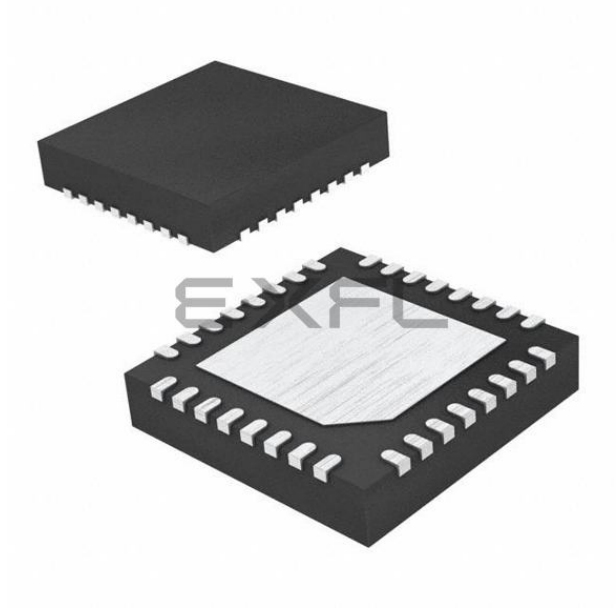
# Microchip Technology - DSPIC33EP32MC202-E/MM Datasheet



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## 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 | 60 MIPs |
| Connectivity | I²C, IrDA, LINbus, QEI, SPI, UART/USART |
| Peripherals | Brown-out Detect/Reset, DMA, Motor Control PWM, POR, PWM, WDT |
| Number of I/O | 21 |
| Program Memory Size | 32KB (10.7K x 24) |
| Program Memory Type | FLASH |
| EEPROM Size | - |
| RAM Size | 2K x 16 |
| Voltage - Supply (Vcc/Vdd) | 3V ~ 3.6V |
| Data Converters | A/D 6x10b/12b |
| Oscillator Type | Internal |
| Operating Temperature | -40°C ~ 125°C (TA) |
| Mounting Type | Surface Mount |
| Package / Case | 28-VQFN Exposed Pad |
| Supplier Device Package | 28-QFN-S (6x6) |
| Purchase URL | https://www.e-xfl.com/product-detail/microchip-technology/dspic33ep32mc202-e-mm |

## dsPIC33EPXXXGP50X, dsPIC33EPXXXMC20X/50X AND PIC24EPXXXGP/MC20X PRODUCT FAMILIES

The device names, pin counts, memory sizes and peripheral availability of each device are listed in Table 1 (General Purpose Families) and Table 2 (Motor Control Families). Their pinout diagrams appear on the following pages.

**TABLE 1: dsPIC33EPXXXGP50X and PIC24EPXXXGP20X GENERAL PURPOSE FAMILIES**

| Device | Page Erase Size (Instructions) | Program Flash Memory (Kbytes) | RAM (Kbyte) | Remappable Peripherals | | | | | | | $I^2C$™ | CRC Generator | 10-Bit/12-Bit ADC (Channels) | Op Amps/Comparators | CTMU | PTG | I/O Pins | Pins | Packages |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 16-Bit/32-Bit Timers | Input Capture | Output Compare | UART | SPI(2) | ECAN™ Technology | External Interrupts(3) | | | | | | | | | |
| PIC24EP32GP202 | 512 | 32 | 4 | 5 | 4 | 4 | 2 | 2 | — | 3 | 2 | 1 | 6 | 2/3(1) | Yes | Yes | 21 | 28 | SPDIP, SOIC, SSOP(4), QFN-S |
| PIC24EP64GP202 | 1024 | 64 | 8 | | | | | | | | | | | | | | | | |
| PIC24EP128GP202 | 1024 | 128 | 16 | | | | | | | | | | | | | | | | |
| PIC24EP256GP202 | 1024 | 256 | 32 | | | | | | | | | | | | | | | | |
| PIC24EP512GP202 | 1024 | 512 | 48 | | | | | | | | | | | | | | | | |
| PIC24EP32GP203 | 512 | 32 | 4 | 5 | 4 | 4 | 2 | 2 | — | 3 | 2 | 1 | 8 | 3/4 | Yes | Yes | 25 | 36 | VTLA |
| PIC24EP64GP203 | 1024 | 64 | 8 | | | | | | | | | | | | | | | | |
| PIC24EP32GP204 | 512 | 32 | 4 | 5 | 4 | 4 | 2 | 2 | — | 3 | 2 | 1 | 9 | 3/4 | Yes | Yes | 35 | 44/48 | VTLA(4), TQFP, QFN, UQFN |
| PIC24EP64GP204 | 1024 | 64 | 8 | | | | | | | | | | | | | | | | |
| PIC24EP128GP204 | 1024 | 128 | 16 | | | | | | | | | | | | | | | | |
| PIC24EP256GP204 | 1024 | 256 | 32 | | | | | | | | | | | | | | | | |
| PIC24EP512GP204 | 1024 | 512 | 48 | | | | | | | | | | | | | | | | |
| PIC24EP64GP206 | 1024 | 64 | 8 | 5 | 4 | 4 | 2 | 2 | — | 3 | 2 | 1 | 16 | 3/4 | Yes | Yes | 53 | 64 | TQFP, QFN |
| PIC24EP128GP206 | 1024 | 128 | 16 | | | | | | | | | | | | | | | | |
| PIC24EP256GP206 | 1024 | 256 | 32 | | | | | | | | | | | | | | | | |
| PIC24EP512GP206 | 1024 | 512 | 48 | | | | | | | | | | | | | | | | |
| dsPIC33EP32GP502 | 512 | 32 | 4 | 5 | 4 | 4 | 2 | 2 | 1 | 3 | 2 | 1 | 6 | 2/3(1) | Yes | Yes | 21 | 28 | SPDIP, SOIC, SSOP(4), QFN-S |
| dsPIC33EP64GP502 | 1024 | 64 | 8 | | | | | | | | | | | | | | | | |
| dsPIC33EP128GP502 | 1024 | 128 | 16 | | | | | | | | | | | | | | | | |
| dsPIC33EP256GP502 | 1024 | 256 | 32 | | | | | | | | | | | | | | | | |
| dsPIC33EP512GP502 | 1024 | 512 | 48 | | | | | | | | | | | | | | | | |
| dsPIC33EP32GP503 | 512 | 32 | 4 | 5 | 4 | 4 | 2 | 2 | 1 | 3 | 2 | 1 | 8 | 3/4 | Yes | Yes | 25 | 36 | VTLA |
| dsPIC33EP64GP503 | 1024 | 64 | 8 | | | | | | | | | | | | | | | | |
| dsPIC33EP32GP504 | 512 | 32 | 4 | 5 | 4 | 4 | 2 | 2 | 1 | 3 | 2 | 1 | 9 | 3/4 | Yes | Yes | 35 | 44/48 | VTLA(4), TQFP, QFN, UQFN |
| dsPIC33EP64GP504 | 1024 | 64 | 8 | | | | | | | | | | | | | | | | |
| dsPIC33EP128GP504 | 1024 | 128 | 16 | | | | | | | | | | | | | | | | |
| dsPIC33EP256GP504 | 1024 | 256 | 32 | | | | | | | | | | | | | | | | |
| dsPIC33EP512GP504 | 1024 | 512 | 48 | | | | | | | | | | | | | | | | |
| dsPIC33EP64GP506 | 1024 | 64 | 8 | 5 | 4 | 4 | 2 | 2 | 1 | 3 | 2 | 1 | 16 | 3/4 | Yes | Yes | 53 | 64 | TQFP, QFN |
| dsPIC33EP128GP506 | 1024 | 128 | 16 | | | | | | | | | | | | | | | | |
| dsPIC33EP256GP506 | 1024 | 256 | 32 | | | | | | | | | | | | | | | | |
| dsPIC33EP512GP506 | 1024 | 512 | 48 | | | | | | | | | | | | | | | | |

**Note 1:** On 28-pin devices, Comparator 4 does not have external connections. Refer to **Section 25.0 "Op Amp/Comparator Module"** for details.
**2:** Only SPI2 is remappable.
**3:** INT0 is not remappable.
**4:** The SSOP and VTLA packages are not available for devices with 512 Kbytes of memory.

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### Errata

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

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- Microchip's Worldwide Web site; **http://www.microchip.com**
- Your local Microchip sales office (see last page)

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**REGISTER 7-1: SR: CPU STATUS REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/C-0 | R/C-0 | R-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| OA | OB | SA | SB | OAB | SAB | DA | DC |
| bit 15 | | | | | | | bit 8 |

| R/W-0(3) | R/W-0(3) | R/W-0(3) | R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| IPL<2:0>(2) | | | RA | N | OV | Z | C |
| bit 7 | | | | | | | bit 0 |

| Legend: | 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 7-5 **IPL<2:0>:** CPU Interrupt Priority Level Status bits(2,3)

111 = CPU Interrupt Priority Level is 7 (15); user interrupts are disabled
110 = CPU Interrupt Priority Level is 6 (14)
101 = CPU Interrupt Priority Level is 5 (13)
100 = CPU Interrupt Priority Level is 4 (12)
011 = CPU Interrupt Priority Level is 3 (11)
010 = CPU Interrupt Priority Level is 2 (10)
001 = CPU Interrupt Priority Level is 1 (9)
000 = CPU Interrupt Priority Level is 0 (8)

**Note 1:** For complete register details, see Register 3-1.

**2:** The IPL<2:0> bits are concatenated with the IPL<3> bit (CORCON<3>) to form the CPU Interrupt Priority Level. The value in parentheses indicates the IPL, if IPL<3> = 1. User interrupts are disabled when IPL<3> = 1.

**3:** The IPL<2:0> Status bits are read-only when the NSTDIS bit (INTCON1<15>) = 1.

**REGISTER 7-5: INTCON3: INTERRUPT CONTROL REGISTER 3**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | DAE | DOOVR | — | — | — | — |
| 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 15-6 **Unimplemented:** Read as ‘0’

bit 5 **DAE:** DMA Address Error Soft Trap Status bit
1 = DMA address error soft trap has occurred
0 = DMA address error soft trap has not occurred

bit 4 **DOOVR:** DO Stack Overflow Soft Trap Status bit
1 = DO stack overflow soft trap has occurred
0 = DO stack overflow soft trap has not occurred

bit 3-0 **Unimplemented:** Read as ‘0’

**REGISTER 7-6: INTCON4: INTERRUPT CONTROL REGISTER 4**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | SGHT |
| 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 15-1 **Unimplemented:** Read as ‘0’

bit 0 **SGHT:** Software Generated Hard Trap Status bit
1 = Software generated hard trap has occurred
0 = Software generated hard trap has not occurred

## 9.1 CPU Clocking System

The dsPIC33EPXXXGP50X, dsPIC33EPXXXMC20X/50X and PIC24EPXXXGP/MC20X family of devices provides six system clock options:

- Fast RC (FRC) Oscillator
- FRC Oscillator with Phase Locked Loop (PLL)
- FRC Oscillator with Postscaler
- Primary (XT, HS or EC) Oscillator
- Primary Oscillator with PLL
- Low-Power RC (LPRC) Oscillator

Instruction execution speed or device operating frequency, FCY, is given by Equation 9-1.

**EQUATION 9-1: DEVICE OPERATING FREQUENCY**

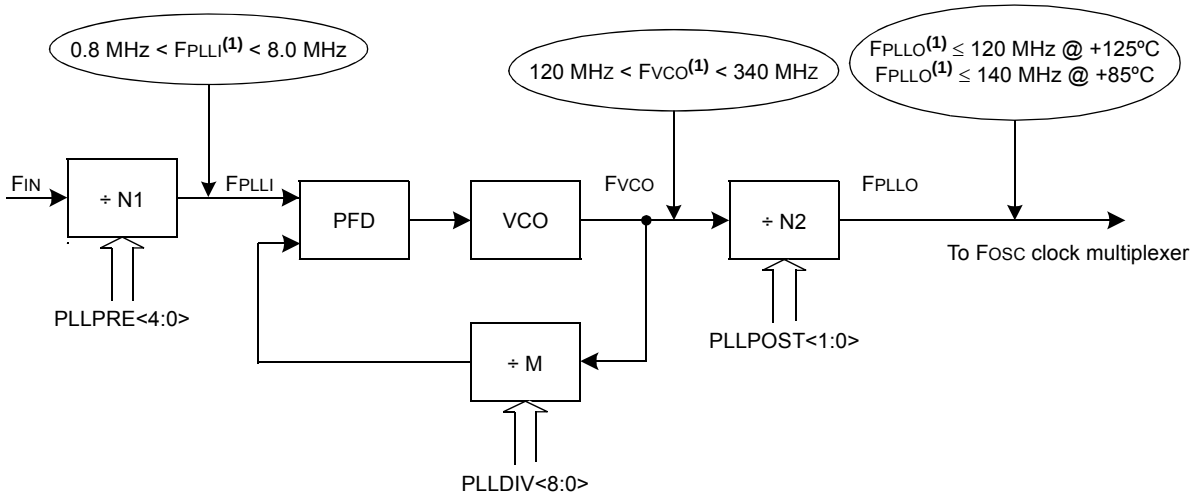
$$FCY = Fosc/2$$

Figure 9-2 is a block diagram of the PLL module.

Equation 9-2 provides the relationship between input frequency (FIN) and output frequency (FPLLO). In clock modes S1 and S3, when the PLL output is selected, FOSC = FPLLO.

Equation 9-3 provides the relationship between input frequency (FIN) and VCO frequency (FVCO).

**FIGURE 9-2: PLL BLOCK DIAGRAM**




**Note 1:** This frequency range must be met at all times.

**EQUATION 9-2: FPLLO CALCULATION**

$$FPLLO = FIN \times \left(\frac{M}{N1 \times N2}\right) = FIN \times \left(\frac{(PLLDIV + 2)}{(PLLPRE + 2) \times 2(PLLPOST + 1)}\right)$$

Where:

$N1 = PLLPRE + 2$

$N2 = 2 \times (PLLPOST + 1)$

$M = PLLDIV + 2$

**EQUATION 9-3: FVCO CALCULATION**

$$Fvco = FIN \times \left(\frac{M}{N1}\right) = FIN \times \left(\frac{(PLLDIV + 2)}{(PLLPRE + 2)}\right)$$

**REGISTER 11-20: RPOR2: PERIPHERAL PIN SELECT OUTPUT REGISTER 2**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP39R<5:0> | | | | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP38R<5:0> | | | | | |
| 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP39R<5:0>:** Peripheral Output Function is Assigned to RP39 Output Pin bits (see Table 11-3 for peripheral function numbers)

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

bit 5-0 **RP38R<5:0>:** Peripheral Output Function is Assigned to RP38 Output Pin bits (see Table 11-3 for peripheral function numbers)

**REGISTER 11-21: RPOR3: PERIPHERAL PIN SELECT OUTPUT REGISTER 3**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP41R<5:0> | | | | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP40R<5:0> | | | | | |
| 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP41R<5:0>:** Peripheral Output Function is Assigned to RP41 Output Pin bits (see Table 11-3 for peripheral function numbers)

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

bit 5-0 **RP40R<5:0>:** Peripheral Output Function is Assigned to RP40 Output Pin bits (see Table 11-3 for peripheral function numbers)

## 14.1 Input Capture Resources

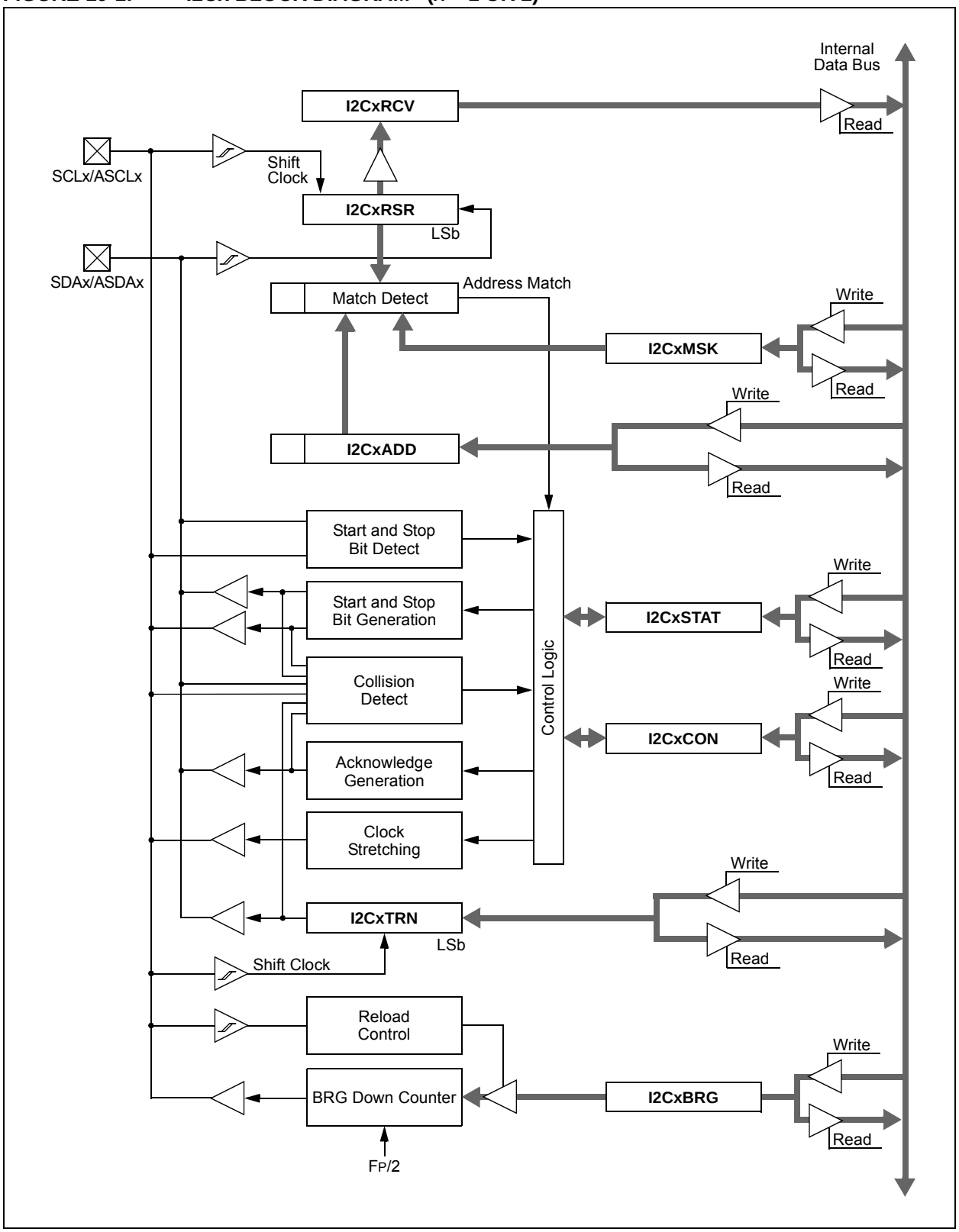
Many useful resources are provided on the main product page of the Microchip web site for the devices listed in this data sheet. This product page, which can be accessed using this link, contains the latest updates and additional information.

| | |
|---|---|
| **Note:** | In the event you are not able to access the product page using the link above, enter this URL in your browser: http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en555464 |

### 14.1.1 KEY RESOURCES

- **"Input Capture"** (DS70352) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

**FIGURE 19-1: I2Cx BLOCK DIAGRAM (x = 1 OR 2)**



**REGISTER 23-2: AD1CON2: ADC1 CONTROL REGISTER 2**

| R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| VCFG2 | VCFG1 | VCFG0 | — | — | CSCNA | CHPS1 | CHPS0 |
| bit 15 | | | | | | | bit 8 |

| R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| BUFS | SMPI4 | SMPI3 | SMPI2 | SMPI1 | SMPI0 | BUFM | ALTS |
| 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 15-13 **VCFG<2:0>:** Converter Voltage Reference Configuration bits

| Value | VREFH | VREFL |
|---|---|---|
| 000 | AVDD | Avss |
| 001 | External VREF+ | Avss |
| 010 | AVDD | External VREF- |
| 011 | External VREF+ | External VREF- |
| 1xx | AVDD | AVSS |

bit 12-11 **Unimplemented:** Read as '0'

bit 10 **CSCNA:** Input Scan Select bit
1 = Scans inputs for CH0+ during Sample MUXA
0 = Does not scan inputs

bit 9-8 **CHPS<1:0>:** Channel Select bits
In 12-bit mode (AD21B = 1), the CHPS<1:0> bits are Unimplemented and are Read as '0':
1x = Converts CH0, CH1, CH2 and CH3
01 = Converts CH0 and CH1
00 = Converts CH0

bit 7 **BUFS:** Buffer Fill Status bit (only valid when BUFM = 1)
1 = ADC is currently filling the second half of the buffer; the user application should access data in the first half of the buffer
0 = ADC is currently filling the first half of the buffer; the user application should access data in the second half of the buffer

bit 6-2 **SMPI<4:0>:** Increment Rate bits
When ADDMAEN = 0:
x1111 = Generates interrupt after completion of every 16th sample/conversion operation
x1110 = Generates interrupt after completion of every 15th sample/conversion operation
•
•
•
x0001 = Generates interrupt after completion of every 2nd sample/conversion operation
x0000 = Generates interrupt after completion of every sample/conversion operation
When ADDMAEN = 1:
11111 = Increments the DMA address after completion of every 32nd sample/conversion operation
11110 = Increments the DMA address after completion of every 31st sample/conversion operation
•
•
•
00001 = Increments the DMA address after completion of every 2nd sample/conversion operation
00000 = Increments the DMA address after completion of every sample/conversion operation

**REGISTER 23-3: AD1CON3: ADC1 CONTROL REGISTER 3**

| R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ADRC | — | — | SAMC4(1) | SAMC3(1) | SAMC2(1) | SAMC1(1) | SAMC0(1) |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ADCS7(2) | ADCS6(2) | ADCS5(2) | ADCS4(2) | ADCS3(2) | ADCS2(2) | ADCS1(2) | ADCS0(2) |
| 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 **ADRC:** ADC1 Conversion Clock Source bit
1 = ADC internal RC clock
0 = Clock derived from system clock

bit 14-13 **Unimplemented:** Read as '0'

bit 12-8 **SAMC<4:0>:** Auto-Sample Time bits(1)
11111 = 31 TAD
•
•
•
00001 = 1 TAD
00000 = 0 TAD

bit 7-0 **ADCS<7:0>:** ADC1 Conversion Clock Select bits(2)
11111111 = TP • (ADCS<7:0> + 1) = TP •256 = TAD
•
•
•
00000010 = TP • (ADCS<7:0> + 1) = TP •3 = TAD
00000001 = TP • (ADCS<7:0> + 1) = TP •2 = TAD
00000000 = TP • (ADCS<7:0> + 1) = TP •1 = TAD

**Note 1:** This bit is only used if SSRC<2:0> (AD1CON1<7:5>) = 111 and SSRCG (AD1CON1<4>) = 0.
**2:** This bit is not used if ADRC (AD1CON3<15>) = 1.

**REGISTER 24-12: PTGQPTR: PTG STEP QUEUE POINTER REGISTER(1)**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | PTGQPTR<4:0> | | | | |
| 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 15-5 **Unimplemented:** Read as ‘0’

bit 4-0 **PTGQPTR<4:0>:** PTG Step Queue Pointer Register bits
This register points to the currently active Step command in the Step queue.

**Note 1:** This register is read-only when the PTG module is executing Step commands (PTGEN = 1 and PTGSTRT = 1).

**REGISTER 24-13: PTGQUEx: PTG STEP QUEUE REGISTER x (x = 0-7)(1,3)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| STEP(2x + 1)<7:0>(2) | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| STEP(2x)<7:0>(2) | | | | | | | |
| 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 15-8 **STEP(2x + 1)<7:0>:** PTG Step Queue Pointer Register bits(2)
A queue location for storage of the STEP(2x + 1) command byte.

bit 7-0 **STEP(2x)<7:0>:** PTG Step Queue Pointer Register bits(2)
A queue location for storage of the STEP(2x) command byte.

**Note 1:** This register is read-only when the PTG module is executing Step commands (PTGEN = 1 and PTGSTRT = 1).

**2:** Refer to Table 24-1 for the Step command encoding.

**3:** The Step registers maintain their values on any type of Reset.

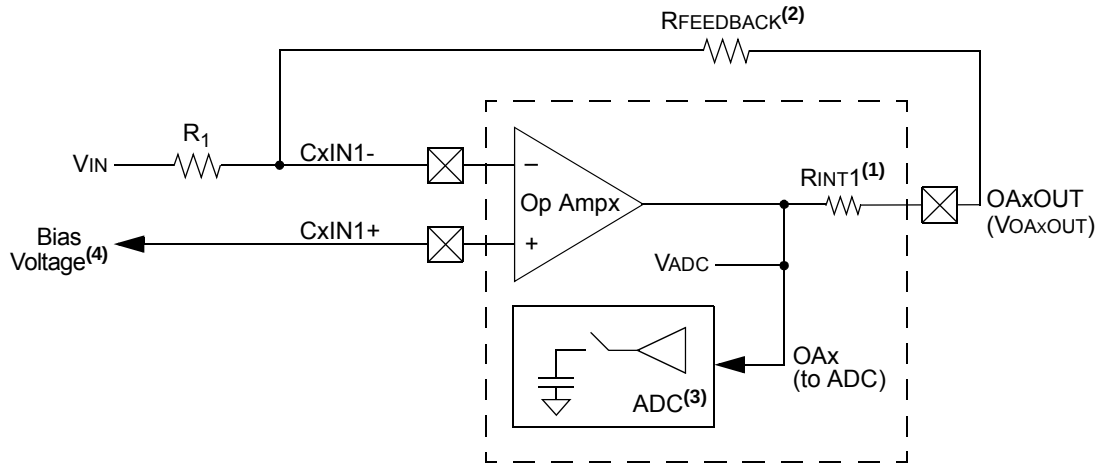
## 25.1 Op Amp Application Considerations

There are two configurations to take into consideration when designing with the op amp modules that are available in the dsPIC33EPXXXGP50X, dsPIC33EPXXXMC20X/50X and PIC24EPXXXGP/MC20X devices. Configuration A (see Figure 25-6) takes advantage of the internal connection to the ADC module to route the output of the op amp directly to the ADC for measurement. Configuration B (see Figure 25-7) requires that the designer externally route the output of the op amp (OAxOUT) to a separate analog input pin (ANy) on the device. Table 30-55 in **Section 30.0 "Electrical Characteristics"** describes the performance characteristics for the op amps, distinguishing between the two configuration types where applicable.

### 25.1.1 OP AMP CONFIGURATION A

Figure 25-6 shows a typical inverting amplifier circuit taking advantage of the internal connections from the op amp output to the input of the ADC. The advantage of this configuration is that the user does not need to consume another analog input (ANy) on the device, and allows the user to simultaneously sample all three op amps with the ADC module, if needed. However, the presence of the internal resistance, RINT1, adds an error in the feedback path. Since RINT1 is an internal resistance, in relation to the op amp output (VOAXOUT) and ADC internal connection (VADC), RINT1 must be included in the numerator term of the transfer function. See Table 30-53 in **Section 30.0 "Electrical Characteristics"** for the typical value of RINT1. Table 30-60 and Table 30-61 in **Section 30.0 "Electrical Characteristics"** describe the minimum sample time (TSAMP) requirements for the ADC module in this configuration. Figure 25-6 also defines the equations that should be used when calculating the expected voltages at points, VADC and VOAXOUT.

**FIGURE 25-6: OP AMP CONFIGURATION A**




$$V_{ADC} = \left(\frac{R_{FEEDBACK} + R_{INT1}}{R_1}\right)( \ Bias\ Voltage - V_{IN} \ )$$

$$V_{OAxOUT} = \left(\frac{R_{FEEDBACK}}{R_1}\right)( \ Bias\ Voltage - V_{IN} \ )$$

**Note 1:** See Table 30-53 for the Typical value.
**2:** See Table 30-53 for the Minimum value for the feedback resistor.
**3:** See Table 30-60 and Table 30-61 for the minimum sample time (TSAMP).
**4:** CVREF1O or CVREF2O are two options that are available for supplying bias voltage to the op amps.

**TABLE 28-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(2) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 25 | DAW | DAW | Wn | Wn = decimal adjust Wn | 1 | 1 | C |
| 26 | DEC | DEC | f | f = f – 1 | 1 | 1 | C,DC,N,OV,Z |
| | | DEC | f,WREG | WREG = f – 1 | 1 | 1 | C,DC,N,OV,Z |
| | | DEC | Ws,Wd | Wd = Ws – 1 | 1 | 1 | C,DC,N,OV,Z |
| 27 | DEC2 | DEC2 | f | f = f – 2 | 1 | 1 | C,DC,N,OV,Z |
| | | DEC2 | f,WREG | WREG = f – 2 | 1 | 1 | C,DC,N,OV,Z |
| | | DEC2 | Ws,Wd | Wd = Ws – 2 | 1 | 1 | C,DC,N,OV,Z |
| 28 | DISI | DISI | #lit14 | Disable Interrupts for k instruction cycles | 1 | 1 | None |
| 29 | DIV | DIV.S | Wm,Wn | Signed 16/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| | | DIV.SD | Wm,Wn | Signed 32/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| | | DIV.U | Wm,Wn | Unsigned 16/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| | | DIV.UD | Wm,Wn | Unsigned 32/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| 30 | DIVF | DIVF | Wm,Wn(1) | Signed 16/16-bit Fractional Divide | 1 | 18 | N,Z,C,OV |
| 31 | DO | DO | #lit15,Expr(1) | Do code to PC + Expr, lit15 + 1 times | 2 | 2 | None |
| | | DO | Wn,Expr(1) | Do code to PC + Expr, (Wn) + 1 times | 2 | 2 | None |
| 32 | ED | ED | Wm*Wm,Acc,Wx,Wy,Wxd(1) | Euclidean Distance (no accumulate) | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 33 | EDAC | EDAC | Wm*Wm,Acc,Wx,Wy,Wxd(1) | Euclidean Distance | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 34 | EXCH | EXCH | Wns,Wnd | Swap Wns with Wnd | 1 | 1 | None |
| 35 | FBCL | FBCL | Ws,Wnd | Find Bit Change from Left (MSb) Side | 1 | 1 | C |
| 36 | FF1L | FF1L | Ws,Wnd | Find First One from Left (MSb) Side | 1 | 1 | C |
| 37 | FF1R | FF1R | Ws,Wnd | Find First One from Right (LSb) Side | 1 | 1 | C |
| 38 | GOTO | GOTO | Expr | Go to address | 2 | 4 | None |
| | | GOTO | Wn | Go to indirect | 1 | 4 | None |
| | | GOTO.L | Wn | Go to indirect (long address) | 1 | 4 | None |
| 39 | INC | INC | f | f = f + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | INC | f,WREG | WREG = f + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | INC | Ws,Wd | Wd = Ws + 1 | 1 | 1 | C,DC,N,OV,Z |
| 40 | INC2 | INC2 | f | f = f + 2 | 1 | 1 | C,DC,N,OV,Z |
| | | INC2 | f,WREG | WREG = f + 2 | 1 | 1 | C,DC,N,OV,Z |
| | | INC2 | Ws,Wd | Wd = Ws + 2 | 1 | 1 | C,DC,N,OV,Z |
| 41 | IOR | IOR | f | f = f .IOR. WREG | 1 | 1 | N,Z |
| | | IOR | f,WREG | WREG = f .IOR. WREG | 1 | 1 | N,Z |
| | | IOR | #lit10,Wn | Wd = lit10 .IOR. Wd | 1 | 1 | N,Z |
| | | IOR | Wb,Ws,Wd | Wd = Wb .IOR. Ws | 1 | 1 | N,Z |
| | | IOR | Wb,#lit5,Wd | Wd = Wb .IOR. lit5 | 1 | 1 | N,Z |
| 42 | LAC | LAC | Wso,#Slit4,Acc | Load Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 43 | LNK | LNK | #lit14 | Link Frame Pointer | 1 | 1 | SFA |
| 44 | LSR | LSR | f | f = Logical Right Shift f | 1 | 1 | C,N,OV,Z |
| | | LSR | f,WREG | WREG = Logical Right Shift f | 1 | 1 | C,N,OV,Z |
| | | LSR | Ws,Wd | Wd = Logical Right Shift Ws | 1 | 1 | C,N,OV,Z |
| | | LSR | Wb,Wns,Wnd | Wnd = Logical Right Shift Wb by Wns | 1 | 1 | N,Z |
| | | LSR | Wb,#lit5,Wnd | Wnd = Logical Right Shift Wb by lit5 | 1 | 1 | N,Z |
| 45 | MAC | MAC | Wm*Wn,Acc,Wx,Wxd,Wy,Wyd,AWB(1) | Multiply and Accumulate | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | MAC | Wm*Wm,Acc,Wx,Wxd,Wy,Wyd(1) | Square and Accumulate | 1 | 1 | OA,OB,OAB, SA,SB,SAB |

**Note 1:** These instructions are available in dsPIC33EPXXXMC20X/50X and PIC24EPXXXMC20X devices only.

**2:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.

**TABLE 28-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles(2) | Status Flags Affected |
|---|---|---|---|---|---|---|
| 52 | MUL | MUL.SS Wb,Ws,Wnd | {Wnd + 1, Wnd} = signed(Wb) * signed(Ws) | 1 | 1 | None |
| | | MUL.SS Wb,Ws,Acc(1) | Accumulator = signed(Wb) * signed(Ws) | 1 | 1 | None |
| | | MUL.SU Wb,Ws,Wnd | {Wnd + 1, Wnd} = signed(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MUL.SU Wb,Ws,Acc(1) | Accumulator = signed(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MUL.SU Wb,#lit5,Acc(1) | Accumulator = signed(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL.US Wb,Ws,Wnd | {Wnd + 1, Wnd} = unsigned(Wb) * signed(Ws) | 1 | 1 | None |
| | | MUL.US Wb,Ws,Acc(1) | Accumulator = unsigned(Wb) * signed(Ws) | 1 | 1 | None |
| | | MUL.UU Wb,Ws,Wnd | {Wnd + 1, Wnd} = unsigned(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MUL.UU Wb,#lit5,Acc(1) | Accumulator = unsigned(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL.UU Wb,Ws,Acc(1) | Accumulator = unsigned(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MULW.SS Wb,Ws,Wnd | Wnd = signed(Wb) * signed(Ws) | 1 | 1 | None |
| | | MULW.SU Wb,Ws,Wnd | Wnd = signed(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MULW.US Wb,Ws,Wnd | Wnd = unsigned(Wb) * signed(Ws) | 1 | 1 | None |
| | | MULW.UU Wb,Ws,Wnd | Wnd = unsigned(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MUL.SU Wb,#lit5,Wnd | {Wnd + 1, Wnd} = signed(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL.SU Wb,#lit5,Wnd | Wnd = signed(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL.UU Wb,#lit5,Wnd | {Wnd + 1, Wnd} = unsigned(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL.UU Wb,#lit5,Wnd | Wnd = unsigned(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL f | W3:W2 = f * WREG | 1 | 1 | None |

**Note 1:** These instructions are available in dsPIC33EPXXXMC20X/50X and PIC24EPXXXMC20X devices only.
**2:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.

**TABLE 28-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(2) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 72 | SL | SL | f | f = Left Shift f | 1 | 1 | C,N,OV,Z |
| | | SL | f,WREG | WREG = Left Shift f | 1 | 1 | C,N,OV,Z |
| | | SL | Ws,Wd | Wd = Left Shift Ws | 1 | 1 | C,N,OV,Z |
| | | SL | Wb,Wns,Wnd | Wnd = Left Shift Wb by Wns | 1 | 1 | N,Z |
| | | SL | Wb,#lit5,Wnd | Wnd = Left Shift Wb by lit5 | 1 | 1 | N,Z |
| 73 | SUB | SUB | Acc(1) | Subtract Accumulators | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | SUB | f | f = f – WREG | 1 | 1 | C,DC,N,OV,Z |
| | | SUB | f,WREG | WREG = f – WREG | 1 | 1 | C,DC,N,OV,Z |
| | | SUB | #lit10,Wn | Wn = Wn – lit10 | 1 | 1 | C,DC,N,OV,Z |
| | | SUB | Wb,Ws,Wd | Wd = Wb – Ws | 1 | 1 | C,DC,N,OV,Z |
| | | SUB | Wb,#lit5,Wd | Wd = Wb – lit5 | 1 | 1 | C,DC,N,OV,Z |
| 74 | SUBB | SUBB | f | f = f – WREG – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB | f,WREG | WREG = f – WREG – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB | #lit10,Wn | Wn = Wn – lit10 – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB | Wb,Ws,Wd | Wd = Wb – Ws – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB | Wb,#lit5,Wd | Wd = Wb – lit5 – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| 75 | SUBR | SUBR | f | f = WREG – f | 1 | 1 | C,DC,N,OV,Z |
| | | SUBR | f,WREG | WREG = WREG – f | 1 | 1 | C,DC,N,OV,Z |
| | | SUBR | Wb,Ws,Wd | Wd = Ws – Wb | 1 | 1 | C,DC,N,OV,Z |
| | | SUBR | Wb,#lit5,Wd | Wd = lit5 – Wb | 1 | 1 | C,DC,N,OV,Z |
| 76 | SUBBR | SUBBR | f | f = WREG – f – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBBR | f,WREG | WREG = WREG – f – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBBR | Wb,Ws,Wd | Wd = Ws – Wb – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBBR | Wb,#lit5,Wd | Wd = lit5 – Wb – ($\overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| 77 | SWAP | SWAP.b | Wn | Wn = nibble swap Wn | 1 | 1 | None |
| | | SWAP | Wn | Wn = byte swap Wn | 1 | 1 | None |
| 78 | TBLRDH | TBLRDH | Ws,Wd | Read Prog<23:16> to Wd<7:0> | 1 | 5 | None |
| 79 | TBLRDL | TBLRDL | Ws,Wd | Read Prog<15:0> to Wd | 1 | 5 | None |
| 80 | TBLWTH | TBLWTH | Ws,Wd | Write Ws<7:0> to Prog<23:16> | 1 | 2 | None |
| 81 | TBLWTL | TBLWTL | Ws,Wd | Write Ws to Prog<15:0> | 1 | 2 | None |
| 82 | ULNK | ULNK | | Unlink Frame Pointer | 1 | 1 | SFA |
| 83 | XOR | XOR | f | f = f .XOR. WREG | 1 | 1 | N,Z |
| | | XOR | f,WREG | WREG = f .XOR. WREG | 1 | 1 | N,Z |
| | | XOR | #lit10,Wn | Wd = lit10 .XOR. Wd | 1 | 1 | N,Z |
| | | XOR | Wb,Ws,Wd | Wd = Wb .XOR. Ws | 1 | 1 | N,Z |
| | | XOR | Wb,#lit5,Wd | Wd = Wb .XOR. lit5 | 1 | 1 | N,Z |
| 84 | ZE | ZE | Ws,Wnd | Wnd = Zero-extend Ws | 1 | 1 | C,Z,N |

**Note 1:** These instructions are available in dsPIC33EPXXXMC20X/50X and PIC24EPXXXMC20X devices only.
**2:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.

**FIGURE 30-11: TIMERQ (QEI MODULE) EXTERNAL CLOCK TIMING CHARACTERISTICS (dsPIC33EPXXXMC20X/50X AND PIC24EPXXXMC20X DEVICES ONLY)**

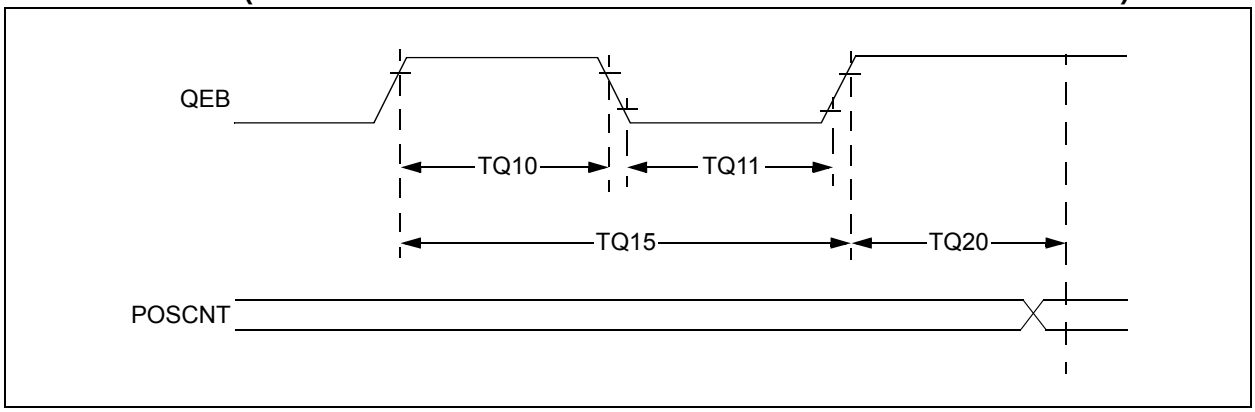



**TABLE 30-30: QEI MODULE EXTERNAL CLOCK TIMING REQUIREMENTS (dsPIC33EPXXXMC20X/50X AND PIC24EPXXXMC20X DEVICES ONLY)**

| 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.** | **Max.** | **Units** | **Conditions** |
| TQ10 | TtQH | TQCK High Time | Synchronous, with prescaler | Greater of 12.5 + 25 or (0.5 TCY/N) + 25 | — | — | ns | Must also meet Parameter TQ15 |
| TQ11 | TtQL | TQCK Low Time | Synchronous, with prescaler | Greater of 12.5 + 25 or (0.5 TCY/N) + 25 | — | — | ns | Must also meet Parameter TQ15 |
| TQ15 | TtQP | TQCP Input Period | Synchronous, with prescaler | Greater of 25 + 50 or (1 TCY/N) + 50 | — | — | ns | |
| TQ20 | TCKEXTMRL | Delay from External TQCK Clock Edge to Timer Increment | | — | 1 | TCY | — | |

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

## 32.0 DC AND AC DEVICE CHARACTERISTICS GRAPHS

**Note:** The graphs provided following this note are a statistical summary based on a limited number of samples and are provided for design guidance purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore, outside the warranted range.

**FIGURE 32-1: VOH – 4x DRIVER PINS**

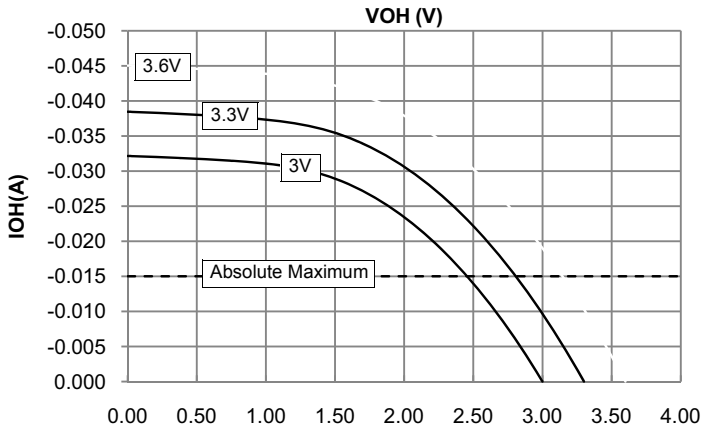



**FIGURE 32-2: VOH – 8x DRIVER PINS**

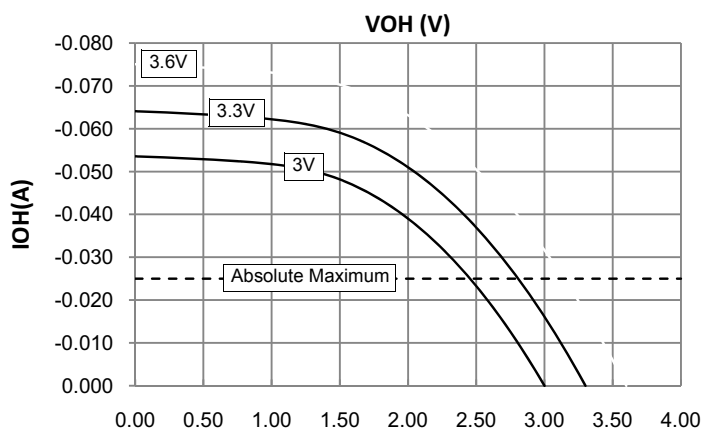



**FIGURE 32-3: VOL – 4x DRIVER PINS**

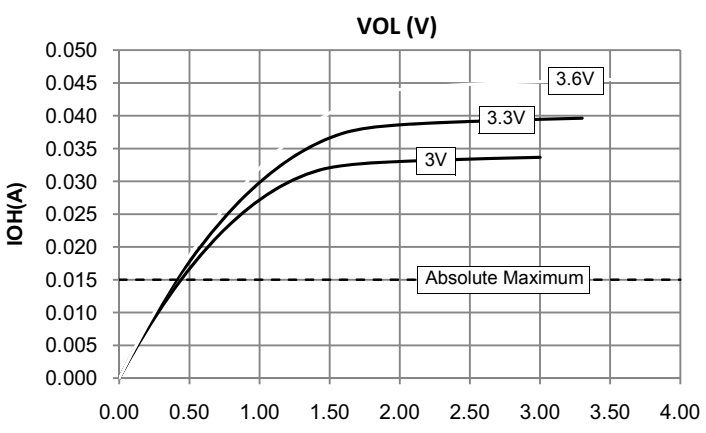
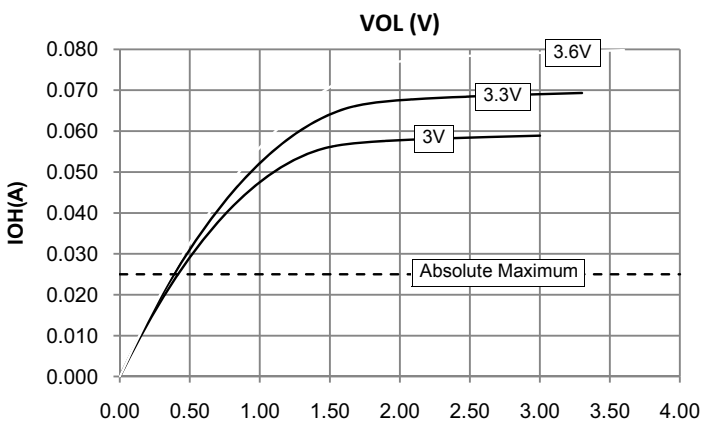
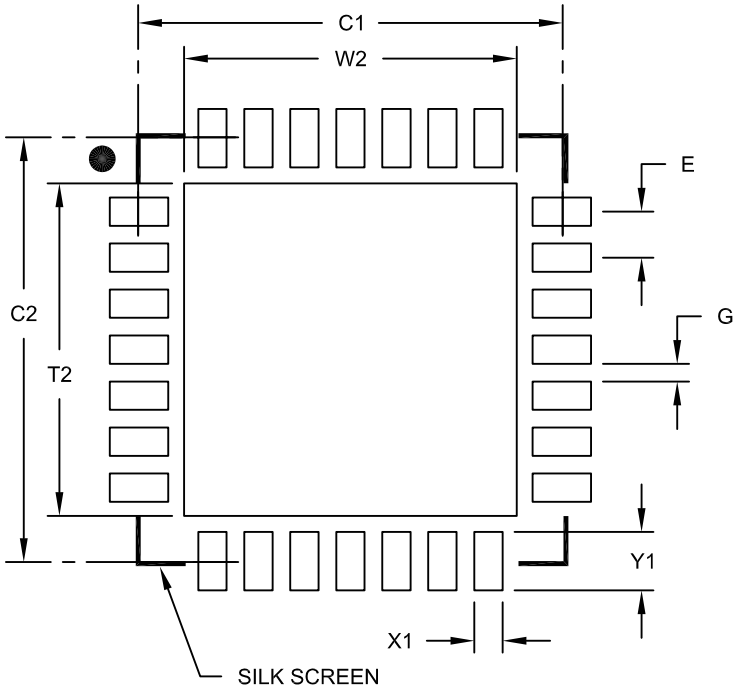



**FIGURE 32-4: VOL – 8x DRIVER PINS**



## 28-Lead Plastic Quad Flat, No Lead Package (MM) – 6x6x0.9 mm Body [QFN-S] 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 | | 0.65 BSC | |
| Optional Center Pad Width | W2 | | | 4.70 |
| Optional Center Pad Length | T2 | | | 4.70 |
| Contact Pad Spacing | C1 | | 6.00 | |
| Contact Pad Spacing | C2 | | 6.00 | |
| Contact Pad Width (X28) | X1 | | | 0.40 |
| Contact Pad Length (X28) | Y1 | | | 0.85 |
| Distance Between Pads | G | 0.25 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2124A

**TABLE A-5: MAJOR SECTION UPDATES (CONTINUED)**

| Section Name | Update Description |
|---|---|
| **Section 30.0 "Electrical Characteristics"** | • Throughout: qualifies all footnotes relating to the operation of analog modules below VDDMIN (replaces "will have" with "may have")<br>• Throughout: changes all references of SPI timing parameter symbol "TscP" to "FscP"<br>• Table 30-1: changes VDD range to 3.0V to 3.6V<br>• Table 30-4: removes Parameter DC12 (RAM Retention Voltage)<br>• Table 30-7: updates Maximum values at 10 and 20 MIPS<br>• Table 30-8: adds Maximum IPD values, and removes all ΔIWDT entries<br>• Adds new Table 30-9 (Watchdog Timer Delta Current) with consolidated values removed from Table 30-8. All subsequent tables are renumbered accordingly.<br>• Table 30-10: adds footnote for all parameters for 1:2 Doze ratio<br>• Table 30-11:<br>- changes Minimum and Maximum values for D120 and D130<br>- adds Minimum and Maximum values for D131<br>- adds Minimum and Maximum values for D150 through D156, and removes Typical values<br>• Table 30-12:<br>- reformats table for readability<br>- changes IOL conditions for DO10<br>• Table 30-14: adds footnote to D135<br>• Table 30-17: changes Minimum and Maximum values for OS30<br>• Table 30-19:<br>- splits temperature range and adds new values for F20a<br>- reduces temperature range for F20b to extended temperatures only<br>• Table 30-20:<br>- splits temperature range and adds new values for F21a<br>- reduces temperature range for F20b to extended temperatures only<br>• Table 30-53:<br>- adds Maximum value to CM30<br>- adds footnote ("Parameter characterized...") to multiple parameters<br>• Table 30-55: adds Minimum and Maximum values for all CTMUI specifications, and removes Typical values<br>• Table 30-57: adds new footnote to AD09<br>• Table 30-58:<br>- removes all specifications for accuracy with external voltage references<br>- removes Typical values for AD23a and AD24a<br>- replaces Minimum and Maximum values for AD21a, AD22a, AD23a and AD24a with new values, split by Industrial and Extended temperatures<br>- removes Maximum value of AD30<br>- removes Minimum values from AD31a and AD32a<br>- adds or changes Typical values for AD30, AD31a, AD32a and AD33a<br>• Table 30-59:<br>- removes all specifications for accuracy with external voltage references<br>- removes Maximum value of AD30<br>- removes Typical values for AD23b and AD24b<br>- replaces Minimum and Maximum values for AD21b, AD22b, AD23b and AD24b with new values, split by Industrial and Extended temperatures<br>- removes Minimum and Maximum values from AD31b, AD32b, AD33b and AD34b<br>- adds or changes Typical values for AD30, AD31a, AD32a and AD33a<br>• Table 30-61: Adds footnote to AD51 |
| **Section 32.0 "DC and AC Device Characteristics Graphs"** | • Updates Figure 32-6 (Typical IDD @ 3.3V) with individual current vs. processor speed curves for the different program memory sizes |
| **Section 33.0 "Packaging Information"** | • Replaces drawing C04-149C (64-pin QFN, 7.15 x 7.15 exposed pad) with C04-154A (64-pin QFN, 5.4 x 5.4 exposed pad) |