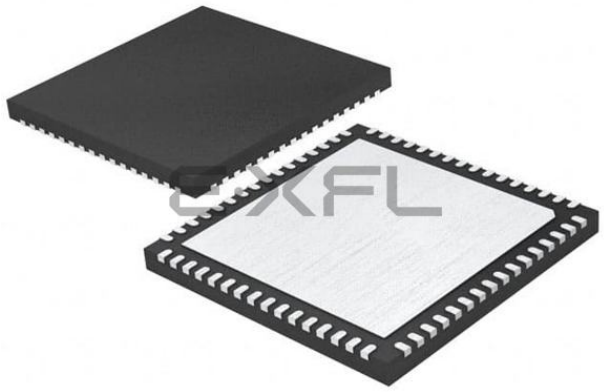


**Welcome to E-XFL.COM**

## What is "Embedded - Microcontrollers"?

"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

## Applications of "Embedded - Microcontrollers"

| Details | |
|---|---|
| Product Status | Active |
| Core Processor | dsPIC |
| Core Size | 16-Bit |
| Speed | 40 MIPs |
| Connectivity | CANbus, I²C, IrDA, LINbus, SPI, UART/USART |
| Peripherals | Brown-out Detect/Reset, DMA, Motor Control PWM, POR, PWM, QEI, WDT |
| Number of I/O | 53 |
| Program Memory Size | 64KB (64K x 8) |
| Program Memory Type | FLASH |
| EEPROM Size | - |
| RAM Size | 8K x 8 |
| Voltage - Supply (Vcc/Vdd) | 3V ~ 3.6V |
| Data Converters | A/D 16x10b/12b |
| Oscillator Type | Internal |
| Operating Temperature | -40°C ~ 125°C (TA) |
| Mounting Type | Surface Mount |
| Package / Case | 64-VFQFN Exposed Pad |
| Supplier Device Package | 64-VQFN (9x9) |
| Purchase URL | https://www.e-xfl.com/product-detail/microchip-technology/dspic33fj64mc506a-e-mr |

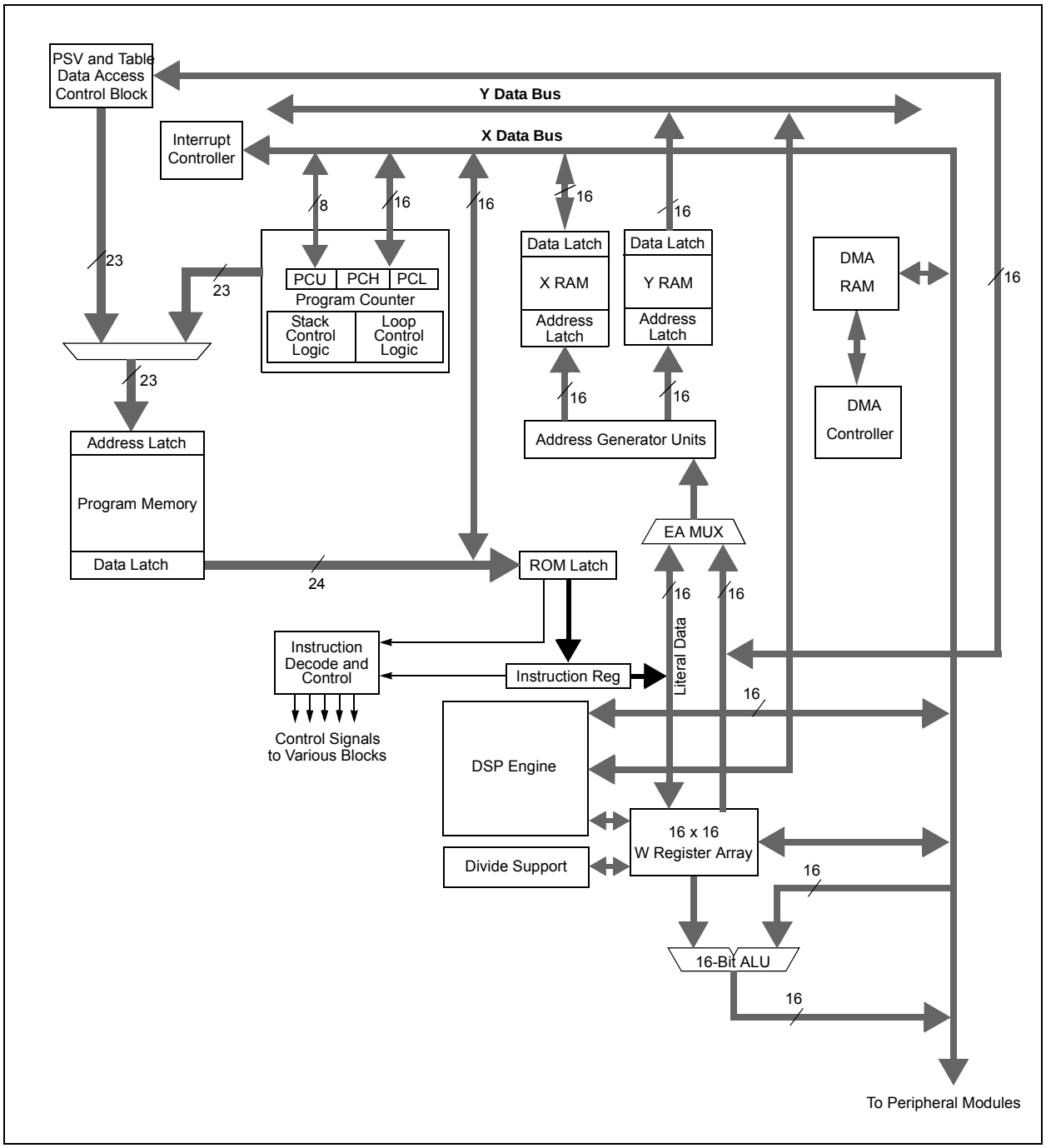
## 3.3 Special MCU Features

The dsPIC33FJXXXMCX06A/X08A/X10A devices feature a 17-bit by 17-bit, single-cycle multiplier that is shared by both the MCU ALU and DSP engine. The multiplier can perform signed, unsigned and mixed sign multiplication. Using a 17-bit by 17-bit multiplier for 16-bit by 16-bit multiplication not only allows you to perform mixed sign multiplication, it also achieves accurate results for special operations, such as (-1.0) x (-1.0).

The dsPIC33FJXXXMCX06A/X08A/X10A devices support 16/16 and 32/16 divide operations, both fractional and integer. All divide instructions are iterative operations. They must be executed within a REPEAT loop, resulting in a total execution time of 19 instruction cycles. The divide operation can be interrupted during any of those 19 cycles without a loss of data.

A 40-bit barrel shifter is used to perform up to a 16-bit left or right shift in a single cycle. The barrel shifter can be used by both MCU and DSP instructions.

**FIGURE 3-1: dsPIC33FJXXXMCX06A/X08A/X10A CPU CORE BLOCK DIAGRAM**



The SA and SB bits are modified each time data passes through the adder/subtracter, but can only be cleared by the user. When set, they indicate that the accumulator has overflowed its maximum range (bit 31 for 32-bit saturation or bit 39 for 40-bit saturation) and will be saturated (if saturation is enabled). When saturation is not enabled, SA and SB default to bit 39 overflow, and thus, indicate that a catastrophic overflow has occurred. If the COVTE bit in the INTCON1 register is set, SA and SB bits will generate an arithmetic warning trap when saturation is disabled.

The Overflow and Saturation Status bits can optionally be viewed in the STATUS Register (SR) as the logical OR of OA and OB (in bit OAB), and the logical OR of SA and SB (in bit SAB). This allows programmers to check one bit in the STATUS register to determine if either accumulator has overflowed or one bit to determine if either accumulator has saturated. This would be useful for complex number arithmetic, which typically uses both the accumulators.

The device supports three Saturation and Overflow modes:

1. Bit 39 Overflow and Saturation:
   When bit 39 overflow and saturation occurs, the saturation logic loads the maximally positive 9.31 (0x7FFFFFFFF) or maximally negative 9.31 value (0x8000000000) into the target accumulator. The SA or SB bit is set and remains set until cleared by the user. This is referred to as 'super saturation' and provides protection against erroneous data or unexpected algorithm problems (e.g., gain calculations).
2. Bit 31 Overflow and Saturation:
   When bit 31 overflow and saturation occurs, the saturation logic then loads the maximally positive 1.31 value (0x007FFFFFFF) or maximally negative 1.31 value (0x0080000000) into the target accumulator. The SA or SB bit is set and remains set until cleared by the user. When this Saturation mode is in effect, the guard bits are not used (so the OA, OB or OAB bits are never set).
3. Bit 39 Catastrophic Overflow:
   The bit 39 Overflow Status bit from the adder is used to set the SA or SB bit, which remains set until cleared by the user. No saturation operation is performed and the accumulator is allowed to overflow (destroying its sign). If the COVTE bit in the INTCON1 register is set, a catastrophic overflow can initiate a trap exception.

#### 3.6.2.2 Accumulator 'Write Back'

The MAC class of instructions (with the exception of MPY, MPY.N, ED and EDAC) can optionally write a rounded version of the high word (bits 31 through 16) of the accumulator that is not targeted by the instruction into data space memory. The write is performed across the X bus into combined X and Y address space. The following addressing modes are supported:

1. W13, Register Direct:
   The rounded contents of the non-target accumulator are written into W13 as a 1.15 fraction.
2. [W13]+ = 2, Register Indirect with Post-Increment:
   The rounded contents of the non-target accumulator are written into the address pointed to by W13 as a 1.15 fraction. W13 is then incremented by 2 (for a word write).

#### 3.6.2.3 Round Logic

The round logic is a combinational block which performs a conventional (biased) or convergent (unbiased) round function during an accumulator write (store). The Round mode is determined by the state of the RND bit in the CORCON register. It generates a 16-bit, 1.15 data value which is passed to the data space write saturation logic. If rounding is not indicated by the instruction, a truncated 1.15 data value is stored and the least significant word is simply discarded.

Conventional rounding zero-extends bit 15 of the accumulator and adds it to the ACCxH word (bits 16 through 31 of the accumulator). If the ACCxL word (bits 0 through 15 of the accumulator) is between 0x8000 and 0xFFFF (0x8000 included), ACCxH is incremented. If ACCxL is between 0x0000 and 0x7FFF, ACCxH is left unchanged. A consequence of this algorithm is that over a succession of random rounding operations, the value tends to be biased slightly positive.

Convergent (or unbiased) rounding operates in the same manner as conventional rounding, except when ACCxL equals 0x8000. In this case, the Least Significant bit (bit 16 of the accumulator) of ACCxH is examined. If it is '1', ACCxH is incremented. If it is '0', ACCxH is not modified. Assuming that bit 16 is effectively random in nature, this scheme removes any rounding bias that may accumulate.

The SAC and SAC.R instructions store either a truncated (SAC) or rounded (SAC.R) version of the contents of the target accumulator to data memory via the X bus, subject to data saturation (see **Section 3.6.2.4 "Data Space Write Saturation"**). For the MAC class of instructions, the accumulator write-back operation will function in the same manner, addressing combined MCU (X and Y) data space though the X bus. For this class of instructions, the data is always subject to rounding.

## 4.2 Data Address Space

The dsPIC33FJXXXMCX06A/X08A/X10A CPU has a separate 16-bit wide data memory space. The data space is accessed using separate Address Generation Units (AGUs) for read and write operations. Data memory maps of devices with different RAM sizes are shown in Figure 4-3 through Figure 4-5.

All Effective Addresses (EAs) in the data memory space are 16 bits wide and point to bytes within the data space. This arrangement gives a data space address range of 64 Kbytes or 32K words. The lower half of the data memory space (that is, when EA<15> = 0) is used for implemented memory addresses, while the upper half (EA<15> = 1) is reserved for the Program Space Visibility area (see **Section 4.6.3 "Reading Data from Program Memory Using Program Space Visibility"**).

dsPIC33FJXXXMCX06A/X08A/X10A devices implement a total of up to 30 Kbytes of data memory. Should an EA point to a location outside of this area, an all-zero word or byte will be returned.

### 4.2.1 DATA SPACE WIDTH

The data memory space is organized in byte addressable, 16-bit wide blocks. Data is aligned in data memory and registers as 16-bit words, but all data space EAs resolve to bytes. The Least Significant Bytes of each word have even addresses, while the Most Significant Bytes have odd addresses.

### 4.2.2 DATA MEMORY ORGANIZATION AND ALIGNMENT

To maintain backward compatibility with PIC® microcontrollers and improve data space memory usage efficiency, the dsPIC33FJXXXMCX06A/X08A/X10A instruction set supports both word and byte operations. As a consequence of byte accessibility, all Effective Address calculations are internally scaled to step through word-aligned memory. For example, the core recognizes that Post-Modified Register Indirect Addressing mode [Ws++] will result in a value of Ws + 1 for byte operations and Ws + 2 for word operations.

Data byte reads will read the complete word that contains the byte, using the LSb of any EA to determine which byte to select. The selected byte is placed onto the LSb of the data path. That is, data memory and registers are organized as two parallel, byte-wide entities with shared (word) address decode but separate write lines. Data byte writes only write to the corresponding side of the array or register which matches the byte address.

All word accesses must be aligned to an even address. Misaligned word data fetches are not supported, so care must be taken when mixing byte and word operations or translating from 8-bit MCU code. If a misaligned read or write is attempted, an address error trap is generated. If the error occurred on a read, the instruction underway is completed; if it occurred on a write, the instruction will be executed but the write does not occur. In either case, a trap is then executed, allowing the system and/or user to examine the machine state prior to execution of the address Fault.

All byte loads into any W register are loaded into the Least Significant Byte. The Most Significant Byte is not modified.

A sign-extend instruction (SE) is provided to allow users to translate 8-bit signed data to 16-bit signed values. Alternatively, for 16-bit unsigned data, users can clear the MSb of any W register by executing a zero-extend (ZE) instruction on the appropriate address.

### 4.2.3 SFR SPACE

The first 2 Kbytes of the Near Data Space, from 0x0000 to 0x07FF, is primarily occupied by Special Function Registers (SFRs). These are used by the dsPIC33FJXXXMCX06A/X08A/X10A core and peripheral modules for controlling the operation of the device.

SFRs are distributed among the modules that they control and are generally grouped together by module. Much of the SFR space contains unused addresses; these are read as '0'.

| | |
|---|---|
| **Note:** | The actual set of peripheral features and interrupts varies by the device. Please refer to the corresponding device tables and pinout diagrams for device-specific information. |

### 4.2.4 NEAR DATA SPACE

The 8-Kbyte area between 0x0000 and 0x1FFF is referred to as the Near Data Space. Locations in this space are directly addressable via a 13-bit absolute address field within all memory direct instructions. Additionally, the whole data space is addressable using MOV instructions, which support Memory Direct Addressing mode with a 16-bit address field, or by using Indirect Addressing mode using a working register as an Address Pointer.

**FIGURE 4-8: BIT-REVERSED ADDRESS EXAMPLE**

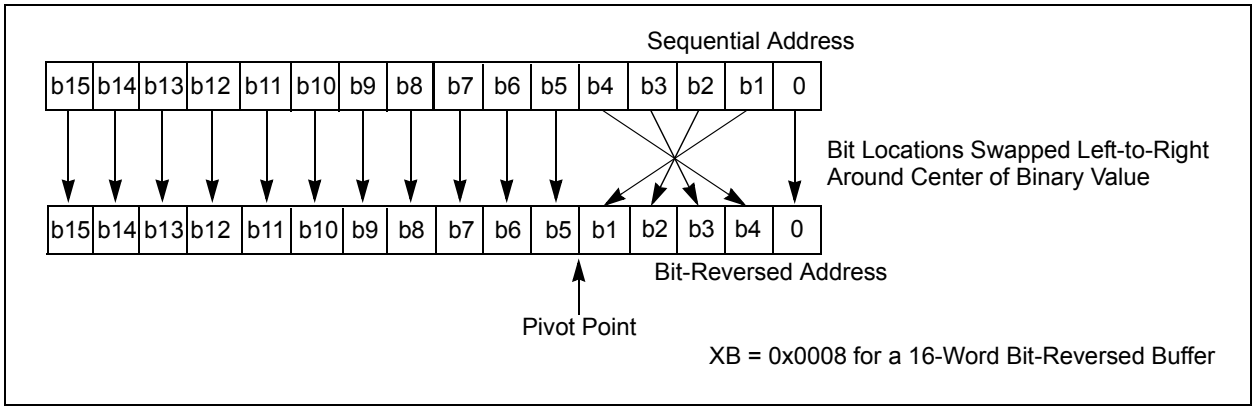



**TABLE 4-37: BIT-REVERSED ADDRESS SEQUENCE (16-ENTRY)**

| Normal Address | | | | | Bit-Reversed Address | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **A3** | **A2** | **A1** | **A0** | **Decimal** | **A3** | **A2** | **A1** | **A0** | **Decimal** |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 8 |
| 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 4 |
| 0 | 0 | 1 | 1 | 3 | 1 | 1 | 0 | 0 | 12 |
| 0 | 1 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 2 |
| 0 | 1 | 0 | 1 | 5 | 1 | 0 | 1 | 0 | 10 |
| 0 | 1 | 1 | 0 | 6 | 0 | 1 | 1 | 0 | 6 |
| 0 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 0 | 14 |
| 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 9 | 1 | 0 | 0 | 1 | 9 |
| 1 | 0 | 1 | 0 | 10 | 0 | 1 | 0 | 1 | 5 |
| 1 | 0 | 1 | 1 | 11 | 1 | 1 | 0 | 1 | 13 |
| 1 | 1 | 0 | 0 | 12 | 0 | 0 | 1 | 1 | 3 |
| 1 | 1 | 0 | 1 | 13 | 1 | 0 | 1 | 1 | 11 |
| 1 | 1 | 1 | 0 | 14 | 0 | 1 | 1 | 1 | 7 |
| 1 | 1 | 1 | 1 | 15 | 1 | 1 | 1 | 1 | 15 |

**REGISTER 7-21: IPC6: INTERRUPT PRIORITY CONTROL REGISTER 6**

| U-0 | R/W-1 | R/W-0 | R/W-0 | U-0 | R/W-1 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | T4IP<2:0> | | | — | OC4IP<2:0> | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-1 | R/W-0 | R/W-0 | U-0 | R/W-1 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | OC3IP<2:0> | | | — | DMA2IP<2:0> | | |
| bit 7 | | | | | | | bit 0 |

| **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 |

bit 15 **Unimplemented:** Read as '0'

bit 14-12 **T4IP<2:0>:** Timer4 Interrupt Priority bits
111 = Interrupt is priority 7 (highest priority interrupt)
•
•
•
001 = Interrupt is priority 1
000 = Interrupt source is disabled

bit 11 **Unimplemented:** Read as '0'

bit 10-8 **OC4IP<2:0>:** Output Compare Channel 4 Interrupt Priority bits
111 = Interrupt is priority 7 (highest priority interrupt)
•
•
•
001 = Interrupt is priority 1
000 = Interrupt source is disabled

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

bit 6-4 **OC3IP<2:0>:** Output Compare Channel 3 Interrupt Priority bits
111 = Interrupt is priority 7 (highest priority interrupt)
•
•
•
001 = Interrupt is priority 1
000 = Interrupt source is disabled

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

bit 2-0 **DMA2IP<2:0>:** DMA Channel 2 Data Transfer Complete Interrupt Priority bits
111 = Interrupt is priority 7 (highest priority interrupt)
•
•
•
001 = Interrupt is priority 1
000 = Interrupt source is disabled

**REGISTER 9-1: OSCCON: OSCILLATOR CONTROL REGISTER(1,3)**

| U-0 | R-0 | R-0 | R-0 | U-0 | R/W-y | R/W-y | R/W-y |
|---|---|---|---|---|---|---|---|
| — | COSC<2:0> | | | — | NOSC<2:0>(2) | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | R-0 | U-0 | R/C-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CLKLOCK | — | LOCK | — | CF | — | LPOSCEN | OSWEN |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | y = Value set from Configuration bits on POR | | |
|---|---|---|---|
| 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 |

bit 15 **Unimplemented:** Read as '0'

bit 14-12 **COSC<2:0>:** Current Oscillator Selection bits (read-only)
111 = Fast RC oscillator (FRC) with Divide-by-N
110 = Fast RC oscillator (FRC) with Divide-by-16
101 = Low-Power RC oscillator (LPRC)
100 = Secondary oscillator (Sosc)
011 = Primary oscillator (XT, HS, EC) with PLL
010 = Primary oscillator (XT, HS, EC)
001 = Fast RC Oscillator (FRC) with Divide-by-N and PLL (FRCDIVN + PLL)
000 = Fast RC oscillator (FRC)

bit 11 **Unimplemented:** Read as '0'

bit 10-8 **NOSC<2:0>:** New Oscillator Selection bits(2)
111 = Fast RC oscillator (FRC) with Divide-by-N
110 = Fast RC oscillator (FRC) with Divide-by-16
101 = Low-Power RC oscillator (LPRC)
100 = Secondary oscillator (Sosc)
011 = Primary oscillator (XT, HS, EC) with PLL
010 = Primary oscillator (XT, HS, EC)
001 = Fast RC Oscillator (FRC) with Divide-by-N and PLL (FRCDIVN + PLL)
000 = Fast RC oscillator (FRC)

bit 7 **CLKLOCK:** Clock Lock Enable bit
1 = If (FCKSM0 = 1), then clock and PLL configurations are locked. If (FCKSM0 = 0), then clock and PLL configurations may be modified.
0 = Clock and PLL selections are not locked; configurations may be modified

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

bit 5 **LOCK:** PLL Lock Status bit (read-only)
1 = Indicates that PLL is in lock or PLL start-up timer is satisfied
0 = Indicates that PLL is out of lock, start-up timer is in progress or PLL is disabled

bit 4 **Unimplemented:** Read as '0'

bit 3 **CF:** Clock Fail Detect bit (read/clear by application)
1 = FSCM has detected clock failure
0 = FSCM has not detected clock failure

**Note 1:** Writes to this register require an unlock sequence. Refer to **Section 7. "Oscillator"** (DS70186) in the *"dsPIC33F/PIC24H Family Reference Manual"* for details.

**2:** Direct clock switches between any primary oscillator mode with PLL and FRCPLL modes are not permitted. This applies to clock switches in either direction. In these instances, the application must switch to FRC mode as a transition clock source between the two PLL modes.

**3:** This register is reset only on a Power-on Reset (POR).

**REGISTER 9-2: CLKDIV: CLOCK DIVISOR REGISTER(2)**

| R/W-0 | R/W-0 | R/W-1 | R/W-1 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ROI | DOZE<2:0> | | | DOZEN(1) | FRCDIV<2:0> | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-1 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PLLPOST<1:0> | | — | PLLPRE<4:0> | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | y = Value set from Configuration bits on POR | | |
|---|---|---|---|
| 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 |

bit 15 **ROI:** Recover on Interrupt bit
1 = Interrupts will clear the DOZEN bit and the processor clock/peripheral clock ratio is set to 1:1
0 = Interrupts have no effect on the DOZEN bit

bit 14-12 **DOZE<2:0>:** Processor Clock Reduction Select bits
000 = FCY/1
001 = FCY/2
010 = FCY/4
011 = FCY/8 (default)
100 = FCY/16
101 = FCY/32
110 = FCY/64
111 = FCY/128

bit 11 **DOZEN:** DOZE Mode Enable bit(1)
1 = DOZE<2:0> field specifies the ratio between the peripheral clocks and the processor clocks
0 = Processor clock/peripheral clock ratio forced to 1:1

bit 10-8 **FRCDIV<2:0>:** Internal Fast RC Oscillator Postscaler bits
000 = FRC divide by 1 (default)
001 = FRC divide by 2
010 = FRC divide by 4
011 = FRC divide by 8
100 = FRC divide by 16
101 = FRC divide by 32
110 = FRC divide by 64
111 = FRC divide by 256

bit 7-6 **PLLPOST<1:0>:** PLL VCO Output Divider Select bits (also denoted as 'N2', PLL postscaler)
00 = Output/2
01 = Output/4 (default)
10 = Reserved
11 = Output/8

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

bit 4-0 **PLLPRE<4:0>:** PLL Phase Detector Input Divider bits (also denoted as 'N1', PLL prescaler)
00000 = Input/2 (default)
00001 = Input/3
•
•
•
11111 = Input/33

**Note 1:** This bit is cleared when the ROI bit is set and an interrupt occurs.
**2:** This register is reset only on a Power-on Reset (POR).

**NOTES:**

## 22.0 10-BIT/12-BIT ANALOG-TO-DIGITAL CONVERTER (ADC)

**Note 1:** This data sheet summarizes the features of the dsPIC33FJXXXMCX06A/X08A/X10A family of devices. However, it is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **Section 16. "Analog-to-Digital Converter (ADC)"** (DS70183) in the *"dsPIC33F/PIC24H Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

**2:** Some registers and associated bits described in this section may not be available on all devices. Refer to **Section 4.0 "Memory Organization"** in this data sheet for device-specific register and bit information.

The dsPIC33FJXXXMCX06A/X08A/X10A devices have up to 32 ADC input channels. These devices also have up to 2 ADC modules (ADCx, where 'x' = 1 or 2), each with its own set of Special Function Registers.

The AD12B bit (ADxCON1<10>) allows each of the ADC modules to be configured by the user as either a 10-bit, 4-sample/hold ADC (default configuration) or a 12-bit, 1-sample/hold ADC.

**Note:** The ADC module needs to be disabled before modifying the AD12B bit.

### 22.1 Key Features

The 10-bit ADC configuration has the following key features:

- Successive Approximation (SAR) conversion
- Conversion speeds of up to 1.1 Msps
- Up to 32 analog input pins
- External voltage reference input pins
- Simultaneous sampling of up to four analog input pins
- Automatic Channel Scan mode
- Selectable conversion trigger source
- Selectable Buffer Fill modes
- Four result alignment options (signed/unsigned, fractional/integer)
- Operation during CPU Sleep and Idle modes

The 12-bit ADC configuration supports all the above features, except:

- In the 12-bit configuration, conversion speeds of up to 500 ksps are supported.
- There is only 1 sample/hold amplifier in the 12-bit configuration, so simultaneous sampling of multiple channels is not supported.

Depending on the particular device pinout, the ADC can have up to 32 analog input pins, designated AN0 through AN31. In addition, there are two analog input pins for external voltage reference connections. These voltage reference inputs may be shared with other analog input pins. The actual number of analog input pins and external voltage reference input configuration will depend on the specific device.

A block diagram of the ADC is shown in Figure 22-1.

### 22.2 ADC Initialization

The following configuration steps should be performed.

1. Configure the ADC module:
   a) Select port pins as analog inputs (ADxPCFGH<15:0> or ADxPCFGL<15:0>)
   b) Select voltage reference source to match expected range on analog inputs (ADxCON2<15:13>)
   c) Select the analog conversion clock to match desired data rate with processor clock (ADxCON3<7:0>)
   d) Determine how many S/H channels will be used (ADxCON2<9:8> and ADxPCFGH<15:0> or ADxPCFGL<15:0>)
   e) Select the appropriate sample/conversion sequence (ADxCON1<7:5> and ADxCON3<12:8>)
   f) Select how conversion results are presented in the buffer (ADxCON1<9:8>)
   g) Turn on ADC module (ADxCON1<15>)
2. Configure ADC interrupt (if required):
   a) Clear the ADxIF bit
   b) Select ADC interrupt priority

### 22.3 ADC and DMA

If more than one conversion result needs to be buffered before triggering an interrupt, DMA data transfers can be used. Both ADC1 and ADC2 can trigger a DMA data transfer. If ADC1 or ADC2 is selected as the DMA IRQ source, a DMA transfer occurs when the AD1IF or AD2IF bit gets set as a result of an ADC1 or ADC2 sample conversion sequence.

The SMPI<3:0> bits (ADxCON2<5:2>) are used to select how often the DMA RAM Buffer Pointer is incremented.

The ADDMABM bit (ADxCON1<12>) determines how the conversion results are filled in the DMA RAM buffer area being used for ADC. If this bit is set, DMA buffers are written in the order of conversion. The module will provide an address to the DMA channel that is the same as the address used for the non-DMA stand-alone buffer. If the ADDMABM bit is cleared, then DMA buffers are written in Scatter/Gather mode. The module will provide a scatter/gather address to the DMA channel, based on the index of the analog input and the size of the DMA buffer.

**REGISTER 22-1: ADxCON1: ADCx CONTROL REGISTER 1 (where x = 1 or 2)**

| R/W-0 | U-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ADON | — | ADSIDL | ADDMABM | — | AD12B | FORM<1:0> | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0, HC,HS | R/C-0, HC, HS |
|---|---|---|---|---|---|---|---|
| SSRC<2:0> | | | — | SIMSAM | ASAM | SAMP | DONE |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware Clearable bit | HS = Hardware Settable bit | C= Clearable bit |
|---|---|---|---|
| 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 |

bit 15 **ADON:** ADC Operating Mode bit
1 = ADC module is operating
0 = ADC is off

bit 14 **Unimplemented:** Read as '0'

bit 13 **ADSIDL:** Stop in Idle Mode bit
1 = Discontinue module operation when device enters Idle mode
0 = Continue module operation in Idle mode

bit 12 **ADDMABM:** DMA Buffer Build Mode bit
1 = DMA buffers are written in the order of conversion. The module will provide an address to the DMA channel that is the same as the address used for the non-DMA stand-alone buffer
0 = DMA buffers are written in Scatter/Gather mode. The module will provide a scatter/gather address to the DMA channel, based on the index of the analog input and the size of the DMA buffer

bit 11 **Unimplemented:** Read as '0'

bit 10 **AD12B:** 10-Bit or 12-Bit Operation Mode bit
1 = 12-bit, 1-channel ADC operation
0 = 10-bit, 4-channel ADC operation

bit 9-8 **FORM<1:0>:** Data Output Format bits
For 10-Bit Operation:
11 = Signed fractional (DOUT = sddd dddd dd00 0000, where s = .NOT.d<9>)
10 = Fractional (DOUT = dddd dddd dd00 0000)
01 = Signed integer (DOUT = ssss sssd dddd dddd, where s = .NOT.d<9>)
00 = Integer (DOUT = 0000 00dd dddd dddd)
For 12-Bit Operation:
11 = Signed fractional (DOUT = sddd dddd dddd 0000, where s = .NOT.d<11>)
10 = Fractional (DOUT = dddd dddd dddd 0000)
01 = Signed Integer (DOUT = ssss sddd dddd dddd, where s = .NOT.d<11>)
00 = Integer (DOUT = 0000 dddd dddd dddd)

bit 7-5 **SSRC<2:0>:** Sample Clock Source Select bits
111 = Internal counter ends sampling and starts conversion (auto-convert)
110 = Reserved
101 = Reserved
100 = GP timer (Timer5 for ADC1, Timer3 for ADC2) compare ends sampling and starts conversion
011 = MPWM interval ends sampling and starts conversion
010 = GP timer (Timer3 for ADC1, Timer5 for ADC2) compare ends sampling and starts conversion
001 = Active transition on INT0 pin ends sampling and starts conversion
000 = Clearing sample bit ends sampling and starts conversion

bit 4 **Unimplemented:** Read as '0'

**TABLE 23-2: CONFIGURATION BITS DESCRIPTION (CONTINUED)**

| Bit Field | Register | RTSP Effect | Description |
|---|---|---|---|
| GWRP | FGS | Immediate | General Segment Write-Protect bit<br>1 = User program memory is not write-protected<br>0 = User program memory is write-protected |
| IESO | FOSCSEL | Immediate | Two-Speed Oscillator Start-up Enable bit<br>1 = Start-up device with FRC, then automatically switch to the user-selected oscillator source when ready<br>0 = Start-up device with user-selected oscillator source |
| FNOSC<2:0> | FOSCSEL | If clock switch is enabled, RTSP effect is on any device Reset; otherwise, Immediate | Initial Oscillator Source Selection bits<br>111 = Internal Fast RC (FRC) oscillator with postscaler<br>110 = Internal Fast RC (FRC) oscillator with divide-by-16<br>101 = LPRC oscillator<br>100 = Secondary (LP) oscillator<br>011 = Primary (XT, HS, EC) oscillator with PLL<br>010 = Primary (XT, HS, EC) oscillator<br>001 = Internal Fast RC (FRC) oscillator with PLL<br>000 = FRC oscillator |
| FCKSM<1:0> | FOSC | Immediate | Clock Switching Mode bits<br>1x = Clock switching is disabled, Fail-Safe Clock Monitor is disabled<br>01 = Clock switching is enabled, Fail-Safe Clock Monitor is disabled<br>00 = Clock switching is enabled, Fail-Safe Clock Monitor is enabled |
| OSCIOFNC | FOSC | Immediate | OSC2 Pin Function bit (except in XT and HS modes)<br>1 = OSC2 is clock output<br>0 = OSC2 is general purpose digital I/O pin |
| POSCMD<1:0> | FOSC | Immediate | Primary Oscillator Mode Select bits<br>11 = Primary oscillator disabled<br>10 = HS Crystal Oscillator mode<br>01 = XT Crystal Oscillator mode<br>00 = EC (External Clock) mode |
| FWDTEN | FWDT | Immediate | Watchdog Timer Enable bit<br>1 = Watchdog Timer always enabled (LPRC oscillator cannot be disabled. Clearing the SWDTEN bit in the RCON register will have no effect.)<br>0 = Watchdog Timer enabled/disabled by user software (LPRC can be disabled by clearing the SWDTEN bit in the RCON register.) |
| WINDIS | FWDT | Immediate | Watchdog Timer Window Enable bit<br>1 = Watchdog Timer in Non-Window mode<br>0 = Watchdog Timer in Window mode |
| PLLKEN | FWDT | Immediate | PLL Lock Enable bit<br>1 = Clock switch to PLL source will wait until the PLL lock signal is valid<br>0 = Clock switch will not wait for the PLL lock signal |
| WDTPRE | FWDT | Immediate | Watchdog Timer Prescaler bit<br>1 = 1:128<br>0 = 1:32 |
| WDTPOST<3:0> | FWDT | Immediate | Watchdog Timer Postscaler bits<br>1111 = 1:32,768<br>1110 = 1:16,384<br>•<br>•<br>•<br>0001 = 1:2<br>0000 = 1:1 |

## 25.7 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.

## 25.8 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.

## 25.9 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.

## 25.10 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.

**TABLE 26-11: ELECTRICAL CHARACTERISTICS: BOR**

| DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param.** | **Symbol** | **Characteristic(1)** | **Min(1)** | **Typ** | **Max(1)** | **Units** | **Conditions** |
| BO10 | VBOR | BOR Event on VDD Transition High-to-Low | 2.40 | — | 2.55 | V | VDD |

**Note 1:** Parameters are for design guidance only and are not tested in manufacturing.

**TABLE 26-12: DC CHARACTERISTICS: PROGRAM MEMORY**

| DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Typ(1)** | **Max** | **Units** | **Conditions** |
| | | **Program Flash Memory** | | | | | |
| D130 | EP | Cell Endurance | 10,000 | — | — | E/W | — |
| D131 | VPR | VDD for Read | VMIN | — | 3.6 | V | VMIN = Minimum operating voltage |
| D132b | VPEW | VDD for Self-Timed Write | VMIN | — | 3.6 | V | VMIN = Minimum operating voltage |
| D134 | TRETD | Characteristic Retention | 20 | — | — | Year | Provided no other specifications are violated |
| D135 | IDDP | Supply Current during Programming | — | 10 | — | mA | — |
| D136a | TRW | Row Write Time | 1.32 | — | 1.74 | ms | TRW = 11064 FRC cycles, TA = +85°C, see **Note 2** |
| D136b | TRW | Row Write Time | 1.28 | — | 1.79 | ms | TRW = 11064 FRC cycles, TA = +150°C, see **Note 2** |
| D137a | TPE | Page Erase Time | 20.1 | — | 26.5 | ms | TPE = 168517 FRC cycles, TA = +85°C, see **Note 2** |
| D137b | TPE | Page Erase Time | 19.5 | — | 27.3 | ms | TPE = 168517 FRC cycles, TA = +150°C, see **Note 2** |
| D138a | TWW | Word Write Cycle Time | 42.3 | — | 55.9 | µs | TWW = 355 FRC cycles, TA = +85°C, see **Note 2** |
| D138b | TWW | Word Write Cycle Time | 41.1 | — | 57.6 | µs | TWW = 355 FRC cycles, TA = +150°C, see **Note 2** |

**Note 1:** Data in "Typ" column is at 3.3V, 25°C unless otherwise stated.

**2:** Other conditions: FRC = 7.37 MHz, TUN<5:0> = b'011111 (for Min), TUN<5:0> = b'100000 (for Max). This parameter depends on the FRC accuracy (see Table 26-19) and the value of the FRC Oscillator Tuning register (see Register 9-4). For complete details on calculating the Minimum and Maximum time, see **Section 5.3 "Programming Operations"**.

**TABLE 26-13: INTERNAL VOLTAGE REGULATOR SPECIFICATIONS**

| Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param.** | **Symbol** | **Characteristics** | **Min** | **Typ** | **Max** | **Units** | **Comments** |
| — | CEFC | External Filter Capacitor Value | 4.7 | 10 | — | µF | Capacitor must be low series resistance (< 5 ohms) |

**TABLE 26-33: SPIx MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY) TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min** | **Typ(2)** | **Max** | **Units** | **Conditions** |
| SP10 | TscP | Maximum SCK Frequency | — | — | 15 | MHz | See **Note 3** |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See parameter DO32 and **Note 4** |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See parameter DO31 and **Note 4** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See parameter DO32 and **Note 4** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See parameter DO31 and **Note 4** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | — |
| SP36 | TdiV2scH, TdiV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | — |

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

**2:** Data in “Typ” column is at 3.3V, 25°C unless otherwise stated.

**3:** The minimum clock period for SCKx is 66.7 ns. Therefore, the clock generated in Master mode must not violate this specification.

**4:** Assumes 50 pF load on all SPIx pins.

**FIGURE 26-20: SPIx SLAVE MODE (FULL-DUPLEX CKE = 0, CKP = 1, SMP = 0) TIMING CHARACTERISTICS**

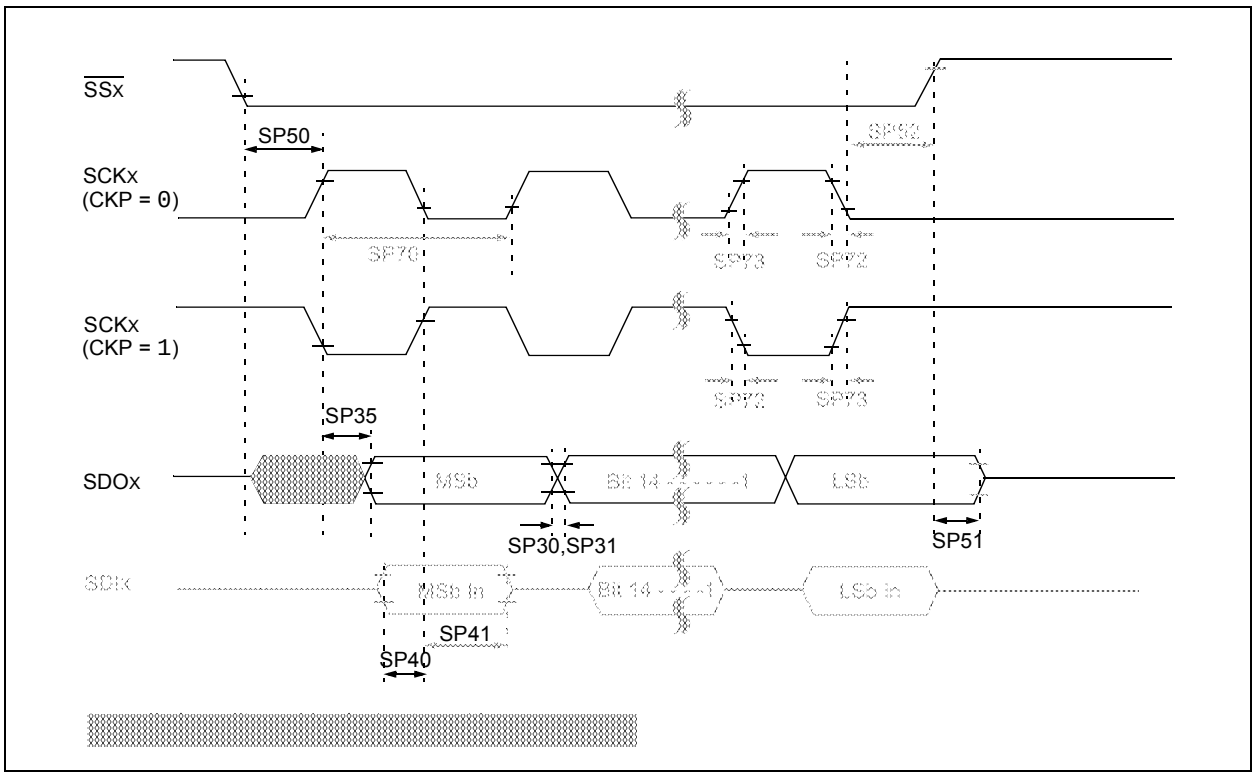


**TABLE 26-47: ADC CONVERSION (10-BIT MODE) TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +85°C | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ(1)** | **Max.** | **Units** | **Conditions** |
| **Clock Parameters** | | | | | | | |
| AD50b | TAD | ADC Clock Period | 76 | — | — | ns | — |
| AD51b | tRC | ADC Internal RC Oscillator Period | — | 250 | — | ns | — |
| **Conversion Rate** | | | | | | | |
| AD55b | tCONV | Conversion Time | — | 12 TAD | — | — | — |
| AD56b | FCNV | Throughput Rate | — | — | 1.1 | Msps | — |
| AD57b | TSAMP | Sample Time | 2 TAD | — | — | — | — |
| **Timing Parameters** | | | | | | | |
| AD60b | tPCS | Conversion Start from Sample Trigger(1,2) | 2.0 TAD | — | 3.0 TAD | — | Auto-Convert Trigger (SSRC<2:0> = 111) not selected |
| AD61b | tPSS | Sample Start from Setting Sample (SAMP) bit(1,2) | 2.0 TAD | — | 3.0 TAD | — | — |
| AD62b | tCSS | Conversion Completion to Sample Start (ASAM = 1)(1,2) | — | 0.5 TAD | — | — | — |
| AD63b | tDPU | Time to Stabilize Analog Stage from ADC Off to ADC On(1,3) | — | — | 20 | μs | — |

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

**2:** Because the sample caps will eventually lose charge, clock rates below 10 kHz can affect linearity performance, especially at elevated temperatures.

**3:** tDPU is the time required for the ADC module to stabilize when it is turned on (AD1CON1<ADON> = 1). During this time, the ADC result is indeterminate.

**TABLE 26-48: DMA READ/WRITE TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|
| **Param No.** | **Characteristic** | **Min.** | **Typ** | **Max.** | **Units** | **Conditions** |
| DM1a | DMA Read/Write Cycle Time | — | — | 2 TCY | ns | This characteristic applies to dsPIC33FJ256MCX06A/X08A/X10A devices only. |
| DM1b | DMA Read/Write Cycle Time | — | — | 1 TCY | ns | This characteristic applies to all devices with the exception of the dsPIC33FJ256MCX06A/X08A/X10A. |

**TABLE 27-9: INTERNAL LPRC ACCURACY**

| AC CHARACTERISTICS | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +150°C for High Temperature | | | | | | |
|---|---|---|---|---|---|---|---|
| Param No. | Characteristic | Min | Typ | Max | Units | Conditions | |
| | **LPRC @ 32.768 kHz (1)** | | | | | | |
| HF21 | LPRC | -70(2) | — | +70(2) | % | -40°C ≤ TA ≤ +150°C | — |

**Note 1:** Change of LPRC frequency as VDD changes.

**2:** Characterized but not tested.

**TABLE 27-10: SPIx MASTER MODE (CKE = 0) TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +150°C for High Temperature | | | | | |
|---|---|---|---|---|---|---|---|
| Param No. | Symbol | Characteristic(1) | Min | Typ | Max | Units | Conditions |
| HSP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 10 | 25 | ns | — |
| HSP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 28 | — | — | ns | — |
| HSP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 35 | — | — | ns | — |

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

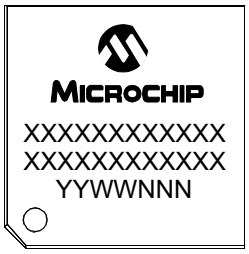
**TABLE 27-11: SPIx MODULE MASTER MODE (CKE = 1) TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +150°C for High Temperature | | | | | |
|---|---|---|---|---|---|---|---|
| Param No. | Symbol | Characteristic(1) | Min | Typ | Max | Units | Conditions |
| HSP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 10 | 25 | ns | — |
| HSP36 | TdoV2sc, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 35 | — | — | ns | — |
| HSP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 28 | — | — | ns | — |
| HSP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 35 | — | — | ns | — |

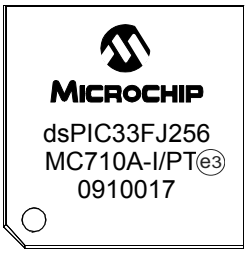
**Note 1:** These parameters are characterized but not tested in manufacturing.

## 29.1 Package Marking Information (Continued)

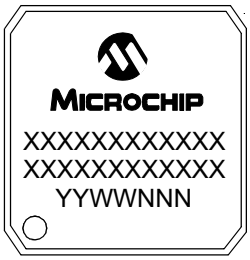
100-Lead TQFP (12x12x1 mm)




Example




100-Lead TQFP (14x14x1mm)



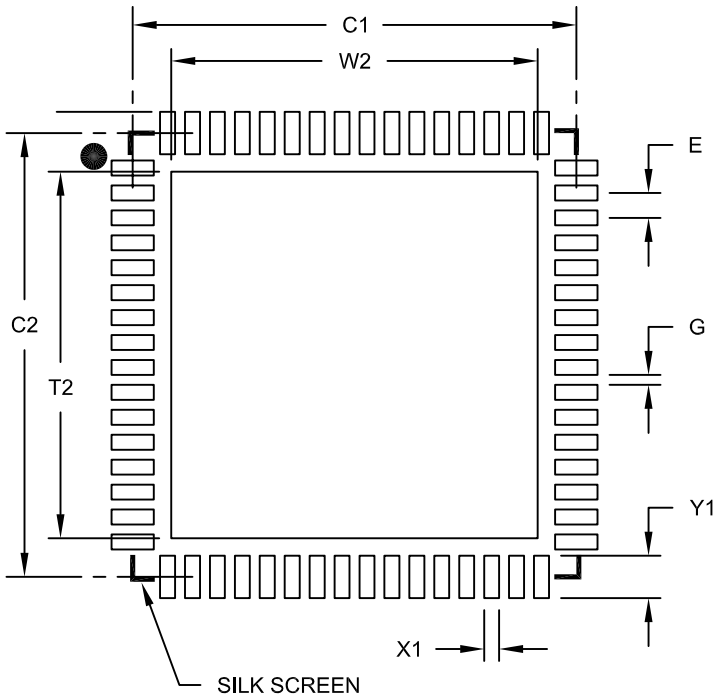

Example


| | | |
|---|---|---|
| **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.

64-Lead Plastic Quad Flat, No Lead Package (MR) – 9x9x0.9 mm Body [QFN]
With 0.40 mm Contact Length

**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 | | 0.50 BSC | |
| Optional Center Pad Width | W2 | | | 7.35 |
| Optional Center Pad Length | T2 | | | 7.35 |
| Contact Pad Spacing | C1 | | 8.90 | |
| Contact Pad Spacing | C2 | | 8.90 | |
| Contact Pad Width (X64) | X1 | | | 0.30 |
| Contact Pad Length (X64) | Y1 | | | 0.85 |
| 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. C04-2149A

# INDEX