, industrial) |
| Input Low Voltage ($V_{IL}$). See parameters # D032 and D034 in the electrical specs for more detail. | $V_{IL}$ (max) = 0.2$V_{DD}$ (OSC1, RC mode) | $V_{IL}$ (max) = 0.1$V_{DD}$ (OSC1, RC mode) | $V_{IL}$ (max) = 0.1$V_{DD}$ (OSC1, RC mode) | $V_{IL}$ (max) = 0.1$V_{DD}$ (OSC1, RC mode) |
| Input High Voltage ($V_{IH}$). See parameter # D040 in the electrical specs for more detail. | $V_{IH}$ (min) = 0.36$V_{DD}$ (I/O Ports with TTL, 4.5V ≤ $V_{DD}$ ≤ 5.5V) | $V_{IH}$ (min) = 2.4V (I/O Ports with TTL, 4.5V ≤ $V_{DD}$ ≤ 5.5V) | $V_{IH}$ (min) = 2.4V (I/O Ports with TTL, 4.5V ≤ $V_{DD}$ ≤ 5.5V) | $V_{IH}$ (min) = 2.4V (I/O Ports with TTL, 4.5V ≤ $V_{DD}$ ≤ 5.5V) |
| Data EEPROM Memory Erase/Write cycle time ($T_{DEW}$). See parameter # D122 in the electrical specs for more detail. | $T_{DEW}$ (typ) = 10 ms<br>$T_{DEW}$ (max) = 20 ms | $T_{DEW}$ (typ) = 10 ms<br>$T_{DEW}$ (max) = 20 ms | $T_{DEW}$ (typ) = 10 ms<br>$T_{DEW}$ (max) = 20 ms | $T_{DEW}$ (typ) = 4 ms<br>$T_{DEW}$ (max) = 8 ms |
| Port Output Rise/Fall time (TioR, TioF). See parameters #20, 20A, 21, and 21A in the electrical specs for more detail. | TioR, TioF (max) = 25 ns (C84)<br>TioR, TioF (max) = 60 ns (LC84) | TioR, TioF (max) = 35 ns (C84)<br>TioR, TioF (max) = 70 ns (LC84) | TioR, TioF (max) = 35 ns (C84)<br>TioR, TioF (max) = 70 ns (LC84) | TioR, TioF (max) = 35 ns (C84)<br>TioR, TioF (max) = 70 ns (LC84) |
| $\overline{MCLR}$ on-chip filter. See parameter #30 in the electrical specs for more detail. | No | Yes | Yes | Yes |
| PORTA and crystal oscillator values less than 500 kHz | For crystal oscillator configurations operating below 500 kHz, the device may generate a spurious internal Q-clock when PORTA<0> switches state. | N/A | N/A | N/A |
| RB0/INT pin | TTL | TTL/ST*<br>(*Schmitt Trigger) | TTL/ST*<br>(*Schmitt Trigger) | TTL/ST*<br>(*Schmitt Trigger) |


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**TABLE 1: CONVERSION CONSIDERATIONS - PIC16C84, PIC16F83/F84, PIC16CR83/CR84, PIC16F84A (CONTINUED)**

| Difference | PIC16C84 | PIC16F83/F84 | PIC16CR83/ CR84 | PIC16F84A |
|---|---|---|---|---|
| EEADR<7:6> and IDD | It is recommended that the EEADR<7:6> bits be cleared. When either of these bits is set, the maximum IDD for the device is higher than when both are cleared. | N/A | N/A | N/A |
| The polarity of the $\overline{\text{PWRTE}}$ bit | PWRTE | $\overline{\text{PWRTE}}$ | $\overline{\text{PWRTE}}$ | $\overline{\text{PWRTE}}$ |
| Recommended value of REXT for RC oscillator circuits | REXT = 3kΩ - 100kΩ | REXT = 5kΩ - 100kΩ | REXT = 5kΩ - 100kΩ | REXT = 3kΩ - 100kΩ |
| GIE bit unintentional enable | If an interrupt occurs while the Global Interrupt Enable (GIE) bit is being cleared, the GIE bit may unintentionally be re-enabled by the user's Interrupt Service Routine (the `RETFIE` instruction). | N/A | N/A | N/A |
| Packages | PDIP, SOIC | PDIP, SOIC | PDIP, SOIC | PDIP, SOIC, SSOP |
| Open Drain High Voltage (VOD) | 14V | 12V | 12V | 8.5V |

## APPENDIX C: MIGRATION FROM BASELINE TO MID-RANGE DEVICES

This section discusses how to migrate from a baseline device (i.e., PIC16C5X) to a mid-range device (i.e., PIC16CXXX).

The following is the list of feature improvements 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 512K before) and the register file (128 bytes now versus 32 bytes before).
2. A PC latch register (PCLATH) is added to handle program memory paging. PA2, PA1 and PA0 bits are removed from the STATUS register and placed in the OPTION register.
3. Data memory paging is redefined slightly. The 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 eight-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, the 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 features.
13. T0CKI pin is also a port pin (RA4/T0CKI).
14. FSR is a full 8-bit register.
15. "In system programming" is made possible. The user can program PIC16CXX devices using only five pins: $V_{DD}$, $V_{SS}$, $V_{PP}$, RB6 (clock) and RB7 (data in/out).

To convert code written for PIC16C5X to PIC16F84A, 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 for reallocation.
4. Verify all writes to STATUS, OPTION, and FSR registers since these have changed.
5. Change RESET vector to 0000h.


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| Frequency Range | 04 = 4 MHz<br>20 = 20 MHz |
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