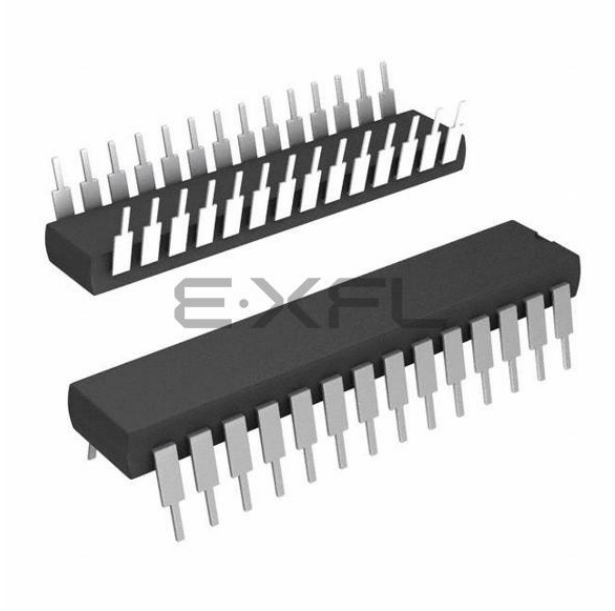

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Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	dsPIC
Core Size	16-Bit
Speed	20 MIPS
Connectivity	I²C, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	20
Program Memory Size	24KB (8K x 24)
Program Memory Type	FLASH
EEPROM Size	1K x 8
RAM Size	2K x 8
Voltage - Supply (Vcc/Vdd)	2.5V ~ 5.5V
Data Converters	A/D 10x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 125°C (TA)
Mounting Type	Through Hole
Package / Case	28-DIP (0.300", 7.62mm)
Supplier Device Package	28-SPDIP
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/dspic30f3013-20e-sp

High-Performance, 16-bit Digital Signal Controllers

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the "*dsPIC30F Family Reference Manual*" (DS70046). For more information on the device instruction set and programming, refer to the "*16-bit MCU and DSC Programmer's Reference Manual*" (DS70157).

High-Performance Modified RISC CPU:

- Modified Harvard architecture
- C compiler optimized instruction set architecture
- Flexible addressing modes
- 83 base instructions
- 24-bit wide instructions, 16-bit wide data path
- Up to 24 Kbytes on-chip Flash program space
- Up to 2 Kbytes of on-chip data RAM
- Up to 1 Kbytes of nonvolatile data EEPROM
- 16 x 16-bit working register array
- Up to 30 MIPS operation:
  - DC to 40 MHz external clock input
  - 4 MHz - 10 MHz oscillator input with PLL active (4x, 8x, 16x)
- Up to 21 interrupt sources:
  - 8 user-selectable priority levels
  - 3 external interrupt sources
  - 4 processor trap sources

DSP Features:

- Dual data fetch
- Modulo and Bit-Reversed modes
- Two 40-bit wide accumulators with optional saturation logic
- 17-bit x 17-bit single-cycle hardware fractional/ integer multiplier
- All DSP instructions are single cycle
  - Multiply-Accumulate (MAC) operation
- Single-cycle ±16 shift

Peripheral Features:

- High-current sink/source I/O pins: 25 mA/25 mA
- Three 16-bit timers/counters; optionally pair up 16-bit timers into 32-bit timer modules
- 16-bit Capture input functions
- 16-bit Compare/PWM output functions
- 3-wire SPI modules (supports four Frame modes)
- I^2C™ module supports Multi-Master/Slave mode and 7-bit/10-bit addressing
- Up to two addressable UART modules with FIFO buffers

Analog Features:

- 12-bit Analog-to-Digital Converter (ADC) with:
  - 200 ksps conversion rate
  - Up to 10 input channels
  - Conversion available during Sleep and Idle
- Programmable Low-Voltage Detection (PLVD)
- Programmable Brown-out Reset

Special Microcontroller Features:

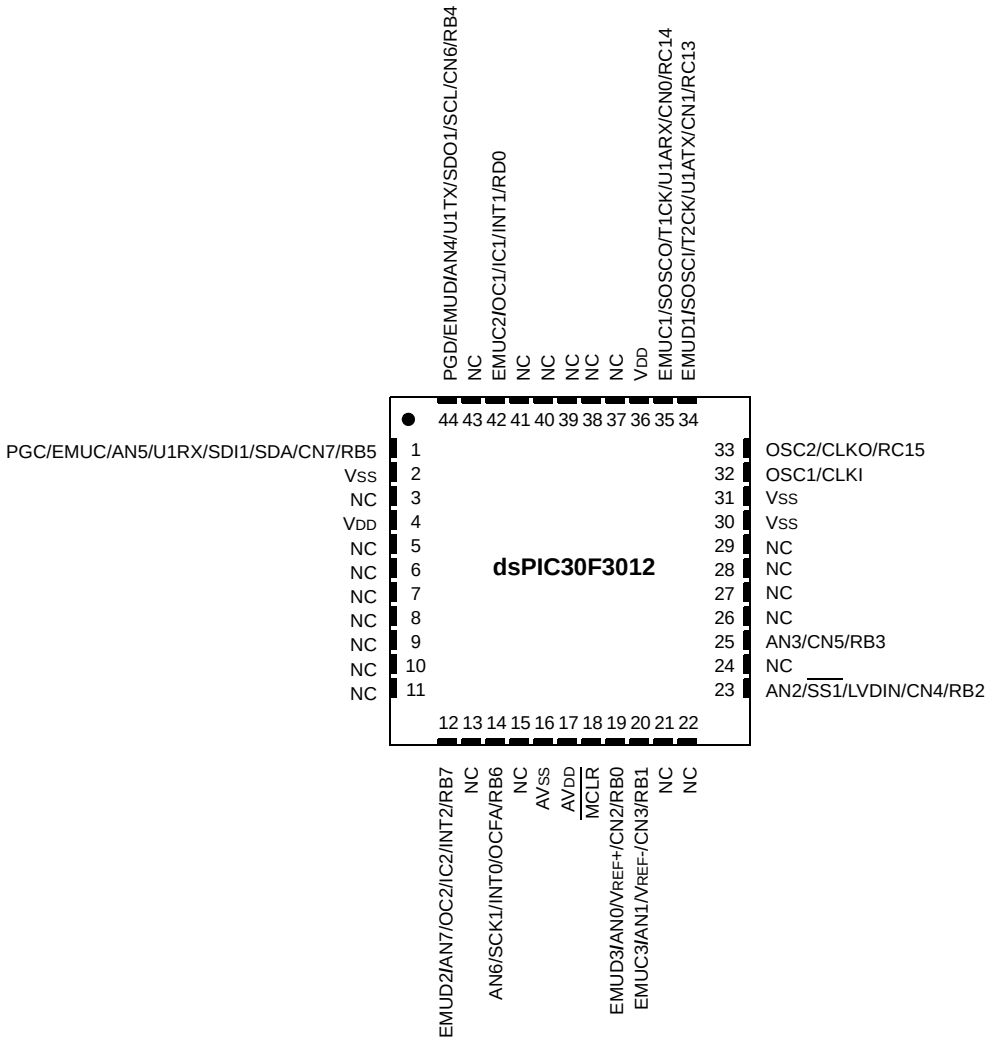
- Enhanced Flash program memory:
  - 10,000 erase/write cycle (min.) for industrial temperature range, 100K (typical)
- Data EEPROM memory:
  - 100,000 erase/write cycle (min.) for industrial temperature range, 1M (typical)
- Self-reprogrammable under software control
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Flexible Watchdog Timer (WDT) with on-chip low-power RC oscillator for reliable operation
- Fail-Safe Clock Monitor operation:
  - Detects clock failure and switches to on-chip low-power RC oscillator
- Programmable code protection
- In-Circuit Serial Programming™ (ICSP™)
- Selectable Power Management modes:
  - Sleep, Idle and Alternate Clock modes

CMOS Technology:

- Low-power, high-speed Flash technology
- Wide operating voltage range (2.5V to 5.5V)
- Industrial and Extended temperature ranges
- Low-power consumption

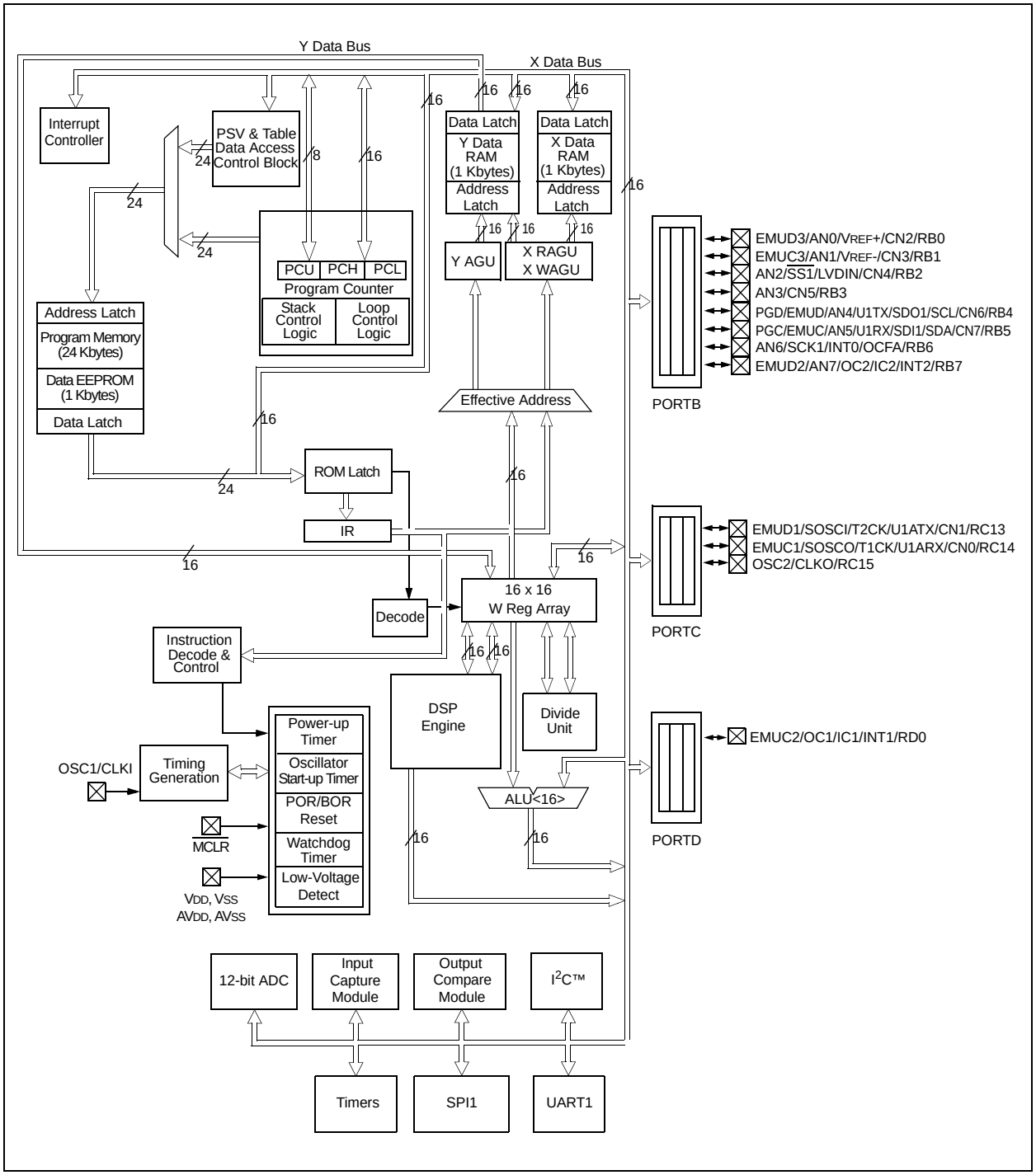
Pin Diagram

44-Pin QFN(1)



Note 1: The metal plane at the bottom of the device is not connected to any pins and is recommended to be connected to VSS externally.

FIGURE 1-3: dsPIC30F3012 BLOCK DIAGRAM



3.2 Data Address Space

The core has two data spaces. The data spaces can be considered either separate (for some DSP instructions), or as one unified linear address range (for MCU instructions). The data spaces are accessed using two Address Generation Units (AGUs) and separate data paths.

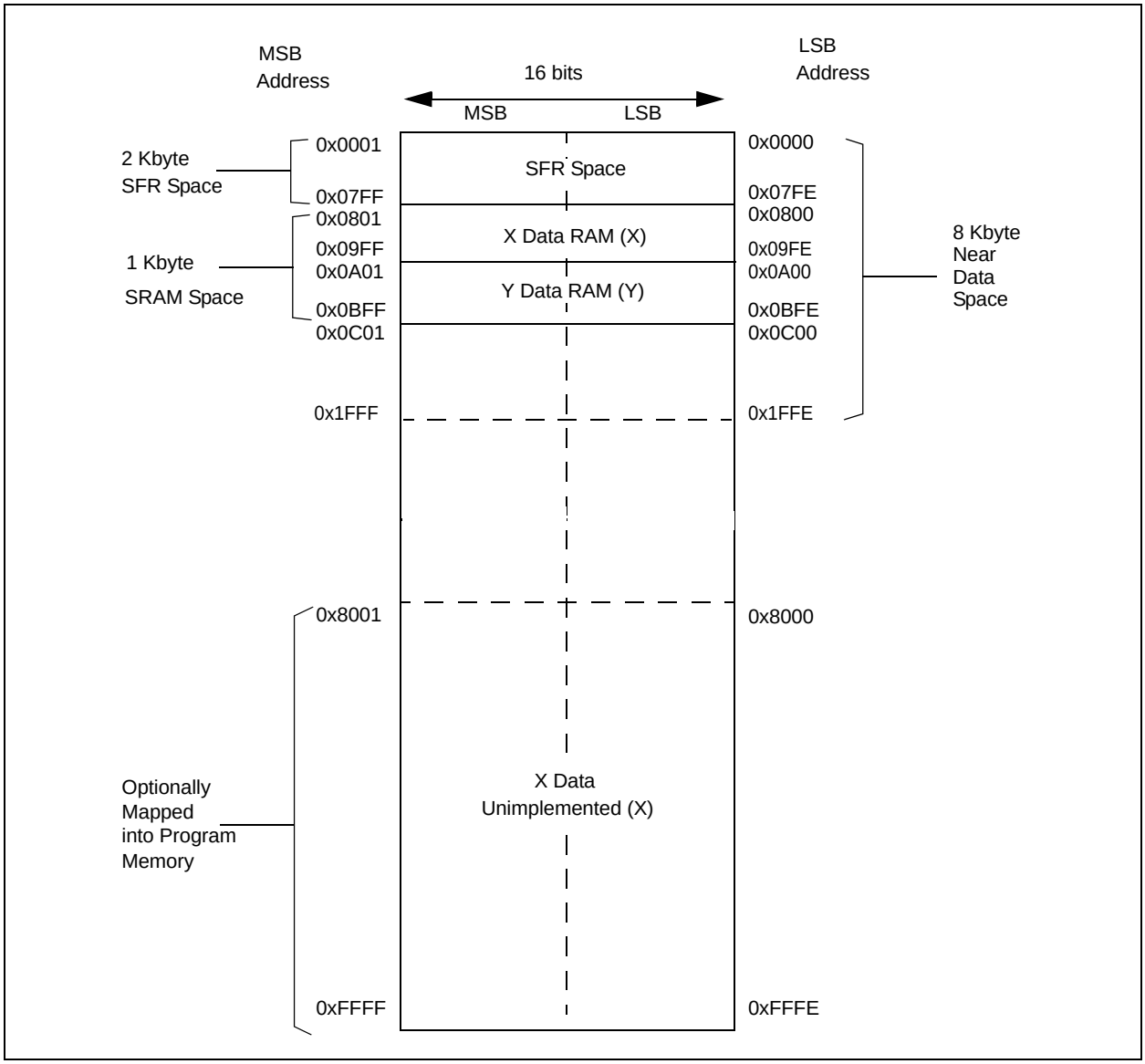
3.2.1 DATA SPACE MEMORY MAP

The data space memory is split into two blocks, X and Y data space. A key element of this architecture is that Y space is a subset of X space, and is fully contained within X space. In order to provide an apparent Linear Addressing space, X and Y spaces have contiguous addresses.

When executing any instruction other than one of the MAC class of instructions, the X block consists of the 64 Kbyte data address space (including all Y addresses). When executing one of the MAC class of instructions, the X block consists of the 64 Kbyte data address space, excluding the Y address block (for data reads only). In other words, all other instructions regard the entire data memory as one composite address space. The MAC class instructions extract the Y address space from data space and address it using EAs sourced from W10 and W11. The remaining X data space is addressed using W8 and W9. Both address spaces are concurrently accessed only with the MAC class instructions.

The data space memory map for the dsPIC30F2011 and dsPIC30F2012 is shown in Figure 3-6. The data space memory map for the dsPIC30F3012 and dsPIC30F3013 is shown in Figure 3-7.

FIGURE 3-6: dsPIC30F2011/2012 DATA SPACE MEMORY MAP



6.3 Writing to the Data EEPROM

To write an EEPROM data location, the following sequence must be followed:

1. Erase data EEPROM word.
   a) Select word, data EEPROM erase, and set WREN bit in NVMCON register.
   b) Write address of word to be erased into NVMADR.
   c) Enable NVM interrupt (optional).
   d) Write 0x55 to NVMKEY.
   e) Write 0xAA to NVMKEY.
   f) Set the WR bit. This begins erase cycle.
   g) Either poll NVMIF bit or wait for NVMIF interrupt.
   h) The WR bit is cleared when the erase cycle ends.
2. Write data word into data EEPROM write latches.
3. Program 1 data word into data EEPROM.
   a) Select word, data EEPROM program, and set WREN bit in NVMCON register.
   b) Enable NVM write done interrupt (optional).
   c) Write 0x55 to NVMKEY.
   d) Write 0xAA to NVMKEY.
   e) Set the WR bit. This begins program cycle.
   f) Either poll NVMIF bit or wait for NVM interrupt.
   g) The WR bit is cleared when the write cycle ends.

The write does not initiate if the above sequence is not exactly followed (write 0x55 to NVMKEY, write 0xAA to NVMCON, then set WR bit) for each word. It is strongly recommended that interrupts be disabled during this code segment.

Additionally, the WREN bit in NVMCON must be set to enable writes. This mechanism prevents accidental writes to data EEPROM due to unexpected code execution. The WREN bit should be kept clear at all times except when updating the EEPROM. The WREN bit is not cleared by hardware.

After a write sequence has been initiated, clearing the WREN bit does not affect the current write cycle. The WR bit is inhibited from being set unless the WREN bit is set. The WREN bit must be set on a previous instruction. Both WR and WREN cannot be set with the same instruction.

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

6.3.1 WRITING A WORD OF DATA EEPROM

Once the user has erased the word to be programmed, then a table write instruction is used to write one write latch, as shown in Example 6-4.

6.3.2 WRITING A BLOCK OF DATA EEPROM

To write a block of data EEPROM, write to all sixteen latches first, then set the NVMCON register and program the block.

EXAMPLE 6-4: DATA EEPROM WORD WRITE

```
; Point to data memory
    MOV         #LOW_ADDR_WORD,W0                ; Init pointer
    MOV         #HIGH_ADDR_WORD,W1
    MOV         W1,TBLPAG
    MOV         #LOW(WORD),W2                    ; Get data
    TBLWTL      W2,[ W0]                         ; Write data
; The NVMADR captures last table access address
; Select data EEPROM for 1 word op
    MOV         #0x4004,W0
    MOV         W0,NVMCON

; Operate key to allow write operation
    DISI        #5                               ; Block all interrupts with priority <7 for
                                                 ; next 5 instructions
    MOV         #0x55,W0
    MOV         W0,NVMKEY                        ; Write the 0x55 key
    MOV         #0xAA,W1
    MOV         W1,NVMKEY                        ; Write the 0xAA key
    BSET        NVMCON,#WR                       ; Initiate program sequence
    NOP
    NOP
; Write cycle will complete in 2mS. CPU is not stalled for the Data Write Cycle
; User can poll WR bit, use NVMIF or Timer IRQ to determine write complete
```

7.0 I/O PORTS

Note:	This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the "*dsPIC30F Family Reference Manual*" (DS70046).

All of the device pins (except VDD, VSS, $\overline{\text{MCLR}}$ and OSC1/CLKI) are shared between the peripherals and the parallel I/O ports.

All I/O input ports feature Schmitt Trigger inputs for improved noise immunity.

7.1 Parallel I/O (PIO) Ports

When a peripheral is enabled and the peripheral is actively driving an associated pin, the use of the pin as a general purpose output pin is disabled. The I/O pin can be read, but the output driver for the parallel port bit is disabled. If a peripheral is enabled, but the peripheral is not actively driving a pin, that pin can be driven by a port.

All port pins have three registers directly associated with the operation of the port pin. The Data Direction register (TRISx) determines whether the pin is an input or an output. If the data direction bit is a '1', then the pin is an input. All port pins are defined as inputs after a Reset. Reads from the latch (LATx), read the latch. Writes to the latch, write the latch (LATx). Reads from the port (PORTx), read the port pins and writes to the port pins, write the latch (LATx).

Any bit and its associated data and Control registers that are not valid for a particular device are disabled. That means the corresponding LATx and TRISx registers and the port pin read as zeros.

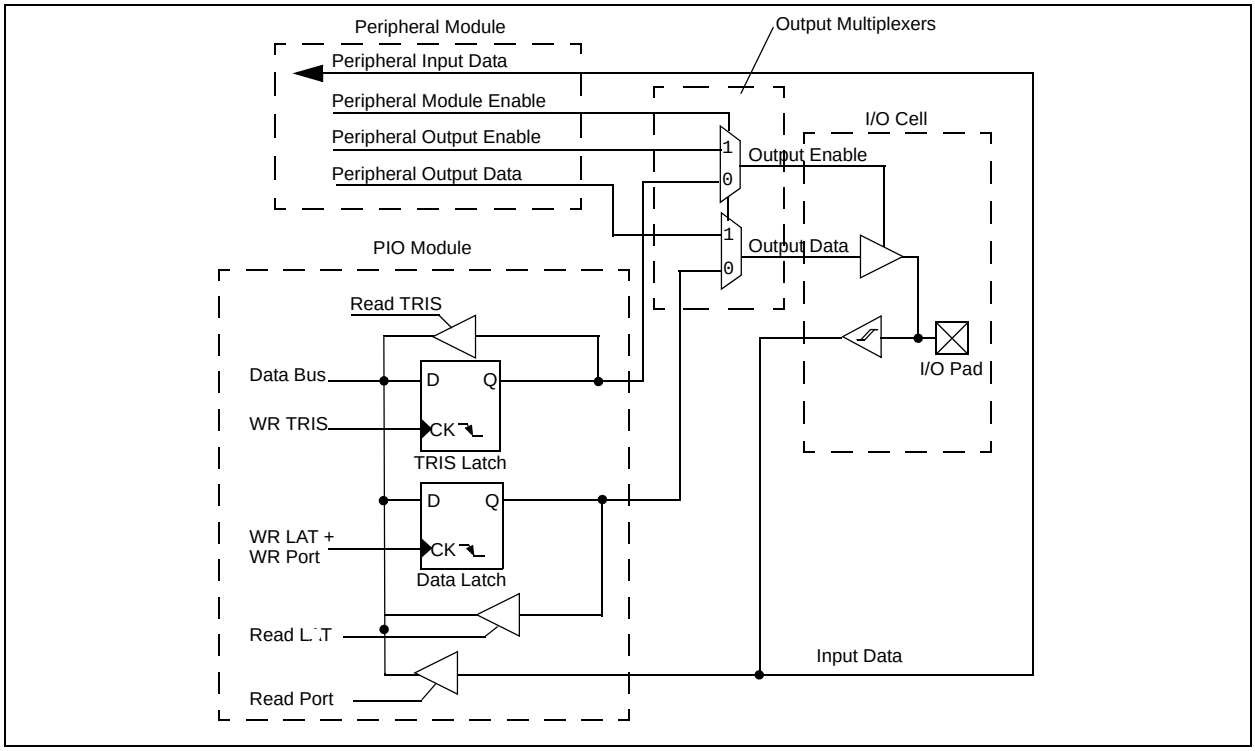
When a pin is shared with another peripheral or function that is defined as an input only, it is nevertheless regarded as a dedicated port because there is no other competing source of outputs.

A parallel I/O (PIO) port that shares a pin with a peripheral is, in general, subservient to the peripheral. The peripheral's output buffer data and control signals are provided to a pair of multiplexers. The multiplexers select whether the peripheral or the associated port has ownership of the output data and control signals of the I/O pad cell. Figure 7-1 illustrates how ports are shared with other peripherals and the associated I/O cell (pad) to which they are connected.

The format of the registers for the shared ports, (PORTB, PORTC, PORTD and PORTF) are shown in Table 7-1 through Table 7-6.

Note:	The actual bits in use vary between devices.

FIGURE 7-1: BLOCK DIAGRAM OF A SHARED PORT STRUCTURE



7.2 Configuring Analog Port Pins

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

When the PORT register is read, all pins configured as analog input channels are read as cleared (a low level).

Pins configured as digital inputs will not convert an analog input. Analog levels on any pin that is defined as a digital input (including the ANx pins) may cause the input buffer to consume the current that exceeds device specifications.

7.2.1 I/O PORT WRITE/READ TIMING

One instruction cycle is required between a port direction change or port write operation and a read operation of the same port. Typically this instruction would be a NOP.

EXAMPLE 7-1: PORT WRITE/READ EXAMPLE

```
MOV  #0xF0, W0  ; Configure PORTB<7:4>
                ; as inputs
MOV  W0, TRISB  ; and PORTB<3:0> as outputs
NOP             ; additional instruction
                    cycle
btss PORTB, #7  ; bit test RB7 and skip if
                    set
```

TABLE 8-3: dsPIC30F3013 INTERRUPT CONTROLLER REGISTER MAP

SFR Name	ADR	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset State
INTCON1	0080	NSTDIS	—	—	—	—	OVATE	OVBTE	COVTE	—	—	—	MATHERR	ADDRERR	STKERR	OSCFAIL	—	0000 0000 0000 0000
INTCON2	0082	ALTIVT	DISI	—	—	—	—	—	—	—	—	—	—	—	INT2EP	INT1EP	INT0EP	0000 0000 0000 0000
IFS0	0084	CNIF	MI2CIF	SI2CIF	NVMIF	ADIF	U1TXIF	U1RXIF	SPI1IF	T3IF	T2IF	OC2IF	IC2IF	T1IF	OC1IF	IC1IF	INT0IF	0000 0000 0000 0000
IFS1	0086	—	—	—	—	—	—	U2TXIF	U2RXIF	INT2IF	—	—	—	—	—	—	INT1IF	0000 0000 0000 0000
IFS2	0088	—	—	—	—	—	LVDIF	—	—	—	—	—	—	—	—	—	—	0000 0000 0000 0000
IEC0	008C	CNIE	MI2CIE	SI2CIE	NVMIE	ADIE	U1TXIE	U1RXIE	SPI1IE	T3IE	T2IE	OC2IE	IC2IE	T1IE	OC1IE	IC1IE	INT0IE	0000 0000 0000 0000
IEC1	008E	—	—	—	—	—		U2TXIE	U2RXIE	INT2IE	—	—	—	—	—	—	INT1IE	0000 0000 0000 0000
IEC2	0090	—	—	—	—	—	LVDIE	—	—	—	—	—	—	—	—	—	—	0000 0000 0000 0000
IPC0	0094	—	T1IP<2:0>			—	OC1IP<2:0>			—	IC1IP<2:0>			—	INT0IP<2:0>			0100 0100 0100 0100
IPC1	0096	—	T31P<2:0>			—	T2IP<2:0>			—	OC2IP<2:0>			—	IC2IP<2:0>			0100 0100 0100 0100
IPC2	0098	—	ADIP<2:0>			—	U1TXIP<2:0>			—	U1RXIP<2:0>			—	SPI1IP<2:0>			0100 0100 0100 0100
IPC3	009A	—	CNIP<2:0>			—	MI2CIP<2:0>			—	SI2CIP<2:0>			—	NVMIP<2:0>			0100 0100 0100 0100
IPC4	009C	—	—	—	—	—	—	—	—	—	—	—	—	—	INT1IP<2:0>			0000 0000 0000 0100
IPC5	009E	—	INT2IP<2:0>			—	—	—	—	—	—	—	—	—				0100 0000 0000 0000
IPC6	00A0	—	—	—	—	—	—	—	—	—	U2TXIP<2:0>			—	U2RXIP<2:0>			0000 0000 0100 0100
IPC7	00A2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0000 0000 0000 0000
IPC8	00A4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0000 0000 0000 0000
IPC9	00A6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0000 0000 0000 0000
IPC10	00A8	—	—	—	—	—	LVDIP<2:0>			—	—	—	—	—	—	—	—	0000 0100 0000 0000

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the "*dsPIC30F Family Reference Manual*" (DS70046) for descriptions of register bit fields.

12.0 OUTPUT COMPARE MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the "*dsPIC30F Family Reference Manual*" (DS70046).

This section describes the output compare module and associated operational modes. The features provided by this module are useful in applications requiring operational modes, such as:

- Generation of Variable Width Output Pulses
- Power Factor Correction

Figure 12-1 depicts a block diagram of the output compare module.

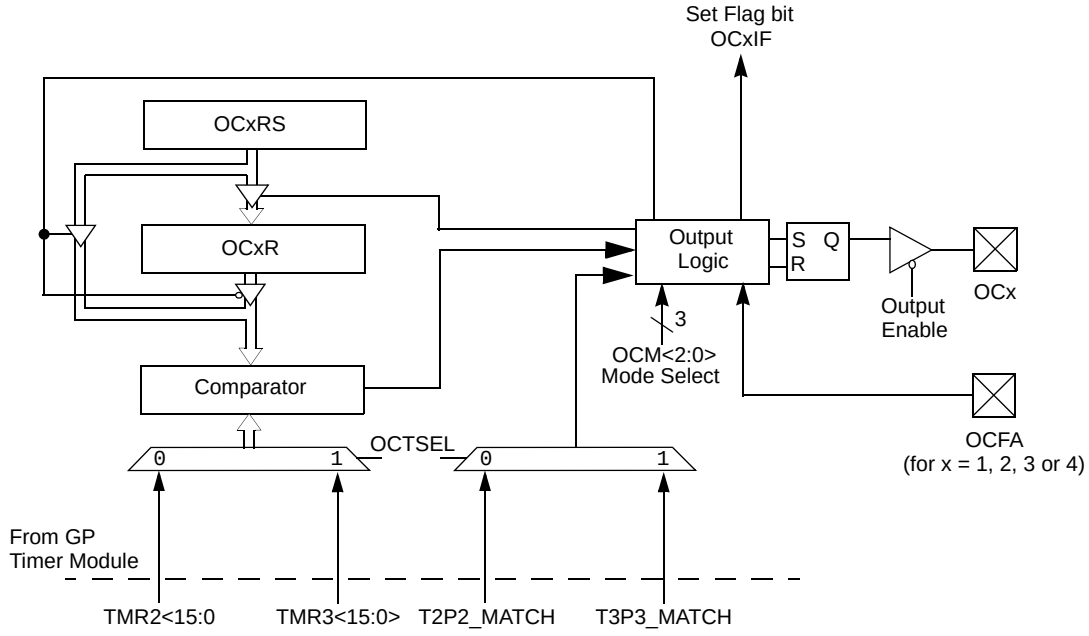
The key operational features of the output compare module include:

- Timer2 and Timer3 Selection mode
- Simple Output Compare Match mode
- Dual Output Compare Match mode
- Simple PWM mode
- Output Compare During Sleep and Idle modes
- Interrupt on Output Compare/PWM Event

These operating modes are determined by setting the appropriate bits in the 16-bit OC1CON and OC2CON registers. The dsPIC30F2011/2012/3012/3013 devices have 2 compare channels.

OCxRS and OCxR in Figure 12-1 represent the Dual Compare registers. In the Dual Compare mode, the OCxR register is used for the first compare and OCxRS is used for the second compare.

FIGURE 12-1: OUTPUT COMPARE MODE BLOCK DIAGRAM(1)



Note 1: Where 'x' is shown, reference is made to the registers associated with the respective output compare channel (1 or 2).

14.0 I²C™ MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the "*dsPIC30F Family Reference Manual*" (DS70046).

The Inter-Integrated Circuit (I²C™) module provides complete hardware support for both Slave and Multi-Master modes of the I²C serial communication standard, with a 16-bit interface.

This module offers the following key features:

- I²C interface supporting both master and slave operation.
- I²C Slave mode supports 7-bit and 10-bit addressing.
- I²C Master mode supports 7-bit and 10-bit addressing.
- I²C port allows bidirectional transfers between master and slaves.
- Serial clock synchronization for I²C port can be used as a handshake mechanism to suspend and resume serial transfer (SCLREL control).
- I²C supports multi-master operation; detects bus collision and will arbitrate accordingly.

14.1 Operating Function Description

The hardware fully implements all the master and slave functions of the I²C Standard and Fast mode specifications, as well as 7 and 10-bit addressing.

Thus, the I²C module can operate either as a slave or a master on an I²C bus.

14.1.1 VARIOUS I²C MODES

The following types of I²C operation are supported:

- I²C slave operation with 7-bit addressing
- I²C slave operation with 10-bit addressing
- I²C master operation with 7-bit or 10-bit addressing

See the I²C programmer's model (Figure 14-1).

14.1.2 PIN CONFIGURATION IN I²C MODE

I²C has a 2-pin interface; the SCL pin is clock and the SDA pin is data.

14.1.3 I²C REGISTERS

I2CCON and I2CSTAT are control and status registers, respectively. The I2CCON register is readable and writable. The lower 6 bits of I2CSTAT are read-only. The remaining bits of the I2CSTAT are read/write.

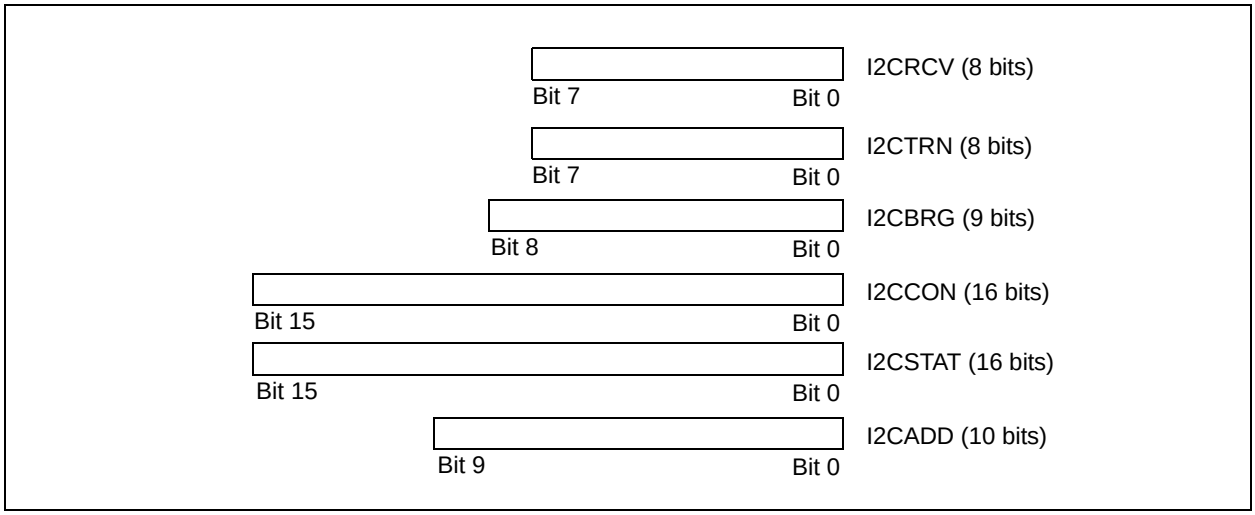
I2CRSR is the shift register used for shifting data, whereas I2CRCV is the buffer register to which data bytes are written, or from which data bytes are read. I2CRCV is the receive buffer as shown in Figure 14-1. I2CTRN is the transmit register to which bytes are written during a transmit operation, as shown in Figure 14-2.

The I2CADD register holds the slave address. A Status bit, ADD10, indicates 10-bit Address mode. The I2CBRG acts as the Baud Rate Generator reload value.

In receive operations, I2CRSR and I2CRCV together form a double-buffered receiver. When I2CRSR receives a complete byte, it is transferred to I2CRCV and an interrupt pulse is generated. During transmission, the I2CTRN is not double-buffered.

Note: Following a Restart condition in 10-bit mode, the user only needs to match the first 7-bit address.

FIGURE 14-1: PROGRAMMER'S MODEL



14.4.1 10-BIT MODE SLAVE TRANSMISSION

Once a slave is addressed in this fashion with the full 10-bit address (we will refer to this state as “PRIOR_ADDR_MATCH”), the master can begin sending data bytes for a slave reception operation.

14.4.2 10-BIT MODE SLAVE RECEPTION

Once addressed, the master can generate a Repeated Start, reset the high byte of the address and set the R_W bit without generating a Stop bit, thus initiating a slave transmit operation.

14.5 Automatic Clock Stretch

In the Slave modes, the module can synchronize buffer reads and write to the master device by clock stretching.

14.5.1 TRANSMIT CLOCK STRETCHING

Both 10-bit and 7-bit Transmit modes implement clock stretching by asserting the SCLREL bit after the falling edge of the ninth clock, if the TBF bit is cleared, indicating the buffer is empty.

In Slave Transmit modes, clock stretching is always performed irrespective of the STREN bit.

Clock synchronization takes place following the ninth clock of the transmit sequence. If the device samples an ACK on the falling edge of the ninth clock and if the TBF bit is still clear, then the SCLREL bit is automatically cleared. The SCLREL being cleared to ‘0’ will assert the SCL line low. The user’s ISR must set the SCLREL bit before transmission is allowed to continue. By holding the SCL line low, the user has time to service the ISR and load the contents of the I2CTRN before the master device can initiate another transmit sequence.

Note 1:	If the user loads the contents of I2CTRN, setting the TBF bit before the falling edge of the ninth clock, the SCLREL bit will not be cleared and clock stretching will not occur.
2:	The SCLREL bit can be set in software, regardless of the state of the TBF bit.

14.5.2 RECEIVE CLOCK STRETCHING

The STREN bit in the I2CCON register can be used to enable clock stretching in Slave Receive mode. When the STREN bit is set, the SCL pin will be held low at the end of each data receive sequence.

14.5.3 CLOCK STRETCHING DURING 7-BIT ADDRESSING (STREN = 1)

When the STREN bit is set in Slave Receive mode, the SCL line is held low when the buffer register is full. The method for stretching the SCL output is the same for both 7 and 10-bit addressing modes.

Clock stretching takes place following the ninth clock of the receive sequence. On the falling edge of the ninth clock at the end of the ACK sequence, if the RBF bit is set, the SCLREL bit is automatically cleared, forcing the SCL output to be held low. The user’s ISR must set the SCLREL bit before reception is allowed to continue. By holding the SCL line low, the user has time to service the ISR and read the contents of the I2CRCV before the master device can initiate another receive sequence. This will prevent buffer overruns from occurring.

Note 1:	If the user reads the contents of the I2CRCV, clearing the RBF bit before the falling edge of the ninth clock, the SCLREL bit will not be cleared and clock stretching will not occur.
2:	The SCLREL bit can be set in software regardless of the state of the RBF bit. The user should be careful to clear the RBF bit in the ISR before the next receive sequence in order to prevent an overflow condition.

14.5.4 CLOCK STRETCHING DURING 10-BIT ADDRESSING (STREN = 1)

Clock stretching takes place automatically during the addressing sequence. Because this module has a register for the entire address, it is not necessary for the protocol to wait for the address to be updated.

After the address phase is complete, clock stretching will occur on each data receive or transmit sequence as was described earlier.

14.6 Software Controlled Clock Stretching (STREN = 1)

When the STREN bit is ‘1’, the SCLREL bit may be cleared by software to allow software to control the clock stretching. The logic will synchronize writes to the SCLREL bit with the SCL clock. Clearing the SCLREL bit will not assert the SCL output until the module detects a falling edge on the SCL output and SCL is sampled low. If the SCLREL bit is cleared by the user while the SCL line has been sampled low, the SCL output will be asserted (held low). The SCL output will remain low until the SCLREL bit is set, and all other devices on the I^2C bus have de-asserted SCL. This ensures that a write to the SCLREL bit will not violate the minimum high time requirement for SCL.

If the STREN bit is ‘0’, a software write to the SCLREL bit will be disregarded and have no effect on the SCLREL bit.

14.12.2 I²C MASTER RECEPTION

Master mode reception is enabled by programming the Receive Enable bit, RCEN (I2CCON<3>). The I²C module must be Idle before the RCEN bit is set, otherwise the RCEN bit will be disregarded. The Baud Rate Generator begins counting and on each rollover, the state of the SCL pin ACK and data are shifted into the I2CRSR on the rising edge of each clock.

14.12.3 BAUD RATE GENERATOR

In I²C Master mode, the reload value for the BRG is located in the I2CBRG register. When the BRG is loaded with this value, the BRG counts down to '0' and stops until another reload has taken place. If clock arbitration is taking place, for instance, the BRG is reloaded when the SCL pin is sampled high.

As per the I²C standard, FSCK may be 100 kHz or 400 kHz. However, the user can specify any baud rate up to 1 MHz. I2CBRG values of '0' or '1' are illegal.

EQUATION 14-1: SERIAL CLOCK RATE

$$I2CBRG = \left(\frac{FCY}{FSCL} - \frac{FCY}{1{,}111{,}111} \right) - 1$$

14.12.4 CLOCK ARBITRATION

Clock arbitration occurs when the master de-asserts the SCL pin (SCL allowed to float high) during any receive, transmit, or Restart/Stop condition. When the SCL pin is allowed to float high, the Baud Rate Generator (BRG) is suspended from counting until the SCL pin is actually sampled high. When the SCL pin is sampled high, the Baud Rate Generator is reloaded with the contents of I2CBRG and begins counting. This ensures that the SCL high time will always be at least one BRG rollover count in the event that the clock is held low by an external device.

14.12.5 MULTI-MASTER COMMUNICATION, BUS COLLISION, AND BUS ARBITRATION

Multi-master operation support is achieved by bus arbitration. When the master outputs address/data bits onto the SDA pin, arbitration takes place when the master outputs a '1' on SDA by letting SDA float high while another master asserts a '0'. When the SCL pin floats high, data should be stable. If the expected data on SDA is a '1' and the data sampled on the SDA pin = 0, then a bus collision has taken place. The master will set the MI2CIF pulse and reset the master portion of the I²C port to its Idle state.

If a transmit was in progress when the bus collision occurred, the transmission is halted, the TBF flag is cleared, the SDA and SCL lines are de-asserted and a value can now be written to I2CTRN. When the user services the I²C master event Interrupt Service Routine, if the I²C bus is free (i.e., the P bit is set), the user can resume communication by asserting a Start condition.

If a Start, Restart, Stop or Acknowledge condition was in progress when the bus collision occurred, the condition is aborted, the SDA and SCL lines are de-asserted, and the respective control bits in the I2CCON register are cleared to '0'. When the user services the bus collision Interrupt Service Routine, and if the I²C bus is free, the user can resume communication by asserting a Start condition.

The master will continue to monitor the SDA and SCL pins, and if a Stop condition occurs, the MI2CIF bit will be set.

A write to the I2CTRN will start the transmission of data at the first data bit regardless of where the transmitter left off when bus collision occurred.

In a multi-master environment, the interrupt generation on the detection of Start and Stop conditions allows the determination of when the bus is free. Control of the I²C bus can be taken when the P bit is set in the I2CSTAT register, or the bus is Idle and the S and P bits are cleared.

14.13 I²C Module Operation During CPU Sleep and Idle Modes

14.13.1 I²C OPERATION DURING CPU SLEEP MODE

When the device enters Sleep mode, all clock sources to the module are shut down and stay at logic '0'. If Sleep occurs in the middle of a transmission and the state machine is partially into a transmission as the clocks stop, then the transmission is aborted. Similarly, if Sleep occurs in the middle of a reception, then the reception is aborted.

14.13.2 I²C OPERATION DURING CPU IDLE MODE

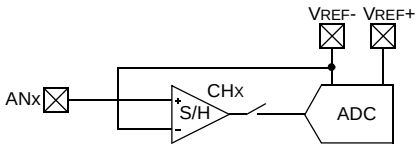
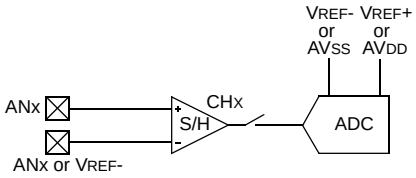
For the I²C, the I2CSIDL bit selects if the module will stop on Idle or continue on Idle. If I2CSIDL = 0, the module will continue operation on assertion of the Idle mode. If I2CSIDL = 1, the module will stop on Idle.

16.7 ADC Speeds

The dsPIC30F 12-bit ADC specifications permit a maximum of 200 ksps sampling rate. Table 16-1 summarizes the conversion speeds for the dsPIC30F 12-bit ADC and the required operating conditions.

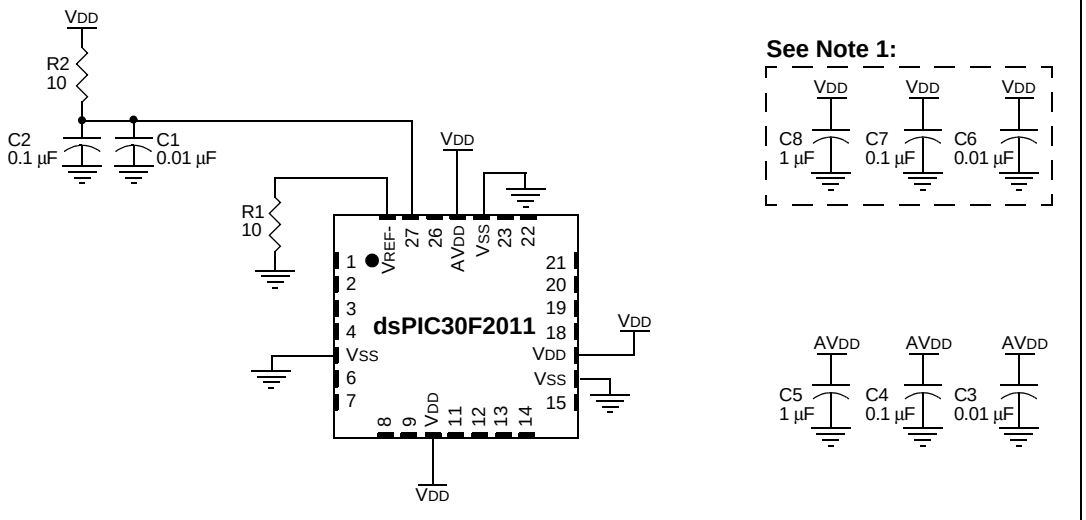
Figure 16-2 depicts the recommended circuit for the conversion rates above 200 ksps. The dsPIC30F2011 is shown as an example.

TABLE 16-1: 12-BIT ADC EXTENDED CONVERSION RATES

dsPIC30F 12-bit ADC Conversion Rates						
Speed	**TAD Minimum**	**Sampling Time Min**	**R_S Max**	**VDD**	**Temperature**	**Channel Configuration**
Up to 200 ksps(1)	334 ns	1 TAD	2.5 kΩ	4.5V to 5.5V	-40°C to +85°C	
Up to 100 ksps	668 ns	1 TAD	2.5 kΩ	3.0V to 5.5V	-40°C to +125°C	

Note 1: External VREF- and VREF+ pins must be used for correct operation. See Figure 16-2 for recommended circuit.

FIGURE 16-2: ADC VOLTAGE REFERENCE SCHEMATIC



Note 1: Ensure adequate bypass capacitors are provided on each VDD pin.

The configuration procedures in the next section provide the required setup values for the conversion speeds above 100 ksps.

16.7.1 200 KSPS CONFIGURATION GUIDELINE

The following configuration items are required to achieve a 200 ksps conversion rate.

- Comply with conditions provided in Table 16-1.
- Connect external VREF+ and VREF- pins following the recommended circuit shown in Figure 16-2.
- Set SSRC<2.0> = 111 in the ADCON1 register to enable the auto convert option.
- Enable automatic sampling by setting the ASAM control bit in the ADCON1 register.
- Write the SMPI<3.0> control bits in the ADCON2 register for the desired number of conversions between interrupts.
- Configure the ADC clock period to be:

$$\frac{1}{(14 + 1) \times 200{,}000} = 334 \text{ ns}$$

  by writing to the ADCS<5:0> control bits in the ADCON3 register.
- Configure the sampling time to be 1 TAD by writing: SAMC<4:0> = 00001.

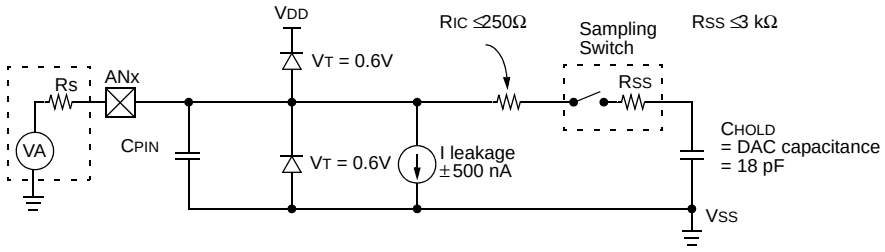
The following figure shows the timing diagram of the ADC running at 200 ksps. The TAD selection in conjunction with the guidelines described above allows a conversion speed of 200 ksps. See Example 16-1 for code example.

16.8 A/D Acquisition Requirements

The analog input model of the 12-bit ADC is shown in Figure 16-3. The total sampling time for the A/D is a function of the internal amplifier settling time and the holding capacitor charge time.

For the ADC to meet its specified accuracy, the charge holding capacitor (CHOLD) must be allowed to fully charge to the voltage level on the analog input pin. The source impedance (RS), the interconnect impedance (RIC) and the internal sampling switch (RSS) impedance combine to directly affect the time required to charge the capacitor CHOLD. The combined impedance of the analog sources must therefore be small enough to fully charge the holding capacitor within the chosen sample time. To minimize the effects of pin leakage currents on the accuracy of the ADC, the maximum recommended source impedance, RS, is 2.5 kΩ. After the analog input channel is selected (changed), this sampling function must be completed prior to starting the conversion. The internal holding capacitor will be in a discharged state prior to each sample operation.

FIGURE 16-3: 12-BIT A/D CONVERTER ANALOG INPUT MODEL



Legend: CPIN = input capacitance; VT = threshold voltage; I leakage = leakage current at the pin due to various junctions; RIC = interconnect resistance; RSS = sampling switch resistance; CHOLD = sample/hold capacitance (from DAC)

Note: CPIN value depends on device package and is not tested. Effect of CPIN negligible if Rs ≤2.5 kΩ

17.2.3 LP OSCILLATOR CONTROL

Enabling the LP oscillator is controlled with two elements:

- The current oscillator group bits COSC<2:0>.
- The LPOSCEN bit (OSCCON register).

The LP oscillator is on (even during Sleep mode) if LPOSCEN = 1. The LP oscillator is the device clock if:

- COSC<2:0> = 000 (LP selected as main osc.) and
- LPOSCEN = 1

Keeping the LP oscillator on at all times allows for a fast switch to the 32 kHz system clock for lower power operation. Returning to the faster main oscillator will still require a start-up time

17.2.4 PHASE LOCKED LOOP (PLL)

The PLL multiplies the clock which is generated by the primary oscillator or Fast RC oscillator. The PLL is selectable to have either gains of x4, x8, and x16. Input and output frequency ranges are summarized in Table 17-3.

TABLE 17-3: PLL FREQUENCY RANGE

FIN	PLL Multiplier	FOUT
4 MHz-10 MHz	x4	16 MHz-40 MHz
4 MHz-10 MHz	x8	32 MHz-80 MHz
4 MHz-7.5 MHz	x16	64 MHz-120 MHz

The PLL features a lock output which is asserted when the PLL enters a phase locked state. Should the loop fall out of lock (e.g., due to noise), the lock signal will be rescinded. The state of this signal is reflected in the read-only LOCK bit in the OSCCON register.

17.2.5 FAST RC OSCILLATOR (FRC)

The FRC oscillator is a fast (7.37 MHz ±2% nominal) internal RC oscillator. This oscillator is intended to provide reasonable device operating speeds without the use of an external crystal, ceramic resonator, or RC network. The FRC oscillator can be used with the PLL to obtain higher clock frequencies.

The dsPIC30F operates from the FRC oscillator whenever the current oscillator selection control bits in the OSCCON register (OSCCON<14:12>) are set to '001'.

The four bit field specified by TUN<3:0> (OSCTUN <3:0>) allows the user to tune the internal fast RC oscillator (nominal 7.37 MHz). The user can tune the FRC oscillator within a range of +10.5% (840 kHz) and -12% (960 kHz) in steps of 1.50% around the factory calibrated setting, as shown in Table 17-4.

Note: OSCTUN functionality has been provided to help customers compensate for temperature effects on the FRC frequency over a wide range of temperatures. The tuning step size is an approximation and is neither characterized nor tested.

If OSCCON<14:12> are set to '111' and FPR<4:0> are set to '00001', '01010' or '00011', a PLL multiplier of 4, 8 or 16 (respectively) is applied.

Note: When a 16x PLL is used, the FRC frequency must not be tuned to a frequency greater than 7.5 MHz.

TABLE 17-4: FRC TUNING

TUN<3:0> Bits	FRC Frequency
0111	+ 10.5%
0110	+ 9.0%
0101	+ 7.5%
0100	+ 6.0%
0011	+ 4.5%
0010	+ 3.0%
0001	+ 1.5%
0000	Center Frequency (oscillator is running at calibrated frequency)
1111	- 1.5%
1110	- 3.0%
1101	- 4.5%
1100	- 6.0%
1011	- 7.5%
1010	- 9.0%
1001	- 10.5%
1000	- 12.0%

17.2.6 LOW-POWER RC OSCILLATOR (LPRC)

The LPRC oscillator is a component of the Watchdog Timer (WDT) and oscillates at a nominal frequency of 512 kHz. The LPRC oscillator is the clock source for the Power-up Timer (PWRT) circuit, WDT and clock monitor circuits. It may also be used to provide a low-frequency clock source option for applications where power consumption is critical and timing accuracy is not required.

The LPRC oscillator is always enabled at a Power-on Reset because it is the clock source for the PWRT. After the PWRT expires, the LPRC oscillator will remain on if one of the following is true:

- The Fail-Safe Clock Monitor is enabled
- The WDT is enabled
- The LPRC oscillator is selected as the system clock via the COSC<2:0> control bits in the OSCCON register

If one of the above conditions is not true, the LPRC will shut-off after the PWRT expires.

Note 1: OSC2 pin function is determined by the Primary Oscillator mode selection (FPR<4:0>).

2: OSC1 pin cannot be used as an I/O pin even if the secondary oscillator or an internal clock source is selected at all times.

17.2.7 FAIL-SAFE CLOCK MONITOR

The Fail-Safe Clock Monitor (FSCM) allows the device to continue to operate even in the event of an oscillator failure. The FSCM function is enabled by appropriately programming the FCKSM Configuration bits (clock switch and monitor selection bits) in the FOSC Device Configuration register. If the FSCM function is enabled, the LPRC internal oscillator will run at all times (except during Sleep mode) and will not be subject to control by the SWDTEN bit.

In the event of an oscillator failure, the FSCM will generate a clock failure trap event and will switch the system clock over to the FRC oscillator. The user will then have the option to either attempt to restart the oscillator or execute a controlled shutdown. The user may decide to treat the trap as a warm Reset by simply loading the Reset address into the oscillator fail trap vector. In this event, the CF (Clock Fail) bit (OSCCON<3>) is also set whenever a clock failure is recognized.

In the event of a clock failure, the WDT is unaffected and continues to run on the LPRC clock.

If the oscillator has a very slow start-up time coming out of POR, BOR or Sleep, it is possible that the PWRT timer will expire before the oscillator has started. In such cases, the FSCM will be activated and the FSCM will initiate a clock failure trap, and the COSC<2:0> bits are loaded with FRC oscillator selection. This will effectively shut-off the original oscillator that was trying to start.

The user may detect this situation and restart the oscillator in the clock fail trap ISR.

Upon a clock failure detection, the FSCM module will initiate a clock switch to the FRC oscillator as follows:

1. The COSC bits (OSCCON<14:12>) are loaded with the FRC oscillator selection value.
2. CF bit is set (OSCCON<3>).
3. OSWEN control bit (OSCCON<0>) is cleared.

For the purpose of clock switching, the clock sources are sectioned into four groups:

- Primary (with or without PLL)
- Secondary
- Internal FRC
- Internal LPRC

The user can switch between these functional groups but cannot switch between options within a group. If the primary group is selected, then the choice within the group is always determined by the FPR<4:0> Configuration bits.

The OSCCON register holds the Control and Status bits related to clock switching.

- COSC<2:0>: Read-only bits always reflect the current oscillator group in effect.
- NOSC<2:0>: Control bits which are written to indicate the new oscillator group of choice.
  - On POR and BOR, COSC<2:0> and NOSC<2:0> are both loaded with the Configuration bit values FOS<2:0>.
- LOCK: The LOCK bit indicates a PLL lock.
- CF: Read-only bit indicating if a clock fail detect has occurred.
- OSWEN: Control bit changes from a '0' to a '1' when a clock transition sequence is initiated. Clearing the OSWEN control bit will abort a clock transition in progress (used for hang-up situations).

If Configuration bits FCKSM<1:0> = 1x, then the clock switching and Fail-Safe Clock monitoring functions are disabled. This is the default Configuration bit setting.

If clock switching is disabled, then the FOS<2:0> and FPR<4:0> bits directly control the oscillator selection and the COSC<2:0> bits do not control the clock selection. However, these bits will reflect the clock source selection.

Note:	The application should not attempt to switch to a clock of frequency lower than 100 kHz when the Fail-Safe Clock Monitor is enabled. If such clock switching is performed, the device may generate an oscillator fail trap and switch to the Fast RC oscillator.

17.2.8 PROTECTION AGAINST ACCIDENTAL WRITES TO OSCCON

A write to the OSCCON register is intentionally made difficult because it controls clock switching and clock scaling.

To write to the OSCCON low byte, the following code sequence must be executed without any other instructions in between:

```
Byte Write 0x46 to OSCCON low
Byte Write 0x57 to OSCCON low
```

Byte write is allowed for one instruction cycle. Write the desired value or use bit manipulation instruction.

To write to the OSCCON high byte, the following instructions must be executed without any other instructions in between:

```
Byte Write 0x78 to OSCCON high
Byte Write 0x9A to OSCCON high
```

Byte write is allowed for one instruction cycle. Write the desired value or use bit manipulation instruction.

20.0 ELECTRICAL CHARACTERISTICS

This section provides an overview of dsPIC30F electrical characteristics. Additional information will be provided in future revisions of this document as it becomes available.

For detailed information about the dsPIC30F architecture and core, refer to the *"dsPIC30F Family Reference Manual"* (DS70046).

Absolute maximum ratings for the dsPIC30F family are listed below. Exposure to these maximum rating conditions for extended periods may affect device reliability. Functional operation of the device at these or any other conditions above the parameters indicated in the operation listings of this specification is not implied.

Absolute Maximum Ratings(†)

Ambient temperature under bias ..... -40°C to +125°C
Storage temperature ..... -65°C to +150°C
Voltage on any pin with respect to V_{SS} (except V_{DD} and $\overline{MCLR}$) **(Note 1)** ..... -0.3V to (V_{DD} + 0.3V)
Voltage on V_{DD} with respect to V_{SS} ..... -0.3V to +5.5V
Voltage on $\overline{MCLR}$ with respect to V_{SS} ..... 0V to +13.25V
Maximum current out of V_{SS} pin ..... 300 mA
Maximum current into V_{DD} pin **(Note 2)** ..... 250 mA
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{DD}) ..... ±20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{DD}) ..... ±20 mA
Maximum output current sunk by any I/O pin ..... 25 mA
Maximum output current sourced by any I/O pin ..... 25 mA
Maximum current sunk by all ports ..... 200 mA
Maximum current sourced by all ports **(Note 2)** ..... 200 mA

Note 1: Voltage spikes below V_{SS} at the $\overline{MCLR}$/V_{PP} pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a "low" level to the $\overline{MCLR}$/V_{PP} pin, rather than pulling this pin directly to V_{SS}.

2: Maximum allowable current is a function of device maximum power dissipation. See Table 20-2 for P_{DMAX}.

†**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.

Note: All peripheral electrical characteristics are specified. For exact peripherals available on specific devices, please refer to the dsPIC30F2011/2012/3012/3013 Sensor Family table on page 4 of this data sheet.

TABLE 20-15: PLL CLOCK TIMING SPECIFICATIONS (V_{DD} = 2.5 TO 5.5 V)

AC CHARACTERISTICS			Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended				
Param No.	**Symbol**	**Characteristic(1)**	**Min**	**Typ(2)**	**Max**	**Units**	**Conditions**
OS50	FPLLI	PLL Input Frequency Range(2)	4	—	10	MHz	EC with 4x PLL
			4	—	10	MHz	EC with 8x PLL
			4	—	7.5(4)	MHz	EC with 16x PLL
			4	—	10	MHz	XT with 4x PLL
			4	—	10	MHz	XT with 8x PLL
			4	—	7.5(4)	MHz	XT with 16x PLL
			5(3)	—	10	MHz	HS/2 with 4x PLL
			5(3)	—	10	MHz	HS/2 with 8x PLL
			5(3)	—	7.5(4)	MHz	HS/2 with 16x PLL
			4	—	8.33(3)	MHz	HS/3 with 4x PLL
			4	—	8.33(3)	MHz	HS/3 with 8x PLL
			4	—	7.5(4)	MHz	HS/3 with 16x PLL
OS51	FSYS	On-Chip PLL Output(2)	16	—	120	MHz	EC, XT, HS/2, HS/3 modes with PLL
OS52	TLOC	PLL Start-up Time (Lock Time)	—	20	50	µs	

Note 1: These parameters are characterized but not tested in manufacturing.

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

3: Limited by oscillator frequency range.

4: Limited by device operating frequency range.

TABLE 20-16: PLL JITTER

AC CHARACTERISTICS		Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended					
Param No.	**Characteristic**	**Min**	**Typ(1)**	**Max**	**Units**	**Conditions**	
OS61	x4 PLL	—	0.251	0.413	%	-40°C ≤TA ≤+85°C	VDD = 3.0 to 3.6V
		—	0.251	0.413	%	-40°C ≤TA ≤+125°C	VDD = 3.0 to 3.6V
		—	0.256	0.47	%	-40°C ≤TA ≤+85°C	VDD = 4.5 to 5.5V
		—	0.256	0.47	%	-40°C ≤TA ≤+125°C	VDD = 4.5 to 5.5V
	x8 PLL	—	0.355	0.584	%	-40°C ≤TA ≤+85°C	VDD = 3.0 to 3.6V
		—	0.355	0.584	%	-40°C ≤TA ≤+125°C	VDD = 3.0 to 3.6V
		—	0.362	0.664	%	-40°C ≤TA ≤+85°C	VDD = 4.5 to 5.5V
		—	0.362	0.664	%	-40°C ≤TA ≤+125°C	VDD = 4.5 to 5.5V
	x16 PLL	—	0.67	0.92	%	-40°C ≤TA ≤+85°C	VDD = 3.0 to 3.6V
		—	0.632	0.956	%	-40°C ≤TA ≤+85°C	VDD = 4.5 to 5.5V
		—	0.632	0.956	%	-40°C ≤TA ≤+125°C	VDD = 4.5 to 5.5V

Note 1: These parameters are characterized but not tested in manufacturing.

FIGURE 20-6: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER TIMING CHARACTERISTICS

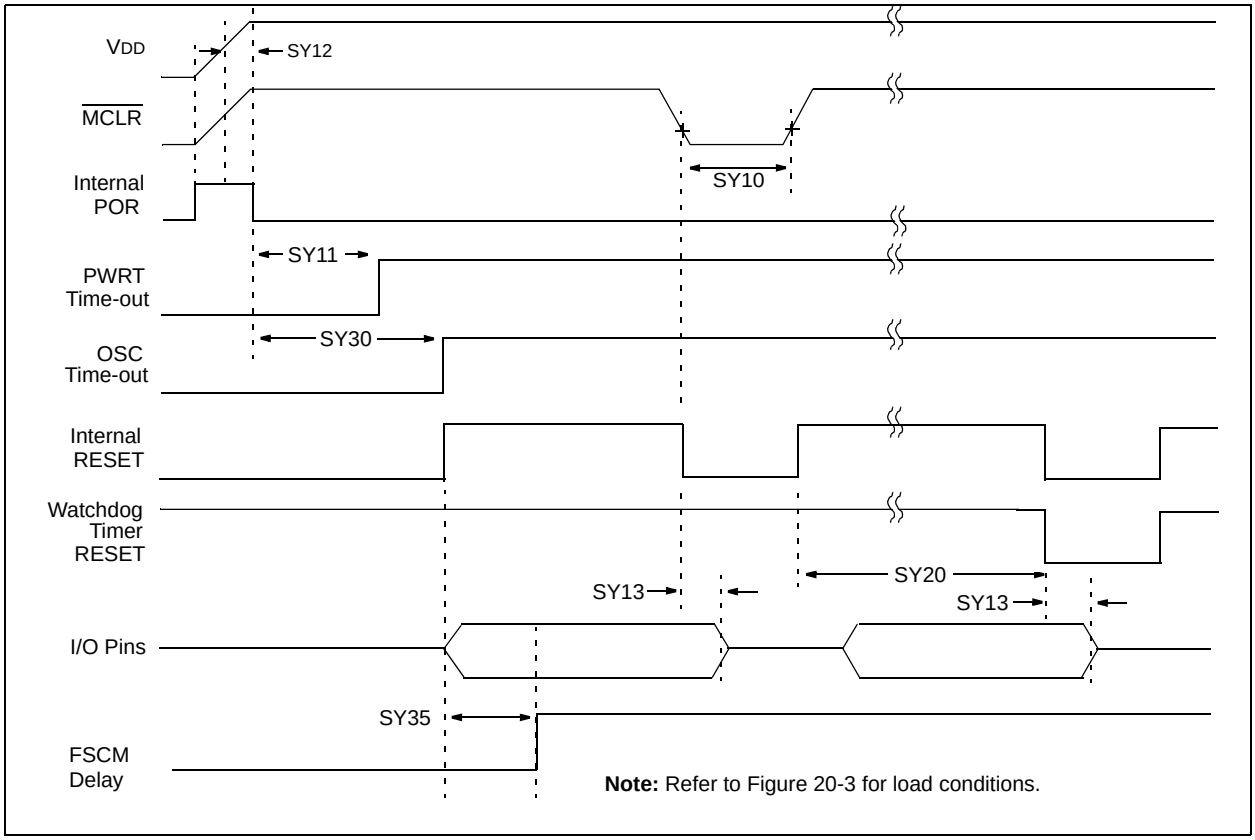


TABLE 20-21: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER, POWER-UP TIMER AND BROWN-OUT RESET TIMING REQUIREMENTS

AC CHARACTERISTICS			Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended				
Param No.	**Symbol**	**Characteristic(1)**	**Min**	**Typ(2)**	**Max**	**Units**	**Conditions**
SY10	TmcL	MCLR Pulse Width (low)	2	—	—	µs	-40°C to +85°C
SY11	TPWRT	Power-up Timer Period	2 10 43	4 16 64	8 32 128	ms	-40°C to +85°C, VDD = 5V User programmable
SY12	TPOR	Power On Reset Delay	3	10	30	µs	-40°C to +85°C
SY13	TIOZ	I/O high impedance from MCLR Low or Watchdog Timer Reset	—	0.8	1.0	µs	
SY20	TWDT1 TWDT2 TWDT3	Watchdog Timer Time-out Period (No Prescaler)	1.1 1.2 1.3	2.0 2.0 2.0	6.6 5.0 4.0	ms ms ms	VDD = 2.5V VDD = 3.3V, ±10% VDD = 5V, ±10%
SY25	TBOR	Brown-out Reset Pulse Width(3)	100	—	—	µs	VDD ≤VBOR (D034)
SY30	TOST	Oscillation Start-up Timer Period	—	1024 TOSC	—	—	TOSC = OSC1 period
SY35	TFSCM	Fail-Safe Clock Monitor Delay	—	500	900	µs	-40°C to +85°C

Note 1: These parameters are characterized but not tested in manufacturing.

2: Data in "Typ" column is at 5V, 25°C unless otherwise stated.

3: Refer to Figure 20-2 and Table 20-11 for BOR.

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