# dsPIC33EPXXXGS70X/80X FAMILY

## 16-Bit Digital Signal Controllers for Digital Power Applications with Interconnected High-Speed PWM, ADC, PGA and Comparators

### Operating Conditions

- 3.0V to 3.6V, -40°C to +85°C, DC to 70 MIPS
- 3.0V to 3.6V, -40°C to +125°C, DC to 60 MIPS

### Flash Architecture

- Dual Partition Flash Program Memory with Live Update:
  - Supports programming while operating
  - Supports partition soft swap

### Core: 16-Bit dsPIC33E CPU

- Code-Efficient (C and Assembly) Architecture
- Two 40-Bit Wide Accumulators
- Single-Cycle (MAC/MPY) with Dual Data Fetch
- Single-Cycle Mixed-Sign MUL plus Hardware Divide
- 32-Bit Multiply Support
- Four Additional Working Register Sets (reduces context switching)

### Clock Management

- ±0.9% Internal Oscillator
- Programmable PLLs and Oscillator Clock Sources
- Fail-Safe Clock Monitor (FSCM)
- Independent Watchdog Timer (WDT)
- Fast Wake-up and Start-up

### Power Management

- Low-Power Management modes (Sleep, Idle, Doze)
- Integrated Power-on Reset and Brown-out Reset
- 0.5 mA/MHz Dynamic Current (typical)
- 20 µA $I_{PD}$ Current (typical)

### High-Speed PWM

- Eight PWM Generators (two outputs per generator)
- Individual Time Base and Duty Cycle for each PWM
- 1.04 ns PWM Resolution (frequency, duty cycle, dead time and phase)
- Supports Center-Aligned, Redundant, Complementary and True Independent Output modes
- Independent Fault and Current-Limit Inputs
- Output Override Control
- PWM Support for AC/DC, DC/DC, Inverters, PFC and Lighting

### Advanced Analog Features

- High-Speed ADC module:
  - 12-bit with 4 dedicated SAR ADC cores and one shared SAR ADC core
  - Configurable resolution (up to 12-bit) for each ADC core
  - Up to 3.25 Msps conversion rate per channel at 12-bit resolution
  - 11 to 22 single-ended inputs
  - Dedicated result buffer for each analog channel
  - Flexible and independent ADC trigger sources
  - Two digital comparators
  - Two oversampling filters for increased resolution
- Four Rail-to-Rail Comparators with Hysteresis:
  - Dedicated 12-bit Digital-to-Analog Converter (DAC) for each analog comparator
  - Up to two DAC reference outputs
  - Up to two external reference inputs
- Two Programmable Gain Amplifiers:
  - Single-ended or independent ground reference
  - Five selectable gains (4x, 8x, 16x, 32x and 64x)
  - 40 MHz gain bandwidth

### Interconnected SMPS Peripherals

- Reduces CPU Interaction to Improve Performance
- Flexible PWM Trigger Options for ADC Conversions
- High-Speed Comparator Truncates PWM (15 ns typical):
  - Supports Cycle-by-Cycle Current mode control
  - Current Reset mode (variable frequency)

### Timers/Output Compare/Input Capture

- Five 16-Bit and up to Two 32-Bit Timers/Counters
- Four Output Compare (OC) modules, Configurable as Timers/Counters
- Four Input Capture (IC) modules

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## Communication Interfaces

- Two UART modules (15 Mbps):
  - Supports LIN/J2602 protocols and IrDA®
- Three Variable Width SPI modules with Operating modes:
  - 3-wire SPI
  - 8x16 or 8x8 FIFO mode
  - $I^2S$ mode
- Two $I^2C$ modules (up to 1 Mbaud) with SMBus Support
- Up to Two CAN modules
- Four-Channel DMA

## Input/Output

- Constant-Current Source (10 µA nominal)
- Sink/Source up to 12 mA/15 mA, respectively; Pin-Specific for Standard VOH/VOL
- 5V Tolerant Pins
- Selectable, Open-Drain Pull-ups and Pull-Downs
- External Interrupts on all I/O Pins
- Peripheral Pin Select (PPS) to allow Function Remap with Six Virtual I/Os

## Qualification and Class B Support

- AEC-Q100 REVG (Grade 1, -40°C to +125°C)
- Class B Safety Library, IEC 60730
- The 6x6x0.55 mm UQFN Package is Designed and Optimized to ease IPC9592B 2nd Level Temperature Cycle Qualification

## Debugger Development Support

- In-Circuit and In-Application Programming
- Five Program and Three Complex Data Breakpoints
- IEEE 1149.2 Compatible (JTAG) Boundary Scan
- Trace and Run-Time Watch

## Digital Peripherals

- Four Configurable Logic Cells
- Peripheral Trigger Generator

| Device | Pins | Program Memory Bytes | RAM (Bytes) | General Purpose I/O (GPIO) | Remappable Peripherals | | | | | | | | | $I^2C$ | CLC | PTG | 12-Bit ADC | | PGA | DMA | Analog Comparator | DAC Output | Constant-Current Source | Packages |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Timers(1) | Input Capture | Output Compare | UART | SPI | PWM(2) | External Interrupts(3) | CAN | Reference Clock | | | | Analog Inputs | S&H Circuits | | | | | | |
| dsPIC33EP128GS702 | 28 | 128K | 8K | 20 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 0 | 1 | 2 | 4 | 1 | 11 | 5 | 2 | 0 | 4 | 1 | 1 | SOIC, QFN-S, UQFN |
| dsPIC33EP64GS804 | 44 | 64K | 8K | 33 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 17 | 5 | 2 | 4 | 4 | 1 | 1 | QFN, TQFP |
| dsPIC33EP128GS704 | 44 | 128K | 8K | 33 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 0 | 1 | 2 | 4 | 1 | 17 | 5 | 2 | 0 | 4 | 1 | 1 | |
| dsPIC33EP128GS804 | 44 | 128K | 8K | 33 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 17 | 5 | 2 | 4 | 4 | 1 | 1 | |
| dsPIC33EP64GS805 | 48 | 64K | 8K | 33 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 17 | 5 | 2 | 4 | 4 | 1 | 1 | TQFP |
| dsPIC33EP128GS705 | 48 | 128K | 8K | 33 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 0 | 1 | 2 | 4 | 1 | 17 | 5 | 2 | 0 | 4 | 1 | 1 | |
| dsPIC33EP128GS805 | 48 | 128K | 8K | 33 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 17 | 5 | 2 | 4 | 4 | 1 | 1 | |
| dsPIC33EP64GS806 | 64 | 64K | 8K | 51 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 4 | 4 | 2 | 1 | TQFP |
| dsPIC33EP128GS706 | 64 | 128K | 8K | 51 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 0 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 0 | 4 | 2 | 1 | |
| dsPIC33EP128GS806 | 64 | 128K | 8K | 51 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 4 | 4 | 2 | 1 | |
| dsPIC33EP64GS708 | 80 | 64K | 8K | 67 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 0 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 0 | 4 | 2 | 1 | TQFP |
| dsPIC33EP64GS808 | 80 | 64K | 8K | 67 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 4 | 4 | 2 | 1 | |
| dsPIC33EP128GS708 | 80 | 128K | 8K | 67 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 0 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 0 | 4 | 2 | 1 | |
| dsPIC33EP128GS808 | 80 | 128K | 8K | 67 | 5 | 4 | 4 | 2 | 3 | 8x2 | 4 | 2 | 1 | 2 | 4 | 1 | 22 | 5 | 2 | 4 | 4 | 2 | 1 | |

**Note 1:** The external clock for Timer1, Timer2 and Timer3 is remappable.

**2:** PWM4 through PWM8 are remappable on 28/44/48-pin devices; on 64-pin devices, only PWM7/PWM8 are remappable.

**3:** External interrupts, INT0 and INT4, are not remappable.


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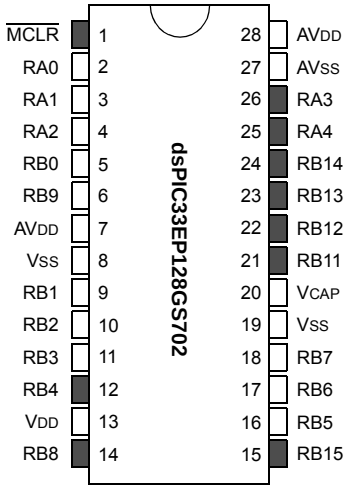
## Pin Diagrams

### 28-Pin SOIC

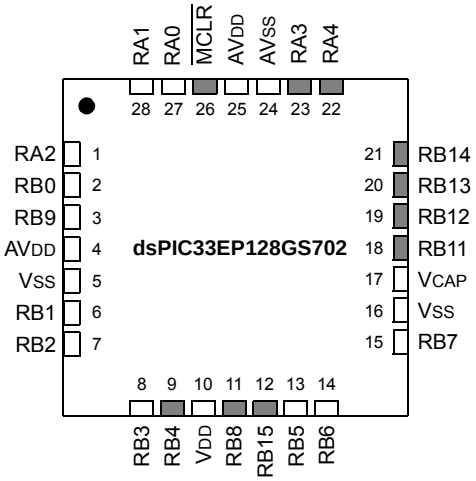



| Pin | Pin Function | Pin | Pin Function |
|---|---|---|---|
| 1 | MCLR | 15 | PGEC3/SCL2/**RP47**/RB15 |
| 2 | AN0/CMP1A/PGA1P1/**RP16**/RA0 | 16 | TDO/AN19/PGA2N2/**RP37**/RB5 |
| 3 | AN1/CMP1B/PGA1P2/PGA2P1/**RP17**/RA1 | 17 | PGED1/TDI/AN20/SCL1/**RP38**/RB6 |
| 4 | AN2/CMP1C/CMP2A/PGA1P3/PGA2P2/**RP18**/RA2 | 18 | PGEC1/AN21/SDA1/**RP39**/RB7 |
| 5 | AN3/CMP1D/CMP2B/PGA2P3/**RP32**/RB0 | 19 | VSS |
| 6 | AN4/CMP2C/CMP3A/ISRC4/**RP41**/RB9 | 20 | VCAP |
| 7 | AVDD | 21 | TMS/PWM3H/**RP43**/RB11 |
| 8 | VSS | 22 | TCK/PWM3L/**RP44**/RB12 |
| 9 | OSCI/CLKI/AN6/CMP3C/CMP4A/ISRC2/**RP33**/RB1 | 23 | PWM2H/**RP45**/RB13 |
| 10 | OSC2/CLKO/AN7/CMP3D/CMP4B/PGA1N2/**RP34**/RB2 | 24 | PWM2L/**RP46**/RB14 |
| 11 | PGED2/DACOUT1/AN18/INT0/**RP35**/RB3 | 25 | PWM1H/**RP20**/RA4 |
| 12 | PGEC2/ADTRG31/EXTREF1/**RP36**/RB4 | 26 | PWM1L/**RP19**/RA3 |
| 13 | VDD | 27 | AVSS |
| 14 | PGED3/SDA2/FLT31/**RP40**/RB8 | 28 | AVDD |

**Legend:** **Shaded pins** are up to 5 VDC tolerant.
**RPn** represents remappable peripheral functions. See Table 11-12 and Table 11-13 for the complete list of remappable sources.

## Pin Diagrams (Continued)

**28-Pin QFN-S, UQFN**




| Pin | Pin Function | Pin | Pin Function |
|---|---|---|---|
| 1 | AN2/CMP1C/CMP2A/PGA1P3/PGA2P2/**RP18**/RA2 | 15 | PGEC1/AN21/SDA1/**RP39**/RB7 |
| 2 | AN3/CMP1D/CMP2B/PGA2P3/**RP32**/RB0 | 16 | VSS |
| 3 | AN4/CMP2C/CMP3A/ISRC4/**RP41**/RB9 | 17 | VCAP |
| 4 | AVDD | 18 | TMS/PWM3H/**RP46**/RB11 |
| 5 | VSS | 19 | TCK/PWM3L/**RP44**/RB12 |
| 6 | OSCI/CLKI/AN6/CMP3C/CMP4A/ISRC2/**RP33**/RB1 | 20 | PWM2H/**RP45**/RB13 |
| 7 | OSC2/CLKO/AN7/CMP3D/CMP4B/PGA1N2/**RP34**/RB2 | 21 | PWM2L/**RP46**/RB14 |
| 8 | PGED2/DACOUT1/AN18/INT0/**RP35**/RB3 | 22 | PWM1H/**RP20**/RA4 |
| 9 | PGEC2/ADTRG31/EXTREF1/**RP36**/RB4 | 23 | PWM1L/**RP19**/RA3 |
| 10 | VDD | 24 | AVSS |
| 11 | PGED3/SDA2/FLT31/**RP40**/RB8 | 25 | AVDD |
| 12 | PGEC3/SCL2/**RP47**/RB15 | 26 | MCLR |
| 13 | TDO/AN19/PGA2N2/**RP37**/RB5 | 27 | AN0/CMP1A/PGA1P1/**RP16**/RA0 |
| 14 | PGED1/TDI/AN20/SCL1/**RP38**/RB6 | 28 | AN1/CMP1B/PGA1P2/PGA2P1/**RP17**/RA1 |

**Legend:** **Shaded pins** are up to 5 VDC tolerant.
**RPn** represents remappable peripheral functions. See Table 11-12 and Table 11-13 for the complete list of remappable sources.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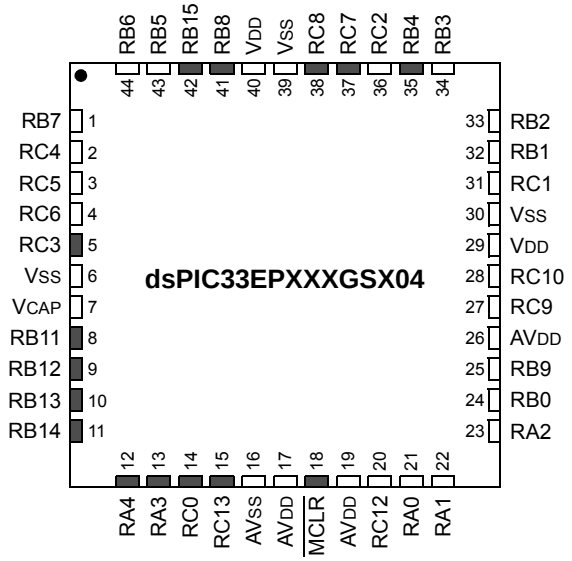
## Pin Diagrams (Continued)

**44-Pin QFN, TQFP**

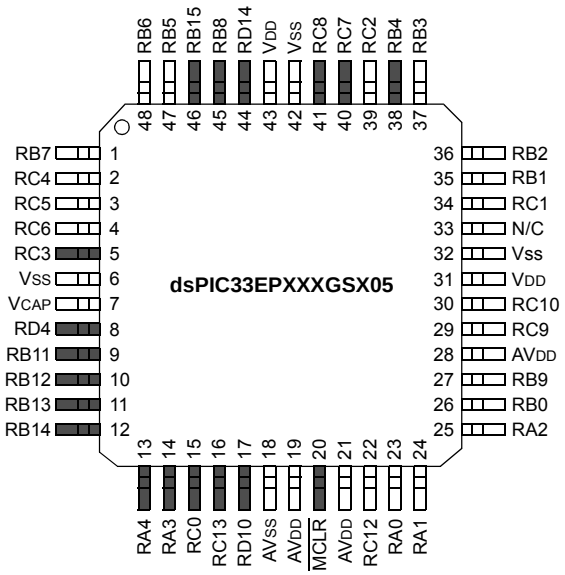



| Pin | Pin Function | Pin | Pin Function |
|---|---|---|---|
| 1 | PGEC1/AN21/SDA1/**RP39**/RB7 | 23 | AN2/CMP1C/CMP2A/PGA1P3/PGA2P2/**RP18**/RA2 |
| 2 | AN1ALT/**RP52**/RC4 | 24 | AN3/CMP1D/CMP2B/PGA2P3/**RP32**/RB0 |
| 3 | AN0ALT/**RP53**/RC5 | 25 | AN4/CMP2C/CMP3A/ISRC4/**RP41**/RB9 |
| 4 | AN17/**RP54**/RC6 | 26 | AVDD |
| 5 | **RP51**/RC3 | 27 | AN11/PGA1N3/**RP57**/RC9 |
| 6 | VSS | 28 | EXTREF2/AN10/PGA1P4/**RP58**/RC10 |
| 7 | VCAP | 29 | VDD |
| 8 | TMS/PWM3H/**RP43**/RB11 | 30 | VSS |
| 9 | TCK/PWM3L/**RP44**/RB12 | 31 | AN8/CMP4C/PGA2P4/**RP49**/RC1 |
| 10 | PWM2H/**RP45**/RB13 | 32 | OSCI/CLKI/AN6/CMP3C/CMP4A/ISRC2/**RP33**/RB1 |
| 11 | PWM2L/**RP46**/RB14 | 33 | OSC2/CLKO/AN7/CMP3D/CMP4B/PGA1N2/**RP34**/RB2 |
| 12 | PWM1H/**RP20**/RA4 | 34 | PGED2/DACOUT1/AN18/INT0/**RP35**/RB3 |
| 13 | PWM1L/**RP19**/RA3 | 35 | PGEC2/ADTRG31/**RP36**/RB4 |
| 14 | FLT12/**RP48**/RC0 | 36 | EXTREF1/AN9/CMP4D/**RP50**/RC2 |
| 15 | FLT11/**RP61**/RC13 | 37 | ASDA1/**RP55**/RC7 |
| 16 | AVSS | 38 | ASCL1/**RP56**/RC8 |
| 17 | AVDD | 39 | VSS |
| 18 | $\overline{\text{MCLR}}$ | 40 | VDD |
| 19 | AVDD | 41 | PGED3/SDA2/FLT31/**RP40**/RB8 |
| 20 | AN14/PGA2N3/**RP60**/RC12 | 42 | PGEC3/SCL2/**RP47**/RB15 |
| 21 | AN0/CMP1A/PGA1P1/**RP16**/RA0 | 43 | TDO/AN19/PGA2N2/**RP37**/RB5 |
| 22 | AN1/CMP1B/PGA1P2/PGA2P1/**RP17**/RA1 | 44 | PGED1/TDI/AN20/SCL1/**RP38**/RB6 |

**Legend:** **Shaded pins** are up to 5 VDC tolerant.
**RPn** represents remappable peripheral functions. See Table 11-12 and Table 11-13 for the complete list of remappable sources.

## Pin Diagrams (Continued)

**48-Pin TQFP**




| Pin | Pin Function | Pin | Pin Function |
|---|---|---|---|
| 1 | PGEC1/AN21/SDA1/**RP39**/RB7 | 25 | AN2/CMP1C/CMP2A/PGA1P3/PGA2P2/**RP18**/RA2 |
| 2 | AN1ALT/**RP52**/RC4 | 26 | AN3/CMP1D/CMP2B/PGA2P3/**RP32**/RB0 |
| 3 | AN0ALT/**RP53**/RC5 | 27 | AN4/CMP2C/CMP3A/ISRC4/**RP41**/RB9 |
| 4 | AN17/**RP54**/RC6 | 28 | AVDD |
| 5 | **RP51**/RC3 | 29 | AN11/PGA1N3/**RP57**/RC9 |
| 6 | VSS | 30 | EXTREF2/AN10/PGA1P4/**RP58**/RC10 |
| 7 | VCAP | 31 | VDD |
| 8 | **RP68**/RD4 | 32 | VSS |
| 9 | TMS/PWM3H/**RP43**/RB11 | 33 | N/C |
| 10 | TCK/PWM3L/**RP44**/RB12 | 34 | AN8/CMP4C/PGA2P4/**RP49**/RC1 |
| 11 | PWM2H/**RP45**/RB13 | 35 | OSCI/CLKI/AN6/CMP3C/CMP4A/ISRC2/**RP33**/RB1 |
| 12 | PWM2L/**RP46**/RB14 | 36 | OSC2/CLKO/AN7/CMP3D/CMP4B/PGA1N2/**RP34**/RB2 |
| 13 | PWM1H/**RP20**/RA4 | 37 | PGED2/DACOUT1/AN18/INT0/**RP35**/RB3 |
| 14 | PWM1L/**RP19**/RA3 | 38 | PGEC2/ADTRG31/**RP36**/RB4 |
| 15 | FLT12/**RP48**/RC0 | 39 | EXTREF1/AN9/CMP4D/**RP50**/RC2 |
| 16 | FLT11/**RP61**/RC13 | 40 | ASDA1/**RP55**/RC7 |
| 17 | CLC4OUT/FLT10/**RP74**/RD10 | 41 | ASCL1/**RP56**/RC8 |
| 18 | AVSS | 42 | VSS |
| 19 | AVDD | 43 | VDD |
| 20 | $\overline{\text{MCLR}}$ | 44 | CLC3OUT/RD14 |
| 21 | AVDD | 45 | PGED3/SDA2/FLT31/**RP40**/RB8 |
| 22 | AN14/PGA2N3/**RP60**/RC12 | 46 | PGEC3/SCL2/**RP47**/RB15 |
| 23 | AN0/CMP1A/PGA1P1/**RP16**/RA0 | 47 | TDO/AN19/PGA2N2/**RP37**/RB5 |
| 24 | AN1/CMP1B/PGA1P2/PGA2P1/**RP17**/RA1 | 48 | PGED1/TDI/AN20/SCL1/**RP38**/RB6 |

**Legend:** **Shaded pins** are up to 5 VDC tolerant.
**RPn** represents remappable peripheral functions. See Table 11-12 and Table 11-13 for the complete list of remappable sources.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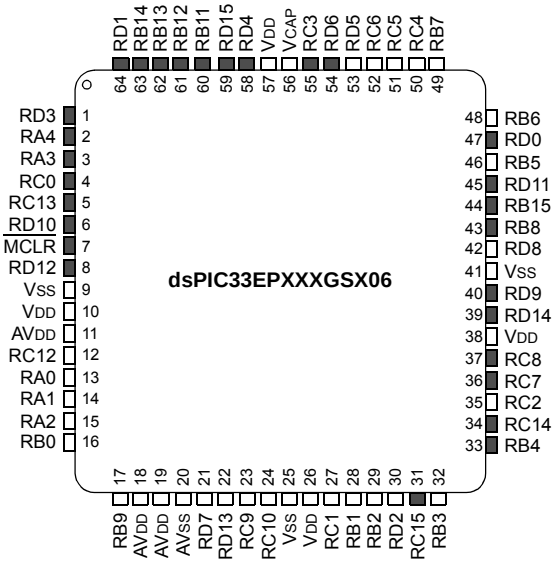
## Pin Diagrams (Continued)

**64-Pin TQFP**

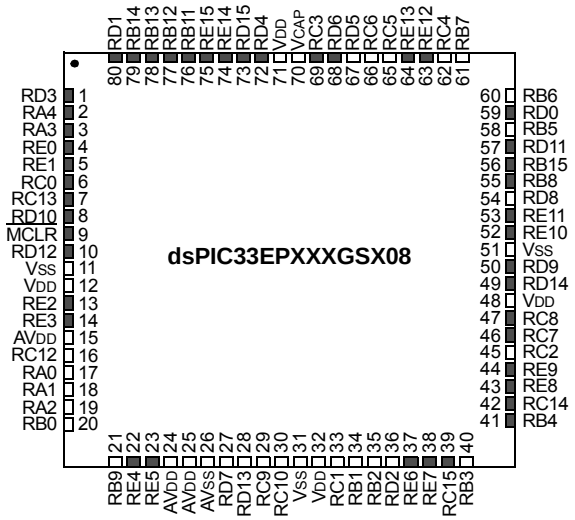



| Pin | Pin Function | Pin | Pin Function |
|---|---|---|---|
| 1 | PWM4L/**RP67**/RD3 | 33 | PGEC2/ADTRG31/**RP36**/RB4 |
| 2 | PWM1H/**RP20**/RA4 | 34 | **RP62**/RC14 |
| 3 | PWM1L/**RP19**/RA3 | 35 | EXTREF1/AN9/CMP4D/**RP50**/RC2 |
| 4 | FLT12/**RP48**/RC0 | 36 | ASDA1/**RP55**/RC7 |
| 5 | FLT11/**RP61**/RC13 | 37 | ASCL1/**RP56**/RC8 |
| 6 | CLC4OUT/FLT10/**RP74**/RD10 | 38 | VDD |
| 7 | MCLR | 39 | CLC3OUT/RD14 |
| 8 | T5CK/FLT9/**RP76**/RD12 | 40 | SCK3/**RP73**/RD9 |
| 9 | VSS | 41 | VSS |
| 10 | VDD | 42 | AN5/CMP2D/CMP3B/ISRC3/**RP72**RD8 |
| 11 | AVDD | 43 | PGED3/SDA2/FLT31/**RP40**/RB8 |
| 12 | AN14/PGA2N3/**RP60**/RC12 | 44 | PGEC3/SCL2/**RP47**/RB15 |
| 13 | AN0/CMP1A/PGA1P1/**RP16**/RA0 | 45 | INT4/**RP75**/RD11 |
| 14 | AN1/CMP1B/PGA1P2/PGA2P1/**RP17**/RA1 | 46 | TDO/AN19/PGA2N2/**RP37**/RB5 |
| 15 | AN2/CMP1C/CMP2A/PGA1P3/PGA2P2/**RP18**/RA2 | 47 | T4CK/**RP64**/RD0 |
| 16 | AN3/CMP1D/CMP2B/PGA2P3/**RP32**/RB0 | 48 | PGED1/TDI/AN20/SCL1/**RP38**/RB6 |
| 17 | AN4/CMP2C/CMP3A/ISRC4/**RP41**/RB9 | 49 | PGEC1/AN21/SDA1/**RP39**/RB7 |
| 18 | AVDD | 50 | AN1ALT/**RP52**/RC4 |
| 19 | AVDD | 51 | AN0ALT/**RP53**/RC5 |
| 20 | AVSS | 52 | AN17/**RP54**/RC6 |
| 21 | AN15/**RP71**/RD7 | 53 | AN12/ISRC1/**RP69**/RD5 |
| 22 | DACOUT2/AN13/RD13 | 54 | PWM5H/**RP70**/RD6 |
| 23 | AN11/PGA1N3/**RP57**/RC9 | 55 | PWM5L/**RP51**/RC3 |
| 24 | EXTREF2/AN10/PGA1P4/**RP58**/RC10 | 56 | VCAP |
| 25 | VSS | 57 | VDD |
| 26 | VDD | 58 | PWM6H/**RP68**/RD4 |
| 27 | AN8/CMP4C/PGA2P4/**RP49**/RC1 | 59 | PWM6L/RD15 |
| 28 | OSCI/CLKI/AN6/CMP3C/CMP4A/ISRC2/**RP33**/RB1 | 60 | TMS/PWM3H/**RP43**/RB11 |
| 29 | OSC2/CLKO/AN7/CMP3D/CMP4B/PGA1N2/**RP34**/RB2 | 61 | TCK/PWM3L/**RP44**/RB12 |
| 30 | AN16/**RP66**/RD2 | 62 | PWM2H/**RP45**/RB13 |
| 31 | ASDA2/**RP63**/RC15 | 63 | PWM2L/**RP46**/RB14 |
| 32 | PGED2/DACOUT1/AN18/ASCL2/INT0/**RP35**/RB3 | 64 | PWM4H/**RP65**/RD1 |

**Legend:** **Shaded pins** are up to 5 VDC tolerant.
**RPn** represents remappable peripheral functions. See Table 11-12 and Table 11-13 for the complete list of remappable sources.

## Pin Diagrams (Continued)

**80-Pin TQFP**




| Pin | Pin Function | Pin | Pin Function |
|---|---|---|---|
| 1 | PWM4L/**RP67**/RD3 | 41 | PGEC2/ADTRG31/**RP36**/RB4 |
| 2 | PWM1H/**RP20**/RA4 | 42 | **RP62**/RC14 |
| 3 | PWM1L/**RP19**/RA3 | 43 | RE8 |
| 4 | PWM8L/RE0 | 44 | RE9 |
| 5 | PWM8H/RE1 | 45 | EXTREF1/AN9/CMP4D/**RP50**/RC2 |
| 6 | FLT12/**RP48**/RC0 | 46 | ASDA1/**RP55**/RC7 |
| 7 | FLT11/**RP61**/RC13 | 47 | ASCL1/**RP56**/RC8 |
| 8 | CLC4OUT/FLT10/**RP74**/RD10 | 48 | VDD |
| 9 | MCLR | 49 | CLC3OUT/RD14 |
| 10 | T5CK/FLT9/**RP76**/RD12 | 50 | SCK3/**RP73**/RD9 |
| 11 | VSS | 51 | VSS |
| 12 | VDD | 52 | FLT21/RE10 |
| 13 | FLT17/RE2 | 53 | FLT22/RE11 |
| 14 | FLT18/RE3 | 54 | AN5/CMP2D/CMP3B/ISRC3/**RP72**/RD8 |
| 15 | AVDD | 55 | PGED3/SDA2/FLT31/**RP40**/RB8 |
| 16 | AN14/PGA2N3/**RP60**/RC12 | 56 | PGEC3/SCL2/**RP47**/RB15 |
| 17 | AN0/CMP1A/PGA1P1/**RP16**/RA0 | 57 | INT4/**RP75**/RD11 |
| 18 | AN1/CMP1B/PGA1P2/PGA2P1/**RP17**/RA1 | 58 | TD0/AN19/PGA2N2/**RP37**/RB5 |
| 19 | AN2/CMP1C/CMP2A/PGA1P3/PGA2P2/**RP18**/RA2 | 59 | T4CK/**RP64**/RD0 |
| 20 | AN3/CMP1D/CMP2B/PGA2P3/**RP32**/RB0 | 60 | PGED1/TDI/AN20/SCL1/**RP38**/RB6 |
| 21 | AN4/CMP2C/CMP3A/ISRC4/**RP41**/RB9 | 61 | PGEC1/AN21/SDA1/**RP39**/RB7 |
| 22 | RE4 | 62 | AN1ALT/**RP52**/RC4 |
| 23 | RE5 | 63 | RE12 |
| 24 | AVDD | 64 | RE13 |
| 25 | AVDD | 65 | AN0ALT/**RP53**/RC5 |
| 26 | AVSS | 66 | AN17/**RP54**/RC6 |
| 27 | AN15/**RP71**/RD7 | 67 | AN12/ISRC1/**RP69**/RD5 |
| 28 | DACOUT2/AN13/RD13 | 68 | PWM5H/**RP70**/RD6 |
| 29 | AN11/PGA1N3/**RP57**/RC9 | 69 | PWM5L/**RP51**/RC3 |
| 30 | EXTREF2/AN10/PGA1P4/**RP58**/RC10 | 70 | VCAP |
| 31 | VSS | 71 | VDD |
| 32 | VDD | 72 | PWM6H/**RP68**/RD4 |
| 33 | AN8/CMP4C/PGA2P4/**RP49**/RC1 | 73 | PWM6L/RD15 |
| 34 | OSCI/CLKI/AN6/CMP3C/CMP4A/ISRC2/**RP33**/RB1 | 74 | PWM7L/RE14 |
| 35 | OSC2/CLKO/AN7/CMP3D/CMP4B/PGA1N2/**RP34**/RB2 | 75 | PWM7H/RE15 |
| 36 | AN16/**RP66**/RD2 | 76 | TMS/PWM3H/**RP43**/RB11 |
| 37 | FLT19/RE6 | 77 | TCK/PWM3L/**RP44**/RB12 |
| 38 | FLT20/RE7 | 78 | PWM2H/**RP45**/RB13 |
| 39 | ASDA2/**RP63**/RC15 | 79 | PWM2L/**RP46**/RB14 |
| 40 | PGED2/DACOUT1/AN18/ASCL2/INT0/**RP35**/RB3 | 80 | PWM4H/**RP65**/RD1 |

**Legend:** **Shaded pins** are up to 5 VDC tolerant.
**RPn** represents remappable peripheral functions. See Table 11-12 and Table 11-13 for the complete list of remappable sources.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## Table of Contents

1.0 Device Overview ..... 11
2.0 Guidelines for Getting Started with 16-Bit Digital Signal Controllers ..... 15
3.0 CPU ..... 21
4.0 Memory Organization ..... 31
5.0 Flash Program Memory ..... 61
6.0 Resets ..... 69
7.0 Interrupt Controller ..... 73
8.0 Direct Memory Access (DMA) ..... 89
9.0 Oscillator Configuration ..... 103
10.0 Power-Saving Features ..... 115
11.0 I/O Ports ..... 125
12.0 Timer1 ..... 169
13.0 Timer2/3 and Timer4/5 ..... 173
14.0 Input Capture ..... 177
15.0 Output Compare ..... 181
16.0 High-Speed PWM ..... 187
17.0 Peripheral Trigger Generator (PTG) Module ..... 213
18.0 Serial Peripheral Interface (SPI) ..... 229
19.0 Inter-Integrated Circuit ($I^2C$) ..... 245
20.0 Universal Asynchronous Receiver Transmitter (UART) ..... 253
21.0 Configurable Logic Cell (CLC) ..... 259
22.0 High-Speed, 12-Bit Analog-to-Digital Converter (ADC) ..... 273
23.0 Controller Area Network (CAN) Module (dsPIC33EPXXXGS80X Devices Only) ..... 307
24.0 High-Speed Analog Comparator ..... 333
25.0 Programmable Gain Amplifier (PGA) ..... 341
26.0 Constant-Current Source ..... 345
27.0 Special Features ..... 347
28.0 Instruction Set Summary ..... 361
29.0 Development Support ..... 371
30.0 Electrical Characteristics ..... 375
31.0 DC and AC Device Characteristics Graphs ..... 435
32.0 Packaging Information ..... 439
Appendix A: Revision History ..... 465
Index ..... 467
The Microchip Web Site ..... 475
Customer Change Notification Service ..... 475
Customer Support ..... 475
Product Identification System ..... 477

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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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## 1.0 DEVICE OVERVIEW

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive resource. To complement the information in this data sheet, refer to the related section of the *"dsPIC33/PIC24 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.

This document contains device-specific information for the dsPIC33EPXXXGS70X/80X Digital Signal Controller (DSC) devices.

dsPIC33EPXXXGS70X/80X devices contain extensive Digital Signal Processor (DSP) functionality with a high-performance, 16-bit MCU architecture.

Figure 1-1 shows a general block diagram of the core and peripheral modules. Table 1-1 lists the functions of the various pins shown in the pinout diagrams.

**FIGURE 1-1: dsPIC33EPXXXGS70X/80X FAMILY BLOCK DIAGRAM**

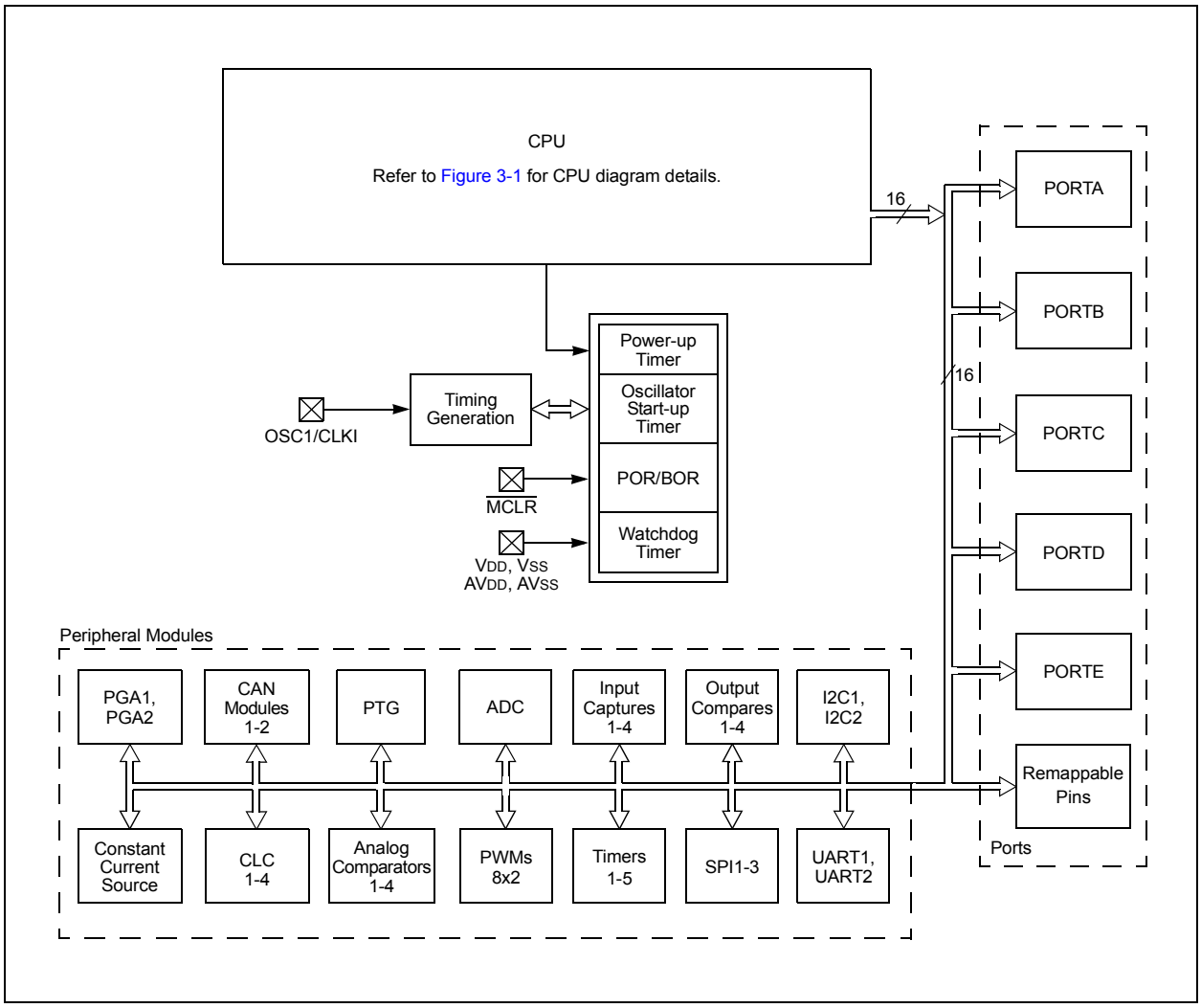

**TABLE 1-1: PINOUT I/O DESCRIPTIONS**

| Pin Name[1] | Pin Type | Buffer Type | PPS | Description |
|---|---|---|---|---|
| AN0-AN21 | I | Analog | No | Analog input channels. |
| AN0ALT-AN1ALT | I | Analog | No | Alternate analog input channels. |
| C1RXR | I | ST | Yes | CAN1 receive. |
| C2RXR | I | ST | Yes | CAN2 receive. |
| C1TX | O | ST | Yes | CAN1 transmit. |
| C2TX | O | ST | Yes | CAN2 transmit. |
| CLKI | I | ST/ CMOS | No | External clock source input. Always associated with OSC1 pin function. |
| CLKO | O | — | No | Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. Optionally functions as CLKO in RC and EC modes. Always associated with OSC2 pin function. |
| OSC1 | I | ST/ CMOS | No | Oscillator crystal input. ST buffer when configured in RC mode; CMOS otherwise. |
| OSC2 | I/O | — | No | Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. Optionally functions as CLKO in RC and EC modes. |
| CLC1OUT | O | DIG | Yes | CLC1 output. |
| CLC2OUT | O | DIG | Yes | CLC2 output. |
| CLC3OUT | O | DIG | No[4] | CLC3 output. |
| CLC4OUT | O | DIG | No[4] | CLC4 output. |
| REFCLKO | O | — | Yes | Reference clock output. |
| IC1-IC4 | I | ST | Yes | Capture Inputs 1 through 4. |
| OCFA | I | ST | Yes | Compare Fault A input (for compare channels). |
| OC1-OC4 | O | — | Yes | Compare Outputs 1 through 4. |
| INT0 | I | ST | No | External Interrupt 0. |
| INT1 | I | ST | Yes | External Interrupt 1. |
| INT2 | I | ST | Yes | External Interrupt 2. |
| INT4 | I | ST | Yes | External Interrupt 4. |
| RA0-RA4 | I/O | ST | No | PORTA is a bidirectional I/O port. |
| RB0-RB15 | I/O | ST | No | PORTB is a bidirectional I/O port. |
| RC0-RC15 | I/O | ST | No | PORTC is a bidirectional I/O port. |
| RD0-RD15 | I/O | ST | No | PORTD is a bidirectional I/O port. |
| RE0-RE15 | I/O | ST | No | PORTE is a bidirectional I/O port. |
| T1CK | I | ST | Yes | Timer1 external clock input. |
| T2CK | I | ST | Yes | Timer2 external clock input. |
| T3CK | I | ST | Yes | Timer3 external clock input. |
| T4CK | I | ST | No | Timer4 external clock input. |
| T5CK | I | ST | No | Timer5 external clock input. |
| $\overline{\text{U1CTS}}$ | I | ST | Yes | UART1 Clear-to-Send. |
| $\overline{\text{U1RTS}}$ | O | — | Yes | UART1 Ready-to-Send. |
| U1RX | I | ST | Yes | UART1 receive. |
| U1TX | O | — | Yes | UART1 transmit. |
| BCLK1 | O | ST | Yes | UART1 IrDA® baud clock output. |

**Legend:** CMOS = CMOS compatible input or output; Analog = Analog input; P = Power; ST = Schmitt Trigger input with CMOS levels; O = Output; I = Input; PPS = Peripheral Pin Select; TTL = TTL input buffer

**1:** Not all pins are available in all package variants. See the **"Pin Diagrams"** section for pin availability.

**2:** PWM4H/L through PWM8H/L are fixed on dsPIC33EPXXXGS708/808 devices. PWM4H/L through PWM6H/L are fixed on dsPIC33EPXXXGS706/806 devices.

**3:** The SCK3 pin is fixed on dsPIC33EPXXXGS706/806 and dsPIC33EPXXXGS708/808 devices.

**4:** PPS is available on dsPIC33EPXXXGS702 devices only.


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**TABLE 1-1: PINOUT I/O DESCRIPTIONS (CONTINUED)**

| Pin Name(1) | Pin Type | Buffer Type | PPS | Description |
|---|---|---|---|---|
| U2CTS | I | ST | Yes | UART2 Clear-to-Send. |
| U2RTS | O | — | Yes | UART2 Ready-to-Send. |
| U2RX | I | ST | Yes | UART2 receive. |
| U2TX | O | — | Yes | UART2 transmit. |
| BCLK2 | O | ST | Yes | UART2 IrDA baud clock output. |
| SCK1 | I/O | ST | Yes | Synchronous serial clock input/output for SPI1. |
| SDI1 | I | ST | Yes | SPI1 data in. |
| SDO1 | O | — | Yes | SPI1 data out. |
| SS1 | I/O | ST | Yes | SPI1 slave synchronization or frame pulse I/O. |
| SCK2 | I/O | ST | Yes | Synchronous serial clock input/output for SPI2. |
| SDI2 | I | ST | Yes | SPI2 data in. |
| SDO2 | O | — | Yes | SPI2 data out. |
| SS2 | I/O | ST | Yes | SPI2 slave synchronization or frame pulse I/O. |
| SCK3 | I/O | ST | Yes(3) | Synchronous serial clock input/output for SPI3. |
| SDI3 | I | ST | Yes | SPI3 data in. |
| SDO3 | O | — | Yes | SPI3 data out. |
| SS3 | I/O | ST | Yes | SPI3 slave synchronization or frame pulse I/O. |
| SCL1 | I/O | ST | No | Synchronous serial clock input/output for I2C1. |
| SDA1 | I/O | ST | No | Synchronous serial data input/output for I2C1. |
| ASCL1 | I/O | ST | No | Alternate synchronous serial clock input/output for I2C1. |
| ASDA1 | I/O | ST | No | Alternate synchronous serial data input/output for I2C1. |
| SCL2 | I/O | ST | No | Synchronous serial clock input/output for I2C2. |
| SDA2 | I/O | ST | No | Synchronous serial data input/output for I2C2. |
| ASCL2 | I/O | ST | No | Alternate synchronous serial clock input/output for I2C2. |
| ASDA2 | I/O | ST | No | Alternate synchronous serial data input/output for I2C2. |
| TMS | I | ST | No | JTAG Test mode select pin. |
| TCK | I | ST | No | JTAG test clock input pin. |
| TDI | I | ST | No | JTAG test data input pin. |
| TDO | O | — | No | JTAG test data output pin. |
| FLT1-FLT8 | I | ST | Yes | PWM Fault Inputs 1 through 8. |
| FLT9-FLT12 | I | ST | No | PWM Fault Inputs 9 through 12. |
| PWM1L-PWM3L | O | — | No | PWM Low Outputs 1 through 3. |
| PWM1H-PWM3H | O | — | No | PWM High Outputs 1 through 3. |
| PWM4L-PWM8L(2) | O | — | Yes | PWM Low Outputs 4 through 8. |
| PWM4H-PWM8H(2) | O | — | Yes | PWM High Outputs 4 through 8. |
| SYNCI1, SYNCI2 | I | ST | Yes | PWM Synchronization Inputs 1 and 2. |
| SYNCO1, SYNCO2 | O | — | Yes | PWM Synchronization Outputs 1 and 2. |

**Legend:** CMOS = CMOS compatible input or output; Analog = Analog input; P = Power
ST = Schmitt Trigger input with CMOS levels; O = Output; I = Input
PPS = Peripheral Pin Select; TTL = TTL input buffer

**1:** Not all pins are available in all package variants. See the **"Pin Diagrams"** section for pin availability.

**2:** PWM4H/L through PWM8H/L are fixed on dsPIC33EPXXXGS708/808 devices. PWM4H/L through PWM6H/L are fixed on dsPIC33EPXXXGS706/806 devices.

**3:** The SCK3 pin is fixed on dsPIC33EPXXXGS706/806 and dsPIC33EPXXXGS708/808 devices.

**4:** PPS is available on dsPIC33EPXXXGS702 devices only.

**TABLE 1-1: PINOUT I/O DESCRIPTIONS (CONTINUED)**

| Pin Name[1] | Pin Type | Buffer Type | PPS | Description |
|---|---|---|---|---|
| CMP1A-CMP4A | I | Analog | No | Comparator Channels 1A through 4A inputs. |
| CMP1B-CMP4B | I | Analog | No | Comparator Channels 1B through 4B inputs. |
| CMP1C-CMP4C | I | Analog | No | Comparator Channels 1C through 4C inputs. |
| CMP1D-CMP4D | I | Analog | No | Comparator Channels 1D through 4D inputs. |
| ACMP1-ACMP4 | O | — | Yes | Analog Comparator Outputs 1-4. |
| DACOUT1, DACOUT2 | O | — | No | DAC Output Voltages 1 and 2. |
| EXTREF1, EXTREF2 | I | Analog | No | External Voltage Reference Inputs 1 and 2 for the Reference DACs. |
| PGA1P1-PGA1P4 | I | Analog | No | PGA1 Positive Inputs 1 through 4. |
| PGA1N1-PGA1N3 | I | Analog | No | PGA1 Negative Inputs 1 through 3. |
| PGA2P1-PGA2P4 | I | Analog | No | PGA2 Positive Inputs 1 through 4. |
| PGA2N1-PGA2N3 | I | Analog | No | PGA2 Negative Inputs 1 through 3. |
| ADTRG31 | I | ST | No | External ADC trigger source. |
| PGED1 | I/O | ST | No | Data I/O pin for Programming/Debugging Communication Channel 1. |
| PGEC1 | I | ST | No | Clock input pin for Programming/Debugging Communication Channel 1. |
| PGED2 | I/O | ST | No | Data I/O pin for Programming/Debugging Communication Channel 2. |
| PGEC2 | I | ST | No | Clock input pin for Programming/Debugging Communication Channel 2. |
| PGED3 | I/O | ST | No | Data I/O pin for Programming/Debugging Communication Channel 3. |
| PGEC3 | I | ST | No | Clock input pin for Programming/Debugging Communication Channel 3. |
| $\overline{MCLR}$ | I/P | ST | No | Master Clear (Reset) input. This pin is an active-low Reset to the device. |
| $AV_{DD}$ | P | P | No | Positive supply for analog modules. This pin must be connected at all times. |
| $AV_{SS}$ | P | P | No | Ground reference for analog modules. This pin must be connected at all times. |
| $V_{DD}$ | P | — | No | Positive supply for peripheral logic and I/O pins. |
| $V_{CAP}$ | P | — | No | CPU logic filter capacitor connection. |
| $V_{SS}$ | P | — | No | Ground reference for logic and I/O pins. |

**Legend:** CMOS = CMOS compatible input or output; Analog = Analog input; P = Power
ST = Schmitt Trigger input with CMOS levels; O = Output; I = Input
PPS = Peripheral Pin Select; TTL = TTL input buffer

**1:** Not all pins are available in all package variants. See the **"Pin Diagrams"** section for pin availability.

**2:** PWM4H/L through PWM8H/L are fixed on dsPIC33EPXXXGS708/808 devices. PWM4H/L through PWM6H/L are fixed on dsPIC33EPXXXGS706/806 devices.

**3:** The SCK3 pin is fixed on dsPIC33EPXXXGS706/806 and dsPIC33EPXXXGS708/808 devices.

**4:** PPS is available on dsPIC33EPXXXGS702 devices only.


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## 2.0 GUIDELINES FOR GETTING STARTED WITH 16-BIT DIGITAL SIGNAL CONTROLLERS

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to the related section of the *"dsPIC33/PIC24 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.

### 2.1 Basic Connection Requirements

Getting started with the dsPIC33EPXXXGS70X/80X family requires attention to a minimal set of device pin connections before proceeding with development. The following is a list of pin names which must always be connected:

- All VDD and VSS pins
  (see **Section 2.2 "Decoupling Capacitors"**)
- All AVDD and AVSS pins
  regardless if ADC module is not used (see **Section 2.2 "Decoupling Capacitors"**)
- VCAP
  (see **Section 2.3 "CPU Logic Filter Capacitor Connection (VCAP)"**)
- $\overline{\text{MCLR}}$ pin
  (see **Section 2.4 "Master Clear (MCLR) Pin"**)
- PGECx/PGEDx pins
  used for In-Circuit Serial Programming™ (ICSP™) and debugging purposes (see **Section 2.5 "ICSP Pins"**)
- OSC1 and OSC2 pins
  when external oscillator source is used (see **Section 2.6 "External Oscillator Pins"**)

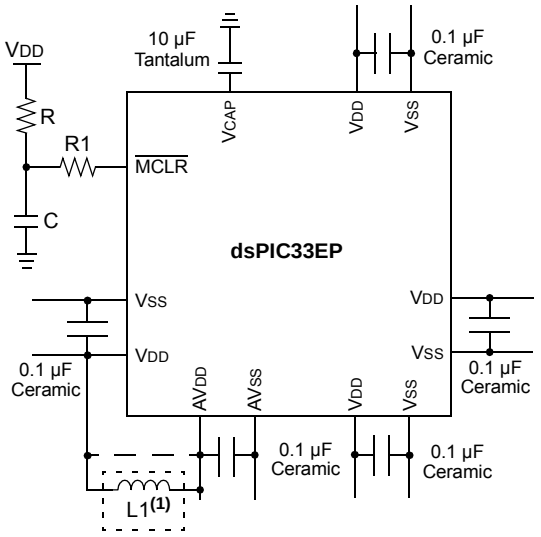
### 2.2 Decoupling Capacitors

The use of decoupling capacitors on every pair of power supply pins, such as VDD, VSS, AVDD and AVSS is required.

Consider the following criteria when using decoupling capacitors:

- **Value and type of capacitor:** Recommendation of 0.1 µF (100 nF), 10-20V. This capacitor should be a low-ESR and have resonance frequency in the range of 20 MHz and higher. It is recommended to use ceramic capacitors.
- **Placement on the printed circuit board:** The decoupling capacitors should be placed as close to the pins as possible. It is recommended to place the capacitors on the same side of the board as the device. If space is constricted, the capacitor can be placed on another layer on the PCB using a via; however, ensure that the trace length from the pin to the capacitor is within one-quarter inch (6 mm) in length.
- **Handling high-frequency noise:** If the board is experiencing high-frequency noise, above tens of MHz, add a second ceramic-type capacitor in parallel to the above described decoupling capacitor. The value of the second capacitor can be in the range of 0.01 µF to 0.001 µF. Place this second capacitor next to the primary decoupling capacitor. In high-speed circuit designs, consider implementing a decade pair of capacitances as close to the power and ground pins as possible. For example, 0.1 µF in parallel with 0.001 µF.
- **Maximizing performance:** On the board layout from the power supply circuit, run the power and return traces to the decoupling capacitors first, and then to the device pins. This ensures that the decoupling capacitors are first in the power chain. Equally important is to keep the trace length between the capacitor and the power pins to a minimum, thereby reducing PCB track inductance.

**FIGURE 2-1: RECOMMENDED MINIMUM CONNECTION**




**Note 1:** As an option, instead of a hard-wired connection, an inductor (L1) can be substituted between VDD and AVDD to improve ADC noise rejection. The inductor impedance should be less than 1Ω and the inductor capacity greater than 10 mA.

Where:

$$f = \frac{FCNV}{2} \quad \text{(i.e., ADC Conversion Rate/2)}$$

$$f = \frac{1}{(2\pi\sqrt{LC})}$$

$$L = \left(\frac{1}{(2\pi f\sqrt{C})}\right)^2$$

### 2.2.1 TANK CAPACITORS

On boards with power traces running longer than six inches in length, it is suggested to use a tank capacitor for integrated circuits, including DSCs, to supply a local power source. The value of the tank capacitor should be determined based on the trace resistance that connects the power supply source to the device and the maximum current drawn by the device in the application. In other words, select the tank capacitor so that it meets the acceptable voltage sag at the device. Typical values range from 4.7 µF to 47 µF.

## 2.3 CPU Logic Filter Capacitor Connection (VCAP)

A low-ESR (< 0.5Ω) capacitor is required on the VCAP pin, which is used to stabilize the voltage regulator output voltage. The VCAP pin must not be connected to VDD and must have a capacitor greater than 4.7 µF (10 µF is recommended), 16V connected to ground. The type can be ceramic or tantalum. See **Section 30.0 "Electrical Characteristics"** for additional information.

The placement of this capacitor should be close to the VCAP pin. It is recommended that the trace length not exceeds one-quarter inch (6 mm). See **Section 27.4 "On-Chip Voltage Regulator"** for details.

## 2.4 Master Clear (MCLR) Pin

The MCLR pin provides two specific device functions:

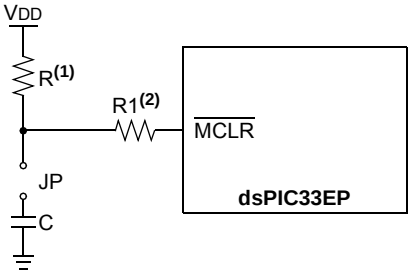
- Device Reset
- Device Programming and Debugging.

During device programming and debugging, the resistance and capacitance that can be added to the pin must be considered. Device programmers and debuggers drive the MCLR pin. Consequently, specific voltage levels (VIH and VIL) and fast signal transitions must not be adversely affected. Therefore, specific values of R and C will need to be adjusted based on the application and PCB requirements.

For example, as shown in Figure 2-2, it is recommended that the capacitor, C, be isolated from the MCLR pin during programming and debugging operations.

Place the components as shown in Figure 2-2, within one-quarter inch (6 mm) from the MCLR pin.

**FIGURE 2-2: EXAMPLE OF MCLR PIN CONNECTIONS**




**Note 1:** R ≤ 10 kΩ is recommended. A suggested starting value is 10 kΩ. Ensure that the MCLR pin VIH and VIL specifications are met.

**2:** R1 ≤ 470Ω will limit any current flowing into MCLR from the external capacitor, C, in the event of MCLR pin breakdown due to Electrostatic Discharge (ESD) or Electrical Overstress (EOS). Ensure that the MCLR pin VIH and VIL specifications are met.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## 2.5 ICSP Pins

The PGECx and PGEDx pins are used for ICSP and debugging purposes. It is recommended to keep the trace length between the ICSP connector and the ICSP pins on the device as short as possible. If the ICSP connector is expected to experience an ESD event, a series resistor is recommended, with the value in the range of a few tens of Ohms, not to exceed 100 Ohms.

Pull-up resistors, series diodes and capacitors on the PGECx and PGEDx pins are not recommended as they will interfere with the programmer/debugger communications to the device. If such discrete components are an application requirement, they should be removed from the circuit during programming and debugging. Alternatively, refer to the AC/DC characteristics and timing requirements information in the respective device Flash programming specification for information on capacitive loading limits and pin Voltage Input High ($V_{IH}$) and Voltage Input Low ($V_{IL}$) requirements.

Ensure that the "Communication Channel Select" (i.e., PGECx/PGEDx pins) programmed into the device matches the physical connections for the ICSP to MPLAB® PICkit™ 3, MPLAB ICD 3, or MPLAB REAL ICE™.

For more information on MPLAB ICD 2, MPLAB ICD 3 and REAL ICE connection requirements, refer to the following documents that are available on the Microchip web site.

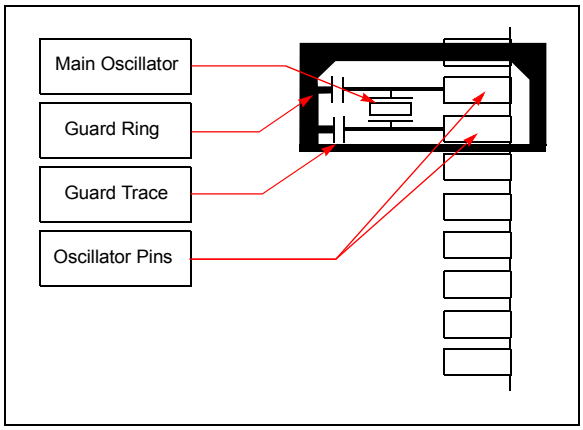
- *"Using MPLAB® ICD 3 In-Circuit Debugger"* (poster) (DS51765)
- *"Development Tools Design Advisory"* (DS51764)
- *"MPLAB® REAL ICE™ In-Circuit Emulator User's Guide"* (DS51616)
- *"Using MPLAB® REAL ICE™ In-Circuit Emulator"* (poster) (DS51749)

## 2.6 External Oscillator Pins

Many DSCs have options for at least two oscillators: a high-frequency primary oscillator and a low-frequency secondary oscillator. For details, see **Section 9.0 "Oscillator Configuration"** for details.

The oscillator circuit should be placed on the same side of the board as the device. Also, place the oscillator circuit close to the respective oscillator pins, not exceeding one-half inch (12 mm) distance between them. The load capacitors should be placed next to the oscillator itself, on the same side of the board. Use a grounded copper pour around the oscillator circuit to isolate them from surrounding circuits. The grounded copper pour should be routed directly to the MCU ground. Do not run any signal traces or power traces inside the ground pour. Also, if using a two-sided board, avoid any traces on the other side of the board where the crystal is placed. A suggested layout is shown in Figure 2-3.

**FIGURE 2-3: SUGGESTED PLACEMENT OF THE OSCILLATOR CIRCUIT**



## 2.7 Oscillator Value Conditions on Device Start-up

If the PLL of the target device is enabled and configured for the device start-up oscillator, the maximum oscillator source frequency must be limited to 3 MHz < FIN < 5.5 MHz to comply with device PLL start-up conditions. This means that if the external oscillator frequency is outside this range, the application must start up in the FRC mode first. The default PLL settings, after a POR with an oscillator frequency outside this range, will violate the device operating speed.

Once the device powers up, the application firmware can initialize the PLL SFRs, CLKDIV and PLLFBD, to a suitable value, and then perform a clock switch to the Oscillator + PLL clock source. Note that clock switching must be enabled in the device Configuration Word.

## 2.8 Unused I/Os

Unused I/O pins should be configured as outputs and driven to a logic low state.

Alternatively, connect a 1k to 10k resistor between VSS and unused pins, and drive the output to logic low.

## 2.9 Targeted Applications

- Power Factor Correction (PFC)
  - Interleaved PFC
  - Critical Conduction PFC
  - Bridgeless PFC
- DC/DC Converters
  - Buck, Boost, Forward, Flyback, Push-Pull
  - Half/Full-Bridge
  - Phase-Shift Full-Bridge
  - Resonant Converters
- DC/AC
  - Half/Full-Bridge Inverter
  - Resonant Inverter

Examples of typical application connections are shown in Figure 2-4 through Figure 2-6.

**FIGURE 2-4: INTERLEAVED PFC**

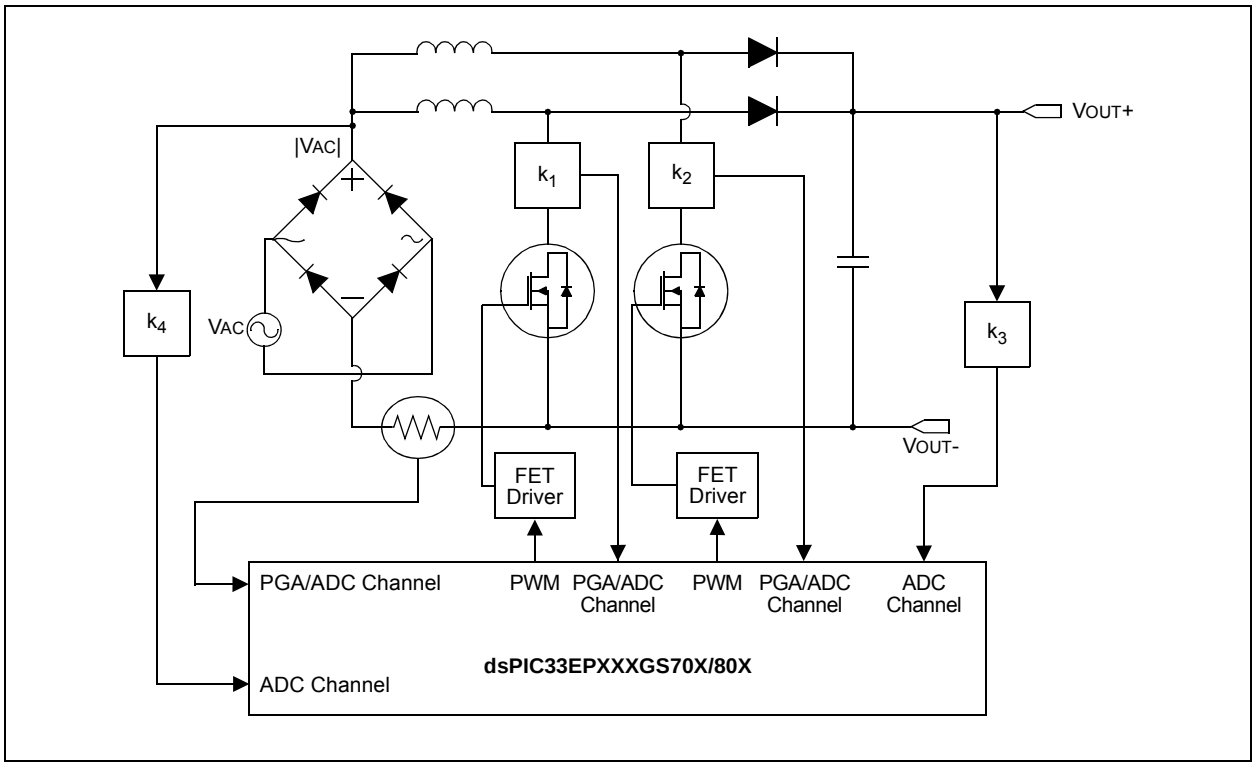




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**FIGURE 2-5: PHASE-SHIFTED FULL-BRIDGE CONVERTER**

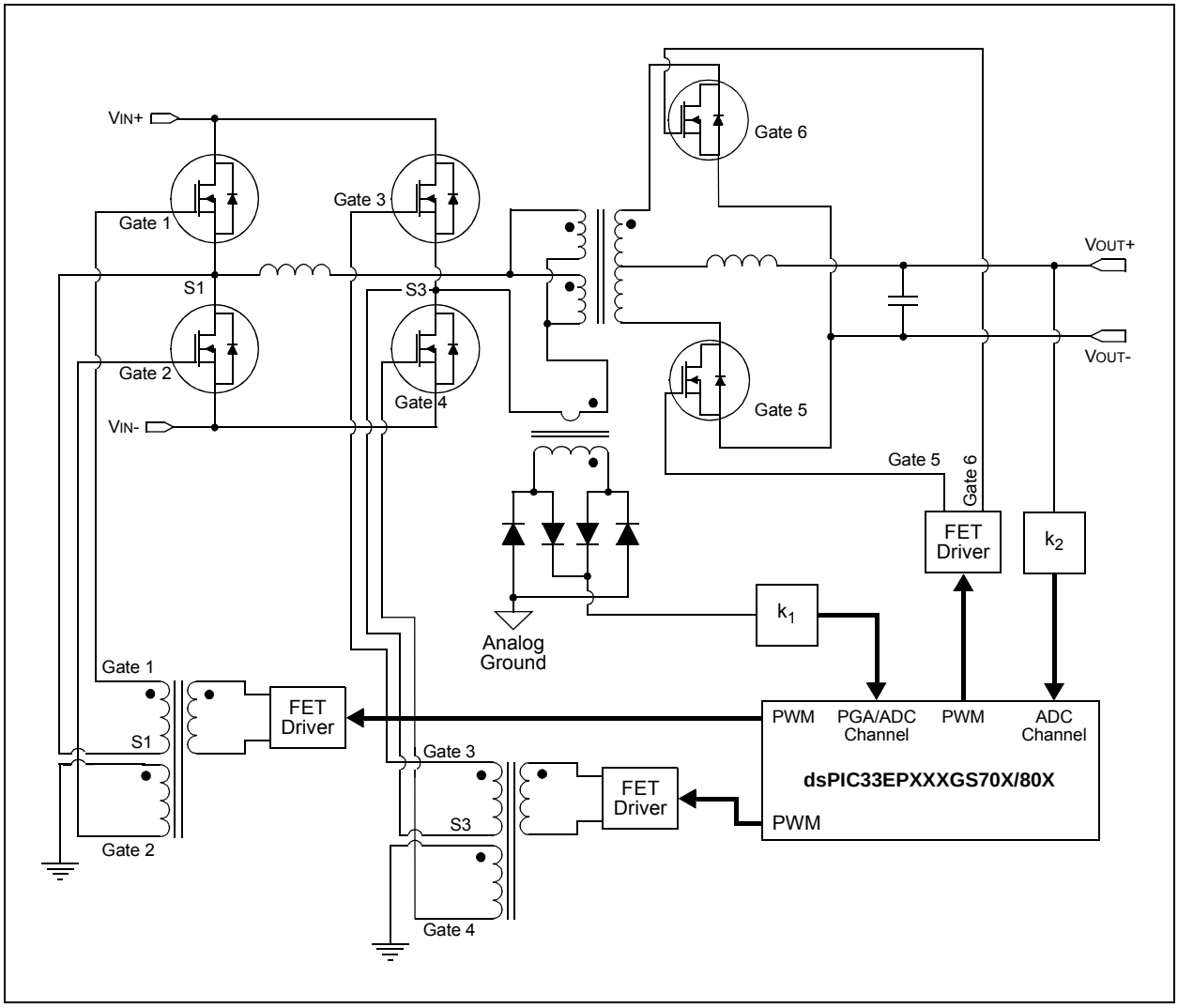
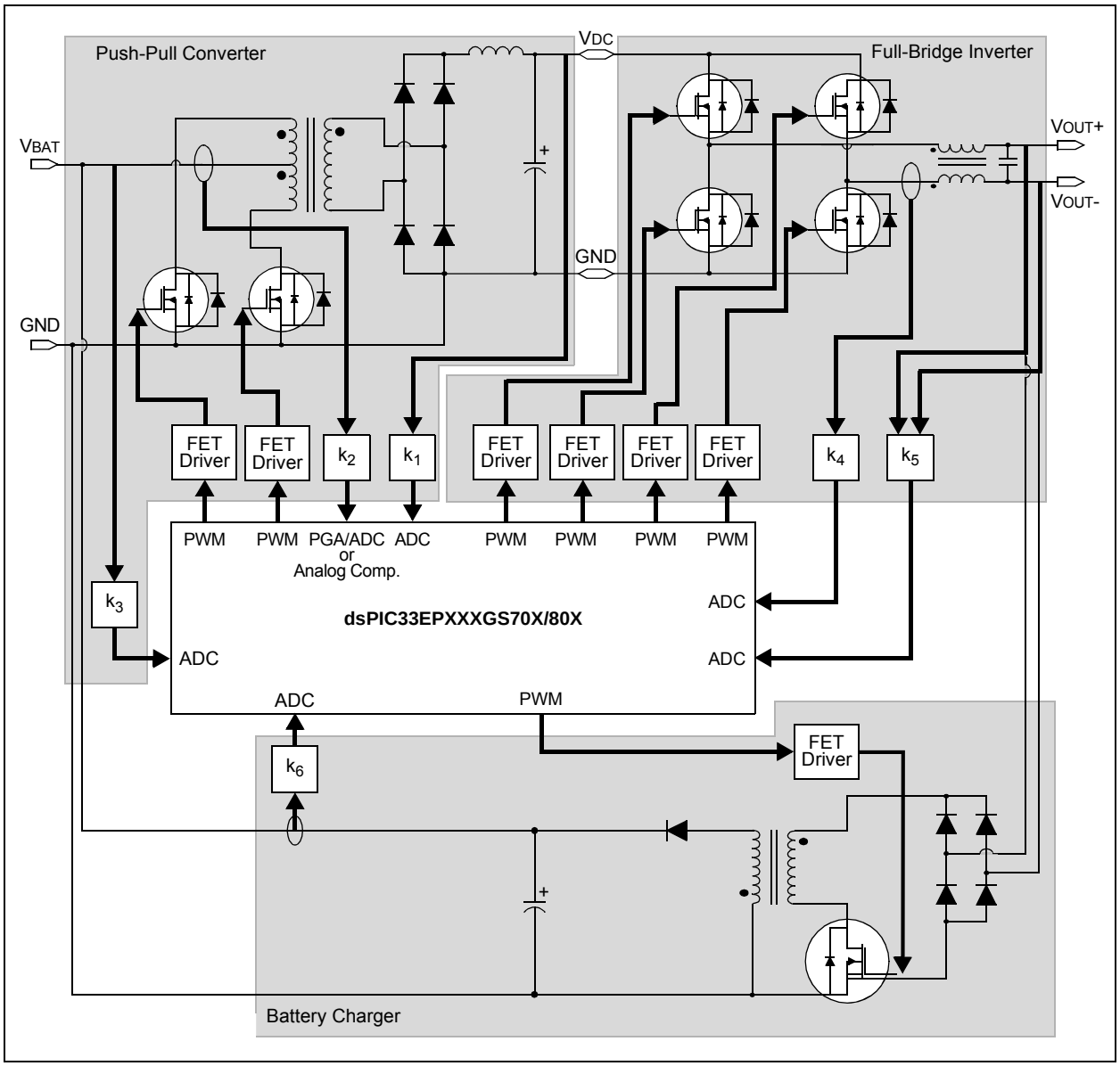


**FIGURE 2-6: OFF-LINE UPS**





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## 3.0 CPU

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"dsPIC33E Enhanced CPU"** (DS70005158) in the *"dsPIC33/PIC24 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 dsPIC33EPXXXGS70X/80X family CPU has a 16-bit (data) modified Harvard architecture with an enhanced instruction set, including significant support for Digital Signal Processing (DSP). The CPU has a 24-bit instruction word with a variable length opcode field. The Program Counter (PC) is 23 bits wide and addresses up to 4M x 24 bits of user program memory space.

An instruction prefetch mechanism helps maintain throughput and provides predictable execution. Most instructions execute in a single-cycle effective execution rate, with the exception of instructions that change the program flow, the double-word move (`MOV.D`) instruction, PSV accesses and the table instructions. Overhead-free program loop constructs are supported using the `DO` and `REPEAT` instructions, both of which are interruptible at any point.

### 3.1 Registers

The dsPIC33EPXXXGS70X/80X devices have sixteen, 16-bit Working registers in the programmer's model. Each of the Working registers can act as a Data, Address or Address Offset register. The 16th Working register (W15) operates as a Software Stack Pointer for interrupts and calls.

In addition, the dsPIC33EPXXXGS70X/80X devices include four Alternate Working register sets which consist of W0 through W14. The Alternate Working registers can be made persistent to help reduce the saving and restoring of register content during Interrupt Service Routines (ISRs). The Alternate Working registers can be assigned to a specific Interrupt Priority Level (IPL1 through IPL7) by configuring the CTXTx<2:0> bits in the FALTREG Configuration register. The Alternate Working registers can also be accessed manually by using the `CTXTSWP` instruction. The CCTXI<2:0> and MCTXI<2:0> bits in the CTXTSTAT register can be used to identify the current, and most recent, manually selected Working register sets.

### 3.2 Instruction Set

The instruction set for dsPIC33EPXXXGS70X/80X devices has two classes of instructions: the MCU class of instructions and the DSP class of instructions. These two instruction classes are seamlessly integrated into the architecture and execute from a single execution unit. The instruction set includes many addressing modes and was designed for optimum C compiler efficiency.

### 3.3 Data Space Addressing

The base Data Space can be addressed as up to 4K words or 8 Kbytes, and is split into two blocks, referred to as X and Y data memory. Each memory block has its own independent Address Generation Unit (AGU). The MCU class of instructions operates solely through the X memory AGU, which accesses the entire memory map as one linear Data Space. Certain DSP instructions operate through the X and Y AGUs to support dual operand reads, which splits the data address space into two parts. The X and Y Data Space boundary is device-specific.

The upper 32 Kbytes of the Data Space memory map can optionally be mapped into Program Space (PS) at any 16K program word boundary. The program-to-Data Space mapping feature, known as Program Space Visibility (PSV), lets any instruction access Program Space as if it were Data Space. Refer to **"Data Memory"** (DS70595) in the *"dsPIC33/PIC24 Family Reference Manual"* for more details on PSV and table accesses.

On dsPIC33EPXXXGS70X/80X devices, overhead-free circular buffers (Modulo Addressing) are supported in both X and Y address spaces. The Modulo Addressing removes the software boundary checking overhead for DSP algorithms. The X AGU Circular Addressing can be used with any of the MCU class of instructions. The X AGU also supports Bit-Reversed Addressing to greatly simplify input or output data re-ordering for radix-2 FFT algorithms.

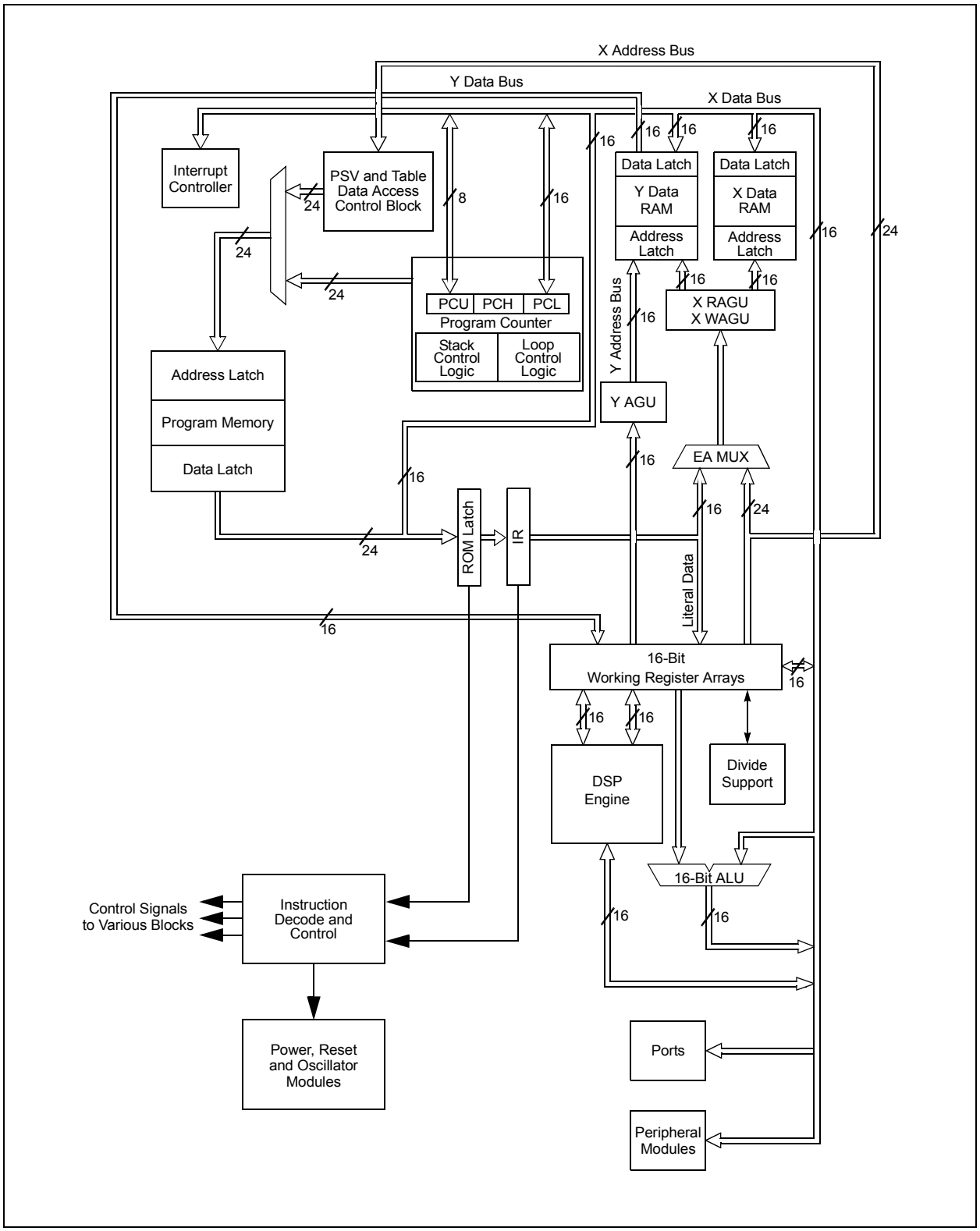
### 3.4 Addressing Modes

The CPU supports these addressing modes:

- Inherent (no operand)
- Relative
- Literal
- Memory Direct
- Register Direct
- Register Indirect

Each instruction is associated with a predefined addressing mode group, depending upon its functional requirements. As many as six addressing modes are supported for each instruction.

**FIGURE 3-1: dsPIC33EPXXXGS70X/80X FAMILY CPU BLOCK DIAGRAM**





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## 3.5 Programmer's Model

The programmer's model for the dsPIC33EPXXXGS70X/80X family is shown in Figure 3-2. All registers in the programmer's model are memory-mapped and can be manipulated directly by instructions. Table 3-1 lists a description of each register.

In addition to the registers contained in the programmer's model, the dsPIC33EPXXXGS70X/80X devices contain control registers for Modulo Addressing, Bit-Reversed Addressing and interrupts. These registers are described in subsequent sections of this document.

All registers associated with the programmer's model are memory-mapped, as shown in Table 3-1.

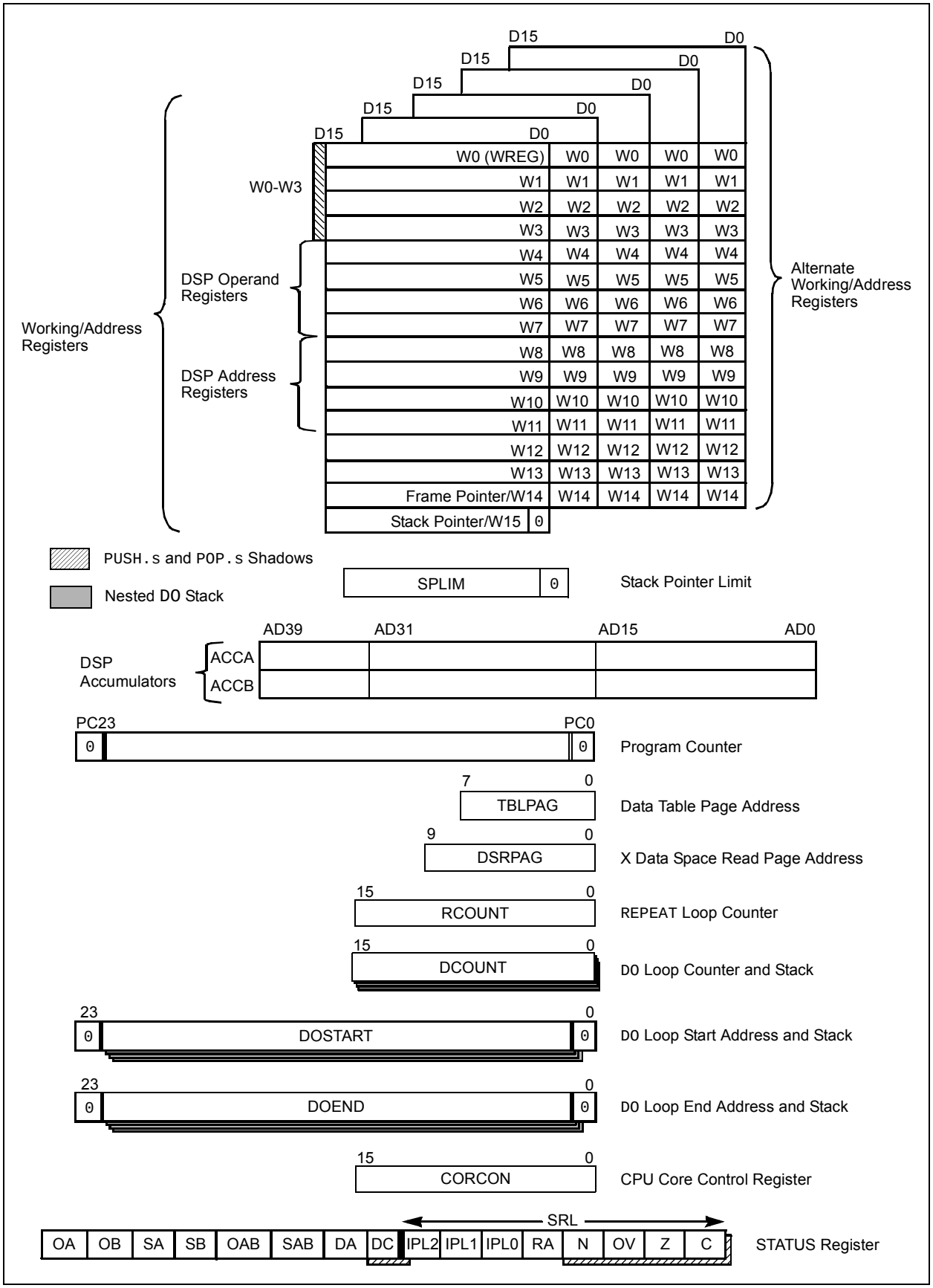
**TABLE 3-1: PROGRAMMER'S MODEL REGISTER DESCRIPTIONS**

| Register(s) Name | Description |
|---|---|
| W0 through W15(1) | Working Register Array |
| W0 through W14(1) | Alternate 1 Working Register Array |
| W0 through W14(1) | Alternate 2 Working Register Array |
| W0 through W14(1) | Alternate 3 Working Register Array |
| W0 through W14(1) | Alternate 4 Working Register Array |
| ACCA, ACCB | 40-Bit DSP Accumulators |
| PC | 23-Bit Program Counter |
| SR | ALU and DSP Engine STATUS Register |
| SPLIM | Stack Pointer Limit Value Register |
| TBLPAG | Table Memory Page Address Register |
| DSRPAG | Extended Data Space (EDS) Read Page Register |
| RCOUNT | REPEAT Loop Counter Register |
| DCOUNT | DO Loop Counter Register |
| DOSTARTH(2), DOSTARTL(2) | DO Loop Start Address Register (High and Low) |
| DOENDH, DOENDL | DO Loop End Address Register (High and Low) |
| CORCON | Contains DSP Engine, DO Loop Control and Trap Status bits |

**Note 1:** Memory-mapped W0 through W14 represent the value of the register in the currently active CPU context.

**2:** The DOSTARTH and DOSTARTL registers are read-only.

**FIGURE 3-2: PROGRAMMER'S MODEL**





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## 3.6 CPU 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 contains the latest updates and additional information.

### 3.6.1 KEY RESOURCES

- **"dsPIC33E Enhanced CPU"** (DS70005158) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

## 3.7 CPU Control Registers

**REGISTER 3-1: SR: CPU STATUS REGISTER**

| 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(3) | SB(3) | OAB | SAB | DA | DC |
| bit 15 | | | | | | | bit 8 |

| R/W-0(2) | R/W-0(2) | R/W-0(2) | R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| IPL2(1) | IPL1(1) | IPL0(1) | 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 15 **OA:** Accumulator A Overflow Status bit
1 = Accumulator A has overflowed
0 = Accumulator A has not overflowed

bit 14 **OB:** Accumulator B Overflow Status bit
1 = Accumulator B has overflowed
0 = Accumulator B has not overflowed

bit 13 **SA:** Accumulator A Saturation 'Sticky' Status bit(3)
1 = Accumulator A is saturated or has been saturated at some time
0 = Accumulator A is not saturated

bit 12 **SB:** Accumulator B Saturation 'Sticky' Status bit(3)
1 = Accumulator B is saturated or has been saturated at some time
0 = Accumulator B is not saturated

bit 11 **OAB:** OA || OB Combined Accumulator Overflow Status bit
1 = Accumulator A or B has overflowed
0 = Neither Accumulator A or B has overflowed

bit 10 **SAB:** SA || SB Combined Accumulator 'Sticky' Status bit
1 = Accumulator A or B is saturated or has been saturated at some time
0 = Neither Accumulator A or B is saturated

bit 9 **DA:** DO Loop Active bit
1 = DO loop is in progress
0 = DO loop is not in progress

bit 8 **DC:** MCU ALU Half Carry/$\overline{\text{Borrow}}$ bit
1 = A carry-out from the 4th low-order bit (for byte-sized data) or 8th low-order bit (for word-sized data) of the result occurred
0 = No carry-out from the 4th low-order bit (for byte-sized data) or 8th low-order bit (for word-sized data) of the result occurred

**Note 1:** 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.

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

**3:** A data write to the SR register can modify the SA and SB bits by either a data write to SA and SB or by clearing the SAB bit. To avoid a possible SA or SB bit write race condition, the SA and SB bits should not be modified using bit operations.


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**REGISTER 3-1: SR: CPU STATUS REGISTER (CONTINUED)**

bit 7-5 **IPL<2:0>:** CPU Interrupt Priority Level Status bits(1,2)
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)

bit 4 **RA:** REPEAT Loop Active bit
1 = REPEAT loop is in progress
0 = REPEAT loop is not in progress

bit 3 **N:** MCU ALU Negative bit
1 = Result was negative
0 = Result was non-negative (zero or positive)

bit 2 **OV:** MCU ALU Overflow bit
This bit is used for signed arithmetic (2's complement). It indicates an overflow of the magnitude that causes the sign bit to change state.
1 = Overflow occurred for signed arithmetic (in this arithmetic operation)
0 = No overflow occurred

bit 1 **Z:** MCU ALU Zero bit
1 = An operation that affects the Z bit has set it at some time in the past
0 = The most recent operation that affects the Z bit has cleared it (i.e., a non-zero result)

bit 0 **C:** MCU ALU Carry/$\overline{\text{Borrow}}$ bit
1 = A carry-out from the Most Significant bit of the result occurred
0 = No carry-out from the Most Significant bit of the result occurred

**Note 1:** 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.

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

**3:** A data write to the SR register can modify the SA and SB bits by either a data write to SA and SB or by clearing the SAB bit. To avoid a possible SA or SB bit write race condition, the SA and SB bits should not be modified using bit operations.

**REGISTER 3-2: CORCON: CORE CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| VAR | — | US1 | US0 | EDT(1) | DL2 | DL1 | DL0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-1 | R/W-0 | R/C-0 | R-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SATA | SATB | SATDW | ACCSAT | IPL3(2) | SFA | RND | IF |
| 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 15 **VAR:** Variable Exception Processing Latency Control bit
1 = Variable exception processing is enabled
0 = Fixed exception processing is enabled

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

bit 13-12 **US<1:0>:** DSP Multiply Unsigned/Signed Control bits
11 = Reserved
10 = DSP engine multiplies are mixed-sign
01 = DSP engine multiplies are unsigned
00 = DSP engine multiplies are signed

bit 11 **EDT:** Early DO Loop Termination Control bit(1)
1 = Terminates executing DO loop at the end of current loop iteration
0 = No effect

bit 10-8 **DL<2:0>:** DO Loop Nesting Level Status bits
111 = 7 DO loops are active
•
•
•
001 = 1 DO loop is active
000 = 0 DO loops are active

bit 7 **SATA:** ACCA Saturation Enable bit
1 = Accumulator A saturation is enabled
0 = Accumulator A saturation is disabled

bit 6 **SATB:** ACCB Saturation Enable bit
1 = Accumulator B saturation is enabled
0 = Accumulator B saturation is disabled

bit 5 **SATDW:** Data Space Write from DSP Engine Saturation Enable bit
1 = Data Space write saturation is enabled
0 = Data Space write saturation is disabled

bit 4 **ACCSAT:** Accumulator Saturation Mode Select bit
1 = 9.31 saturation (super saturation)
0 = 1.31 saturation (normal saturation)

bit 3 **IPL3:** CPU Interrupt Priority Level Status bit 3(2)
1 = CPU Interrupt Priority Level is greater than 7
0 = CPU Interrupt Priority Level is 7 or less

**Note 1:** This bit is always read as '0'.
**2:** The IPL3 bit is concatenated with the IPL<2:0> bits (SR<7:5>) to form the CPU Interrupt Priority Level.


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**REGISTER 3-2: CORCON: CORE CONTROL REGISTER (CONTINUED)**

bit 2 **SFA:** Stack Frame Active Status bit
1 = Stack frame is active; W14 and W15 address 0x0000 to 0xFFFF, regardless of DSRPAG
0 = Stack frame is not active; W14 and W15 address the base Data Space

bit 1 **RND:** Rounding Mode Select bit
1 = Biased (conventional) rounding is enabled
0 = Unbiased (convergent) rounding is enabled

bit 0 **IF:** Integer or Fractional Multiplier Mode Select bit
1 = Integer mode is enabled for DSP multiply
0 = Fractional mode is enabled for DSP multiply

**Note 1:** This bit is always read as '0'.
**2:** The IPL3 bit is concatenated with the IPL<2:0> bits (SR<7:5>) to form the CPU Interrupt Priority Level.

**REGISTER 3-3: CTXTSTAT: CPU W REGISTER CONTEXT STATUS REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | CCTXI2 | CCTXI1 | CCTXI0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | MCTXI2 | MCTXI1 | MCTXI0 |
| 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 15-11 **Unimplemented:** Read as '0'

bit 10-8 **CCTXI<2:0>:** Current (W Register) Context Identifier bits
111 = Reserved
•
•
•
101 = Reserved
100 = Alternate Working Register Set 4 is currently in use
011 = Alternate Working Register Set 3 is currently in use
010 = Alternate Working Register Set 2 is currently in use
001 = Alternate Working Register Set 1 is currently in use
000 = Default register set is currently in use

bit 7-3 **Unimplemented:** Read as '0'

bit 2-0 **MCTXI<2:0>:** Manual (W Register) Context Identifier bits
111 = Reserved
•
•
•
101 = Reserved
100 = Alternate Working Register Set 4 was most recently manually selected
011 = Alternate Working Register Set 3 was most recently manually selected
010 = Alternate Working Register Set 2 was most recently manually selected
001 = Alternate Working Register Set 1 was most recently manually selected
000 = Default register set was most recently manually selected

## 3.8 Arithmetic Logic Unit (ALU)

The dsPIC33EPXXXGS70X/80X family ALU is 16 bits wide and is capable of addition, subtraction, bit shifts and logic operations. Unless otherwise mentioned, arithmetic operations are two's complement in nature. Depending on the operation, the ALU can affect the values of the Carry (C), Zero (Z), Negative (N), Overflow (OV) and Digit Carry (DC) Status bits in the SR register. The C and DC Status bits operate as Borrow and Digit Borrow bits, respectively, for subtraction operations.

The ALU can perform 8-bit or 16-bit operations, depending on the mode of the instruction that is used. Data for the ALU operation can come from the W register array or data memory, depending on the addressing mode of the instruction. Likewise, output data from the ALU can be written to the W register array or a data memory location.

Refer to the *"16-bit MCU and DSC Programmer's Reference Manual"* (DS70157) for information on the SR bits affected by each instruction.

The core CPU incorporates hardware support for both multiplication and division. This includes a dedicated hardware multiplier and support hardware for 16-bit divisor division.

### 3.8.1 MULTIPLIER

Using the high-speed, 17-bit x 17-bit multiplier, the ALU supports unsigned, signed or mixed-sign operation in several MCU Multiplication modes:

- 16-bit x 16-bit signed
- 16-bit x 16-bit unsigned
- 16-bit signed x 5-bit (literal) unsigned
- 16-bit signed x 16-bit unsigned
- 16-bit unsigned x 5-bit (literal) unsigned
- 16-bit unsigned x 16-bit signed
- 8-bit unsigned x 8-bit unsigned

### 3.8.2 DIVIDER

The divide block supports 32-bit/16-bit and 16-bit/16-bit signed and unsigned integer divide operations with the following data sizes:

- 32-bit signed/16-bit signed divide
- 32-bit unsigned/16-bit unsigned divide
- 16-bit signed/16-bit signed divide
- 16-bit unsigned/16-bit unsigned divide

The quotient for all divide instructions ends up in W0 and the remainder in W1. 16-bit signed and unsigned `DIV` instructions can specify any W register for both the 16-bit divisor (Wn) and any W register (aligned) pair (W(m + 1):Wm) for the 32-bit dividend. The divide algorithm takes one cycle per bit of divisor, so both 32-bit/16-bit and 16-bit/16-bit instructions take the same number of cycles to execute.

## 3.9 DSP Engine

The DSP engine consists of a high-speed 17-bit x 17-bit multiplier, a 40-bit barrel shifter and a 40-bit adder/subtracter (with two target accumulators, round and saturation logic).

The DSP engine can also perform inherent accumulator-to-accumulator operations that require no additional data. These instructions are, `ADD`, `SUB` and `NEG`.

The DSP engine has options selected through bits in the CPU Core Control register (CORCON), as listed below:

- Fractional or Integer DSP Multiply (IF)
- Signed, Unsigned or Mixed-Sign DSP Multiply (USx)
- Conventional or Convergent Rounding (RND)
- Automatic Saturation On/Off for ACCA (SATA)
- Automatic Saturation On/Off for ACCB (SATB)
- Automatic Saturation On/Off for Writes to Data Memory (SATDW)
- Accumulator Saturation mode Selection (ACCSAT)

**TABLE 3-2: DSP INSTRUCTIONS SUMMARY**

| Instruction | Algebraic Operation | ACC Write-Back |
|---|---|---|
| `CLR` | $A = 0$ | Yes |
| `ED` | $A = (x - y)^2$ | No |
| `EDAC` | $A = A + (x - y)^2$ | No |
| `MAC` | $A = A + (x \cdot y)$ | Yes |
| `MAC` | $A = A + x^2$ | No |
| `MOVSAC` | No change in A | Yes |
| `MPY` | $A = x \cdot y$ | No |
| `MPY` | $A = x^2$ | No |
| `MPY.N` | $A = -x \cdot y$ | No |
| `MSC` | $A = A - x \cdot y$ | Yes |


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## 4.0 MEMORY ORGANIZATION

| | |
|---|---|
| **Note:** | This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"dsPIC33E/PIC24E Program Memory"** (DS70000613) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com). |

The dsPIC33EPXXXGS70X/80X family architecture features separate program and data memory spaces, and buses. This architecture also allows the direct access of program memory from the Data Space (DS) during code execution.

### 4.1 Program Address Space

The program address memory space of the dsPIC33EPXXXGS70X/80X family devices is 4M instructions. The space is addressable by a 24-bit value derived either from the 23-bit PC during program execution, or from table operation or Data Space remapping, as described in **Section 4.9 "Interfacing Program and Data Memory Spaces"**.

User application access to the program memory space is restricted to the lower half of the address range (0x000000 to 0x7FFFFF). The exception is the use of TBLRD operations, which use TBLPAG<7> to permit access to calibration data and Device ID sections of the configuration memory space.

The program memory maps for dsPIC33EPXXXGS70X/80X devices not operating in Dual Partition mode are shown in Figure 4-1 and Figure 4-2.

The dsPIC33EPXXXGS70X/80X devices can operate in a Dual Partition Flash Program Memory mode, where the user Program Flash Memory is arranged as two separate address spaces, one for each of the Flash partitions. The Active Partition always starts at address, 0x000000, and contains half of the available Flash memory (64k/128k, depends on device). The Inactive Partition always starts at address, 0x400000, and implements the remaining half of Flash memory. As shown in Figure 4-3 and Figure 4-4, the Active and Inactive Partitions are identical, and both contain unique copies of the Reset vector, Interrupt Vector Tables (IVT and AIVT if enabled) and the Flash Configuration Words.

## 4.2 Unique Device Identifier (UDID)

All dsPIC33EPXXXGS70X/80X family devices are individually encoded during final manufacturing with a Unique Device Identifier or UDID. This feature allows for manufacturing traceability of Microchip Technology devices in applications where this is a requirement. It may also be used by the application manufacturer for any number of things that may require unique identification, such as:

- Tracking the device
- Unique serial number
- Unique security key

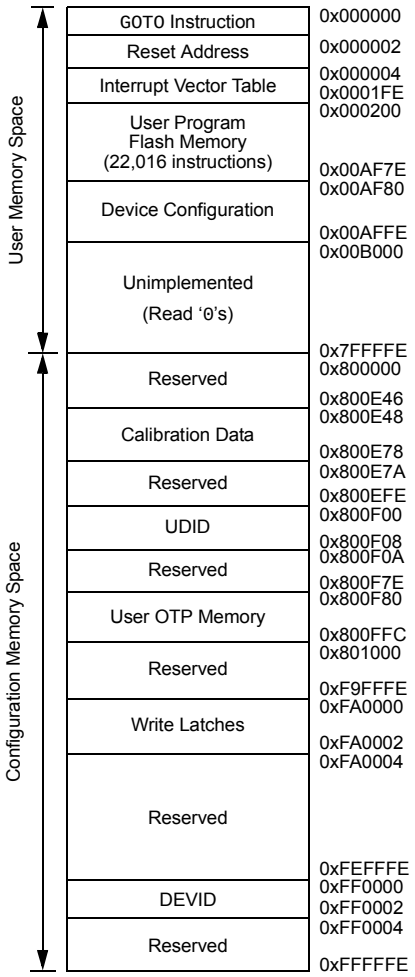
The UDID comprises five 24-bit program words. When taken together, these fields form a unique 120-bit identifier.

The UDID is stored in five read-only locations, located between 800F00h and 800F08h in the device configuration space. Table 4-1 lists the addresses of the identifier words and shows their contents.

**TABLE 4-1: UDID ADDRESSES**

| Name | Address | Bits 23:16 | Bits 15:8 | Bits 7:0 |
|---|---|---|---|---|
| UDID1 | 800F00 | UDID Word 1 | | |
| UDID2 | 800F02 | UDID Word 2 | | |
| UDID3 | 800F04 | UDID Word 3 | | |
| UDID4 | 800F06 | UDID Word 4 | | |
| UDID5 | 800F08 | UDID Word 5 | | |

**FIGURE 4-1: PROGRAM MEMORY MAP FOR dsPIC33EP64GS70X/80X DEVICES**




**Note:** Memory areas are not shown to scale.


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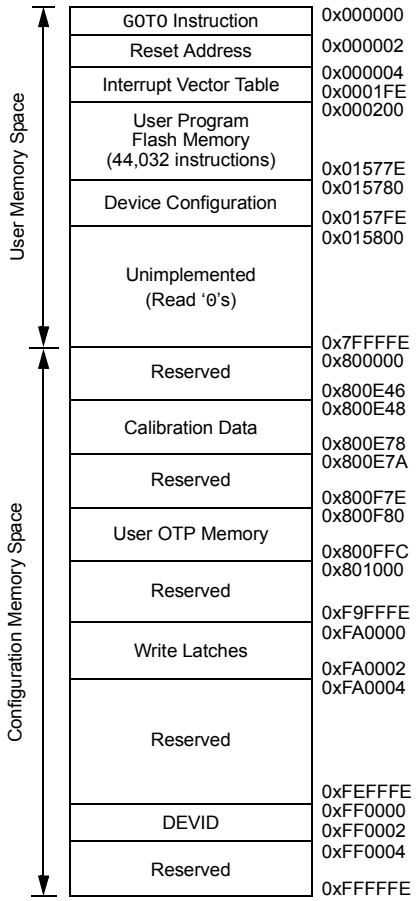
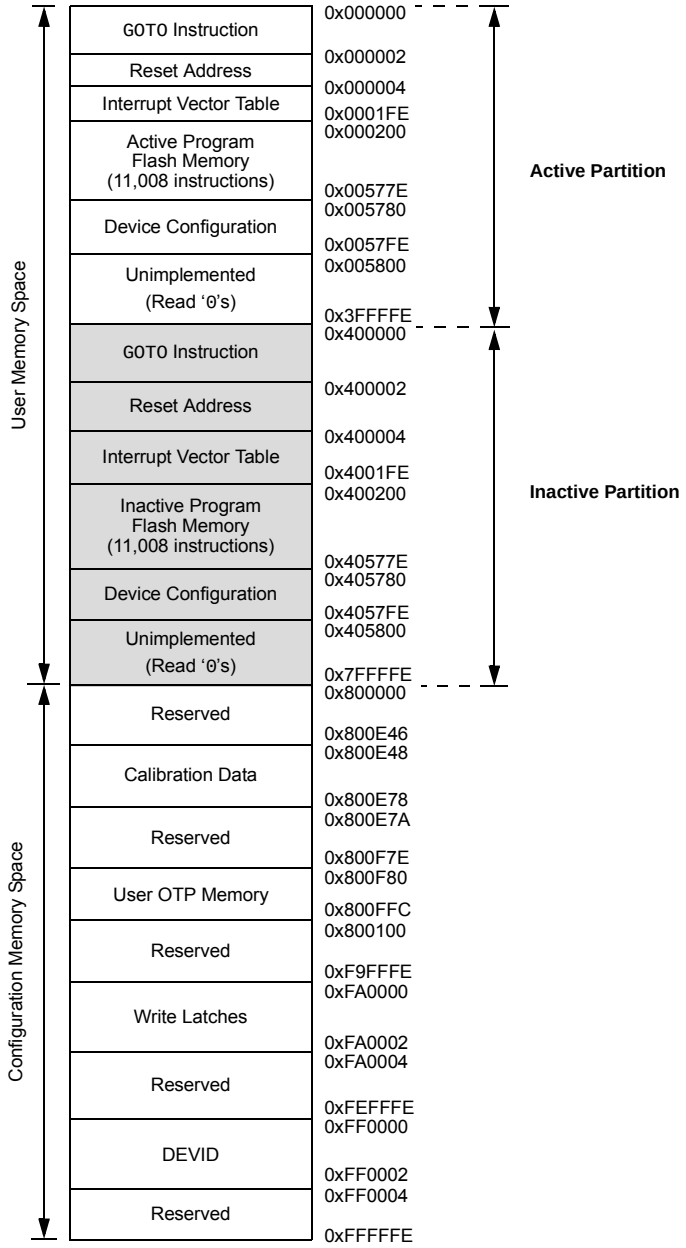
**FIGURE 4-2: PROGRAM MEMORY MAP FOR dsPIC33EP128GS70X/80X DEVICES**




**Note:** Memory areas are not shown to scale.

**FIGURE 4-3: PROGRAM MEMORY MAP FOR dsPIC33EP64GS70X/80X DEVICES (DUAL PARTITION)**




**Note:** Memory areas are not shown to scale.


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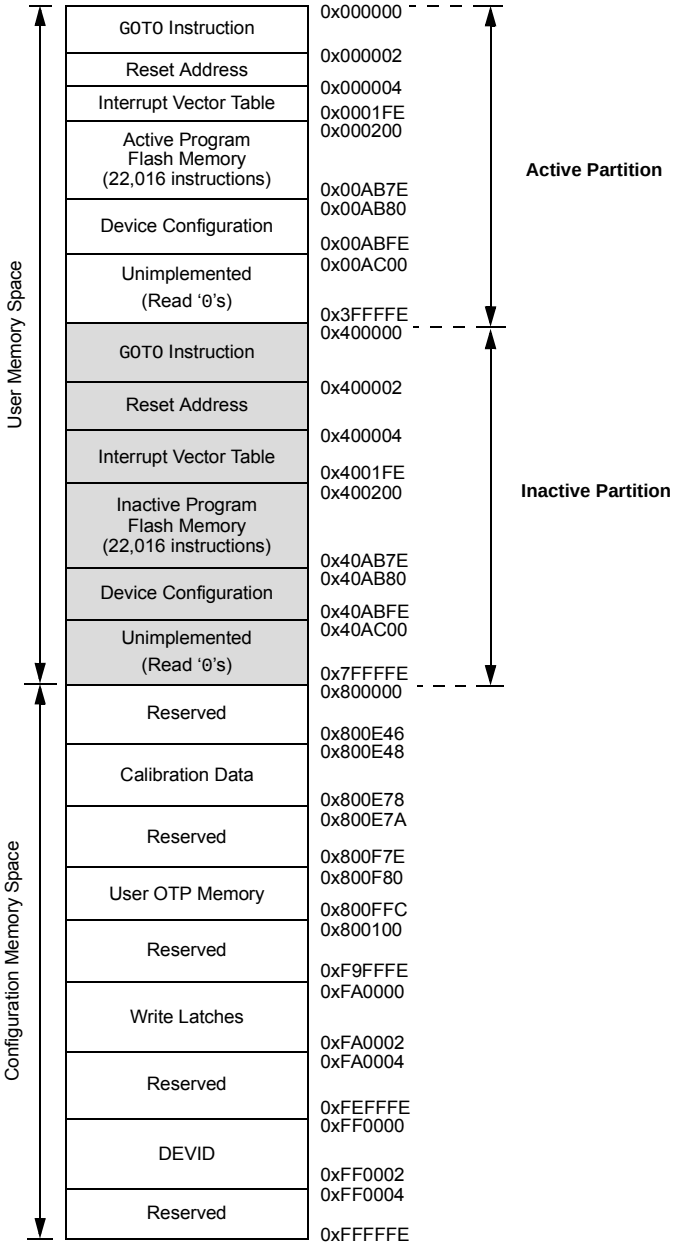
**FIGURE 4-4: PROGRAM MEMORY MAP FOR dsPIC33EP128GS70X/80X DEVICES (DUAL PARTITION)**




**Note:** Memory areas are not shown to scale.

### 4.2.1 PROGRAM MEMORY ORGANIZATION

The program memory space is organized in word-addressable blocks. Although it is treated as 24 bits wide, it is more appropriate to think of each address of the program memory as a lower and upper word, with the upper byte of the upper word being unimplemented. The lower word always has an even address, while the upper word has an odd address (Figure 4-5).

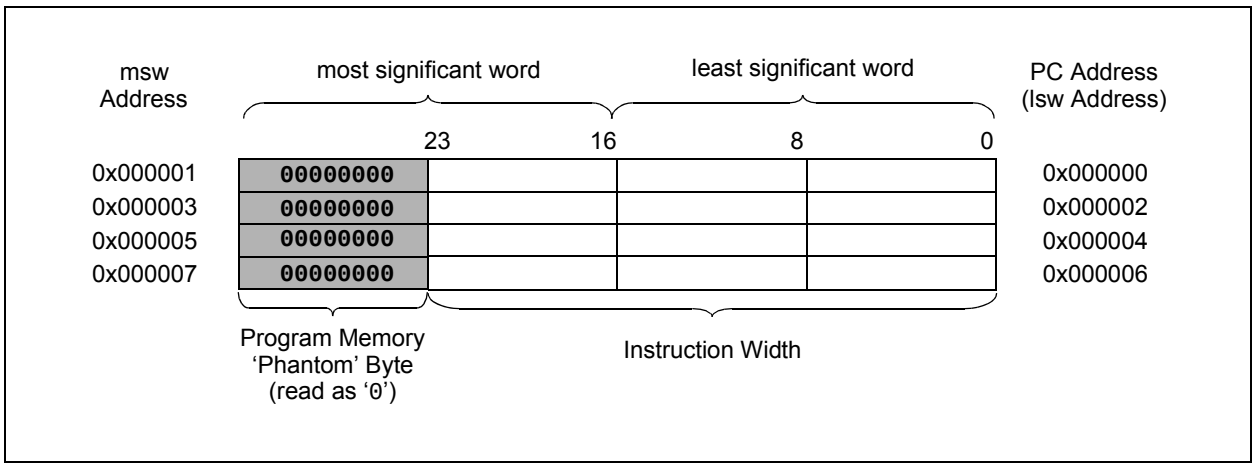
Program memory addresses are always word-aligned on the lower word, and addresses are incremented or decremented by two, during code execution. This arrangement provides compatibility with data memory space addressing and makes data in the program memory space accessible.

### 4.2.2 INTERRUPT AND TRAP VECTORS

All dsPIC33EPXXXGS70X/80X family devices reserve the addresses between 0x000000 and 0x000200 for hard-coded program execution vectors. A hardware Reset vector is provided to redirect code execution from the default value of the PC on device Reset to the actual start of code. A GOTO instruction is programmed by the user application at address, 0x000000, of Flash memory, with the actual address for the start of code at address, 0x000002, of Flash memory.

A more detailed discussion of the Interrupt Vector Tables (IVTs) is provided in **Section 7.1 "Interrupt Vector Table"**.

**FIGURE 4-5: PROGRAM MEMORY ORGANIZATION**





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## 4.3 Data Address Space

The dsPIC33EPXXXGS70X/80X family 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. The data memory map is shown in Figure 4-6.

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 base Data Space address range of 64 Kbytes or 32K words.

The lower half of the data memory space (i.e., when EA<15> = 0) is used for implemented memory addresses, while the upper half (EA<15> = 1) is reserved for the Program Space Visibility (PSV).

dsPIC33EPXXXGS70X/80X family devices implement up to 12 Kbytes of data memory. If an EA points to a location outside of this area, an all-zero word or byte is returned.

### 4.3.1 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 (LSBs) of each word have even addresses, while the Most Significant Bytes (MSBs) have odd addresses.

### 4.3.2 DATA MEMORY ORGANIZATION AND ALIGNMENT

To maintain backward compatibility with PIC® MCU devices and improve Data Space memory usage efficiency, the dsPIC33EPXXXGS70X/80X family 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++] results in a value of Ws + 1 for byte operations and Ws + 2 for word operations.

A data byte read, reads 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 that 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 the error occurred on a write, the instruction is executed but the write does not occur. In either case, a trap is then executed, allowing the system and/or user application to examine the machine state prior to execution of the address Fault.

All byte loads into any W register are loaded into the LSB; the MSB is not modified.

A Sign-Extend (SE) instruction is provided to allow user applications to translate 8-bit signed data to 16-bit signed values. Alternatively, for 16-bit unsigned data, user applications can clear the MSB of any W register by executing a Zero-Extend (ZE) instruction on the appropriate address.

### 4.3.3 SFR SPACE

The first 4 Kbytes of the Near Data Space, from 0x0000 to 0x0FFF, is primarily occupied by Special Function Registers (SFRs). These are used by the dsPIC33EPXXXGS70X/80X family core and peripheral modules for controlling the operation of the device.

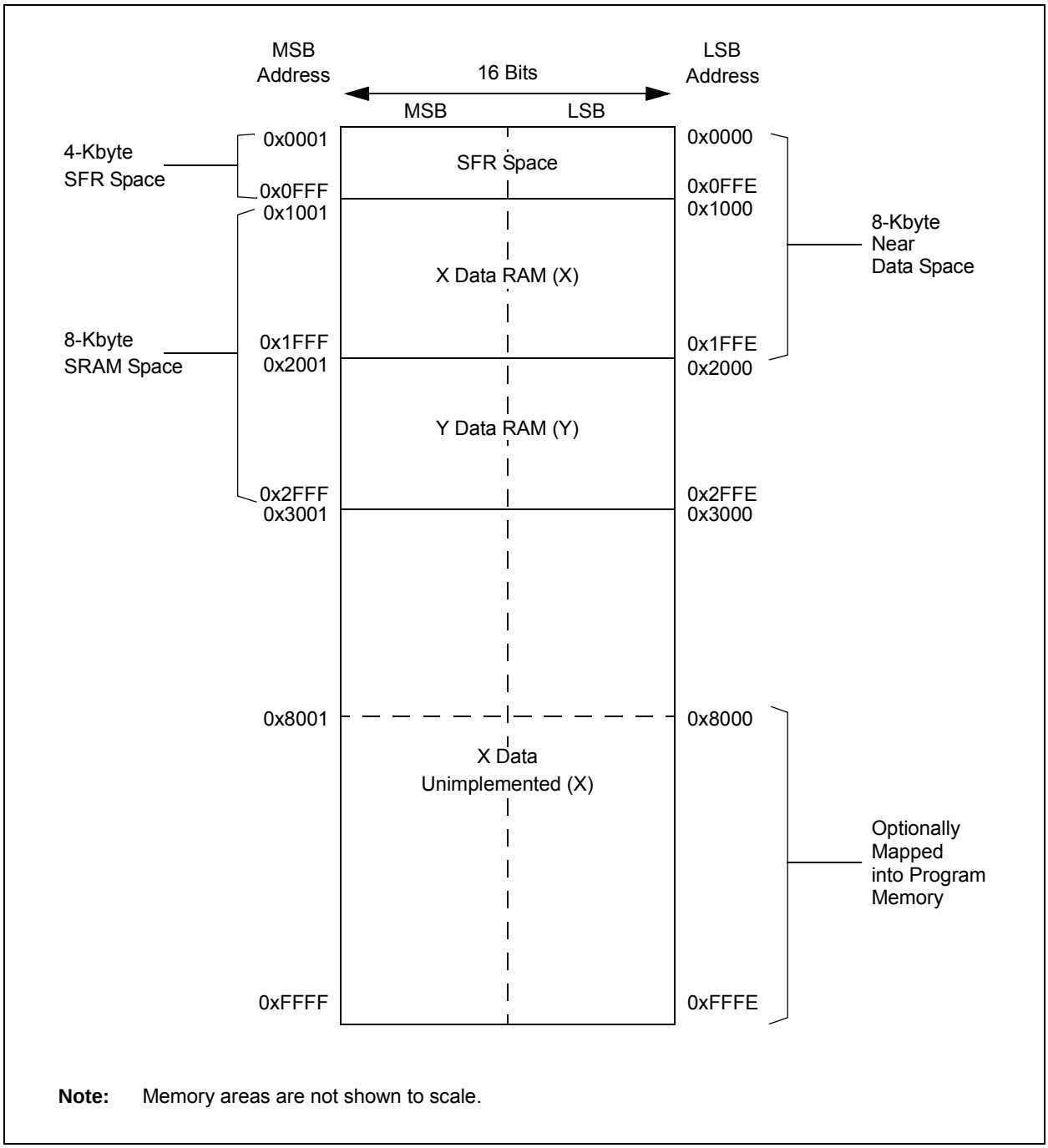
SFRs are distributed among the modules that they control and are generally grouped together by module. Much of the SFR space contains unused addresses; these are read as '0'.

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

### 4.3.4 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 through 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 4-6: DATA MEMORY MAP FOR dsPIC33EP64GS70X/80X DEVICES**




**Note:** Memory areas are not shown to scale.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#### 4.3.5 X AND Y DATA SPACES

The dsPIC33EPXXXGS70X/80X core has two Data Spaces, X and Y. These 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. This feature allows certain instructions to concurrently fetch two words from RAM, thereby enabling efficient execution of DSP algorithms, such as Finite Impulse Response (FIR) filtering and Fast Fourier Transform (FFT).

The X Data Space is used by all instructions and supports all addressing modes. X Data Space has separate read and write data buses. The X read data bus is the read data path for all instructions that view Data Space as combined X and Y address space. It is also the X data prefetch path for the dual operand DSP instructions (MAC class).

The Y Data Space is used in concert with the X Data Space by the MAC class of instructions (CLR, ED, EDAC, MAC, MOVSAC, MPY, MPY.N and MSC) to provide two concurrent data read paths.

Both the X and Y Data Spaces support Modulo Addressing mode for all instructions, subject to addressing mode restrictions. Bit-Reversed Addressing mode is only supported for writes to X Data Space.

All data memory writes, including in DSP instructions, view Data Space as combined X and Y address space. The boundary between the X and Y Data Spaces is device-dependent and is not user-programmable.

### 4.4 Memory 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 contains the latest updates and additional information.

#### 4.4.1 KEY RESOURCES

- **"dsPIC33E/PIC24E Program Memory"** (DS70000613) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

## 4.5 Special Function Register Maps

**TABLE 4-2: SFR BLOCK 000h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Core** | | | WREG14 | 01C | 0000000000000000 | DOSTARTL | 03A | xxxxxxxxxxxxxx0 |
| WREG0 | 000 | 0000000000000000 | WREG15 | 01E | 0000100000000000 | DOSTARTH | 03C | 0000000000xxxxxx |
| WREG1 | 002 | 0000000000000000 | SPLIM | 020 | xxxxxxxxxxxxxx0 | DOENDL | 03E | xxxxxxxxxxxxxx0 |
| WREG2 | 004 | 0000000000000000 | ACCAL | 022 | xxxxxxxxxxxxxxx | DOENDH | 040 | 0000000000xxxxxx |
| WREG3 | 006 | 0000000000000000 | ACCAH | 024 | xxxxxxxxxxxxxxx | SR | 042 | 0000000000000000 |
| WREG4 | 008 | 0000000000000000 | ACCAU | 026 | 00000000xxxxxxx | CORCON | 044 | 0000000000100000 |
| WREG5 | 00A | 0000000000000000 | ACCBL | 028 | xxxxxxxxxxxxxxx | MODCON | 046 | 0000000000000000 |
| WREG6 | 00C | 0000000000000000 | ACCBH | 02A | xxxxxxxxxxxxxxx | XMODSRT | 048 | xxxxxxxxxxxxxx0 |
| WREG7 | 00E | 0000000000000000 | ACCBU | 02C | 00000000xxxxxxx | XMODEND | 04A | xxxxxxxxxxxxxx1 |
| WREG8 | 010 | 0000000000000000 | PCL | 02E | 0000000000000000 | YMODSRT | 04C | xxxxxxxxxxxxxx0 |
| WREG9 | 012 | 0000000000000000 | PCH | 030 | 0000000000000000 | YMODEND | 04E | xxxxxxxxxxxxxx1 |
| WREG10 | 014 | 0000000000000000 | DSRPAG | 032 | 0000000000000001 | XBREV | 050 | xxxxxxxxxxxxxxx |
| WREG11 | 016 | 0000000000000000 | DSWPAG | 034 | 0000000000000001 | DISICNT | 052 | 00xxxxxxxxxxxxx |
| WREG12 | 018 | 0000000000000000 | RCOUNT | 036 | xxxxxxxxxxxxxxx | TBLPAG | 054 | 00000000xxxxxxx |
| WREG13 | 01A | 0000000000000000 | DCOUNT | 038 | xxxxxxxxxxxxxxx | CTXTSTAT | 05A | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-3: SFR BLOCK 100h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Timers** | | | TMR5HLD | 116 | xxxxxxxxxxxxxxx | IC2CON2 | 14A | 0000000000001101 |
| TMR1 | 100 | xxxxxxxxxxxxxxx | TMR5 | 118 | xxxxxxxxxxxxxxx | IC2BUF | 14C | xxxxxxxxxxxxxxx |
| PR1 | 102 | 1111111111111111 | PR4 | 11A | 1111111111111111 | IC2TMR | 14E | 0000000000000000 |
| T1CON | 104 | 0000000000000000 | PR5 | 11C | 1111111111111111 | IC3CON1 | 150 | 0000000000000000 |
| TMR2 | 106 | xxxxxxxxxxxxxxx | T4CON | 11E | 0000000000000000 | IC3CON2 | 152 | 0000000000001101 |
| TMR3HLD | 108 | xxxxxxxxxxxxxxx | T5CON | 120 | 0000000000000000 | IC3BUF | 154 | xxxxxxxxxxxxxxx |
| TMR3 | 10A | xxxxxxxxxxxxxxx | **Input Capture** | | | IC3TMR | 156 | 0000000000000000 |
| PR2 | 10C | 1111111111111111 | IC1CON1 | 140 | 0000000000000000 | IC4CON1 | 158 | 0000000000000000 |
| PR3 | 10E | 1111111111111111 | IC1CON2 | 142 | 0000000000001101 | IC4CON2 | 15A | 0000000000001101 |
| T2CON | 110 | 0000000000000000 | IC1BUF | 144 | xxxxxxxxxxxxxxx | IC4BUF | 15C | xxxxxxxxxxxxxxx |
| T3CON | 112 | 0000000000000000 | IC1TMR | 146 | 0000000000000000 | IC4TMR | 15E | 0000000000000000 |
| TMR4 | 114 | xxxxxxxxxxxxxxx | IC2CON1 | 148 | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-4: SFR BLOCK 200h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **I2C1 and I2C2** | | | U1STA | 222 | 0000000010010000 | SPI1BRGH | 252 | 0000000000000000 |
| I2C1CONL | 200 | 0001000000000000 | U1TXREG | 224 | 0000000xxxxxxxxx | SPI1IMSKL | 254 | 0000000000000000 |
| I2C1CONH | 202 | 0000000000000000 | U1RXREG | 226 | 0000000000000000 | SPI1IMSKH | 256 | 0000000000000000 |
| I2C1STAT | 204 | 0000000000000000 | U1BRG | 228 | 0000000000000000 | SPI1URDTL | 258 | 0000000000000000 |
| I2C1ADD | 206 | 0000000000000000 | U2MODE | 230 | 0000000000000000 | SPI1URDTH | 25A | 0000000000000000 |
| I2C1MSK | 208 | 0000000000000000 | U2STA | 232 | 0000000010010000 | SPI2CON1L | 260 | 0000000000000000 |
| I2C1BRG | 20A | 0000000000000000 | U2TXREG | 234 | 0000000xxxxxxxxx | SPI2CON1H | 262 | 0000000000000000 |
| I2C1TRN | 20C | 0000000011111111 | U2RXREG | 236 | 0000000000000000 | SPI2CON2L | 264 | 0000000000000000 |
| I2C1RCV | 20E | 0000000000000000 | U2BRG | 238 | 0000000000000000 | SPI2CON2H | 266 | 0000000000000000 |
| I2C2CON1 | 210 | 0001000000000000 | **SPI** | | | SPI2STATL | 268 | 0000000000101000 |
| I2C2CON2 | 212 | 0000000000000000 | SPI1CON1L | 240 | 0000000000000000 | SPI2STATH | 26A | 0000000000000000 |
| I2C2STAT | 214 | 0000000000000000 | SPI1CON1H | 242 | 0000000000000000 | SPI2BUFL | 26C | 0000000000000000 |
| I2C2ADD | 216 | 0000000000000000 | SPI1CON2L | 244 | 0000000000000000 | SPI2BUFH | 26E | 0000000000000000 |
| I2C2MSK | 218 | 0000000000000000 | SPI1CON2H | 246 | 0000000000000000 | SPI3STAT | 270 | 000xxxxxxxxxxxx |
| I2C2BRG | 21A | 0000000000000000 | SPI1STATL | 248 | 0000000000101000 | SPI2BRGH | 272 | 0000000000000000 |
| I2C2TRN | 21C | 0000000011111111 | SPI1STATH | 24A | 0000000000000000 | SPI2IMSKL | 274 | 0000000000000000 |
| I2C2RCV | 21E | 0000000000000000 | SPI1BUFL | 24C | 0000000000000000 | SPI2IMSKH | 276 | 0000000000000000 |
| **UART1 and UART2** | | | SPI1BUFH | 24E | 0000000000000000 | SPI2URDTL | 278 | 0000000000000000 |
| U1MODE | 220 | 0000000000000000 | SPI1BRGL | 250 | 000xxxxxxxxxxxx | SPI2URDTH | 27A | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-5: SFR BLOCK 300h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **ADC** | | | ADCMP0ENH | 33A | 0000000000000000 | ADTRIG4L | 390 | 0000000000000000 |
| ADCON1L | 300 | 0000000000000000 | ADCMP0LO | 33C | 0000000000000000 | ADTRIG4H | 392 | 0000000000000000 |
| ADCON1H | 302 | 0000000001100000 | ADCMP0HI | 33E | 0000000000000000 | ADCMP0CON | 3A0 | 0000000000000000 |
| ADCON2L | 304 | 0000000000000000 | ADCMP1ENL | 340 | 0000000000000000 | ADCMP1CON | 3A4 | 0000000000000000 |
| ADCON2H | 306 | 0000000000000000 | ADCMP1ENH | 342 | 0000000000000000 | ADBASE | 3C0 | 0000000000000000 |
| ADCON3L | 308 | 0000000000000000 | ADCMP1LO | 344 | 0000000000000000 | ADLVLTRGL | 3D0 | 0000000000000000 |
| ADCON3H | 30A | 0000000000000000 | ADCMP1HI | 346 | 0000000000000000 | ADLVLTRGH | 3D2 | 0000000000000000 |
| ADCON4L | 30C | 0000000000000000 | ADFL0DAT | 368 | 0000000000000000 | ADCORE0L | 3D4 | 0000000000000000 |
| ADCON4H | 30E | 0000000000000000 | ADFL0CON | 36A | 0000000000000000 | ADCORE0H | 3D6 | 0000001100000000 |
| ADMOD0L | 310 | 0000000000000000 | ADFL1DAT | 36C | 0000000000000000 | ADCORE1L | 3D8 | 0000000000000000 |
| ADMOD0H | 312 | 0000000000000000 | ADFL1CON | 36E | 0000000000000000 | ADCORE1H | 3DA | 0000001100000000 |
| ADMOD1L | 314 | 0000000000000000 | ADTRIG0L | 380 | 0000000000000000 | ADCORE2L | 3DC | 0000000000000000 |
| ADIEL | 320 | 0000000000000000 | ADTRIG0H | 382 | 0000000000000000 | ADCORE2H | 3DE | 0000001100000000 |
| ADIEH | 322 | 0000000000000000 | ADTRIG1L | 384 | 0000000000000000 | ADCORE3L | 3E0 | 0000000000000000 |
| ADCSS1L | 328 | 0000000000000000 | ADTRIG1H | 386 | 0000000000000000 | ADCORE3H | 3E2 | 0000001100000000 |
| ADCSS1H | 32A | 0000000000000000 | ADTRIG2L | 388 | 0000000000000000 | ADEIEL | 3F0 | 0000000000000000 |
| ADSTATL | 330 | 0000000000000000 | ADTRIG2H | 38A | 0000000000000000 | ADEIEH | 3F2 | 0000000000000000 |
| ADSTATH | 332 | 0000000000000000 | ADTRIG3L | 38C | 0000000000000000 | ADEISTATL | 3F8 | 0000000000000000 |
| ADCMP0ENL | 338 | 0000000000000000 | ADTRIG3H | 38E | 0000000000000000 | ADEISTATH | 3FA | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-6: SFR BLOCK 400h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **ADC** | | | C1FCTRL | 486 | 0000000000000000 | C1RXM2EID | 4BA | xxxxxxxxxxxxxxxx |
| ADCON5L | 400 | 0000000000000000 | C1FIFO | 488 | 0000000000000000 | C1RXF1SID | 4C4 | xxxxxxxxxxxxxxxx |
| ADCON5H | 402 | 0000000000000000 | C1INTF | 48A | 0000000000000000 | C1RXF1EID | 4C6 | xxxxxxxxxxxxxxxx |
| ADCAL0L | 404 | 0000000000000000 | C1INTE | 48C | 0000000000000000 | C1RXF2SID | 4C8 | xxxxxxxxxxxxxxxx |
| ADCAL0H | 406 | 0000000000000000 | C1EC | 48E | 0000000000000000 | C1RXF2EID | 4CA | xxxxxxxxxxxxxxxx |
| ADCAL1H | 40A | 0000000000000000 | C1CFG1 | 490 | 0000000000000000 | C1RXF3SID | 4CC | xxxxxxxxxxxxxxxx |
| ADCBUF0 | 40C | 0000000000000000 | C1CFG2 | 492 | 0x000xxxxxxxxxxx | C1RXF3EID | 4CE | xxxxxxxxxxxxxxxx |
| ADCBUF1 | 40E | 0000000000000000 | C1FEN1 | 494 | 1111111111111111 | C1RXF4SID | 4D0 | xxxxxxxxxxxxxxxx |
| ADCBUF2 | 410 | 0000000000000000 | C1FMSKSEL1 | 498 | 0000000000000000 | C1RXF4EID | 4D2 | xxxxxxxxxxxxxxxx |
| ADCBUF3 | 412 | 0000000000000000 | C1FMSKSEL2 | 49A | 0000000000000000 | C1RXF5SID | 4D4 | xxxxxxxxxxxxxxxx |
| ADCBUF4 | 414 | 0000000000000000 | **CAN (WIN (C1CTRL<0>) = 0)** | | | C1RXF5EID | 4D6 | xxxxxxxxxxxxxxxx |
| ADCBUF5 | 416 | 0000000000000000 | C1RXFUL1 | 4A0 | 0000000000000000 | C1RXF6SID | 4D8 | xxxxxxxxxxxxxxxx |
| ADCBUF6 | 418 | 0000000000000000 | C1RXFUL2 | 4A2 | 0000000000000000 | C1RXF6EID | 4DA | xxxxxxxxxxxxxxxx |
| ADCBUF7 | 41A | 0000000000000000 | C1RXOVF1 | 4A8 | 0000000000000000 | C1RXF7SID | 4DC | xxxxxxxxxxxxxxxx |
| ADCBUF8 | 41C | 0000000000000000 | C1RXOVF2 | 4AA | 0000000000000000 | C1RXF7EID | 4DE | xxxxxxxxxxxxxxxx |
| ADCBUF9 | 41E | 0000000000000000 | C1TR01CON | 4B0 | 0000000000000000 | C1RXF8SID | 4E0 | xxxxxxxxxxxxxxxx |
| ADCBUF10 | 420 | 0000000000000000 | C1TR23CON | 4B2 | 0000000000000000 | C1RXF8EID | 4E2 | xxxxxxxxxxxxxxxx |
| ADCBUF11 | 422 | 0000000000000000 | C1TR45CON | 4B4 | 0000000000000000 | C1RXF9SID | 4E4 | xxxxxxxxxxxxxxxx |
| ADCBUF12 | 424 | 0000000000000000 | C1TR67CON | 4B6 | xxxxxxxxxxxxxxxx | C1RXF9EID | 4E6 | xxxxxxxxxxxxxxxx |
| ADCBUF13 | 426 | 0000000000000000 | C1RXD | 4C0 | xxxxxxxxxxxxxxxx | C1RXF10SID | 4E8 | xxxxxxxxxxxxxxxx |
| ADCBUF14 | 428 | 0000000000000000 | C1TXD | 4C2 | xxxxxxxxxxxxxxxx | C1RXF10EID | 4EA | xxxxxxxxxxxxxxxx |
| ADCBUF15 | 42A | 0000000000000000 | **CAN (WIN (C1CTR1<0>) = 1)** | | | C1RXF11SID | 4EC | xxxxxxxxxxxxxxxx |
| ADCBUF16 | 42C | 0000000000000000 | C1BUFPNT1 | 4A0 | 0000000000000000 | C1RXF11EID | 4EE | xxxxxxxxxxxxxxxx |
| ADCBUF17 | 42E | 0000000000000000 | C1BUFPNT2 | 4A2 | 0000000000000000 | C1RXF12SID | 4F0 | xxxxxxxxxxxxxxxx |
| ADCBUF18 | 430 | 0000000000000000 | C1BUFPNT3 | 4A4 | 0000000000000000 | C1RXF12EID | 4F2 | xxxxxxxxxxxxxxxx |
| ADCBUF19 | 432 | 0000000000000000 | C1BUFPNT4 | 4A6 | 0000000000000000 | C1RXF13SID | 4F4 | xxxxxxxxxxxxxxxx |
| ADCBUF20 | 434 | 0000000000000000 | C1RXM0SID | 4B0 | xxxxxxxxxxxxxxxx | C1RXF13EID | 4F6 | xxxxxxxxxxxxxxxx |
| ADCBUF21 | 436 | 0000000000000000 | C1RXM0EID | 4B2 | xxxxxxxxxxxxxxxx | C1RXF14SID | 4F8 | xxxxxxxxxxxxxxxx |
| **CAN (WIN (C1CTRL<0>) = 0 OR 1)** | | | C1RXM1SID | 4B4 | xxxxxxxxxxxxxxxx | C1RXF14EID | 4FA | xxxxxxxxxxxxxxxx |
| C1CTRL1 | 480 | 000010010000000 | C1RXM1EID | 4B6 | xxxxxxxxxxxxxxxx | C1RXF15SID | 4FC | xxxxxxxxxxxxxxxx |
| C1CTRL2 | 482 | 000000000000000 | **CAN** | | | C1RXF15EID | 4FE | xxxxxxxxxxxxxxxx |
| C1VEC | 484 | 000000001000000 | C1RXM2SID | 4B8 | xxxxxxxxxxxxxxxx | | | |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-7: SFR BLOCK 500h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **PGA** | | | PGA2CAL | 50A | 0000000000000000 | CMP2DAC | 546 | 0000000000000000 |
| ISRCCON | 500 | 0000000000000000 | **Comparators** | | | CMP3CON | 548 | 0000000000000000 |
| PGA1CON | 504 | 0000000000000000 | CMP1CON | 540 | 0000000000000000 | CMP3DAC | 54A | 0000000000000000 |
| PGA1CAL | 506 | 0000000000000000 | CMP1DAC | 542 | 0000000000000000 | CMP4CON | 54C | 0000000000000000 |
| PGA2CON | 508 | 0000000000000000 | CMP2CON | 544 | 0000000000000000 | CMP4DAC | 54E | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-8: SFR BLOCK 600h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **SPI** | | | RPOR8 | 678 | 0000000000000000 | RPINR7 | 6AE | 0000000000000000 |
| SPI3CON1L | 600 | 0000000000000000 | RPOR9 | 67A | 0000000000000000 | RPINR8 | 6B0 | 0000000000000000 |
| SPI3CON1H | 602 | 0000000000000000 | RPOR10 | 67C | 0000000000000000 | RPINR11 | 6B6 | 0000000000000000 |
| SPI3CON2L | 604 | 0000000000000000 | RPOR11 | 67E | 0000000000000000 | RPINR12 | 6B8 | 0000000000000000 |
| SPI3CON2H | 606 | 0000000000000000 | RPOR12 | 680 | 0000000000000000 | RPINR13 | 6BA | 0000000000000000 |
| SPI3STATL | 608 | 0000000000101000 | RPOR13 | 682 | 0000000000000000 | RPINR18 | 6C4 | 0000000000000000 |
| SPI3STATH | 60A | 0000000000000000 | RPOR14 | 684 | 0000000000000000 | RPINR19 | 6C6 | 0000000000000000 |
| SPI3BUFL | 60C | 0000000000000000 | RPOR15 | 686 | 0000000000000000 | RPINR20 | 6C8 | 0000000000000000 |
| SPI3BUFH | 60E | 0000000000000000 | RPOR17 | 68A | 0000000000000000 | RPINR21 | 6CA | 0000000000000000 |
| SPI3BRGL | 610 | 000xxxxxxxxxxxx | RPOR18 | 68C | 0000000000000000 | RPINR22 | 6CC | 0000000000000000 |
| SPI3BRGH | 612 | 0000000000000000 | RPOR19 | 68E | 0000000000000000 | RPINR23 | 6CE | 0000000000000000 |
| SPI3IMSKL | 614 | 0000000000000000 | RPOR20 | 690 | 0000000000000000 | RPINR26 | 6D4 | 0000000000000000 |
| SPI3IMSKH | 616 | 0000000000000000 | RPOR21 | 692 | 0000000000000000 | RPINR29 | 6DA | 0000000000000000 |
| SPI3URDTL | 618 | 0000000000000000 | RPOR22 | 694 | 0000000000000000 | RPINR30 | 6DC | 0000000000000000 |
| SPI3URDTH | 61A | 0000000000000000 | RPOR23 | 696 | 0000000000000000 | RPINR37 | 6EA | 0000000000000000 |
| RPOR0 | 668 | 0000000000000000 | RPOR24 | 698 | 0000000000000000 | RPINR38 | 6EC | 0000000000000000 |
| RPOR1 | 66A | 0000000000000000 | RPOR25 | 69A | 0000000000000000 | RPINR42 | 6F4 | 0000000000000000 |
| RPOR2 | 66C | 0000000000000000 | RPOR26 | 69C | 0000000000000000 | RPINR43 | 6F6 | 0000000000000000 |
| RPOR3 | 66E | 0000000000000000 | RPINR0 | 6A0 | 0000000000000000 | RPINR45 | 6FA | 0000000000000000 |
| RPOR4 | 670 | 0000000000000000 | RPINR1 | 6A2 | 0000000000000000 | RPINR46 | 6FC | 0000000000000000 |
| RPOR5 | 672 | 0000000000000000 | RPINR2 | 6A4 | 0000000000000000 | | | |
| RPOR6 | 674 | 0000000000000000 | RPINR3 | 6A6 | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-9: SFR BLOCK 700h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **NVM** | | | C2INTF | 78A | 0000000000000000 | C2RXF1SID | 7C4 | xxxxxxxxxxxxxxxx |
| NVMCON | 728 | 0000000000000000 | C2INTE | 78C | 0000000000000000 | C2RXF1EID | 7C6 | xxxxxxxxxxxxxxxx |
| NVMADR | 72A | 0000000000000000 | C2EC | 78E | 0000000000000000 | C2RXF2SID | 7C8 | xxxxxxxxxxxxxxxx |
| NVMADRU | 72C | 0000000000000000 | C2CFG1 | 790 | 0000000000000000 | C2RXF2EID | 7CA | xxxxxxxxxxxxxxxx |
| NVMKEY | 72E | 0000000000000000 | C2CFG2 | 792 | 0x000xxxxxxxxxxx | C2RXF3SID | 7CC | xxxxxxxxxxxxxxxx |
| NVMSRCADR | 730 | 0000000000000000 | C2FEN1 | 794 | 1111111111111111 | C2RXF3EID | 7CE | xxxxxxxxxxxxxxxx |
| NVMSRCADRH | 732 | 0000000000000000 | C2FMSKSEL1 | 798 | 0000000000000000 | C2RXF4SID | 7D0 | xxxxxxxxxxxxxxxx |
| **System Control** | | | C2FMSKSEL2 | 79A | 0000000000000000 | C2RXF4EID | 7D2 | xxxxxxxxxxxxxxxx |
| RCON | 740 | 0x00x0x01x0xxxxx | **CAN (WIN (C1CTR1<0>) = 0)** | | | C2RXF5SID | 7D4 | xxxxxxxxxxxxxxxx |
| OSCCON | 742 | 0000000000000000 | C2RXFUL1 | 7A0 | 0000000000000000 | C2RXF5EID | 7D6 | xxxxxxxxxxxxxxxx |
| CLKDIV | 744 | 0000000000000000 | C2RXFUL2 | 7A2 | 0000000000000000 | C2RXF6SID | 7D8 | xxxxxxxxxxxxxxxx |
| PLLFBD | 746 | 0000000000000000 | C2RXOVF1 | 7A8 | 0000000000000000 | C2RXF6EID | 7DA | xxxxxxxxxxxxxxxx |
| OSCTUN | 748 | 0000000000000000 | C2RXOVF2 | 7AA | 0000000000000000 | C2RXF7SID | 7DC | xxxxxxxxxxxxxxxx |
| LFSR | 74C | 0000000000000000 | C2TR01CON | 7B0 | 0000000000000000 | C2RXF7EID | 7DE | xxxxxxxxxxxxxxxx |
| REFOCON | 74E | 0000000000000000 | C2TR23CON | 7B2 | 0000000000000000 | C2RXF8SID | 7E0 | xxxxxxxxxxxxxxxx |
| ACLKCON | 750 | 0000000000000000 | C2TR45CON | 7B4 | 0000000000000000 | C2RXF8EID | 7E2 | xxxxxxxxxxxxxxxx |
| **PMD** | | | C2TR67CON | 7B6 | xxxxxxxxxxxxxxxx | C2RXF9SID | 7E4 | xxxxxxxxxxxxxxxx |
| PMD1 | 760 | 0000000000000000 | C2RXD | 7C0 | xxxxxxxxxxxxxxxx | C2RXF9EID | 7E6 | xxxxxxxxxxxxxxxx |
| PMD2 | 762 | 0000000000000000 | C2TXD | 7C2 | xxxxxxxxxxxxxxxx | C2RXF10SID | 7E8 | xxxxxxxxxxxxxxxx |
| PMD3 | 764 | 0000000000000000 | **CAN (WIN (C1CTR1<0>) = 1)** | | | C2RXF10EID | 7EA | xxxxxxxxxxxxxxxx |
| PMD4 | 766 | 0000000000000000 | C2BUFPNT1 | 7A0 | 0000000000000000 | C2RXF11SID | 7EC | xxxxxxxxxxxxxxxx |
| PMD6 | 76A | 0000000000000000 | C2BUFPNT2 | 7A2 | 0000000000000000 | C2RXF11EID | 7EE | xxxxxxxxxxxxxxxx |
| PMD7 | 76C | 0000000000000000 | C2BUFPNT3 | 7A4 | 0000000000000000 | C2RXF12SID | 7F0 | xxxxxxxxxxxxxxxx |
| PMD8 | 76E | 0000000000000000 | C2BUFPNT4 | 7A6 | 0000000000000000 | C2RXF12EID | 7F2 | xxxxxxxxxxxxxxxx |
| **CAN (WIN (C1CTR1<0>) = 0 or 1)** | | | C2RXM0SID | 7B0 | xxxxxxxxxxxxxxxx | C2RXF13SID | 7F4 | xxxxxxxxxxxxxxxx |
| C2CTRL1 | 780 | 0000010010000000 | C2RXM0EID | 7B2 | xxxxxxxxxxxxxxxx | C2RXF13EID | 7F6 | xxxxxxxxxxxxxxxx |
| C2CTRL2 | 782 | 0000000000000000 | C2RXM1SID | 7B4 | xxxxxxxxxxxxxxxx | C2RXF14SID | 7F8 | xxxxxxxxxxxxxxxx |
| C2VEC | 784 | 0000000001000000 | C2RXM1EID | 7B6 | xxxxxxxxxxxxxxxx | C2RXF14EID | 7FA | xxxxxxxxxxxxxxxx |
| C2FCTRL | 786 | 0000000000000000 | C2RXM2SID | 7B8 | xxxxxxxxxxxxxxxx | C2RXF15SID | 7FC | xxxxxxxxxxxxxxxx |
| C2FIFO | 788 | 0000000000000000 | C2RXM2EID | 7BA | xxxxxxxxxxxxxxxx | C2RXF15EID | 7FE | xxxxxxxxxxxxxxxx |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-10: SFR BLOCK 800h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Interrupt Controller** | | | IEC9 | 832 | 0000000000000000 | IPC26 | 874 | 0000000001000100 |
| IFS0 | 800 | 0000000000000000 | IEC10 | 834 | 0000000000000000 | IPC27 | 876 | 0100010000000000 |
| IFS1 | 802 | 0000000000000000 | IEC11 | 836 | 0000000000000000 | IPC28 | 878 | 0100010001000100 |
| IFS2 | 804 | 0000000000000000 | IPC0 | 840 | 0100010001000100 | IPC29 | 87A | 0000000001000100 |
| IFS3 | 806 | 0000000000000000 | IPC1 | 842 | 0100010001000000 | IPC35 | 886 | 0100010000000000 |
| IFS4 | 808 | 0000000000000000 | IPC2 | 844 | 0100010001000100 | IPC36 | 888 | 0000000000000000 |
| IFS5 | 80A | 0000000000000000 | IPC3 | 846 | 0100000001000100 | IPC37 | 88A | 0100000000000000 |
| IFS6 | 80C | 0000000000000000 | IPC4 | 848 | 0100010001000100 | IPC38 | 88C | 0100010001000100 |
| IFS7 | 80E | 0000000000000000 | IPC5 | 84A | 0000000000000100 | IPC39 | 88E | 0100010001000100 |
| IFS8 | 810 | 0000000000000000 | IPC6 | 84C | 0100010001000000 | IPC40 | 890 | 0100010001000100 |
| IFS9 | 812 | 0000000000000000 | IPC7 | 84E | 0100010001000100 | IPC41 | 892 | 0100010001000100 |
| IFS10 | 814 | 0000000000000000 | IPC8 | 850 | 0000000001000100 | IPC42 | 894 | 0000000001000100 |
| IFS11 | 816 | 0000000000000000 | IPC9 | 852 | 0000010001000000 | IPC43 | 896 | 0000010001000000 |
| IEC0 | 820 | 0000000000000000 | IPC11 | 856 | 0000000000000000 | IPC44 | 898 | 0100010001000000 |
| IEC1 | 822 | 0000000000000000 | IPC12 | 858 | 0000010001000000 | IPC45 | 89A | 0000000000000100 |
| IEC2 | 824 | 0000000000000000 | IPC13 | 85A | 0000010000000000 | IPC46 | 89C | 0100010000000000 |
| IEC3 | 826 | 0000000000000000 | IPC14 | 85C | 0000000001000000 | IPC47 | 89E | 0000010001000100 |
| IEC4 | 828 | 0000000000000000 | IPC16 | 860 | 0000010001000000 | INTCON1 | 8C0 | 0000000000000000 |
| IEC5 | 82A | 0000000000000000 | IPC18 | 864 | 0000000001000000 | INTCON2 | 8C2 | 0000000000000000 |
| IEC6 | 82C | 0000000000000000 | IPC23 | 86E | 0100010000000000 | INTCON3 | 8C4 | 0000000000000000 |
| IEC7 | 82E | 0000000000000000 | IPC24 | 870 | 0000010001000100 | INTCON4 | 8C6 | 0000000000000000 |
| IEC8 | 830 | 0000000000000000 | IPC25 | 872 | 0100000000000000 | INTTREG | 8C8 | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-11: SFR BLOCK 900h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Output Compare** | | | OC3R | 91A | xxxxxxxxxxxxxxxx | CLC2CONH | 9CE | 0000000000000000 |
| OC1CON1 | 900 | 0000000000000000 | OC3TMR | 91C | 0000000000000000 | CLC2SEL | 9D0 | 0000000000000000 |
| OC1CON2 | 902 | 0000000000001100 | OC4CON1 | 91E | 0000000000000000 | CLC2GLSL | 9D4 | 0000000000000000 |
| OC1RS | 904 | xxxxxxxxxxxxxxxx | OC4CON2 | 920 | 0000000000001100 | CLC2GLSH | 9D6 | 0000000000000000 |
| OC1R | 906 | xxxxxxxxxxxxxxxx | OC4RS | 922 | xxxxxxxxxxxxxxxx | CLC3CONL | 9D8 | 0000000000000000 |
| OC1TMR | 908 | 0000000000000000 | OC4R | 924 | xxxxxxxxxxxxxxxx | CLC3CONH | 9DA | 0000000000000000 |
| OC2CON1 | 90A | 0000000000000000 | OC4TMR | 926 | 0000000000000000 | CLC3SEL | 9DC | 0000000000000000 |
| OC2CON2 | 90C | 0000000000001100 | **CLC** | | | CLC3GLSL | 9E0 | 0000000000000000 |
| OC2RS | 90E | xxxxxxxxxxxxxxxx | CLC1CONL | 9C0 | 0000000000000000 | CLC3GLSH | 9E2 | 0000000000000000 |
| OC2R | 910 | xxxxxxxxxxxxxxxx | CLC1CONH | 9C2 | 0000000000000000 | CLC4CONL | 9E4 | 0000000000000000 |
| OC2TMR | 912 | 0000000000000000 | CLC1SEL | 9C4 | 0000000000000000 | CLC4CONH | 9E6 | 0000000000000000 |
| OC3CON1 | 914 | 0000000000000000 | CLC1GLSL | 9C8 | 0000000000000000 | CLC4SEL | 9E8 | 0000000000000000 |
| OC3CON2 | 916 | 0000000000001100 | CLC1GLSH | 9CA | 0000000000000000 | CLC4GLSL | 9EC | 0000000000000000 |
| OC3RS | 918 | xxxxxxxxxxxxxxxx | CLC2CONL | 9CC | 0000000000000000 | CLC4GLSH | 9EE | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-12: SFR BLOCK A00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **PTG** | | | PTGADJ | AD2 | 0000000000000000 | PTGQUE7 | AE6 | xxxxxxxxxxxxxxxx |
| PTGCST | AC0 | 0000000000000000 | PTGL0 | AD4 | 0000000000000000 | PTGQUE8 | AE8 | xxxxxxxxxxxxxxxx |
| PTGCON | AC2 | 0000000000000000 | PTGQPTR | AD6 | 0000000000000000 | PTGQUE9 | AEA | xxxxxxxxxxxxxxxx |
| PTGBTE | AC4 | 0000000000000000 | PTGQUE0 | AD8 | xxxxxxxxxxxxxxxx | PTGQUE10 | AEC | xxxxxxxxxxxxxxxx |
| PTGHOLD | AC6 | 0000000000000000 | PTGQUE1 | ADA | xxxxxxxxxxxxxxxx | PTGQUE11 | AEE | xxxxxxxxxxxxxxxx |
| PTGT0LIM | AC8 | 0000000000000000 | PTGQUE2 | ADC | xxxxxxxxxxxxxxxx | PTGQUE12 | AF0 | xxxxxxxxxxxxxxxx |
| PTGT1LIM | ACA | 0000000000000000 | PTGQUE3 | ADE | xxxxxxxxxxxxxxxx | PTGQUE13 | AF2 | xxxxxxxxxxxxxxxx |
| PTGSDLIM | ACC | 0000000000000000 | PTGQUE4 | AE0 | xxxxxxxxxxxxxxxx | PTGQUE14 | AF4 | xxxxxxxxxxxxxxxx |
| PTGC0LIM | ACE | 0000000000000000 | PTGQUE5 | AE2 | xxxxxxxxxxxxxxxx | PTGQUE15 | AF6 | xxxxxxxxxxxxxxxx |
| PTGC1LIM | AD0 | 0000000000000000 | PTGQUE6 | AE4 | xxxxxxxxxxxxxxxx | | | |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-13: SFR BLOCK B00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **DMA** | | | DMA1STBL | B18 | 0000000000000000 | DMA3REQ | B32 | 0000000000000000 |
| DMA0CON | B00 | 0000000000000000 | DMA1STBH | B1A | 0000000000000000 | DMA3STAL | B34 | 0000000000000000 |
| DMA0REQ | B02 | 0000000000000000 | DMA1PAD | B1C | 0000000000000000 | DMA3STAH | B36 | 0000000000000000 |
| DMA0STAL | B04 | 0000000000000000 | DMA1CNT | B1E | 0000000000000000 | DMA3STBL | B38 | 0000000000000000 |
| DMA0STAH | B06 | 0000000000000000 | DMA2CON | B20 | 0000000000000000 | DMA3STBH | B3A | 0000000000000000 |
| DMA0STBL | B08 | 0000000000000000 | DMA2REQ | B22 | 0000000000000000 | DMA3PAD | B3C | 0000000000000000 |
| DMA0STBH | B0A | 0000000000000000 | DMA2STAL | B24 | 0000000000000000 | DMA3CNT | B3E | 0000000000000000 |
| DMA0PAD | B0C | 0000000000000000 | DMA2STAH | B26 | 0000000000000000 | DMAPWC | BF0 | 0000000000000000 |
| DMA0CNT | B0E | 0000000000000000 | DMA2STBL | B28 | 0000000000000000 | DMARQC | BF2 | 0000000000000000 |
| DMA1CON | B10 | 0000000000000000 | DMA2STBH | B2A | 0000000000000000 | DMAPPS | BF4 | 0000000000000000 |
| DMA1REQ | B12 | 0000000000000000 | DMA2PAD | B2C | 0000000000000000 | DMALCA | BF6 | 0000000000001111 |
| DMA1STAL | B14 | 0000000000000000 | DMA2CNT | B2E | 0000000000000000 | DSADRL | BF8 | 0000000000000000 |
| DMA1STAH | B16 | 0000000000000000 | DMA3CON | B30 | 0000000000000000 | DSADRH | BFA | 0000000000000000 |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-14: SFR BLOCK C00h-D00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **PWM** | | | FCLCON3 | C64 | 0000000000000000 | IOCON6 | CC2 | 1100000000000000 |
| PTCON | C00 | 0000000000000000 | PDC3 | C66 | 0000000000000000 | FCLCON6 | CC4 | 0000000000000000 |
| PTCON2 | C02 | 0000000000000000 | PHASE3 | C68 | 0000000000000000 | PDC6 | CC6 | 0000000000000000 |
| PTPER | C04 | 1111111111111000 | DTR3 | C6A | 0000000000000000 | PHASE6 | CC8 | 0000000000000000 |
| SEVTCMP | C06 | 0000000000000000 | ALTDTR3 | C6C | 0000000000000000 | DTR6 | CCA | 0000000000000000 |
| MDC | C0A | 0000000000000000 | SDC3 | C6E | 0000000000000000 | ALTDTR6 | CCC | 0000000000000000 |
| STCON | C0E | 0000000000000000 | SPHASE3 | C70 | 0000000000000000 | SDC6 | CCE | 0000000000000000 |
| STCON2 | C10 | 0000000000000000 | TRIG3 | C72 | 0000000000000000 | SPHASE6 | CD0 | 0000000000000000 |
| STPER | C12 | 1111111111111000 | TRGCON3 | C74 | 0000000000000000 | TRIG6 | CD2 | 0000000000000000 |
| SSEVTCMP | C14 | 0000000000000000 | STRIG3 | C76 | 0000000000000000 | TRGCON6 | CD4 | 0000000000000000 |
| CHOP | C1A | 0000000000000000 | PWMCAP3 | C78 | 0000000000000000 | STRIG6 | CD6 | 0000000000000000 |
| PWMKEY | C1E | xxxxxxxxxxxxxxxx | LEBCON3 | C7A | 0000000000000000 | PWMCAP6 | CD8 | 0000000000000000 |
| **PWM Generator** | | | LEBDLY3 | C7C | 0000000000000000 | LEBCON6 | CDA | 0000000000000000 |
| PWMCON1 | C20 | 0000000000000000 | AUXCON3 | C7E | 0000000000000000 | LEBDLY6 | CDC | 0000000000000000 |
| IOCON1 | C22 | 1100000000000000 | PWMCON4 | C80 | 0000000000000000 | AUXCON6 | CDE | 0000000000000000 |
| FCLCON1 | C24 | 0000000000000000 | IOCON4 | C82 | 1100000000000000 | PWMCON7 | CE0 | 0000000000000000 |
| PDC1 | C26 | 0000000000000000 | FCLCON4 | C84 | 0000000000000000 | IOCON7 | CE2 | 1100000000000000 |
| PHASE1 | C28 | 0000000000000000 | PDC4 | C86 | 0000000000000000 | FCLCON7 | CE4 | 0000000000000000 |
| DTR1 | C2A | 0000000000000000 | PHASE4 | C88 | 0000000000000000 | PDC7 | CE6 | 0000000000000000 |
| ALTDTR1 | C2C | 0000000000000000 | DTR4 | C8A | 0000000000000000 | PHASE7 | CE8 | 0000000000000000 |
| SDC1 | C2E | 0000000000000000 | ALTDTR4 | C8C | 0000000000000000 | DTR7 | CEA | 0000000000000000 |
| SPHASE1 | C30 | 0000000000000000 | SDC4 | C8E | 0000000000000000 | ALTDTR7 | CEC | 0000000000000000 |
| TRIG1 | C32 | 0000000000000000 | SPHASE4 | C90 | 0000000000000000 | SDC7 | CEE | 0000000000000000 |
| TRGCON1 | C34 | 0000000000000000 | TRIG4 | C92 | 0000000000000000 | SPHASE7 | CF0 | 0000000000000000 |
| STRIG1 | C36 | 0000000000000000 | TRGCON4 | C94 | 0000000000000000 | TRIG7 | CF2 | 0000000000000000 |
| PWMCAP1 | C38 | 0000000000000000 | STRIG4 | C96 | 0000000000000000 | TRGCON7 | CF4 | 0000000000000000 |
| LEBCON1 | C3A | 0000000000000000 | PWMCAP4 | C98 | 0000000000000000 | STRIG7 | CF6 | 0000000000000000 |
| LEBDLY1 | C3C | 0000000000000000 | LEBCON4 | C9A | 0000000000000000 | PWMCAP7 | CF8 | 0000000000000000 |
| AUXCON1 | C3E | 0000000000000000 | LEBDLY4 | C9C | 0000000000000000 | LEBCON7 | CFA | 0000000000000000 |
| PWMCON2 | C40 | 0000000000000000 | AUXCON4 | C9E | 0000000000000000 | LEBDLY7 | CFC | 0000000000000000 |
| IOCON2 | C42 | 1100000000000000 | PWMCON5 | CA0 | 0000000000000000 | AUXCON7 | CFE | 0000000000000000 |
| FCLCON2 | C44 | 0000000000000000 | IOCON5 | CA2 | 1100000000000000 | PWMCON8 | D00 | 0000000000000000 |
| PDC2 | C46 | 0000000000000000 | FCLCON5 | CA4 | 0000000000000000 | IOCON8 | D02 | 1100000000000000 |
| PHASE2 | C48 | 0000000000000000 | PDC5 | CA6 | 0000000000000000 | FCLCON8 | D04 | 0000000000000000 |
| DTR2 | C4A | 0000000000000000 | PHASE5 | CA8 | 0000000000000000 | PDC8 | D06 | 0000000000000000 |
| ALTDTR2 | C4C | 0000000000000000 | DTR5 | CAA | 0000000000000000 | PHASE8 | D08 | 0000000000000000 |
| SDC2 | C4E | 0000000000000000 | ALTDTR5 | CAC | 0000000000000000 | ALTDTR8 | D0C | 0000000000000000 |
| SPHASE2 | C50 | 0000000000000000 | SDC5 | CAE | 0000000000000000 | SDC8 | D0E | 0000000000000000 |
| TRIG2 | C52 | 0000000000000000 | SPHASE5 | CB0 | 0000000000000000 | SPHASE8 | D10 | 0000000000000000 |
| TRGCON2 | C54 | 0000000000000000 | TRIG5 | CB2 | 0000000000000000 | TRIG8 | D12 | 0000000000000000 |
| STRIG2 | C56 | 0000000000000000 | TRGCON5 | CB4 | 0000000000000000 | TRGCON8 | D14 | 0000000000000000 |
| PWMCAP2 | C58 | 0000000000000000 | STRIG5 | CB6 | 0000000000000000 | STRIG8 | D16 | 0000000000000000 |
| LEBCON2 | C5A | 0000000000000000 | PWMCAP5 | CB8 | 0000000000000000 | PWMCAP8 | D18 | 0000000000000000 |
| LEBDLY2 | C5C | 0000000000000000 | LEBCON5 | CBA | 0000000000000000 | LEBCON8 | D1A | 0000000000000000 |
| AUXCON2 | C5E | 0000000000000000 | LEBDLY5 | CBC | 0000000000000000 | LEBDLY8 | D1C | 0000000000000000 |
| PWMCON3 | C60 | 0000000000000000 | AUXCON5 | CBE | 0000000000000000 | AUXCON8 | D1E | 0000000000000000 |
| IOCON3 | C62 | 1100000000000000 | PWMCON6 | CC0 | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-15: SFR BLOCK E00h-F00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **PORTA** | | | ANSELB | E1E | 0000001011101111 | CNPDD | E3C | 0000000000000000 |
| TRISA | E00 | 0000000000011111 | **PORTC** | | | ANSELD | E3E | 0110000110100000 |
| PORTA | E02 | 0000000000000000 | TRISC | E20 | 0111011111111111 | **PORTE** | | |
| LATA | E04 | 0000000000000000 | PORTC | E22 | 0000000000000000 | TRISE | E40 | 1111111111111111 |
| ODCA | E06 | 0000000000000000 | LATC | E24 | 0000000000000000 | PORTE | E42 | 0000000000000000 |
| CNENA | E08 | 0000000000000000 | ODCC | E26 | 0000000000000000 | LATE | E44 | 0000000000000000 |
| CNPUA | E0A | 0000000000000000 | CNENC | E28 | 0000000000000000 | ODCE | E46 | 0000000000000000 |
| CNPDA | E0C | 0000000000000000 | CNPUC | E2A | 0000000000000000 | CNENE | E48 | 0000000000000000 |
| ANSELA | E0E | 0000000000000111 | CNPDC | E2C | 0000000000000000 | CNPUE | E4A | 0000000000000000 |
| **PORTB** | | | ANSELC | E2E | 0001011001110111 | CNPDE | E4C | 0000000000000000 |
| TRISB | E10 | 0111101111111111 | **PORTD** | | | ANSELE | E4E | 1100000100000000 |
| PORTB | E12 | 0000000000000000 | TRISD | E30 | 1111111111111111 | **CPU** | | |
| LATB | E14 | 0000000000000000 | PORTD | E32 | 0000000000000000 | VISI | F88 | 0000000000000000 |
| ODCB | E16 | 0000000000000000 | LATD | E34 | 0000000000000000 | **JTAG** | | |
| CNENB | E18 | 0000000000000000 | ODCD | E36 | 0000000000000000 | JDATAH | FF0 | 0000000000000000 |
| CNPUB | E1A | 0000000000000000 | CNEND | E38 | 0000000000000000 | JDATAL | FF2 | 0000000000000000 |
| CNPDB | E1C | 0000000000000000 | CNPUD | E3A | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value. Address values are in hexadecimal. Reset values are in binary.


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### 4.5.1 PAGED MEMORY SCHEME

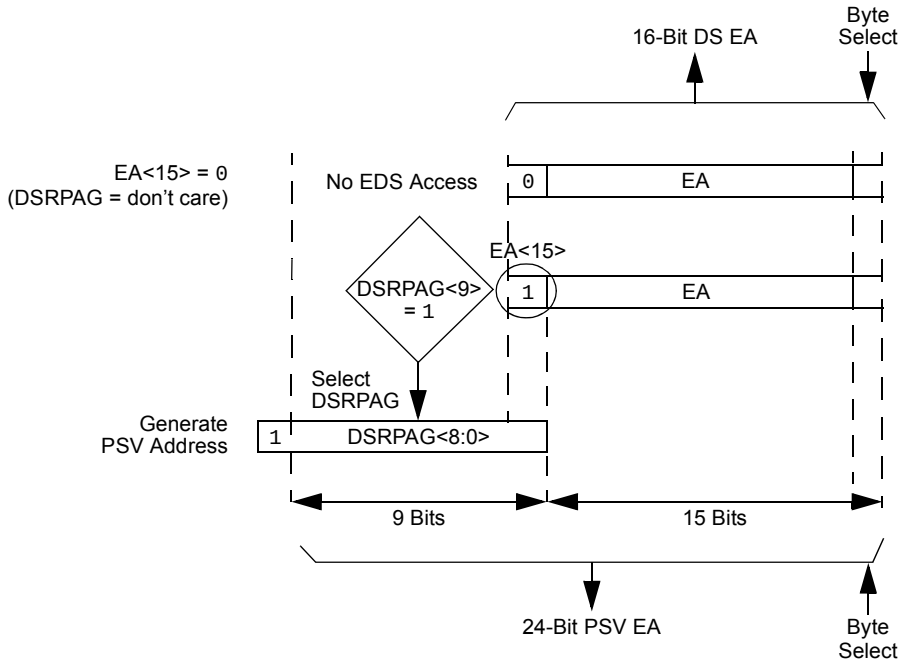
The dsPIC33EPXXXGS70X/80X family architecture extends the available Data Space through a paging scheme, which allows the available Data Space to be accessed using MOV instructions in a linear fashion for pre- and post-modified Effective Addresses (EAs). The upper half of the base Data Space address is used in conjunction with the Data Space Read Page (DSRPAG) register to form the Program Space Visibility (PSV) address.

The Data Space Read Page (DSRPAG) register is located in the SFR space. Construction of the PSV address is shown in Figure 4-7. When DSRPAG<9> = 1 and the base address bit, EA<15> = 1, the DSRPAG<8:0> bits are concatenated onto EA<14:0> to form the 24-bit PSV read address.

The paged memory scheme provides access to multiple 32-Kbyte windows in the PSV memory. The Data Space Read Page (DSRPAG) register, in combination with the upper half of the Data Space address, can provide up to 8 Mbytes of PSV address space. The paged data memory space is shown in Figure 4-8.

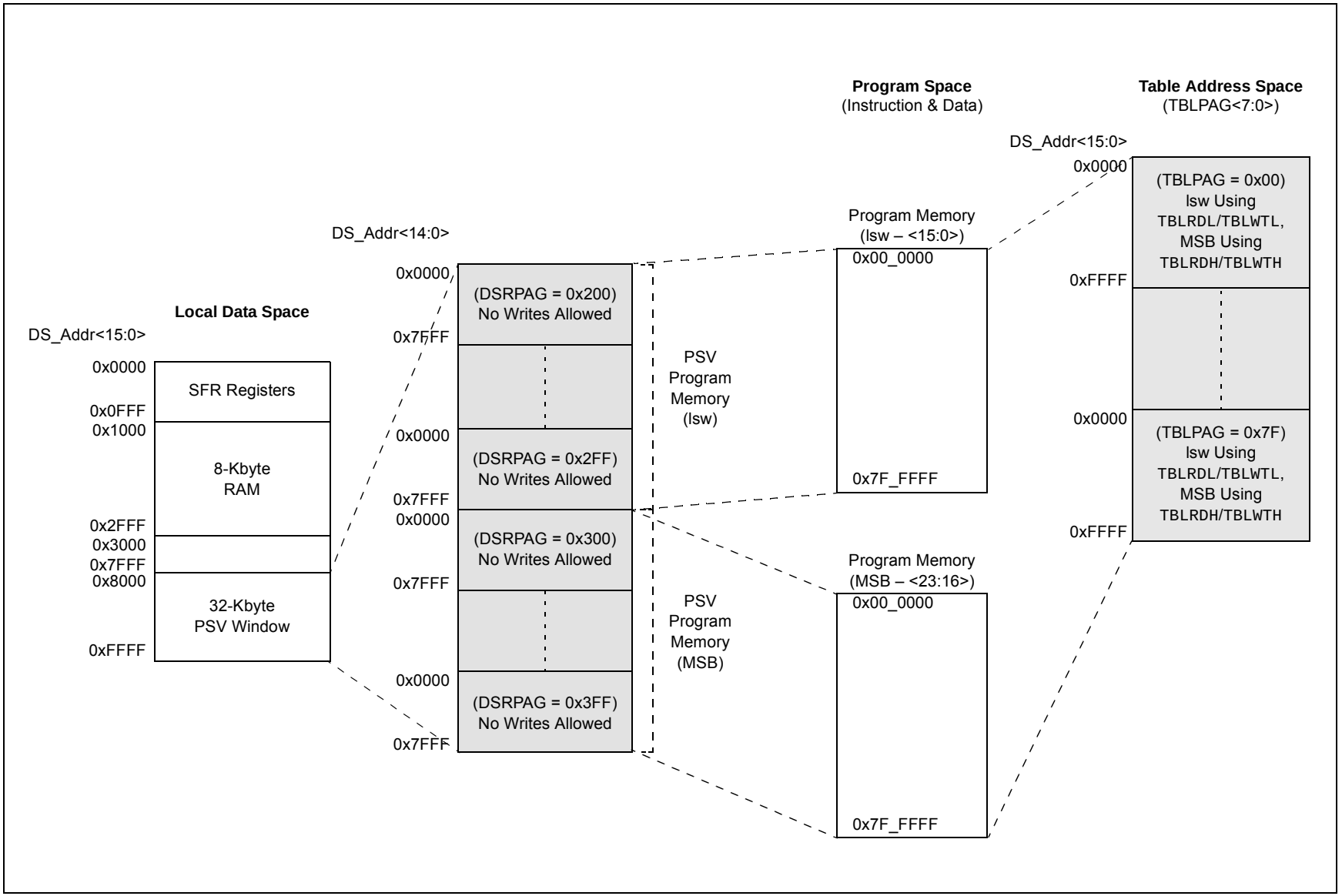
The Program Space (PS) can be accessed with a DSRPAG of 0x200 or greater. Only reads from PS are supported using the DSRPAG register.

**FIGURE 4-7: PROGRAM SPACE VISIBILITY (PSV) READ ADDRESS GENERATION**




**Note:** DS read access when DSRPAG = 0x000 will force an address error trap.

**FIGURE 4-8: PAGED DATA MEMORY SPACE**



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When a PSV page overflow or underflow occurs, EA<15> is cleared as a result of the register indirect EA calculation. An overflow or underflow of the EA in the PSV pages can occur at the page boundaries when:

- The initial address, prior to modification, addresses the PSV page
- The EA calculation uses Pre- or Post-Modified Register Indirect Addressing; however, this does not include Register Offset Addressing

In general, when an overflow is detected, the DSRPAG register is incremented and the EA<15> bit is set to keep the base address within the PSV window. When an underflow is detected, the DSRPAG register is decremented and the EA<15> bit is set to keep the base address within the PSV window. This creates a linear PSV address space, but only when using Register Indirect Addressing modes.

Exceptions to the operation described above arise when entering and exiting the boundaries of Page 0 and PSV spaces. Table 4-16 lists the effects of overflow and underflow scenarios at different boundaries.

In the following cases, when overflow or underflow occurs, the EA<15> bit is set and the DSRPAG is not modified; therefore, the EA will wrap to the beginning of the current page:

- Register Indirect with Register Offset Addressing
- Modulo Addressing
- Bit-Reversed Addressing

**TABLE 4-16: OVERFLOW AND UNDERFLOW SCENARIOS AT PAGE 0 AND PSV SPACE BOUNDARIES(2,3,4)**

| O/U, R/W | Operation | Before | | | After | | |
|---|---|---|---|---|---|---|---|
| | | DSxPAG | DS EA<15> | Page Description | DSxPAG | DS EA<15> | Page Description |
| O, Read | [++Wn] or [Wn++] | DSRPAG = 0x2FF | 1 | PSV: Last lsw page | DSRPAG = 0x300 | 1 | PSV: First MSB page |
| O, Read | | DSRPAG = 0x3FF | 1 | PSV: Last MSB page | DSRPAG = 0x3FF | 0 | See **Note 1** |
| U, Read | [--Wn] or [Wn--] | DSRPAG = 0x001 | 1 | PSV page | DSRPAG = 0x001 | 0 | See **Note 1** |
| U, Read | | DSRPAG = 0x200 | 1 | PSV: First lsw page | DSRPAG = 0x200 | 0 | See **Note 1** |
| U, Read | | DSRPAG = 0x300 | 1 | PSV: First MSB page | DSRPAG = 0x2FF | 1 | PSV: Last lsw page |

**Legend:** O = Overflow, U = Underflow, R = Read, W = Write

**Note 1:** The Register Indirect Addressing now addresses a location in the base Data Space (0x0000-0x7FFF).

**2:** An EDS access, with DSRPAG = 0x000, will generate an address error trap.

**3:** Only reads from PS are supported using DSRPAG.

**4:** Pseudolinear Addressing is not supported for large offsets.

### 4.5.2 EXTENDED X DATA SPACE

The lower portion of the base address space range, between 0x0000 and 0x7FFF, is always accessible, regardless of the contents of the Data Space Read Page register. It is indirectly addressable through the register indirect instructions. It can be regarded as being located in the default EDS Page 0 (i.e., EDS address range of 0x000000 to 0x007FFF with the base address bit, EA<15> = 0, for this address range). However, Page 0 cannot be accessed through the upper 32 Kbytes, 0x8000 to 0xFFFF, of base Data Space in combination with DSRPAG = 0x00. Consequently, DSRPAG is initialized to 0x001 at Reset.

| | |
|---|---|
| **Note 1:** | DSRPAG should not be used to access Page 0. An EDS access with DSRPAG set to 0x000 will generate an address error trap. |
| **2:** | Clearing the DSRPAG in software has no effect. |

The remaining PSV pages are only accessible using the DSRPAG register in combination with the upper 32 Kbytes, 0x8000 to 0xFFFF, of the base address, where base address bit, EA<15> = 1.

### 4.5.3 SOFTWARE STACK

The W15 register serves as a dedicated Software Stack Pointer (SSP), and is automatically modified by exception processing, subroutine calls and returns; however, W15 can be referenced by any instruction in the same manner as all other W registers. This simplifies reading, writing and manipulating the Stack Pointer (for example, creating stack frames).

| | |
|---|---|
| **Note:** | To protect against misaligned stack accesses, W15<0> is fixed to '0' by the hardware. |

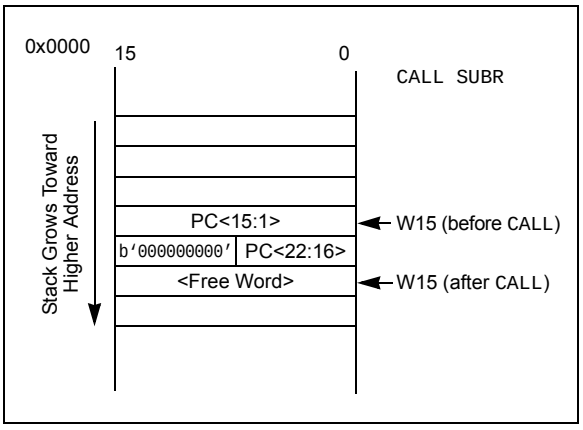
W15 is initialized to 0x1000 during all Resets. This address ensures that the SSP points to valid RAM in all dsPIC33EPXXXGS70X/80X devices and permits stack availability for non-maskable trap exceptions. These can occur before the SSP is initialized by the user software. You can reprogram the SSP during initialization to any location within Data Space.

The Software Stack Pointer always points to the first available free word and fills the software stack, working from lower toward higher addresses. Figure 4-9 illustrates how it pre-decrements for a stack pop (read) and post-increments for a stack push (writes).

When the PC is pushed onto the stack, PC<15:0> are pushed onto the first available stack word, then PC<22:16> are pushed into the second available stack location. For a PC push during any CALL instruction, the MSB of the PC is zero-extended before the push, as shown in Figure 4-9. During exception processing, the MSB of the PC is concatenated with the lower 8 bits of the CPU STATUS Register, SR. This allows the contents of SRL to be preserved automatically during interrupt processing.

| | |
|---|---|
| **Note 1:** | To maintain system Stack Pointer (W15) coherency, W15 is never subject to (EDS) paging, and is therefore, restricted to an address range of 0x0000 to 0xFFFF. The same applies to the W14 when used as a Stack Frame Pointer (SFA = 1). |
| **2:** | As the stack can be placed in, and can access X and Y spaces, care must be taken regarding its use, particularly with regard to local automatic variables in a C development environment |

**FIGURE 4-9: CALL STACK FRAME**





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## 4.6 Instruction Addressing Modes

The addressing modes shown in Table 4-17 form the basis of the addressing modes optimized to support the specific features of individual instructions. The addressing modes provided in the MAC class of instructions differ from those in the other instruction types.

### 4.6.1 FILE REGISTER INSTRUCTIONS

Most file register instructions use a 13-bit address field (f) to directly address data present in the first 8192 bytes of data memory (Near Data Space). Most file register instructions employ a Working register, W0, which is denoted as WREG in these instructions. The destination is typically either the same file register or WREG (with the exception of the MUL instruction), which writes the result to a register or register pair. The MOV instruction allows additional flexibility and can access the entire Data Space.

### 4.6.2 MCU INSTRUCTIONS

The three-operand MCU instructions are of the form:

```
Operand 3 = Operand 1 <function> Operand 2
```

where Operand 1 is always a Working register (that is, the addressing mode can only be Register Direct), which is referred to as Wb. Operand 2 can be a W register fetched from data memory or a 5-bit literal. The result location can either be a W register or a data memory location. The following addressing modes are supported by MCU instructions:

- Register Direct
- Register Indirect
- Register Indirect Post-Modified
- Register Indirect Pre-Modified
- 5-Bit or 10-Bit Literal

**Note:** Not all instructions support all the addressing modes given above. Individual instructions can support different subsets of these addressing modes.

**TABLE 4-17: FUNDAMENTAL ADDRESSING MODES SUPPORTED**

| Addressing Mode | Description |
|---|---|
| File Register Direct | The address of the file register is specified explicitly. |
| Register Direct | The contents of a register are accessed directly. |
| Register Indirect | The contents of Wn form the Effective Address (EA). |
| Register Indirect Post-Modified | The contents of Wn form the EA. Wn is post-modified (incremented or decremented) by a constant value. |
| Register Indirect Pre-Modified | Wn is pre-modified (incremented or decremented) by a signed constant value to form the EA. |
| Register Indirect with Register Offset (Register Indexed) | The sum of Wn and Wb forms the EA. |
| Register Indirect with Literal Offset | The sum of Wn and a literal forms the EA. |

### 4.6.3 MOVE AND ACCUMULATOR INSTRUCTIONS

Move instructions, and the DSP accumulator class of instructions, provide a greater degree of addressing flexibility than other instructions. In addition to the addressing modes supported by most MCU instructions, move and accumulator instructions also support Register Indirect with Register Offset Addressing mode, also referred to as Register Indexed mode.

| | |
|---|---|
| **Note:** | For the MOV instructions, the addressing mode specified in the instruction can differ for the source and destination EA. However, the 4-bit Wb (Register Offset) field is shared by both source and destination (but typically only used by one). |

In summary, the following addressing modes are supported by move and accumulator instructions:

- Register Direct
- Register Indirect
- Register Indirect Post-modified
- Register Indirect Pre-modified
- Register Indirect with Register Offset (Indexed)
- Register Indirect with Literal Offset
- 8-Bit Literal
- 16-Bit Literal

| | |
|---|---|
| **Note:** | Not all instructions support all the addressing modes given above. Individual instructions may support different subsets of these addressing modes. |

### 4.6.4 MAC INSTRUCTIONS

The dual source operand DSP instructions (CLR, ED, EDAC, MAC, MPY, MPY.N, MOVSAC and MSC), also referred to as MAC instructions, use a simplified set of addressing modes to allow the user application to effectively manipulate the Data Pointers through register indirect tables.

The two-source operand prefetch registers must be members of the set {W8, W9, W10, W11}. For data reads, W8 and W9 are always directed to the X RAGU, and W10 and W11 are always directed to the Y AGU. The Effective Addresses generated (before and after modification) must therefore, be valid addresses within X Data Space for W8 and W9, and Y Data Space for W10 and W11.

| | |
|---|---|
| **Note:** | Register Indirect with Register Offset Addressing mode is available only for W9 (in X space) and W11 (in Y space). |

In summary, the following addressing modes are supported by the MAC class of instructions:

- Register Indirect
- Register Indirect Post-Modified by 2
- Register Indirect Post-Modified by 4
- Register Indirect Post-Modified by 6
- Register Indirect with Register Offset (Indexed)

### 4.6.5 OTHER INSTRUCTIONS

Besides the addressing modes outlined previously, some instructions use literal constants of various sizes. For example, BRA (branch) instructions use 16-bit signed literals to specify the branch destination directly, whereas the DISI instruction uses a 14-bit unsigned literal field. In some instructions, such as ULNK, the source of an operand or result is implied by the opcode itself. Certain operations, such as a NOP, do not have any operands.


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## 4.7 Modulo Addressing

Modulo Addressing mode is a method of providing an automated means to support circular data buffers using hardware. The objective is to remove the need for software to perform data address boundary checks when executing tightly looped code, as is typical in many DSP algorithms.

Modulo Addressing can operate in either Data or Program Space (since the Data Pointer mechanism is essentially the same for both). One circular buffer can be supported in each of the X (which also provides the pointers into Program Space) and Y Data Spaces. Modulo Addressing can operate on any W Register Pointer. However, it is not advisable to use W14 or W15 for Modulo Addressing since these two registers are used as the Stack Frame Pointer and Stack Pointer, respectively.

In general, any particular circular buffer can be configured to operate in only one direction, as there are certain restrictions on the buffer start address (for incrementing buffers) or end address (for decrementing buffers), based upon the direction of the buffer.

The only exception to the usage restrictions is for buffers that have a power-of-two length. As these buffers satisfy the start and end address criteria, they can operate in a Bidirectional mode (that is, address boundary checks are performed on both the lower and upper address boundaries).

### 4.7.1 START AND END ADDRESS

The Modulo Addressing scheme requires that a starting and ending address be specified and loaded into the 16-bit Modulo Buffer Address registers: XMODSRT, XMODEND, YMODSRT and YMODEND (see Table 4-2).

| **Note:** | Y space Modulo Addressing EA calculations assume word-sized data (LSb of every EA is always clear). |
|---|---|

The length of a circular buffer is not directly specified. It is determined by the difference between the corresponding start and end addresses. The maximum possible length of the circular buffer is 32K words (64 Kbytes).

### 4.7.2 W ADDRESS REGISTER SELECTION

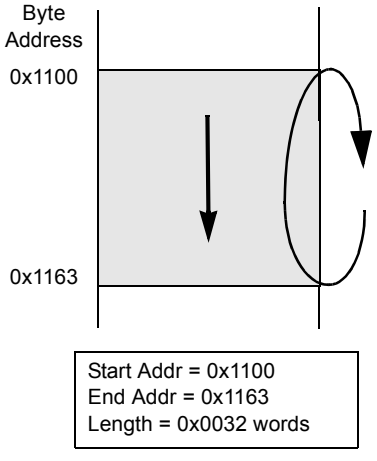
The Modulo and Bit-Reversed Addressing Control register, MODCON<15:0>, contains enable flags, as well as a W register field to specify the W Address registers. The XWM and YWM fields select the registers that operate with Modulo Addressing:

- If XWM = 1111, X RAGU and X WAGU Modulo Addressing is disabled
- If YWM = 1111, Y AGU Modulo Addressing is disabled

The X Address Space Pointer W (XWM) register, to which Modulo Addressing is to be applied, is stored in MODCON<3:0> (see Table 4-2). Modulo Addressing is enabled for X Data Space when XWM is set to any value other than '1111' and the XMODEN bit is set (MODCON<15>).

The Y Address Space Pointer W (YWM) register, to which Modulo Addressing is to be applied, is stored in MODCON<7:4>. Modulo Addressing is enabled for Y Data Space when YWM is set to any value other than '1111' and the YMODEN bit (MODCON<14>) is set.

**FIGURE 4-10: MODULO ADDRESSING OPERATION EXAMPLE**




```
MOV     #0x1100, W0
MOV     W0, XMODSRT     ;set modulo start address
MOV     #0x1163, W0
MOV     W0, MODEND      ;set modulo end address
MOV     #0x8001, W0
MOV     W0, MODCON      ;enable W1, X AGU for modulo

MOV     #0x0000, W0     ;W0 holds buffer fill value

MOV     #0x1110, W1     ;point W1 to buffer

DO      AGAIN, #0x31    ;fill the 50 buffer locations
MOV     W0, [W1++]      ;fill the next location
AGAIN:  INC W0, W0      ;increment the fill value
```

#### 4.7.3 MODULO ADDRESSING APPLICABILITY

Modulo Addressing can be applied to the Effective Address (EA) calculation associated with any W register. Address boundaries check for addresses equal to:

- The upper boundary addresses for incrementing buffers
- The lower boundary addresses for decrementing buffers

It is important to realize that the address boundaries check for addresses less than or greater than the upper (for incrementing buffers) and lower (for decrementing buffers) boundary addresses (not just equal to). Address changes can, therefore, jump beyond boundaries and still be adjusted correctly.

| | |
|---|---|
| **Note:** | The modulo corrected Effective Address is written back to the register only when Pre-Modify or Post-Modify Addressing mode is used to compute the Effective Address. When an address offset (such as [W7 + W2]) is used, Modulo Addressing correction is performed, but the contents of the register remain unchanged. |

### 4.8 Bit-Reversed Addressing

Bit-Reversed Addressing mode is intended to simplify data reordering for radix-2 FFT algorithms. It is supported by the X AGU for data writes only.

The modifier, which can be a constant value or register contents, is regarded as having its bit order reversed. The address source and destination are kept in normal order. Thus, the only operand requiring reversal is the modifier.

#### 4.8.1 BIT-REVERSED ADDRESSING IMPLEMENTATION

Bit-Reversed Addressing mode is enabled when all of these situations are met:

- BWMx bits (W register selection) in the MODCON register are any value other than '1111' (the stack cannot be accessed using Bit-Reversed Addressing)
- The BREN bit is set in the XBREV register
- The addressing mode used is Register Indirect with Pre-Increment or Post-Increment

If the length of a bit-reversed buffer is $M = 2^N$ bytes, the last 'N' bits of the data buffer start address must be zeros.

XB<14:0> is the Bit-Reversed Addressing modifier, or 'pivot point', which is typically a constant. In the case of an FFT computation, its value is equal to half of the FFT data buffer size.

| | |
|---|---|
| **Note:** | All bit-reversed EA calculations assume word-sized data (LSb of every EA is always clear). The XB value is scaled accordingly to generate compatible (byte) addresses. |

When enabled, Bit-Reversed Addressing is executed only for Register Indirect with Pre-Increment or Post-Increment Addressing and word-sized data writes. It does not function for any other addressing mode or for byte-sized data and normal addresses are generated instead. When Bit-Reversed Addressing is active, the W Address Pointer is always added to the address modifier (XB) and the offset associated with the Register Indirect Addressing mode is ignored. In addition, as word-sized data is a requirement, the LSb of the EA is ignored (and always clear).

| | |
|---|---|
| **Note:** | Modulo Addressing and Bit-Reversed Addressing can be enabled simultaneously using the same W register, but Bit-Reversed Addressing operation will always take precedence for data writes when enabled. |

If Bit-Reversed Addressing has already been enabled by setting the BREN (XBREV<15>) bit, a write to the XBREV register should not be immediately followed by an indirect read operation using the W register that has been designated as the Bit-Reversed Pointer.


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**FIGURE 4-11: BIT-REVERSED ADDRESSING EXAMPLE**

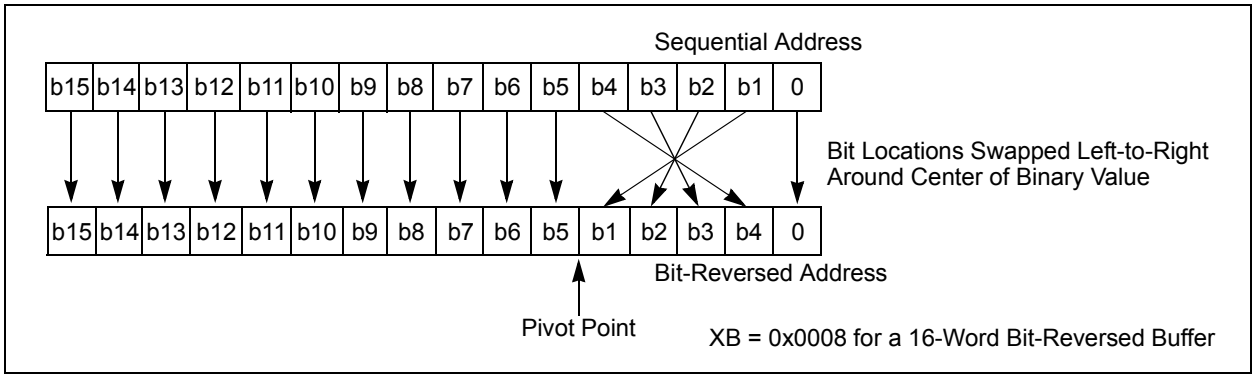



**TABLE 4-18: BIT-REVERSED ADDRESSING SEQUENCE (16-ENTRY)**

| 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 |

## 4.9 Interfacing Program and Data Memory Spaces

The dsPIC33EPXXXGS70X/80X family architecture uses a 24-bit wide Program Space (PS) and a 16-bit wide Data Space (DS). The architecture is also a modified Harvard scheme, meaning that data can also be present in the Program Space. To use this data successfully, it must be accessed in a way that preserves the alignment of information in both spaces.

Aside from normal execution, the architecture of the dsPIC33EPXXXGS70X/80X family devices provides two methods by which Program Space can be accessed during operation:

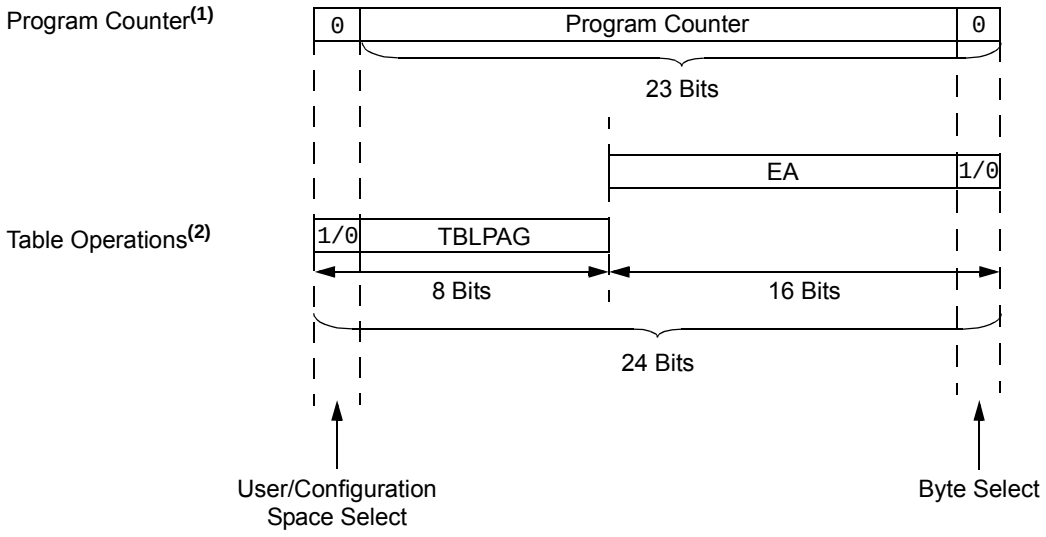
- Using table instructions to access individual bytes or words anywhere in the Program Space
- Remapping a portion of the Program Space into the Data Space (Program Space Visibility)

Table instructions allow an application to read or write to small areas of the program memory. This capability makes the method ideal for accessing data tables that need to be updated periodically. It also allows access to all bytes of the program word. The remapping method allows an application to access a large block of data on a read-only basis, which is ideal for look-ups from a large table of static data. The application can only access the least significant word of the program word.

**TABLE 4-19: PROGRAM SPACE ADDRESS CONSTRUCTION**

| Access Type | Access Space | Program Space Address | | | | |
|---|---|---|---|---|---|---|
| | | <23> | <22:16> | <15> | <14:1> | <0> |
| Instruction Access (Code Execution) | User | 0 | PC<22:1> | | | 0 |
| | | 0xxx xxxx xxxx xxxx xxxx xxx0 | | | | |
| TBLRD/TBLWT (Byte/Word Read/Write) | User | TBLPAG<7:0> | | Data EA<15:0> | | |
| | | 0xxx xxxx | | xxxx xxxx xxxx xxxx | | |
| | Configuration | TBLPAG<7:0> | | Data EA<15:0> | | |
| | | 1xxx xxxx | | xxxx xxxx xxxx xxxx | | |

**FIGURE 4-12: DATA ACCESS FROM PROGRAM SPACE ADDRESS GENERATION**




**Note 1:** The Least Significant bit (LSb) of Program Space addresses is always fixed as '0' to maintain word alignment of data in the Program and Data Spaces.

**2:** Table operations are not required to be word-aligned. Table Read operations are permitted in the configuration memory space.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### 4.9.1 DATA ACCESS FROM PROGRAM MEMORY USING TABLE INSTRUCTIONS

The TBLRDL and TBLWTL instructions offer a direct method of reading or writing the lower word of any address within the Program Space without going through Data Space. The TBLRDH and TBLWTH instructions are the only method to read or write the upper 8 bits of a Program Space word as data.

The PC is incremented by two for each successive 24-bit program word. This allows program memory addresses to directly map to Data Space addresses. Program memory can thus be regarded as two 16-bit wide word address spaces, residing side by side, each with the same address range. TBLRDL and TBLWTL access the space that contains the least significant data word. TBLRDH and TBLWTH access the space that contains the upper data byte.

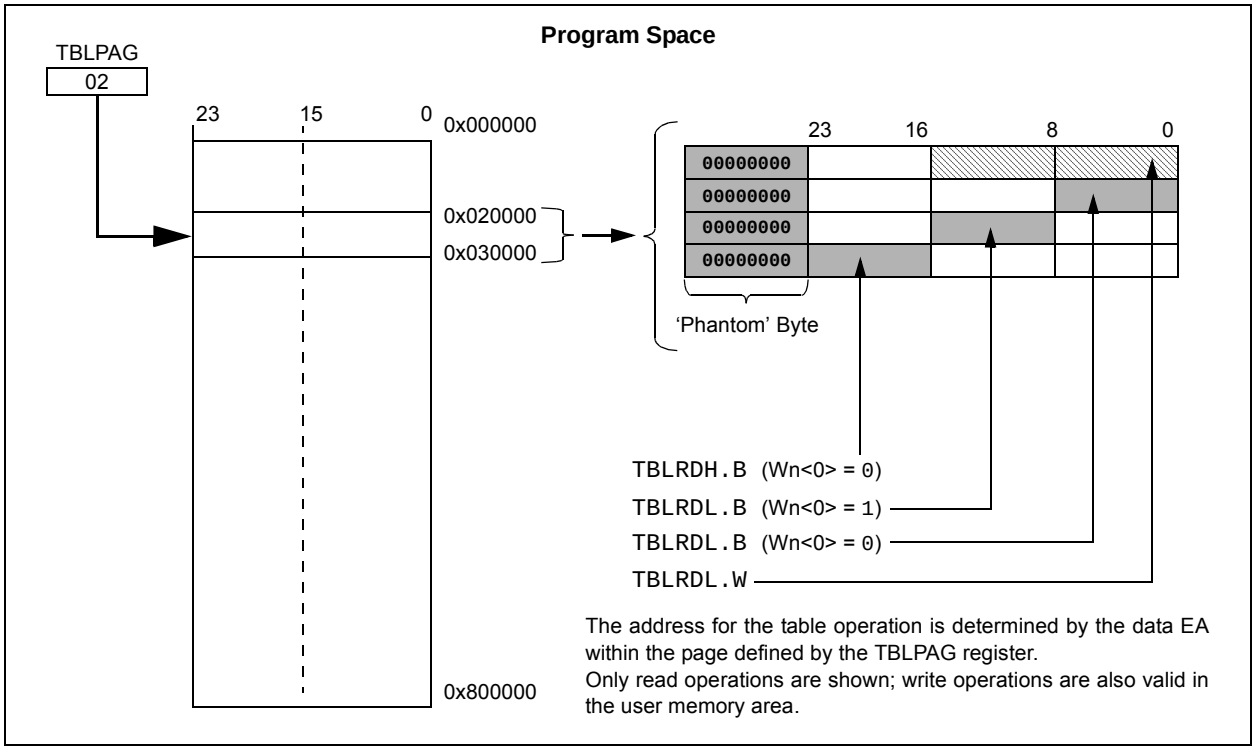
Two table instructions are provided to move byte or word-sized (16-bit) data to and from Program Space. Both function as either byte or word operations.

- TBLRDL (Table Read Low):
  - In Word mode, this instruction maps the lower word of the Program Space location (P<15:0>) to a data address (D<15:0>)
  - In Byte mode, either the upper or lower byte of the lower program word is mapped to the lower byte of a data address. The upper byte is selected when Byte Select is '1'; the lower byte is selected when it is '0'.
- TBLRDH (Table Read High):
  - In Word mode, this instruction maps the entire upper word of a program address (P<23:16>) to a data address. The 'phantom' byte (D<15:8>) is always '0'.
  - In Byte mode, this instruction maps the upper or lower byte of the program word to D<7:0> of the data address in the TBLRDL instruction. The data is always '0' when the upper 'phantom' byte is selected (Byte Select = 1).

In a similar fashion, two table instructions, TBLWTH and TBLWTL, are used to write individual bytes or words to a Program Space address. The details of their operation are explained in **Section 5.0 "Flash Program Memory"**.

For all table operations, the area of program memory space to be accessed is determined by the Table Page register (TBLPAG). TBLPAG covers the entire program memory space of the device, including user application and configuration spaces. When TBLPAG<7> = 0, the table page is located in the user memory space. When TBLPAG<7> = 1, the page is located in configuration space.

**FIGURE 4-13: ACCESSING PROGRAM MEMORY WITH TABLE INSTRUCTIONS**



**NOTES:**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## 5.0 FLASH PROGRAM MEMORY

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Dual Partition Flash Program Memory"** (DS70005156) in the *"dsPIC33/PIC24 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 dsPIC33EPXXXGS70X/80X family devices contain internal Program Flash Memory for storing and executing application code. The memory is readable, writable and erasable during normal operation over the entire VDD range.

Flash memory can be programmed in three ways:

- In-Circuit Serial Programming™ (ICSP™) programming capability
- Enhanced In-Circuit Serial Programming (Enhanced ICSP)
- Run-Time Self-Programming (RTSP)

ICSP allows for a dsPIC33EPXXXGS70X/80X family device to be serially programmed while in the end application circuit. This is done with a programming clock and programming data (PGECx/PGEDx) line, and three other lines for power (VDD), ground (VSS) and Master Clear (MCLR). This allows customers to manufacture boards with unprogrammed devices and then program the device just before shipping the product. This also allows the most recent firmware or a custom firmware to be programmed.

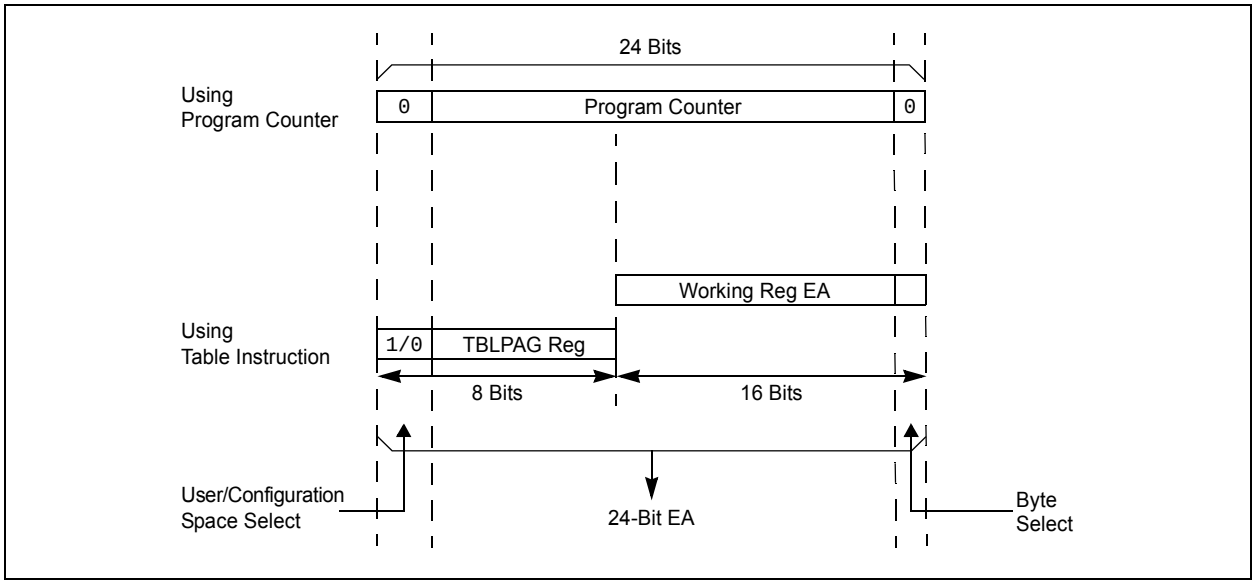
Enhanced In-Circuit Serial Programming uses an on-board bootloader, known as the Program Executive, to manage the programming process. Using an SPI data frame format, the Program Executive can erase, program and verify program memory. For more information on Enhanced ICSP, see the device programming specification.

RTSP is accomplished using TBLRD (Table Read) and TBLWT (Table Write) instructions. With RTSP, the user application can write program memory data with a single program memory word and erase program memory in blocks or 'pages' of 512 instructions (1536 bytes) at a time.

### 5.1 Table Instructions and Flash Programming

Regardless of the method used, all programming of Flash memory is done with the Table Read and Table Write instructions. These instructions allow direct read and write access to the program memory space, from the data memory, while the device is in normal operating mode. The 24-bit target address in the program memory is formed using bits<7:0> of the TBLPAG register and the Effective Address (EA) from a W register, specified in the table instruction, as shown in Figure 5-1. The TBLRDL and the TBLWTL instructions are used to read or write to bits<15:0> of program memory. TBLRDL and TBLWTL can access program memory in both Word and Byte modes. The TBLRDH and TBLWTH instructions are used to read or write to bits<23:16> of program memory. TBLRDH and TBLWTH can also access program memory in Word or Byte mode.

**FIGURE 5-1: ADDRESSING FOR TABLE REGISTERS**



## 5.2 RTSP Operation

The dsPIC33EPXXXGS70X/80X family Flash program memory array is organized into rows of 64 instructions or 192 bytes. RTSP allows the user application to erase a single page (8 rows or 512 instructions) of memory at a time and to program one row at a time. It is possible to program two instructions at a time as well.

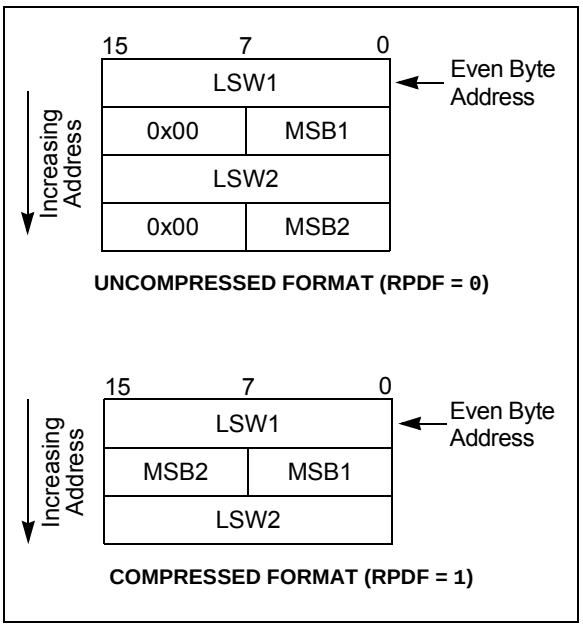
The page erase and single row write blocks are edge-aligned, from the beginning of program memory, on boundaries of 1536 bytes and 192 bytes, respectively. Figure 30-14 in **Section 30.0 "Electrical Characteristics"** lists the typical erase and programming times.

Row programming is performed by loading 192 bytes into data memory and then loading the address of the first byte in that row into the NVMSRCADR register. Once the write has been initiated, the device will automatically load the write latches and increment the NVMSRCADR and the NVMADR(U) registers until all bytes have been programmed. The RPDF bit (NVMCON<9>) selects the format of the stored data in RAM to be either compressed or uncompressed. See Figure 5-2 for data formatting. Compressed data helps to reduce the amount of required RAM by using the upper byte of the second word for the MSB of the second instruction.

The basic sequence for RTSP word programming is to use the TBLWTL and TBLWTH instructions to load two of the 24-bit instructions into the write latches found in configuration memory space. Refer to Figure 4-1 through Figure 4-4 for write latch addresses. Programming is performed by unlocking and setting the control bits in the NVMCON register.

All erase and program operations may optionally use the NVM interrupt to signal the successful completion of the operation. For example, when performing Flash write operations on the Inactive Partition in Dual Partition mode, where the CPU remains running, it is necessary to wait for the NVM interrupt before programming the next block of Flash program memory.

**FIGURE 5-2: UNCOMPRESSED/ COMPRESSED FORMAT**




## 5.3 Programming Operations

A complete programming sequence is necessary for programming or erasing the internal Flash in RTSP mode. The processor stalls (waits) until the programming operation is finished. Setting the WR bit (NVMCON<15>) starts the operation and the WR bit is automatically cleared when the operation is finished.

### 5.3.1 PROGRAMMING ALGORITHM FOR FLASH PROGRAM MEMORY

Programmers can program two adjacent words (24 bits x 2) of Program Flash Memory at a time on every other word address boundary (0x000000, 0x000004, 0x000008, etc.). To do this, it is necessary to erase the page that contains the desired address of the location the user wants to change. For protection against accidental operations, the write initiate sequence for NVMKEY must be used to allow any erase or program operation to proceed. After the programming command has been executed, the user application must wait for the programming time until programming is complete. The two instructions following the start of the programming sequence should be NOPs.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## 5.4 Dual Partition Flash Configuration

For dsPIC33EPXXXGS70X/80X devices operating in Dual Partition Flash Program Memory modes, the Inactive Partition can be erased and programmed without stalling the processor. The same programming algorithms are used for programming and erasing the Flash in the Inactive Partition, as described in **Section 5.2 "RTSP Operation"**. On top of the page erase option, the entire Flash memory of the Inactive Partition can be erased by configuring the NVMOP<3:0> bits in the NVMCON register.

| | |
|---|---|
| **Note 1:** | The application software to be loaded into the Inactive Partition will have the address of the Active Partition. The bootloader firmware will need to offset the address by 0x400000 in order to write to the Inactive Partition. |

### 5.4.1 FLASH PARTITION SWAPPING

The Boot Sequence Number is used for determining the Active Partition at start-up and is encoded within the FBTSEQ Configuration register bits. Unlike most Configuration registers, which only utilize the lower 16 bits of the program memory, FBTSEQ is a 24-bit Configuration Word. The Boot Sequence Number (BSEQ) is a 12-bit value and is stored in FBTSEQ twice. The true value is stored in bits, FBTSEQ<11:0>, and its complement is stored in bits, FBTSEQ<23:12>. At device Reset, the sequence numbers are read and the partition with the lowest sequence number becomes the Active Partition. If one of the Boot Sequence Numbers is invalid, the device will select the partition with the valid Boot Sequence Number, or default to Partition 1 if both sequence numbers are invalid. See **Section 27.0 "Special Features"** for more information.

The BOOTSWP instruction provides an alternative means of swapping the Active and Inactive Partitions (soft swap) without the need for a device Reset. The BOOTSWP must always be followed by a GOTO instruction. The BOOTSWP instruction swaps the Active and Inactive Partitions, and the PC vectors to the location specified by the GOTO instruction in the newly Active Partition.

It is important to note that interrupts should temporarily be disabled while performing the soft swap sequence and that after the partition swap, all peripherals and interrupts which were enabled remain enabled. Additionally, the RAM and stack will maintain state after the switch. As a result, it is recommended that applications using soft swaps jump to a routine that will reinitialize the device in order to ensure the firmware runs as expected. The Configuration registers will have no effect during a soft swap.

For robustness of operation, in order to execute the BOOTSWP instruction, it is necessary to execute the NVM unlocking sequence as follows:

1. Write 0x55 to NVMKEY.
2. Write 0xAA to NVMKEY.
3. Execute the BOOTSWP instruction.

If the unlocking sequence is not performed, the BOOTSWP instruction will be executed as a forced NOP and a GOTO instruction, following the BOOTSWP instruction, will be executed, causing the PC to jump to that location in the current operating partition.

The SFTSWP and P2ACTIV bits in the NVMCON register are used to determine a successful swap of the Active and Inactive Partitions, as well as which partition is active. After the BOOTSWP and GOTO instructions, the SFTSWP bit should be polled to verify the partition swap has occurred and then cleared for the next panel swap event.

### 5.4.2 DUAL PARTITION MODES

While operating in Dual Partition mode, the dsPIC33EPXXXGS70X/80X family devices have the option for both partitions to have their own defined security segments, as shown in Figure 27-4. Alternatively, the device can operate in Protected Dual Partition mode, where Partition 1 becomes permanently erase/write-protected. Protected Dual Partition mode allows for a "Factory Default" mode, which provides a fail-safe backup image to be stored in Partition 1.

dsPIC33EPXXXGS70X/80X family devices can also operate in Privileged Dual Partition mode, where additional security protections are implemented to allow for protection of intellectual property when multiple parties have software within the device. In Privileged Dual Partition mode, both partitions place additional restrictions on the FBSLIM register. These prevent changes to the size of the Boot Segment and General Segment, ensuring that neither segment will be altered.

## 5.5 Flash Memory 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 contains the latest updates and additional information.

### 5.5.1 KEY RESOURCES

- **"Dual Partition Flash Program Memory"** (DS70005156) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

## 5.6 Control Registers

Five SFRs are used to write and erase the Program Flash Memory: NVMCON, NVMKEY, NVMADR, NVMADRU and NVMSRCADR/H.

The NVMCON register (Register 5-1) selects the operation to be performed (page erase, word/row program, Inactive Partition erase), initiates the program or erase cycle and is used to determine the Active Partition in Dual Partition modes.

NVMKEY (Register 5-4) is a write-only register that is used for write protection. To start a programming or erase sequence, the user application must consecutively write 0x55 and 0xAA to the NVMKEY register.

There are two NVM Address registers: NVMADRU and NVMADR. These two registers, when concatenated, form the 24-bit Effective Address (EA) of the selected word/row for programming operations, or the selected page for erase operations. The NVMADRU register is used to hold the upper 8 bits of the EA, while the NVMADR register is used to hold the lower 16 bits of the EA.

For row programming operation, data to be written to Program Flash Memory is written into data memory space (RAM) at an address defined by the NVMSRCADR register (location of first element in row programming data).


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**REGISTER 5-1: NVMCON: NONVOLATILE MEMORY (NVM) CONTROL REGISTER**

| R/SO-0(1) | R/W-0(1) | R/W-0(1) | R/W-0 | R/C-0 | R-0 | R/W-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| WR | WREN | WRERR | NVMSIDL(2) | SFTSWP(6) | P2ACTIV(6) | RPDF | URERR |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | R/W-0(1) | R/W-0(1) | R/W-0(1) | R/W-0(1) |
|---|---|---|---|---|---|---|---|
| — | — | — | — | NVMOP3(3,4) | NVMOP2(3,4) | NVMOP1(3,4) | NVMOP0(3,4) |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Clearable bit | SO = Settable Only 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 **WR:** Write Control bit(1)
- 1 = Initiates a Program Flash Memory or erase operation; the operation is self-timed and the bit is cleared by hardware once the operation is complete
- 0 = Program or erase operation is complete and inactive

bit 14 **WREN:** Write Enable bit(1)
- 1 = Enables Flash program/erase operations
- 0 = Inhibits Flash program/erase operations

bit 13 **WRERR:** Write Sequence Error Flag bit(1)
- 1 = An improper program or erase sequence attempt, or termination has occurred (bit is set automatically on any set attempt of the WR bit)
- 0 = The program or erase operation completed normally

bit 12 **NVMSIDL:** NVM Stop in Idle Control bit(2)
- 1 = Flash voltage regulator goes into Standby mode during Idle mode
- 0 = Flash voltage regulator is active during Idle mode

bit 11 **SFTSWP:** Partition Soft Swap Status bit(6)
- 1 = Partitions have been successfully swapped using the BOOTSWP instruction (soft swap)
- 0 = Awaiting successful partition swap using the BOOTSWP instruction or a device Reset will determine the Active Partition based on the FBTSEQ register

bit 10 **P2ACTIV:** Partition 2 Active Status bit(6)
- 1 = Partition 2 Flash is mapped into the active region
- 0 = Partition 1 Flash is mapped into the active region

bit 9 **RPDF:** Row Programming Data Format bit
- 1 = Row data to be stored in RAM is in compressed format
- 0 = Row data to be stored in RAM is in uncompressed format

bit 8 **URERR:** Row Programming Data Underrun Error bit
- 1 = Indicates row programming operation has been terminated
- 0 = No data underrun error is detected

bit 7-4 **Unimplemented:** Read as '0'

**Note 1:** These bits can only be reset on a POR.

**2:** If this bit is set, power consumption will be further reduced ($I_{IDLE}$) and upon exiting Idle mode, there is a delay ($T_{VREG}$) before Flash memory becomes operational.

**3:** All other combinations of NVMOP<3:0> are unimplemented.

**4:** Execution of the PWRSAV instruction is ignored while any of the NVM operations are in progress.

**5:** Two adjacent words on a 4-word boundary are programmed during execution of this operation.

**6:** Only applicable when operating in Dual Partition mode.

**REGISTER 5-1: NVMCON: NONVOLATILE MEMORY (NVM) CONTROL REGISTER (CONTINUED)**

bit 3-0 **NVMOP<3:0>:** NVM Operation Select bits(1,3,4)

1111 = Reserved
•
•
•
0101 = Reserved
0100 = Inactive Partition memory erase operation
0011 = Memory page erase operation
0010 = Memory row program operation
0001 = Memory double-word program operation(5)
0000 = Reserved

**Note 1:** These bits can only be reset on a POR.

**2:** If this bit is set, power consumption will be further reduced (IIDLE) and upon exiting Idle mode, there is a delay (TVREG) before Flash memory becomes operational.

**3:** All other combinations of NVMOP<3:0> are unimplemented.

**4:** Execution of the PWRSAV instruction is ignored while any of the NVM operations are in progress.

**5:** Two adjacent words on a 4-word boundary are programmed during execution of this operation.

**6:** Only applicable when operating in Dual Partition mode.


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**REGISTER 5-2: NVMADR: NONVOLATILE MEMORY LOWER ADDRESS REGISTER**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| NVMADR<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| NVMADR<7:0> | | | | | | | |
| 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 15-0 **NVMADR<15:0>:** Nonvolatile Memory Lower Write Address bits

Selects the lower 16 bits of the location to program or erase in Program Flash Memory. This register may be read or written to by the user application.

**REGISTER 5-3: NVMADRU: NONVOLATILE MEMORY UPPER ADDRESS REGISTER**

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

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| NVMADRU<23:16> | | | | | | | |
| 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 **Unimplemented:** Read as '0'

bit 7-0 **NVMADRU<23:16>:** Nonvolatile Memory Upper Write Address bits

Selects the upper 8 bits of the location to program or erase in Program Flash Memory. This register may be read or written to by the user application.

**REGISTER 5-4: NVMKEY: NONVOLATILE MEMORY KEY REGISTER**

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

| W-0 | W-0 | W-0 | W-0 | W-0 | W-0 | W-0 | W-0 |
|---|---|---|---|---|---|---|---|
| NVMKEY<7:0> | | | | | | | |
| 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 15-8 **Unimplemented:** Read as ‘0’

bit 7-0 **NVMKEY<7:0>:** NVM Key Register bits (write-only)

**REGISTER 5-5: NVMSRCADR: NVM SOURCE DATA ADDRESS REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| NVMSRCADR<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| NVMSRCADR<7:0> | | | | | | | |
| 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 15-0 **NVMSRCADR<15:0>:** NVM Source Data Address bits

The RAM address of the data to be programmed into Flash when the NVMOP<3:0> bits are set to row programming.


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## 6.0 RESETS

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Reset"** (DS70602) in the *"dsPIC33/PIC24 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 Reset module combines all Reset sources and controls the device Master Reset Signal, $\overline{\text{SYSRST}}$. The following is a list of device Reset sources:

- POR: Power-on Reset
- BOR: Brown-out Reset
- $\overline{\text{MCLR}}$: Master Clear Pin Reset
- SWR: RESET Instruction
- WDTO: Watchdog Timer Time-out Reset
- CM: Configuration Mismatch Reset
- TRAPR: Trap Conflict Reset
- IOPUWR: Illegal Condition Device Reset
  - Illegal Opcode Reset
  - Uninitialized W Register Reset
  - Security Reset

A simplified block diagram of the Reset module is shown in Figure 6-1.

Any active source of Reset will make the $\overline{\text{SYSRST}}$ signal active. On system Reset, some of the registers associated with the CPU and peripherals are forced to a known Reset state, and some are unaffected.

**Note:** Refer to the specific peripheral section or **Section 4.0 "Memory Organization"** of this data sheet for register Reset states.

All types of device Reset set a corresponding status bit in the RCON register to indicate the type of Reset (see Register 6-1).

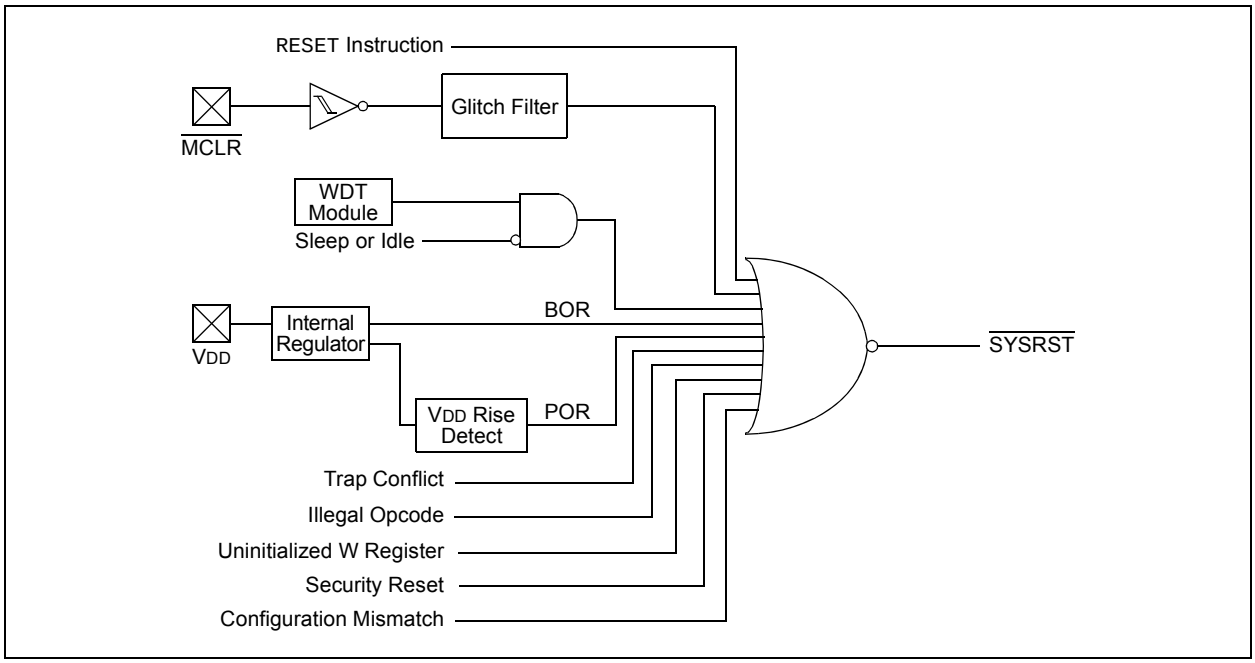
A POR clears all the bits, except for the BOR and POR bits (RCON<1:0>) that are set. The user application can set or clear any bit, at any time, during code execution. The RCON bits only serve as status bits. Setting a particular Reset status bit in software does not cause a device Reset to occur.

The RCON register also has other bits associated with the Watchdog Timer and device power-saving states. The function of these bits is discussed in other sections of this manual.

**Note:** The status bits in the RCON register should be cleared after they are read so that the next RCON register value after a device Reset is meaningful.

For all Resets, the default clock source is determined by the FNOSC<2:0> bits in the FOSCSEL Configuration register. The value of the FNOSCx bits is loaded into the NOSC<2:0> (OSCCON<10:8>) bits on Reset, which in turn, initializes the system clock.

**FIGURE 6-1: RESET SYSTEM BLOCK DIAGRAM**



## 6.1 Reset 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 contains the latest updates and additional information.

### 6.1.1 KEY RESOURCES

- **"Reset"** (DS70602) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools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**REGISTER 6-1: RCON: RESET CONTROL REGISTER(1)**

| R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TRAPR | IOPUWR | — | — | VREGSF | — | CM | VREGS |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| EXTR | SWR | SWDTEN(2) | WDTO | SLEEP | IDLE | BOR | POR |
| 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 **TRAPR:** Trap Reset Flag bit
1 = A Trap Conflict Reset has occurred
0 = A Trap Conflict Reset has not occurred

bit 14 **IOPUWR:** Illegal Opcode or Uninitialized W Register Access Reset Flag bit
1 = An illegal opcode detection, an illegal address mode or Uninitialized W register used as an Address Pointer caused a Reset
0 = An illegal opcode or Uninitialized W register Reset has not occurred

bit 13-12 **Unimplemented:** Read as '0'

bit 11 **VREGSF:** Flash Voltage Regulator Standby During Sleep bit
1 = Flash voltage regulator is active during Sleep
0 = Flash voltage regulator goes into Standby mode during Sleep

bit 10 **Unimplemented:** Read as '0'

bit 9 **CM:** Configuration Mismatch Flag bit
1 = A Configuration Mismatch Reset has occurred.
0 = A Configuration Mismatch Reset has not occurred

bit 8 **VREGS:** Voltage Regulator Standby During Sleep bit
1 = Voltage regulator is active during Sleep
0 = Voltage regulator goes into Standby mode during Sleep

bit 7 **EXTR:** External Reset ($\overline{MCLR}$) Pin bit
1 = A Master Clear (pin) Reset has occurred
0 = A Master Clear (pin) Reset has not occurred

bit 6 **SWR:** Software RESET (Instruction) Flag bit
1 = A RESET instruction has been executed
0 = A RESET instruction has not been executed

bit 5 **SWDTEN:** Software Enable/Disable of WDT bit(2)
1 = WDT is enabled
0 = WDT is disabled

bit 4 **WDTO:** Watchdog Timer Time-out Flag bit
1 = WDT time-out has occurred
0 = WDT time-out has not occurred

**Note 1:** All of the Reset status bits can be set or cleared in software. Setting one of these bits in software does not cause a device Reset.

**2:** If the WDTEN<1:0> Configuration bits are '11' (unprogrammed), the WDT is always enabled, regardless of the SWDTEN bit setting.

**REGISTER 6-1: RCON: RESET CONTROL REGISTER(1) (CONTINUED)**

bit 3 **SLEEP:** Wake-up from Sleep Flag bit
1 = Device has been in Sleep mode
0 = Device has not been in Sleep mode

bit 2 **IDLE:** Wake-up from Idle Flag bit
1 = Device has been in Idle mode
0 = Device has not been in Idle mode

bit 1 **BOR:** Brown-out Reset Flag bit
1 = A Brown-out Reset has occurred
0 = A Brown-out Reset has not occurred

bit 0 **POR:** Power-on Reset Flag bit
1 = A Power-on Reset has occurred
0 = A Power-on Reset has not occurred

**Note 1:** All of the Reset status bits can be set or cleared in software. Setting one of these bits in software does not cause a device Reset.

**2:** If the WDTEN<1:0> Configuration bits are '11' (unprogrammed), the WDT is always enabled, regardless of the SWDTEN bit setting.


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# 7.0 INTERRUPT CONTROLLER

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Interrupts"** (DS70000600) in the *"dsPIC33/PIC24 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 dsPIC33EPXXXGS70X/80X family interrupt controller reduces the numerous peripheral interrupt request signals to a single interrupt request signal to the dsPIC33EPXXXGS70X/80X family CPU.

The interrupt controller has the following features:

- Six Processor Exceptions and Software Traps
- Seven User-Selectable Priority Levels
- Interrupt Vector Table (IVT) with a Unique Vector for each Interrupt or Exception Source
- Fixed Priority within a Specified User Priority Level
- Fixed Interrupt Entry and Return Latencies
- Alternate Interrupt Vector Table (AIVT) for Debug Support

## 7.1 Interrupt Vector Table

The dsPIC33EPXXXGS70X/80X family Interrupt Vector Table (IVT), shown in Figure 7-1, resides in program memory, starting at location, 000004h. The IVT contains six non-maskable trap vectors and up to 246 sources of interrupts. In general, each interrupt source has its own vector. Each interrupt vector contains a 24-bit wide address. The value programmed into each interrupt vector location is the starting address of the associated Interrupt Service Routine (ISR).

Interrupt vectors are prioritized in terms of their natural priority. This priority is linked to their position in the vector table. Lower addresses generally have a higher natural priority. For example, the interrupt associated with Vector 0 takes priority over interrupts at any other vector address.

### 7.1.1 ALTERNATE INTERRUPT VECTOR TABLE

The Alternate Interrupt Vector Table (AIVT), shown in Figure 7-2, is available only when the Boot Segment is defined and the AIVT has been enabled. To enable the Alternate Interrupt Vector Table, the Configuration bit, AIVTDIS in the FSEC register, must be programmed and the AIVTEN bit must be set (INTCON2<8> = 1). When the AIVT is enabled, all interrupt and exception processes use the alternate vectors instead of the default vectors. The AIVT begins at the start of the last page of the Boot Segment, defined by BSLIM<12:0>. The second half of the page is no longer usable space. The Boot Segment must be at least 2 pages to enable the AIVT.

**Note:** Although the Boot Segment must be enabled in order to enable the AIVT, application code does not need to be present inside of the Boot Segment. The AIVT (and IVT) will inherit the Boot Segment code protection.

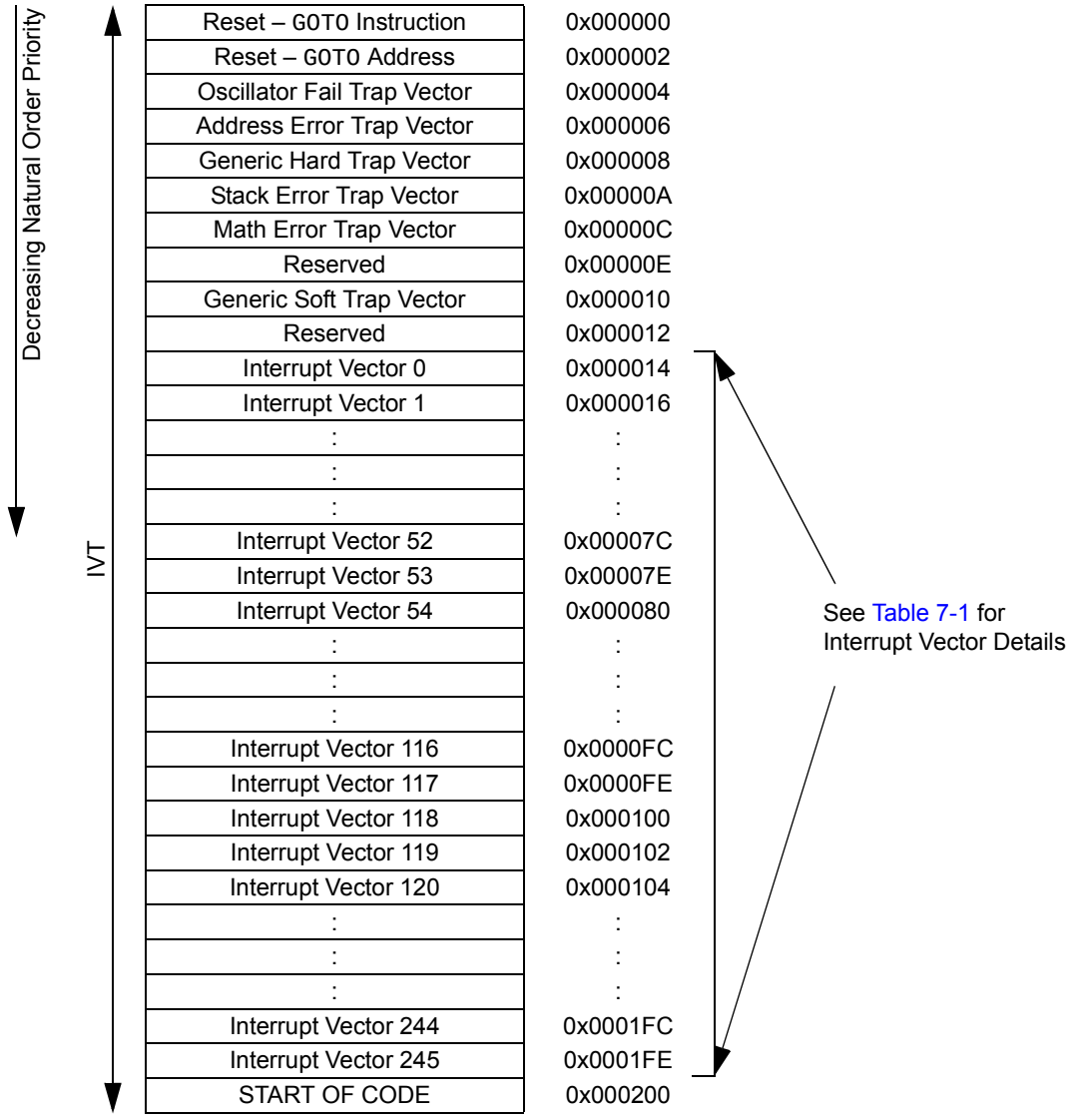
The AIVT supports debugging by providing a means to switch between an application and a support environment without requiring the interrupt vectors to be reprogrammed. This feature also enables switching between applications for evaluation of different software algorithms at run time.

## 7.2 Reset Sequence

A device Reset is not a true exception because the interrupt controller is not involved in the Reset process. The dsPIC33EPXXXGS70X/80X family devices clear their registers in response to a Reset, which forces the PC to zero. The device then begins program execution at location, 0x000000. A GOTO instruction at the Reset address can redirect program execution to the appropriate start-up routine.

**Note:** Any unimplemented or unused vector locations in the IVT should be programmed with the address of a default interrupt handler routine that contains a RESET instruction.

**FIGURE 7-1: dsPIC33EPXXXGS70X/80X FAMILY INTERRUPT VECTOR TABLE**




**Note:** In Dual Partition Flash modes, each partition has a dedicated Interrupt Vector Table.


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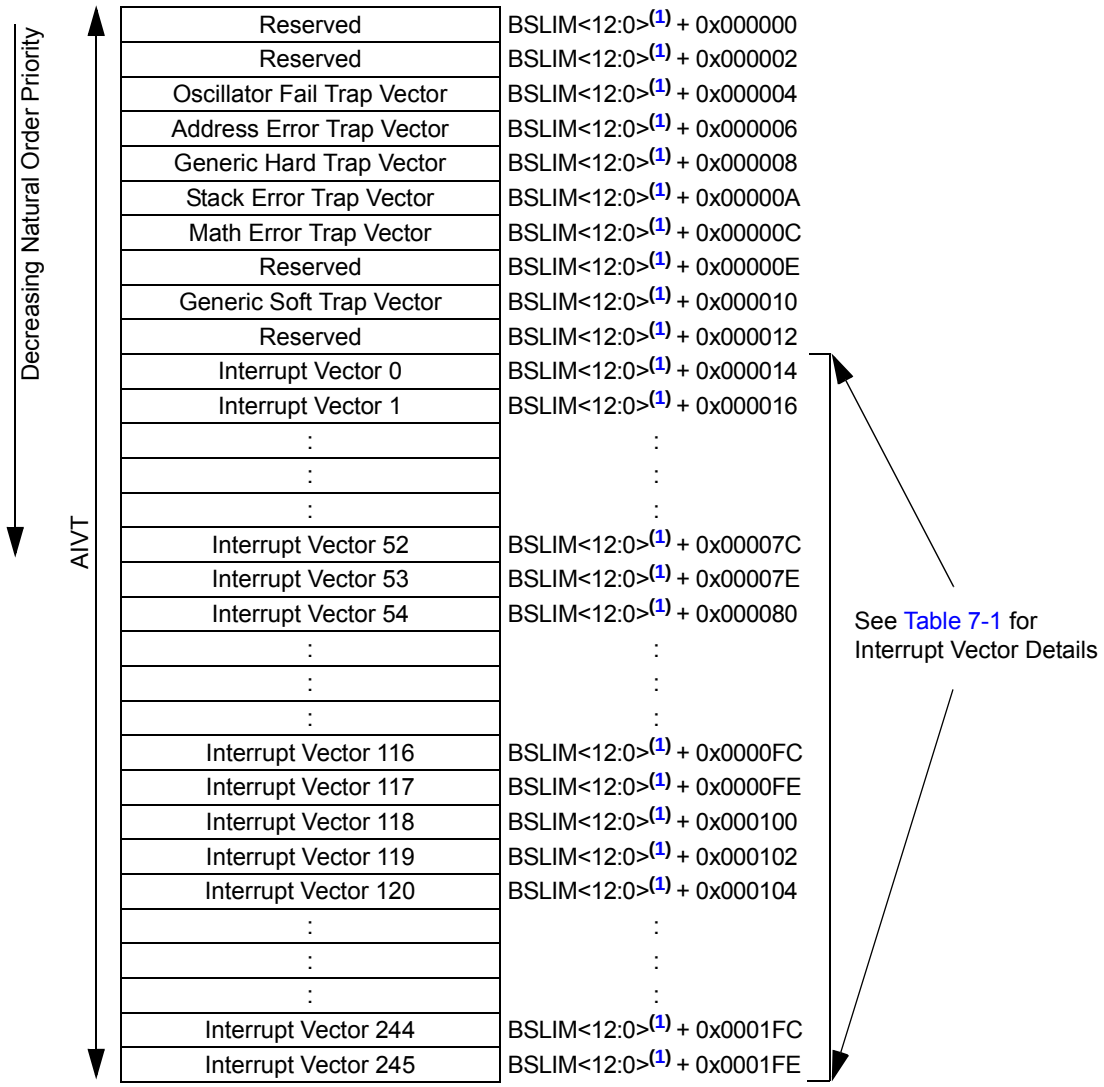
**FIGURE 7-2: dsPIC33EPXXXGS70X/80X ALTERNATE INTERRUPT VECTOR TABLE(2)**




**Note 1:** The address depends on the size of the Boot Segment defined by BSLIM<12:0>. [(BSLIM<12:0> – 1) x 0x400] + Offset.

**2:** In Dual Partition Flash modes, each partition has a dedicated Alternate Interrupt Vector Table (if enabled).

**TABLE 7-1: INTERRUPT VECTOR DETAILS**

| Interrupt Source | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|
| | | | | Flag | Enable | Priority |
| Highest Natural Order Priority | | | | | | |
| INT0 – External Interrupt 0 | 8 | 0 | 0x000014 | IFS0<0> INT0IF | IEC0<0> INT0IE | IPC0<2:0> INT0IP<2:0> |
| IC1 – Input Capture 1 | 9 | 1 | 0x000016 | IFS0<1> IC1IF | IEC0<1> IC1IE | IPC0<6:4> IC1IP<2:0> |
| OC1 – Output Compare 1 | 10 | 2 | 0x000018 | IFS0<2> OC1IF | IEC0<2> OC1IE | IPC0<10:8> OC1IP<2:0> |
| T1 – Timer1 | 11 | 3 | 0x00001A | IFS0<3> T1IF | IEC0<3> T1IE | IPC0<14:12> T1IP<2:0> |
| DMA0 – DMA Channel 0 | 12 | 4 | 0x00001C | IFS0<4> DMA0IF | IEC0<4> DMA0IE | IPC1<2:0> DMA0IP<2:0> |
| IC2 – Input Capture 2 | 13 | 5 | 0x00001E | IFS0<5> IC2IF | IEC0<5> IC2IE | IPC1<6:4> IC2IP<2:0> |
| OC2 – Output Compare 2 | 14 | 6 | 0x000020 | IFS0<6> OC2IF | IEC0<6> OC2IE | IPC1<10:8> OC2IP<2:0> |
| T2 – Timer2 | 15 | 7 | 0x000022 | IFS0<7> T2IF | IEC0<7> T2IE | IPC1<14:12> T2IP<2:0> |
| T3 – Timer3 | 16 | 8 | 0x000024 | IFS0<8> T3IF | IEC0<8> T3IE | IPC2<2:0> T3IP<2:0> |
| SPI1TX – SPI1 Transfer Done | 17 | 9 | 0x000026 | IFS0<9> SPI1TXIF | IEC0<9> SPI1TXIE | IPC2<6:4> SPI1TXIP<2:0> |
| SPI1RX – SPI1 Receive Done | 18 | 10 | 0x000028 | IFS0<10> SPI1RXIF | IEC0<10> SPI1RXIE | IPC2<10:8> SPI1RXIP<2:0> |
| U1RX – UART1 Receiver | 19 | 11 | 0x00002A | IFS0<11> U1RXIF | IEC0<11> U1RXIE | IPC2<14:12> U1RXIP<2:0> |
| U1TX – UART1 Transmitter | 20 | 12 | 0x00002C | IFS0<12> U1TXIF | IEC0<12> U1TXIE | IPC3<2:0> U1TXIP<2:0> |
| ADC – ADC Global Convert Done | 21 | 13 | 0x00002E | IFS0<13> ADCIF | IEC0<13> ADCIE | IPC3<6:4> ADCIP<2:0> |
| DMA1 – DMA Channel 1 | 22 | 14 | 0x000030 | IFS0<14> DMA1IF | IEC0<14> DMA1IE | IPC3<10:8> DMA1IP<2:0> |
| NVM – NVM Write Complete | 23 | 15 | 0x000032 | IFS0<15> NVMIF | IEC0<15> NVMIE | IPC3<14:12> NVMIP<2:0> |
| SI2C1 – I2C1 Slave Event | 24 | 16 | 0x000034 | IFS1<0> SI2C1IF | IEC1<0> SI2C1IE | IPC4<2:0> SI2C1IP<2:0> |
| MI2C1 – I2C1 Master Event | 25 | 17 | 0x000036 | IFS1<1> MI2C1IF | IEC1<1> MI2C1IE | IPC4<6:4> MI2C1IP<2:0> |
| AC1 – Analog Comparator 1 Interrupt | 26 | 18 | 0x000038 | IFS1<2> AC1IF | IEC1<2> AC1IE | IPC4<10:8> AC1IP<2:0> |
| CN – Input Change Interrupt | 27 | 19 | 0x00003A | IFS1<3> CNIF | IEC1<3> CNIE | IPC4<14:12> CNIP<2:0> |
| INT1 – External Interrupt 1 | 28 | 20 | 0x00003C | IFS1<4> INT1IF | IEC1<4> INT1IE | IPC5<2:0> INT1IP<2:0> |
| Reserved | 29-31 | 21-23 | 0x00003E-0x000043 | — | — | — |
| DMA2 – DMA Channel 2 | 32 | 24 | 0x00044 | IFS1<8> DMA2IF | IEC1<8> DMA2IE | IPC6<2:0> DMA2IP<2:0> |
| OC3 – Output Compare 3 | 33 | 25 | 0x000046 | IFS1<9> OC3IF | IEC1<9> OC3IE | IPC6<6:4> OC3IP<2:0> |
| OC4 – Output Compare 4 | 34 | 26 | 0x000048 | IFS1<10> OC4IF | IEC1<10> OC4IE | IPC6<10:8> OC4IP<2:0> |


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**TABLE 7-1: INTERRUPT VECTOR DETAILS (CONTINUED)**

| Interrupt Source | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|
| | | | | Flag | Enable | Priority |
| T4 – Timer4 | 35 | 27 | 0x00004A | IFS1<11> T4IF | IEC1<11> T4IE | IPC6<14:12> T4IP<2:0> |
| T5 – Timer5 | 36 | 28 | 0x00004C | IFS1<12> T5IF | IEC1<12> T5IE | IPC7<2:0> T5IP<2:0> |
| INT2 – External Interrupt 2 | 37 | 29 | 0x00004E | IFS1<13> INT2IF | IEC1<13> INT2IE | IPC7<6:4> INT2IP<2:0> |
| U2RX – UART2 Receiver | 38 | 30 | 0x000050 | IFS1<14> U2RXIF | IEC1<14> U2RXIE | IPC7<10:8> U2RXIP<2:0> |
| U2TX – UART2 Transmitter | 39 | 31 | 0x000052 | IFS1<15> U2TXIF | IEC1<15> U2TXIE | IPC7<14:12> U2TXIP<2:0> |
| SPI2TX – SPI2 Transfer Done | 40 | 32 | 0x000054 | IFS2<0> SPI2TXIF | IEC2<0> SPI2TXIE | IPC8<2:0> SPI2TXIP<2:0> |
| SPI2RX – SPI2 Receive Done | 41 | 33 | 0x000056 | IFS2<1> SPI2RXIF | IEC2<1> SPI2RXIE | IPC8<6:4> SPI2RXIP<2:0> |
| C1RX – CAN1 RX Data Ready | 42 | 34 | 0x000058 | IFS2<2> C1RXIF | IEC2<2> C1RXIE | IPC8<10:8> C1RXIP<2:0> |
| C1 – CAN1 Combined Error | 43 | 35 | 0x000059 | IFS2<3> C1IF | IEC2<3> C1IE | IPC8<14:12> C1IP<2:0> |
| DMA3 – DMA Channel 3 | 44 | 36 | 0x00005A | IFS2<4> DMA3IF | IEC2<4> DMA3IE | IPC9<2:0> DMA3IP<2:0> |
| IC3 – Input Capture 3 | 45 | 37 | 0x00005E | IFS2<5> IC3IF | IEC2<5> IC3IE | IPC9<6:4> IC3IP<2:0> |
| IC4 – Input Capture 4 | 46 | 38 | 0x000060 | IFS2<6> IC4IF | IEC2<6> IC4IE | IPC9<10:8> IC4IP<2:0> |
| Reserved | 47-56 | 39-48 | 0x000062-0x000074 | — | — | — |
| SI2C2 – I2C2 Slave Event | 57 | 49 | 0x000076 | IFS3<1> SI2C2IF | IEC3<1> SI2C2IE | IPC12<6:4> SI2C2IP<2:0> |
| MI2C2 – I2C2 Master Event | 58 | 50 | 0x000078 | IFS3<2> MI2C2IF | IEC3<2> MI2C2IE | IPC12<10:8> MI2C2IP<2:0> |
| Reserved | 59-61 | 51-53 | 0x00007A-0x00007E | — | — | — |
| INT4 – External Interrupt 4 | 62 | 54 | 0x000080 | IFS3<6> INT4IF | IEC3<6> INT4IE | IPC13<10:8> INT4IP<2:0> |
| C2RX – CAN2 RX Data Ready | 63 | 55 | 0x000082 | IFS3<7> C2RXIF | IEC3<7> C2RXIE | IPC13<14:12> C2RXIP<2:0> |
| C2 – CAN 2 Combined Error | 64 | 56 | 0x000083 | IFS3<8> C2IF | IEC3<8> C2IE | IPC14<2:0> C2IP<2:0> |
| PSEM – PWM Special Event Match | 65 | 57 | 0x000086 | IFS3<9> PSEMIF | IEC3<9> PSEMIE | IPC14<6:4> PSEMIP<2:0> |
| Reserved | 66-72 | 58-64 | 0x000088-0x000094 | — | — | — |
| U1E – UART1 Error Interrupt | 73 | 65 | 0x000096 | IFS4<1> U1EIF | IEC4<1> U1EIE | IPC16<6:4> U1EIP<2:0> |
| U2E – UART2 Error Interrupt | 74 | 66 | 0x000098 | IFS4<2> U2EIF | IEC4<2> U2EIE | IPC16<10:8> U2EIP<2:0> |
| Reserved | 75-77 | 67-69 | 0x00009A-0x0000A2 | — | — | — |
| C1TX – CAN1 TX Data Request | 78 | 70 | 0x0000A0 | IFS4<6> C1TXIF | IEC4<6> C1TXIE | IPC17<10:8> C1TXIP<2:0> |
| C2TX – CAN2 TX Data Request | 79 | 71 | 0x0000A | IFS4<7> C2TXIF | IEC4<7> C2TXIE | IPC17<14:12> C2TXIP<2:0> |
| Reserved | 80 | 72 | 0x0000A4 | — | — | — |

**TABLE 7-1: INTERRUPT VECTOR DETAILS (CONTINUED)**

| Interrupt Source | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|
| | | | | Flag | Enable | Priority |
| PSES – PWM Secondary Special Event Match | 81 | 73 | 0x0000A6 | IFS4<9> PSESIF | IEC4<9> PSESIE | IPC18<6:4> PSESIP<2:0> |
| Reserved | 82-97 | 74-89 | 0x0000A8-0x0000C6 | — | — | — |
| SPI3TX – SPI3 Transfer Done | 98 | 90 | 0x0000C8 | IFS5<10> SPI3TXIF | IEC5<10> SPI3TXIE | IPC22<10:8> SPI3TXIP<2:0> |
| SPI3RX – SPI3 Receive Done | 99 | 91 | 0x0000CA | IFS5<10> SPI3RXIF | IEC5<11> SPI3RXIE | IPC22<14:12> SPI3RXIP<2:0> |
| Reserved | 100-101 | 92-93 | 0x0000CC-0x0000CE | — | — | — |
| PWM1 – PWM1 Interrupt | 102 | 94 | 0x0000D0 | IFS5<14> PWM1IF | IEC5<14> PWM1IE | IPC23<10:8> PWM1IP<2:0> |
| PWM2 – PWM2 Interrupt | 103 | 95 | 0x0000D2 | IFS5<15> PWM2IF | IEC5<15> PWM2IE | IPC23<14:12> PWM2IP<2:0> |
| PWM3 – PWM3 Interrupt | 104 | 96 | 0x0000D4 | IFS6<0> PWM3IF | IEC6<0> PWM3IE | IPC24<2:0> PWM3IP<2:0> |
| PWM4 – PWM4 Interrupt | 105 | 97 | 0x0000D6 | IFS6<1> PWM4IF | IEC6<1> PWM4IE | IPC24<6:4> PWM4IP<2:0> |
| PWM5 – PWM5 Interrupt | 106 | 98 | 0x0000D8 | IFS6<2> PWM5IF | IEC6<2> PWM5IE | IPC24<10:8> PWM5IP<2:0> |
| PWM6 – PWM6 Interrupt | 107 | 99 | 0x0000DA | IFS6<3> PWM6IF | IEC6<3> PWM6IE | IPC24<14:12> PWM6IP<2:0> |
| PWM7 – PWM7 Interrupt | 108 | 100 | 0x0000DC | IFS6<4> PWM7IF | IEC6<4> PWM7IE | IPC25<2:0> PWM7IP<2:0> |
| PWM8 – PWM8 Interrupt | 109 | 101 | 0x0000DE | IFS6<5> PWM8IF | IEC6<5> PWM8IE | IPC25<6:4> PWM8IP<2:0> |
| Reserved | 110 | 102 | 0x0000E0 | — | — | — |
| AC2 – Analog Comparator 2 Interrupt | 111 | 103 | 0x0000E2 | IFS6<7> AC2IF | IEC6<7> AC2IE | IPC25<14:12> AC2IP<2:0> |
| AC3 – Analog Comparator 3 Interrupt | 112 | 104 | 0x0000E4 | IFS6<8> AC3IF | IEC6<8> AC3IE | IPC26<2:0> AC3IP<2:0> |
| AC4 – Analog Comparator 4 Interrupt | 113 | 105 | 0x0000E6 | IFS6<9> AC4IF | IEC6<9> AC4IE | IPC26<6:4> AC4IP<2:0> |
| Reserved | 114-117 | 106-109 | 0x0000E8-0x0000EE | — | — | — |
| AN0 Conversion Done | 118 | 110 | 0x0000F0 | IFS6<14> AN0IF | IEC6<14> AN0IE | IPC27<10:8> AN0IP<2:0> |
| AN1 Conversion Done | 119 | 111 | 0x0000F2 | IFS6<15> AN1IF | IEC6<15> AN1IE | IPC27<14:12> AN1IP<2:0> |
| AN2 Conversion Done | 120 | 112 | 0x0000F4 | IFS7<0> AN2IF | IEC7<0> AN2IE | IPC28<2:0> AN2IP<2:0> |
| AN3 Conversion Done | 121 | 113 | 0x0000F6 | IFS7<1> AN3IF | IEC7<1> AN3IE | IPC28<6:4> AN3IP<2:0> |
| AN4 Conversion Done | 122 | 114 | 0x0000F8 | IFS7<2> AN4IF | IEC7<2> AN4IE | IPC28<10:8> AN4IP<2:0> |
| AN5 Conversion Done | 123 | 115 | 0x0000FA | IFS7<3> AN5IF | IEC7<3> AN5IE | IPC28<14:12> AN5IP<2:0> |
| AN6 Conversion Done | 124 | 116 | 0x0000FC | IFS7<4> AN6IF | IEC7<4> AN6IE | IPC29<2:0> AN6IP<2:0> |
| AN7 Conversion Done | 125 | 117 | 0x0000FE | IFS7<5> AN7IF | IEC7<5> AN7IE | IPC29<6:4> AN7IP<2:0> |
| Reserved | 126-131 | 118-123 | 0x000100-0x00010A | — | — | — |


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**TABLE 7-1: INTERRUPT VECTOR DETAILS (CONTINUED)**

| Interrupt Source | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|
| | | | | Flag | Enable | Priority |
| SPI1 Error Interrupt | 132 | 124 | 0x00010C | IFS7<12> SPI1IF | IEC7<12> SPI1IE | IPC31<2:0> SPI1IP<2:0> |
| SPI2 Error Interrupt | 133 | 125 | 0x00010E | IFS7<13> SPI2IF | IEC7<13> SPI2IE | IPC31<6:4> SPI2IP<2:0> |
| SPI3 Error Interrupt | 134 | 126 | 0x000110 | IFS7<13> SPI3IF | IEC7<13> SPI3IE | IPC31<10:8> SPI3IP<2:0> |
| Reserved | 135-145 | 127-137 | 0x000112-0x000126 | — | — | — |
| CLC1 Interrupt | 146 | 138 | 0x000128 | IFS8<10> CLC1IF | IEC8<10> CLC1IE | IPC34<10:8> CLC1IP<2:0> |
| CLC2 Interrupt | 147 | 139 | 0x00012A | IFS8<11> CLC2IF | IEC8<11> CLC2IE | IPC34<14:12> CLC2IP<2:0> |
| CLC3 Interrupt | 148 | 140 | 0x00012C | IFS8<12> CLC3IF | IEC8<12> CLC3IE | IPC35<2:0> CLC3IP<2:0> |
| CLC4 Interrupt | 149 | 141 | 0x00012E | IFS8<13> CLC4IF | IEC8<13> CLC4IE | IPC35<6:4> CLC4IP<2:0> |
| ICD – ICD Application | 150 | 142 | 0x000130 | IFS8<14> ICDIF | IEC8<14> ICDIE | IPC35<10:8> ICDIP<2:0> |
| JTAG – JTAG Programming | 151 | 143 | 0x000132 | IFS8<15> JTAGIF | IEC8<15> JTAGIE | IPC35<14:12> JTAGIP<2:0> |
| Reserved | 152 | 144 | 0x000134 | — | — | — |
| PTGSTEP – PTG Step | 153 | 145 | 0x000136 | IFS9<1> PTGSTEPIF | IEC9<1> PTGSTEPIE | IPC36<6:4> PTGSTEP<2:0> |
| PTGWDT – PTG WDT Time-out | 154 | 146 | 0x000138 | IFS9<2> PTGWDTIF | IEC9<2> PTGWDTIE | IPC36<10:8> PTGWDT<2:0> |
| PTG0 – PTG Interrupt Trigger 0 | 155 | 147 | 0x00013A | IFS9<3> PTG0IF | IEC9<3> PTG0IE | IPC36<14:12> PTG0IP<2:0> |
| PTG1 – PTG Interrupt Trigger 1 | 156 | 148 | 0x00013C | IFS9<4> PTG1IF | IEC9<4> PTG1IE | IPC37<2:0> PTG1IP<2:0> |
| PTG2 – PTG Interrupt Trigger 2 | 157 | 149 | 0x00013E | IFS9<5> PTG2IF | IEC9<5> PTG2IE | IPC37<6:4> PTG2IP<2:0> |
| PTG3 – PTG Interrupt Trigger 3 | 158 | 150 | 0x000140 | IFS9<6> PTG3IF | IEC9<6> PTG3IE | IPC37<10:8> PTG3IP<2:0> |
| AN8 Conversion Done | 159 | 151 | 0x000142 | IFS9<7> AN8IF | IEC9<7> AN8IE | IPC37<14:12> AN8IP<2:0> |
| AN9 Conversion Done | 160 | 152 | 0x000144 | IFS9<8> AN9IF | IEC9<8> AN9IE | IPC38<2:0> AN9IP<2:0> |
| AN10 Conversion Done | 161 | 153 | 0x000146 | IFS9<9> AN10IF | IEC9<9> AN10IE | IPC38<6:4> AN10IP<2:0> |
| AN11 Conversion Done | 162 | 154 | 0x000148 | IFS9<10> AN11IF | IEC9<10> AN11IE | IPC38<10:8> AN11IP<2:0> |
| AN12 Conversion Done | 163 | 155 | 0x00014A | IFS9<11> AN12IF | IEC9<11> AN12IE | IPC38<14:12> AN12IP<2:0> |
| AN13 Conversion Done | 164 | 156 | 0x00014C | IFS9<12> AN13IF | IEC9<12> AN13IE | IPC39<2:0> AN13IP<2:0> |
| AN14 Conversion Done | 165 | 157 | 0x00014E | IFS9<13> AN14IF | IEC9<13> AN14IE | IPC39<6:4> AN14IP<2:0> |
| AN15 Conversion Done | 166 | 158 | 0x000150 | IFS9<14> AN15IF | IEC9<14> AN15IE | IPC39<10:8> AN15IP<2:0> |
| AN16 Conversion Done | 167 | 159 | 0x000152 | IFS9<15> AN16IF | IEC9<15> AN16IE | IPC39<14:12> AN16IP<2:0> |

**TABLE 7-1: INTERRUPT VECTOR DETAILS (CONTINUED)**

| Interrupt Source | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|
| | | | | Flag | Enable | Priority |
| AN17 Conversion Done | 168 | 160 | 0x000154 | IFS10<0> AN17IF | IEC10<0> AN17IE | IPC40<2:0> AN17IP<2:0> |
| AN18 Conversion Done | 169 | 161 | 0x000156 | IFS10<1> AN18IF | IEC10<1> AN18IE | IPC40<6:4> AN18IP<2:0> |
| AN19 Conversion Done | 170 | 162 | 0x000158 | IFS10<2> AN19IF | IEC10<2> AN19IE | IPC40<10:8> AN19IP<2:0> |
| AN20 Conversion Done | 171 | 163 | 0x00015A | IFS10<3> AN20IF | IEC10<3> AN20IE | IPC40<14:12> AN20IP<2:0> |
| AN21 Conversion Done | 172 | 164 | 0x00015C | IFS10<4> AN21IF | IEC10<4> AN21IE | IPC41<2:0> AN21IP<2:0> |
| Reserved | 173-180 | 165-172 | 0x00015C-0x00016C | — | — | — |
| I2C1 – I2C1 Bus Collision | 181 | 173 | 0x00016E | IFS10<13> I2C1IF | IEC10<13> I2C1IE | IPC43<6:4> I2C1IP<2:0> |
| I2C2 – I2C2 Bus Collision | 182 | 174 | 0x000170 | IFS10<14> I2C2IF | IEC10<14> I2C2IE | IPC43<10:8> I2C2IP<2:0> |
| Reserved | 183-184 | 175-176 | 0x000172-0x000174 | — | — | — |
| ADCMP0 – ADC Digital Comparator 0 | 185 | 177 | 0x000176 | IFS11<1> ADCMP0IF | IEC11<1> ADCMP0IE | IPC44<6:4> ADCMP0IP<2:0> |
| ADCMP1 – ADC Digital Comparator 1 | 186 | 178 | 0x000178 | IFS11<2> ADCMP1IF | IEC11<2> ADCMP1IE | IPC44<10:8> ADCMP1IP<2:0> |
| ADFLTR0 – ADC Filter 0 | 187 | 179 | 0x00017A | IFS11<3> ADFLTR0IF | IEC11<3> ADFLTR0IE | IPC44<14:12> ADFLTR0IP<2:0> |
| ADFLTR1 – ADC Filter 1 | 188 | 180 | 0x00017C | IFS11<4> ADFLTR1IF | IEC11<4> ADFLTR1IE | IPC45<2:0> ADFLTR1IP<2:0> |
| Reserved | 189-253 | 181-245 | 0x00017E-0x000192 | — | — | — |


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## 7.3 Interrupt 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 contains the latest updates and additional information.

### 7.3.1 KEY RESOURCES

- **"Interrupts"** (DS70000600) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

## 7.4 Interrupt Control and Status Registers

dsPIC33EPXXXGS70X/80X family devices implement the following registers for the interrupt controller:

- INTCON1
- INTCON2
- INTCON3
- INTCON4
- INTTREG

### 7.4.1 INTCON1 THROUGH INTCON4

Global interrupt control functions are controlled from INTCON1, INTCON2, INTCON3 and INTCON4.

INTCON1 contains the Interrupt Nesting Disable bit (NSTDIS), as well as the control and status flags for the processor trap sources.

The INTCON2 register controls external interrupt request signal behavior, contains the Global Interrupt Enable bit (GIE) and the Alternate Interrupt Vector Table Enable bit (AIVTEN).

INTCON3 contains the status flags for the Auxiliary PLL and DO stack overflow status trap sources.

The INTCON4 register contains the Software Generated Hard Trap Status bit (SGHT).

### 7.4.2 IFSx

The IFSx registers maintain all of the interrupt request flags. Each source of interrupt has a status bit, which is set by the respective peripherals or external signal and is cleared via software.

### 7.4.3 IECx

The IECx registers maintain all of the interrupt enable bits. These control bits are used to individually enable interrupts from the peripherals or external signals.

### 7.4.4 IPCx

The IPCx registers are used to set the Interrupt Priority Level (IPL) for each source of interrupt. Each user interrupt source can be assigned to one of seven priority levels.

### 7.4.5 INTTREG

The INTTREG register contains the associated interrupt vector number and the new CPU Interrupt Priority Level, which are latched into the Vector Number of Pending Interrupt bits (VECNUM<7:0>) and New CPU Interrupt Priority Level bits (ILR<3:0>) fields in the INTTREG register. The new Interrupt Priority Level is the priority of the pending interrupt.

The interrupt sources are assigned to the IFSx, IECx and IPCx registers in the same sequence as they are listed in Table 7-1. For example, the INT0 (External Interrupt 0) is shown as having Vector Number 8 and a natural order priority of 0. Thus, the INT0IF bit is found in IFS0<0>, the INT0IE bit in IEC0<0> and the INT0IP<2:0> bits in the first position of IPC0 (IPC0<2:0>).

### 7.4.6 STATUS/CONTROL REGISTERS

Although these registers are not specifically part of the interrupt control hardware, two of the CPU Control registers contain bits that control interrupt functionality. For more information on these registers, refer to **"dsPIC33E Enhanced CPU"** (DS70005158) in the *"dsPIC33/PIC24 Family Reference Manual"*.

- The CPU STATUS Register, SR, contains the IPL<2:0> bits (SR<7:5>). These bits indicate the current CPU Interrupt Priority Level. The user software can change the current CPU Interrupt Priority Level by writing to the IPLx bits.
- The CORCON register contains the IPL3 bit which, together with IPL<2:0>, also indicates the current CPU priority level. IPL3 is a read-only bit so that trap events cannot be masked by the user software.

All Interrupt registers are described in Register 7-3 through Register 7-7 in the following pages.

**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 |
|---|---|---|---|---|---|---|---|
| IPL2(2) | IPL1(2) | IPL0(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.


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**REGISTER 7-2: CORCON: CORE CONTROL REGISTER(1)**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| VAR | — | US1 | US0 | EDT | DL2 | DL1 | DL0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-1 | R/W-0 | R/C-0 | R-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SATA | SATB | SATDW | ACCSAT | IPL3(2) | SFA | RND | IF |
| 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 15 **VAR:** Variable Exception Processing Latency Control bit
1 = Variable exception processing is enabled
0 = Fixed exception processing is enabled

bit 3 **IPL3:** CPU Interrupt Priority Level Status bit 3(2)
1 = CPU Interrupt Priority Level is greater than 7
0 = CPU Interrupt Priority Level is 7 or less

**Note 1:** For complete register details, see Register 3-2.
**2:** The IPL3 bit is concatenated with the IPL<2:0> bits (SR<7:5>) to form the CPU Interrupt Priority Level.

**REGISTER 7-3: INTCON1: INTERRUPT CONTROL REGISTER 1**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| NSTDIS | OVAERR | OVBERR | COVAERR | COVBERR | OVATE | OVBTE | COVTE |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SFTACERR | DIV0ERR | — | MATHERR | ADDRERR | STKERR | OSCFAIL | — |
| 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 **NSTDIS:** Interrupt Nesting Disable bit
1 = Interrupt nesting is disabled
0 = Interrupt nesting is enabled

bit 14 **OVAERR:** Accumulator A Overflow Trap Flag bit
1 = Trap was caused by overflow of Accumulator A
0 = Trap was not caused by overflow of Accumulator A

bit 13 **OVBERR:** Accumulator B Overflow Trap Flag bit
1 = Trap was caused by overflow of Accumulator B
0 = Trap was not caused by overflow of Accumulator B

bit 12 **COVAERR:** Accumulator A Catastrophic Overflow Trap Flag bit
1 = Trap was caused by catastrophic overflow of Accumulator A
0 = Trap was not caused by catastrophic overflow of Accumulator A

bit 11 **COVBERR:** Accumulator B Catastrophic Overflow Trap Flag bit
1 = Trap was caused by catastrophic overflow of Accumulator B
0 = Trap was not caused by catastrophic overflow of Accumulator B

bit 10 **OVATE:** Accumulator A Overflow Trap Enable bit
1 = Trap overflow of Accumulator A
0 = Trap is disabled

bit 9 **OVBTE:** Accumulator B Overflow Trap Enable bit
1 = Trap overflow of Accumulator B
0 = Trap is disabled

bit 8 **COVTE:** Catastrophic Overflow Trap Enable bit
1 = Trap on catastrophic overflow of Accumulator A or B is enabled
0 = Trap is disabled

bit 7 **SFTACERR:** Shift Accumulator Error Status bit
1 = Math error trap was caused by an invalid accumulator shift
0 = Math error trap was not caused by an invalid accumulator shift

bit 6 **DIV0ERR:** Divide-by-Zero Error Status bit
1 = Math error trap was caused by a divide-by-zero
0 = Math error trap was not caused by a divide-by-zero

bit 5 **Unimplemented:** Read as ‘0’

bit 4 **MATHERR:** Math Error Status bit
1 = Math error trap has occurred
0 = Math error trap has not occurred

bit 3 **ADDRERR:** Address Error Trap Status bit
1 = Address error trap has occurred
0 = Address error trap has not occurred


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**REGISTER 7-3: INTCON1: INTERRUPT CONTROL REGISTER 1 (CONTINUED)**

bit 2 **STKERR:** Stack Error Trap Status bit
1 = Stack error trap has occurred
0 = Stack error trap has not occurred

bit 1 **OSCFAIL:** Oscillator Failure Trap Status bit
1 = Oscillator failure trap has occurred
0 = Oscillator failure trap has not occurred

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

**REGISTER 7-4: INTCON2: INTERRUPT CONTROL REGISTER 2**

| R/W-1 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| GIE | DISI | SWTRAP | — | — | — | — | AIVTEN |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | INT4EP | — | INT2EP | INT1EP | INT0EP |
| 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 **GIE:** Global Interrupt Enable bit
1 = Interrupts and associated IE bits are enabled
0 = Interrupts are disabled, but traps are still enabled

bit 14 **DISI:** DISI Instruction Status bit
1 = DISI instruction is active
0 = DISI instruction is not active

bit 13 **SWTRAP:** Software Trap Status bit
1 = Software trap is enabled
0 = Software trap is disabled

bit 12-9 **Unimplemented:** Read as ‘0’

bit 8 **AIVTEN:** Alternate Interrupt Vector Table Enable
1 = Uses Alternate Interrupt Vector Table
0 = Uses standard Interrupt Vector Table

bit 7-5 **Unimplemented:** Read as ‘0’

bit 4 **INT4EP:** External Interrupt 4 Edge Detect Polarity Select bit
1 = Interrupt on negative edge
0 = Interrupt on positive edge

bit 3 **Unimplemented:** Read as ‘0’

bit 2 **INT2EP:** External Interrupt 2 Edge Detect Polarity Select bit
1 = Interrupt on negative edge
0 = Interrupt on positive edge

bit 1 **INT1EP:** External Interrupt 1 Edge Detect Polarity Select bit
1 = Interrupt on negative edge
0 = Interrupt on positive edge

bit 0 **INT0EP:** External Interrupt 0 Edge Detect Polarity Select bit
1 = Interrupt on negative edge
0 = Interrupt on positive edge


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

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | NAE |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | DOOVR | — | — | — | APLL |
| 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 15-9 **Unimplemented:** Read as '0'

bit 8 **NAE:** NVM Address Error Soft Trap Status bit
1 = NVM address error soft trap has occurred
0 = NVM address error soft trap has not occurred

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

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 3-1 **Unimplemented:** Read as '0'

bit 0 **APLL:** Auxiliary PLL Loss of Lock Soft Trap Status bit
1 = APLL lock soft trap has occurred
0 = APLL lock soft trap has not occurred

**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

**REGISTER 7-7: INTTREG: INTERRUPT CONTROL AND STATUS REGISTER**

| U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | ILR3 | ILR2 | ILR1 | ILR0 |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| VECNUM7 | VECNUM6 | VECNUM5 | VECNUM4 | VECNUM3 | VECNUM2 | VECNUM1 | VECNUM0 |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11-8 **ILR<3:0>:** New CPU Interrupt Priority Level bits
1111 = CPU Interrupt Priority Level is 15
•
•
•
0001 = CPU Interrupt Priority Level is 1
0000 = CPU Interrupt Priority Level is 0

bit 7-0 **VECNUM<7:0>:** Vector Number of Pending Interrupt bits
11111111 = 255, Reserved; do not use
•
•
•
00001001 = 9, IC1 – Input Capture 1
00001000 = 8, INT0 – External Interrupt 0
00000111 = 7, Reserved; do not use
00000110 = 6, Generic soft error trap
00000101 = 5, Reserved; do not use
00000100 = 4, Math error trap
00000011 = 3, Stack error trap
00000010 = 2, Generic hard trap
00000001 = 1, Address error trap
00000000 = 0, Oscillator fail trap


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## 8.0 DIRECT MEMORY ACCESS (DMA)

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Direct Memory Access (DMA)"** (DS70348) in the *"dsPIC33/PIC24 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 DMA Controller transfers data between Peripheral Data registers and Data Space SRAM

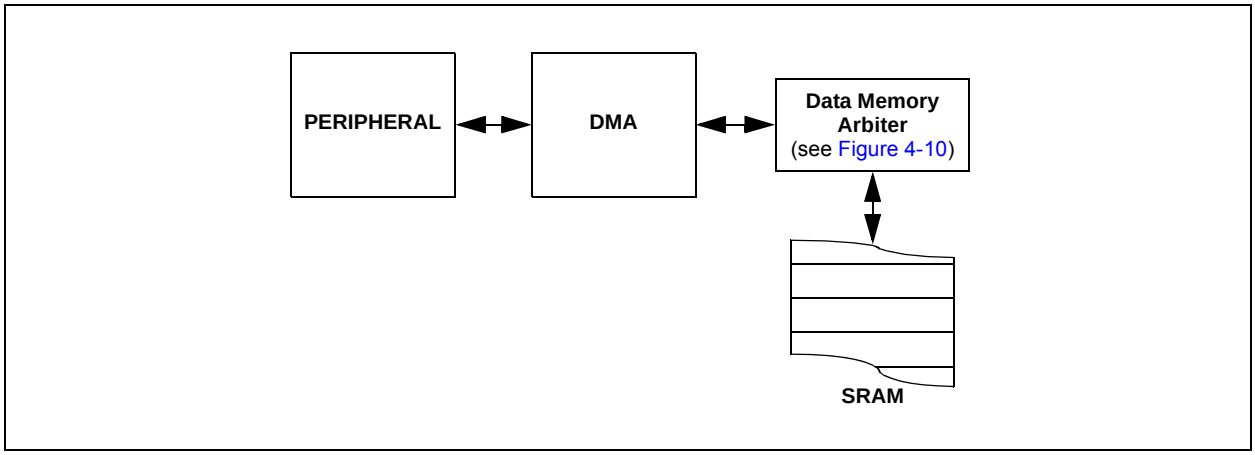
In addition, DMA can access the entire data memory space. The data memory bus arbiter is utilized when either the CPU or DMA attempts to access SRAM, resulting in potential DMA or CPU Stalls.

The DMA Controller supports 4 independent channels. Each channel can be configured for transfers to or from selected peripherals. The peripherals supported by the DMA Controller include:

- CAN
- UART
- Input Capture
- Output Compare
- Timers

Refer to Table 8-1 for a complete list of supported peripherals.

**FIGURE 8-1: PERIPHERAL TO DMA CONTROLLER**



In addition, DMA transfers can be triggered by timers as well as external interrupts. Each DMA channel is uni-directional. Two DMA channels must be allocated to read and write to a peripheral. If more than one channel receives a request to transfer data, a simple fixed priority scheme, based on channel number, dictates which channel completes the transfer and which channel, or channels, are left pending. Each DMA channel moves a block of data, after which, it generates an interrupt to the CPU to indicate that the block is available for processing.

The DMA Controller provides these functional capabilities:

- Four DMA Channels
- Register Indirect with Post-Increment Addressing mode
- Register Indirect without Post-Increment Addressing mode
- Peripheral Indirect Addressing mode (peripheral generates destination address)
- CPU Interrupt after Half or Full Block Transfer Complete
- Byte or Word Transfers
- Fixed Priority Channel Arbitration
- Manual (software) or Automatic (peripheral DMA requests) Transfer Initiation
- One-Shot or Auto-Repeat Block Transfer modes
- Ping-Pong mode (automatic switch between two SRAM Start addresses after each block transfer complete)
- DMA Request for each Channel can be Selected from any Supported Interrupt Source
- Debug Support Features

The peripherals that can utilize DMA are listed in Table 8-1.

**TABLE 8-1: DMA CHANNEL TO PERIPHERAL ASSOCIATIONS**

| Peripheral to DMA Association | DMAxREQ Register IRQSEL<7:0> Bits | DMAxPAD Register (Values to Read from Peripheral) | DMAxPAD Register (Values to Write to Peripheral) |
|---|---|---|---|
| INT0 – External Interrupt 0 | 00000000 | — | — |
| IC1 – Input Capture 1 | 00000001 | 0x0144 (IC1BUF) | — |
| IC2 – Input Capture 2 | 00000101 | 0x014C (IC2BUF) | — |
| IC3 – Input Capture 3 | 00100101 | 0x0154 (IC3BUF) | — |
| IC4 – Input Capture 4 | 00100110 | 0x015C (IC4BUF) | — |
| OC1 – Output Compare 1 | 00000010 | — | 0x0906 (OC1R)<br>0x0904 (OC1RS) |
| OC2 – Output Compare 2 | 00000110 | — | 0x0910 (OC2R)<br>0x090E (OC2RS) |
| OC3 – Output Compare 3 | 00011001 | — | 0x091A (OC3R)<br>0x0918 (OC3RS) |
| OC4 – Output Compare 4 | 00011010 | — | 0x0924 (OC4R)<br>0x0922 (OC4RS) |
| TMR2 – Timer2 | 00000111 | — | — |
| TMR3 – Timer3 | 00001000 | — | — |
| TMR4 – Timer4 | 00011011 | — | — |
| TMR5 – Timer5 | 00011100 | — | — |
| UART1RX – UART1 Receiver | 00001011 | 0x0226 (U1RXREG) | — |
| UART1TX – UART1 Transmitter | 00001100 | — | 0x0224 (U1TXREG) |
| UART2RX – UART2 Receiver | 00011110 | 0x0236 (U2RXREG) | — |
| UART2TX – UART2 Transmitter | 00011111 | — | 0x0234 (U2TXREG) |
| CAN1 – RX Data Ready | 00100010 | 0x0440 (C1RXD) | — |
| CAN1 – TX Data Request | 01000110 | — | 0x0442 (C1TXD) |
| CAN2 – RX Data Ready | 00110111 | 0X0540(C2RXD) | — |
| CAN2 – TX Data Request | 01000111 | — | 0X0542(C2TXD) |


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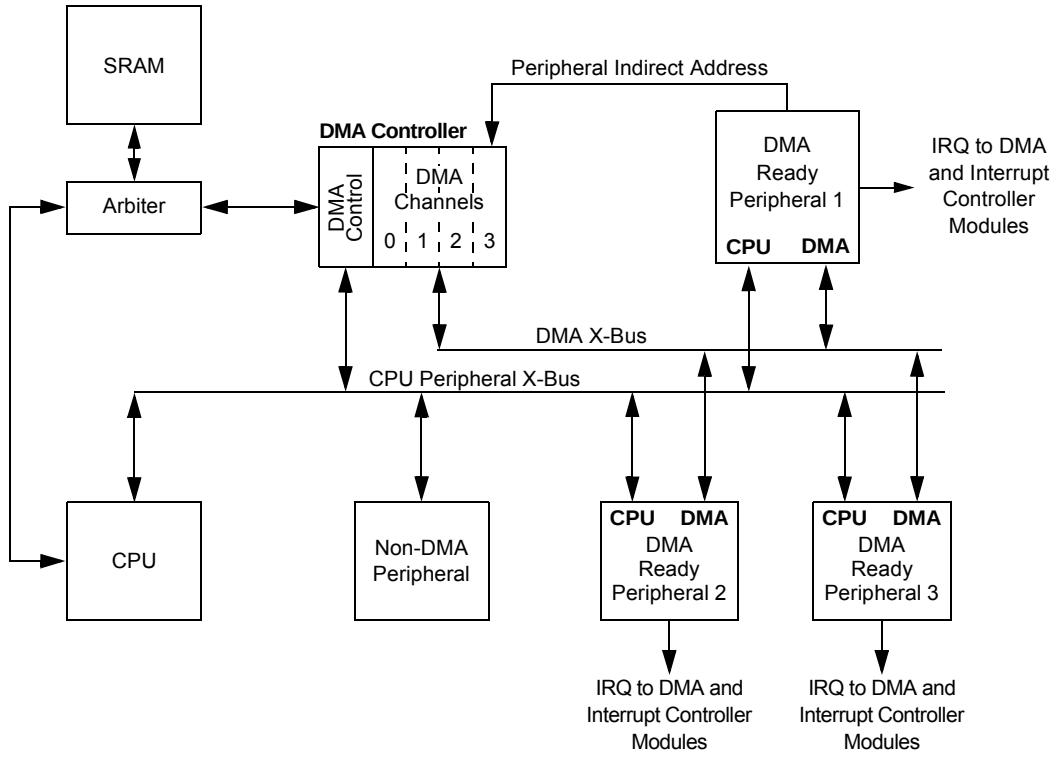
**FIGURE 8-2: DMA CONTROLLER BLOCK DIAGRAM**




**Note:** CPU and DMA address buses are not shown for clarity.

## 8.1 DMA Controller Registers

Each DMA Controller Channel x (where x = 0 through 3) contains the following registers:

- 16-Bit DMA Channel x Control Register (DMAxCON)
- 16-Bit DMA Channel x IRQ Select Register (DMAxREQ)
- 32-Bit DMA Channel x Start Address Register A (DMAxSTAL/H)
- 32-Bit DMA Channel x Start Address Register B (DMAxSTBL/H)
- 16-Bit DMA Channel x Peripheral Address Register (DMAxPAD)
- 14-Bit DMA Channel x Transfer Count Register (DMAxCNT)

Additional status registers (DMAPWC, DMARQC, DMAPPS, DMALCA and DSADRL/H) are common to all DMA Controller channels. These status registers provide information on write and request collisions, as well as on last address and channel access information.

The interrupt flags (DMAxIF) are located in an IFSx register in the interrupt controller. The corresponding interrupt enable control bits (DMAxIE) are located in an IECx register in the interrupt controller and the corresponding interrupt priority control bits (DMAxIP) are located in an IPCx register in the interrupt controller.

**REGISTER 8-1: DMAxCON: DMA CHANNEL x CONTROL REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| CHEN | SIZE | DIR | HALF | NULLW | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | AMODE1 | AMODE0 | — | — | MODE1 | MODE0 |
| 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 **CHEN:** DMA Channel Enable bit
1 = Channel is enabled
0 = Channel is disabled

bit 14 **SIZE:** DMA Data Transfer Size bit
1 = Byte
0 = Word

bit 13 **DIR:** Transfer Direction bit (source/destination bus select)
1 = Reads from RAM address, writes to peripheral address
0 = Reads from peripheral address, writes to RAM address

bit 12 **HALF:** Block Transfer Interrupt Select bit
1 = Initiates interrupt when half of the data has been moved
0 = Initiates interrupt when all of the data has been moved

bit 11 **NULLW:** Null Data Peripheral Write Mode Select bit
1 = Null data write to peripheral in addition to RAM write (DIR bit must also be clear)
0 = Normal operation

bit 10-6 **Unimplemented:** Read as '0'

bit 5-4 **AMODE<1:0>:** DMA Channel Addressing Mode Select bits
11 = Reserved
10 = Peripheral Indirect mode
01 = Register Indirect without Post-Increment mode
00 = Register Indirect with Post-Increment mode

bit 3-2 **Unimplemented:** Read as '0'

bit 1-0 **MODE<1:0>:** DMA Channel Operating Mode Select bits
11 = One-Shot, Ping-Pong modes are enabled (one block transfer from/to each DMA buffer)
10 = Continuous, Ping-Pong modes are enabled
01 = One-Shot, Ping-Pong modes are disabled
00 = Continuous, Ping-Pong modes are disabled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**REGISTER 8-2: DMAxREQ: DMA CHANNEL x IRQ SELECT REGISTER**

| R/S-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| FORCE(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 |
|---|---|---|---|---|---|---|---|
| IRQSEL7 | IRQSEL6 | IRQSEL5 | IRQSEL4 | IRQSEL3 | IRQSEL2 | IRQSEL1 | IRQSEL0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | S = Settable 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 **FORCE:** Force DMA Transfer bit(1)
1 = Forces a single DMA transfer (Manual mode)
0 = Automatic DMA transfer initiation by DMA request

bit 14-8 **Unimplemented:** Read as '0'

bit 7-0 **IRQSEL<7:0>:** DMA Peripheral IRQ Number Select bits
01000111 = CAN2 – TX data request
01000110 = CAN1 – TX data request
00110111 = CAN2 – RX data ready
00100110 = IC4 – Input Capture 4
00100101 = IC3 – Input Capture 3
00100010 = CAN1 – RX data ready
00011111 = UART2TX – UART2 transmitter
00011110 = UART2RX – UART2 receiver
00011100 = TMR5 – Timer5
00011011 = TMR4 – Timer4
00011010 = OC4 – Output Compare 4
00011001 = OC3 – Output Compare 3
00001100 = UART1TX – UART1 transmitter
00001011 = UART1RX – UART1 receiver
00001000 = TMR3 – Timer3
00000111 = TMR2 – Timer2
00000110 = OC2 – Output Compare 2
00000101 = IC2 – Input Capture 2
00000010 = OC1 – Output Compare 1
00000001 = IC1 – Input Capture 1
00000000 = INT0 – External Interrupt 0

**Note 1:** The FORCE bit cannot be cleared by user software. The FORCE bit is cleared by hardware when the forced DMA transfer is complete or the channel is disabled (CHEN = 0).

**REGISTER 8-3: DMAxSTAH: DMA CHANNEL x START ADDRESS REGISTER A (HIGH)**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| STA<23:16> | | | | | | | |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **STA<23:16>:** DMA Primary Start Address bits (source or destination)

**REGISTER 8-4: DMAxSTAL: DMA CHANNEL x START ADDRESS REGISTER A (LOW)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| STA<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| STA<7:0> | | | | | | | |
| 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 15-0 **STA<15:0>:** DMA Primary Start Address bits (source or destination)


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**REGISTER 8-5: DMAxSTBH: DMA CHANNEL x START ADDRESS REGISTER B (HIGH)**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| STB<23:16> | | | | | | | |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **STB<23:16>:** DMA Secondary Start Address bits (source or destination)

**REGISTER 8-6: DMAxSTBL: DMA CHANNEL x START ADDRESS REGISTER B (LOW)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| STB<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| STB<7:0> | | | | | | | |
| 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 15-0 **STB<15:0>:** DMA Secondary Start Address bits (source or destination)

**REGISTER 8-7: DMAxPAD: DMA CHANNEL x PERIPHERAL ADDRESS REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PAD<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PAD<7:0> | | | | | | | |
| 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 15-0 **PAD<15:0>:** DMA Peripheral Address Register bits

**Note 1:** If the channel is enabled (i.e., active), writes to this register may result in unpredictable behavior of the DMA channel and should be avoided.

**REGISTER 8-8: DMAxCNT: DMA CHANNEL x TRANSFER COUNT REGISTER(1)**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | CNT<13:8>(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 |
|---|---|---|---|---|---|---|---|
| CNT<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 15-14 **Unimplemented:** Read as '0'

bit 13-0 **CNT<13:0>:** DMA Transfer Count Register bits(2)

**Note 1:** If the channel is enabled (i.e., active), writes to this register may result in unpredictable behavior of the DMA channel and should be avoided.

**2:** The number of DMA transfers = CNT<13:0> + 1.


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**REGISTER 8-9: DSADRH: DMA MOST RECENT RAM HIGH ADDRESS REGISTER**

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

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| DSADR<23:16> | | | | | | | |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **DSADR<23:16>:** Most Recent DMA Address Accessed by DMA bits

**REGISTER 8-10: DSADRL: DMA MOST RECENT RAM LOW ADDRESS REGISTER**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| DSADR<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| DSADR<7:0> | | | | | | | |
| 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 15-0 **DSADR<15:0>:** Most Recent DMA Address Accessed by DMA bits

**REGISTER 8-11: DMAPWC: DMA PERIPHERAL WRITE COLLISION STATUS REGISTER**

| 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 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | PWCOL3 | PWCOL2 | PWCOL1 | PWCOL0 |
| 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 15-4 **Unimplemented:** Read as ‘0’

bit 3 **PWCOL3:** Channel 3 Peripheral Write Collision Flag bit
1 = Write collision is detected
0 = No write collision is detected

bit 2 **PWCOL2:** Channel 2 Peripheral Write Collision Flag bit
1 = Write collision is detected
0 = No write collision is detected

bit 1 **PWCOL1:** Channel 1 Peripheral Write Collision Flag bit
1 = Write collision is detected
0 = No write collision is detected

bit 0 **PWCOL0:** Channel 0 Peripheral Write Collision Flag bit
1 = Write collision is detected
0 = No write collision is detected


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**REGISTER 8-12: DMARQC: DMA REQUEST COLLISION STATUS REGISTER**

| 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 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | RQCOL3 | RQCOL2 | RQCOL1 | RQCOL0 |
| 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 15-4 **Unimplemented:** Read as ‘0’

bit 3 **RQCOL3:** Channel 3 Transfer Request Collision Flag bit
1 = User FORCE and interrupt-based request collision are detected
0 = No request collision is detected

bit 2 **RQCOL2:** Channel 2 Transfer Request Collision Flag bit
1 = User FORCE and interrupt-based request collision are detected
0 = No request collision is detected

bit 1 **RQCOL1:** Channel 1 Transfer Request Collision Flag bit
1 = User FORCE and interrupt-based request collision are detected
0 = No request collision is detected

bit 0 **RQCOL0:** Channel 0 Transfer Request Collision Flag bit
1 = User FORCE and interrupt-based request collision are detected
0 = No request collision is detected

**REGISTER 8-13: DMALCA: DMA LAST CHANNEL ACTIVE STATUS REGISTER**

| 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 | R-1 | R-1 | R-1 | R-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | LSTCH<3:0> | | | |
| 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 15-4 **Unimplemented:** Read as ‘0’

bit 3-0 **LSTCH<3:0>:** Last DMA Controller Channel Active Status bits

1111 = No DMA transfer has occurred since system Reset
1110 = Reserved
•
•
•
0100 = Reserved
0011 = Last data transfer was handled by Channel 3
0010 = Last data transfer was handled by Channel 2
0001 = Last data transfer was handled by Channel 1
0000 = Last data transfer was handled by Channel 0


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**REGISTER 8-14: DMAPPS: DMA PING-PONG STATUS REGISTER**

| 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 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | PPST3 | PPST2 | PPST1 | PPST0 |
| 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 15-4 **Unimplemented:** Read as ‘0’

bit 3 **PPST3:** Channel 3 Ping-Pong Mode Status Flag bit
1 = DMA3STB register is selected
0 = DMA3STA register is selected

bit 2 **PPST2:** Channel 2 Ping-Pong Mode Status Flag bit
1 = DMA2STB register is selected
0 = DMA2STA register is selected

bit 1 **PPST1:** Channel 1 Ping-Pong Mode Status Flag bit
1 = DMA1STB register is selected
0 = DMA1STA register is selected

bit 0 **PPST0:** Channel 0 Ping-Pong Mode Status Flag bit
1 = DMA0STB register is selected
0 = DMA0STA register is selected

**NOTES:**


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## 9.0 OSCILLATOR CONFIGURATION

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Oscillator Module"** (DS70005131) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

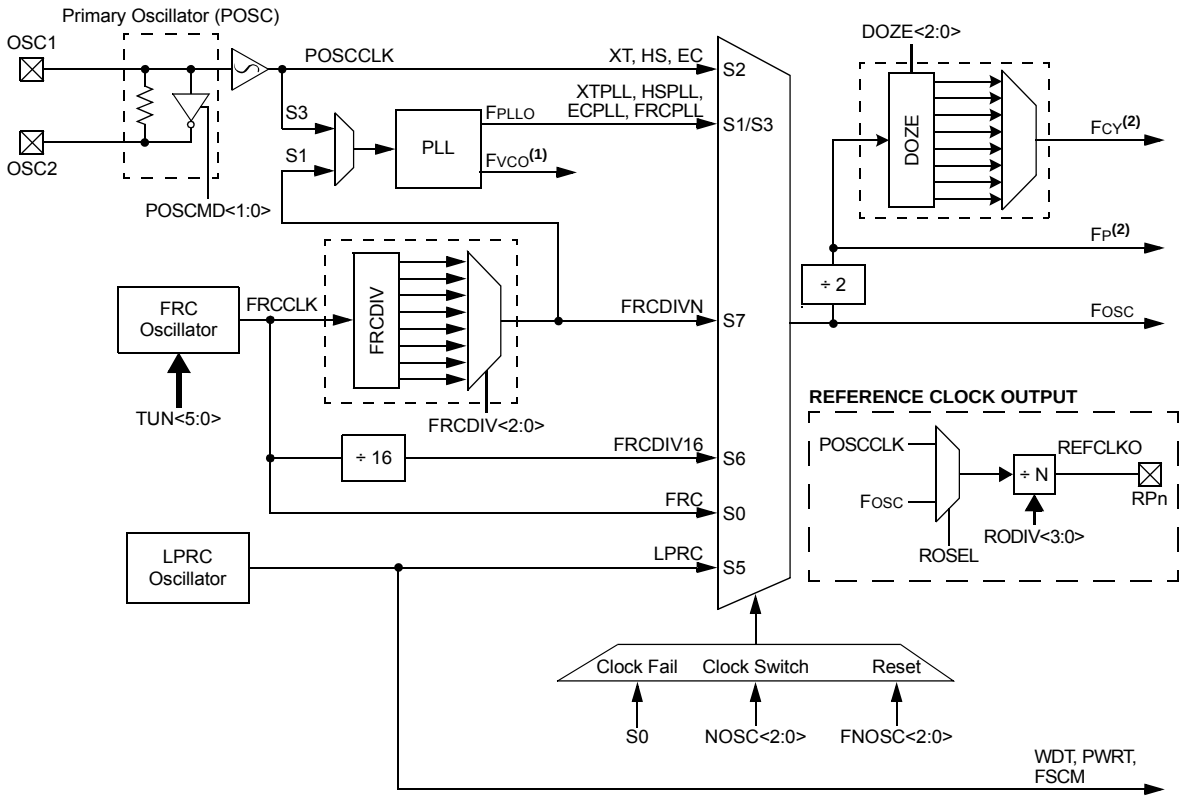
**2:** Some registers and associated bits described in this section may not be available on all devices. Refer to **Section 4.0 "Memory Organization"** in this data sheet for device-specific register and bit information.

The dsPIC33EPXXXGS70X/80X family oscillator system provides:

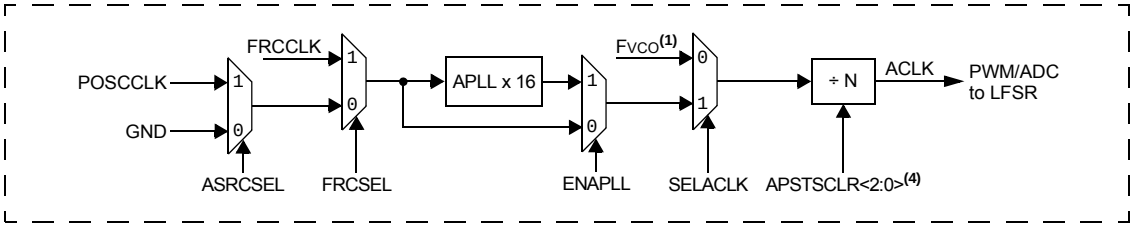
- On-Chip Phase-Locked Loop (PLL) to Boost Internal Operating Frequency on Select Internal and External Oscillator Sources
- On-the-Fly Clock Switching between Various Clock Sources
- Doze mode for System Power Savings
- Fail-Safe Clock Monitor (FSCM) that Detects Clock Failure and Permits Safe Application Recovery or Shutdown
- Configuration Bits for Clock Source Selection
- Auxiliary PLL for ADC and PWM

A simplified diagram of the oscillator system is shown in Figure 9-1.

**FIGURE 9-1: OSCILLATOR SYSTEM DIAGRAM**




**AUXILIARY CLOCK GENERATOR CIRCUIT BLOCK DIAGRAM**




**Note 1:** See Figure 9-2 for the source of the FVCO signal.

**2:** FP refers to the clock source for all the peripherals, while FCY (or MIPS) refers to the clock source for the CPU. Throughout this document, FCY and FP are used interchangeably, except in the case of Doze mode. FP and FCY will be different when Doze mode is used in any ratio other than 1:1.

**3:** The auxiliary clock postscaler must be configured to divide-by-1 (APSTSCLR<2:0> = 111) for proper operation of the PWM and ADC modules.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## 9.1 CPU Clocking System

The dsPIC33EPXXXGS70X/80X family of devices provides six system clock options:

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

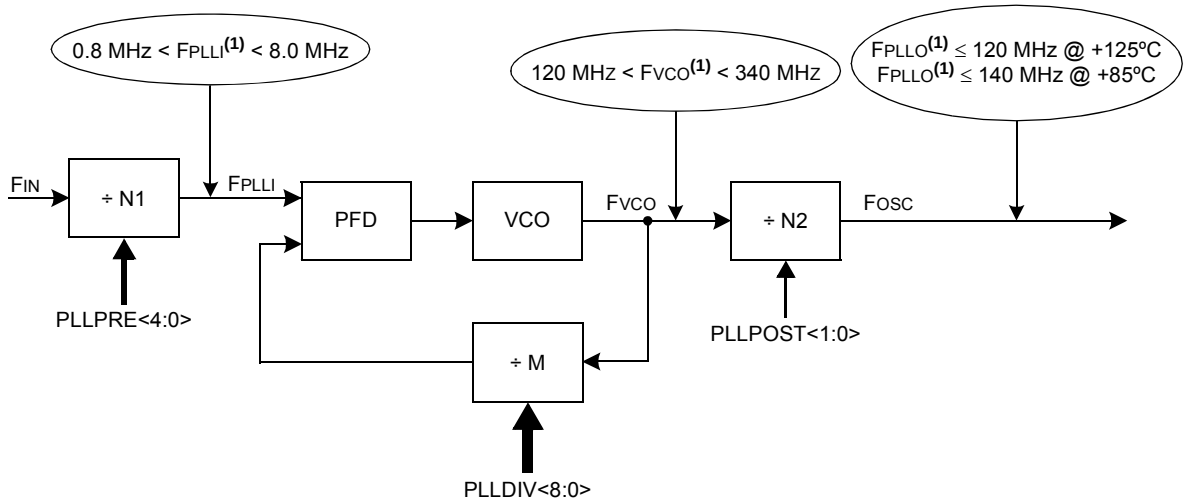
Instruction execution speed or device operating frequency, FCY, is given by Equation 9-1.

**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). 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**

$$FPLLO = FIN \times \left(\frac{M}{N1 \times N2}\right) = FIN \times \left(\frac{PLLDIV\langle 8:0\rangle + 2}{(PLLPRE\langle 4:0\rangle + 2) \times 2(PLLPOST\langle 1:0\rangle + 1)}\right)$$

Where:

$N1 = PLLPRE\langle 4:0\rangle + 2$

$N2 = 2 \text{ x } (PLLPOST\langle 1:0\rangle + 1)$

$M = PLLDIV\langle 8:0\rangle + 2$

**EQUATION 9-3: FVCO CALCULATION**

$$FVCO = FIN \times \left(\frac{M}{N1}\right) = FIN \times \left(\frac{PLLDIV\langle 8:0\rangle + 2}{(PLLPRE\langle 4:0\rangle + 2)}\right)$$

**TABLE 9-1: CONFIGURATION BIT VALUES FOR CLOCK SELECTION**

| Oscillator Mode | Oscillator Source | POSCMD<1:0> | FNOSC<2:0> | See Notes |
|---|---|---|---|---|
| Fast RC Oscillator with Divide-by-n (FRCDIVN) | Internal | xx | 111 | 1, 2 |
| Fast RC Oscillator with Divide-by-16 | Internal | xx | 110 | 1 |
| Low-Power RC Oscillator (LPRC) | Internal | xx | 101 | 1 |
| Primary Oscillator (HS) with PLL (HSPLL) | Primary | 10 | 011 | |
| Primary Oscillator (XT) with PLL (XTPLL) | Primary | 01 | 011 | |
| Primary Oscillator (EC) with PLL (ECPLL) | Primary | 00 | 011 | 1 |
| Primary Oscillator (HS) | Primary | 10 | 010 | |
| Primary Oscillator (XT) | Primary | 01 | 010 | |
| Primary Oscillator (EC) | Primary | 00 | 010 | 1 |
| Fast RC Oscillator (FRC) with Divide-by-N and PLL (FRCPLL) | Internal | xx | 001 | 1 |
| Fast RC Oscillator (FRC) | Internal | xx | 000 | 1 |

**Note 1:** OSC2 pin function is determined by the OSCIOFNC Configuration bit.

**2:** This is the default Oscillator mode for an unprogrammed (erased) device.

## 9.2 Auxiliary Clock Generation

The auxiliary clock generation is used for peripherals that need to operate at a frequency unrelated to the system clock, such as PWM or ADC.

The primary oscillator and internal FRC oscillator sources can be used with an Auxiliary PLL (APLL) to obtain the auxiliary clock. The Auxiliary PLL has a fixed 16x multiplication factor.

The auxiliary clock has the following configuration restrictions:

- For proper PWM operation, auxiliary clock generation must be configured for 120 MHz (see Parameter OS56 in **Section 30.0 "Electrical Characteristics"**). If a slower frequency is desired, the PWM Input Clock Prescaler (Divider) Select bits (PCLKDIV<2:0>) should be used.
- To achieve 1.04 ns PWM resolution, the auxiliary clock must use the 16x Auxiliary PLL (APLL). All other clock sources will have a minimum PWM resolution of 8 ns.
- If the primary PLL is used as a source for the auxiliary clock, the primary PLL should be configured up to a maximum operation of 30 MIPS or less.

## 9.3 Reference Clock Generation

The reference clock output logic provides the user with the ability to output a clock signal based on the system clock or the crystal oscillator on a device pin. The user application can specify a wide range of clock scaling prior to outputting the reference clock.

## 9.4 Oscillator 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 contains the latest updates and additional information.

### 9.4.1 KEY RESOURCES

- **"Oscillator Module"** (DS70005131) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools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## 9.5 Oscillator Control Registers

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

| U-0 | R-0 | R-0 | R-0 | U-0 | R/W-y | R/W-y | R/W-y |
|---|---|---|---|---|---|---|---|
| — | COSC2 | COSC1 | COSC0 | — | NOSC2(2) | NOSC1(2) | NOSC0(2) |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R-0 | U-0 | R/W-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CLKLOCK | IOLOCK | LOCK | — | CF(3) | — | — | 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 = Reserved
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 (FRCPLL)
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 = Reserved
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 (FRCPLL)
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 **IOLOCK:** I/O Lock Enable bit
1 = I/O lock is active
0 = I/O lock is not active

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

**Note 1:** Writes to this register require an unlock sequence.

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

**3:** This bit should only be cleared in software. Setting the bit in software (= 1) will have the same effect as an actual oscillator failure and will trigger an oscillator failure trap.

**REGISTER 9-1: OSCCON: OSCILLATOR CONTROL REGISTER(1) (CONTINUED)**

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

bit 3 **CF:** Clock Fail Detect bit(3)
1 = FSCM has detected a clock failure
0 = FSCM has not detected a clock failure

bit 2-1 **Unimplemented:** Read as '0'

bit 0 **OSWEN:** Oscillator Switch Enable bit
1 = Requests oscillator switch to the selection specified by the NOSC<2:0> bits
0 = Oscillator switch is complete

**Note 1:** Writes to this register require an unlock sequence.

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

**3:** This bit should only be cleared in software. Setting the bit in software (= 1) will have the same effect as an actual oscillator failure and will trigger an oscillator failure trap.


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

| 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 | DOZE2(1) | DOZE1(1) | DOZE0(1) | DOZEN(2,3) | FRCDIV2 | FRCDIV1 | FRCDIV0 |
| 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 |
|---|---|---|---|---|---|---|---|
| PLLPOST1 | PLLPOST0 | — | PLLPRE4 | PLLPRE3 | PLLPRE2 | PLLPRE1 | PLLPRE0 |
| 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 **ROI:** Recover on Interrupt bit
1 = Interrupts will clear the DOZEN bit and the processor clock, and the 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(1)
111 = FCY divided by 128
110 = FCY divided by 64
101 = FCY divided by 32
100 = FCY divided by 16
011 = FCY divided by 8 (default)
010 = FCY divided by 4
001 = FCY divided by 2
000 = FCY divided by 1

bit 11 **DOZEN:** Doze Mode Enable bit(2,3)
1 = DOZE<2:0> field specifies the ratio between the peripheral clocks and the processor clocks
0 = Processor clock and peripheral clock ratio is forced to 1:1

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

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

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

**Note 1:** The DOZE<2:0> bits can only be written to when the DOZEN bit is clear. If DOZEN = 1, any writes to DOZE<2:0> are ignored.

**2:** This bit is cleared when the ROI bit is set and an interrupt occurs.

**3:** The DOZEN bit cannot be set if DOZE<2:0> = 000. If DOZE<2:0> = 000, any attempt by user software to set the DOZEN bit is ignored.

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

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

**Note 1:** The DOZE<2:0> bits can only be written to when the DOZEN bit is clear. If DOZEN = 1, any writes to DOZE<2:0> are ignored.
**2:** This bit is cleared when the ROI bit is set and an interrupt occurs.
**3:** The DOZEN bit cannot be set if DOZE<2:0> = 000. If DOZE<2:0> = 000, any attempt by user software to set the DOZEN bit is ignored.

**REGISTER 9-3: PLLFBD: PLL FEEDBACK DIVISOR REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | PLLDIV8 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-1 | R/W-1 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PLLDIV<7:0> | | | | | | | |
| 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 15-9 **Unimplemented:** Read as '0'

bit 8-0 **PLLDIV<8:0>:** PLL Feedback Divisor bits (also denoted as 'M', PLL multiplier)
111111111 = 513
•
•
•
000110000 = 50 (default)
•
•
•
000000010 = 4
000000001 = 3
000000000 = 2


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**REGISTER 9-4: OSCTUN: FRC OSCILLATOR TUNING REGISTER**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | TUN<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 15-6 **Unimplemented:** Read as ‘0’

bit 5-0 **TUN<5:0>:** FRC Oscillator Tuning bits

011111 = Maximum frequency deviation of 1.457% (7.477 MHz)
011110 = Center frequency + 1.41% (7.474 MHz)
•
•
•
000001 = Center frequency + 0.047% (7.373 MHz)
000000 = Center frequency (7.37 MHz nominal)
111111 = Center frequency – 0.047% (7.367 MHz)
•
•
•
100001 = Center frequency – 1.457% (7.263 MHz)
100000 = Minimum frequency deviation of -1.5% (7.259 MHz)

**REGISTER 9-5: ACLKCON: AUXILIARY CLOCK DIVISOR CONTROL REGISTER**

| R/W-0 | R-0 | R/W-1 | U-0 | U-0 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| ENAPLL | APLLCK | SELACLK | — | — | APSTSCLR2 | APSTSCLR1 | APSTSCLR0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| ASRCSEL | FRCSEL | — | — | — | — | — | — |
| 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 **ENAPLL:** Auxiliary PLL Enable bit
1 = APLL is enabled
0 = APLL is disabled

bit 14 **APLLCK:** APLL Locked Status bit (read-only)
1 = Indicates that Auxiliary PLL is in lock
0 = Indicates that Auxiliary PLL is not in lock

bit 13 **SELACLK:** Select Auxiliary Clock Source for Auxiliary Clock Divider bit
1 = Auxiliary oscillators provide the source clock for the auxiliary clock divider
0 = Primary PLL (FVCO) provides the source clock for the auxiliary clock divider

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

bit 10-8 **APSTSCLR<2:0>:** Auxiliary Clock Output Divider bits
111 = Divided by 1
110 = Divided by 2
101 = Divided by 4
100 = Divided by 8
011 = Divided by 16
010 = Divided by 32
001 = Divided by 64
000 = Divided by 256

bit 7 **ASRCSEL:** Select Reference Clock Source for Auxiliary Clock bit
1 = Primary oscillator is the clock source
0 = No clock input is selected

bit 6 **FRCSEL:** Select Reference Clock Source for Auxiliary PLL bit
1 = Selects the FRC clock for Auxiliary PLL
0 = Input clock source is determined by the ASRCSEL bit setting

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


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**REGISTER 9-6: REFOCON: REFERENCE OSCILLATOR CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ROON | — | ROSSLP | ROSEL | RODIV3(1) | RODIV2(1) | RODIV1(1) | RODIV0(1) |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 **ROON:** Reference Oscillator Output Enable bit
1 = Reference oscillator output is enabled on the RPn pin(2)
0 = Reference oscillator output is disabled

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

bit 13 **ROSSLP:** Reference Oscillator Run in Sleep bit
1 = Reference oscillator output continues to run in Sleep
0 = Reference oscillator output is disabled in Sleep

bit 12 **ROSEL:** Reference Oscillator Source Select bit
1 = Oscillator crystal is used as the reference clock
0 = System clock is used as the reference clock

bit 11-8 **RODIV<3:0>:** Reference Oscillator Divider bits(1)
1111 = Reference clock divided by 32,768
1110 = Reference clock divided by 16,384
1101 = Reference clock divided by 8,192
1100 = Reference clock divided by 4,096
1011 = Reference clock divided by 2,048
1010 = Reference clock divided by 1,024
1001 = Reference clock divided by 512
1000 = Reference clock divided by 256
0111 = Reference clock divided by 128
0110 = Reference clock divided by 64
0101 = Reference clock divided by 32
0100 = Reference clock divided by 16
0011 = Reference clock divided by 8
0010 = Reference clock divided by 4
0001 = Reference clock divided by 2
0000 = Reference clock

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

**Note 1:** The reference oscillator output must be disabled (ROON = 0) before writing to these bits.
**2:** This pin is remappable. See **Section 11.6 "Peripheral Pin Select (PPS)"** for more information.

**REGISTER 9-7: LFSR: LINEAR FEEDBACK SHIFT REGISTER**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | LFSR<14:8> | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| LFSR<7:0> | | | | | | | |
| 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 14-0 **LFSR<14:0>:** Pseudorandom Data bits


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## 10.0 POWER-SAVING FEATURES

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Watchdog Timer and Power-Saving Modes"** (DS70615) in the "*dsPIC33/PIC24 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 dsPIC33EPXXXGS70X/80X family devices provide the ability to manage power consumption by selectively managing clocking to the CPU and the peripherals. In general, a lower clock frequency and a reduction in the number of peripherals being clocked constitutes lower consumed power.

dsPIC33EPXXXGS70X/80X family devices can manage power consumption in four ways:

- Clock Frequency
- Instruction-Based Sleep and Idle modes
- Software-Controlled Doze mode
- Selective Peripheral Control in Software

Combinations of these methods can be used to selectively tailor an application's power consumption while still maintaining critical application features, such as timing-sensitive communications.

### 10.1 Clock Frequency and Clock Switching

The dsPIC33EPXXXGS70X/80X family devices allow a wide range of clock frequencies to be selected under application control. If the system clock configuration is not locked, users can choose low-power or high-precision oscillators by simply changing the NOSCx bits (OSCCON<10:8>). The process of changing a system clock during operation, as well as limitations to the process, are discussed in more detail in **Section 9.0 "Oscillator Configuration"**.

### 10.2 Instruction-Based Power-Saving Modes

The dsPIC33EPXXXGS70X/80X family devices have two special power-saving modes that are entered through the execution of a special PWRSAV instruction. Sleep mode stops clock operation and halts all code execution. Idle mode halts the CPU and code execution, but allows peripheral modules to continue operation. The assembler syntax of the PWRSAV instruction is shown in Example 10-1.

**Note:** SLEEP_MODE and IDLE_MODE are constants defined in the assembler include file for the selected device.

Sleep and Idle modes can be exited as a result of an enabled interrupt, WDT time-out or a device Reset. When the device exits these modes, it is said to "wake-up".

**EXAMPLE 10-1: PWRSAV INSTRUCTION SYNTAX**

```
PWRSAV  #SLEEP_MODE    ; Put the device into Sleep mode
PWRSAV  #IDLE_MODE     ; Put the device into Idle mode
```

### 10.2.1 SLEEP MODE

The following occurs in Sleep mode:

- The system clock source is shut down. If an on-chip oscillator is used, it is turned off.
- The device current consumption is reduced to a minimum, provided that no I/O pin is sourcing current.
- The Fail-Safe Clock Monitor does not operate, since the system clock source is disabled.
- The LPRC clock continues to run in Sleep mode if the WDT is enabled.
- The WDT, if enabled, is automatically cleared prior to entering Sleep mode.
- Some device features or peripherals can continue to operate. This includes items such as the Input Change Notification on the I/O ports or peripherals that use an external clock input.
- Any peripheral that requires the system clock source for its operation is disabled.

The device wakes up from Sleep mode on any of the these events:

- Any interrupt source that is individually enabled
- Any form of device Reset
- A WDT time-out

On wake-up from Sleep mode, the processor restarts with the same clock source that was active when Sleep mode was entered.

For optimal power savings, the internal regulator and the Flash regulator can be configured to go into stand-by when Sleep mode is entered by clearing the VREGS (RCON<8>) and VREGSF (RCON<11>) bits (default configuration).

If the application requires a faster wake-up time, and can accept higher current requirements, the VREGS (RCON<8>) and VREGSF (RCON<11>) bits can be set to keep the internal regulator and the Flash regulator active during Sleep mode.

### 10.2.2 IDLE MODE

The following occurs in Idle mode:

- The CPU stops executing instructions.
- The WDT is automatically cleared.
- The system clock source remains active. By default, all peripheral modules continue to operate normally from the system clock source, but can also be selectively disabled (see **Section 10.4 “Peripheral Module Disable”**).
- If the WDT or FSCM is enabled, the LPRC also remains active.

The device wakes from Idle mode on any of these events:

- Any interrupt that is individually enabled
- Any device Reset
- A WDT time-out

On wake-up from Idle mode, the clock is reapplied to the CPU and instruction execution will begin (2-4 clock cycles later), starting with the instruction following the PWRSAV instruction or the first instruction in the ISR.

All peripherals also have the option to discontinue operation when Idle mode is entered to allow for increased power savings. This option is selectable in the control register of each peripheral (for example, the TSIDL bit in the Timer1 Control register (T1CON<13>).

### 10.2.3 INTERRUPTS COINCIDENT WITH POWER SAVE INSTRUCTIONS

Any interrupt that coincides with the execution of a PWRSAV instruction is held off until entry into Sleep or Idle mode has completed. The device then wakes up from Sleep or Idle mode.


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## 10.3 Doze Mode

The preferred strategies for reducing power consumption are changing clock speed and invoking one of the power-saving modes. In some circumstances, this cannot be practical. For example, it may be necessary for an application to maintain uninterrupted synchronous communication, even while it is doing nothing else. Reducing system clock speed can introduce communication errors, while using a power-saving mode can stop communications completely.

Doze mode is a simple and effective alternative method to reduce power consumption while the device is still executing code. In this mode, the system clock continues to operate from the same source and at the same speed. Peripheral modules continue to be clocked at the same speed, while the CPU clock speed is reduced. Synchronization between the two clock domains is maintained, allowing the peripherals to access the SFRs while the CPU executes code at a slower rate.

Doze mode is enabled by setting the DOZEN bit (CLKDIV<11>). The ratio between peripheral and core clock speed is determined by the DOZE<2:0> bits (CLKDIV<14:12>). There are eight possible configurations, from 1:1 to 1:128, with 1:1 being the default setting.

Programs can use Doze mode to selectively reduce power consumption in event-driven applications. This allows clock-sensitive functions, such as synchronous communications, to continue without interruption while the CPU Idles, waiting for something to invoke an interrupt routine. An automatic return to full-speed CPU operation on interrupts can be enabled by setting the ROI bit (CLKDIV<15>). By default, interrupt events have no effect on Doze mode operation.

## 10.4 Peripheral Module Disable

The Peripheral Module Disable (PMD) registers provide a method to disable a peripheral module by stopping all clock sources supplied to that module. When a peripheral is disabled using the appropriate PMD control bit, the peripheral is in a minimum power consumption state. The control and status registers associated with the peripheral are also disabled, so writes to those registers do not have any effect and read values are invalid.

A peripheral module is enabled only if both the associated bit in the PMD register is cleared and the peripheral is supported by the specific dsPIC® DSC variant. If the peripheral is present in the device, it is enabled in the PMD register by default.

| | |
|---|---|
| **Note:** | If a PMD bit is set, the corresponding module is disabled after a delay of one instruction cycle. Similarly, if a PMD bit is cleared, the corresponding module is enabled after a delay of one instruction cycle (assuming the module control registers are already configured to enable module operation). |

## 10.5 Power-Saving 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 contains the latest updates and additional information.

### 10.5.1 KEY RESOURCES

- **"Watchdog Timer and Power-Saving Modes"** (DS70615) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

**REGISTER 10-1: PMD1: PERIPHERAL MODULE DISABLE CONTROL REGISTER 1**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| T5MD | T4MD | T3MD | T2MD | T1MD | — | PWMMD | — |
| 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 |
|---|---|---|---|---|---|---|---|
| I2C1MD | U2MD | U1MD | SPI2MD | SPI1MD | C2MD | C1MD | ADCMD |
| 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 **T5MD:** Timer5 Module Disable bit
1 = Timer5 module is disabled
0 = Timer5 module is enabled

bit 14 **T4MD:** Timer4 Module Disable bit
1 = Timer4 module is disabled
0 = Timer4 module is enabled

bit 13 **T3MD:** Timer3 Module Disable bit
1 = Timer3 module is disabled
0 = Timer3 module is enabled

bit 12 **T2MD:** Timer2 Module Disable bit
1 = Timer2 module is disabled
0 = Timer2 module is enabled

bit 11 **T1MD:** Timer1 Module Disable bit
1 = Timer1 module is disabled
0 = Timer1 module is enabled

bit 10 **Unimplemented:** Read as '0'

bit 9 **PWMMD:** PWMx Module Disable bit
1 = PWMx module is disabled
0 = PWMx module is enabled

bit 8 **Unimplemented:** Read as '0'

bit 7 **I2C1MD:** I2C1 Module Disable bit
1 = I2C1 module is disabled
0 = I2C1 module is enabled

bit 6 **U2MD:** UART2 Module Disable bit
1 = UART2 module is disabled
0 = UART2 module is enabled

bit 5 **U1MD:** UART1 Module Disable bit
1 = UART1 module is disabled
0 = UART1 module is enabled

bit 4 **SPI2MD:** SPI2 Module Disable bit
1 = SPI2 module is disabled
0 = SPI2 module is enabled

bit 3 **SPI1MD:** SPI1 Module Disable bit
1 = SPI1 module is disabled
0 = SPI1 module is enabled

bit 2 **C2MD:** CAN2 Module Disable bit
1 = CAN2 module is disabled
0 = CAN2 module is enabled


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**REGISTER 10-1: PMD1: PERIPHERAL MODULE DISABLE CONTROL REGISTER 1 (CONTINUED)**

bit 1 **C1MD:** CAN1 Module Disable bit
1 = CAN1 module is disabled
0 = CAN1 module is enabled

bit 0 **ADCMD:** ADC Module Disable bit
1 = ADC module is disabled
0 = ADC module is enabled

**REGISTER 10-2: PMD2: PERIPHERAL MODULE DISABLE CONTROL REGISTER 2**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | IC4MD | IC3MD | IC2MD | IC1MD |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | OC4MD | OC3MD | OC2MD | OC1MD |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11 **IC4MD:** Input Capture 4 Module Disable bit
1 = Input Capture 4 module is disabled
0 = Input Capture 4 module is enabled

bit 10 **IC3MD:** Input Capture 3 Module Disable bit
1 = Input Capture 3 module is disabled
0 = Input Capture 3 module is enabled

bit 9 **IC2MD:** Input Capture 2 Module Disable bit
1 = Input Capture 2 module is disabled
0 = Input Capture 2 module is enabled

bit 8 **IC1MD:** Input Capture 1 Module Disable bit
1 = Input Capture 1 module is disabled
0 = Input Capture 1 module is enabled

bit 7-4 **Unimplemented:** Read as '0'

bit 3 **OC4MD:** Output Compare 4 Module Disable bit
1 = Output Compare 4 module is disabled
0 = Output Compare 4 module is enabled

bit 2 **OC3MD:** Output Compare 3 Module Disable bit
1 = Output Compare 3 module is disabled
0 = Output Compare 3 module is enabled

bit 1 **OC2MD:** Output Compare 2 Module Disable bit
1 = Output Compare 2 module is disabled
0 = Output Compare 2 module is enabled

bit 0 **OC1MD:** Output Compare 1 Module Disable bit
1 = Output Compare 1 module is disabled
0 = Output Compare 1 module is enabled


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**REGISTER 10-3: PMD3: PERIPHERAL MODULE DISABLE CONTROL REGISTER 3**

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | CMPMD | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | I2C2MD | — |
| 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 15-11 **Unimplemented:** Read as '0'

bit 10 **CMPMD:** Comparator Module Disable bit
1 = Comparator module is disabled
0 = Comparator module is enabled

bit 9-2 **Unimplemented:** Read as '0'

bit 1 **I2C2MD:** I2C2 Module Disable bit
1 = I2C2 module is disabled
0 = I2C2 module is enabled

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

**REGISTER 10-4: PMD4: PERIPHERAL MODULE DISABLE 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 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | REFOMD | — | — | — |
| 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 15-4 **Unimplemented:** Read as '0'

bit 3 **REFOMD:** Reference Clock Module Disable bit
1 = Reference clock module is disabled
0 = Reference clock module is enabled

bit 2-0 **Unimplemented:** Read as '0'

**REGISTER 10-5: PMD6: PERIPHERAL MODULE DISABLE CONTROL REGISTER 6**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PWM8MD | PWM7MD | PWM6MD | PWM5MD | PWM4MD | PWM3MD | PWM2MD | PWM1MD |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | SPI3MD |
| 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 **PWM8MD:** PWM8 Module Disable bit
1 = PWM8 module is disabled
0 = PWM8 module is enabled

bit 14 **PWM7MD:** PWM7 Module Disable bit
1 = PWM7 module is disabled
0 = PWM7 module is enabled

bit 13 **PWM6MD:** PWM6 Module Disable bit
1 = PWM6 module is disabled
0 = PWM6 module is enabled

bit 12 **PWM5MD:** PWM5 Module Disable bit
1 = PWM5 module is disabled
0 = PWM5 module is enabled

bit 11 **PWM4MD:** PWM4 Module Disable bit
1 = PWM4 module is disabled
0 = PWM4 module is enabled

bit 10 **PWM3MD:** PWM3 Module Disable bit
1 = PWM3 module is disabled
0 = PWM3 module is enabled

bit 9 **PWM2MD:** PWM2 Module Disable bit
1 = PWM2 module is disabled
0 = PWM2 module is enabled

bit 8 **PWM1MD:** PWM1 Module Disable bit
1 = PWM1 module is disabled
0 = PWM1 module is enabled

bit 7-1 **Unimplemented:** Read as ‘0’

bit 0 **SPI3MD:** SPI3 Module Disable bit
1 = SPI3 module is disabled
0 = SPI3 module is enabled


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**REGISTER 10-6: PMD7: PERIPHERAL MODULE DISABLE CONTROL REGISTER 7**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | CMP4MD | CMP3MD | CMP2MD | CMP1MD |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | DMAMD | PTGMD | — | PGA1MD | — |
| 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 15-12 **Unimplemented:** Read as ‘0’

bit 11 **CMP4MD:** CMP4 Module Disable bit
1 = CMP4 module is disabled
0 = CMP4 module is enabled

bit 10 **CMP3MD:** CMP3 Module Disable bit
1 = CMP3 module is disabled
0 = CMP3 module is enabled

bit 9 **CMP2MD:** CMP2 Module Disable bit
1 = CMP2 module is disabled
0 = CMP2 module is enabled

bit 8 **CMP1MD:** CMP1 Module Disable bit
1 = CMP1 module is disabled
0 = CMP1 module is enabled

bit 7-5 **Unimplemented:** Read as ‘0’

bit 4 **DMAMD:** DMA Module Disable bit
1 = DMA module is disabled
0 = DMA module is enabled

bit 3 **PTGMD:** PTG Module Disable bit
1 = PTG module is disabled
0 = PTG module is enabled

bit 2 **Unimplemented:** Read as ‘0’

bit 1 **PGA1MD:** PGA1 Module Disable bit
1 = PGA1 module is disabled
0 = PGA1 module is enabled

bit 0 **Unimplemented:** Read as ‘0’

**REGISTER 10-7: PMD8: PERIPHERAL MODULE DISABLE CONTROL REGISTER 8**

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | PGA2MD | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | CLC4MD | CLC3MD | CLC2MD | CLC1MD | CCSMD | — |
| 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 15-11 **Unimplemented:** Read as '0'

bit 10 **PGA2MD:** PGA2 Module Disable bit
1 = PGA2 module is disabled
0 = PGA2 module is enabled

bit 9-6 **Unimplemented:** Read as '0'

bit 5 **CLC4MD:** CLC4 Module Disable bit
1 = CLC4 module is disabled
0 = CLC4 module is enabled

bit 4 **CLC3MD:** CLC3 Module Disable bit
1 = CLC3 module is disabled
0 = CLC3 module is enabled

bit 3 **CLC2MD:** CLC2 Module Disable bit
1 = CLC2 module is disabled
0 = CLC2 module is enabled

bit 2 **CLC1MD:** CLC1 Module Disable bit
1 = CLC1 module is disabled
0 = CLC1 module is enabled

bit 1 **CCSMD:** Constant-Current Source Module Disable bit
1 = Constant-current source module is disabled
0 = Constant-current source module is enabled

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


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## 11.0 I/O PORTS

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"I/O Ports"** (DS70000598) in the *"dsPIC33/PIC24 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.

Many of the device pins are shared among the peripherals and the Parallel I/O ports. All I/O input ports feature Schmitt Trigger inputs for improved noise immunity.

### 11.1 Parallel I/O (PIO) Ports

Generally, a Parallel I/O port that shares a pin with a peripheral is 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 pin. The logic also prevents "loop through", in which a port's digital output can drive the input of a peripheral that shares the same pin. Figure 11-1 illustrates how ports are shared with other peripherals and the associated I/O pin to which they are connected.

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 eight registers directly associated with their operation as digital I/Os. 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. Reads from the port (PORTx), read the port pins, while writes to the port pins, write the latch.

Any bit and its associated data and control registers that are not valid for a particular device are disabled. This means the corresponding LATx and TRISx registers, and the port pin are read as zeros. Table 11-1 through Table 11-5 show ANSELx bits' availability for device variants.

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.

**FIGURE 11-1: BLOCK DIAGRAM OF A TYPICAL SHARED PORT STRUCTURE**

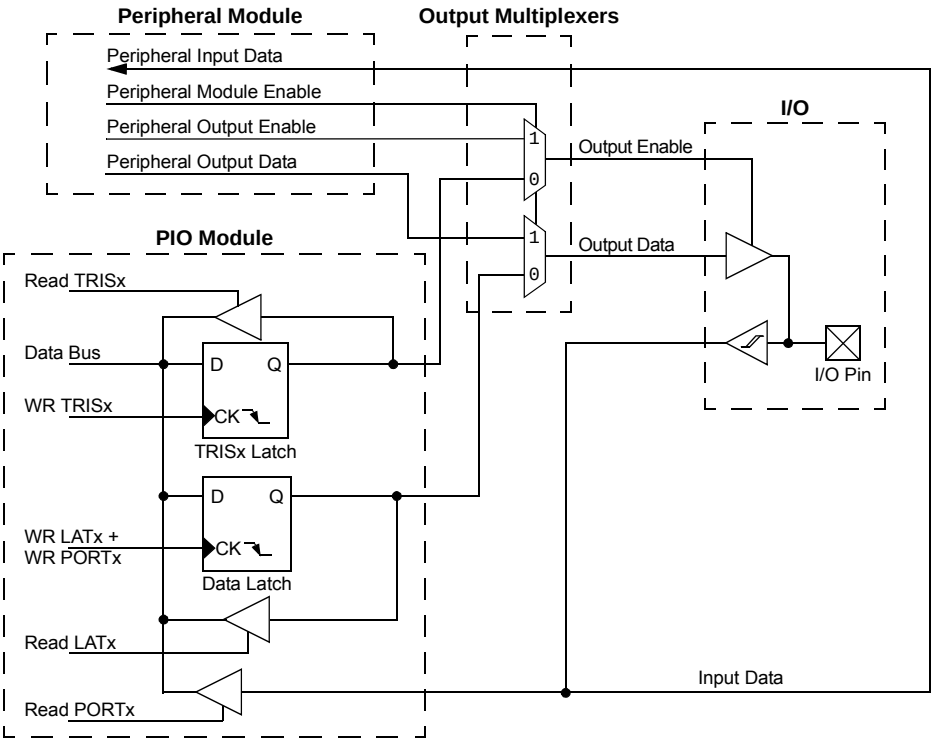

**TABLE 11-1: PORTA PIN AND ANSELA AVAILABILITY**

| Device | PORTA I/O Pins | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RA15 | RA14 | RA13 | RA12 | RA11 | RA10 | RA9 | RA8 | RA7 | RA6 | RA5 | RA4 | RA3 | RA2 | RA1 | RA0 |
| dsPIC33EPXXXGSX08 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| dsPIC33EPXXXGSX06 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| dsPIC33EPXXXGSX05 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| dsPIC33EPXXXGSX04 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| dsPIC33EPXXXGS702 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| ANSELA Bit Present | — | — | — | — | — | — | — | — | — | — | — | — | — | X | X | X |

**TABLE 11-2: PORTB PIN AND ANSELB AVAILABILITY**

| Device | PORTB I/O Pins | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RB15 | RB14 | RB13 | RB12 | RB11 | RB10 | RB9 | RB8 | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0 |
| dsPIC33EPXXXGSX08 | X | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX06 | X | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX05 | X | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX04 | X | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGS702 | X | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X |
| ANSELB Bit Present | — | — | — | — | — | — | X | — | X | X | X | — | X | X | X | X |

**TABLE 11-3: PORTC PIN AND ANSELC AVAILABILITY**

| Device | PORTC I/O Pins | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RC15 | RC14 | RC13 | RC12 | RC11 | RC10 | RC9 | RC8 | RC7 | RC6 | RC5 | RC4 | RC3 | RC2 | RC1 | RC0 |
| dsPIC33EPXXXGSX08 | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX06 | X | X | X | X | — | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX05 | — | — | X | X | — | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX04 | — | — | X | X | — | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGS702 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| ANSELC Bit Present | — | — | — | X | — | X | X | — | — | X | X | X | — | X | X | — |

**TABLE 11-4: PORTD PIN AND ANSELD AVAILABILITY**

| Device | PORTD I/O Pins | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RD15 | RD14 | RD13 | RD12 | RD11 | RD10 | RD9 | RD8 | RD7 | RD6 | RD5 | RD4 | RD3 | RD2 | RD1 | RD0 |
| dsPIC33EPXXXGSX08 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX06 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX05 | — | X | — | — | — | X | — | — | — | — | — | X | — | — | — | — |
| dsPIC33EPXXXGSX04 | — | X | — | — | — | X | — | — | — | — | — | X | — | — | — | — |
| dsPIC33EPXXXGS702 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| ANSELD Bit Present | — | — | X | — | — | — | — | X | X | — | X | — | — | X | — | — |

**TABLE 11-5: PORTE PIN AND ANSELE AVAILABILITY**

| Device | PORTE I/O Pins | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RE15 | RE14 | RE13 | RE12 | RE11 | RE10 | RE9 | RE8 | RE7 | RE6 | RE5 | RE4 | RE3 | RE2 | RE1 | RE0 |
| dsPIC33EPXXXGSX08 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33EPXXXGSX06 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| dsPIC33EPXXXGSX05 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| dsPIC33EPXXXGSX04 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| dsPIC33EPXXXGS702 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| ANSELE Bit Present | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |


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## 11.2 I/O Port Control Register Maps

**TABLE 11-6: PORTA REGISTER MAP(1)**

| File Name | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRISA | — | — | — | — | — | — | — | — | — | — | — | TRISA<4:0> | | | | |
| PORTA | — | — | — | — | — | — | — | — | — | — | — | RA<4:0> | | | | |
| LATA | — | — | — | — | — | — | — | — | — | — | — | LATA<4:0> | | | | |
| ODCA | — | — | — | — | — | — | — | — | — | — | — | ODCA<4:0> | | | | |
| CNENA | — | — | — | — | — | — | — | — | — | — | — | CNIEA<4:0> | | | | |
| CNPUA | — | — | — | — | — | — | — | — | — | — | — | CNPUA<4:0> | | | | |
| CNPDA | — | — | — | — | — | — | — | — | — | — | — | CNPDA<4:0> | | | | |
| ANSELA | — | — | — | — | — | — | — | — | — | — | — | — | — | ANSA<2:0> | | |

**Legend:** — = unimplemented, read as '0'.

**Note 1:** Refer to Table 11-1 for bit availability on each pin count variant.

**TABLE 11-7: PORTB REGISTER MAP(1)**

| File Name | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRISB | TRISB<15:11> | | | | | — | TRISB<9:0> | | | | | | | | | |
| PORTB | RB<15:11> | | | | | — | RB<9:0> | | | | | | | | | |
| LATB | LATB<15:11> | | | | | — | LATB<9:0> | | | | | | | | | |
| ODCB | ODCB<15:11> | | | | | — | ODCB<9:0> | | | | | | | | | |
| CNENB | CNIEB<15:11> | | | | | — | CNIEB<9:0> | | | | | | | | | |
| CNPUB | CNPUB<15:11> | | | | | — | CNPUB<9:0> | | | | | | | | | |
| CNPDB | CNPDB<15:11> | | | | | — | CNPDB<9:0> | | | | | | | | | |
| ANSELB | — | — | — | — | — | — | ANSB9 | — | ANSB<7:5> | | | — | ANSB<3:0> | | | |

**Legend:** — = unimplemented, read as '0'.

**Note 1:** Refer to Table 11-2 for bit availability on each pin count variant.

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**TABLE 11-8: PORTC REGISTER MAP(1)**

| File Name | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRISC | TRISC<15:12> | | | | — | TRISC<10:0> | | | | | | | | | | |
| PORTC | RC<15:12> | | | | — | RC<10:0> | | | | | | | | | | |
| LATC | LATC<15:12> | | | | — | LATC<10:0> | | | | | | | | | | |
| ODCC | ODCC<15:12> | | | | — | ODCC<10:0> | | | | | | | | | | |
| CNENC | CNIEC<15:12> | | | | — | CNIEC<10:0> | | | | | | | | | | |
| CNPUC | CNPUC<15:12> | | | | — | CNPUC<10:0> | | | | | | | | | | |
| CNPDC | CNPDC<15:12> | | | | — | CNPDC<10:0> | | | | | | | | | | |
| ANSELC | — | — | — | ANSC12 | — | ANSC<10:9> | | — | — | ANSC<6:4> | | | — | ANSC<2:1> | | — |

**Legend:** — = unimplemented, read as '0'.

**Note 1:** Refer to Table 11-3 for bit availability on each pin count variant.

**TABLE 11-9: PORTD REGISTER MAP(1)**

| File Name | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRISD | TRISD<15:0> | | | | | | | | | | | | | | | |
| PORTD | RD<15:0> | | | | | | | | | | | | | | | |
| LATD | LATD<15:0> | | | | | | | | | | | | | | | |
| ODCD | ODCD<15:0> | | | | | | | | | | | | | | | |
| CNEND | CNIED<15:0> | | | | | | | | | | | | | | | |
| CNPUD | CNPUD<15:0> | | | | | | | | | | | | | | | |
| CNPDD | CNPDD<15:0> | | | | | | | | | | | | | | | |
| ANSELD | — | — | ANSD13 | — | — | — | — | ANSD<8:7> | | — | ANSD5 | — | — | ANSD2 | — | — |

**Legend:** — = unimplemented, read as '0'.

**Note 1:** Refer to Table 11-4 for bit availability on each pin count variant.



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**TABLE 11-10: PORTE REGISTER MAP(1)**

| File Name | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TRISE | TRISE<15:0> | | | | | | | | | | | | | | | |
| PORTE | RE<15:0> | | | | | | | | | | | | | | | |
| LATE | LATE<15:0> | | | | | | | | | | | | | | | |
| ODCE | ODCE<15:0> | | | | | | | | | | | | | | | |
| CNENE | CNIEE<15:0> | | | | | | | | | | | | | | | |
| CNPUE | CNPUE<15:0> | | | | | | | | | | | | | | | |
| CNPDE | CNPDE<15:0> | | | | | | | | | | | | | | | |
| ANSELE | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

**Legend:** — = unimplemented, read as '0'.

**Note 1:** Refer to Table 11-5 for bit availability on each pin count variant.

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### 11.2.1 OPEN-DRAIN CONFIGURATION

In addition to the PORTx, LATx and TRISx registers for data control, port pins can also be individually configured for either digital or open-drain output. This is controlled by the Open-Drain Control x register, ODCx, associated with each port. Setting any of the bits configures the corresponding pin to act as an open-drain output.

The open-drain feature allows the generation of outputs other than VDD by using external pull-up resistors. The maximum open-drain voltage allowed on any pin is the same as the maximum VIH specification for that particular pin. See the **"Pin Diagrams"** section for the available 5V tolerant pins and Table 30-11 for the maximum VIH specification for each pin.

## 11.3 Configuring Analog and Digital Port Pins

The ANSELx register controls the operation of the analog port pins. The port pins that are to function as analog inputs or outputs must have their corresponding ANSELx and TRISx bits set. In order to use port pins for I/O functionality with digital modules, such as timers, UARTs, etc., the corresponding ANSELx bit must be cleared.

The ANSELx register has a default value of 0xFFFF; therefore, all pins that share analog functions are analog (not digital) by default.

Pins with analog functions affected by the ANSELx registers are listed with a buffer type of analog in the Pinout I/O Descriptions (see Table 1-1). Table 11-1 through Table 11-5 show ANSELx bits' availability for device variants.

If the TRISx bit is cleared (output) while the ANSELx bit is set, the digital output level (VOH or VOL) is converted by an analog peripheral, such as the ADC module or comparator module.

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

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

### 11.3.1 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, as shown in Example 11-1.

## 11.4 Input Change Notification (ICN)

The Input Change Notification function of the I/O ports allows devices to generate interrupt requests to the processor in response to a Change-of-State (COS) on selected input pins. This feature can detect input Change-of-States, even in Sleep mode, when the clocks are disabled. Every I/O port pin can be selected (enabled) for generating an interrupt request on a Change-of-State.

Three control registers are associated with the ICN functionality of each I/O port. The CNENx registers contain the ICN interrupt enable control bits for each of the input pins. Setting any of these bits enables an ICN interrupt for the corresponding pins.

Each I/O pin also has a weak pull-up and a weak pull-down connected to it. The pull-ups and pull-downs act as a current source, or sink source, connected to the pin, and eliminate the need for external resistors when push button or keypad devices are connected. The pull-ups and pull-downs are enabled separately, using the CNPUx and the CNPDx registers, which contain the control bits for each of the pins. Setting any of the control bits enables the weak pull-ups and/or pull-downs for the corresponding pins.

| **Note:** | Pull-ups and pull-downs on Input Change Notification pins should always be disabled when the port pin is configured as a digital output. |
|---|---|

**EXAMPLE 11-1: PORT WRITE/READ EXAMPLE**

```
MOV   0xFF00, W0   ; Configure PORTB<15:8>
                   ; as inputs
MOV   W0, TRISB    ; and PORTB<7:0>
                   ; as outputs
NOP                ; Delay 1 cycle
BTSS  PORTB, #13   ; Next Instruction
```


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## 11.5 I/O Port Control Registers

**REGISTER 11-1: TRISx: PORTx DATA DIRECTION CONTROL REGISTER(1)**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| TRISx<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| TRISx<7:0> | | | | | | | |
| 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 15-8 **TRISx<15:0>:** PORTx Data Direction Control bits
1 = The pin is an input
0 = The pin is an output

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.

**REGISTER 11-2: PORTx: I/O PORTx REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PORTx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PORTx<7:0> | | | | | | | |
| 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 15-8 **PORTx<15:0>:** I/O PORTx bits
1 = The pin data is '1'
0 = The pin data is '0'

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.

**REGISTER 11-3: LATx: PORTx DATA LATCH REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| LATx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| LATx<7:0> | | | | | | | |
| 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 15-8 **LATx<15:0>:** PORTx Data Latch bits
1 = The latch content is '1'
0 = The latch content is '0'

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.

**REGISTER 11-4: ODCx: PORTx OPEN-DRAIN CONTROL REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ODCx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| ODCx<7:0> | | | | | | | |
| 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 15-8 **PORTx<15:0>:** PORTx Open-Drain Control bits
1 = The pin acts as an open-drain output pin if TRISx is '0'
0 = The pin acts as a normal pin

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.


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**REGISTER 11-5: CNENx: INPUT CHANGE NOTIFICATION INTERRUPT ENABLE x REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CNIEx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| CNIEx<7:0> | | | | | | | |
| 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 15-8 **CNIEx<15:0>:** Input Change Notification Interrupt Enable x bits
1 = Enables interrupt on input change
0 = Disables interrupt on input change

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.

**REGISTER 11-6: CNPUx: INPUT CHANGE NOTIFICATION PULL-UP ENABLE x REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CNPUx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| CNPUx<7:0> | | | | | | | |
| 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 15-8 **CNPUx<15:0>:** Input Change Notification Pull-up Enable bits
1 = Enables pull-up on PORTx pin
0 = Disables pull-up on PORTx pin

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.

**REGISTER 11-7: CNPDx: INPUT CHANGE NOTIFICATION PULL-DOWN ENABLE x REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CNPDx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| CNPDx<7:0> | | | | | | | |
| 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 15-8 **CNPDx<15:0>:** Input Change Notification Pull-Down Enable x bits
1 = Enables pull-down on PORTx pin
0 = Disables pull-down on PORTx pin

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.

**REGISTER 11-8: ANSELx: ANALOG SELECT CONTROL x REGISTER(1)**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| ANSx<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| ANSx<7:0> | | | | | | | |
| 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 15-8 **ANSx<15:0>:** Analog PORTx Enable bits
1 = Enables analog PORTx pin
0 = Disables digital PORTx pin

**Note 1:** See Table 11-1, Table 11-2, Table 11-3, Table 11-4 and Table 11-5 for individual bit availability in this register.


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## 11.6 Peripheral Pin Select (PPS)

A major challenge in general purpose devices is providing the largest possible set of peripheral features, while minimizing the conflict of features on I/O pins. The challenge is even greater on low pin count devices. In an application where more than one peripheral needs to be assigned to a single pin, inconvenient work arounds in application code, or a complete redesign, may be the only option.

Peripheral Pin Select configuration provides an alternative to these choices by enabling peripheral set selection and placement on a wide range of I/O pins. By increasing the pinout options available on a particular device, users can better tailor the device to their entire application, rather than trimming the application to fit the device.

The Peripheral Pin Select configuration feature operates over a fixed subset of digital I/O pins. Users may independently map the input and/or output of most digital peripherals to any one of these I/O pins. Hardware safeguards are included that prevent accidental or spurious changes to the peripheral mapping once it has been established.

### 11.6.1 AVAILABLE PINS

The number of available pins is dependent on the particular device and its pin count. Pins that support the Peripheral Pin Select feature include the label, “RPn”, in their full pin designation, where “n” is the remappable pin number. “RP” is used to designate pins that support both remappable input and output functions.

### 11.6.2 AVAILABLE PERIPHERALS

The peripherals managed by the Peripheral Pin Select are all digital only peripherals. These include general serial communications (UART and SPI), general purpose timer clock inputs, timer-related peripherals (input capture and output compare) and interrupt-on-change inputs.

In comparison, some digital only peripheral modules are never included in the Peripheral Pin Select feature. This is because the peripheral’s function requires special I/O circuitry on a specific port and cannot be easily connected to multiple pins. One example includes $I^2C$ modules. A similar requirement excludes all modules with analog inputs, such as the ADC Converter.

A key difference between remappable and non-remappable peripherals is that remappable peripherals are not associated with a default I/O pin. The peripheral must always be assigned to a specific I/O pin before it can be used. In contrast, non-remappable peripherals are always available on a default pin, assuming that the peripheral is active and not conflicting with another peripheral.

When a remappable peripheral is active on a given I/O pin, it takes priority over all other digital I/Os and digital communication peripherals associated with the pin. Priority is given regardless of the type of peripheral that is mapped. Remappable peripherals never take priority over any analog functions associated with the pin.

### 11.6.3 CONTROLLING PERIPHERAL PIN SELECT

Peripheral Pin Select features are controlled through two sets of SFRs: one to map peripheral inputs and one to map outputs. Because they are separately controlled, a particular peripheral’s input and output (if the peripheral has both) can be placed on any selectable function pin without constraint.

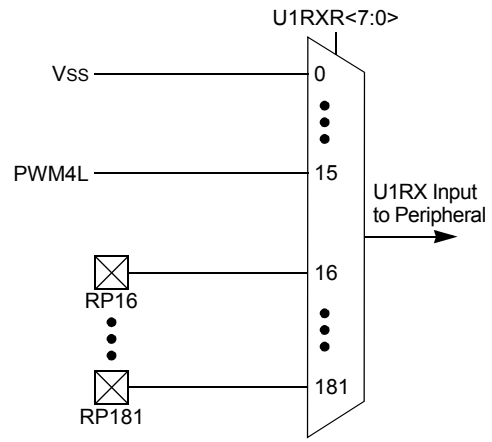
The association of a peripheral to a peripheral-selectable pin is handled in two different ways, depending on whether an input or output is being mapped.

### 11.6.4 INPUT MAPPING

The inputs of the Peripheral Pin Select options are mapped on the basis of the peripheral. That is, a control register associated with a peripheral dictates the pin it will be mapped to. The RPINRx registers are used to configure peripheral input mapping (see Register 11-9 through Register 11-32). Each register contains sets of 8-bit fields, with each set associated with one of the remappable peripherals. Programming a given peripheral's bit field with an appropriate 8-bit index value maps the RPn pin with the corresponding value, or internal signal, to that peripheral. See Table 11-11 for a list of available inputs.

For example, Figure 11-2 illustrates remappable pin selection for the U1RX input.

**FIGURE 11-2: REMAPPABLE INPUT FOR U1RX**




**Note:** For input only, Peripheral Pin Select functionality does not have priority over TRISx settings. Therefore, when configuring an RPn pin for input, the corresponding bit in the TRISx register must also be configured for input (set to '1').

#### 11.6.4.1 Virtual Connections

The dsPIC33EPXXXGS70X/80X devices support six virtual RPn pins (RP176-RP181), which are identical in functionality to all other RPn pins, with the exception of pinouts. These six pins are internal to the devices and are not connected to a physical device pin.

These pins provide a simple way for inter-peripheral connection without utilizing a physical pin. For example, the output of the analog comparator can be connected to RP176 and the PWM Fault input can be configured for RP176 as well. This configuration allows the analog comparator to trigger PWM Faults without the use of an actual physical pin on the device.

**TABLE 11-11: REMAPPABLE SOURCES**

| Remap Index | Output Function |
|---|---|
| 0 | Vss |
| 1 | CMP1 |
| 2 | CMP2 |
| 3 | CMP3 |
| 4 | CMP4 |
| 5 | PWM4H |
| 6 | PTGO30 |
| 7 | PTGO31 |
| 8-11 | Reserved |
| 12 | REFO |
| 13 | SYNCO1 |
| 14 | SYNCO2 |
| 15 | PWM4L |
| 16-20 | RP16-RP20 |
| 21-31 | Reserved |
| 32-41 | RP32-RP41 |
| 42 | Reserved |
| 43-58 | RP43-RP58 |
| 59 | Reserved |
| 60-76 | RP60-RP76 |
| 77-175 | Reserved |
| 176-181 | RP176-RP181 |


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**TABLE 11-12: SELECTABLE INPUT SOURCES (MAPS INPUT TO FUNCTION)**

| Input Name[(1)] | Function Name | Register | Configuration Bits |
|---|---|---|---|
| External Interrupt 1 | INT1 | RPINR0 | INT1R<7:0> |
| External Interrupt 2 | INT2 | RPINR1 | INT2R<7:0> |
| Timer1 External Clock | T1CK | RPINR2 | T1CKR<7:0> |
| Timer2 External Clock | T2CK | RPINR3 | T2CKR<7:0> |
| Timer3 External Clock | T3CK | RPINR3 | T3CKR<7:0> |
| Input Capture 1 | IC1 | RPINR7 | IC1R<7:0> |
| Input Capture 2 | IC2 | RPINR7 | IC2R<7:0> |
| Input Capture 3 | IC3 | RPINR8 | IC3R<7:0> |
| Input Capture 4 | IC4 | RPINR8 | IC4R<7:0> |
| Output Compare Fault A | OCFA | RPINR11 | OCFAR<7:0> |
| PWM Fault 1 | FLT1 | RPINR12 | FLT1R<7:0> |
| PWM Fault 2 | FLT2 | RPINR12 | FLT2R<7:0> |
| PWM Fault 3 | FLT3 | RPINR13 | FLT3R<7:0> |
| PWM Fault 4 | FLT4 | RPINR13 | FLT4R<7:0> |
| UART1 Receive | U1RX | RPINR18 | U1RXR<7:0> |
| UART1 Clear-to-Send | $\overline{\text{U1CTS}}$ | RPINR18 | U1CTSR<7:0> |
| UART2 Receive | U2RX | RPINR19 | U2RXR<7:0> |
| UART2 Clear-to-Send | $\overline{\text{U2CTS}}$ | RPINR19 | U2CTSR<7:0> |
| SPI1 Data Input | SDI1 | RPINR20 | SDI1R<7:0> |
| SPI1 Clock Input | SCK1 | RPINR20 | SCK1R<7:0> |
| SPI1 Slave Select | $\overline{\text{SS1}}$ | RPINR21 | SS1R<7:0> |
| CAN1 Receive | C1RX | PRINR26 | C1RXR<7:0> |
| CAN2 Receive | C2RX | PRINR26 | C2RXR<7:0> |
| SPI3 Data Input | SDI3 | RPINR29 | SDI3R<7:0> |
| SPI3 Clock Input | SCK3 | RPINR29 | SCK3R<7:0> |
| SPI3 Slave Select | $\overline{\text{SS3}}$ | RPINR30 | SS3R<7:0> |
| SPI2 Data Input | SDI2 | RPINR22 | SDI2R<7:0> |
| SPI2 Clock Input | SCK2 | RPINR22 | SCK2R<7:0> |
| SPI2 Slave Select | $\overline{\text{SS2}}$ | RPINR23 | SS2R<7:0> |
| PWM Synchronous Input 1 | SYNCI1 | RPINR37 | SYNCI1R<7:0> |
| PWM Synchronous Input 2 | SYNCI2 | RPINR38 | SYNCI2R<7:0> |
| PWM Fault 5 | FLT5 | RPINR42 | FLT5R<7:0> |
| PWM Fault 6 | FLT6 | RPINR42 | FLT6R<7:0> |
| PWM Fault 7 | FLT7 | RPINR43 | FLT7R<7:0> |
| PWM Fault 8 | FLT8 | RPINR43 | FLT8R<7:0> |
| CLC Input A | CLCINA | RPINR45 | CLCINA<7:0> |
| CLC Input B | CLCINB | RPINR46 | CLCINB<7:0> |

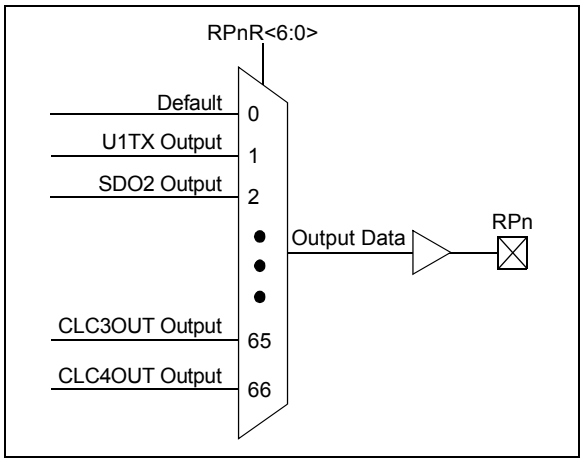
**Note 1:** Unless otherwise noted, all inputs use the Schmitt Trigger input buffers.

### 11.6.5 OUTPUT MAPPING

In contrast to inputs, the outputs of the Peripheral Pin Select options are mapped on the basis of the pin. In this case, a control register associated with a particular pin dictates the peripheral output to be mapped. The RPORx registers are used to control output mapping. Each register contains sets of 6-bit fields, with each set associated with one RPn pin (see Register 11-33 through Register 11-56). The value of the bit field corresponds to one of the peripherals and that peripheral's output is mapped to the pin (see Table 11-13 and Figure 11-3).

A null output is associated with the output register Reset value of '0'. This is done to ensure that remappable outputs remain disconnected from all output pins by default.

**FIGURE 11-3: MULTIPLEXING REMAPPABLE OUTPUTS FOR RPn**




#### 11.6.5.1 Mapping Limitations

The control schema of the peripheral select pins is not limited to a small range of fixed peripheral configurations. There are no mutual or hardware-enforced lockouts between any of the peripheral mapping SFRs. Literally any combination of peripheral mappings, across any or all of the RPn pins, is possible. This includes both many-to-one and one-to-many mappings of peripheral inputs, and outputs to pins. While such mappings may be technically possible from a configuration point of view, they may not be supportable from an electrical point of view.


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**TABLE 11-13: OUTPUT SELECTION FOR REMAPPABLE PINS (RPn)**

| Function | RPnR<6:0> | Output Name |
|---|---|---|
| Default PORT | 0000000 | RPn tied to Default Pin |
| U1TX | 0000001 | RPn tied to UART1 Transmit |
| $\overline{U1RTS}$ | 0000010 | RPn tied to UART1 Request-to-Send |
| U2TX | 0000011 | RPn tied to UART2 Transmit |
| $\overline{U2RTS}$ | 0000100 | RPn tied to UART2 Request-to-Send |
| SDO1 | 0000101 | RPn tied to SPI1 Data Output |
| SCK1 | 0000110 | RPn tied to SPI1 Clock Output |
| $\overline{SS1}$ | 0000111 | RPn tied to SPI1 Slave Select |
| SDO2 | 0001000 | RPn tied to SPI2 Data Output |
| SCK2 | 0001001 | RPn tied to SPI2 Clock Output |
| $\overline{SS2}$ | 0001010 | RPn tied to SPI2 Slave Select |
| C1TX | 0001110 | RPn tied to CAN1 Transmit |
| C2TX | 0001111 | RPn tied to CAN2 Transmit |
| OC1 | 0010000 | RPn tied to Output Compare 1 Output |
| OC2 | 0010001 | RPn tied to Output Compare 2 Output |
| OC3 | 0010010 | RPn tied to Output Compare 3 Output |
| OC4 | 0010011 | RPn tied to Output Compare 4 Output |
| ACMP1 | 0011000 | RPn tied to Analog Comparator 1 Output |
| ACMP2 | 0011001 | RPn tied to Analog Comparator 2 Output |
| ACMP3 | 0011010 | RPn tied to Analog Comparator 3 Output |
| SDO3 | 0011111 | RPn tied to SPI3 Data Output |
| SCK3 | 0100000 | RPn tied to SPI3 Clock Output |
| $\overline{SS3}$ | 0100001 | RPn tied to SPI3 Slave Select |
| SYNCO1 | 0101101 | RPn tied to PWM Primary Master Time Base Sync Output |
| SYNCO2 | 0101110 | RPn tied to PWM Secondary Master Time Base Sync Output |
| REFCLKO | 0110001 | RPn tied to Reference Clock Output |
| ACMP4 | 0110010 | RPn tied to Analog Comparator 4 Output |
| PWM4H | 0110011 | RPn tied to PWM Output Pins Associated with PWM Generator 4 |
| PWM4L | 0110100 | RPn tied to PWM Output Pins Associated with PWM Generator 4 |
| PWM5H | 0110101 | RPn tied to PWM Output Pins Associated with PWM Generator 5 |
| PWM5L | 0110110 | RPn tied to PWM Output Pins Associated with PWM Generator 5 |
| PWM6H | 0111001 | RPn tied to PWM Output Pins Associated with PWM Generator 6 |
| PWM6L | 0111010 | RPn tied to PWM Output Pins Associated with PWM Generator 6 |
| PWM7H | 0111011 | RPn tied to PWM Output Pins Associated with PWM Generator 7 |
| PWM7L | 0111100 | RPn tied to PWM Output Pins Associated with PWM Generator 7 |
| PWM8H | 0111101 | RPn tied to PWM Output Pins Associated with PWM Generator 8 |
| PWM8L | 0111110 | RPn tied to PWM Output Pins Associated with PWM Generator 8 |
| CLC1OUT | 0111111 | RPn tied to CLC1 Output |
| CLC2OUT | 1000000 | RPn tied to CLC2 Output |
| CLC3OUT(1) | 1000001 | RPn tied to CLC3 Output |
| CLC4OUT(1) | 1000010 | RPn tied to CLC4 Output |

**Note 1:** PPS outputs are only available on dsPIC33EPXXXGS702 (28-pin) devices.

## 11.7 I/O Helpful Tips

1. In some cases, certain pins, as defined in Table 30-11 under “Injection Current”, have internal protection diodes to VDD and VSS. The term, “Injection Current”, is also referred to as “Clamp Current”. On designated pins, with sufficient external current-limiting precautions by the user, I/O pin input voltages are allowed to be greater or less than the data sheet absolute maximum ratings, with respect to the VSS and VDD supplies. Note that when the user application forward biases either of the high or low-side internal input clamp diodes, that the resulting current being injected into the device, that is clamped internally by the VDD and VSS power rails, may affect the ADC accuracy by four to six counts.
2. I/O pins that are shared with any analog input pin (i.e., ANx) are always analog pins, by default, after any Reset. Consequently, configuring a pin as an analog input pin automatically disables the digital input pin buffer and any attempt to read the digital input level by reading PORTx or LATx will always return a ‘0’, regardless of the digital logic level on the pin. To use a pin as a digital I/O pin on a shared ANx pin, the user application needs to configure the Analog Pin Configuration registers (i.e., ANSELx) in the I/O ports module by setting the appropriate bit that corresponds to that I/O port pin to a ‘0’.

| **Note:** | Although it is not possible to use a digital input pin when its analog function is enabled, it is possible to use the digital I/O output function, TRISx = 0x0, while the analog function is also enabled. However, this is not recommended, particularly if the analog input is connected to an external analog voltage source, which would create signal contention between the analog signal and the output pin driver. |
|---|---|

3. Most I/O pins have multiple functions. Referring to the device pin diagrams in this data sheet, the priorities of the functions allocated to any pins are indicated by reading the pin name from left-to-right. The left most function name takes precedence over any function to its right in the naming convention. For example: AN16/T2CK/T7CK/RC1; this indicates that AN16 is the highest priority in this example and will supersede all other functions to its right in the list. Those other functions to its right, even if enabled, would not work as long as any other function to its left was enabled. This rule applies to all of the functions listed for a given pin.
4. Each pin has an internal weak pull-up resistor and pull-down resistor that can be configured using the CNPUx and CNPDx registers, respectively. These resistors eliminate the need for external resistors in certain applications. The internal pull-up is up to ~(VDD – 0.8), not VDD. This value is still above the minimum VIH of CMOS and TTL devices.
5. When driving LEDs directly, the I/O pin can source or sink more current than what is specified in the VOH/IOH and VOL/IOL DC characteristics specification. The respective IOH and IOL current rating only applies to maintaining the corresponding output at or above the VOH, and at or below the VOL levels. However, for LEDs, unlike digital inputs of an externally connected device, they are not governed by the same minimum VIH/VIL levels. An I/O pin output can safely sink or source any current less than that listed in the Absolute Maximum Ratings in **Section 30.0 “Electrical Characteristics”**of this data sheet. For example:

   VOH = 2.4v @ IOH = -8 mA and VDD = 3.3V

   The maximum output current sourced by any 8 mA I/O pin = 12 mA.

   LED source current < 12 mA is technically permitted. Refer to the VOH/IOH graphs in **Section 31.0 “DC and AC Device Characteristics Graphs”** for additional information.


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6. The Peripheral Pin Select (PPS) pin mapping rules are as follows:
   a) Only one “output” function can be active on a given pin at any time, regardless if it is a dedicated or remappable function (one pin, one output).
   b) It is possible to assign a “remappable output” function to multiple pins and externally short or tie them together for increased current drive.
   c) If any “dedicated output” function is enabled on a pin, it will take precedence over any remappable “output” function.
   d) If any “dedicated digital” (input or output) function is enabled on a pin, any number of “input” remappable functions can be mapped to the same pin.
   e) If any “dedicated analog” function(s) are enabled on a given pin, “digital input(s)” of any kind will all be disabled, although a single “digital output”, at the user’s cautionary discretion, can be enabled and active as long as there is no signal contention with an external analog input signal. For example, it is possible for the ADC to convert the digital output logic level, or to toggle a digital output on a comparator or ADC input, provided there is no external analog input, such as for a built-in self-test.
   f) Any number of “input” remappable functions can be mapped to the same pin(s) at the same time, including to any pin with a single output from either a dedicated or remappable “output”.
   g) The TRISx registers control *only* the digital I/O output buffer. Any other dedicated or remappable active “output” will automatically override the TRISx setting. The TRISx register *does not* control the digital logic “input” buffer. Remappable digital “inputs” do not automatically override TRISx settings, which means that the TRISx bit must be set to input for pins with only remappable input function(s) assigned.
   h) All analog pins are enabled by default after any Reset and the corresponding digital input buffer on the pin has been disabled. Only the Analog Pin Select x (ANSELx) registers control the digital input buffer, *not* the TRISx register. The user must disable the analog function on a pin using the Analog Pin Select x registers in order to use any “digital input(s)” on a corresponding pin, no exceptions.

## 11.8 I/O Ports 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 contains the latest updates and additional information.

### 11.8.1 KEY RESOURCES

- **“I/O Ports”** (DS70000598) in the *“dsPIC33/PIC24 Family Reference Manual”*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *“dsPIC33/PIC24 Family Reference Manual”* Sections
- Development Tools

## 11.9 Peripheral Pin Select Registers

**REGISTER 11-9: RPINR0: PERIPHERAL PIN SELECT INPUT REGISTER 0**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| INT1R7 | INT1R6 | INT1R5 | INT1R4 | INT1R3 | INT1R2 | INT1R1 | INT1R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 15-8 **INT1R<7:0>:** Assign External Interrupt 1 (INT1) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **Unimplemented:** Read as ‘0’

**REGISTER 11-10: RPINR1: PERIPHERAL PIN SELECT INPUT REGISTER 1**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| INT2R7 | INT2R6 | INT2R5 | INT2R4 | INT2R3 | INT2R2 | INT2R1 | INT2R0 |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **INT2R<7:0>:** Assign External Interrupt 2 (INT2) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.


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**REGISTER 11-11: RPINR2: PERIPHERAL PIN SELECT INPUT REGISTER 2**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| T1CKR7 | T1CKR6 | T1CKR5 | T1CKR4 | T1CKR3 | T1CKR2 | T1CKR1 | T1CKR0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 15-8 **T1CKR<7:0>:** Assign Timer1 External Clock (T1CK) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **Unimplemented:** Read as ‘0’

**REGISTER 11-12: RPINR3: PERIPHERAL PIN SELECT INPUT REGISTER 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 |
|---|---|---|---|---|---|---|---|
| T3CKR7 | T3CKR6 | T3CKR5 | T3CKR4 | T3CKR3 | T3CKR2 | T3CKR1 | T3CKR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| T2CKR7 | T2CKR6 | T2CKR5 | T2CKR4 | T2CKR3 | T2CKR2 | T2CKR1 | T2CKR0 |
| 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 **T3CKR<7:0>:** Assign Timer3 External Clock (T3CK) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **T2CKR<7:0>:** Assign Timer2 External Clock (T2CK) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-13: RPINR7: PERIPHERAL PIN SELECT INPUT REGISTER 7**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| IC2R7 | IC2R6 | IC2R5 | IC2R4 | IC2R3 | IC2R2 | IC2R1 | IC2R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| IC1R7 | IC1R6 | IC1R5 | IC1R4 | IC1R3 | IC1R2 | IC1R1 | IC1R0 |
| 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 **IC2R<7:0>:** Assign Input Capture 2 (IC2) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **IC1R<7:0>:** Assign Input Capture 1 (IC1) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-14: RPINR8: PERIPHERAL PIN SELECT INPUT REGISTER 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 |
|---|---|---|---|---|---|---|---|
| IC4R7 | IC4R6 | IC4R5 | IC4R4 | IC4R3 | IC4R2 | IC4R1 | IC4R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| IC3R7 | IC3R6 | IC3R5 | IC3R4 | IC3R3 | IC3R2 | IC3R1 | IC3R0 |
| 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 **IC4R<7:0>:** Assign Input Capture 4 (IC4) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **IC3R<7:0>:** Assign Input Capture 3 (IC3) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.


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**REGISTER 11-15: RPINR11: PERIPHERAL PIN SELECT INPUT REGISTER 11**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| OCFAR7 | OCFAR6 | OCFAR5 | OCFAR4 | OCFAR3 | OCFAR2 | OCFAR1 | OCFAR0 |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **OCFAR<7:0>:** Assign Output Compare Fault A (OCFA) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-16: RPINR12: PERIPHERAL PIN SELECT INPUT REGISTER 12**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLT2R7 | FLT2R6 | FLT2R5 | FLT2R4 | FLT2R3 | FLT2R2 | FLT2R1 | FLT2R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| FLT1R7 | FLT1R6 | FLT1R5 | FLT1R4 | FLT1R3 | FLT1R2 | FLT1R1 | FLT1R0 |
| 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 **FLT2R<7:0>:** Assign PWM Fault 2 (FLT2) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **FLT1R<7:0>:** Assign PWM Fault 1 (FLT1) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-17: RPINR13: PERIPHERAL PIN SELECT INPUT REGISTER 13**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLT4R7 | FLT4R6 | FLT4R5 | FLT4R4 | FLT4R3 | FLT4R2 | FLT4R1 | FLT4R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| FLT3R7 | FLT3R6 | FLT3R5 | FLT3R4 | FLT3R3 | FLT3R2 | FLT3R1 | FLT3R0 |
| 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 **FLT4R<7:0>:** Assign PWM Fault 4 (FLT4) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **FLT3R<7:0>:** Assign PWM Fault 3 (FLT3) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-18: RPINR18: PERIPHERAL PIN SELECT INPUT REGISTER 18**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| U1CTSR7 | U1CTSR6 | U1CTSR5 | U1CTSR4 | U1CTSR3 | U1CTSR2 | U1CTSR1 | U1CTSR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| U1RXR7 | U1RXR6 | U1RXR5 | U1RXR4 | U1RXR3 | U1RXR2 | U1RXR1 | U1RXR0 |
| 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 **U1CTSR<7:0>:** Assign UART1 Clear-to-Send ($\overline{\text{U1CTS}}$) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **U1RXR<7:0>:** Assign UART1 Receive (U1RX) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.


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**REGISTER 11-19: RPINR19: PERIPHERAL PIN SELECT INPUT REGISTER 19**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| U2CTSR7 | U2CTSR6 | U2CTSR5 | U2CTSR4 | U2CTSR3 | U2CTSR2 | U2CTSR1 | U2CTSR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| U2RXR7 | U2RXR6 | U2RXR5 | U2RXR4 | U2RXR3 | U2RXR2 | U2RXR1 | U2RXR0 |
| 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 **U2CTSR<7:0>:** Assign UART2 Clear-to-Send ($\overline{\text{U2CTS}}$) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **U2RXR<7:0>:** Assign UART2 Receive (U2RX) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-20: RPINR20: PERIPHERAL PIN SELECT INPUT REGISTER 20**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SCK1INR7 | SCK1INR6 | SCK1INR5 | SCK1INR4 | SCK1INR3 | SCK1INR2 | SCK1INR1 | SCK1INR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| SDI1R7 | SDI1R6 | SDI1R5 | SDI1R4 | SDI1R3 | SDI1R2 | SDI1R1 | SDI1R0 |
| 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 **SCK1INR<7:0>:** Assign SPI1 Clock Input (SCK1) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **SDI1R<7:0>:** Assign SPI1 Data Input (SDI1) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-21: RPINR21: PERIPHERAL PIN SELECT INPUT REGISTER 21**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| SS1R7 | SS1R6 | SS1R5 | SS1R4 | SS1R3 | SS1R2 | SS1R1 | SS1R0 |
| 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 **Unimplemented:** Read as '0'

bit 7-0 **SS1R<7:0>:** Assign SPI1 Slave Select ($\overline{SS1}$) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-22: RPINR22: PERIPHERAL PIN SELECT INPUT REGISTER 22**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SCK2INR7 | SCK2INR6 | SCK2INR5 | SCK2INR4 | SCK2INR3 | SCK2INR2 | SCK2INR1 | SCK2INR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| SDI2R7 | SDI2R6 | SDI2R5 | SDI2R4 | SDI2R3 | SDI2R2 | SDI2R1 | SDI2R0 |
| 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 **SCK2INR<7:0>:** Assign SPI2 Clock Input (SCK2) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **SDI2R<7:0>:** Assign SPI2 Data Input (SDI2) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.


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**REGISTER 11-23: RPINR23: PERIPHERAL PIN SELECT INPUT REGISTER 23**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| SS2R7 | SS2R6 | SS2R5 | SS2R4 | SS2R3 | SS2R2 | SS2R1 | SS2R0 |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **SS2R<7:0>:** Assign SPI2 Slave Select ($\overline{SS2}$) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-24: RPINR26: PERIPHERAL PIN SELECT INPUT REGISTER 26**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| C2RXR7 | C2RXR6 | C2RXR5 | C2RXR4 | C2RXR3 | C2RXR2 | C2RXR1 | C2RXR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| C1RXR7 | C1RXR6 | C1RXR5 | C1RXR4 | C1RXR3 | C1RXR2 | C1RXR1 | C1RXR0 |
| 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 **C2RXR<7:0>:** Assign CAN2 Receive (C2RX) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **C1RXR<7:0>:** Assign CAN1 Receive (C1RX) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-25: RPINR29: PERIPHERAL PIN SELECT INPUT REGISTER 29**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SCK3R7 | SCK3R6 | SCK3R5 | SCK3R4 | SCK3R3 | SCK3R2 | SCK3R1 | SCK3R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| SDI3R7 | SDI3R6 | SDI3R5 | SDI3R4 | SDI3R3 | SDI3R2 | SDI3R1 | SDI3R0 |
| 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 **SCK3R<7:0>:** Assign SPI3 Clock Input (SCK3) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **SDI3R<7:0>:** Assign SPI3 Data Input (SDI3) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-26: RPINR30: PERIPHERAL PIN SELECT INPUT REGISTER 30**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| SS3R7 | SS3R6 | SS3R5 | SS3R4 | SS3R3 | SS3R2 | SS3R1 | SS3R0 |
| 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 **Unimplemented:** Read as '0'

bit 7-0 **SS3R<7:0>:** Assign SPI3 Slave Select ($\overline{SS3}$) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.


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**REGISTER 11-27: RPINR37: PERIPHERAL PIN SELECT INPUT REGISTER 37**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SYNCI1R7 | SYNCI1R6 | SYNCI1R5 | SYNCI1R4 | SYNCI1R3 | SYNCI1R2 | SYNCI1R1 | SYNCI1R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 15-8 **SYNCI1R<7:0>:** Assign PWM Synchronization Input 1 (SYNCI1) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **Unimplemented:** Read as ‘0’

**REGISTER 11-28: RPINR38: PERIPHERAL PIN SELECT INPUT REGISTER 38**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| SYNCI2R7 | SYNCI2R6 | SYNCI2R5 | SYNCI2R4 | SYNCI2R3 | SYNCI2R2 | SYNCI2R1 | SYNCI2R0 |
| 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 **Unimplemented:** Read as ‘0’

bit 7-0 **SYNCI2R<7:0>:** Assign PWM Synchronization Input 2 (SYNCI2) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-29: RPINR42: PERIPHERAL PIN SELECT INPUT REGISTER 42**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLT6R7 | FLT6R6 | FLT6R5 | FLT6R4 | FLT6R3 | FLT6R2 | FLT6R1 | FLT6R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| FLT5R7 | FLT5R6 | FLT5R5 | FLT5R4 | FLT5R3 | FLT5R2 | FLT5R1 | FLT5R0 |
| 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 **FLT6R<7:0>:** Assign PWM Fault 6 (FLT6) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **FLT5R<7:0>:** Assign PWM Fault 5 (FLT5) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-30: RPINR43: PERIPHERAL PIN SELECT INPUT REGISTER 43**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLT8R7 | FLT8R6 | FLT8R5 | FLT8R4 | FLT8R3 | FLT8R2 | FLT8R1 | FLT8R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| FLT7R7 | FLT7R6 | FLT7R5 | FLT7R4 | FLT7R3 | FLT7R2 | FLT7R1 | FLT7R0 |
| 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 **FLT8R<7:0>:** Assign PWM Fault 8 (FLT8) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

bit 7-0 **FLT7R<7:0>:** Assign PWM Fault 7 (FLT7) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.


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**REGISTER 11-31: RPINR45: PERIPHERAL PIN SELECT INPUT REGISTER 45**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CLCINAR7 | CLCINAR6 | CLCINAR5 | CLCINAR4 | CLCINAR3 | CLCINAR2 | CLCINAR1 | CLCINAR0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 15-8 **CLCINAR<7:0>:** Assign CLC Input A (CLCINA) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

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

**REGISTER 11-32: RPINR46: PERIPHERAL PIN SELECT INPUT REGISTER 46**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| CLCINBR7 | CLCINBR6 | CLCINBR5 | CLCINBR4 | CLCINBR3 | CLCINBR2 | CLCINBR1 | CLCINBR0 |
| 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 **Unimplemented:** Read as '0'

bit 7-0 **CLCINBR<7:0>:** Assign CLC Input B (CLCINB) to the Corresponding RPn Pin bits
See Table 11-11 which contains a list of remappable inputs for the index value.

**REGISTER 11-33: RPOR0: PERIPHERAL PIN SELECT OUTPUT REGISTER 0**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP17R6 | RP17R5 | RP17R4 | RP17R3 | RP17R2 | RP17R1 | RP17R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP16R6 | RP16R5 | RP16R4 | RP16R3 | RP16R2 | RP16R1 | RP16R0 |
| 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 14-8 **RP17R<6:0>:** Peripheral Output Function is Assigned to RP17 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP16R<6:0>:** Peripheral Output Function is Assigned to RP16 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-34: RPOR1: PERIPHERAL PIN SELECT OUTPUT REGISTER 1**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP19R6 | RP19R5 | RP19R4 | RP19R3 | RP19R2 | RP19R1 | RP19R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP18R6 | RP18R5 | RP18R4 | RP18R3 | RP18R2 | RP18R1 | RP18R0 |
| 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 14-8 **RP19R<6:0>:** Peripheral Output Function is Assigned to RP19 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP18R<6:0>:** Peripheral Output Function is Assigned to RP18 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-35: RPOR2: PERIPHERAL PIN SELECT OUTPUT REGISTER 2**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP32R6 | RP32R5 | RP32R4 | RP32R3 | RP32R2 | RP32R1 | RP32R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP20R6 | RP20R5 | RP20R4 | RP20R3 | RP20R2 | RP20R1 | RP20R0 |
| 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 14-8 **RP32R<6:0>:** Peripheral Output Function is Assigned to RP32 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP20R<6:0>:** Peripheral Output Function is Assigned to RP20 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-36: RPOR3: PERIPHERAL PIN SELECT OUTPUT REGISTER 3**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP34R6 | RP34R5 | RP34R4 | RP34R3 | RP34R2 | RP34R1 | RP34R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP33R6 | RP33R5 | RP33R4 | RP33R3 | RP33R2 | RP33R1 | RP33R0 |
| 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 14-8 **RP34R<6:0>:** Peripheral Output Function is Assigned to RP34 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP33R<6:0>:** Peripheral Output Function is Assigned to RP33 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-37: RPOR4: PERIPHERAL PIN SELECT OUTPUT REGISTER 4**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP36R6 | RP36R5 | RP36R4 | RP36R3 | RP36R2 | RP36R1 | RP36R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP35R6 | RP35R5 | RP35R4 | RP35R3 | RP35R2 | RP35R1 | RP35R0 |
| 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 14-8 **RP36R<6:0>:** Peripheral Output Function is Assigned to RP36 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP35R<6:0>:** Peripheral Output Function is Assigned to RP35 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-38: RPOR5: PERIPHERAL PIN SELECT OUTPUT REGISTER 5**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP38R6 | RP38R5 | RP38R4 | RP38R3 | RP38R2 | RP38R1 | RP38R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP37R6 | RP37R5 | RP37R4 | RP37R3 | RP37R2 | RP37R1 | RP37R0 |
| 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 14-8 **RP38R<6:0>:** Peripheral Output Function is Assigned to RP38 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP37R<6:0>:** Peripheral Output Function is Assigned to RP37 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-39: RPOR6: PERIPHERAL PIN SELECT OUTPUT REGISTER 6**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP40R6 | RP40R5 | RP40R4 | RP40R3 | RP40R2 | RP40R1 | RP40R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP39R6 | RP39R5 | RP39R4 | RP39R3 | RP39R2 | RP39R1 | RP39R0 |
| 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 14-8 **RP40R<6:0>:** Peripheral Output Function is Assigned to RP40 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP39R<6:0>:** Peripheral Output Function is Assigned to RP39 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-40: RPOR7: PERIPHERAL PIN SELECT OUTPUT REGISTER 7**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP43R6 | RP43R5 | RP43R4 | RP43R3 | RP43R2 | RP43R1 | RP43R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP41R6 | RP41R5 | RP41R4 | RP41R3 | RP41R2 | RP41R1 | RP41R0 |
| 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 14-8 **RP43R<6:0>:** Peripheral Output Function is Assigned to RP43 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP41R<6:0>:** Peripheral Output Function is Assigned to RP41 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-41: RPOR8: PERIPHERAL PIN SELECT OUTPUT REGISTER 8**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP45R6 | RP45R5 | RP45R4 | RP45R3 | RP45R2 | RP45R1 | RP45R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP44R6 | RP44R5 | RP44R4 | RP44R3 | RP44R2 | RP44R1 | RP44R0 |
| 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 14-8 **RP45R<6:0>:** Peripheral Output Function is Assigned to RP45 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP44R<6:0>:** Peripheral Output Function is Assigned to RP44 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-42: RPOR9: PERIPHERAL PIN SELECT OUTPUT REGISTER 9**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP47R6 | RP47R5 | RP47R4 | RP47R3 | RP47R2 | RP47R1 | RP47R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP46R6 | RP46R5 | RP46R4 | RP46R3 | RP46R2 | RP46R1 | RP46R0 |
| 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 14-8 **RP47R<6:0>:** Peripheral Output Function is Assigned to RP47 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP46R<6:0>:** Peripheral Output Function is Assigned to RP46 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-43: RPOR10: PERIPHERAL PIN SELECT OUTPUT REGISTER 10**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP49R6 | RP49R5 | RP49R4 | RP49R3 | RP49R2 | RP49R1 | RP49R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP48R6 | RP48R5 | RP48R4 | RP48R3 | RP48R2 | RP48R1 | RP48R0 |
| 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 14-8 **RP49R<6:0>:** Peripheral Output Function is Assigned to RP49 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP48R<6:0>:** Peripheral Output Function is Assigned to RP48 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-44: RPOR11: PERIPHERAL PIN SELECT OUTPUT REGISTER 11**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP51R6 | RP51R5 | RP51R4 | RP51R3 | RP51R2 | RP51R1 | RP51R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP50R6 | RP50R5 | RP50R4 | RP50R3 | RP50R2 | RP50R1 | RP50R0 |
| 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 14-8 **RP51R<6:0>:** Peripheral Output Function is Assigned to RP51 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP50R<6:0>:** Peripheral Output Function is Assigned to RP50 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-45: RPOR12: PERIPHERAL PIN SELECT OUTPUT REGISTER 12**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP53R6 | RP53R5 | RP53R4 | RP53R3 | RP53R2 | RP53R1 | RP53R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP52R6 | RP52R5 | RP52R4 | RP52R3 | RP52R2 | RP52R1 | RP52R0 |
| 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 14-8 **RP53R<6:0>:** Peripheral Output Function is Assigned to RP53 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP52R<6:0>:** Peripheral Output Function is Assigned to RP52 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-46: RPOR13: PERIPHERAL PIN SELECT OUTPUT REGISTER 13**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP55R6 | RP55R5 | RP55R4 | RP55R3 | RP55R2 | RP55R1 | RP55R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP54R6 | RP54R5 | RP54R4 | RP54R3 | RP54R2 | RP54R1 | RP54R0 |
| 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 14-8 **RP55R<6:0>:** Peripheral Output Function is Assigned to RP55 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP54R<6:0>:** Peripheral Output Function is Assigned to RP54 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-47: RPOR14: PERIPHERAL PIN SELECT OUTPUT REGISTER 14**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP57R6 | RP57R5 | RP57R4 | RP57R3 | RP57R2 | RP57R1 | RP57R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP56R6 | RP56R5 | RP56R4 | RP56R3 | RP56R2 | RP56R1 | RP56R0 |
| 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 14-8 **RP57R<6:0>:** Peripheral Output Function is Assigned to RP57 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP56R<6:0>:** Peripheral Output Function is Assigned to RP56 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-48: RPOR15: PERIPHERAL PIN SELECT OUTPUT REGISTER 15**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP60R6 | RP60R5 | RP60R4 | RP60R3 | RP60R2 | RP60R1 | RP60R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP58R6 | RP58R5 | RP58R4 | RP58R3 | RP58R2 | RP58R1 | RP58R0 |
| 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 14-8 **RP60R<6:0>:** Peripheral Output Function is Assigned to RP60 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP58R<6:0>:** Peripheral Output Function is Assigned to RP58 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-49: RPOR16: PERIPHERAL PIN SELECT OUTPUT REGISTER 16**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP62R6 | RP62R5 | RP62R4 | RP62R3 | RP62R2 | RP62R1 | RP62R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP61R6 | RP61R5 | RP61R4 | RP61R3 | RP61R2 | RP61R1 | RP61R0 |
| 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 14-8 **RP62R<6:0>:** Peripheral Output Function is Assigned to RP62 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP61R<6:0>:** Peripheral Output Function is Assigned to RP61 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-50: RPOR17: PERIPHERAL PIN SELECT OUTPUT REGISTER 17**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP64R6 | RP64R5 | RP64R4 | RP64R3 | RP64R2 | RP64R1 | RP64R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP63R6 | RP63R5 | RP63R4 | RP63R3 | RP63R2 | RP63R1 | RP63R0 |
| 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 14-8 **RP64R<6:0>:** Peripheral Output Function is Assigned to RP64 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP63R<6:0>:** Peripheral Output Function is Assigned to RP63 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-51: RPOR18: PERIPHERAL PIN SELECT OUTPUT REGISTER 18**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP66R6 | RP66R5 | RP66R4 | RP66R3 | RP66R2 | RP66R1 | RP66R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP65R6 | RP65R5 | RP65R4 | RP65R3 | RP65R2 | RP65R1 | RP65R0 |
| 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 14-8 **RP66R<6:0>:** Peripheral Output Function is Assigned to RP66 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP65R<6:0>:** Peripheral Output Function is Assigned to RP65 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-52: RPOR19: PERIPHERAL PIN SELECT OUTPUT REGISTER 19**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP68R6 | RP68R5 | RP68R4 | RP68R3 | RP68R2 | RP68R1 | RP68R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP67R6 | RP67R5 | RP67R4 | RP67R3 | RP67R2 | RP67R1 | RP67R0 |
| 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 14-8 **RP68R<6:0>:** Peripheral Output Function is Assigned to RP68 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP67R<6:0>:** Peripheral Output Function is Assigned to RP67 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-53: RPOR20: PERIPHERAL PIN SELECT OUTPUT REGISTER 20**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP70R6 | RP70R5 | RP70R4 | RP70R3 | RP70R2 | RP70R1 | RP70R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP69R6 | RP69R5 | RP69R4 | RP69R3 | RP69R2 | RP69R1 | RP69R0 |
| 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 14-8 **RP70R<6:0>:** Peripheral Output Function is Assigned to RP70 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP69R<6:0>:** Peripheral Output Function is Assigned to RP69 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-54: RPOR21: PERIPHERAL PIN SELECT OUTPUT REGISTER 21**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP72R6 | RP72R5 | RP72R4 | RP72R3 | RP72R2 | RP72R1 | RP72R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP71R6 | RP71R5 | RP71R4 | RP71R3 | RP71R2 | RP71R1 | RP71R0 |
| 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 14-8 **RP72R<6:0>:** Peripheral Output Function is Assigned to RP72 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP71R<6:0>:** Peripheral Output Function is Assigned to RP71 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-55: RPOR22: PERIPHERAL PIN SELECT OUTPUT REGISTER 22**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP74R6 | RP74R5 | RP74R4 | RP74R3 | RP74R2 | RP74R1 | RP74R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP73R6 | RP73R5 | RP73R4 | RP73R3 | RP73R2 | RP73R1 | RP73R0 |
| 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 14-8 **RP74R<6:0>:** Peripheral Output Function is Assigned to RP74 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP73R<6:0>:** Peripheral Output Function is Assigned to RP73 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-56: RPOR23: PERIPHERAL PIN SELECT OUTPUT REGISTER 23**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP76R6 | RP76R5 | RP76R4 | RP76R3 | RP76R2 | RP76R1 | RP76R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP75R6 | RP75R5 | RP75R4 | RP75R3 | RP75R2 | RP75R1 | RP75R0 |
| 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 14-8 **RP76R<6:0>:** Peripheral Output Function is Assigned to RP76 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP75R<6:0>:** Peripheral Output Function is Assigned to RP75 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-57: RPOR24: PERIPHERAL PIN SELECT OUTPUT REGISTER 24**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP177R6 | RP177R5 | RP177R4 | RP177R3 | RP177R2 | RP177R1 | RP177R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP176R6 | RP176R5 | RP176R4 | RP176R3 | RP176R2 | RP176R1 | RP176R0 |
| 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 14-8 **RP177R<6:0>:** Peripheral Output Function is Assigned to RP177 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP176R<6:0>:** Peripheral Output Function is Assigned to RP176 Output Pin bits (see Table 11-13 for peripheral function numbers)

**REGISTER 11-58: RPOR25: PERIPHERAL PIN SELECT OUTPUT REGISTER 25**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP179R6 | RP179R5 | RP179R4 | RP179R3 | RP179R2 | RP179R1 | RP179R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP178R6 | RP178R5 | RP178R4 | RP178R3 | RP178R2 | RP178R1 | RP178R0 |
| 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 14-8 **RP179R<6:0>:** Peripheral Output Function is Assigned to RP179 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP178R<6:0>:** Peripheral Output Function is Assigned to RP178 Output Pin bits (see Table 11-13 for peripheral function numbers)


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**REGISTER 11-59: RPOR26: PERIPHERAL PIN SELECT OUTPUT REGISTER 26**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP181R6 | RP181R5 | RP181R4 | RP181R3 | RP181R2 | RP181R1 | RP181R0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RP180R6 | RP180R5 | RP180R4 | RP180R3 | RP180R2 | RP180R1 | RP180R0 |
| 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 14-8 **RP181R<6:0>:** Peripheral Output Function is Assigned to RP181 Output Pin bits (see Table 11-13 for peripheral function numbers)

bit 7 **Unimplemented:** Read as ‘0’

bit 6-0 **RP180R<6:0>:** Peripheral Output Function is Assigned to RP180 Output Pin bits (see Table 11-13 for peripheral function numbers)

**NOTES:**


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## 12.0 TIMER1

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Timers"** (DS70362) in the *"dsPIC33/PIC24 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 Timer1 module is a 16-bit timer that can operate as a free-running interval timer/counter.

The Timer1 module has the following unique features over other timers:

- Can be Operated in Asynchronous Counter mode from an External Clock Source
- The External Clock Input (T1CK) can Optionally be Synchronized to the Internal Device Clock and the Clock Synchronization is Performed after the prescaler

A block diagram of Timer1 is shown in Figure 12-1.

The Timer1 module can operate in one of the following modes:

- Timer mode
- Gated Timer mode
- Synchronous Counter mode
- Asynchronous Counter mode

In Timer and Gated Timer modes, the input clock is derived from the internal instruction cycle clock (FCY). In Synchronous and Asynchronous Counter modes, the input clock is derived from the external clock input at the T1CK pin.

The Timer modes are determined by the following bits:

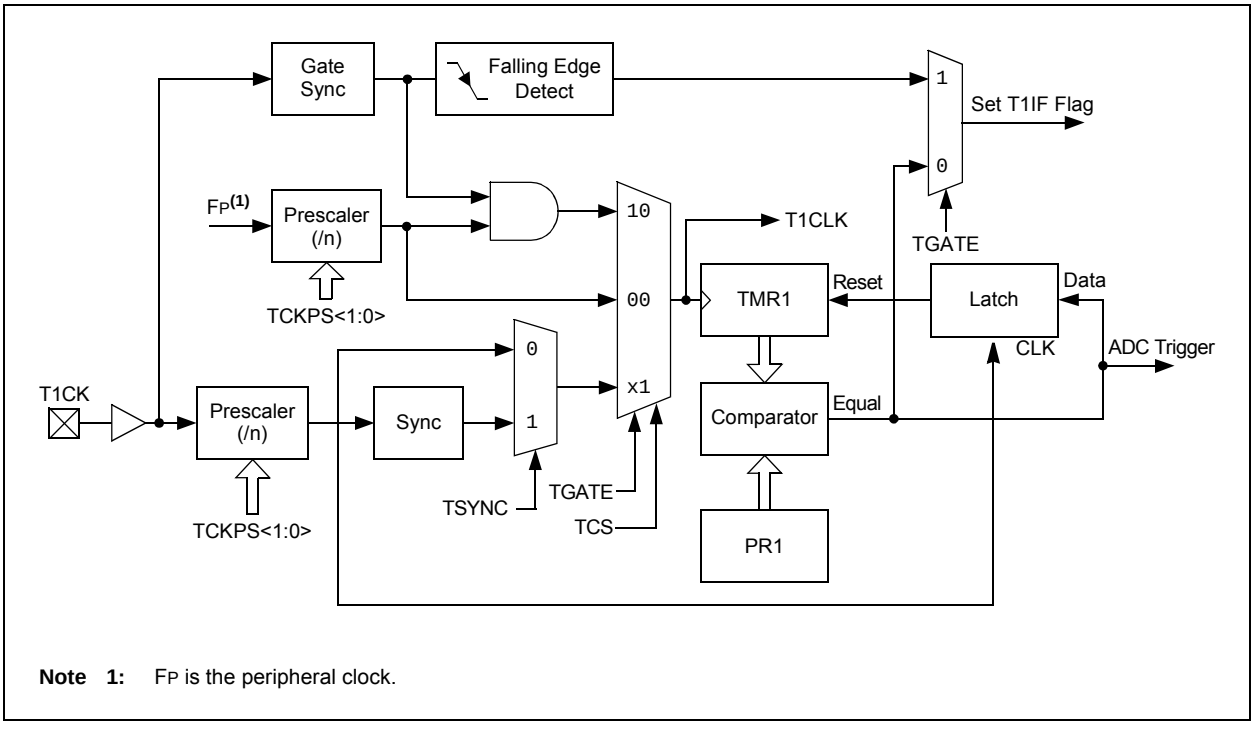
- Timer1 Clock Source Select bit (TCS): T1CON<1>
- Timer1 External Clock Input Synchronization Select bit (TSYNC): T1CON<2>
- Timer1 Gated Time Accumulation Enable bit (TGATE): T1CON<6>

Timer control bit settings for different operating modes are provided in Table 12-1.

**TABLE 12-1: TIMER1 MODE SETTINGS**

| Mode | TCS | TGATE | TSYNC |
|---|---|---|---|
| Timer | 0 | 0 | x |
| Gated Timer | 0 | 1 | x |
| Synchronous Counter | 1 | x | 1 |
| Asynchronous Counter | 1 | x | 0 |

**FIGURE 12-1: 16-BIT TIMER1 MODULE BLOCK DIAGRAM**




**Note 1:** FP is the peripheral clock.

## 12.1 Timer1 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 contains the latest updates and additional information.

### 12.1.1 KEY RESOURCES

- **"Timers"** (DS70362) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools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## 12.2 Timer1 Control Register

**REGISTER 12-1: T1CON: TIMER1 CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| TON(1) | — | TSIDL | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | TGATE | TCKPS1 | TCKPS0 | — | TSYNC(1) | TCS(1) | — |
| 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 **TON:** Timer1 On bit(1)
1 = Starts 16-bit Timer1
0 = Stops 16-bit Timer1

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

bit 13 **TSIDL:** Timer1 Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-7 **Unimplemented:** Read as '0'

bit 6 **TGATE:** Timer1 Gated Time Accumulation Enable bit
When TCS = 1:
This bit is ignored.
When TCS = 0:
1 = Gated time accumulation is enabled
0 = Gated time accumulation is disabled

bit 5-4 **TCKPS<1:0>:** Timer1 Input Clock Prescale Select bits
11 = 1:256
10 = 1:64
01 = 1:8
00 = 1:1

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

bit 2 **TSYNC:** Timer1 External Clock Input Synchronization Select bit(1)
When TCS = 1:
1 = Synchronizes external clock input
0 = Does not synchronize external clock input
When TCS = 0:
This bit is ignored.

bit 1 **TCS:** Timer1 Clock Source Select bit(1)
1 = External clock is from pin, T1CK (on the rising edge)
0 = Internal clock (FP)

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

**Note 1:** When Timer1 is enabled in External Synchronous Counter mode (TCS = 1, TSYNC = 1, TON = 1), any attempts by user software to write to the TMR1 register are ignored.

**NOTES:**


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## 13.0 TIMER2/3 AND TIMER4/5

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Timers"** (DS70362) in the *"dsPIC33/PIC24 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 Timer2/3 and Timer4/5 modules are 32-bit timers, which can also be configured as four independent 16-bit timers with selectable operating modes.

As 32-bit timers, Timer2/3 and Timer4/5 operate in three modes:

- Two Independent 16-Bit Timers (e.g., Timer2 and Timer3) with all 16-Bit Operating modes (except Asynchronous Counter mode)
- Single 32-Bit Timer
- Single 32-Bit Synchronous Counter

They also support these features:

- Timer Gate Operation
- Selectable Prescaler Settings
- Timer Operation during Idle and Sleep modes
- Interrupt on a 32-Bit Period Register Match
- Time Base for Input Capture and Output Compare modules (Timer2 and Timer3 only)

Individually, all four of the 16-bit timers can function as synchronous timers or counters. They also offer the features listed previously, except for the event trigger; this is implemented only with Timer2/3. The operating modes and enabled features are determined by setting the appropriate bit(s) in the T2CON, T3CON, T4CON and T5CON registers. T2CON and T4CON are shown in generic form in Register 13-1. T3CON and T5CON are shown in Register 13-2.

For 32-bit timer/counter operation, Timer2 and Timer4 are the least significant word (lsw); Timer3 and Timer5 are the most significant word (msw) of the 32-bit timers.

**Note:** For 32-bit operation, T3CON and T5CON control bits are ignored. Only T2CON and T4CON control bits are used for setup and control. Timer2 and Timer4 clock and gate inputs are utilized for the 32-bit timer modules, but an interrupt is generated with the Timer3 and Timer5 interrupt flags.

A block diagram for an example 32-bit timer pair (Timer2/3 and Timer4/5) is shown in Figure 13-2.

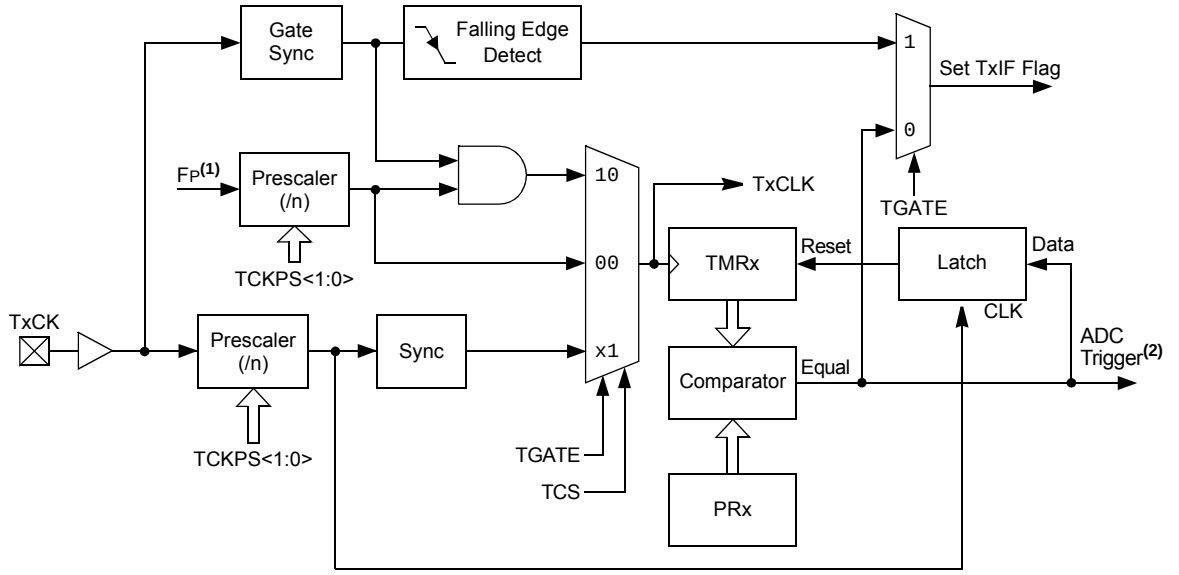
### 13.1 Timer Resources

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 contains the latest updates and additional information.

#### 13.1.1 KEY RESOURCES

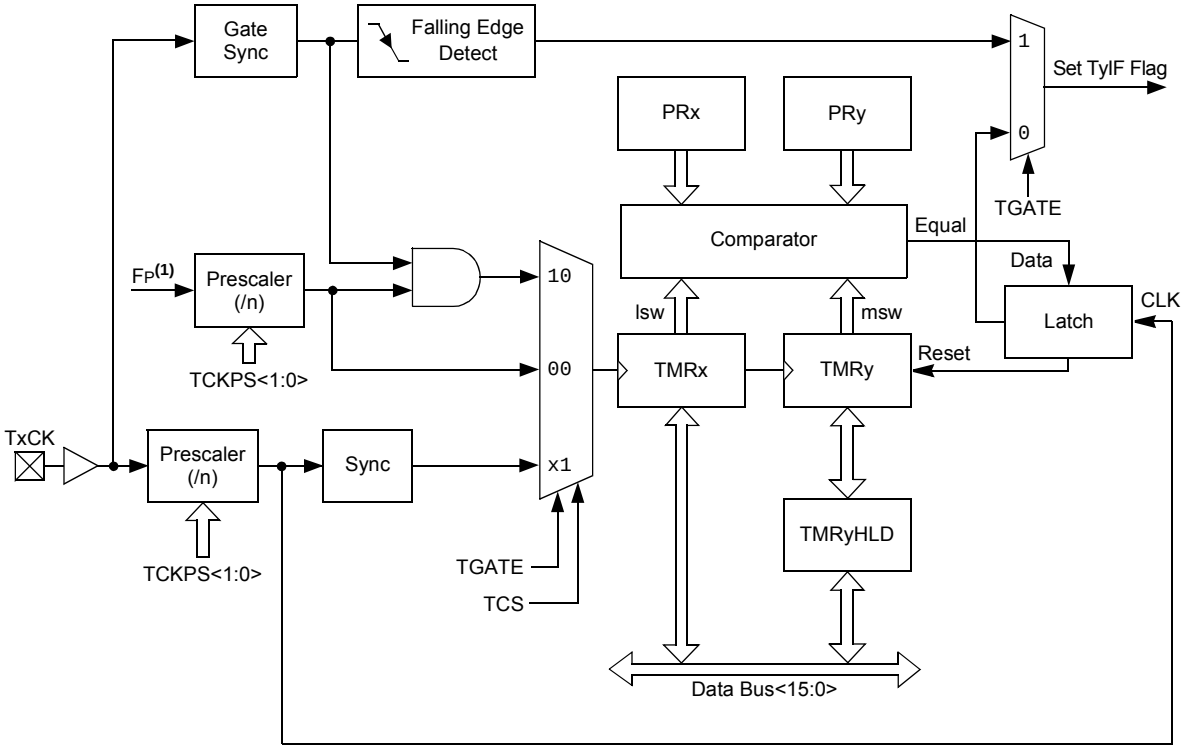
- **"Timers"** (DS70362) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

**FIGURE 13-1: TIMERx BLOCK DIAGRAM (x = 2 THROUGH 5)**




**Note 1:** FP is the peripheral clock.
**2:** The ADC trigger is only available on TMR2.

**FIGURE 13-2: TYPE B/TYPE C TIMER PAIR BLOCK DIAGRAM (32-BIT TIMER)**




**Note 1:** Timerx is a Type B timer (x = 2 and 4).
**2:** Timery is a Type C timer (y = 3 and 5).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## 13.2 Timer2/3 and Timer4/5 Control Registers

**REGISTER 13-1: TxCON: (TIMER2 AND TIMER4) CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| TON | — | TSIDL | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | TGATE | TCKPS1 | TCKPS0 | T32 | — | TCS(1) | — |
| 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 **TON:** Timerx On bit
When T32 = 1:
1 = Starts 32-bit Timerx/y
0 = Stops 32-bit Timerx/y
When T32 = 0:
1 = Starts 16-bit Timerx
0 = Stops 16-bit Timerx

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

bit 13 **TSIDL:** Timerx Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-7 **Unimplemented:** Read as '0'

bit 6 **TGATE:** Timerx Gated Time Accumulation Enable bit
When TCS = 1:
This bit is ignored.
When TCS = 0:
1 = Gated time accumulation is enabled
0 = Gated time accumulation is disabled

bit 5-4 **TCKPS<1:0>:** Timerx Input Clock Prescale Select bits
11 = 1:256
10 = 1:64
01 = 1:8
00 = 1:1

bit 3 **T32:** 32-Bit Timer Mode Select bit
1 = Timerx and Timery form a single 32-bit timer
0 = Timerx and Timery act as two 16-bit timers

bit 2 **Unimplemented:** Read as '0'

bit 1 **TCS:** Timerx Clock Source Select bit(1)
1 = External clock is from pin, TxCK (on the rising edge)
0 = Internal clock (FP)

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

**Note 1:** The TxCK pin is not available on all devices. Refer to the **"Pin Diagrams"** section for the available pins.

**REGISTER 13-2: TyCON: (TIMER3 AND TIMER5) CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| TON(1) | — | TSIDL(2) | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | TGATE(1) | TCKPS1(1) | TCKPS0(1) | — | — | TCS(1,3) | — |
| 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 **TON:** Timery On bit(1)
1 = Starts 16-bit Timery
0 = Stops 16-bit Timery

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

bit 13 **TSIDL:** Timery Stop in Idle Mode bit(2)
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-7 **Unimplemented:** Read as '0'

bit 6 **TGATE:** Timery Gated Time Accumulation Enable bit(1)
When TCS = 1:
This bit is ignored.
When TCS = 0:
1 = Gated time accumulation is enabled
0 = Gated time accumulation is disabled

bit 5-4 **TCKPS<1:0>:** Timery Input Clock Prescale Select bits(1)
11 = 1:256
10 = 1:64
01 = 1:8
00 = 1:1

bit 3-2 **Unimplemented:** Read as '0'

bit 1 **TCS:** Timery Clock Source Select bit(1,3)
1 = External clock is from pin, TyCK (on the rising edge)
0 = Internal clock (FP)

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

**Note 1:** When 32-bit operation is enabled (TxCON<3> = 1), these bits have no effect on Timery operation; all timer functions are set through TxCON.

**2:** When 32-bit timer operation is enabled (T32 = 1) in the Timerx Control register (TxCON<3>), the TSIDL bit must be cleared to operate the 32-bit timer in Idle mode.

**3:** The TyCK pin is not available on all devices. See the **"Pin Diagrams"** section for the available pins.


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## 14.0 INPUT CAPTURE

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Input Capture with Dedicated Timer"** (DS70000352) in the *"dsPIC33/PIC24 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 input capture module is useful in applications requiring frequency (period) and pulse measurements. The dsPIC33EPXXXGS70X/80X devices support four input capture channels.

Key features of the input capture module include:

- Hardware-Configurable for 32-Bit Operation in all modes by Cascading Two Adjacent modules
- Synchronous and Trigger modes of Output Compare Operation, with up to 21 User-Selectable Trigger/Sync Sources available
- A 4-Level FIFO Buffer for Capturing and Holding Timer Values for Several Events
- Configurable Interrupt Generation
- Up to Six Clock Sources available for each module, Driving a Separate Internal 16-Bit Counter

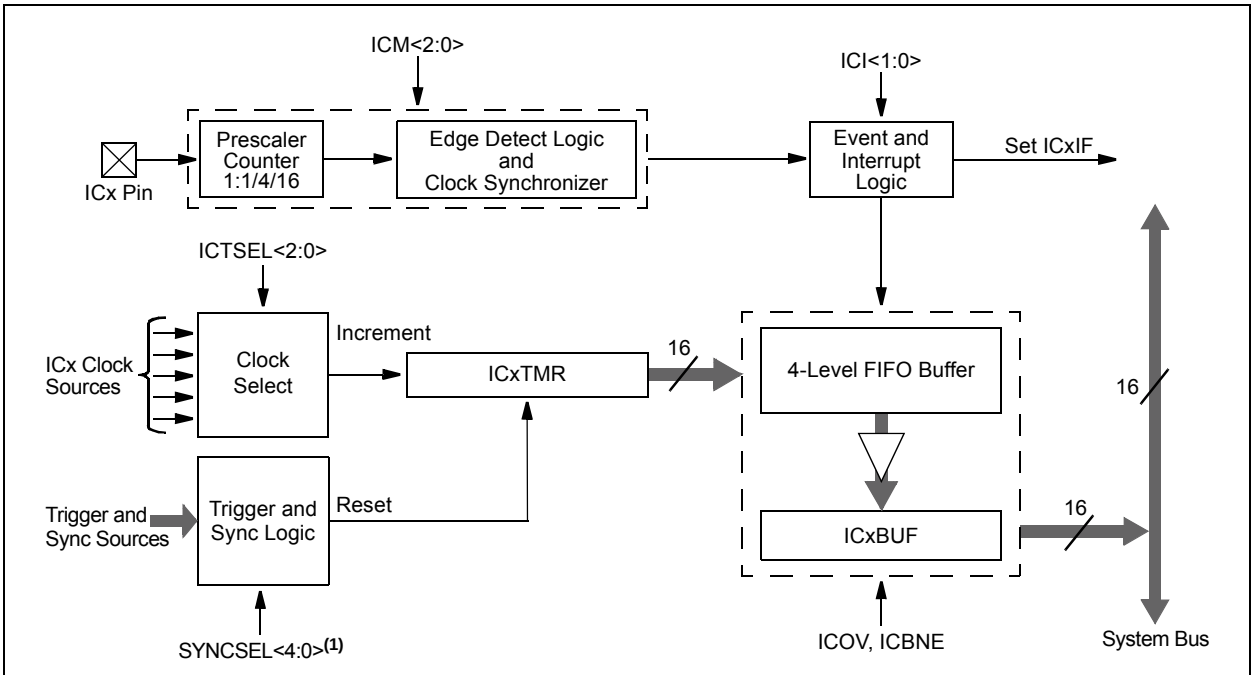
### 14.1 Input Capture Resources

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 contains the latest updates and additional information.

#### 14.1.1 KEY RESOURCES

- **"Input Capture with Dedicated Timer"** (DS70000352) 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 14-1: INPUT CAPTURE x MODULE BLOCK DIAGRAM**




**Note 1:** The trigger/sync source is enabled by default and is set to Timer3 as a source. This timer must be enabled for proper ICx module operation or the trigger/sync source must be changed to another source option.

## 14.2 Input Capture Registers

**REGISTER 14-1: ICxCON1: INPUT CAPTURE x CONTROL REGISTER 1**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | ICSIDL | ICTSEL2 | ICTSEL1 | ICTSEL0 | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R-0, HC, HS | R-0, HC, HS | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | ICI1 | ICI0 | ICOV | ICBNE | ICM2 | ICM1 | ICM0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware Clearable bit | HS = Hardware Settable 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 15-14 **Unimplemented:** Read as '0'

bit 13 **ICSIDL:** Input Capture x Stop in Idle Control bit
- 1 = Input capture will halt in CPU Idle mode
- 0 = Input capture will continue to operate in CPU Idle mode

bit 12-10 **ICTSEL<2:0>:** Input Capture x Timer Select bits
- 111 = Peripheral clock (FP) is the clock source of the ICx
- 110 = Reserved
- 101 = Reserved
- 100 = T1CLK is the clock source of the ICx (only the synchronous clock is supported)
- 011 = T5CLK is the clock source of the ICx
- 010 = T4CLK is the clock source of the ICx
- 001 = T2CLK is the clock source of the ICx
- 000 = T3CLK is the clock source of the ICx

bit 9-7 **Unimplemented:** Read as '0'

bit 6-5 **ICI<1:0>:** Number of Captures per Interrupt Select bits (this field is not used if ICM<2:0> = 001 or 111)
- 11 = Interrupt on every fourth capture event
- 10 = Interrupt on every third capture event
- 01 = Interrupt on every second capture event
- 00 = Interrupt on every capture event

bit 4 **ICOV:** Input Capture x Overflow Status Flag bit (read-only)
- 1 = Input capture buffer overflow has occurred
- 0 = No input capture buffer overflow has occurred

bit 3 **ICBNE:** Input Capture x Buffer Not Empty Status bit (read-only)
- 1 = Input capture buffer is not empty, at least one more capture value can be read
- 0 = Input capture buffer is empty

bit 2-0 **ICM<2:0>:** Input Capture x Mode Select bits
- 111 = Input Capture x functions as an interrupt pin only in CPU Sleep and Idle modes (rising edge detect only, all other control bits are not applicable)
- 110 = Unused (module is disabled)
- 101 = Capture mode, every 16th rising edge (Prescaler Capture mode)
- 100 = Capture mode, every 4th rising edge (Prescaler Capture mode)
- 011 = Capture mode, every rising edge (Simple Capture mode)
- 010 = Capture mode, every falling edge (Simple Capture mode)
- 001 = Capture mode, every rising and falling edge (Edge Detect mode, ICI<1:0>, is not used in this mode)
- 000 = Input Capture x is turned off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**REGISTER 14-2: ICxCON2: INPUT CAPTURE x CONTROL REGISTER 2**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | IC32 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0, HS | U-0 | R/W-0 | R/W-1 | R/W-1 | R/W-0 | R/W-1 |
|---|---|---|---|---|---|---|---|
| ICTRIG(2) | TRIGSTAT(3) | — | SYNCSEL4(4) | SYNCSEL3(4) | SYNCSEL2(4) | SYNCSEL1(4) | SYNCSEL0(4) |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable 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 15-9 **Unimplemented:** Read as '0'

bit 8 **IC32:** Input Capture x 32-Bit Timer Mode Select bit (Cascade mode)
- 1 = Odd ICx and even ICx form a single 32-bit input capture module(1)
- 0 = Cascade module operation is disabled

bit 7 **ICTRIG:** Input Capture x Trigger Operation Select bit(2)
- 1 = Input source is used to trigger the input capture timer (Trigger mode)
- 0 = Input source is used to synchronize the input capture timer to a timer of another module (Synchronization mode)

bit 6 **TRIGSTAT:** Timer Trigger Status bit(3)
- 1 = ICxTMR has been triggered and is running
- 0 = ICxTMR has not been triggered and is being held clear

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

**Note 1:** The IC32 bit in both the odd and even ICx must be set to enable Cascade mode.

**2:** The input source is selected by the SYNCSEL<4:0> bits of the ICxCON2 register.

**3:** This bit is set by the selected input source (selected by SYNCSEL<4:0> bits); it can be read, set and cleared in software.

**4:** Do not use the ICx module as its own sync or trigger source.

**5:** This option should only be selected as a trigger source and not as a synchronization source.

**REGISTER 14-2: ICxCON2: INPUT CAPTURE x CONTROL REGISTER 2 (CONTINUED)**

bit 4-0 **SYNCSEL<4:0>:** Input Source Select for Synchronization and Trigger Operation bits(4)

11111 = No sync or trigger source for ICx
11110 = Reserved
11101 = Reserved
11100 = Reserved
11011 = CMP4 module synchronizes or triggers ICx(5)
11010 = CMP3 module synchronizes or triggers ICx(5)
11001 = CMP2 module synchronizes or triggers ICx(5)
11000 = CMP1 module synchronizes or triggers ICx(5)
10111 = Reserved
10110 = Reserved
10101 = Reserved
10100 = Reserved
10011 = IC4 module interrupt synchronizes or triggers ICx
10010 = IC3 module interrupt synchronizes or triggers ICx
10001 = IC2 module interrupt synchronizes or triggers ICx
10000 = IC1 module interrupt synchronizes or triggers ICx
01111 = Timer5 synchronizes or triggers ICx
01110 = Timer4 synchronizes or triggers ICx
01101 = Timer3 synchronizes or triggers ICx **(default)**
01100 = Timer2 synchronizes or triggers ICx
01011 = Timer1 synchronizes or triggers ICx
01010 = Reserved
01001 = Reserved
01000 = IC4 module synchronizes or triggers ICx
00111 = IC3 module synchronizes or triggers ICx
00110 = IC2 module synchronizes or triggers ICx
00101 = IC1 module synchronizes or triggers ICx
00100 = OC4 module synchronizes or triggers ICx
00011 = OC3 module synchronizes or triggers ICx
00010 = OC2 module synchronizes or triggers ICx
00001 = OC1 module synchronizes or triggers ICx
00000 = No sync or trigger source for ICx

**Note 1:** The IC32 bit in both the odd and even ICx must be set to enable Cascade mode.
**2:** The input source is selected by the SYNCSEL<4:0> bits of the ICxCON2 register.
**3:** This bit is set by the selected input source (selected by SYNCSEL<4:0> bits); it can be read, set and cleared in software.
**4:** Do not use the ICx module as its own sync or trigger source.
**5:** This option should only be selected as a trigger source and not as a synchronization source.


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## 15.0 OUTPUT COMPARE

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Output Compare with Dedicated Timer"** (DS70005159) in the *"dsPIC33/PIC24 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 output compare module can select one of six available clock sources for its time base. The module compares the value of the timer with the value of one or two Compare registers, depending on the operating mode selected. The state of the output pin changes when the timer value matches the Compare register value. The output compare module generates either a single output pulse, or a sequence of output pulses, by changing the state of the output pin on the compare match events. The output compare module can also generate interrupts on compare match events.

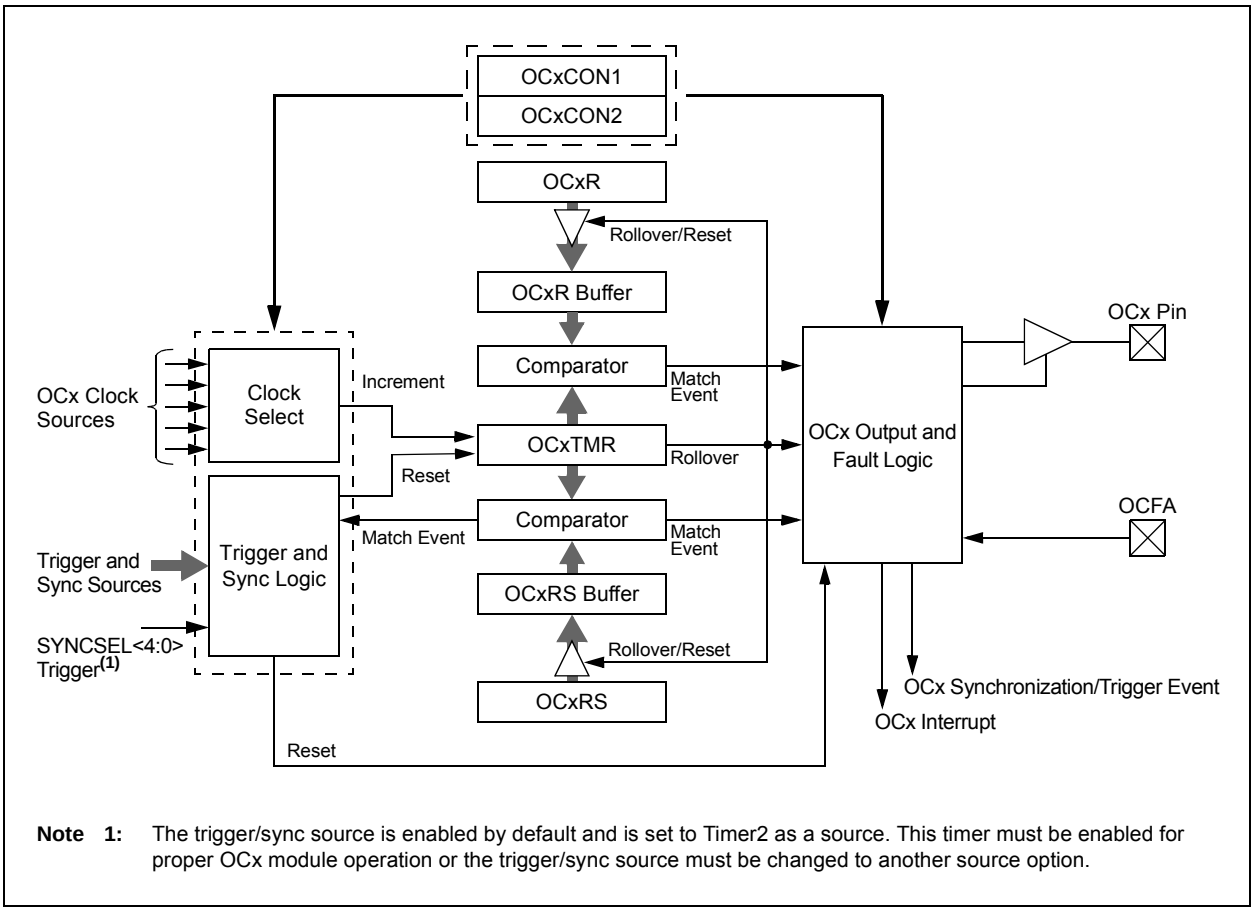
### 15.1 Output Compare Resources

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 contains the latest updates and additional information.

#### 15.1.1 KEY RESOURCES

- **"Output Compare with Dedicated Timer"** (DS70005159) 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 15-1: OUTPUT COMPARE x MODULE BLOCK DIAGRAM**




**Note 1:** The trigger/sync source is enabled by default and is set to Timer2 as a source. This timer must be enabled for proper OCx module operation or the trigger/sync source must be changed to another source option.

## 15.2 Output Compare Control Registers

**REGISTER 15-1: OCxCON1: OUTPUT COMPARE x CONTROL REGISTER 1**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | OCSIDL | OCTSEL2 | OCTSEL1 | OCTSEL0 | — | — |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | R/W-0, HSC | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ENFLTA | — | — | OCFLTA | TRIGMODE | OCM2 | OCM1 | OCM0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HSC = Hardware Settable/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 15-14 **Unimplemented:** Read as '0'

bit 13 **OCSIDL:** Output Compare x Stop in Idle Mode Control bit
- 1 = Output Compare x halts in CPU Idle mode
- 0 = Output Compare x continues to operate in CPU Idle mode

bit 12-10 **OCTSEL<2:0>:** Output Compare x Clock Select bits
- 111 = Peripheral clock (FP)
- 110 = Reserved
- 101 = Reserved
- 100 = T1CLK is the clock source of the OCx (only the synchronous clock is supported)
- 011 = T5CLK is the clock source of the OCx
- 010 = T4CLK is the clock source of the OCx
- 001 = T3CLK is the clock source of the OCx
- 000 = T2CLK is the clock source of the OCx

bit 9-8 **Unimplemented:** Read as '0'

bit 7 **ENFLTA:** Fault A Input Enable bit
- 1 = Output Compare Fault A input (OCFA) is enabled
- 0 = Output Compare Fault A input (OCFA) is disabled

bit 6-5 **Unimplemented:** Read as '0'

bit 4 **OCFLTA:** PWM Fault A Condition Status bit
- 1 = PWM Fault A condition on the OCFA pin has occurred
- 0 = No PWM Fault A condition on the OCFA pin has occurred

bit 3 **TRIGMODE:** Trigger Status Mode Select bit
- 1 = TRIGSTAT (OCxCON2<6>) is cleared when OCxRS = OCxTMR or in software
- 0 = TRIGSTAT is cleared only by software

**Note 1:** OCxR and OCxRS are double-buffered in PWM mode only.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**REGISTER 15-1: OCxCON1: OUTPUT COMPARE x CONTROL REGISTER 1 (CONTINUED)**

bit 2-0 **OCM<2:0>:** Output Compare x Mode Select bits

- 111 = Center-Aligned PWM mode: Output is set high when OCxTMR = OCxR and set low when OCxTMR = OCxRS(1)
- 110 = Edge-Aligned PWM mode: Output is set high when OCxTMR = 0 and set low when OCxTMR = OCxR(1)
- 101 = Double Compare Continuous Pulse mode: Initializes OCx pin low, toggles OCx state continuously on alternate matches of OCxR and OCxRS
- 100 = Double Compare Single-Shot mode: Initializes OCx pin low, toggles OCx state on matches of OCxR and OCxRS for one cycle
- 011 = Single Compare mode: Compare event with OCxR, continuously toggles OCx pin
- 010 = Single Compare Single-Shot mode: Initializes OCx pin high, compare event with OCxR, forces OCx pin low
- 001 = Single Compare Single-Shot mode: Initializes OCx pin low, compare event with OCxR, forces OCx pin high
- 000 = Output compare channel is disabled

**Note 1:** OCxR and OCxRS are double-buffered in PWM mode only.

**REGISTER 15-2: OCxCON2: OUTPUT COMPARE x CONTROL REGISTER 2**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLTMD | FLTOUT | FLTTRIEN | OCINV | — | — | — | OC32 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0, HS | R/W-0 | R/W-0 | R/W-1 | R/W-1 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| OCTRIG | TRIGSTAT | OCTRIS | SYNCSEL4 | SYNCSEL3 | SYNCSEL2 | SYNCSEL1 | SYNCSEL0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable 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 **FLTMD:** Fault Mode Select bit
- 1 = Fault mode is maintained until the Fault source is removed; the corresponding OCFLTA bit is cleared in software and a new PWMx period starts
- 0 = Fault mode is maintained until the Fault source is removed and a new PWMx period starts

bit 14 **FLTOUT:** Fault Out bit
- 1 = PWMx output is driven high on a Fault
- 0 = PWMx output is driven low on a Fault

bit 13 **FLTTRIEN:** Fault Output State Select bit
- 1 = OCx pin is tri-stated on a Fault condition
- 0 = OCx pin I/O state is defined by the FLTOUT bit on a Fault condition

bit 12 **OCINV:** Output Compare x Invert bit
- 1 = OCx output is inverted
- 0 = OCx output is not inverted

bit 11-9 **Unimplemented:** Read as '0'

bit 8 **OC32:** Cascade Two OCx Modules Enable bit (32-bit operation)
- 1 = Cascade module operation is enabled
- 0 = Cascade module operation is disabled

bit 7 **OCTRIG:** Output Compare x Trigger/Sync Select bit
- 1 = Triggers OCx from the source designated by the SYNCSELx bits
- 0 = Synchronizes OCx with the source designated by the SYNCSELx bits

bit 6 **TRIGSTAT:** Timer Trigger Status bit
- 1 = Timer source has been triggered and is running
- 0 = Timer source has not been triggered and is being held clear

bit 5 **OCTRIS:** Output Compare x Output Pin Direction Select bit
- 1 = OCx is tri-stated
- 0 = OCx module drives the OCx pin

**Note 1:** Do not use the OCx module as its own synchronization or trigger source.

**2:** When the OCy module is turned off, it sends a trigger out signal. If the OCx module uses the OCy module as a trigger source, the OCy module must be unselected as a trigger source prior to disabling it.

**3:** For each OCMPx instance, a different PTG trigger out is used:
OCMP1 – PTG trigger out [0]
OCMP2 – PTG trigger out [1]
OCMP3 – PTG trigger out [2]
OCMP4 – PTG trigger out [3]


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**REGISTER 15-2: OCxCON2: OUTPUT COMPARE x CONTROL REGISTER 2 (CONTINUED)**

bit 4-0 **SYNCSEL<4:0>:** Trigger/Synchronization Source Selection bits

11111 = OCxRS compare event is used for synchronization
11110 = INT2 pin synchronizes or triggers OCx
11101 = INT1 pin synchronizes or triggers OCx
11100 = Reserved
11011 = CMP4 module synchronizes or triggers OCx
11010 = CMP3 module synchronizes or triggers OCx
11001 = CMP2 module synchronizes or triggers OCx
11000 = CMP1 module synchronizes or triggers OCx
10111 = Reserved
10110 = Reserved
10101 = Reserved
10100 = Reserved
10011 = IC4 input capture interrupt event synchronizes or triggers OCx
10010 = IC3 input capture interrupt event synchronizes or triggers OCx
10001 = IC2 input capture interrupt event synchronizes or triggers OCx
10000 = IC1 input capture interrupt event synchronizes or triggers OCx
01111 = Timer5 synchronizes or triggers OCx
01110 = Timer4 synchronizes or triggers OCx
01101 = Timer3 synchronizes or triggers OCx
01100 = Timer2 synchronizes or triggers OCx **(default)**
01011 = Timer1 synchronizes or triggers OCx
01010 = PTG Trigger Output x(3)
01001 = Reserved
01000 = IC4 input capture event synchronizes or triggers OCx
00111 = IC3 input capture event synchronizes or triggers OCx
00110 = IC2 input capture event synchronizes or triggers OCx
00101 = IC1 input capture event synchronizes or triggers OCx
00100 = OC4 module synchronizes or triggers OCx(1,2)
00011 = OC3 module synchronizes or triggers OCx(1,2)
00010 = OC2 module synchronizes or triggers OCx(1,2)
00001 = OC1 module synchronizes or triggers OCx(1,2)
00000 = No sync or trigger source for OCx

**Note 1:** Do not use the OCx module as its own synchronization or trigger source.

**2:** When the OCy module is turned off, it sends a trigger out signal. If the OCx module uses the OCy module as a trigger source, the OCy module must be unselected as a trigger source prior to disabling it.

**3:** For each OCMPx instance, a different PTG trigger out is used:
OCMP1 – PTG trigger out [0]
OCMP2 – PTG trigger out [1]
OCMP3 – PTG trigger out [2]
OCMP4 – PTG trigger out [3]

**NOTES:**


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## 16.0 HIGH-SPEED PWM

**Note:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"High-Speed PWM Module"** (DS70000323) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

The high-speed PWM on dsPIC33EPXXXGS70X/80X devices supports a wide variety of PWM modes and output formats. This PWM module is ideal for power conversion applications, such as:

- AC/DC Converters
- DC/DC Converters
- Power Factor Correction
- Uninterruptible Power Supply (UPS)
- Inverters
- Battery Chargers
- Digital Lighting

### 16.1 Features Overview

The high-speed PWM module incorporates the following features:

- Eight PWMx Generators with Two Outputs per Generator
- Two Master Time Base modules
- Individual Time Base and Duty Cycle for each PWM Output
- Duty Cycle, Dead Time, Phase Shift and a Frequency Resolution of 1.04 ns
- Independent Fault and Current-Limit Inputs
- Redundant Output
- True Independent Output
- Center-Aligned PWM mode
- Output override control
- Chop mode (also known as Gated mode)
- Special Event Trigger
- Dual Trigger from PWMx to Analog-to-Digital Converter (ADC)
- PWMxL and PWMxH Output Pin Swapping
- Independent PWMx Frequency, Duty Cycle and Phase-Shift Changes
- Enhanced Leading-Edge Blanking (LEB) Functionality
- PWM Capture Functionality

**Note:** Duty cycle, dead time, phase shift and frequency resolution is 8.32 ns in Center-Aligned PWM mode.

Figure 16-1 conceptualizes the PWM module in a simplified block diagram. Figure 16-2 illustrates how the module hardware is partitioned for each PWMx output pair for the Complementary PWM mode.

The PWM module contains eight PWM generators. The module has up to 16 PWMx output pins: PWM1H/PWM1L through PWM8H/PWM8L. For complementary outputs, these 16 I/O pins are grouped into high/low pairs. PWM1 through PWM6 can be used to trigger an ADC conversion.

### 16.2 Feature Description

The PWM module is designed for applications that require:

- High resolution at high PWM frequencies
- The ability to drive Standard, Edge-Aligned, Center-Aligned Complementary mode and Push-Pull mode outputs
- The ability to create multiphase PWM outputs

Two common, medium power converter topologies are push-pull and half-bridge. These designs require the PWM output signal to be switched between alternate pins, as provided by the Push-Pull PWM mode.

Phase-shifted PWM describes the situation where each PWM generator provides outputs, but the phase relationship between the generator outputs is specifiable and changeable.

Multiphase PWM is often used to improve DC/DC Converter load transient response, and reduce the size of output filter capacitors and inductors. Multiple DC/DC Converters are often operated in parallel, but phase shifted in time. A single PWM output, operating at 250 kHz, has a period of 4 μs but an array of four PWM channels, staggered by 1 μs each, yields an effective switching frequency of 1 MHz. Multiphase PWM applications typically use a fixed-phase relationship.

Variable phase PWM is useful in Zero Voltage Transition (ZVT) power converters. Here, the PWM duty cycle is always 50% and the power flow is controlled by varying the relative phase shift between the two PWM generators.

### 16.2.1 WRITE-PROTECTED REGISTERS

On dsPIC33EPXXXGS70X/80X family devices, write protection is implemented for the IOCONx and FCLCONx registers. The write protection feature prevents any inadvertent writes to these registers. This protection feature can be controlled by the PWMLOCK Configuration bit (FDEVOPT<0>). The default state of the write protection feature is enabled (PWMLOCK = 1). The write protection feature can be disabled by configuring PWMLOCK = 0.

To gain write access to these locked registers, the user application must write two consecutive values (0xABCD and 0x4321) to the PWMKEY register to perform the unlock operation. The write access to the IOCONx or FCLCONx registers must be the next SFR access following the unlock process. There can be no other SFR accesses during the unlock process and subsequent write access. To write to both the IOCONx and FCLCONx registers requires two unlock operations.

The correct unlocking sequence is described in Example 16-1.

**EXAMPLE 16-1: PWM WRITE-PROTECTED REGISTER UNLOCK SEQUENCE**

```
; Writing to FCLCON1 register requires unlock sequence

mov #0xabcd, w10       ; Load first unlock key to w10 register
mov #0x4321, w11       ; Load second unlock key to w11 register
mov #0x0000, w0        ; Load desired value of FCLCON1 register in w0
mov w10, PWMKEY        ; Write first unlock key to PWMKEY register
mov w11, PWMKEY        ; Write second unlock key to PWMKEY register
mov w0, FCLCON1        ; Write desired value to FCLCON1 register

; Set PWM ownership and polarity using the IOCON1 register
; Writing to IOCON1 register requires unlock sequence

mov #0xabcd, w10       ; Load first unlock key to w10 register
mov #0x4321, w11       ; Load second unlock key to w11 register
mov #0xF000, w0        ; Load desired value of IOCON1 register in w0
mov w10, PWMKEY        ; Write first unlock key to PWMKEY register
mov w11, PWMKEY        ; Write second unlock key to PWMKEY register
mov w0, IOCON1         ; Write desired value to IOCON1 register
```

## 16.3 PWM 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 contains the latest updates and additional information.

### 16.3.1 KEY RESOURCES

- **"High-Speed PWM Module"** (DS70000323) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools


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**FIGURE 16-1: HIGH-SPEED PWM MODULE ARCHITECTURAL DIAGRAM**

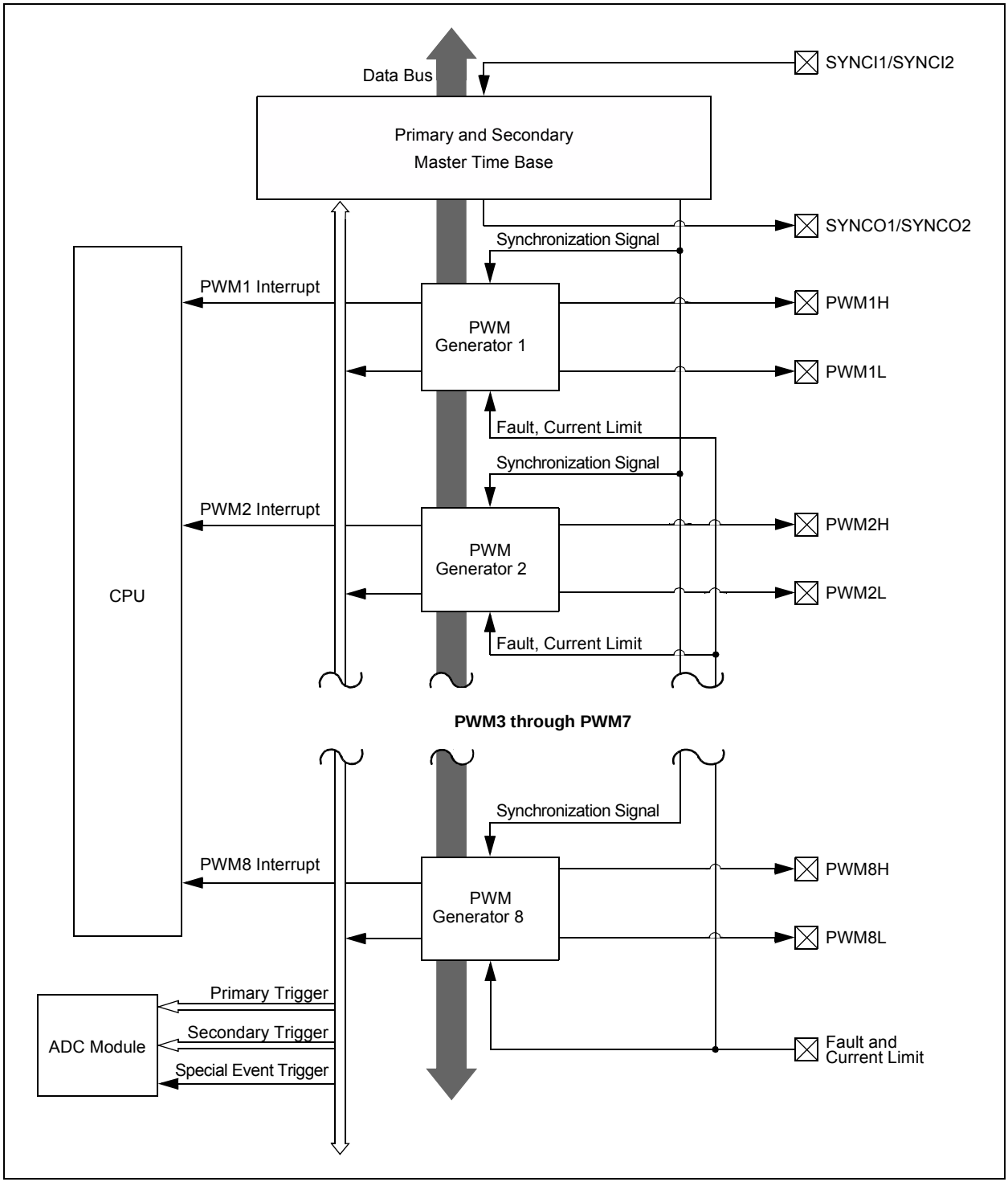
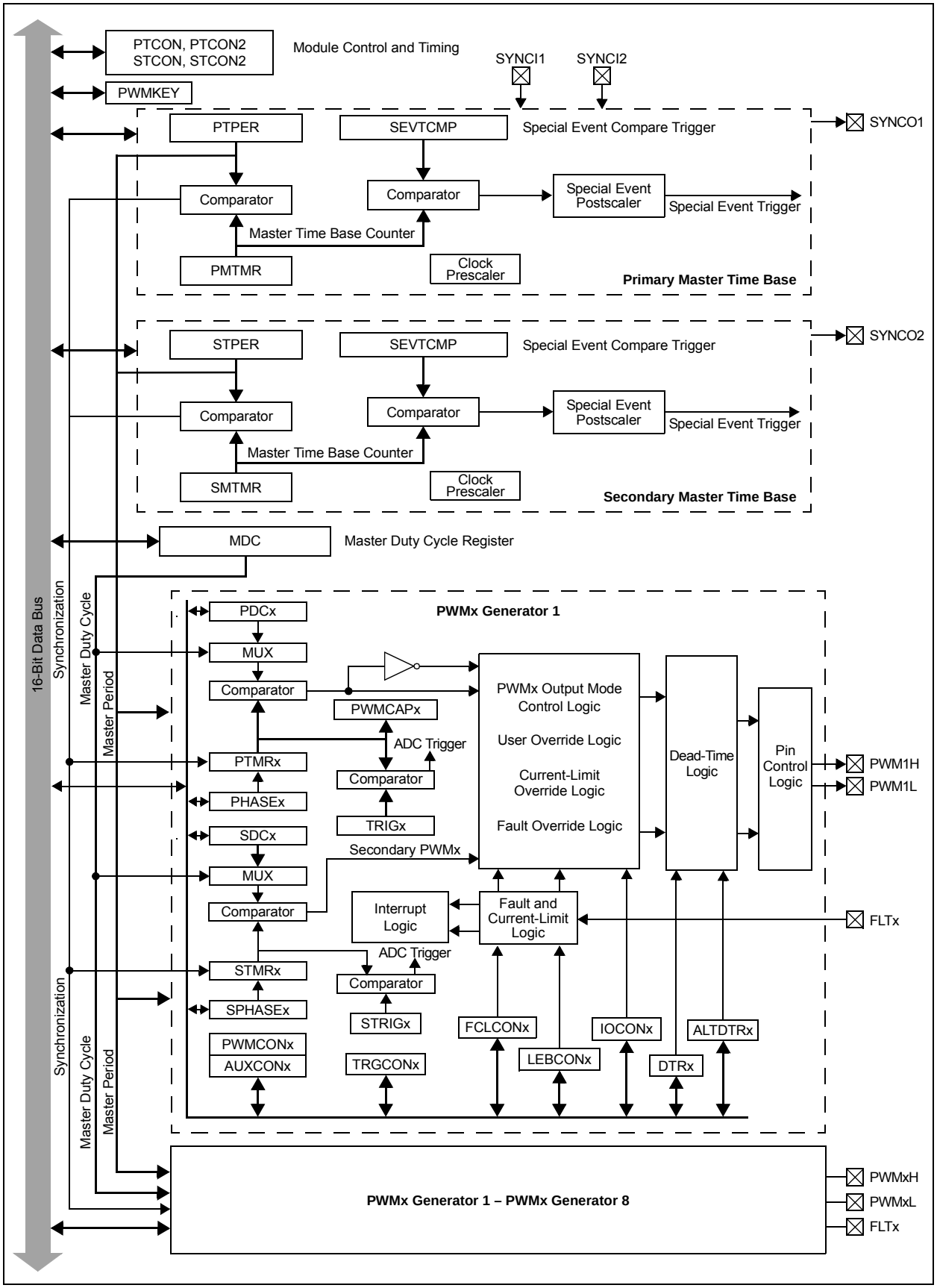


**FIGURE 16-2: SIMPLIFIED CONCEPTUAL BLOCK DIAGRAM OF THE HIGH-SPEED PWM**





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**REGISTER 16-1: PTCON: PWMx TIME BASE CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | R-0, HSC | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTEN | — | PTSIDL | SESTAT | SEIEN | EIPU(1) | SYNCPOL(1) | SYNCOEN(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 |
|---|---|---|---|---|---|---|---|
| SYNCEN(1) | SYNCSRC2(1) | SYNCSRC1(1) | SYNCSRC0(1) | SEVTPS3(1) | SEVTPS2(1) | SEVTPS1(1) | SEVTPS0(1) |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HSC = Hardware Settable/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 **PTEN:** PWMx Module Enable bit
1 = PWMx module is enabled
0 = PWMx module is disabled

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

bit 13 **PTSIDL:** PWMx Time Base Stop in Idle Mode bit
1 = PWMx time base halts in CPU Idle mode
0 = PWMx time base runs in CPU Idle mode

bit 12 **SESTAT:** Special Event Interrupt Status bit
1 = Special event interrupt is pending
0 = Special event interrupt is not pending

bit 11 **SEIEN:** Special Event Interrupt Enable bit
1 = Special event interrupt is enabled
0 = Special event interrupt is disabled

bit 10 **EIPU:** Enable Immediate Period Updates bit(1)
1 = Active Period register is updated immediately
0 = Active Period register updates occur on PWMx cycle boundaries

bit 9 **SYNCPOL:** Synchronize Input and Output Polarity bit(1)
1 = SYNCIx/SYNCO1 polarity is inverted (active-low)
0 = SYNCIx/SYNCO1 is active-high

bit 8 **SYNCOEN:** Primary Time Base Synchronization Enable bit(1)
1 = SYNCO1 output is enabled
0 = SYNCO1 output is disabled

bit 7 **SYNCEN:** External Time Base Synchronization Enable bit(1)
1 = External synchronization of primary time base is enabled
0 = External synchronization of primary time base is disabled

bit 6-4 **SYNCSRC<2:0>:** Synchronous Source Selection bits(1)
111 = Reserved
101 = Reserved
100 = Reserved
011 = PTG Trigger Output 17
010 = PTG Trigger Output 16
001 = SYNCI2
000 = SYNCI1

**Note 1:** These bits should be changed only when PTEN = 0. In addition, when using the SYNCIx feature, the user application must program the Period register with a value that is slightly larger than the expected period of the external synchronization input signal.

**REGISTER 16-1: PTCON: PWMx TIME BASE CONTROL REGISTER (CONTINUED)**

bit 3-0 **SEVTPS<3:0>:** PWMx Special Event Trigger Output Postscaler Select bits(1)
1111 = 1:16 postscaler generates a Special Event Trigger on every sixteenth compare match event
•
•
•
0001 = 1:2 postscaler generates a Special Event Trigger on every second compare match event
0000 = 1:1 postscaler generates a Special Event Trigger on every compare match event

**Note 1:** These bits should be changed only when PTEN = 0. In addition, when using the SYNCIx feature, the user application must program the Period register with a value that is slightly larger than the expected period of the external synchronization input signal.

**REGISTER 16-2: PTCON2: PWMx CLOCK DIVIDER SELECT REGISTER**

| 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 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | PCLKDIV<2:0>(1) | | |
| 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 15-3 **Unimplemented:** Read as ‘0’

bit 2-0 **PCLKDIV<2:0>:** PWMx Input Clock Prescaler (Divider) Select bits(1)
111 = Reserved
110 = Divide-by-64, maximum PWM timing resolution
101 = Divide-by-32, maximum PWM timing resolution
100 = Divide-by-16, maximum PWM timing resolution
011 = Divide-by-8, maximum PWM timing resolution
010 = Divide-by-4, maximum PWM timing resolution
001 = Divide-by-2, maximum PWM timing resolution
000 = Divide-by-1, maximum PWM timing resolution (power-on default)

**Note 1:** These bits should be changed only when PTEN = 0. Changing the clock selection during operation will yield unpredictable results.


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**REGISTER 16-3: PTPER: PWMx PRIMARY MASTER TIME BASE PERIOD REGISTER(1,2)**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| PTPER<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| PTPER<7:0> | | | | | | | |
| 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 15-0 **PTPER<15:0>:** Primary Master Time Base (PMTMR) Period Value bits

**Note 1:** The PWMx time base has a minimum value of 0x0010 and a maximum value of 0xFFF8.

**2:** Any period value that is less than 0x0028 must have the Least Significant 3 bits set to '0', thus yielding a period resolution at 8.32 ns (at fastest auxiliary clock rate).

**REGISTER 16-4: SEVTCMP: PWMx SPECIAL EVENT COMPARE REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SEVTCMP<12:5> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SEVTCMP<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 15-3 **SEVTCMP<12:0>:** Special Event Compare Count Value bits

bit 2-0 **Unimplemented:** Read as '0'

**Note 1:** One LSB = 1.04 ns (at fastest auxiliary clock rate); therefore, the minimum SEVTCMP resolution is 8.32 ns.

**REGISTER 16-5: STCON: PWMx SECONDARY MASTER TIME BASE CONTROL REGISTER**

| U-0 | U-0 | U-0 | R-0, HSC | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | SESTAT | SEIEN | EIPU(1) | SYNCPOL | SYNCOEN |
| 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 |
|---|---|---|---|---|---|---|---|
| SYNCEN | SYNCSRC2 | SYNCSRC1 | SYNCSRC0 | SEVTPS3 | SEVTPS2 | SEVTPS1 | SEVTPS0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HSC = Hardware Settable/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 15-13 **Unimplemented:** Read as '0'

bit 12 **SESTAT:** Special Event Interrupt Status bit
1 = Secondary special event interrupt is pending
0 = Secondary special event interrupt is not pending

bit 11 **SEIEN:** Special Event Interrupt Enable bit
1 = Secondary special event interrupt is enabled
0 = Secondary special event interrupt is disabled

bit 10 **EIPU:** Enable Immediate Period Updates bit(1)
1 = Active Secondary Period register is updated immediately
0 = Active Secondary Period register updates occur on PWMx cycle boundaries

bit 9 **SYNCPOL:** Synchronize Input and Output Polarity bit
1 = SYNCIx/SYNCO2 polarity is inverted (active-low)
0 = SYNCIx/SYNCO2 polarity is active-high

bit 8 **SYNCOEN:** Secondary Master Time Base Synchronization Enable bit
1 = SYNCO2 output is enabled
0 = SYNCO2 output is disabled

bit 7 **SYNCEN:** External Secondary Master Time Base Synchronization Enable bit
1 = External synchronization of secondary time base is enabled
0 = External synchronization of secondary time base is disabled

bit 6-4 **SYNCSRC<2:0>:** Secondary Time Base Sync Source Selection bits
111 = Reserved
101 = Reserved
100 = Reserved
011 = PTG Trigger Output 17
010 = PTG Trigger Output 16
001 = SYNCI2
000 = SYNCI1

bit 3-0 **SEVTPS<3:0>:** PWMx Secondary Special Event Trigger Output Postscaler Select bits
1111 = 1:16 postcaler
0001 = 1:2 postcaler
•
•
•
0000 = 1:1 postscaler

**Note 1:** This bit only applies to the secondary master time base period.


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**REGISTER 16-6: STCON2: PWMx SECONDARY CLOCK DIVIDER SELECT REGISTER**

| 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 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | PCLKDIV<2:0>(1) | | |
| 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 15-3 **Unimplemented:** Read as '0'

bit 2-0 **PCLKDIV<2:0>:** PWMx Input Clock Prescaler (Divider) Select bits(1)

111 = Reserved
110 = Divide-by-64, maximum PWM timing resolution
101 = Divide-by-32, maximum PWM timing resolution
100 = Divide-by-16, maximum PWM timing resolution
011 = Divide-by-8, maximum PWM timing resolution
010 = Divide-by-4, maximum PWM timing resolution
001 = Divide-by-2, maximum PWM timing resolution
000 = Divide-by-1, maximum PWM timing resolution (power-on default)

**Note 1:** These bits should be changed only when PTEN = 0. Changing the clock selection during operation will yield unpredictable results.

**REGISTER 16-7: STPER: PWMx SECONDARY MASTER TIME BASE PERIOD REGISTER(1,2)**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| STPER<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| STPER<7:0> | | | | | | | |
| 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 15-0 **STPER<15:0>:** Secondary Master Time Base (SMTMR) Period Value bits

**Note 1:** The PWMx time base has a minimum value of 0x0010 and a maximum value of 0xFFF8.

**2:** Any period value that is less than 0x0028 must have the Least Significant 3 bits set to '0', thus yielding a period resolution at 8.32 ns (at fastest auxiliary clock rate).

**REGISTER 16-8: SSEVTCMP: PWMx SECONDARY SPECIAL EVENT COMPARE REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SSEVTCMP<12:5> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SSEVTCMP<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 15-3 **SSEVTCMP<12:0>:** Special Event Compare Count Value bits

bit 2-0 **Unimplemented:** Read as '0'

**Note 1:** One LSB = 1.04 ns (at fastest auxiliary clock rate); therefore, the minimum SSEVTCMP resolution is 8.32 ns.

**REGISTER 16-9: CHOP: PWMx CHOP CLOCK GENERATOR REGISTER(1)**

| R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CHPCLKEN | — | — | — | — | — | CHOPCLK6 | CHOPCLK5 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| CHOPCLK4 | CHOPCLK3 | CHOPCLK2 | CHOPCLK1 | CHOPCLK0 | — | — | — |
| 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 **CHPCLKEN:** Enable Chop Clock Generator bit
1 = Chop clock generator is enabled
0 = Chop clock generator is disabled

bit 14-10 **Unimplemented:** Read as '0'

bit 9-3 **CHOPCLK<6:0>:** Chop Clock Divider bits
Value is in 8.32 ns increments. The frequency of the chop clock signal is given by:
Chop Frequency = 1/(16.64 * (CHOP<7:3> + 1) * Primary Master PWM Input Clock Period)

bit 2-0 **Unimplemented:** Read as '0'

**Note 1:** The chop clock generator operates with the primary PWMx clock prescaler (PCLKDIV<2:0>) in the PTCON2 register (Register 16-2).


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**REGISTER 16-10: MDC: PWMx MASTER DUTY CYCLE REGISTER(1,2)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| MDC<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| MDC<7:0> | | | | | | | |
| 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 15-0 **MDC<15:0>:** PWMx Master Duty Cycle Value bits

**Note 1:** The smallest pulse width that can be generated on the PWMx output corresponds to a value of 0x0008, while the maximum pulse width generated corresponds to a value of Period – 0x0008.

**2:** As the duty cycle gets closer to 0% or 100% of the PWMx period (0 to 40 ns, depending on the mode of operation), PWMx duty cycle resolution will increase from 1 to 3 LSBs.

**REGISTER 16-11: PWMKEY: PWMx PROTECTION LOCK/UNLOCK KEY REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PWMKEY<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PWMKEY<7:0> | | | | | | | |
| 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 15-0 **PWMKEY<15:0>:** PWMx Protection Lock/Unlock Key Value bits

**REGISTER 16-12: PWMCONx: PWMx CONTROL REGISTER (x = 1 to 8)**

| R-0, HSC | R-0, HSC | R-0, HSC | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLTSTAT(1) | CLSTAT(1) | TRGSTAT | FLTIEN | CLIEN | TRGIEN | ITB(3) | MDCS(3) |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| DTC1 | DTC0 | — | — | MTBS | CAM(2,3,4) | XPRES(5) | IUE |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HSC = Hardware Settable/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 **FLTSTAT:** Fault Interrupt Status bit(1)
1 = Fault interrupt is pending
0 = No Fault interrupt is pending
This bit is cleared by setting FLTIEN = 0.

bit 14 **CLSTAT:** Current-Limit Interrupt Status bit(1)
1 = Current-limit interrupt is pending
0 = No current-limit interrupt is pending
This bit is cleared by setting CLIEN = 0.

bit 13 **TRGSTAT:** Trigger Interrupt Status bit
1 = Trigger interrupt is pending
0 = No trigger interrupt is pending
This bit is cleared by setting TRGIEN = 0.

bit 12 **FLTIEN:** Fault Interrupt Enable bit
1 = Fault interrupt is enabled
0 = Fault interrupt is disabled and the FLTSTAT bit is cleared

bit 11 **CLIEN:** Current-Limit Interrupt Enable bit
1 = Current-limit interrupt is enabled
0 = Current-limit interrupt is disabled and the CLSTAT bit is cleared

bit 10 **TRGIEN:** Trigger Interrupt Enable bit
1 = A trigger event generates an interrupt request
0 = Trigger event interrupts are disabled and the TRGSTAT bit is cleared

bit 9 **ITB:** Independent Time Base Mode bit(3)
1 = PHASEx/SPHASEx registers provide the time base period for this PWMx generator
0 = PTPER register provides timing for this PWMx generator

bit 8 **MDCS:** Master Duty Cycle Register Select bit(3)
1 = MDC register provides duty cycle information for this PWMx generator
0 = PDCx and SDCx registers provide duty cycle information for this PWMx generator

**Note 1:** Software must clear the interrupt status here and in the corresponding IFSx bit in the interrupt controller.
**2:** The Independent Time Base mode (ITB = 1) must be enabled to use Center-Aligned mode. If ITB = 0, the CAM bit is ignored.
**3:** These bits should not be changed after the PWMx is enabled by setting PTEN (PTCON<15>) = 1.
**4:** Center-Aligned mode ignores the Least Significant 3 bits of the Duty Cycle, Phase and Dead-Time registers. The highest Center-Aligned mode resolution available is 8.32 ns with the clock prescaler set to the fastest clock.
**5:** Configure CLMOD (FCLCONx<8>) = 0 and ITB (PWMCONx<9>) = 1 to operate in External Period Reset mode.


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**REGISTER 16-12: PWMCONx: PWMx CONTROL REGISTER (x = 1 to 8) (CONTINUED)**

bit 7-6 **DTC<1:0>:** Dead-Time Control bits
11 = Reserved
10 = Dead-time function is disabled
01 = Negative dead time is actively applied for Complementary Output mode
00 = Positive dead time is actively applied for all Output modes

bit 5-4 **Unimplemented:** Read as '0'

bit 3 **MTBS:** Master Time Base Select bit
1 = PWMx generator uses the secondary master time base for synchronization and the clock source for the PWMx generation logic (if secondary time base is available)
0 = PWMx generator uses the primary master time base for synchronization and the clock source for the PWMx generation logic

bit 2 **CAM:** Center-Aligned Mode Enable bit(2,3,4)
1 = Center-Aligned mode is enabled
0 = Edge-Aligned mode is enabled

bit 1 **XPRES:** External PWMx Reset Control bit(5)
1 = Current-limit source resets the time base for this PWMx generator if it is in Independent Time Base mode
0 = External pins do not affect the PWMx time base

bit 0 **IUE:** Immediate Update Enable bit
1 = Updates to the active Duty Cycle, Phase Offset, Dead-Time and local Time Base Period registers are immediate
0 = Updates to the active Duty Cycle, Phase Offset, Dead-Time and local Time Base Period registers are synchronized to the local PWMx time base

**Note 1:** Software must clear the interrupt status here and in the corresponding IFSx bit in the interrupt controller.
**2:** The Independent Time Base mode (ITB = 1) must be enabled to use Center-Aligned mode. If ITB = 0, the CAM bit is ignored.
**3:** These bits should not be changed after the PWMx is enabled by setting PTEN (PTCON<15>) = 1.
**4:** Center-Aligned mode ignores the Least Significant 3 bits of the Duty Cycle, Phase and Dead-Time registers. The highest Center-Aligned mode resolution available is 8.32 ns with the clock prescaler set to the fastest clock.
**5:** Configure CLMOD (FCLCONx<8>) = 0 and ITB (PWMCONx<9>) = 1 to operate in External Period Reset mode.

**REGISTER 16-13: PDCx: PWMx GENERATOR DUTY CYCLE REGISTER (x = 1 to 8)(1,2,3)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PDCx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PDCx<7:0> | | | | | | | |
| 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 15-0 **PDCx<15:0>:** PWMx Generator Duty Cycle Value bits

**Note 1:** In Independent PWM mode, the PDCx register controls the PWMxH duty cycle only. In the Complementary, Redundant and Push-Pull PWM modes, the PDCx register controls the duty cycle of both the PWMxH and PWMxL.

**2:** The smallest pulse width that can be generated on the PWMx output corresponds to a value of 0x0008, while the maximum pulse width generated corresponds to a value of Period – 0x0008.

**3:** As the duty cycle gets closer to 0% or 100% of the PWMx period (0 to 40 ns, depending on the mode of operation), PWMx duty cycle resolution will increase from 1 to 3 LSBs.

**REGISTER 16-14: SDCx: PWMx SECONDARY DUTY CYCLE REGISTER (x = 1 to 8)(1,2,3)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SDCx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| SDCx<7:0> | | | | | | | |
| 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 15-0 **SDCx<15:0>:** PWMx Secondary Duty Cycle for PWMxL Output Pin bits

**Note 1:** The SDCx register is used in Independent PWM mode only. When used in Independent PWM mode, the SDCx register controls the PWMxL duty cycle.

**2:** The smallest pulse width that can be generated on the PWMx output corresponds to a value of 0x0008, while the maximum pulse width generated corresponds to a value of Period – 0x0008.

**3:** As the duty cycle gets closer to 0% or 100% of the PWMx period (0 to 40 ns, depending on the mode of operation), PWMx duty cycle resolution will increase from 1 to 3 LSBs.


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**REGISTER 16-15: PHASEx: PWMx PRIMARY PHASE-SHIFT REGISTER (x = 1 to 8)(1,2)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PHASEx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PHASEx<7:0> | | | | | | | |
| 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 15-0 **PHASEx<15:0>:** PWMx Phase-Shift Value or Independent Time Base Period for the PWMx Generator bits

**Note 1:** If PWMCONx<9> = 0, the following applies based on the mode of operation:

- Complementary, Redundant and Push-Pull Output mode (IOCONx<11:10> = 00, 01 or 10); PHASEx<15:0> = Phase-shift value for PWMxH and PWMxL outputs
- True Independent Output mode (IOCONx<11:10> = 11); PHASEx<15:0> = Phase-shift value for PWMxH only
- When the PHASEx/SPHASEx registers provide the phase shift with respect to the master time base; therefore, the valid range is 0x0000 through period

**2:** If PWMCONx<9> = 1, the following applies based on the mode of operation:

- Complementary, Redundant and Push-Pull Output mode (IOCONx<11:10> = 00, 01 or 10); PHASEx<15:0> = Independent time base period value for PWMxH and PWMxL
- True Independent Output mode (IOCONx<11:10> = 11); PHASEx<15:0> = Independent time base period value for PWMxH only
- When the PHASEx/SPHASEx registers provide the local period, the valid range is 0x0000-0xFFF8

**REGISTER 16-16: SPHASEx: PWMx SECONDARY PHASE-SHIFT REGISTER (x = 1 to 8)(1,2)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SPHASEx<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| SPHASEx<7:0> | | | | | | | |
| 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 15-0 **SPHASEx<15:0>:** Secondary Phase Offset for PWMxL Output Pin bits (used in Independent PWM mode only)

**Note 1:** If PWMCONx<9> = 0, the following applies based on the mode of operation:
- Complementary, Redundant and Push-Pull Output mode (IOCONx<11:10> = 00, 01 or 10); SPHASEx<15:0> = Not used
- True Independent Output mode (IOCONx<11:10> = 11), PHASEx<15:0> = Phase-shift value for PWMxL only

**2:** If PWMCONx<9> = 1, the following applies based on the mode of operation:
- Complementary, Redundant and Push-Pull Output mode (IOCONx<11:10> = 00, 01 or 10); SPHASEx<15:0> = Not used
- True Independent Output mode (IOCONx<11:10> = 11); PHASEx<15:0> = Independent time base period value for PWMxL only
- When the PHASEx/SPHASEx registers provide the local period, the valid range of values is 0x0010-0xFFF8


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**REGISTER 16-17: DTRx: PWMx DEAD-TIME REGISTER (x = 1 to 8)**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | DTRx<13:8> | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| DTRx<7:0> | | | | | | | |
| 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 13-0 **DTRx<13:0>:** Unsigned 14-Bit Dead-Time Value for PWMx Dead-Time Unit bits

**REGISTER 16-18: ALTDTRx: PWMx ALTERNATE DEAD-TIME REGISTER (x = 1 to 8)**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | ALTDTRx<13:8> | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| ALTDTRx<7:0> | | | | | | | |
| 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 13-0 **ALTDTRx<13:0>:** Unsigned 14-Bit Alternate Dead-Time Value for PWMx Dead-Time Unit bits

**REGISTER 16-19: TRGCONx: PWMx TRIGGER CONTROL REGISTER (x = 1 to 8)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| TRGDIV3 | TRGDIV2 | TRGDIV1 | TRGDIV0 | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| DTM(1) | — | TRGSTRT5 | TRGSTRT4 | TRGSTRT3 | TRGSTRT2 | TRGSTRT1 | TRGSTRT0 |
| 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 15-12 **TRGDIV<3:0>:** Trigger # Output Divider bits

1111 = Trigger output for every 16th trigger event
1110 = Trigger output for every 15th trigger event
1101 = Trigger output for every 14th trigger event
1100 = Trigger output for every 13th trigger event
1011 = Trigger output for every 12th trigger event
1010 = Trigger output for every 11th trigger event
1001 = Trigger output for every 10th trigger event
1000 = Trigger output for every 9th trigger event
0111 = Trigger output for every 8th trigger event
0110 = Trigger output for every 7th trigger event
0101 = Trigger output for every 6th trigger event
0100 = Trigger output for every 5th trigger event
0011 = Trigger output for every 4th trigger event
0010 = Trigger output for every 3rd trigger event
0001 = Trigger output for every 2nd trigger event
0000 = Trigger output for every trigger event

bit 11-8 **Unimplemented:** Read as '0'

bit 7 **DTM:** Dual Trigger Mode bit(1)

1 = Secondary trigger event is combined with the primary trigger event to create a PWM trigger
0 = Secondary trigger event is not combined with the primary trigger event to create a PWM trigger; two separate PWM triggers are generated

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

bit 5-0 **TRGSTRT<5:0>:** Trigger Postscaler Start Enable Select bits

111111 = Wait 63 PWM cycles before generating the first trigger event after the module is enabled
•
•
•
000010 = Wait 2 PWM cycles before generating the first trigger event after the module is enabled
000001 = Wait 1 PWM cycle before generating the first trigger event after the module is enabled
000000 = Wait 0 PWM cycles before generating the first trigger event after the module is enabled

**Note 1:** The secondary PWMx generator cannot generate PWM trigger interrupts.


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**REGISTER 16-20: IOCONx: PWMx I/O CONTROL REGISTER (x = 1 to 8)**

| R/W-1 | R/W-1 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PENH | PENL | POLH | POLL | PMOD1(1) | PMOD0(1) | OVRENH | OVRENL |
| 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 |
|---|---|---|---|---|---|---|---|
| OVRDAT1 | OVRDAT0 | FLTDAT1(2) | FLTDAT0(2) | CLDAT1(2) | CLDAT0(2) | SWAP | OSYNC |
| 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 **PENH:** PWMxH Output Pin Ownership bit
1 = PWMx module controls the PWMxH pin
0 = GPIO module controls the PWMxH pin

bit 14 **PENL:** PWMxL Output Pin Ownership bit
1 = PWMx module controls the PWMxL pin
0 = GPIO module controls the PWMxL pin

bit 13 **POLH:** PWMxH Output Pin Polarity bit
1 = PWMxH pin is active-low
0 = PWMxH pin is active-high

bit 12 **POLL:** PWMxL Output Pin Polarity bit
1 = PWMxL pin is active-low
0 = PWMxL pin is active-high

bit 11-10 **PMOD<1:0>:** PWMx I/O Pin Mode bits(1)
11 = PWMx I/O pin pair is in the True Independent Output mode
10 = PWMx I/O pin pair is in the Push-Pull Output mode
01 = PWMx I/O pin pair is in the Redundant Output mode
00 = PWMx I/O pin pair is in the Complementary Output mode

bit 9 **OVRENH:** Override Enable for PWMxH Pin bit
1 = OVRDAT1 provides data for output on the PWMxH pin
0 = PWMx generator provides data for the PWMxH pin

bit 8 **OVRENL:** Override Enable for PWMxL Pin bit
1 = OVRDAT0 provides data for output on the PWMxL pin
0 = PWMx generator provides data for the PWMxL pin

bit 7-6 **OVRDAT<1:0>:** Data for PWMxH, PWMxL Pins if Override is Enabled bits
If OVRENH = 1, OVRDAT1 provides data for the PWMxH pin
If OVRENL = 1, OVRDAT0 provides data for the PWMxL pin

bit 5-4 **FLTDAT<1:0>:** State for PWMxH and PWMxL Pins if FLTMOD<1:0> are Enabled bits(2)
IFLTMOD (FCLCONx<15>) = 0: Normal Fault mode:
If Fault is active, then FLTDAT1 provides the state for the PWMxH pin.
If Fault is active, then FLTDAT0 provides the state for the PWMxL pin.
IFLTMOD (FCLCONx<15>) = 1: Independent Fault mode:
If current limit is active, then FLTDAT1 provides the state for the PWMxH pin.
If Fault is active, then FLTDAT0 provides the state for the PWMxL pin.

**Note 1:** These bits should not be changed after the PWMx module is enabled (PTEN = 1).
**2:** State represents the active/inactive state of the PWMx depending on the POLH and POLL bits settings.

**REGISTER 16-20: IOCONx: PWMx I/O CONTROL REGISTER (x = 1 to 8) (CONTINUED)**

bit 3-2 **CLDAT<1:0>:** State for PWMxH and PWMxL Pins if CLMOD is Enabled bits(2)
IFLTMOD (FCLCONx<15>) = 0: Normal Fault mode:
If current limit is active, then CLDAT1 provides the state for the PWMxH pin.
If current limit is active, then CLDAT0 provides the state for the PWMxL pin.
IFLTMOD (FCLCONx<15>) = 1: Independent Fault mode:
CLDAT<1:0> bits are ignored.

bit 1 **SWAP:** SWAP PWMxH and PWMxL Pins bit
1 = PWMxH output signal is connected to the PWMxL pins; PWMxL output signal is connected to the PWMxH pins
0 = PWMxH and PWMxL pins are mapped to their respective pins

bit 0 **OSYNC:** Output Override Synchronization bit
1 = Output overrides via the OVRDAT<1:0> bits are synchronized to the PWMx time base
0 = Output overrides via the OVRDAT<1:0> bits occur on the next CPU clock boundary

**Note 1:** These bits should not be changed after the PWMx module is enabled (PTEN = 1).
**2:** State represents the active/inactive state of the PWMx depending on the POLH and POLL bits settings.

**REGISTER 16-21: TRIGx: PWMx PRIMARY TRIGGER COMPARE VALUE REGISTER (x = 1 to 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 |
|---|---|---|---|---|---|---|---|
| TRGCMP<12:5> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| TRGCMP<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 15-3 **TRGCMP<12:0>:** Trigger Compare Value bits
When the primary PWMx functions in the local time base, this register contains the compare values that can trigger the ADC module.

bit 2-0 **Unimplemented:** Read as '0'


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**REGISTER 16-22: FCLCONx: PWMx FAULT CURRENT-LIMIT CONTROL REGISTER (x = 1 to 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 |
|---|---|---|---|---|---|---|---|
| IFLTMOD | CLSRC4 | CLSRC3 | CLSRC2 | CLSRC1 | CLSRC0 | CLPOL(1) | CLMOD |
| 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 |
|---|---|---|---|---|---|---|---|
| FLTSRC4 | FLTSRC3 | FLTSRC2 | FLTSRC1 | FLTSRC0 | FLTPOL(1) | FLTMOD1 | FLTMOD0 |
| 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 **IFLTMOD:** Independent Fault Mode Enable bit
- 1 = Independent Fault mode: Current-limit input maps FLTDAT1 to the PWMxH output and the Fault input maps FLTDAT0 to the PWMxL output; the CLDAT<1:0> bits are not used for override functions
- 0 = Normal Fault mode: Current-Limit mode maps CLDAT<1:0> bits to the PWMxH and PWMxL outputs; the PWM Fault mode maps FLTDAT<1:0> to the PWMxH and PWMxL outputs

bit 14-10 **CLSRC<4:0>:** Current-Limit Control Signal Source Select for PWMx Generator bits
- 11111 = Reserved
- 10001 = Reserved
- 10000 = Analog Comparator 4
- 01111 = Analog Comparator 3
- 01110 = Analog Comparator 2
- 01101 = Analog Comparator 1
- 01100 = Fault 12
- 01011 = Fault 11
- 01010 = Fault 10
- 01001 = Fault 9
- 01000 = Fault 8
- 00111 = Fault 7
- 00110 = Fault 6
- 00101 = Fault 5
- 00100 = Fault 4
- 00011 = Fault 3
- 00010 = Fault 2
- 00001 = Fault 1
- 00000 = Reserved

bit 9 **CLPOL:** Current-Limit Polarity for PWMx Generator bit(1)
- 1 = The selected current-limit source is active-low
- 0 = The selected current-limit source is active-high

bit 8 **CLMOD:** Current-Limit Mode Enable for PWMx Generator bit
- 1 = Current-Limit mode is enabled
- 0 = Current-Limit mode is disabled

**Note 1:** These bits should be changed only when PTEN = 0 (PTCON<15>).

**REGISTER 16-22: FCLCONx: PWMx FAULT CURRENT-LIMIT CONTROL REGISTER (x = 1 to 8) (CONTINUED)**

bit 7-3 **FLTSRC<4:0>:** Fault Control Signal Source Select for PWMx Generator bits
11111 = Reserved
10001 = Reserved
10000 = Analog Comparator 4
01111 = Analog Comparator 3
01110 = Analog Comparator 2
01101 = Analog Comparator 1
01100 = Fault 12
01011 = Fault 11
01010 = Fault 10
01001 = Fault 9
01000 = Fault 8
00111 = Fault 7
00110 = Fault 6
00101 = Fault 5
00100 = Fault 4
00011 = Fault 3
00010 = Fault 2
00001 = Fault 1
00000 = Reserved

bit 2 **FLTPOL:** Fault Polarity for PWMx Generator bit(1)
1 = The selected Fault source is active-low
0 = The selected Fault source is active-high

bit 1-0 **FLTMOD<1:0>:** Fault Mode for PWMx Generator bits
11 = Fault input is disabled
10 = Reserved
01 = The selected Fault source forces the PWMxH, PWMxL pins to FLTDATx values (cycle)
00 = The selected Fault source forces the PWMxH, PWMxL pins to FLTDATx values (latched condition)

**Note 1:** These bits should be changed only when PTEN = 0 (PTCON<15>).

**REGISTER 16-23: STRIGx: PWMx SECONDARY TRIGGER COMPARE VALUE REGISTER (x = 1 to 8)(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| STRGCMP<12:5> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| STRGCMP<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 15-3 **STRGCMP<12:0>:** Secondary Trigger Compare Value bits
When the secondary PWMx functions in the local time base, this register contains the compare values that can trigger the ADC module.

bit 2-0 **Unimplemented:** Read as ‘0’

**Note 1:** STRIGx cannot generate the PWM trigger interrupts.


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**REGISTER 16-24: LEBCONx: PWMx LEADING-EDGE BLANKING (LEB) CONTROL REGISTER (x = 1 to 8)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| PHR | PHF | PLR | PLF | FLTLEBEN | CLLEBEN | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | BCH(1) | BCL(1) | BPHH | BPHL | BPLH | BPLL |
| 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 **PHR:** PWMxH Rising Edge Trigger Enable bit
1 = Rising edge of PWMxH will trigger the Leading-Edge Blanking counter
0 = Leading-Edge Blanking ignores the rising edge of PWMxH

bit 14 **PHF:** PWMxH Falling Edge Trigger Enable bit
1 = Falling edge of PWMxH will trigger the Leading-Edge Blanking counter
0 = Leading-Edge Blanking ignores the falling edge of PWMxH

bit 13 **PLR:** PWMxL Rising Edge Trigger Enable bit
1 = Rising edge of PWMxL will trigger the Leading-Edge Blanking counter
0 = Leading-Edge Blanking ignores the rising edge of PWMxL

bit 12 **PLF:** PWMxL Falling Edge Trigger Enable bit
1 = Falling edge of PWMxL will trigger the Leading-Edge Blanking counter
0 = Leading-Edge Blanking ignores the falling edge of PWMxL

bit 11 **FLTLEBEN:** Fault Input Leading-Edge Blanking Enable bit
1 = Leading-Edge Blanking is applied to the selected Fault input
0 = Leading-Edge Blanking is not applied to the selected Fault input

bit 10 **CLLEBEN:** Current-Limit Leading-Edge Blanking Enable bit
1 = Leading-Edge Blanking is applied to the selected current-limit input
0 = Leading-Edge Blanking is not applied to the selected current-limit input

bit 9-6 **Unimplemented:** Read as '0'

bit 5 **BCH:** Blanking in Selected Blanking Signal High Enable bit(1)
1 = State blanking (of current-limit and/or Fault input signals) when the selected blanking signal is high
0 = No blanking when the selected blanking signal is high

bit 4 **BCL:** Blanking in Selected Blanking Signal Low Enable bit(1)
1 = State blanking (of current-limit and/or Fault input signals) when the selected blanking signal is low
0 = No blanking when the selected blanking signal is low

bit 3 **BPHH:** Blanking in PWMxH High Enable bit
1 = State blanking (of current-limit and/or Fault input signals) when the PWMxH output is high
0 = No blanking when the PWMxH output is high

bit 2 **BPHL:** Blanking in PWMxH Low Enable bit
1 = State blanking (of current-limit and/or Fault input signals) when the PWMxH output is low
0 = No blanking when the PWMxH output is low

**Note 1:** The blanking signal is selected via the BLANKSEL<3:0> bits in the AUXCONx register.

**REGISTER 16-24: LEBCONx: PWMx LEADING-EDGE BLANKING (LEB) CONTROL REGISTER (x = 1 to 8) (CONTINUED)**

bit 1 **BPLH:** Blanking in PWMxL High Enable bit
1 = State blanking (of current-limit and/or Fault input signals) when the PWMxL output is high
0 = No blanking when the PWMxL output is high

bit 0 **BPLL:** Blanking in PWMxL Low Enable bit
1 = State blanking (of current-limit and/or Fault input signals) when the PWMxL output is low
0 = No blanking when the PWMxL output is low

**Note 1:** The blanking signal is selected via the BLANKSEL<3:0> bits in the AUXCONx register.

**REGISTER 16-25: LEBDLYx: PWMx LEADING-EDGE BLANKING DELAY REGISTER (x = 1 to 8)**

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

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| LEB<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 15-12 **Unimplemented:** Read as ‘0’

bit 11-3 **LEB<8:0>:** Leading-Edge Blanking Delay for Current-Limit and Fault Inputs bits
The value is in 8.32 ns increments.

bit 2-0 **Unimplemented:** Read as ‘0’


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**REGISTER 16-26: AUXCONx: PWMx AUXILIARY CONTROL REGISTER (x = 1 to 8)**

| R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| HRPDIS | HRDDIS | — | — | BLANKSEL3 | BLANKSEL2 | BLANKSEL1 | BLANKSEL0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | CHOPSEL3 | CHOPSEL2 | CHOPSEL1 | CHOPSEL0 | CHOPHEN | CHOPLEN |
| 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 **HRPDIS:** High-Resolution PWMx Period Disable bit
1 = High-resolution PWMx period is disabled to reduce power consumption
0 = High-resolution PWMx period is enabled

bit 14 **HRDDIS:** High-Resolution PWMx Duty Cycle Disable bit
1 = High-resolution PWMx duty cycle is disabled to reduce power consumption
0 = High-resolution PWMx duty cycle is enabled

bit 13-12 **Unimplemented:** Read as ‘0’

bit 11-8 **BLANKSEL<3:0>:** PWMx State Blank Source Select bits
The selected state blank signal will block the current-limit and/or Fault input signals (if enabled via the BCH and BCL bits in the LEBCONx register).
1001 = Reserved
1000 = PWM8H is selected as the state blank source
0111 = PWM7H is selected as the state blank source
0110 = PWM6H is selected as the state blank source
0101 = PWM5H is selected as the state blank source
0100 = PWM4H is selected as the state blank source
0011 = PWM3H is selected as the state blank source
0010 = PWM2H is selected as the state blank source
0001 = PWM1H is selected as the state blank source
0000 = No state blanking

bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-2 **CHOPSEL<3:0>:** PWMx Chop Clock Source Select bits
The selected signal will enable and disable (chop) the selected PWMx outputs.
1001 = Reserved
1000 = PWM8H is selected as the chop clock source
0111 = PWM7H is selected as the chop clock source
0110 = PWM6H is selected as the chop clock source
0101 = PWM5H is selected as the chop clock source
0100 = PWM4H is selected as the chop clock source
0011 = PWM3H is selected as the chop clock source
0010 = PWM2H is selected as the chop clock source
0001 = PWM1H is selected as the chop clock source
0000 = Chop clock generator is selected as the chop clock source

bit 1 **CHOPHEN:** PWMxH Output Chopping Enable bit
1 = PWMxH chopping function is enabled
0 = PWMxH chopping function is disabled

bit 0 **CHOPLEN:** PWMxL Output Chopping Enable bit
1 = PWMxL chopping function is enabled
0 = PWMxL chopping function is disabled

**REGISTER 16-27: PWMCAPx: PWMx PRIMARY TIME BASE CAPTURE REGISTER (x = 1 to 8)**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PWMCAP<12:5>(1,2,3,4) | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| PWMCAP<4:0>(1,2,3,4) | | | | | — | — | — |
| 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 15-3 **PWMCAP<12:0>:** PWMx Primary Time Base Capture Value bits(1,2,3,4)
The value in this register represents the captured PWMx time base value when a leading edge is detected on the current-limit input.

bit 2-0 **Unimplemented:** Read as ‘0’

**Note 1:** The capture feature is only available on a primary output (PWMxH).
**2:** This feature is active only after LEB processing on the current-limit input signal is complete.
**3:** The minimum capture resolution is 8.32 ns.
**4:** This feature can be used when the XPRES bit (PWMCONx<1>) is set to ‘0’.


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## 17.0 PERIPHERAL TRIGGER GENERATOR (PTG) MODULE

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Peripheral Trigger Generator (PTG)"** (DS70669) in the *"dsPIC33/PIC24 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.

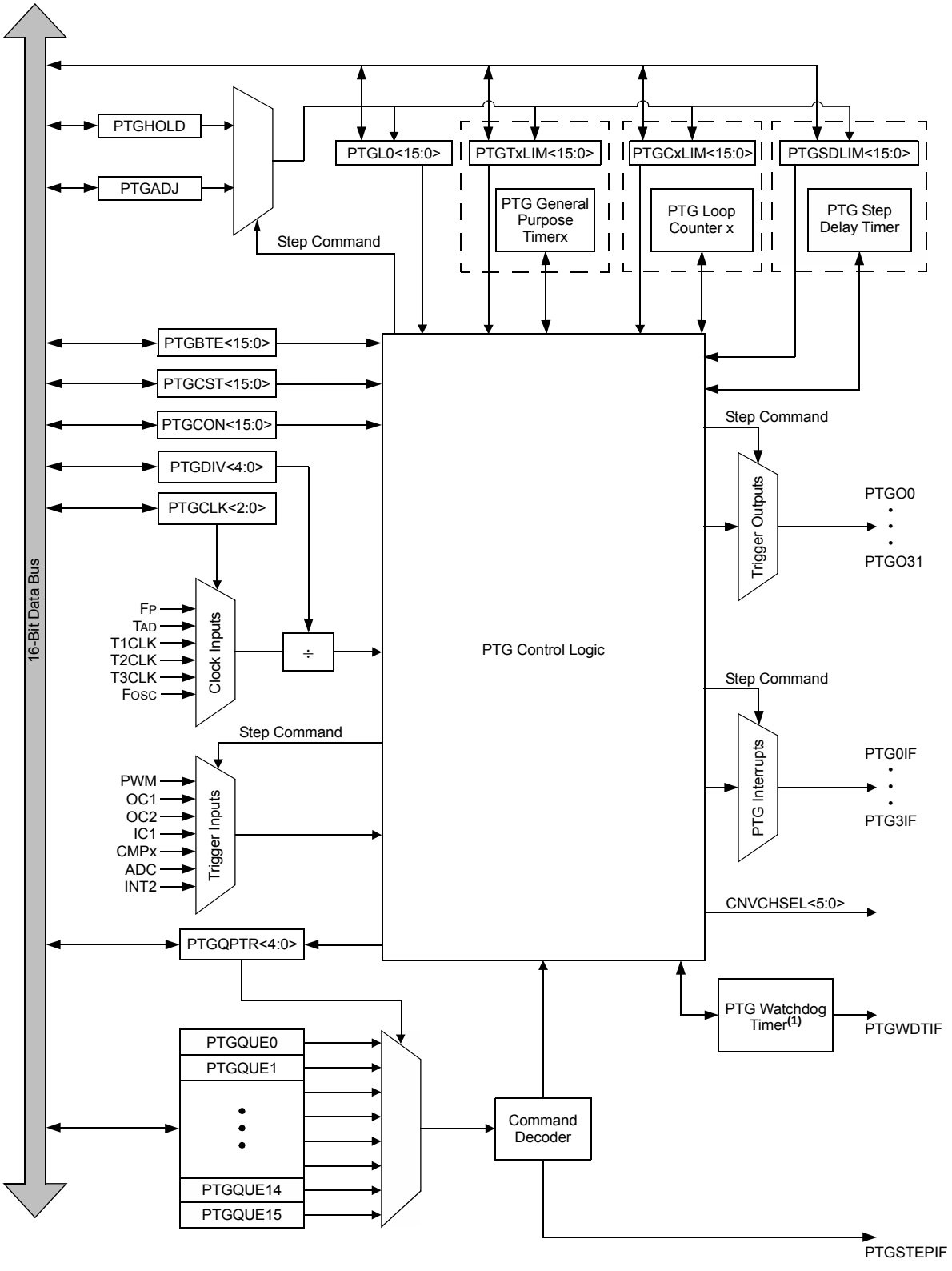
### 17.1 Module Introduction

The Peripheral Trigger Generator (PTG) provides a means to schedule complex, high-speed peripheral operations that would be difficult to achieve using software. The PTG module uses 8-bit commands, called "Steps", that the user writes to the PTG Queue register (PTGQUE0-PTQUE15) which performs operations, such as wait for input signal, generate output trigger and wait for timer.

The PTG module has the following major features:

- Multiple Clock Sources
- Two 16-Bit General Purpose Timers
- Two 16-Bit General Limit Counters
- Configurable for Rising or Falling Edge Triggering
- Generates Processor Interrupts to include:
  - Four configurable processor interrupts
  - Interrupt on a Step event in Single-Step mode
  - Interrupt on a PTG Watchdog Timer time-out
- Able to Receive Trigger Signals from these Peripherals:
  - ADC
  - PWM
  - Output Compare
  - Input Capture
  - Comparator
  - INT2
- Able to Trigger or Synchronize to these Peripherals:
  - Watchdog Timer
  - Output Compare
  - Input Capture
  - ADC
  - PWM
  - Comparator

**FIGURE 17-1: PTG BLOCK DIAGRAM**




**Note 1:** This is a dedicated Watchdog Timer for the PTG module and is independent of the device Watchdog Timer.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## 17.2 PTG Control Registers

**REGISTER 17-1: PTGCST: PTG CONTROL/STATUS REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGEN | — | PTGSIDL | PTGTOGL | — | PTGSWT(2) | PTGSSEN | PTGIVIS |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | HS-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGSTRT | PTGWDTO | — | — | — | — | PTGITM1(1) | PTGITM0(1) |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable 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 **PTGEN:** PTG Module Enable bit
1 = PTG module is enabled
0 = PTG module is disabled

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

bit 13 **PTGSIDL:** PTG Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **PTGTOGL:** PTG TRIG Output Toggle Mode bit
1 = Toggles the state of the PTGOx for each execution of the PTGTRIG command
0 = Each execution of the PTGTRIG command will generate a single PTGOx pulse determined by the value in the PTGPWDx bits

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

bit 10 **PTGSWT:** PTG Software Trigger bit(2)
1 = Triggers the PTG module
0 = No action (clearing this bit will have no effect)

bit 9 **PTGSSEN:** PTG Enable Single-Step bit
1 = Enables Single-Step mode
0 = Disables Single-Step mode

bit 8 **PTGIVIS:** PTG Counter/Timer Visibility Control bit
1 = Reads of the PTGSDLIM, PTGCxLIM or PTGTxLIM registers return the current values of their corresponding Counter/Timer registers (PTGSD, PTGCx, PTGTx)
0 = Reads of the PTGSDLIM, PTGCxLIM or PTGTxLIM registers return the value previously written to those PTG Limit registers

bit 7 **PTGSTRT:** Start PTG Sequencer bit
1 = Starts to sequentially execute commands (Continuous mode)
0 = Stops executing commands

bit 6 **PTGWDTO:** PTG Watchdog Timer Time-out Status bit
1 = PTG Watchdog Timer has timed out
0 = PTG Watchdog Timer has not timed out.

bit 5-2 **Unimplemented:** Read as '0'

**Note 1:** These bits apply to the PTGWHI and PTGWLO commands only.
**2:** This bit is only used with the PTGCTRL Step command software trigger option.

**REGISTER 17-1: PTGCST: PTG CONTROL/STATUS REGISTER (CONTINUED)**

bit 1-0 **PTGITM<1:0>:** PTG Input Trigger Command Operating Mode bits(1)

11 = Single level detect with Step delay is not executed on exit of command (regardless of PTGCTRL command)
10 = Single level detect with Step delay is executed on exit of command
01 = Continuous edge detect with Step delay is not executed on exit of command (regardless of PTGCTRL command)
00 = Continuous edge detect with Step delay is executed on exit of command

**Note 1:** These bits apply to the PTGWHI and PTGWLO commands only.

**2:** This bit is only used with the PTGCTRL Step command software trigger option.


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**REGISTER 17-2: PTGCON: PTG CONTROL REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGCLK2 | PTGCLK1 | PTGCLK0 | PTGDIV4 | PTGDIV3 | PTGDIV2 | PTGDIV1 | PTGDIV0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGPWD3 | PTGPWD2 | PTGPWD1 | PTGPWD0 | — | PTGWDT2 | PTGWDT1 | PTGWDT0 |
| 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 **PTGCLK<2:0>:** Select PTG Module Clock Source bits
111 = CLC2
110 = CLC1
101 = PTG module clock source will be T3CLK
100 = PTG module clock source will be T2CLK
011 = PTG module clock source will be T1CLK
010 = PTG module clock source will be TAD
001 = PTG module clock source will be FOSC
000 = PTG module clock source will be FP

bit 12-8 **PTGDIV<4:0>:** PTG Module Clock Prescaler (divider) bits
11111 = Divide-by-32
11110 = Divide-by-31
•
•
•
00001 = Divide-by-2
00000 = Divide-by-1

bit 7-4 **PTGPWD<3:0>:** PTG Trigger Output Pulse-Width bits
1111 = All trigger outputs are 16 PTG clock cycles wide
1110 = All trigger outputs are 15 PTG clock cycles wide
•
•
•
0001 = All trigger outputs are 2 PTG clock cycles wide
0000 = All trigger outputs are 1 PTG clock cycle wide

bit 3 **Unimplemented:** Read as ‘0’

bit 2-0 **PTGWDT<2:0>:** Select PTG Watchdog Timer Time-out Count Value bits
111 = Watchdog Timer will time-out after 512 PTG clocks
110 = Watchdog Timer will time-out after 256 PTG clocks
101 = Watchdog Timer will time-out after 128 PTG clocks
100 = Watchdog Timer will time-out after 64 PTG clocks
011 = Watchdog Timer will time-out after 32 PTG clocks
010 = Watchdog Timer will time-out after 16 PTG clocks
001 = Watchdog Timer will time-out after 8 PTG clocks
000 = Watchdog Timer is disabled

**REGISTER 17-3: PTGBTE: PTG BROADCAST TRIGGER ENABLE REGISTER(1,2)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ADCTS4 | ADCTS3 | ADCTS2 | ADCTS1 | IC4TSS | IC3TSS | IC2TSS | IC1TSS |
| 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 |
|---|---|---|---|---|---|---|---|
| OC4CS | OC3CS | OC2CS | OC1CS | OC4TSS | OC3TSS | OC2TSS | OC1TSS |
| 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 **ADCTS4:** Sample Trigger PTGO15 for ADCx bit
1 = Generates trigger when the broadcast command is executed
0 = Does not generate trigger when the broadcast command is executed

bit 14 **ADCTS3:** Sample Trigger PTGO14 for ADCx bit
1 = Generates trigger when the broadcast command is executed
0 = Does not generate trigger when the broadcast command is executed

bit 13 **ADCTS2:** Sample Trigger PTGO13 for ADCx bit
1 = Generates trigger when the broadcast command is executed
0 = Does not generate trigger when the broadcast command is executed

bit 12 **ADCTS1:** Sample Trigger PTGO12 for ADCx bit
1 = Generates trigger when the broadcast command is executed
0 = Does not generate trigger when the broadcast command is executed

bit 11 **IC4TSS:** Trigger/Synchronization Source for IC4 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 10 **IC3TSS:** Trigger/Synchronization Source for IC3 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 9 **IC2TSS:** Trigger/Synchronization Source for IC2 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 8 **IC1TSS:** Trigger/Synchronization Source for IC1 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 7 **OC4CS:** Clock Source for OC4 bit
1 = Generates clock pulse when the broadcast command is executed
0 = Does not generate clock pulse when the broadcast command is executed

bit 6 **OC3CS:** Clock Source for OC3 bit
1 = Generates clock pulse when the broadcast command is executed
0 = Does not generate clock pulse when the broadcast command is executed

bit 5 **OC2CS:** Clock Source for OC2 bit
1 = Generates clock pulse when the broadcast command is executed
0 = Does not generate clock pulse when the broadcast command is executed

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

**2:** This register is only used with the PTGCTRL OPTION = 1111 Step command.


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**REGISTER 17-3: PTGBTE: PTG BROADCAST TRIGGER ENABLE REGISTER(1,2) (CONTINUED)**

bit 4 **OC1CS:** Clock Source for OC1 bit
1 = Generates clock pulse when the broadcast command is executed
0 = Does not generate clock pulse when the broadcast command is executed

bit 3 **OC4TSS:** Trigger/Synchronization Source for OC4 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 2 **OC3TSS:** Trigger/Synchronization Source for OC3 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 1 **OC2TSS:** Trigger/Synchronization Source for OC2 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

bit 0 **OC1TSS:** Trigger/Synchronization Source for OC1 bit
1 = Generates trigger/synchronization when the broadcast command is executed
0 = Does not generate trigger/synchronization when the broadcast command is executed

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

**2:** This register is only used with the PTGCTRL OPTION = 1111 Step command.

**REGISTER 17-4: PTGT0LIM: PTG TIMER0 LIMIT REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGT0LIM<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGT0LIM<7:0> | | | | | | | |
| 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 15-0 **PTGT0LIM<15:0>:** PTG Timer0 Limit Register bits
General purpose Timer0 Limit register (effective only with a PTGT0 Step command).

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

**REGISTER 17-5: PTGT1LIM: PTG TIMER1 LIMIT REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGT1LIM<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGT1LIM<7:0> | | | | | | | |
| 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 15-0 **PTGT1LIM<15:0>:** PTG Timer1 Limit Register bits
General purpose Timer1 Limit register (effective only with a PTGT1 Step command).

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


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**REGISTER 17-6: PTGSDLIM: PTG STEP DELAY LIMIT REGISTER(1,2)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGSDLIM<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGSDLIM<7:0> | | | | | | | |
| 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 15-0 **PTGSDLIM<15:0>:** PTG Step Delay Limit Register bits
Holds a PTG Step delay value, representing the number of additional PTG clocks, between the start of a Step command and the completion of a Step command.

**Note 1:** A base Step delay of one PTG clock is added to any value written to the PTGSDLIM register (Step Delay = (PTGSDLIM) + 1).

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

**REGISTER 17-7: PTGC0LIM: PTG COUNTER 0 LIMIT REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGC0LIM<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGC0LIM<7:0> | | | | | | | |
| 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 15-0 **PTGC0LIM<15:0>:** PTG Counter 0 Limit Register bits
May be used to specify the loop count for the PTGJMPC0 Step command or as a limit register for the General Purpose Counter 0.

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

**REGISTER 17-8: PTGC1LIM: PTG COUNTER 1 LIMIT REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGC1LIM<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGC1LIM<7:0> | | | | | | | |
| 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 15-0 **PTGC1LIM<15:0>:** PTG Counter 1 Limit Register bits
May be used to specify the loop count for the PTGJMPC1 Step command or as a limit register for the General Purpose Counter 1.

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

**REGISTER 17-9: PTGHOLD: PTG HOLD REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGHOLD<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGHOLD<7:0> | | | | | | | |
| 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 15-0 **PTGHOLD<15:0>:** PTG General Purpose Hold Register bits
Holds user-supplied data to be copied to the PTGTxLIM, PTGCxLIM, PTGSDLIM or PTGL0 register with the PTGCOPY command.

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


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**REGISTER 17-10: PTGADJ: PTG ADJUST REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGADJ<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGADJ<7:0> | | | | | | | |
| 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 15-0 **PTGADJ<15:0>:** PTG Adjust Register bits
This register holds user-supplied data to be added to the PTGTxLIM, PTGCxLIM, PTGSDLIM or PTGL0 register with the PTGADD command.

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

**REGISTER 17-11: PTGL0: PTG LITERAL 0 REGISTER(1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGL0<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGL0<7:0> | | | | | | | |
| 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 15-0 **PTGL0<15:0>:** PTG Literal 0 Register bits
This register holds the 6-bit value to be written to the CNVCHSEL<5:0> bits (ADCON3L<5:0>) with the PTGCTRL Step command.

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

**REGISTER 17-12: 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 17-13: PTGQUEx: PTG STEP QUEUE REGISTER x (x = 0-15)(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 17-1 for the Step command encoding.

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


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## 17.3 Step Commands and Format

**TABLE 17-1: PTG STEP COMMAND FORMAT**

| Step Command Byte: | | | |
|---|---|---|---|
| STEPx<7:0> | | | |
| CMD<3:0> | | OPTION<3:0> | |
| bit 7 | bit 4 | bit 3 | bit 0 |

| bit 7-4 | CMD<3:0> | Step Command | Command Description |
|---|---|---|---|
| | 0000 | PTGCTRL | Execute control command as described by OPTION<3:0> |
| | 0001 | PTGADD | Add contents of PTGADJ register to target register as described by OPTION<3:0> |
| | | PTGCOPY | Copy contents of PTGHOLD register to target register as described by OPTION<3:0> |
| | 001x | PTGSTRB | Copy the value contained in CMD0:OPTION<3:0> to the CNVCHSEL<5:0> bits (ADCON3L<5:0>) |
| | 0100 | PTGWHI | Wait for a low-to-high edge input from selected PTG trigger input as described by OPTION<3:0> |
| | 0101 | PTGWLO | Wait for a high-to-low edge input from selected PTG trigger input as described by OPTION<3:0> |
| | 0110 | Reserved | Reserved |
| | 0111 | PTGIRQ | Generate individual interrupt request as described by OPTION<3:0> |
| | 100x | PTGTRIG | Generate individual trigger output as described by <<CMD0>:OPTION<3:0>> |
| | 101x | PTGJMP | Copy the value indicated in <<CMD0>:OPTION<3:0>> to the PTG Queue Pointer (PTGQPTR) and jump to that Step queue |
| | 110x | PTGJMPC0 | PTGC0 = PTGC0LIM: Increment the PTG Queue Pointer (PTGQPTR) |
| | | | PTGC0 ≠ PTGC0LIM: Increment PTG Counter 0 (PTGC0) and copy the value indicated in <<CMD0>:OPTION<3:0>> to the PTG Queue Pointer (PTGQPTR) and jump to that Step queue |
| | 111x | PTGJMPC1 | PTGC1 = PTGC1LIM: Increment the PTG Queue Pointer (PTGQPTR) |
| | | | PTGC1 ≠ PTGC1LIM: Increment PTG Counter 1 (PTGC1) and copy the value indicated in <<CMD0>:OPTION<3:0>> to the PTG Queue Pointer (PTGQPTR) and jump to that Step queue |

**Note 1:** All reserved commands or options will execute but have no effect (i.e., execute as a NOP instruction).

**2:** Refer to Table 17-2 for the trigger output descriptions.

**TABLE 17-1: PTG STEP COMMAND FORMAT (CONTINUED)**

| bit 3-0 | Step Command | OPTION<3:0> | Option Description |
|---|---|---|---|
| | PTGCTRL(1) | 0000 | Reserved |
| | | 0001 | Reserved |
| | | 0010 | Disable PTG Step Delay Timer (PTGSD) |
| | | 0011 | Reserved |
| | | 0100 | Reserved |
| | | 0101 | Reserved |
| | | 0110 | Enable PTG Step Delay Timer (PTGSD) |
| | | 0111 | Reserved |
| | | 1000 | Start and wait for the PTG Timer0 to match the PTG Timer0 Limit register |
| | | 1001 | Start and wait for the PTG Timer1 to match the PTG Timer1 Limit register |
| | | 1010 | Reserved |
| | | 1011 | Wait for software trigger bit transition from low-to-high before continuing (PTGSWT = 0 to 1) |
| | | 1100 | Copy contents of the PTG Counter 0 register to the CNVCHSEL<5:0> bits (ADCON3L<5:0>) |
| | | 1101 | Copy contents of the PTG Counter 1 register to the CNVCHSEL<5:0> bits (ADCON3L<5:0>) |
| | | 1110 | Copy contents of the PTG Literal 0 register to the CNVCHSEL<5:0> bits (ADCON3L<5:0>) |
| | | 1111 | Generate the triggers indicated in the PTG Broadcast Trigger Enable register (PTGBTE) |
| | PTGADD(1) | 0000 | Add contents of PTGADJ register to the PTG Counter 0 Limit register (PTGC0LIM) |
| | | 0001 | Add contents of PTGADJ register to the PTG Counter 1 Limit register (PTGC1LIM) |
| | | 0010 | Add contents of PTGADJ register to the PTG Timer0 Limit register (PTGT0LIM) |
| | | 0011 | Add contents of PTGADJ register to the PTG Timer1 Limit register (PTGT1LIM) |
| | | 0100 | Add contents of PTGADJ register to the PTG Step Delay Limit register (PTGSDLIM) |
| | | 0101 | Add contents of PTGADJ register to the PTG Literal 0 register (PTGL0) |
| | | 0110 | Reserved |
| | | 0111 | Reserved |
| | PTGCOPY(1) | 1000 | Copy contents of PTGHOLD register to the PTG Counter 0 Limit register (PTGC0LIM) |
| | | 1001 | Copy contents of PTGHOLD register to the PTG Counter 1 Limit register (PTGC1LIM) |
| | | 1010 | Copy contents of PTGHOLD register to the PTG Timer0 Limit register (PTGT0LIM) |
| | | 1011 | Copy contents of PTGHOLD register to the PTG Timer1 Limit register (PTGT1LIM) |
| | | 1100 | Copy contents of PTGHOLD register to the PTG Step Delay Limit register (PTGSDLIM) |
| | | 1101 | Copy contents of PTGHOLD register to the PTG Literal 0 register (PTGL0) |
| | | 1110 | Reserved |
| | | 1111 | Reserved |

**Note 1:** All reserved commands or options will execute but have no effect (i.e., execute as a NOP instruction).

**2:** Refer to Table 17-2 for the trigger output descriptions.


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**TABLE 17-1: PTG STEP COMMAND FORMAT (CONTINUED)**

| bit 3-0 | Step Command | OPTION<3:0> | Option Description |
|---|---|---|---|
| | PTGWHI(1) or PTGWLO(1) | 0000 | PWM Special Event Trigger |
| | | 0001 | PWM master time base synchronization output |
| | | 0010 | PWM1 interrupt |
| | | 0011 | PWM2 interrupt |
| | | 0100 | PWM3 interrupt |
| | | 0101 | PWM4 interrupt |
| | | 0110 | PWM5 interrupt |
| | | 0111 | OC1 trigger event |
| | | 1000 | OC2 trigger event |
| | | 1001 | IC1 trigger event |
| | | 1010 | CMP1 trigger event |
| | | 1011 | CMP2 trigger event |
| | | 1100 | CMP3 trigger event |
| | | 1101 | CMP4 trigger event |
| | | 1110 | ADC conversion done interrupt |
| | | 1111 | INT2 external interrupt |
| | PTGIRQ(1) | 0000 | Generate PTG Interrupt 0 |
| | | 0001 | Generate PTG Interrupt 1 |
| | | 0010 | Generate PTG Interrupt 2 |
| | | 0011 | Generate PTG Interrupt 3 |
| | | 0100 | Reserved |
| | | • • • | • • • |
| | | 1111 | Reserved |
| | PTGTRIG(2) | 00000 | PTGO0 |
| | | 00001 | PTGO1 |
| | | • • • | • • • |
| | | 11110 | PTGO30 |
| | | 11111 | PTGO31 |

**Note 1:** All reserved commands or options will execute but have no effect (i.e., execute as a NOP instruction).

**2:** Refer to Table 17-2 for the trigger output descriptions.

**TABLE 17-2: PTG OUTPUT DESCRIPTIONS**

| PTG Output Number | PTG Output Description |
|---|---|
| PTGO0 | Trigger/synchronization source for OC1 |
| PTGO1 | Trigger/synchronization source for OC2 |
| PTGO2 | Trigger/synchronization source for OC3 |
| PTGO3 | Trigger/synchronization source for OC4 |
| PTGO4 | Clock source for OC1 |
| PTGO5 | Clock source for OC2 |
| PTGO6 | Clock source for OC3 |
| PTGO7 | Clock source for OC4 |
| PTGO8 | Trigger/synchronization source for IC1 |
| PTGO9 | Trigger/synchronization source for IC2 |
| PTGO10 | Trigger/synchronization source for IC3 |
| PTGO11 | Trigger/synchronization source for IC4 |
| PTGO12 | Sample trigger for ADC |
| PTGO13 | Reserved |
| PTGO14 | Reserved |
| PTGO15 | Reserved |
| PTGO16 | PWM time base synchronous source for PWM3 |
| PTGO17 | PWM time base synchronous source for PWM4 |
| PTGO18 | PWM time base synchronous source for PWM5 |
| PTGO19 | PWM time base synchronous source for PWM6 |
| PTGO20 | Reserved |
| PTGO21 | Reserved |
| PTGO22 | Reserved |
| PTGO23 | Reserved |
| PTGO24 | Reserved |
| PTGO25 | Reserved |
| PTGO26 | CLC1 input |
| PTGO27 | CLC2 input |
| PTGO28 | CLC3 input |
| PTGO29 | CLC4 input |
| PTGO30 | PTG output to PPS input selection, RPI6 |
| PTGO31 | PTG output to PPS input selection, RPI7 |


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## 18.0 SERIAL PERIPHERAL INTERFACE (SPI)

**Note:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Serial Peripheral Interface (SPI) with Audio Codec Support"** (DS70005136) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

The Serial Peripheral Interface (SPI) module is a synchronous serial interface useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be serial EEPROMs, shift registers, display drivers, A/D Converters, etc. The SPI module is compatible with the Motorola® SPI and SIOP interfaces. All devices in the dsPIC33EPXXXGS70X/80X family include three SPI modules.

The module supports operation in two buffer modes. In Standard mode, data is shifted through a single serial buffer. In Enhanced Buffer mode, data is shifted through a FIFO buffer. The FIFO level depends on the configured mode.

Variable length data can be transmitted and received, from 2 to 32 bits.

**Note:** Do not perform Read-Modify-Write operations (such as bit-oriented instructions) on the SPIxBUF register in either Standard or Enhanced Buffer mode.

The module also supports a basic framed SPI protocol while operating in either Master or Slave mode. A total of four framed SPI configurations are supported.

SPI3 also supports Audio modes. Four different Audio modes are available.

- $I^2S$
- Left Justified
- Right Justified
- PCM/DSP

In each of these modes, the serial clock is free-running and audio data is always transferred.

If an audio protocol data transfer takes place between two devices, then usually one device is the master and the other is the slave. However, audio data can be transferred between two slaves. Because the audio protocols require free-running clocks, the master can be a third party controller. In either case, the master generates two free-running clocks: SCKx and LRC (Left, Right Channel Clock/$\overline{SS}$x/FSYNC).

The SPI serial interface consists of four pins:

- SDIx: Serial Data Input
- SDOx: Serial Data Output
- SCKx: Shift Clock Input or Output
- $\overline{SS}$x: Active-Low Slave Select or Frame Synchronization I/O Pulse

The SPI module can be configured to operate using 2, 3 or 4 pins. In the 3-pin mode, $\overline{SS}$x is not used. In the 2-pin mode, both SDOx and $\overline{SS}$x are not used.

The SPI module has the ability to generate three interrupts, reflecting the events that occur during the data communication. The following types of interrupts can be generated:

1. Receive interrupts are signalled by SPIxRXIF. This event occurs when:
   - RX watermark interrupt
   - SPIROV = 1
   - SPIRBF = 1
   - SPIRBE = 1

   provided the respective mask bits are enabled in SPIxIMSKL/H.
2. Transmit interrupts are signalled by SPIxTXIF. This event occurs when:
   - TX watermark interrupt
   - SPITUR = 1
   - SPITBF = 1
   - SPITBE = 1

   provided the respective mask bits are enabled in SPIxIMSKL/H.
3. General interrupts are signalled by SPIxIF. This event occurs when
   - FRMERR = 1
   - SPIBUSY = 1
   - SRMT = 1

   provided the respective mask bits are enabled in SPIxIMSKL/H.

Block diagrams of the module in Standard and Enhanced modes are shown in Figure 18-1 and Figure 18-2.

**Note:** In this section, the SPI modules are referred to together as SPIx, or separately as SPI1, SPI2 or SPI3. Special Function Registers will follow a similar notation. For example, SPIxCON1 and SPIxCON2 refer to the control registers for any of the three SPI modules.

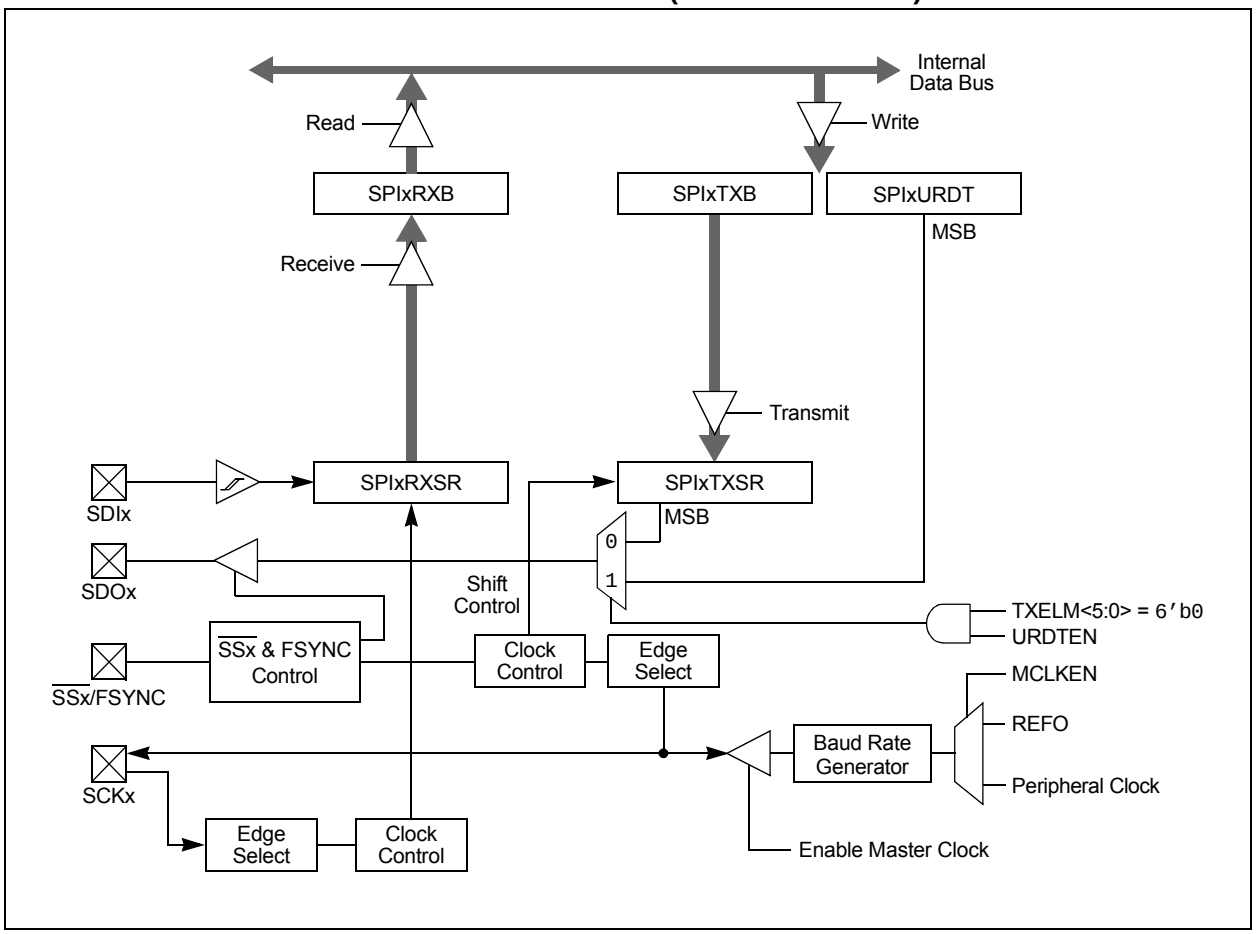
To set up the SPIx module for the Standard Master mode of operation:

1. If using interrupts:
   a) Clear the interrupt flag bits in the respective IFSx register.
   b) Set the interrupt enable bits in the respective IECx register.
   c) Write the SPIxIP bits in the respective IPCx register to set the interrupt priority.
2. Write the desired settings to the SPIxCON1L and SPIxCON1H registers with the MSTEN bit (SPIxCON1L<5>) = 1.
3. Clear the SPIROV bit (SPIxSTATL<6>).
4. Enable SPIx operation by setting the SPIEN bit (SPIxCON1L<15>).
5. Write the data to be transmitted to the SPIxBUFL and SPIxBUFH registers. Transmission (and reception) will start as soon as data is written to the SPIxBUFL and SPIxBUFH registers.

To set up the SPIx module for the Standard Slave mode of operation:

1. Clear the SPIxBUF registers.
2. If using interrupts:
   a) Clear the SPIxBUFL and SPIxBUFH registers.
   b) Set the interrupt enable bits in the respective IECx register.
   c) Write the SPIxIP bits in the respective IPCx register to set the interrupt priority.
3. Write the desired settings to the SPIxCON1L, SPIxCON1H and SPIxCON2L registers with the MSTEN bit (SPIxCON1L<5>) = 0.
4. Clear the SMP bit.
5. If the CKE bit (SPIxCON1L<8>) is set, then the SSEN bit (SPIxCON1L<7>) must be set to enable the $\overline{SSx}$ pin.
6. Clear the SPIROV bit (SPIxSTATL<6>).
7. Enable SPIx operation by setting the SPIEN bit (SPIxCON1L<15>).

**FIGURE 18-1: SPIx MODULE BLOCK DIAGRAM (STANDARD MODE)**





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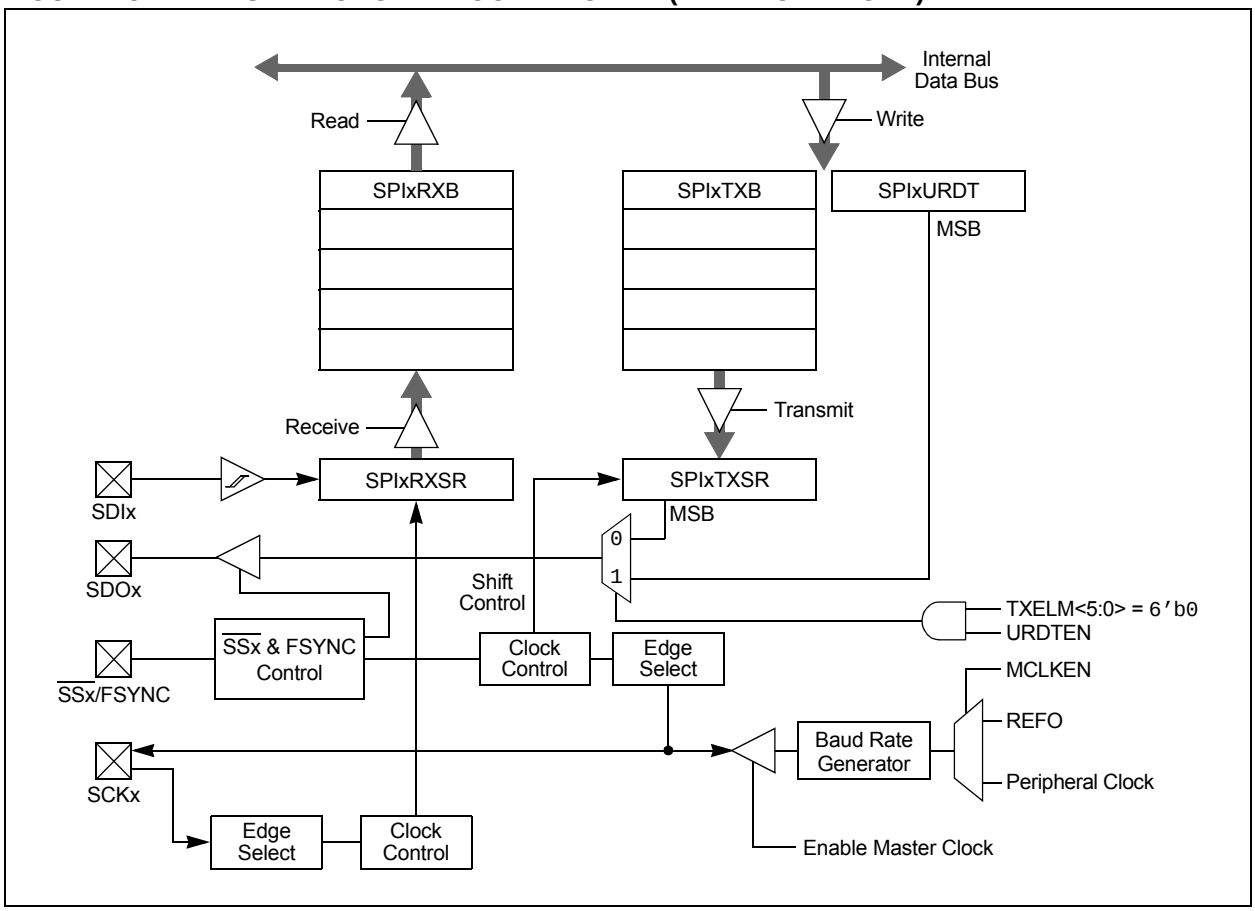
To set up the SPIx module for the Enhanced Buffer Master mode of operation:

1. If using interrupts:
   a) Clear the interrupt flag bits in the respective IFSx register.
   b) Set the interrupt enable bits in the respective IECx register.
   c) Write the SPIxIP bits in the respective IPCx register.
2. Write the desired settings to the SPIxCON1L, SPIxCON1H and SPIxCON2L registers with MSTEN (SPIxCON1L<5>) = 1.
3. Clear the SPIROV bit (SPIxSTATL<6>).
4. Select Enhanced Buffer mode by setting the ENHBUF bit (SPIxCON1L<0>).
5. Enable SPIx operation by setting the SPIEN bit (SPIxCON1L<15>).
6. Write the data to be transmitted to the SPIxBUFL and SPIxBUFH registers. Transmission (and reception) will start as soon as data is written to the SPIxBUFL and SPIxBUFH registers.

To set up the SPIx module for the Enhanced Buffer Slave mode of operation:

1. Clear the SPIxBUFL and SPIxBUFH registers.
2. If using interrupts:
   a) Clear the interrupt flag bits in the respective IFSx register.
   b) Set the interrupt enable bits in the respective IECx register.
   c) Write the SPIxIP bits in the respective IPCx register to set the interrupt priority.
3. Write the desired settings to the SPIxCON1L, SPIxCON1H and SPIxCON2L registers with the MSTEN bit (SPIxCON1L<5>) = 0.
4. Clear the SMP bit.
5. If the CKE bit is set, then the SSEN bit must be set, thus enabling the $\overline{SSx}$ pin.
6. Clear the SPIROV bit (SPIxSTATL<6>).
7. Select Enhanced Buffer mode by setting the ENHBUF bit (SPIxCON1L<0>).
8. Enable SPIx operation by setting the SPIEN bit (SPIxCON1L<15>).

**FIGURE 18-2: SPIx MODULE BLOCK DIAGRAM (ENHANCED MODE)**



To set up the SPIx module for Audio mode:

1. Clear the SPIxBUFL and SPIxBUFH registers.
2. If using interrupts:
   a) Clear the interrupt flag bits in the respective IFSx register.
   b) Set the interrupt enable bits in the respective IECx register.
   a) Write the SPIxIP bits in the respective IPCx register to set the interrupt priority.
3. Write the desired settings to the SPIxCON1L, SPIxCON1H and SPIxCON2L registers with AUDEN (SPIxCON1H<15>) = 1.
4. Clear the SPIROV bit (SPIxSTATL<6>).
5. Enable SPIx operation by setting the SPIEN bit (SPIxCON1L<15>).
6. Write the data to be transmitted to the SPIxBUFL and SPIxBUFH registers. Transmission (and reception) will start as soon as data is written to the SPIxBUFL and SPIxBUFH registers.

**REGISTER 18-1: SPIxCON1L: SPIx CONTROL REGISTER 1 LOW**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SPIEN | — | SPISIDL | DISSDO | MODE32(1,4) | MODE16(1,4) | SMP | CKE(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 |
|---|---|---|---|---|---|---|---|
| SSEN(2) | CKP | MSTEN | DISSDI | DISSCK | MCLKEN(3) | SPIFE | ENHBUF |
| 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 **SPIEN:** SPIx On bit
1 = Enables module
0 = Turns off and resets module, disables clocks, disables interrupt event generation, allows SFR modifications

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

bit 13 **SPISIDL:** SPIx Stop in Idle Mode bit
1 = Halts in CPU Idle mode
0 = Continues to operate in CPU Idle mode

bit 12 **DISSDO:** Disable SDOx Output Port bit
1 = SDOx pin is not used by the module; pin is controlled by port function
0 = SDOx pin is controlled by the module

bit 11-10 **MODE32** and **MODE16:** Serial Word Length Select bits(1,4)

| MODE32 | MODE16 | AUDEN | Communication |
|---|---|---|---|
| 1 | x | 0 | 32-Bit |
| 0 | 1 | | 16-Bit |
| 0 | 0 | | 8-Bit |
| 1 | 1 | 1 | 24-Bit Data, 32-Bit FIFO, 32-Bit Channel/64-Bit Frame |
| 1 | 0 | | 32-Bit Data, 32-Bit FIFO, 32-Bit Channel/64-Bit Frame |
| 0 | 1 | | 16-Bit Data, 16-Bit FIFO, 32-Bit Channel/64-Bit Frame |
| 0 | 0 | | 16-Bit FIFO, 16-Bit Channel/32-Bit Frame |

**Note 1:** When AUDEN (SPIxCON1H<15>) = 1, this module functions as if CKE = 0, regardless of its actual value.
**2:** When FRMEN = 1, SSEN is not used.
**3:** MCLKEN can only be written when the SPIEN bit = 0.
**4:** This channel is not meaningful for DSP/PCM mode as LRC follows FRMSYPW.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**REGISTER 18-1: SPIxCON1L: SPIx CONTROL REGISTER 1 LOW (CONTINUED)**

bit 9 **SMP:** SPIx Data Input Sample Phase bit
Master Mode:
1 = Input data is sampled at the end of data output time
0 = Input data is sampled at the middle of data output time
Slave Mode:
Input data is always sampled at the middle of data output time, regardless of the SMP setting.

bit 8 **CKE:** SPIx Clock Edge Select bit(1)
1 = Transmit happens on transition from active clock state to Idle clock state
0 = Transmit happens on transition from Idle clock state to active clock state

bit 7 **SSEN:** Slave Select Enable bit (Slave mode)(2)
1 = $\overline{SSx}$ pin is used by the macro in Slave mode; $\overline{SSx}$ pin is used as the slave select input
0 = $\overline{SSx}$ pin is not used by the macro ($\overline{SSx}$ pin will be controlled by the port I/O)

bit 6 **CKP:** Clock Polarity Select bit
1 = Idle state for clock is a high level; active state is a low level
0 = Idle state for clock is a low level; active state is a high level

bit 5 **MSTEN:** Master Mode Enable bit
1 = Master mode
0 = Slave mode

bit 4 **DISSDI:** Disable SDIx Input Port bit
1 = SDIx pin is not used by the module; pin is controlled by port function
0 = SDIx pin is controlled by the module

bit 3 **DISSCK:** Disable SCKx Output Port bit
1 = SCKx pin is not used by the module; pin is controlled by port function
0 = SCKx pin is controlled by the module

bit 2 **MCLKEN:** Master Clock Enable bit(3)
1 = REFO is used by the Baud Rate Generator (BRG)
0 = Peripheral clock is used by the BRG

bit 1 **SPIFE:** Frame Sync Pulse Edge Select bit
1 = Frame Sync pulse (Idle-to-active edge) coincides with the first bit clock
0 = Frame Sync pulse (Idle-to-active edge) precedes the first bit clock

bit 0 **ENHBUF:** Enhanced Buffer Enable bit
1 = Enhanced Buffer mode is enabled
0 = Enhanced Buffer mode is disabled

**Note 1:** When AUDEN (SPIxCON1H<15>) = 1, this module functions as if CKE = 0, regardless of its actual value.
**2:** When FRMEN = 1, SSEN is not used.
**3:** MCLKEN can only be written when the SPIEN bit = 0.
**4:** This channel is not meaningful for DSP/PCM mode as LRC follows FRMSYPW.

**REGISTER 18-2: SPIxCON1H: SPIx CONTROL REGISTER 1 HIGH**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| AUDEN(1) | SPISGNEXT | IGNROV | IGNTUR | AUDMONO(2) | URDTEN(3) | AUDMOD1(4) | AUDMOD0(4) |
| 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 |
|---|---|---|---|---|---|---|---|
| FRMEN | FRMSYNC | FRMPOL | MSSEN | FRMSYPW | FRMCNT2 | FRMCNT1 | FRMCNT0 |
| 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 **AUDEN:** Audio Codec Support Enable bit(1)
- 1 = Audio protocol is enabled; MSTEN controls the direction of both SCKx and frame (a.k.a. LRC), and this module functions as if FRMEN = 1, FRMSYNC = MSTEN, FRMCNT<2:0> = 001 and SMP = 0, regardless of their actual values
- 0 = Audio protocol is disabled

bit 14 **SPISGNEXT:** SPIx Sign-Extend RX FIFO Read Data Enable bit
- 1 = Data from RX FIFO is sign-extended
- 0 = Data from RX FIFO is not sign-extended

bit 13 **IGNROV:** Ignore Receive Overflow bit
- 1 = A Receive Overflow (ROV) is NOT a critical error; during ROV, data in the FIFO is not overwritten by the receive data
- 0 = A ROV is a critical error that stops SPI operation

bit 12 **IGNTUR:** Ignore Transmit Underrun bit
- 1 = A Transmit Underrun (TUR) is NOT a critical error and data indicated by URDTEN is transmitted until the SPIxTXB is not empty
- 0 = A TUR is a critical error that stops SPI operation

bit 11 **AUDMONO:** Audio Data Format Transmit bit(2)
- 1 = Audio data is mono (i.e., each data word is transmitted on both left and right channels)
- 0 = Audio data is stereo

bit 10 **URDTEN:** Transmit Underrun Data Enable bit(3)
- 1 = Transmits data out of SPIxURDT register during Transmit Underrun conditions
- 0 = Transmits the last received data during Transmit Underrun conditions

bit 9-8 **AUDMOD<1:0>:** Audio Protocol Mode Selection bits(4)
- 11 = PCM/DSP mode
- 10 = Right Justified mode: This module functions as if SPIFE = 1, regardless of its actual value
- 01 = Left Justified mode: This module functions as if SPIFE = 1, regardless of its actual value
- 00 = $I^2S$ mode: This module functions as if SPIFE = 0, regardless of its actual value

bit 7 **FRMEN:** Framed SPIx Support bit
- 1 = Framed SPIx support is enabled ($\overline{SSx}$ pin is used as the FSYNC input/output)
- 0 = Framed SPIx support is disabled

**Note 1:** AUDEN can only be written when the SPIEN bit = 0.
**2:** AUDMONO can only be written when the SPIEN bit = 0 and is only valid for AUDEN = 1.
**3:** URDTEN is only valid when IGNTUR = 1.
**4:** The AUDMOD<1:0> bits can only be written when the SPIEN bit = 0 and are only valid when AUDEN = 1. When NOT in PCM/DSP mode, this module functions as if FRMSYPW = 1, regardless of its actual value.


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**REGISTER 18-2: SPIxCON1H: SPIx CONTROL REGISTER 1 HIGH (CONTINUED)**

bit 6 **FRMSYNC:** Frame Sync Pulse Direction Control bit
1 = Frame Sync pulse input (slave)
0 = Frame Sync pulse output (master)

bit 5 **FRMPOL:** Frame Sync/Slave Select Polarity bit
1 = Frame Sync pulse/slave select is active-high
0 = Frame Sync pulse/slave select is active-low

bit 4 **MSSEN:** Master Mode Slave Select Enable bit
1 = SPIx slave select support is enabled with polarity determined by FRMPOL ($\overline{SSx}$ pin is automatically driven during transmission in Master mode)
0 = Slave select SPIx support is disabled ($\overline{SSx}$ pin will be controlled by port I/O)

bit 3 **FRMSYPW:** Frame Sync Pulse-Width bit
1 = Frame Sync pulse is one serial word length wide (as defined by MODE<32,16>/WLENGTH<4:0>)
0 = Frame Sync pulse is one clock (SCK) wide

bit 2-0 **FRMCNT<2:0>:** Frame Sync Pulse Counter bits
Controls the number of serial words transmitted per Sync pulse.
111 = Reserved
110 = Reserved
101 = Generates a Frame Sync pulse on every 32 serial words
100 = Generates a Frame Sync pulse on every 16 serial words
011 = Generates a Frame Sync pulse on every 8 serial words
010 = Generates a Frame Sync pulse on every 4 serial words
001 = Generates a Frame Sync pulse on every 2 serial words (value used by audio protocols)
000 = Generates a Frame Sync pulse on each serial word

**Note 1:** AUDEN can only be written when the SPIEN bit = 0.
**2:** AUDMONO can only be written when the SPIEN bit = 0 and is only valid for AUDEN = 1.
**3:** URDTEN is only valid when IGNTUR = 1.
**4:** The AUDMOD<1:0> bits can only be written when the SPIEN bit = 0 and are only valid when AUDEN = 1. When NOT in PCM/DSP mode, this module functions as if FRMSYPW = 1, regardless of its actual value.

**REGISTER 18-3: SPIxCON2L: SPIx CONTROL REGISTER 2 LOW**

| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | WLENGTH<4:0>(1,2) | | | | |
| 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 15-5 **Unimplemented:** Read as '0'

bit 4-0 **WLENGTH<4:0>:** Variable Word Length bits(1,2)

11111 = 32-bit data
11110 = 31-bit data
11101 = 30-bit data
11100 = 29-bit data
11011 = 28-bit data
11010 = 27-bit data
11001 = 26-bit data
11000 = 25-bit data
10111 = 24-bit data
10110 = 23-bit data
10101 = 22-bit data
10100 = 21-bit data
10011 = 20-bit data
10010 = 19-bit data
10001 = 18-bit data
10000 = 17-bit data
01111 = 16-bit data
01110 = 15-bit data
01101 = 14-bit data
01100 = 13-bit data
01011 = 12-bit data
01010 = 11-bit data
01001 = 10-bit data
01000 = 9-bit data
00111 = 8-bit data
00110 = 7-bit data
00101 = 6-bit data
00100 = 5-bit data
00011 = 4-bit data
00010 = 3-bit data
00001 = 2-bit data
00000 = See MODE<32,16> bits in SPIxCON1L<11:10>

**Note 1:** These bits are effective when AUDEN = 0 only.
**2:** Varying the length by changing these bits does not affect the depth of the TX/RX FIFO.


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**REGISTER 18-4: SPIxSTATL: SPIx STATUS REGISTER LOW**

| U-0 | U-0 | U-0 | R/C-0, HS | R-0, HSC | U-0 | U-0 | R-0, HSC |
|---|---|---|---|---|---|---|---|
| — | — | — | FRMERR | SPIBUSY | — | — | SPITUR(1) |
| bit 15 | | | | | | | bit 8 |

| R-0, HSC | R/C-0, HS | R-1, HSC | U-0 | R-1, HSC | U-0 | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| SRMT | SPIROV | SPIRBE | — | SPITBE | — | SPITBF | SPIRBF |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Clearable bit | U = Unimplemented, read as '0' | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | HSC = Hardware Settable/Clearable bit | |
| -n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | HS = Hardware Settable bit |

bit 15-13 **Unimplemented:** Read as '0'

bit 12 **FRMERR**: SPIx Frame Error Status bit
1 = Frame error is detected
0 = No frame error is detected

bit 11 **SPIBUSY:** SPIx Activity Status bit
1 = Module is currently busy with some transactions
0 = No ongoing transactions (at time of read)

bit 10-9 **Unimplemented:** Read as '0'

bit 8 **SPITUR:** SPIx Transmit Underrun Status bit(1)
1 = Transmit buffer has encountered a Transmit Underrun condition
0 = Transmit buffer does not have a Transmit Underrun condition

bit 7 **SRMT:** Shift Register Empty Status bit
1 = No current or pending transactions (i.e., neither SPIxTXB or SPIxTXSR contains data to transmit)
0 = Current or pending transactions

bit 6 **SPIROV:** SPIx Receive Overflow Status bit
1 = A new byte/half-word/word has been completely received when the SPIxRXB was full
0 = No overflow

bit 5 **SPIRBE:** SPIx RX Buffer Empty Status bit
1 = RX buffer is empty
0 = RX buffer is not empty
Standard Buffer mode:
Automatically set in hardware when SPIxBUF is read from, reading SPIxRXB. Automatically cleared in hardware when SPIx transfers data from SPIxRXSR to SPIxRXB.
Enhanced Buffer mode:
Indicates RXELM<5:0> = 000000.

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

**Note 1:** SPITUR is cleared when SPIEN = 0. When IGNTUR = 1, SPITUR provides dynamic status of the Transmit Underrun condition, but does not stop RX/TX operation and does not need to be cleared by software.

**REGISTER 18-4: SPIxSTATL: SPIx STATUS REGISTER LOW (CONTINUED)**

bit 3 **SPITBE:** SPIx Transmit Buffer Empty Status bit
1 = SPIxTXB is empty
0 = SPIxTXB is not empty
Standard Buffer mode:
Automatically set in hardware when SPIx transfers data from SPIxTXB to SPIxTXSR. Automatically cleared in hardware when SPIxBUF is written, loading SPIxTXB.
Enhanced Buffer mode:
Indicates TXELM<5:0> = 000000.

bit 2 **Unimplemented:** Read as '0'

bit 1 **SPITBF:** SPIx Transmit Buffer Full Status bit
1 = SPIxTXB is full
0 = SPIxTXB not full
Standard Buffer mode:
Automatically set in hardware when SPIxBUF is written, loading SPIxTXB. Automatically cleared in hardware when SPIx transfers data from SPIxTXB to SPIxTXSR.
Enhanced Buffer mode:
Indicates TXELM<5:0> = 111111.

bit 0 **SPIRBF:** SPIx Receive Buffer Full Status bit
1 = SPIxRXB is full
0 = SPIxRXB is not full
Standard Buffer mode:
Automatically set in hardware when SPIx transfers data from SPIxRXSR to SPIxRXB. Automatically cleared in hardware when SPIxBUF is read from, reading SPIxRXB.
Enhanced Buffer mode:
Indicates RXELM<5:0> = 111111.

**Note 1:** SPITUR is cleared when SPIEN = 0. When IGNTUR = 1, SPITUR provides dynamic status of the Transmit Underrun condition, but does not stop RX/TX operation and does not need to be cleared by software.


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**REGISTER 18-5: SPIxSTATH: SPIx STATUS REGISTER HIGH**

| U-0 | U-0 | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| — | — | RXELM5(3) | RXELM4(2) | RXELM3(1) | RXELM2 | RXELM1 | RXELM0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| — | — | TXELM5(3) | TXELM4(2) | TXELM3(1) | TXELM2 | TXELM1 | TXELM0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HSC = Hardware Settable/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 15-14 **Unimplemented:** Read as ‘0’

bit 13-8 **RXELM<5:0>:** Receive Buffer Element Count bits (valid in Enhanced Buffer mode)(1,2,3)

bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-0 **TXELM<5:0>:** Transmit Buffer Element Count bits (valid in Enhanced Buffer mode)(1,2,3)

**Note 1:** RXELM3 and TXELM3 bits are only present when FIFODEPTH = 8 or higher.

**2:** RXELM4 and TXELM4 bits are only present when FIFODEPTH = 16 or higher.

**3:** RXELM5 and TXELM5 bits are only present when FIFODEPTH = 32.

**REGISTER 18-6: SPIxIMSKL: SPIx INTERRUPT MASK REGISTER LOW**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | FRMERREN | BUSYEN | — | — | SPITUREN |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SRMTEN | SPIROVEN | SPIRBEN | — | SPITBEN | — | SPITBFEN | SPIRBFEN |
| 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 **Unimplemented:** Read as '0'

bit 12 **FRMERREN:** Enable Interrupt Events via FRMERR bit
1 = Frame error generates an interrupt event
0 = Frame error does not generate an interrupt event

bit 11 **BUSYEN:** Enable Interrupt Events via SPIBUSY bit
1 = SPIBUSY generates an interrupt event
0 = SPIBUSY does not generate an interrupt event

bit 10-9 **Unimplemented:** Read as '0'

bit 8 **SPITUREN:** Enable Interrupt Events via SPITUR bit
1 = Transmit Underrun (TUR) generates an interrupt event
0 = Transmit Underrun does not generate an interrupt event

bit 7 **SRMTEN:** Enable Interrupt Events via SRMT bit
1 = Shift Register Empty (SRMT) generates interrupt events
0 = Shift Register Empty does not generate interrupt events

bit 6 **SPIROVEN:** Enable Interrupt Events via SPIROV bit
1 = SPIx Receive Overflow (ROV) generates an interrupt event
0 = SPIx Receive Overflow does not generate an interrupt event

bit 5 **SPIRBEN:** Enable Interrupt Events via SPIRBE bit
1 = SPIx RX buffer empty generates an interrupt event
0 = SPIx RX buffer empty does not generate an interrupt event

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

bit 3 **SPITBEN:** Enable Interrupt Events via SPITBE bit
1 = SPIx transmit buffer empty generates an interrupt event
0 = SPIx transmit buffer empty does not generate an interrupt event

bit 2 **Unimplemented:** Read as '0'

bit 1 **SPITBFEN:** Enable Interrupt Events via SPITBF bit
1 = SPIx transmit buffer full generates an interrupt event
0 = SPIx transmit buffer full does not generate an interrupt event

bit 0 **SPIRBFEN:** Enable Interrupt Events via SPIRBF bit
1 = SPIx receive buffer full generates an interrupt event
0 = SPIx receive buffer full does not generate an interrupt event


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**REGISTER 18-7: SPIxIMSKH: SPIx INTERRUPT MASK REGISTER HIGH**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| RXWIEN | — | RXMSK5(1) | RXMSK4(1,4) | RXMSK3(1,3) | RXMSK2(1,2) | RXMSK1(1) | RXMSK0(1) |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TXWIEN | — | TXMSK5(1) | TXMSK4(1,4) | TXMSK3(1,3) | TXMSK2(1,2) | TXMSK1(1) | TXMSK0(1) |
| 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 **RXWIEN:** Receive Watermark Interrupt Enable bit
1 = Triggers receive buffer element watermark interrupt when RXMSK<5:0> ≤ RXELM<5:0>
0 = Disables receive buffer element watermark interrupt

bit 14 **Unimplemented:** Read as ‘0’

bit 13-8 **RXMSK<5:0>:** RX Buffer Mask bits(1,2,3,4)
RX mask bits; used in conjunction with the RXWIEN bit.

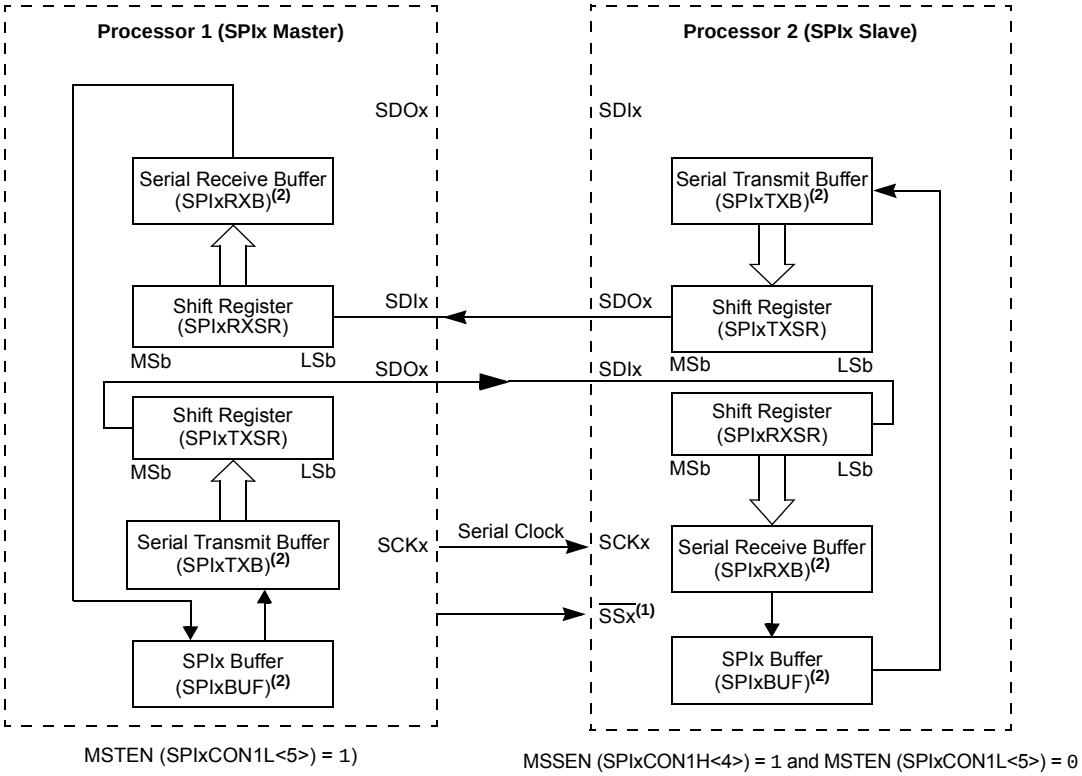
bit 7 **TXWIEN:** Transmit Watermark Interrupt Enable bit
1 = Triggers transmit buffer element watermark interrupt when TXMSK<5:0> = TXELM<5:0>
0 = Disables transmit buffer element watermark interrupt

bit 6 **Unimplemented:** Read as ‘0’

bit 5-0 **TXMSK<5:0>:** TX Buffer Mask bits(1,2,3,4)
TX mask bits; used in conjunction with the TXWIEN bit.

**Note 1:** Mask values higher than FIFODEPTH are not valid. The module will not trigger a match for any value in this case.
**2:** RXMSK2 and TXMSK2 bits are only present when FIFODEPTH = 8 or higher.
**3:** RXMSK3 and TXMSK3 bits are only present when FIFODEPTH = 16 or higher.
**4:** RXMSK4 and TXMSK4 bits are only present when FIFODEPTH = 32.

**FIGURE 18-3: SPIx MASTER/SLAVE CONNECTION (STANDARD MODE)**




**Note 1:** Using the $\overline{SSx}$ pin in Slave mode of operation is optional.

**2:** User must write transmit data to read the received data from SPIxBUF. The SPIxTXB and SPIxRXB registers are memory-mapped to SPIxBUF.


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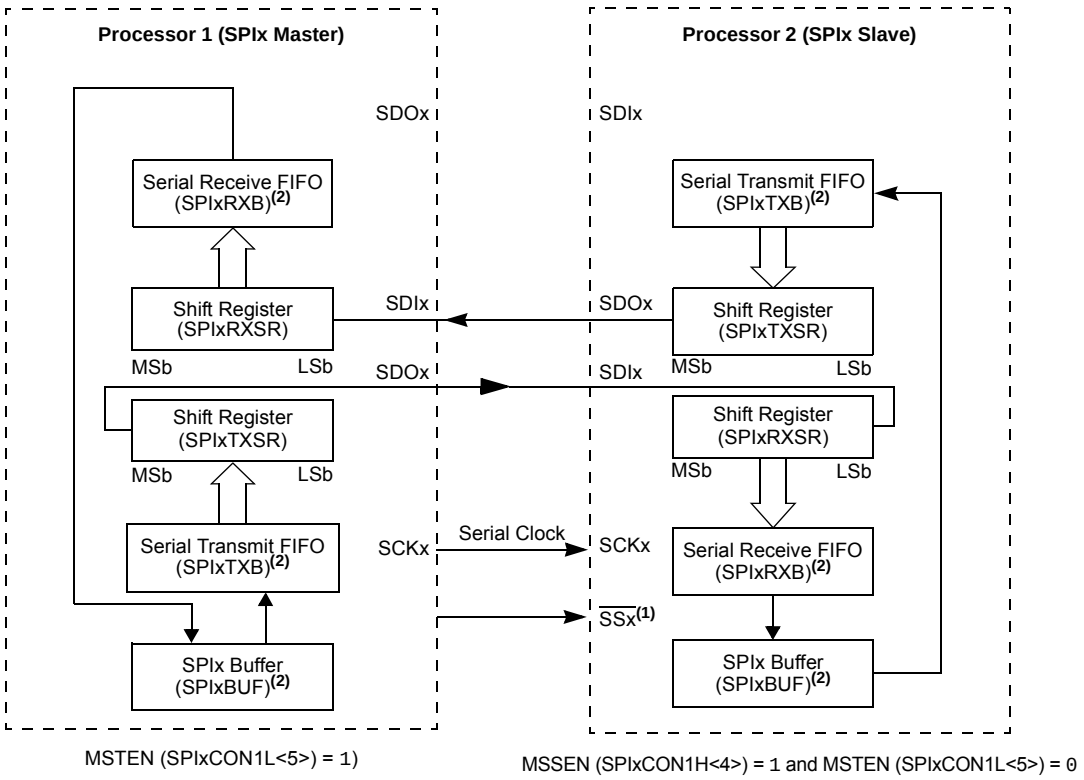
**FIGURE 18-4: SPIx MASTER/SLAVE CONNECTION (ENHANCED BUFFER MODES)**




**Note 1:** Using the $\overline{SSx}$ pin in Slave mode of operation is optional.

**2:** User must write transmit data to read the received data from SPIxBUF. The SPIxTXB and SPIxRXB registers are memory-mapped to SPIxBUF.

**FIGURE 18-5: SPIx MASTER, FRAME MASTER CONNECTION DIAGRAM**

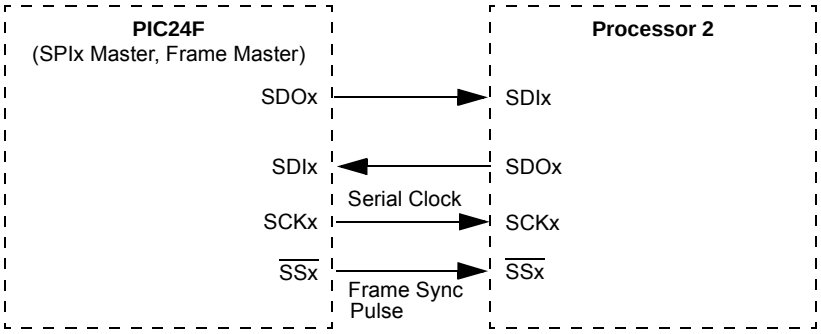


**FIGURE 18-6: SPIx MASTER, FRAME SLAVE CONNECTION DIAGRAM**

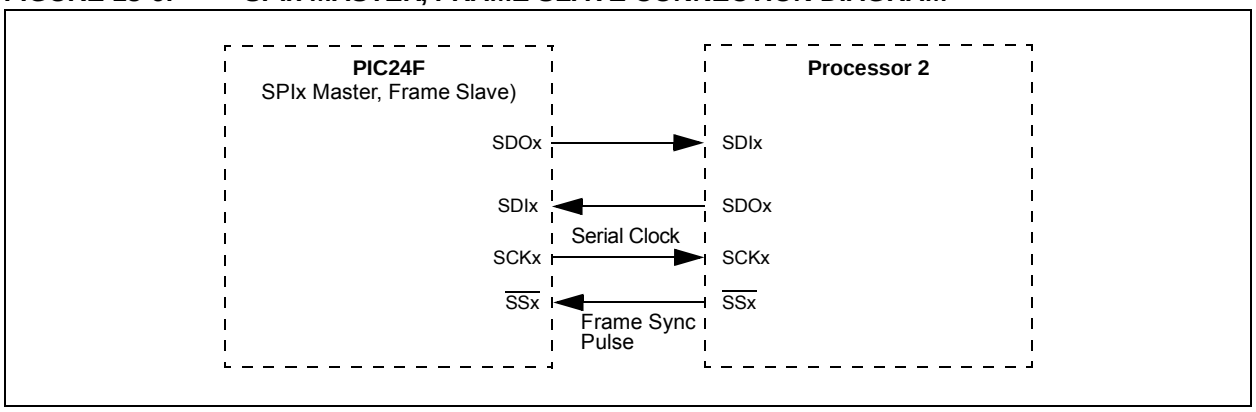



**FIGURE 18-7: SPIx SLAVE, FRAME MASTER CONNECTION DIAGRAM**

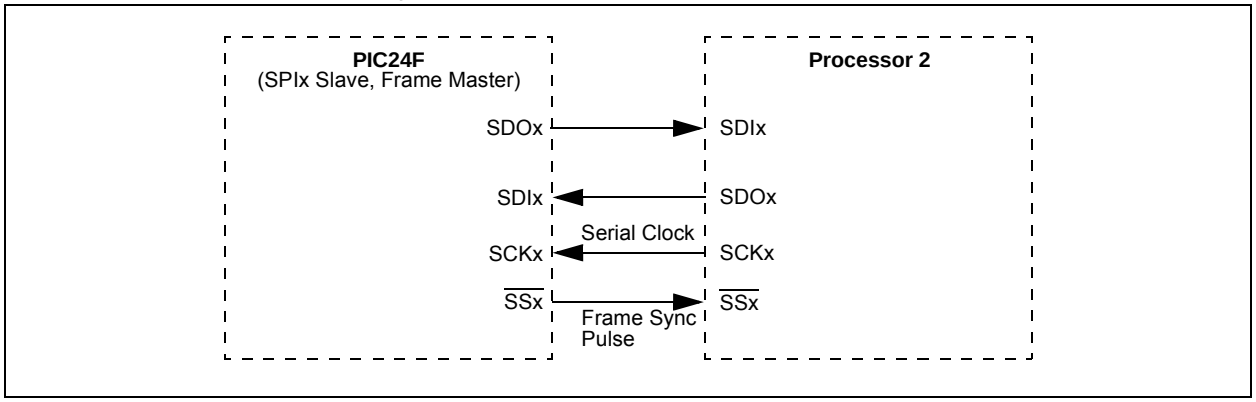
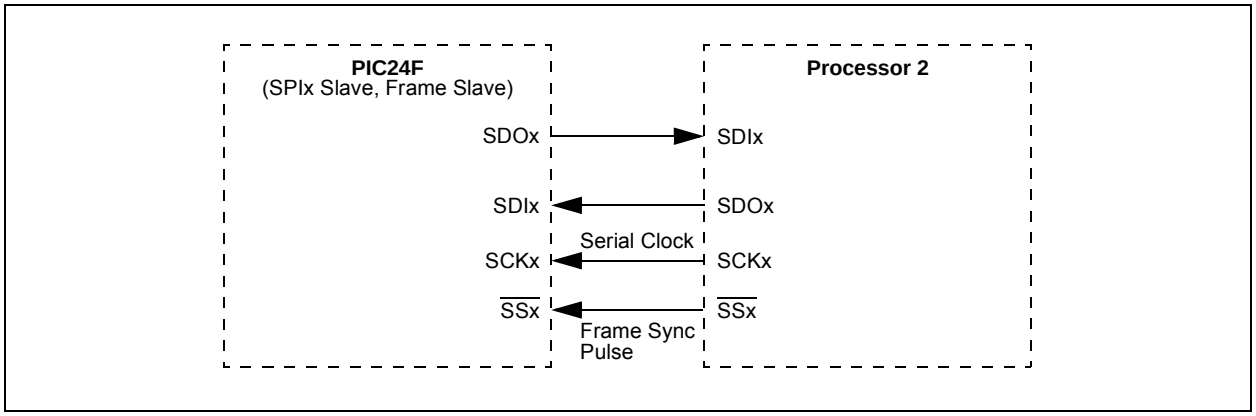



**FIGURE 18-8: SPIx SLAVE, FRAME SLAVE CONNECTION DIAGRAM**




**EQUATION 18-1: RELATIONSHIP BETWEEN DEVICE AND SPIx CLOCK SPEED**

$$\text{Baud Rate} = \frac{F_{PB}}{(2 * (\text{SPIxBRG} + 1))}$$

Where:

$F_{PB}$ is the Peripheral Bus Clock Frequency.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## 19.0 INTER-INTEGRATED CIRCUIT ($I^2C$)

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Inter-Integrated Circuit ($I^2C$)"** (DS70000195) in the *"dsPIC33/PIC24 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 dsPIC33EPXXXGS70X/80X family of devices contains two Inter-Integrated Circuit ($I^2C$) modules: I2C1 and I2C2.

The $I^2C$ module provides complete hardware support for both Slave and Multi-Master modes of the $I^2C$ serial communication standard, with a 16-bit interface.

The $I^2C$ module has a 2-pin interface:

- The SCLx/ASCLx pin is clock
- The SDAx/ASDAx pin is data

The $I^2C$ module offers the following key features:

- $I^2C$ Interface supporting both Master and Slave modes of Operation
- $I^2C$ Slave mode Supports 7 and 10-Bit Addressing
- $I^2C$ Master mode Supports 7 and 10-Bit Addressing
- $I^2C$ Port allows Bidirectional Transfers between Master and Slaves
- Serial Clock Synchronization for $I^2C$ Port can be used as a Handshake Mechanism to Suspend and Resume Serial Transfer (SCLREL control)
- $I^2C$ Supports Multi-Master Operation, Detects Bus Collision and Arbitrates Accordingly
- System Management Bus (SMBus) Support
- Alternate $I^2C$ Pin Mapping (ASCLx/ASDAx)

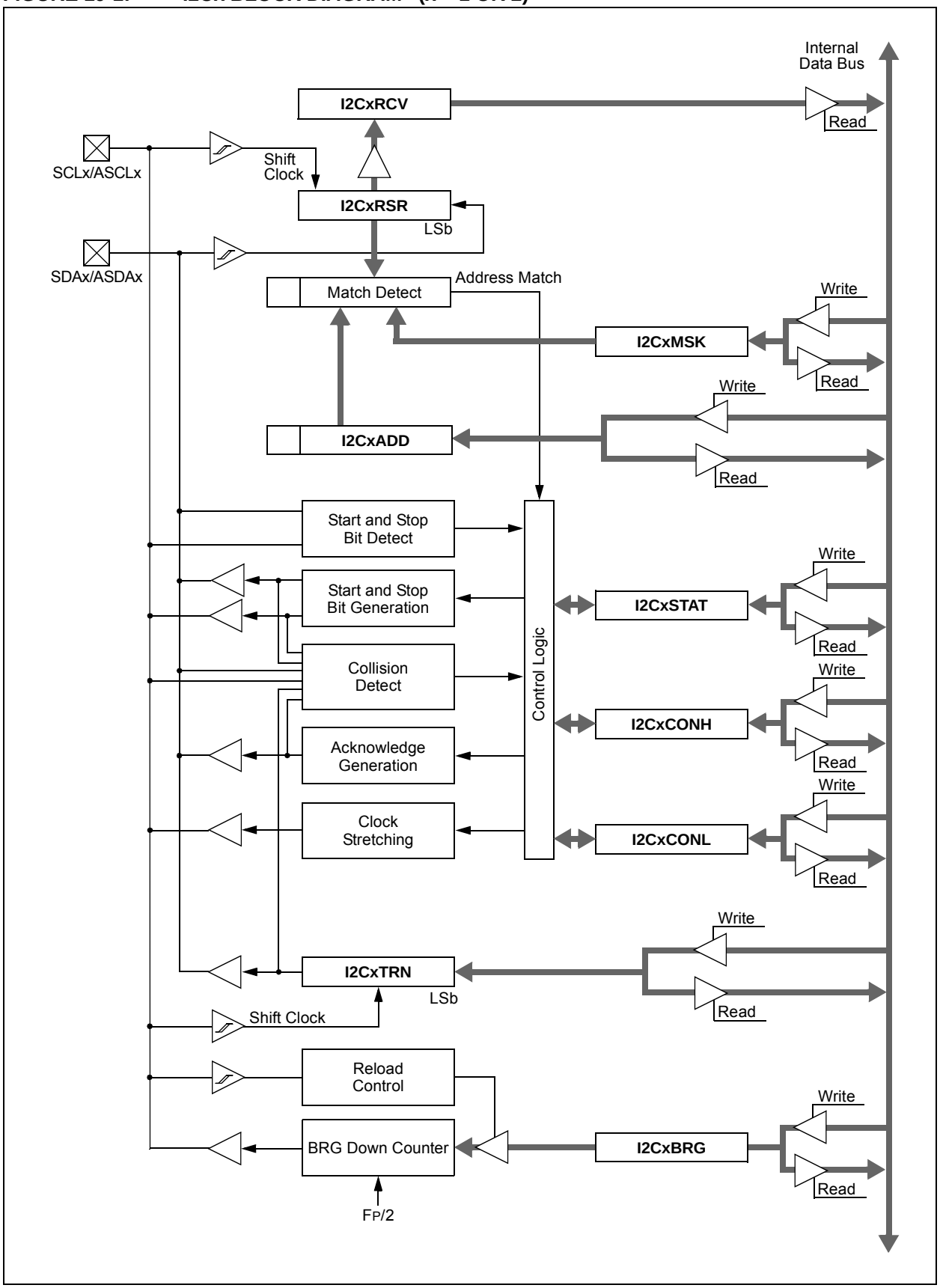
### 19.1 $I^2C$ Resources

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 contains the latest updates and additional information.

#### 19.1.1 KEY RESOURCES

- **"Inter-Integrated Circuit ($I^2C$)"** (DS70000195) 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)**





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## 19.2 I²C Control Registers

**REGISTER 19-1: I2CxCONL: I2Cx CONTROL REGISTER LOW**

| R/W-0 | U-0 | R/W-0 | R/W-1, HC | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| I2CEN | — | I2CSIDL | SCLREL | STRICT | A10M | DISSLW | SMEN |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0, HC | R/W-0, HC | R/W-0, HC | R/W-0, HC | R/W-0, HC |
|---|---|---|---|---|---|---|---|
| GCEN | STREN | ACKDT | ACKEN | RCEN | PEN | RSEN | SEN |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware 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 **I2CEN:** I2Cx Enable bit
1 = Enables the I2Cx module and configures the SDAx and SCLx pins as serial port pins
0 = Disables the I2Cx module; all I²C pins are controlled by port functions

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

bit 13 **I2CSIDL:** I2Cx Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **SCLREL:** SCLx Release Control bit (when operating as I²C slave)
1 = Releases SCLx clock
0 = Holds SCLx clock low (clock stretch)
If STREN = 1:
Bit is R/W (i.e., software can write '0' to initiate stretch and write '1' to release clock). Hardware is clear at the beginning of every slave data byte transmission. Hardware is clear at the end of every slave address byte reception. Hardware is clear at the end of every slave data byte reception.
If STREN = 0:
Bit is R/S (i.e., software can only write '1' to release clock). Hardware is clear at the beginning of every slave data byte transmission. Hardware is clear at the end of every slave address byte reception.

bit 11 **STRICT:** Strict I2Cx Reserved Address Enable bit
1 = Strict Reserved Addressing is Enabled:
In Slave mode, the device will NACK any reserved address. In Master mode, the device is allowed to generate addresses within the reserved address space.
0 = Reserved Addressing is Acknowledged:
In Slave mode, the device will ACK any reserved address. In Master mode, the device should not address a slave device with a reserved address.

bit 10 **A10M:** 10-Bit Slave Address bit
1 = I2CxADD is a 10-bit slave address
0 = I2CxADD is a 7-bit slave address

bit 9 **DISSLW:** Disable Slew Rate Control bit
1 = Slew rate control is disabled
0 = Slew rate control is enabled

bit 8 **SMEN:** SMBus Input Levels bit
1 = Enables I/O pin thresholds compliant with SMBus specification
0 = Disables SMBus input thresholds

bit 7 **GCEN:** General Call Enable bit (when operating as I²C slave)
1 = Enables interrupt when a general call address is received in I2CxRSR (module is enabled for reception)
0 = General call address is disabled

**REGISTER 19-1: I2CxCONL: I2Cx CONTROL REGISTER LOW (CONTINUED)**

bit 6 **STREN:** SCLx Clock Stretch Enable bit (when operating as $I^2C$ slave)
Used in conjunction with the SCLREL bit.
1 = Enables software or receives clock stretching
0 = Disables software or receives clock stretching

bit 5 **ACKDT:** Acknowledge Data bit (when operating as $I^2C$ master, applicable during master receive)
Value that is transmitted when the software initiates an Acknowledge sequence.
1 = Sends NACK during Acknowledge
0 = Sends ACK during Acknowledge

bit 4 **ACKEN:** Acknowledge Sequence Enable bit
(when operating as $I^2C$ master, applicable during master receive)
1 = Initiates Acknowledge sequence on SDAx and SCLx pins and transmits ACKDT data bit; hardware is clear at the end of the master Acknowledge sequence
0 = Acknowledge sequence is not in progress

bit 3 **RCEN:** Receive Enable bit (when operating as $I^2C$ master)
1 = Enables Receive mode for $I^2C$; hardware is clear at the end of the eighth bit of the master receive data byte
0 = Receive sequence is not in progress

bit 2 **PEN:** Stop Condition Enable bit (when operating as $I^2C$ master)
1 = Initiates Stop condition on SDAx and SCLx pins; hardware is clear at the end of the master Stop sequence
0 = Stop condition is not in progress

bit 1 **RSEN:** Repeated Start Condition Enable bit (when operating as $I^2C$ master)
1 = Initiates Repeated Start condition on SDAx and SCLx pins; hardware is clear at the end of the master Repeated Start sequence
0 = Repeated Start condition is not in progress

bit 0 **SEN:** Start Condition Enable bit (when operating as $I^2C$ master)
1 = Initiates Start condition on SDAx and SCLx pins; hardware is clear at the end of the master Start sequence
0 = Start condition is not in progress


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**REGISTER 19-2: I2CxCONH: I2Cx CONTROL REGISTER HIGH**

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

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | PCIE | SCIE | BOEN | SDAHT | SBCDE | AHEN | DHEN |
| 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 15-7 **Unimplemented:** Read as ‘0’

bit 6 **PCIE:** Stop Condition Interrupt Enable bit ($I^2C$ Slave mode only)
1 = Enables interrupt on detection of Stop condition
0 = Stop detection interrupts are disabled

bit 5 **SCIE:** Start Condition Interrupt Enable bit ($I^2C$ Slave mode only)
1 = Enables interrupt on detection of Start or Restart conditions
0 = Start detection interrupts are disabled

bit 4 **BOEN:** Buffer Overwrite Enable bit ($I^2C$ Slave mode only)
1 = I2CxRCV is updated and ACK is generated for a received address/data byte, ignoring the state of the I2COV only if the RBF bit = 0
0 = I2CxRCV is only updated when I2COV is clear

bit 3 **SDAHT:** SDAx Hold Time Selection bit
1 = Minimum of 300 ns hold time on SDAx after the falling edge of SCLx
0 = Minimum of 100 ns hold time on SDAx after the falling edge of SCLx

bit 2 **SBCDE:** Slave Mode Bus Collision Detect Enable bit ($I^2C$ Slave mode only)
1 = Enables slave bus collision interrupts
0 = Slave bus collision interrupts are disabled
If the rising edge of SCLx and SDAx is sampled low when the module is in a high state, the BCL bit is set and the bus goes Idle. This Detection mode is only valid during data and ACK transmit sequences.

bit 1 **AHEN:** Address Hold Enable bit ($I^2C$ Slave mode only)
1 = Following the 8th falling edge of SCLx for a matching received address byte, the SCLREL (I2CxCONL<12>) bit will be cleared and SCLx will be held low
0 = Address holding is disabled

bit 0 **DHEN:** Data Hold Enable bit ($I^2C$ Slave mode only)
1 = Following the 8th falling edge of SCLx for a received data byte, the slave hardware clears the SCLREL (I2CxCONL<12>) bit and SCLx is held low
0 = Data holding is disabled

**REGISTER 19-3: I2CxSTAT: I2Cx STATUS REGISTER**

| R-0, HSC | R-0, HSC | R-0, HSC | U-0 | U-0 | R/C-0, HS | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| ACKSTAT | TRSTAT | ACKTIM | — | — | BCL | GCSTAT | ADD10 |
| bit 15 | | | | | | | bit 8 |

| R/C-0, HS | R/C-0, HS | R-0, HSC | R/C-0, HSC | R/C-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| IWCOL | I2COV | D_A | P | S | R_W | RBF | TBF |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Clearable bit | '0' = Bit is cleared | HS = Hardware Settable bit |
|---|---|---|---|
| R = Readable bit | W = Writable bit | HSC = Hardware Settable/Clearable bit | |
| -n = Value at POR | '1' = Bit is set | U = Unimplemented bit, read as '0' | |

bit 15 **ACKSTAT:** Acknowledge Status bit (when operating as $I^2C$ master, applicable to master transmit operation)
1 = NACK was received from slave
0 = ACK was received from slave
Hardware is set or clear at the end of a slave Acknowledge.

bit 14 **TRSTAT:** Transmit Status bit (when operating as $I^2C$ master, applicable to master transmit operation)
1 = Master transmit is in progress (8 bits + ACK)
0 = Master transmit is not in progress
Hardware is set at the beginning of master transmission. Hardware is clear at the end of slave Acknowledge.

bit 13 **ACKTIM:** Acknowledge Time Status bit ($I^2C$ Slave mode only)
1 = $I^2C$ bus is an Acknowledge sequence, set on the 8th falling edge of SCLx
0 = Not an Acknowledge sequence, cleared on the 9th rising edge of SCLx

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

bit 10 **BCL:** Master Bus Collision Detect bit
1 = A bus collision has been detected during a master operation
0 = No bus collision detected
Hardware is set at detection of a bus collision.

bit 9 **GCSTAT:** General Call Status bit
1 = General call address was received
0 = General call address was not received
Hardware is set when address matches the general call address. Hardware is clear at Stop detection.

bit 8 **ADD10:** 10-Bit Address Status bit
1 = 10-bit address was matched
0 = 10-bit address was not matched
Hardware is set at the match of the 2nd byte of the matched 10-bit address. Hardware is clear at Stop detection.

bit 7 **IWCOL:** I2Cx Write Collision Detect bit
1 = An attempt to write to the I2CxTRN register failed because the $I^2C$ module is busy
0 = No collision
Hardware is set at the occurrence of a write to I2CxTRN while busy (cleared by software).

bit 6 **I2COV:** I2Cx Receive Overflow Flag bit
1 = A byte was received while the I2CxRCV register was still holding the previous byte
0 = No overflow
Hardware is set at an attempt to transfer I2CxRSR to I2CxRCV (cleared by software).

bit 5 **D_A:** Data/Address bit ($I^2C$ Slave mode only)
1 = Indicates that the last byte received was data
0 = Indicates that the last byte received was a device address
Hardware is clear at a device address match. Hardware is set by reception of a slave byte.


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**REGISTER 19-3: I2CxSTAT: I2Cx STATUS REGISTER (CONTINUED)**

bit 4 **P:** Stop bit
1 = Indicates that a Stop bit has been detected last
0 = Stop bit was not detected last
Hardware is set or clear when a Start, Repeated Start or Stop is detected.

bit 3 **S:** Start bit
1 = Indicates that a Start (or Repeated Start) bit has been detected last
0 = Start bit was not detected last
Hardware is set or clear when a Start, Repeated Start or Stop is detected.

bit 2 **R_W:** Read/Write Information bit ($I^2C$ Slave mode only)
1 = Read – Indicates data transfer is output from the slave
0 = Write – Indicates data transfer is input to the slave
Hardware is set or clear after reception of an $I^2C$ device address byte.

bit 1 **RBF:** Receive Buffer Full Status bit
1 = Receive is complete, I2CxRCV is full
0 = Receive is not complete, I2CxRCV is empty
Hardware is set when I2CxRCV is written with a received byte. Hardware is clear when software reads I2CxRCV.

bit 0 **TBF:** Transmit Buffer Full Status bit
1 = Transmit is in progress, I2CxTRN is full
0 = Transmit is complete, I2CxTRN is empty
Hardware is set when software writes to I2CxTRN. Hardware is clear at completion of a data transmission.

**REGISTER 19-4: I2CxMSK: I2Cx SLAVE MODE ADDRESS MASK REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | AMSK<9:8> | |
| 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 |
|---|---|---|---|---|---|---|---|
| AMSK<7:0> | | | | | | | |
| 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 15-10 **Unimplemented:** Read as ‘0’

bit 9-0 **AMSK<9:0>:** Address Mask Select bits

For 10-Bit Address:

1 = Enables masking for bit Ax of incoming message address; bit match is not required in this position

0 = Disables masking for bit Ax; bit match is required in this position

For 7-Bit Address (I2CxMSK<6:0> only):

1 = Enables masking for bit Ax + 1 of incoming message address; bit match is not required in this position

0 = Disables masking for bit Ax + 1; bit match is required in this position


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## 20.0 UNIVERSAL ASYNCHRONOUS RECEIVER TRANSMITTER (UART)

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Universal Asynchronous Receiver Transmitter (UART)"** (DS70000582) in the *"dsPIC33/PIC24 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 dsPIC33EPXXXGS70X/80X family of devices contains two UART modules.

The Universal Asynchronous Receiver Transmitter (UART) module is one of the serial I/O modules available in the dsPIC33EPXXXGS70X/80X device family. The UART is a full-duplex, asynchronous system that can communicate with peripheral devices, such as personal computers, LIN/J2602, RS-232 and RS-485 interfaces. The module also supports a hardware flow control option with the $\overline{\text{UxCTS}}$ and $\overline{\text{UxRTS}}$ pins, and also includes an IrDA® encoder and decoder.

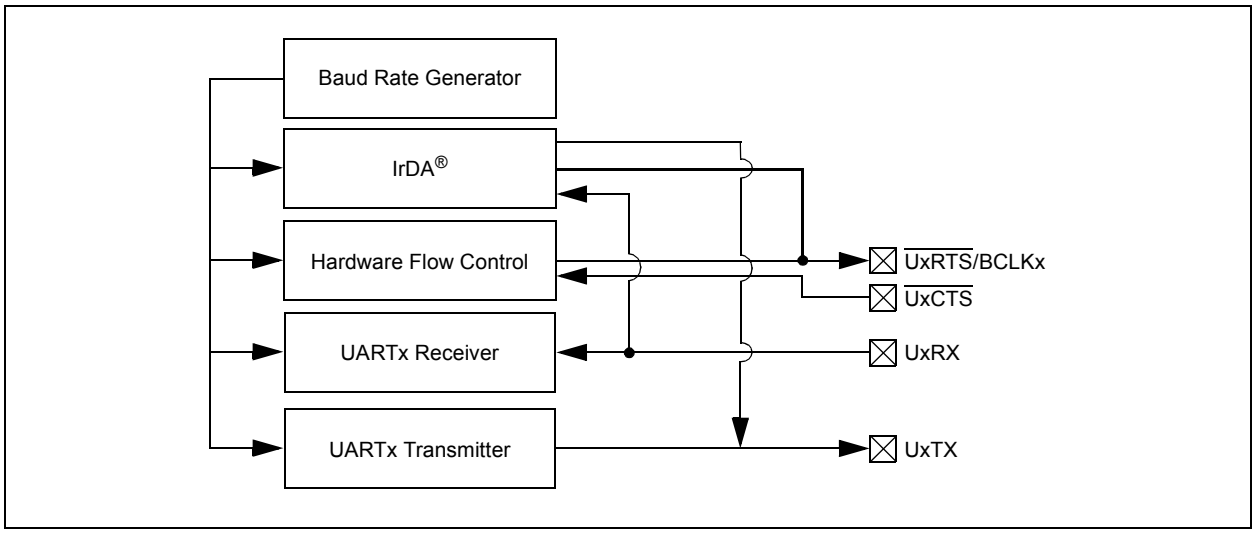
The primary features of the UARTx module are:

- Full-Duplex, 8 or 9-Bit Data Transmission through the UxTX and UxRX Pins
- Even, Odd or No Parity Options (for 8-bit data)
- One or Two Stop bits
- Hardware Flow Control Option with $\overline{\text{UxCTS}}$ and $\overline{\text{UxRTS}}$ Pins
- Fully Integrated Baud Rate Generator with 16-Bit Prescaler
- Baud Rates Ranging from 4.375 Mbps to 67 bps in 16x mode at 70 MIPS
- Baud Rates Ranging from 17.5 Mbps to 267 bps in 4x mode at 70 MIPS
- 4-Deep First-In First-Out (FIFO) Transmit Data Buffer
- 4-Deep FIFO Receive Data Buffer
- Parity, Framing and Buffer Overrun Error Detection
- Support for 9-Bit mode with Address Detect (9th bit = 1)
- Transmit and Receive Interrupts
- A Separate Interrupt for all UARTx Error Conditions
- Loopback mode for Diagnostic Support
- Support for Sync and Break Characters
- Support for Automatic Baud Rate Detection
- IrDA® Encoder and Decoder Logic
- 16x Baud Clock Output for IrDA Support

A simplified block diagram of the UARTx module is shown in Figure 20-1. The UARTx module consists of these key hardware elements:

- Baud Rate Generator
- Asynchronous Transmitter
- Asynchronous Receiver

**FIGURE 20-1: UARTx SIMPLIFIED BLOCK DIAGRAM**



## 20.1 UART Helpful Tips

1. In multi-node, direct connect UART networks, UART receive inputs react to the complementary logic level defined by the URXINV bit (UxMODE<4>), which defines the Idle state, the default of which is logic high (i.e., URXINV = 0). Because remote devices do not initialize at the same time, it is likely that one of the devices, because the RX line is floating, will trigger a Start bit detection and will cause the first byte received, after the device has been initialized, to be invalid. To avoid this situation, the user should use a pull-up or pull-down resistor on the RX pin depending on the value of the URXINV bit.
   a) If URXINV = 0, use a pull-up resistor on the UxRX pin.
   b) If URXINV = 1, use a pull-down resistor on the UxRX pin.
2. The first character received on a wake-up from Sleep mode, caused by activity on the UxRX pin of the UARTx module, will be invalid. In Sleep mode, peripheral clocks are disabled. By the time the oscillator system has restarted and stabilized from Sleep mode, the baud rate bit sampling clock, relative to the incoming UxRX bit timing, is no longer synchronized, resulting in the first character being invalid; this is to be expected.

## 20.2 UART 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 contains the latest updates and additional information.

### 20.2.1 KEY RESOURCES

- **"Universal Asynchronous Receiver Transmitter (UART)"** (DS70000582) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools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## 20.3 UART Control Registers

**REGISTER 20-1: UxMODE: UARTx MODE REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| UARTEN(1) | — | USIDL | IREN(2) | RTSMD | — | UEN1 | UEN0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0, HC | R/W-0 | R/W-0, HC | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| WAKE | LPBACK | ABAUD | URXINV | BRGH | PDSEL1 | PDSEL0 | STSEL |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware 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 **UARTEN:** UARTx Enable bit(1)
- 1 = UARTx is enabled; all UARTx pins are controlled by UARTx as defined by UEN<1:0>
- 0 = UARTx is disabled; all UARTx pins are controlled by PORT latches; UARTx power consumption is minimal

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

bit 13 **USIDL:** UARTx Stop in Idle Mode bit
- 1 = Discontinues module operation when device enters Idle mode
- 0 = Continues module operation in Idle mode

bit 12 **IREN:** IrDA® Encoder and Decoder Enable bit(2)
- 1 = IrDA encoder and decoder are enabled
- 0 = IrDA encoder and decoder are disabled

bit 11 **RTSMD:** Mode Selection for $\overline{\text{UxRTS}}$ Pin bit
- 1 = $\overline{\text{UxRTS}}$ pin is in Simplex mode
- 0 = $\overline{\text{UxRTS}}$ pin is in Flow Control mode

bit 10 **Unimplemented:** Read as '0'

bit 9-8 **UEN<1:0>:** UARTx Pin Enable bits
- 11 = UxTX, UxRX and BCLKx pins are enabled and used; $\overline{\text{UxCTS}}$ pin is controlled by PORT latches
- 10 = UxTX, UxRX, $\overline{\text{UxCTS}}$ and $\overline{\text{UxRTS}}$ pins are enabled and used
- 01 = UxTX, UxRX and $\overline{\text{UxRTS}}$ pins are enabled and used; $\overline{\text{UxCTS}}$ pin is controlled by PORT latches
- 00 = UxTX and UxRX pins are enabled and used; $\overline{\text{UxCTS}}$ and $\overline{\text{UxRTS}}$/BCLKx pins are controlled by PORT latches

bit 7 **WAKE:** Wake-up on Start Bit Detect During Sleep Mode Enable bit
- 1 = UARTx continues to sample the UxRX pin, interrupt is generated on the falling edge; bit is cleared in hardware on the following rising edge
- 0 = No wake-up is enabled

bit 6 **LPBACK:** UARTx Loopback Mode Select bit
- 1 = Enables Loopback mode
- 0 = Loopback mode is disabled

**Note 1:** Refer to **"Universal Asynchronous Receiver Transmitter (UART)"** (DS70000582) in the *"dsPIC33/PIC24 Family Reference Manual"* for information on enabling the UARTx module for receive or transmit operation.

**2:** This feature is only available for the 16x BRG mode (BRGH = 0).

**REGISTER 20-1: UxMODE: UARTx MODE REGISTER (CONTINUED)**

bit 5 **ABAUD:** Auto-Baud Enable bit
1 = Enables baud rate measurement on the next character – requires reception of a Sync field (55h) before other data; cleared in hardware upon completion
0 = Baud rate measurement is disabled or completed

bit 4 **URXINV:** UARTx Receive Polarity Inversion bit
1 = UxRX Idle state is '0'
0 = UxRX Idle state is '1'

bit 3 **BRGH:** High Baud Rate Enable bit
1 = BRG generates 4 clocks per bit period (4x baud clock, High-Speed mode)
0 = BRG generates 16 clocks per bit period (16x baud clock, Standard mode)

bit 2-1 **PDSEL<1:0>:** Parity and Data Selection bits
11 = 9-bit data, no parity
10 = 8-bit data, odd parity
01 = 8-bit data, even parity
00 = 8-bit data, no parity

bit 0 **STSEL:** Stop Bit Selection bit
1 = Two Stop bits
0 = One Stop bit

**Note 1:** Refer to **"Universal Asynchronous Receiver Transmitter (UART)"** (DS70000582) in the *"dsPIC33/PIC24 Family Reference Manual"* for information on enabling the UARTx module for receive or transmit operation.

**2:** This feature is only available for the 16x BRG mode (BRGH = 0).


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**REGISTER 20-2: UxSTA: UARTx STATUS AND CONTROL REGISTER**

| R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0, HC | R/W-0 | R-0 | R-1 |
|---|---|---|---|---|---|---|---|
| UTXISEL1 | UTXINV | UTXISEL0 | — | UTXBRK | UTXEN(1) | UTXBF | TRMT |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R-1 | R-0 | R-0 | R/C-0 | R-0 |
|---|---|---|---|---|---|---|---|
| URXISEL1 | URXISEL0 | ADDEN | RIDLE | PERR | FERR | OERR | URXDA |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Clearable bit | HC = Hardware 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 15,13 **UTXISEL<1:0>:** UARTx Transmission Interrupt Mode Selection bits
- 11 = Reserved; do not use
- 10 = Interrupt when a character is transferred to the Transmit Shift Register (TSR), and as a result, the transmit buffer becomes empty
- 01 = Interrupt when the last character is shifted out of the Transmit Shift Register; all transmit operations are completed
- 00 = Interrupt when a character is transferred to the Transmit Shift Register (this implies there is at least one character open in the transmit buffer)

bit 14 **UTXINV:** UARTx Transmit Polarity Inversion bit

If IREN = 0:
- 1 = UxTX Idle state is '0'
- 0 = UxTX Idle state is '1'

If IREN = 1:
- 1 = IrDA® encoded, UxTX Idle state is '1'
- 0 = IrDA encoded, UxTX Idle state is '0'

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

bit 11 **UTXBRK:** UARTx Transmit Break bit
- 1 = Sends Sync Break on next transmission – Start bit, followed by twelve '0' bits, followed by Stop bit; cleared by hardware upon completion
- 0 = Sync Break transmission is disabled or completed

bit 10 **UTXEN:** UARTx Transmit Enable bit(1)
- 1 = Transmit is enabled, UxTX pin is controlled by UARTx
- 0 = Transmit is disabled, any pending transmission is aborted and buffer is reset; UxTX pin is controlled by the PORT

bit 9 **UTXBF:** UARTx Transmit Buffer Full Status bit (read-only)
- 1 = Transmit buffer is full
- 0 = Transmit buffer is not full, at least one more character can be written

bit 8 **TRMT:** Transmit Shift Register Empty bit (read-only)
- 1 = Transmit Shift Register is empty and transmit buffer is empty (the last transmission has completed)
- 0 = Transmit Shift Register is not empty, a transmission is in progress or queued

bit 7-6 **URXISEL<1:0>:** UARTx Receive Interrupt Mode Selection bits
- 11 = Interrupt is set on UxRSR transfer, making the receive buffer full (i.e., has 4 data characters)
- 10 = Interrupt is set on UxRSR transfer, making the receive buffer 3/4 full (i.e., has 3 data characters)
- 0x = Interrupt is set when any character is received and transferred from the UxRSR to the receive buffer; receive buffer has one or more characters

**Note 1:** Refer to **"Universal Asynchronous Receiver Transmitter (UART)"** (DS70000582) in the *"dsPIC33/PIC24 Family Reference Manual"* for information on enabling the UARTx module for transmit operation.

**REGISTER 20-2: UxSTA: UARTx STATUS AND CONTROL REGISTER (CONTINUED)**

bit 5 **ADDEN:** Address Character Detect bit (bit 8 of received data = 1)
1 = Address Detect mode is enabled; if 9-bit mode is not selected, this does not take effect
0 = Address Detect mode is disabled

bit 4 **RIDLE:** Receiver Idle bit (read-only)
1 = Receiver is Idle
0 = Receiver is active

bit 3 **PERR:** Parity Error Status bit (read-only)
1 = Parity error has been detected for the current character (character at the top of the receive FIFO)
0 = Parity error has not been detected

bit 2 **FERR:** Framing Error Status bit (read-only)
1 = Framing error has been detected for the current character (character at the top of the receive FIFO)
0 = Framing error has not been detected

bit 1 **OERR:** Receive Buffer Overrun Error Status bit (clear/read-only)
1 = Receive buffer has overflowed
0 = Receive buffer has not overflowed; clearing a previously set OERR bit (1 → 0 transition) resets the receiver buffer and the UxRSR to the empty state

bit 0 **URXDA:** UARTx Receive Buffer Data Available bit (read-only)
1 = Receive buffer has data, at least one more character can be read
0 = Receive buffer is empty

**Note 1:** Refer to **"Universal Asynchronous Receiver Transmitter (UART)"** (DS70000582) in the *"dsPIC33/PIC24 Family Reference Manual"* for information on enabling the UARTx module for transmit operation.


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## 21.0 CONFIGURABLE LOGIC CELL (CLC)

**Note:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Configurable Logic Cell (CLC)"** (DS70005298) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

The Configurable Logic Cell (CLC) module allows the user to specify combinations of signals as inputs to a logic function and to use the logic output to control other peripherals or I/O pins. This provides greater flexibility and potential in embedded designs since the CLC module can operate outside the limitations of software execution and supports a vast amount of output designs.

There are four input gates to the selected logic function. These four input gates select from a pool of up to 32 signals that are selected using four data source selection multiplexers. Figure 21-1 shows an overview of the module. Figure 21-3 shows the details of the data source multiplexers and logic input gate connections.

**FIGURE 21-1: CLCx MODULE**

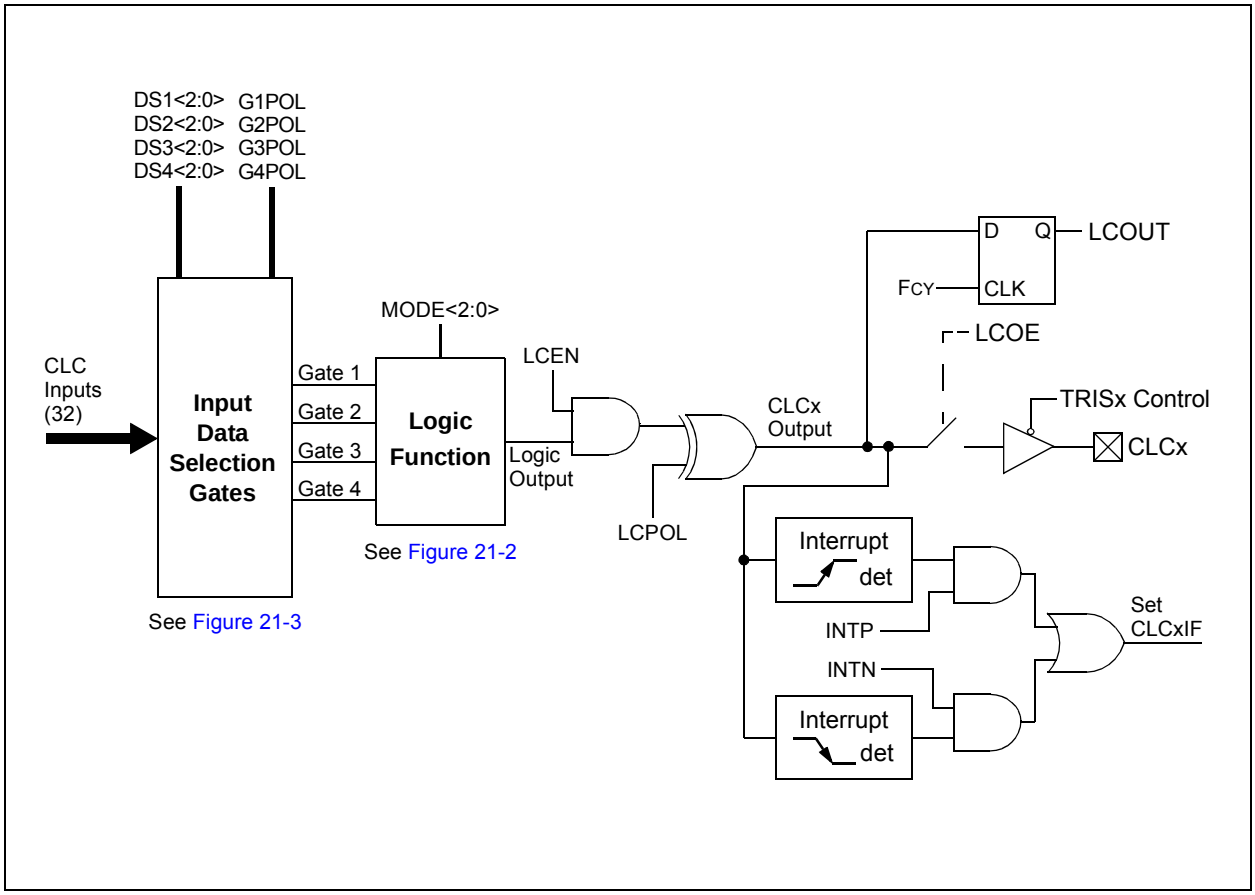
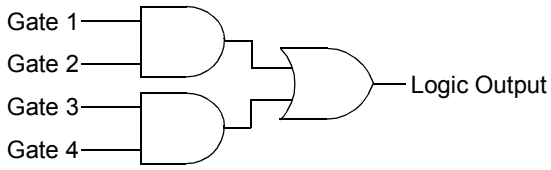


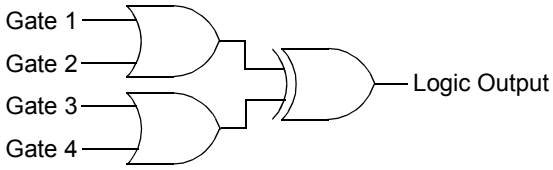
**FIGURE 21-2: CLCx LOGIC FUNCTION COMBINATORIAL OPTIONS**

**AND – OR**



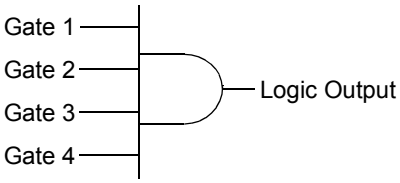

MODE<2:0> = 000

**OR – XOR**



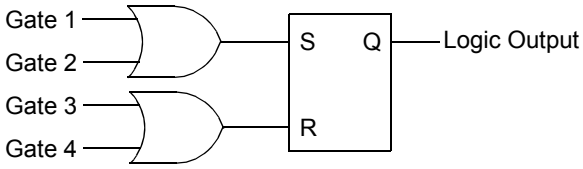

MODE<2:0> = 001

**4-Input AND**



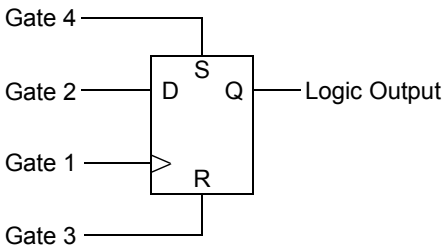

MODE<2:0> = 010

**S-R Latch**



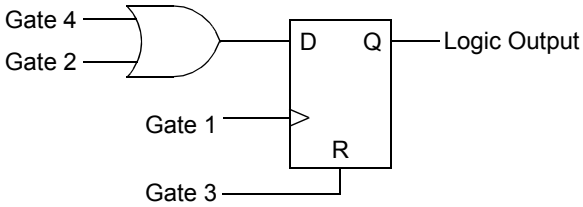

MODE<2:0> = 011

**1-Input D Flip-Flop with S and R**



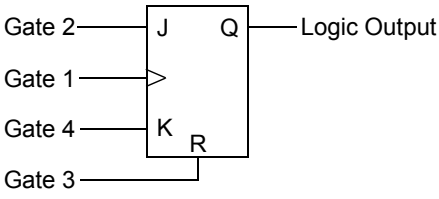

MODE<2:0> = 100

**2-Input D Flip-Flop with R**



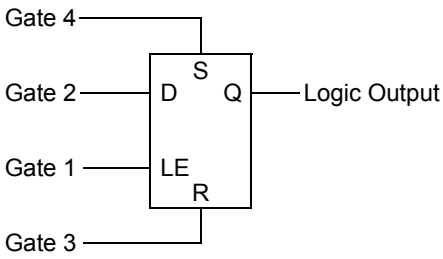

MODE<2:0> = 101

**J-K Flip-Flop with R**




MODE<2:0> = 110

**1-Input Transparent Latch with S and R**




MODE<2:0> = 111


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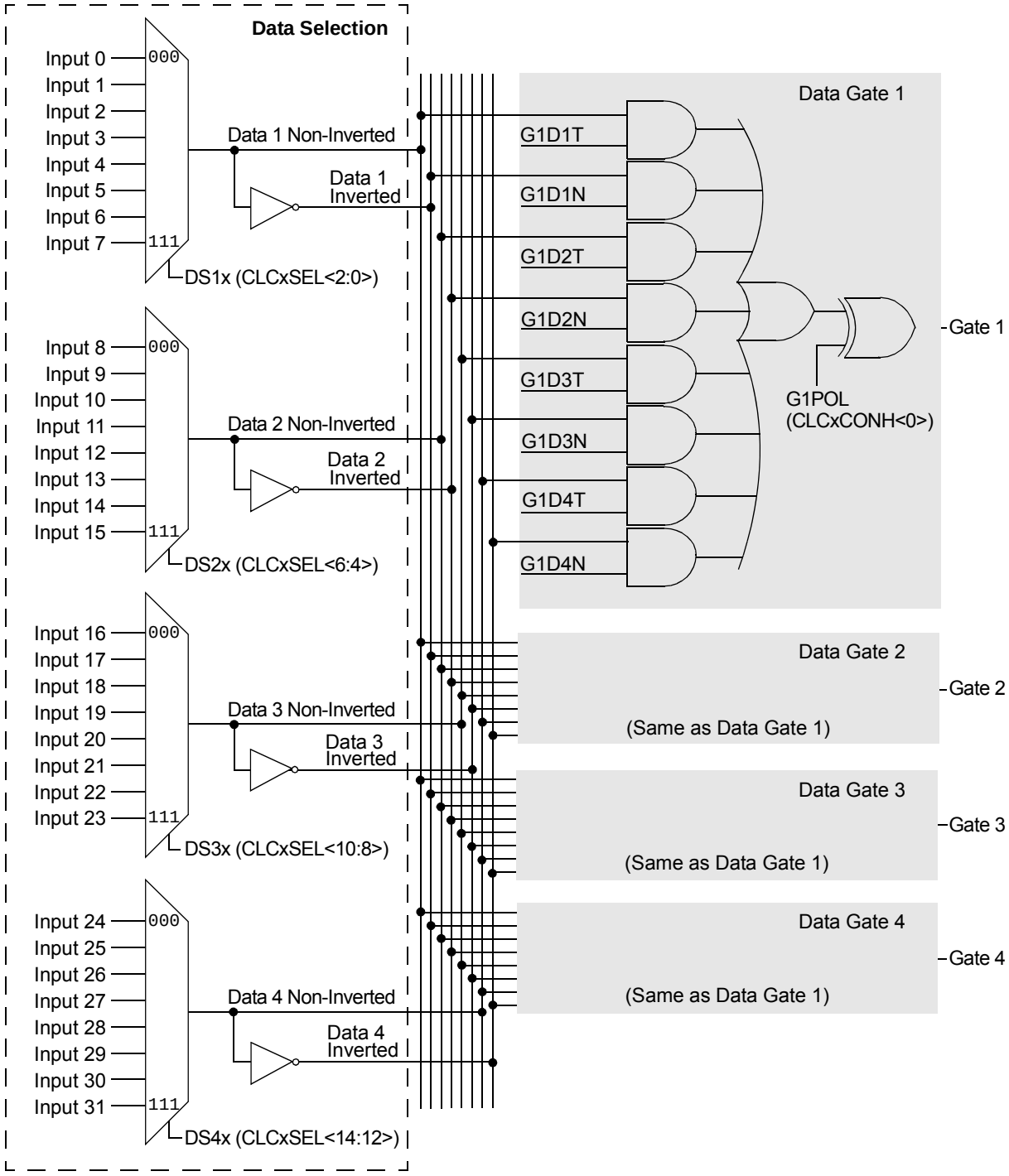
**FIGURE 21-3: CLCx INPUT SOURCE SELECTION DIAGRAM**




**Note:** All controls are undefined at power-up.

## 21.1 Control Registers

The CLCx module is controlled by the following registers:

- CLCxCONL
- CLCxCONH
- CLCxSEL
- CLCxGLSL
- CLCxGLSH

The CLCx Control registers (CLCxCONL and CLCxCONH) are used to enable the module and interrupts, control the output enable bit, select output polarity and select the logic function. The CLCx Control registers also allow the user to control the logic polarity of not only the cell output, but also some intermediate variables.

The CLCx Input MUX Select register (CLCxSEL) allows the user to select up to 4 data input sources using the 4 data input selection multiplexers. Each multiplexer has a list of 8 data sources available.

The CLCx Gate Logic Input Select registers (CLCxGLSL and CLCxGLSH) allow the user to select which outputs from each of the selection MUXes are used as inputs to the input gates of the logic cell. Each data source MUX outputs both a true and a negated version of its output. All of these 8 signals are enabled, ORed together by the logic cell input gates.

**REGISTER 21-1: CLCxCONL: CLCx CONTROL REGISTER (LOW)**

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| LCEN | — | — | — | INTP | INTN | — | — |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| LCOE | LCOUT | LCPOL | — | — | MODE2 | MODE1 | MODE0 |
| 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 **LCEN:** CLCx Enable bit
1 = CLCx is enabled and mixing input signals
0 = CLCx is disabled and has logic zero outputs

bit 14-12 **Unimplemented:** Read as ‘0’

bit 11 **INTP:** CLCx Positive Edge Interrupt Enable bit
1 = Interrupt will be generated when a rising edge occurs on LCOUT
0 = Interrupt will not be generated

bit 10 **INTN:** CLCx Negative Edge Interrupt Enable bit
1 = Interrupt will be generated when a falling edge occurs on LCOUT
0 = Interrupt will not be generated

bit 9-8 **Unimplemented:** Read as ‘0’

bit 7 **LCOE:** CLCx Port Enable bit
1 = CLCx port pin output is enabled
0 = CLCx port pin output is disabled

bit 6 **LCOUT:** CLCx Data Output Status bit
1 = CLCx output high
0 = CLCx output low

bit 5 **LCPOL:** CLCx Output Polarity Control bit
1 = The output of the module is inverted
0 = The output of the module is not inverted

bit 4-3 **Unimplemented:** Read as ‘0’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**REGISTER 21-1: CLCxCONL: CLCx CONTROL REGISTER (LOW) (CONTINUED)**

bit 2-0 **MODE<2:0>:** CLCx Mode bits
111 = Single Input Transparent Latch with S and R
110 = JK Flip-Flop with R
101 = Two-Input D Flip-Flop with R
100 = Single Input D Flip-Flop with S and R
011 = SR Latch
010 = Four-Input AND
001 = Four-Input OR-XOR
000 = Four-Input AND-OR

**REGISTER 21-2: CLCxCONH: CLCx CONTROL REGISTER (HIGH)**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | G4POL | G3POL | G2POL | G1POL |
| 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 15-4 **Unimplemented:** Read as '0'

bit 3 **G4POL:** Gate 4 Polarity Control bit
1 = Channel 4 logic output is inverted when applied to the logic cell
0 = Channel 4 logic output is not inverted

bit 2 **G3POL:** Gate 3 Polarity Control bit
1 = Channel 3 logic output is inverted when applied to the logic cell
0 = Channel 3 logic output is not inverted

bit 1 **G2POL:** Gate 2 Polarity Control bit
1 = Channel 2 logic output is inverted when applied to the logic cell
0 = Channel 2 logic output is not inverted

bit 0 **G1POL:** Gate 1 Polarity Control bit
1 = Channel 1 logic output is inverted when applied to the logic cell
0 = Channel 1 logic output is not inverted

**REGISTER 21-3: CLCxSEL: CLCx INPUT MUX SELECT REGISTER**

| U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | DS4<2:0> | | | — | DS3<2:0> | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | DS2<2:0> | | | — | DS1<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 **DS4<2:0>:** Data Selection MUX 4 Signal Selection bits
See Table Table 21-1 for input selections.

bit 11 **Unimplemented:** Read as ‘0’

bit 10-8 **DS3<2:0>:** Data Selection MUX 3 Signal Selection bits
See Table Table 21-1 for input selections.

bit 7 **Unimplemented:** Read as ‘0’

bit 6-4 **DS2<2:0>:** Data Selection MUX 2 Signal Selection bits
See Table Table 21-1 for input selections.

bit 3 **Unimplemented:** Read as ‘0’

bit 2-0 **DS1<2:0>:** Data Selection MUX 1 Signal Selection bits
See Table Table 21-1 for input selections.


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**TABLE 21-1: CLC1 MULTIPLEXER INPUT SOURCES**

| DSx<2:0> | | Signal Source |
|---|---|---|
| DS1<2:0> | 000 | CLCINA |
| | 001 | System Clock |
| | 010 | Timer1 Match |
| | 011 | PWM1H |
| | 100 | PWM5L |
| | 101 | High-Speed PWM Clock |
| | 110 | Timer2 Match |
| | 111 | Timer3 Match |
| DS2<2:0> | 000 | CLCINB |
| | 001 | CLC2 Out |
| | 010 | CMP1 Out |
| | 011 | UART1 TX Out |
| | 100 | ADC End-of-Conversion |
| | 101 | DMA Channel 0 Interrupt |
| | 110 | PWM1L |
| | 111 | PWM5H |
| DS3<2:0> | 000 | CLCINA |
| | 001 | CLC1 Out |
| | 010 | CMP2 Out |
| | 011 | SPI1 SDO Out |
| | 100 | UART1 RX |
| | 101 | PWM2H |
| | 110 | PWM6L |
| | 111 | OCMP2 |
| DS4<2:0> | 000 | CLCINB |
| | 001 | CLC2 Out |
| | 010 | CMP3 Out |
| | 011 | SDI1 |
| | 100 | PTG |
| | 101 | ECAN1 |
| | 110 | PWM2L |
| | 111 | PWM6H |

**TABLE 21-2: CLC2 MULTIPLEXER INPUT SOURCES**

| DSx<2:0> | | Signal Source |
|---|---|---|
| DS1<2:0> | 000 | CLCINA |
| | 001 | System Clock |
| | 010 | Timer1 Match |
| | 011 | PWM3H |
| | 100 | PWM7L |
| | 101 | High-Speed PWM Clock |
| | 110 | Timer2 Match |
| | 111 | Timer3 Match |
| DS2<2:0> | 000 | CLCINB |
| | 001 | CLC1 Out |
| | 010 | CMP1 Out |
| | 011 | UART2 TX Out |
| | 100 | ADC End-of-Conversion |
| | 101 | DMA Channel 0 Interrupt |
| | 110 | PWM3L |
| | 111 | PWM7H |
| DS3<2:0> | 000 | CLCINA |
| | 001 | CLC2 Out |
| | 010 | CMP2 Out |
| | 011 | SPI2 SDO Out |
| | 100 | UART2 RX |
| | 101 | PWM4H |
| | 110 | PWM8L |
| | 111 | OCMP2 |
| DS4<2:0> | 000 | CLCINB |
| | 001 | CLC1 Out |
| | 010 | CMP3 Out |
| | 011 | SDI2 |
| | 100 | PTG |
| | 101 | ECAN1 |
| | 110 | PWM4L |
| | 111 | PWM8H |


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**TABLE 21-3: CLC3 MULTIPLEXER INPUT SOURCES**

| DSx<2:0> | | Signal Source |
|---|---|---|
| DS1<2:0> | 000 | CLCINA |
| | 001 | System Clock |
| | 010 | Timer1 Match |
| | 011 | PWM5H |
| | 100 | REFO1 Clock Output |
| | 101 | High-Speed PWM Clock |
| | 110 | Timer2 Match |
| | 111 | PWM3L |
| DS2<2:0> | 000 | CLCINB |
| | 001 | CLC4 Out |
| | 010 | CMP1 Out |
| | 011 | PWM5L |
| | 100 | ADC End-of-Conversion |
| | 101 | PWM3H |
| | 110 | ICAP1 |
| | 111 | ICAP2 |
| DS3<2:0> | 000 | CLCINA |
| | 001 | CLC3 Out |
| | 010 | CMP2 Out |
| | 011 | PWM6H |
| | 100 | UART1 RX |
| | 101 | DMA Channel 1 Interrupt |
| | 110 | OCMP1 |
| | 111 | PWM4L |
| DS4<2:0> | 000 | CLCINB |
| | 001 | CLC4 Out |
| | 010 | CMP3 Out |
| | 011 | PWM6L |
| | 100 | PTG |
| | 101 | PWM4H |
| | 110 | PC_PWM |
| | 111 | OCMP3 |

**TABLE 21-4: CLC4 MULTIPLEXER INPUT SOURCES**

| DSx<2:0> | | Signal Source |
|---|---|---|
| DS1<2:0> | 000 | CLCINA |
| | 001 | PWM7H |
| | 010 | Timer1 Match |
| | 011 | INTOSC/LPRC Clock |
| | 100 | REFO1 Clock Output |
| | 101 | High-Speed PWM Clock |
| | 110 | Timer2 Match |
| | 111 | PWM1L |
| DS2<2:0> | 000 | CLCINB |
| | 001 | CLC3 Out |
| | 010 | CMP1 Out |
| | 011 | PWM7L |
| | 100 | ADC End-of-Conversion |
| | 101 | PWM1H |
| | 110 | ICAP1 |
| | 111 | ICAP2 |
| DS3<2:0> | 000 | CLCINA |
| | 001 | CLC4 Out |
| | 010 | CMP2 Out |
| | 011 | PWM8H |
| | 100 | UART2 RX |
| | 101 | DMA Channel 1 Interrupt |
| | 110 | OCMP1 |
| | 111 | PWM2L |
| DS4<2:0> | 000 | CLCINB |
| | 001 | CLC3 Out |
| | 010 | CMP3 Out |
| | 011 | PWM8L |
| | 100 | PTG |
| | 101 | PWM2H |
| | 110 | PC_PWM |
| | 111 | OCMP3 |


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**REGISTER 21-4: CLCxGLSL: CLCx GATE LOGIC INPUT SELECT LOW REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| G2D4T | G2D4N | G2D3T | G2D3N | G2D2T | G2D2N | G2D1T | G2D1N |
| 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 |
|---|---|---|---|---|---|---|---|
| G1D4T | G1D4N | G1D3T | G1D3N | G1D2T | G1D2N | G1D1T | G1D1N |
| 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 **G2D4T:** Gate 2 Data Source 4 True Enable bit
1 = Data Source 4 non-inverted signal is enabled for Gate 2
0 = Data Source 4 non-inverted signal is disabled for Gate 2

bit 14 **G2D4N:** Gate 2 Data Source 4 Negated Enable bit
1 = Data Source 4 inverted signal is enabled for Gate 2
0 = Data Source 4 inverted signal is disabled for Gate 2

bit 13 **G2D3T:** Gate 2 Data Source 3 True Enable bit
1 = Data Source 3 non-inverted signal is enabled for Gate 2
0 = Data Source 3 non-inverted signal is disabled for Gate 2

bit 12 **G2D3N:** Gate 2 Data Source 3 Negated Enable bit
1 = Data Source 3 inverted signal is enabled for Gate 2
0 = Data Source 3 inverted signal is disabled for Gate 2

bit 11 **G2D2T:** Gate 2 Data Source 2 True Enable bit
1 = Data Source 2 non-inverted signal is enabled for Gate 2
0 = Data Source 2 non-inverted signal is disabled for Gate 2

bit 10 **G2D2N:** Gate 2 Data Source 2 Negated Enable bit
1 = Data Source 2 inverted signal is enabled for Gate 2
0 = Data Source 2 inverted signal is disabled for Gate 2

bit 9 **G2D1T:** Gate 2 Data Source 1 True Enable bit
1 = Data Source 1 non-inverted signal is enabled for Gate 2
0 = Data Source 1 non-inverted signal is disabled for Gate 2

bit 8 **G2D1N:** Gate 2 Data Source 1 Negated Enable bit
1 = Data Source 1 inverted signal is enabled for Gate 2
0 = Data Source 1 inverted signal is disabled for Gate 2

bit 7 **G1D4T:** Gate 1 Data Source 4 True Enable bit
1 = Data Source 4 non-inverted signal is enabled for Gate 1
0 = Data Source 4 non-inverted signal is disabled for Gate 1

bit 6 **G1D4N:** Gate 1 Data Source 4 Negated Enable bit
1 = Data Source 4 inverted signal is enabled for Gate 1
0 = Data Source 4 inverted signal is disabled for Gate 1

bit 5 **G1D3T:** Gate 1 Data Source 3 True Enable bit
1 = Data Source 3 non-inverted signal is enabled for Gate 1
0 = Data Source 3 non-inverted signal is disabled for Gate 1

bit 4 **G1D3N:** Gate 1 Data Source 3 Negated Enable bit
1 = Data Source 3 inverted signal is enabled for Gate 1
0 = Data Source 3 inverted signal is disabled for Gate 1

**REGISTER 21-4: CLCxGLSL: CLCx GATE LOGIC INPUT SELECT LOW REGISTER (CONTINUED)**

bit 3 **G1D2T:** Gate 1 Data Source 2 True Enable bit
1 = Data Source 2 non-inverted signal is enabled for Gate 1
0 = Data Source 2 non-inverted signal is disabled for Gate 1

bit 2 **G1D2N:** Gate 1 Data Source 2 Negated Enable bit
1 = Data Source 2 inverted signal is enabled for Gate 1
0 = Data Source 2 inverted signal is disabled for Gate 1

bit 1 **G1D1T:** Gate 1 Data Source 1 True Enable bit
1 = Data Source 1 non-inverted signal is enabled for Gate 1
0 = Data Source 1 non-inverted signal is disabled for Gate 1

bit 0 **G1D1N:** Gate 1 Data Source 1 Negated Enable bit
1 = Data Source 1 inverted signal is enabled for Gate 1
0 = Data Source 1 inverted signal is disabled for Gate 1


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**REGISTER 21-5: CLCxGLSH: CLCx GATE LOGIC INPUT SELECT HIGH REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| G4D4T | G4D4N | G4D3T | G4D3N | G4D2T | G4D2N | G4D1T | G4D1N |
| 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 |
|---|---|---|---|---|---|---|---|
| G3D4T | G3D4N | G3D3T | G3D3N | G3D2T | G3D2N | G3D1T | G3D1N |
| 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 **G4D4T:** Gate 4 Data Source 4 True Enable bit
1 = Data Source 4 non-inverted signal is enabled for Gate 4
0 = Data Source 4 non-inverted signal is disabled for Gate 4

bit 14 **G4D4N:** Gate 4 Data Source 4 Negated Enable bit
1 = Data Source 4 inverted signal is enabled for Gate 4
0 = Data Source 4 inverted signal is disabled for Gate 4

bit 13 **G4D3T:** Gate 4 Data Source 3 True Enable bit
1 = Data Source 3 non-inverted signal is enabled for Gate 4
0 = Data Source 3 non-inverted signal is disabled for Gate 4

bit 12 **G4D3N:** Gate 4 Data Source 3 Negated Enable bit
1 = Data Source 3 inverted signal is enabled for Gate 4
0 = Data Source 3 inverted signal is disabled for Gate 4

bit 11 **G4D2T:** Gate 4 Data Source 2 True Enable bit
1 = Data Source 2 non-inverted signal is enabled for Gate 4
0 = Data Source 2 non-inverted signal is disabled for Gate 4

bit 10 **G4D2N:** Gate 4 Data Source 2 Negated Enable bit
1 = Data Source 2 inverted signal is enabled for Gate 4
0 = Data Source 2 inverted signal is disabled for Gate 4

bit 9 **G4D1T:** Gate 4 Data Source 1 True Enable bit
1 = Data Source 1 non-inverted signal is enabled for Gate 4
0 = Data Source 1 non-inverted signal is disabled for Gate 4

bit 8 **G4D1N:** Gate 4 Data Source 1 Negated Enable bit
1 = Data Source 1 inverted signal is enabled for Gate 4
0 = Data Source 1 inverted signal is disabled for Gate 4

bit 7 **G3D4T:** Gate 3 Data Source 4 True Enable bit
1 = Data Source 4 non-inverted signal is enabled for Gate 3
0 = Data Source 4 non-inverted signal is disabled for Gate 3

bit 6 **G3D4N:** Gate 3 Data Source 4 Negated Enable bit
1 = Data Source 4 inverted signal is enabled for Gate 3
0 = Data Source 4 inverted signal is disabled for Gate 3

bit 5 **G3D3T:** Gate 3 Data Source 3 True Enable bit
1 = Data Source 3 non-inverted signal is enabled for Gate 3
0 = Data Source 3 non-inverted signal is disabled for Gate 3

bit 4 **G3D3N:** Gate 3 Data Source 3 Negated Enable bit
1 = Data Source 3 inverted signal is enabled for Gate 3
0 = Data Source 3 inverted signal is disabled for Gate 3

**REGISTER 21-5: CLCxGLSH: CLCx GATE LOGIC INPUT SELECT HIGH REGISTER (CONTINUED)**

bit 3 **G3D2T:** Gate 3 Data Source 2 True Enable bit
1 = Data Source 2 non-inverted signal is enabled for Gate 3
0 = Data Source 2 non-inverted signal is disabled for Gate 3

bit 2 **G3D2N:** Gate 3 Data Source 2 Negated Enable bit
1 = Data Source 2 inverted signal is enabled for Gate 3
0 = Data Source 2 inverted signal is disabled for Gate 3

bit 1 **G3D1T:** Gate 3 Data Source 1 True Enable bit
1 = Data Source 1 non-inverted signal is enabled for Gate 3
0 = Data Source 1 non-inverted signal is disabled for Gate 3

bit 0 **G3D1N:** Gate 3 Data Source 1 Negated Enable bit
1 = Data Source 1 inverted signal is enabled for Gate 3
0 = Data Source 1 inverted signal is disabled for Gate 3


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## 22.0 HIGH-SPEED, 12-BIT ANALOG-TO-DIGITAL CONVERTER (ADC)

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"12-Bit High-Speed, Multiple SARs A/D Converter (ADC)**" (DS70005213) in the *"dsPIC33/PIC24 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.

dsPIC33EPXXXGS70X/80X devices have a high-speed, 12-bit Analog-to-Digital Converter (ADC) that features a low conversion latency, high resolution and oversampling capabilities to improve performance in AC/DC, DC/DC power converters.

### 22.1 Features Overview

The high-speed, 12-bit multiple SARs Analog-to-Digital Converter (ADC) includes the following features:

- Five ADC Cores: Four Dedicated Cores and One Shared (common) Core
- User-Configurable Resolution of up to 12 Bits for each Core
- Up to 3.25 Msps Conversion Rate per Channel at 12-Bit Resolution
- Low Latency Conversion
- Up to 22 Analog Input Channels, with a Separate 16-Bit Conversion Result Register for each Input
- Conversion Result can be Formatted as Unsigned or Signed Data, on a per Channel Basis, for All Channels
- Single-Ended and Pseudodifferential Conversions are available on All ADC Cores
- Simultaneous Sampling of up to 5 Analog Inputs
- Channel Scan Capability
- Multiple Conversion Trigger Options for each Core, including:
  - PWM1 through PWM6 (primary and secondary triggers, and current-limit event trigger)
  - PWM Special Event Trigger
  - Timer1/Timer2 period match
  - Output Compare 1 and event trigger
  - External pin trigger event (ADTRG31)
  - Software trigger
- Two Integrated Digital Comparators with Dedicated Interrupts:
  - Multiple comparison options
  - Assignable to specific analog inputs
- Two Oversampling Filters with Dedicated Interrupts:
  - Provide increased resolution
  - Assignable to a specific analog input

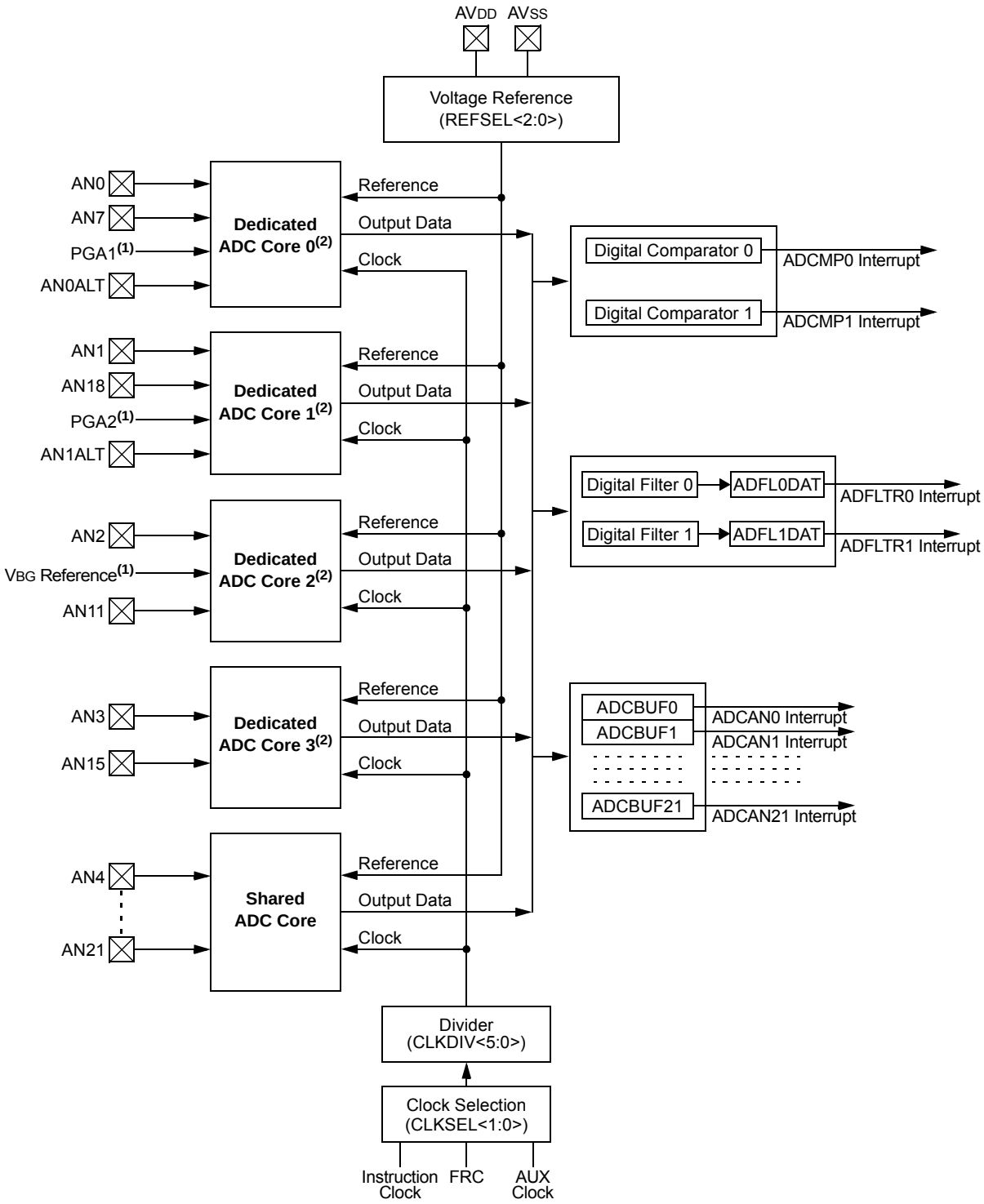
The module consists of five independent SAR ADC cores. Simplified block diagrams of the multiple SARs 12-bit ADC are shown in Figure 22-1, Figure 22-2 and Figure 22-3.

The analog inputs (channels) are connected through multiplexers and switches to the Sample-and-Hold (S&H) circuit of each ADC core. The core uses the channel information (the output format, the Measurement mode and the input number) to process the analog sample. When conversion is complete, the result is stored in the result buffer for the specific analog input, and passed to the digital filter and digital comparator if they were configured to use data from this particular channel.

The ADC module can sample up to five inputs at a time (four inputs from the dedicated SAR cores and one from the shared SAR core). If multiple ADC inputs request conversion on the shared core, the module will convert them in a sequential manner, starting with the lowest order input.

The ADC provides each analog input the ability to specify its own trigger source. This capability allows the ADC to sample and convert analog inputs that are associated with PWM generators operating on independent time bases.

**FIGURE 22-1: ADC MODULE BLOCK DIAGRAM**




**Note 1:** PGA1, PGA2 and the Band Gap Reference ($V_{BG}$) are internal analog inputs and are not available on device pins.

**2:** If the dedicated core uses an alternate channel, then shared core function cannot be used.


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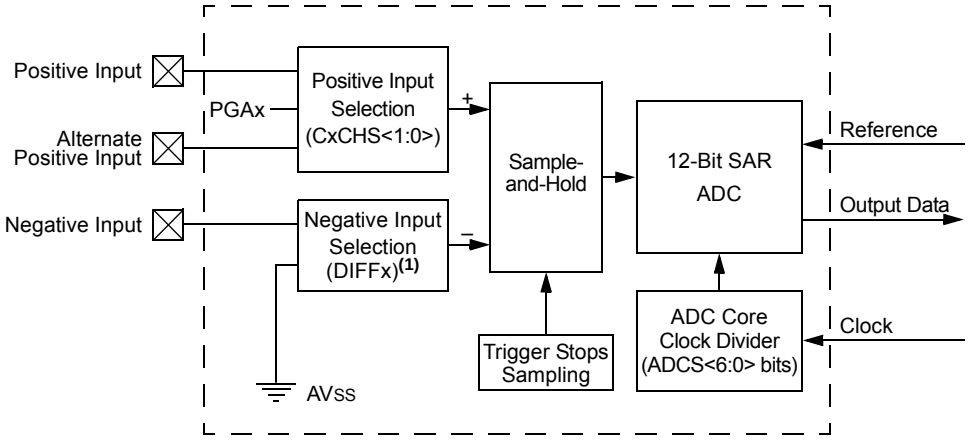
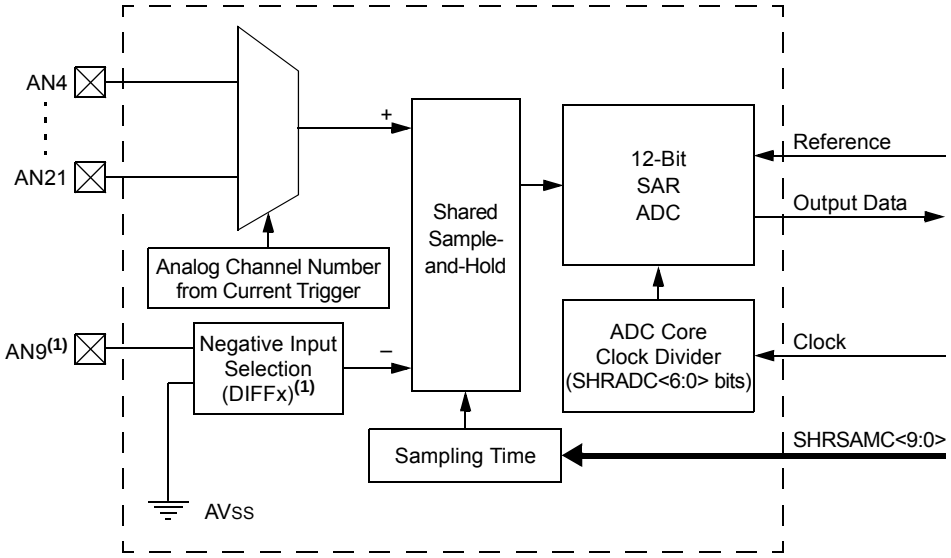
**FIGURE 22-2: DEDICATED ADC CORES 0 TO 3 BLOCK DIAGRAM**




**Note 1:** The DIFFx bit for the corresponding positive input channel must be set in order to use the negative differential input.

**FIGURE 22-3: SHARED ADC CORE BLOCK DIAGRAM**




**Note 1:** Differential-mode conversion is not available for the shared ADC core in dsPIC33EPXXGS70X/80X devices. For all other devices, the DIFFx bit for the corresponding positive input channel must be set to use AN9 as the negative differential input.

## 22.2 Analog-to-Digital Converter 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 contains the latest updates and additional information.

### 22.2.1 KEY RESOURCES

- **"12-Bit High-Speed, Multiple SARs A/D Converter (ADC)**" (DS70005213) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

**REGISTER 22-1: ADCON1L: ADC CONTROL REGISTER 1 LOW**

| R/W-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| ADON(1) | — | ADSIDL | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | r-0 | r-0 | r-0 | r-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | r = Reserved 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 Enable bit(1)
1 = ADC module is enabled
0 = ADC module is off

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

bit 13 **ADSIDL:** ADC Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-7 **Unimplemented:** Read as '0'

bit 6-3 **Reserved:** Maintain as '0'

bit 2-0 **Unimplemented:** Read as '0'

**Note 1:** Set the ADON bit only after the ADC module has been configured. Changing ADC Configuration bits when ADON = 1 will result in unpredictable behavior.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**REGISTER 22-2: ADCON1H: ADC CONTROL REGISTER 1 HIGH**

| r-0 | r-0 | r-0 | r-0 | r-0 | r-0 | r-0 | r-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-1 | R/W-1 | r-0 | r-0 | r-0 | r-0 | r-0 |
|---|---|---|---|---|---|---|---|
| FORM | SHRRES1 | SHRRES0 | — | — | — | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | r = Reserved 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 15-8 **Reserved:** Maintain as ‘0’

bit 7 **FORM:** Fractional Data Output Format bit
1 = Fractional
0 = Integer

bit 6-5 **SHRRES<1:0>:** Shared ADC Core Resolution Selection bits
11 = 12-bit resolution
10 = 10-bit resolution
01 = 8-bit resolution
00 = 6-bit resolution

bit 4-0 **Reserved:** Maintain as ‘0’

**REGISTER 22-3: ADCON2L: ADC CONTROL REGISTER 2 LOW**

| R/W-0 | R/W-0 | r-0 | R/W-0 | r-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| REFCIE | REFERCIE | — | EIEN | — | SHREISEL2(1) | SHREISEL1(1) | SHREISEL0(1) |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | SHRADCS6 | SHRADCS5 | SHRADCS4 | SHRADCS3 | SHRADCS2 | SHRADCS1 | SHRADCS0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | r = Reserved 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 **REFCIE:** Band Gap and Reference Voltage Ready Common Interrupt Enable bit
1 = Common interrupt will be generated when the band gap will become ready
0 = Common interrupt is disabled for the band gap ready event

bit 14 **REFERCIE:** Band Gap or Reference Voltage Error Common Interrupt Enable bit
1 = Common interrupt will be generated when a band gap or reference voltage error is detected
0 = Common interrupt is disabled for the band gap and reference voltage error event

bit 13 **Reserved:** Maintain as '0'

bit 12 **EIEN:** Early Interrupts Enable bit
1 = The early interrupt feature is enabled for the input channel interrupts (when the EISTATx flag is set)
0 = The individual interrupts are generated when conversion is done (when the ANxRDY flag is set)

bit 11 **Reserved:** Maintain as '0'

bit 10-8 **SHREISEL<2:0>:** Shared Core Early Interrupt Time Selection bits(1)
111 = Early interrupt is set and interrupt is generated 8 TADCORE clocks prior to when the data is ready
110 = Early interrupt is set and interrupt is generated 7 TADCORE clocks prior to when the data is ready
101 = Early interrupt is set and interrupt is generated 6 TADCORE clocks prior to when the data is ready
100 = Early interrupt is set and interrupt is generated 5 TADCORE clocks prior to when the data is ready
011 = Early interrupt is set and interrupt is generated 4 TADCORE clocks prior to when the data is ready
010 = Early interrupt is set and interrupt is generated 3 TADCORE clocks prior to when the data is ready
001 = Early interrupt is set and interrupt is generated 2 TADCORE clocks prior to when the data is ready
000 = Early interrupt is set and interrupt is generated 1 TADCORE clock prior to when the data is ready

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

bit 6-0 **SHRADCS<6:0>:** Shared ADC Core Input Clock Divider bits
These bits determine the number of TCORESRC (Source Clock Periods) for one shared TADCORE (Core Clock Period).
1111111 = 254 Source Clock Periods
•
•
•
0000011 = 6 Source Clock Periods
0000010 = 4 Source Clock Periods
0000001 = 2 Source Clock Periods
0000000 = 2 Source Clock Periods

**Note 1:** For the 6-bit shared ADC core resolution (SHRRES<1:0> = 00), the SHREISEL<2:0> settings, from '100' to '111', are not valid and should not be used. For the 8-bit shared ADC core resolution (SHRRES<1:0> = 01), the SHREISEL<2:0> settings, '110' and '111', are not valid and should not be used.


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**REGISTER 22-4: ADCON2H: ADC CONTROL REGISTER 2 HIGH**

| R-0, HSC | R-0, HSC | r-0 | r-0 | r-0 | r-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| REFRDY | REFERR | — | — | — | — | SHRSAMC9 | SHRSAMC8 |
| 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 |
|---|---|---|---|---|---|---|---|
| SHRSAMC7 | SHRSAMC6 | SHRSAMC5 | SHRSAMC4 | SHRSAMC3 | SHRSAMC2 | SHRSAMC1 | SHRSAMC0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | r = Reserved bit | U = Unimplemented bit, read as ‘0’ | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | HSC = Hardware Settable/Clearable bit | |
| -n = Value at POR | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 15 **REFRDY:** Band Gap and Reference Voltage Ready Flag bit
1 = Band gap is ready
0 = Band gap is not ready

bit 14 **REFERR:** Band Gap or Reference Voltage Error Flag bit
1 = Band gap was removed after the ADC module was enabled (ADON = 1)
0 = No band gap error was detected

bit 13-10 **Reserved:** Maintain as ‘0’

bit 9-0 **SHRSAMC<9:0>:** Shared ADC Core Sample Time Selection bits
These bits specify the number of shared ADC Core Clock Periods (TADCORE) for the shared ADC core sample time.
1111111111 = 1025 TADCORE
•
•
•
0000000001 = 3 TADCORE
0000000000 = 2 TADCORE

**REGISTER 22-5: ADCON3L: ADC CONTROL REGISTER 3 LOW**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-0, HSC | R/W-0 | R-0, HSC |
|---|---|---|---|---|---|---|---|
| REFSEL2 | REFSEL1 | REFSEL0 | SUSPEND | SUSPCIE | SUSPRDY | SHRSAMP | CNVRTCH |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0, HSC | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SWLCTRG | SWCTRG | CNVCHSEL5 | CNVCHSEL4 | CNVCHSEL3 | CNVCHSEL2 | CNVCHSEL1 | CNVCHSEL0 |
| bit 7 | | | | | | | bit 0 |

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

bit 15-13 **REFSEL<2:0>:** ADC Reference Voltage Selection bits

| Value | VREFH | VREFL |
|---|---|---|
| 000 | AVDD | AVSS |

001-111 = **Unimplemented:** Do not use

bit 12 **SUSPEND:** All ADC Cores Triggers Disable bit

1 = All new trigger events for all ADC cores are disabled
0 = All ADC cores can be triggered

bit 11 **SUSPCIE:** Suspend All ADC Cores Common Interrupt Enable bit

1 = Common interrupt will be generated when ADC core triggers are suspended (SUSPEND bit = 1) and all previous conversions are finished (SUSPRDY bit becomes set)
0 = Common interrupt is not generated for suspend ADC cores event

bit 10 **SUSPRDY:** All ADC Cores Suspended Flag bit

1 = All ADC cores are suspended (SUSPEND bit = 1) and have no conversions in progress
0 = ADC cores have previous conversions in progress

bit 9 **SHRSAMP:** Shared ADC Core Sampling Direct Control bit

This bit should be used with the individual channel conversion trigger controlled by the CNVRTCH bit. It connects an analog input, specified by the CNVCHSEL<5:0> bits, to the shared ADC core and allows extending the sampling time. This bit is not controlled by hardware and must be cleared before the conversion starts (setting CNVRTCH to '1').

1 = Shared ADC core samples an analog input specified by the CNVCHSEL<5:0> bits
0 = Sampling is controlled by the shared ADC core hardware

bit 8 **CNVRTCH:** Software Individual Channel Conversion Trigger bit

1 = Single trigger is generated for an analog input specified by the CNVCHSEL<5:0> bits; when the bit is set, it is automatically cleared by hardware on the next instruction cycle
0 = Next individual channel conversion trigger can be generated

bit 7 **SWLCTRG:** Software Level-Sensitive Common Trigger bit

1 = Triggers are continuously generated for all channels with the software, level-sensitive common trigger selected as a source in the ADTRIGxL and ADTRIGxH registers
0 = No software, level-sensitive common triggers are generated

bit 6 **SWCTRG:** Software Common Trigger bit

1 = Single trigger is generated for all channels with the software, common trigger selected as a source in the ADTRIGxL and ADTRIGxH registers; when the bit is set, it is automatically cleared by hardware on the next instruction cycle
0 = Ready to generate the next software common trigger

bit 5-0 **CNVCHSEL <5:0>:** Channel Number Selection for Software Individual Channel Conversion Trigger bits

These bits define a channel to be converted when the CNVRTCH bit is set.


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**REGISTER 22-6: ADCON3H: ADC CONTROL REGISTER 3 HIGH**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CLKSEL1 | CLKSEL0 | CLKDIV5 | CLKDIV4 | CLKDIV3 | CLKDIV2 | CLKDIV1 | CLKDIV0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SHREN | — | — | — | C3EN | C2EN | C1EN | C0EN |
| 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 **CLKSEL<1:0>:** ADC Module Clock Source Selection bits
11 = APLL
10 = FRC
01 = FOSC (System Clock x 2)
00 = FSYS (System Clock)

bit 13-8 **CLKDIV<5:0>:** ADC Module Clock Source Divider bits
The divider forms a TCORESRC clock used by all ADC cores (shared and dedicated) from the TSRC ADC module clock source selected by the CLKSEL<1:0> bits. Then, each ADC core individually divides the TCORESRC clock to get a core-specific TADCORE clock using the ADCS<6:0> bits in the ADCOREXH register or the SHRADCS<6:0> bits in the ADCON2L register.
111111 = 64 Source Clock Periods
•
•
•
000011 = 4 Source Clock Periods
000010 = 3 Source Clock Periods
000001 = 2 Source Clock Periods
000000 = 1 Source Clock Period

bit 7 **SHREN:** Shared ADC Core Enable bit
1 = Shared ADC core is enabled
0 = Shared ADC core is disabled

bit 6-4 **Unimplemented:** Read as ‘0’

bit 3 **C3EN:** Dedicated ADC Core 3 Enable bits
1 = Dedicated ADC Core 3 is enabled
0 = Dedicated ADC Core 3 is disabled

bit 2 **C2EN:** Dedicated ADC Core 2 Enable bits
1 = Dedicated ADC Core 2 is enabled
0 = Dedicated ADC Core 2 is disabled

bit 1 **C1EN:** Dedicated ADC Core 1 Enable bits
1 = Dedicated ADC Core 1 is enabled
0 = Dedicated ADC Core 1 is disabled

bit 0 **C0EN:** Dedicated ADC Core 0 Enable bits
1 = Dedicated ADC Core 0 is enabled
0 = Dedicated ADC Core 0 is disabled

**REGISTER 22-7: ADCON4L: ADC CONTROL REGISTER 4 LOW**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | SAMC3EN | SAMC2EN | SAMC1EN | SAMC0EN |
| 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 15-4 **Unimplemented:** Read as ‘0’

bit 3 **SAMC3EN:** Dedicated ADC Core 3 Conversion Delay Enable bit
- 1 = After trigger, the conversion will be delayed and the ADC core will continue sampling during the time specified by the SAMC<9:0> bits in the ADCORE3L register
- 0 = After trigger, the sampling will be stopped immediately and the conversion will be started on the next core clock cycle

bit 2 **SAMC2EN:** Dedicated ADC Core 2 Conversion Delay Enable bit
- 1 = After trigger, the conversion will be delayed and the ADC core will continue sampling during the time specified by the SAMC<9:0> bits in the ADCORE2L register
- 0 = After trigger, the sampling will be stopped immediately and the conversion will be started on the next core clock cycle

bit 1 **SAMC1EN:** Dedicated ADC Core 1 Conversion Delay Enable bit
- 1 = After trigger, the conversion will be delayed and the ADC core will continue sampling during the time specified by the SAMC<9:0> bits in the ADCORE1L register
- 0 = After trigger, the sampling will be stopped immediately and the conversion will be started on the next core clock cycle

bit 0 **SAMC0EN:** Dedicated ADC Core 0 Conversion Delay Enable bit
- 1 = After trigger, the conversion will be delayed and the ADC core will continue sampling during the time specified by the SAMC<9:0> bits in the ADCORE0L register
- 0 = After trigger, the sampling will be stopped immediately and the conversion will be started on the next core clock cycle


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**REGISTER 22-8: ADCON4H: ADC CONTROL REGISTER 4 HIGH**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| C3CHS1 | C3CHS0 | C2CHS1 | C2CHS0 | C1CHS1 | C1CHS0 | C0CHS1 | C0CHS0 |
| 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 **Unimplemented:** Read as ‘0’

bit 7-6 **C3CHS<1:0>:** Dedicated ADC Core 3 Input Channel Selection bits
1x = Reserved
01 = AN15 (differential negative input when DIFF3 (ADMOD0L<7>) = 1)
00 = AN3

bit 5-4 **C2CHS<1:0>:** Dedicated ADC Core 2 Input Channel Selection bits
11 = Reserved
10 = VREF band gap
01 = AN11 (differential negative input when DIFF2 (ADMOD0L<5>) = 1)
00 = AN2

bit 3-2 **C1CHS<1:0>:** Dedicated ADC Core 1 Input Channel Selection bits
11 = AN1ALT
10 = PGA2
01 = AN18 (differential negative input when DIFF1 (ADMOD0L<3>) = 1)
00 = AN1

bit 1-0 **C0CHS<1:0>:** Dedicated ADC Core 0 Input Channel Selection bits
11 = AN0ALT
10 = PGA1
01 = AN7 (differential negative input when DIFF0 (ADMOD0L<1>) = 1)
00 = AN0

**REGISTER 22-9: ADCON5L: ADC CONTROL REGISTER 5 LOW**

| R-0, HSC | U-0 | U-0 | U-0 | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| SHRRDY | — | — | — | C3RDY | C2RDY | C1RDY | C0RDY |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SHRPWR | — | — | — | C3PWR | C2PWR | C1PWR | C0PWR |
| bit 7 | | | | | | | bit 0 |

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

bit 15 **SHRRDY:** Shared ADC Core Ready Flag bit
1 = ADC core is powered and ready for operation
0 = ADC core is not ready for operation

bit 14-12 **Unimplemented:** Read as '0'

bit 11 **C3RDY:** Dedicated ADC Core 3 Ready Flag bit
1 = ADC core is powered and ready for operation
0 = ADC core is not ready for operation

bit 10 **C2RDY:** Dedicated ADC Core 2 Ready Flag bit
1 = ADC core is powered and ready for operation
0 = ADC core is not ready for operation

bit 9 **C1RDY:** Dedicated ADC Core 1 Ready Flag bit
1 = ADC core is powered and ready for operation
0 = ADC core is not ready for operation

bit 8 **C0RDY:** Dedicated ADC Core 0 Ready Flag bit
1 = ADC core is powered and ready for operation
0 = ADC core is not ready for operation

bit 7 **SHRPWR:** Shared ADC Core x Power Enable bit
1 = ADC Core x is powered
0 = ADC Core x is off

bit 6-4 **Unimplemented:** Read as '0'

bit 3 **C3PWR:** Dedicated ADC Core 3 Power Enable bit
1 = ADC core is powered
0 = ADC core is off

bit 2 **C2PWR:** Dedicated ADC Core 2 Power Enable bit
1 = ADC core is powered
0 = ADC core is off

bit 1 **C1PWR:** Dedicated ADC Core 1 Power Enable bit
1 = ADC core is powered
0 = ADC core is off

bit 0 **C0PWR:** Dedicated ADC Core 0 Power Enable bit
1 = ADC core is powered
0 = ADC core is off


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**REGISTER 22-10: ADCON5H: ADC CONTROL REGISTER 5 HIGH**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | WARMTIME3 | WARMTIME2 | WARMTIME1 | WARMTIME0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SHRCIE | — | — | — | C3CIE | C2CIE | C1CIE | C0CIE |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11-8 **WARMTIME<3:0>:** ADC Dedicated Core x Power-up Delay bits

These bits determine the power-up delay in the number of the Core Source Clock Periods (TCORESRC) for all ADC cores.

1111 = 32768 Source Clock Periods
1110 = 16384 Source Clock Periods
1101 = 8192 Source Clock Periods
1100 = 4096 Source Clock Periods
1011 = 2048 Source Clock Periods
1010 = 1024 Source Clock Periods
1001 = 512 Source Clock Periods
1000 = 256 Source Clock Periods
0111 = 128 Source Clock Periods
0110 = 64 Source Clock Periods
0101 = 32 Source Clock Periods
0100 = 16 Source Clock Periods
00xx = 16 Source Clock Periods

bit 7 **SHRCIE:** Shared ADC Core Ready Common Interrupt Enable bit

1 = Common interrupt will be generated when ADC core is powered and ready for operation
0 = Common interrupt is disabled for an ADC core ready event

bit 6-4 **Unimplemented:** Read as '0'

bit 3 **C3CIE:** Dedicated ADC Core 3 Ready Common Interrupt Enable bit

1 = Common interrupt will be generated when ADC Core 3 is powered and ready for operation
0 = Common interrupt is disabled for an ADC Core 3 ready event

bit 2 **C2CIE:** Dedicated ADC Core 2 Ready Common Interrupt Enable bit

1 = Common interrupt will be generated when ADC Core 2 is powered and ready for operation
0 = Common interrupt is disabled for an ADC Core 2 ready event

bit 1 **C1CIE:** Dedicated ADC Core 1 Ready Common Interrupt Enable bit

1 = Common interrupt will be generated when ADC Core 1 is powered and ready for operation
0 = Common interrupt is disabled for an ADC Core 1 ready event

bit 0 **C0CIE:** Dedicated ADC Core 0 Ready Common Interrupt Enable bit

1 = Common interrupt will be generated when ADC Core 0 is powered and ready for operation
0 = Common interrupt is disabled for an ADC Core 0 ready event

**REGISTER 22-11: ADCOREXL: DEDICATED ADC CORE x CONTROL REGISTER LOW (x = 0 to 3)**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | SAMC<9:8> | |
| 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 |
|---|---|---|---|---|---|---|---|
| SAMC<7:0> | | | | | | | |
| 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 15-10 **Unimplemented:** Read as '0'

bit 9-0 **SAMC<9:0>:** Dedicated ADC Core x Conversion Delay Selection bits

These bits determine the time between the trigger event and the start of conversion in the number of the Core Clock Periods (TADCORE). During this time, the ADC Core x still continues sampling. This feature is enabled by the SAMCxEN bits in the ADCON4L register.

1111111111 = 1025 TADCORE

•

•

•

0000000001 = 3 TADCORE

0000000000 = 2 TADCORE



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**REGISTER 22-12: ADCOREXH: DEDICATED ADC CORE x CONTROL REGISTER HIGH (x = 0 to 3)(1)**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | EISEL2 | EISEL1 | EISEL0 | RES1 | RES0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | ADCS6 | ADCS5 | ADCS4 | ADCS3 | ADCS2 | ADCS1 | ADCS0 |
| 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 **Unimplemented:** Read as '0'

bit 12-10 **EISEL<2:0>:** ADC Core x Early Interrupt Time Selection bits

111 = Early interrupt is set and an interrupt is generated 8 TADCORE clocks prior to when the data is ready
110 = Early interrupt is set and an interrupt is generated 7 TADCORE clocks prior to when the data is ready
101 = Early interrupt is set and an interrupt is generated 6 TADCORE clocks prior to when the data is ready
100 = Early interrupt is set and an interrupt is generated 5 TADCORE clocks prior to when the data is ready
011 = Early interrupt is set and an interrupt is generated 4 TADCORE clocks prior to when the data is ready
010 = Early interrupt is set and an interrupt is generated 3 TADCORE clocks prior to when the data is ready
001 = Early interrupt is set and an interrupt is generated 2 TADCORE clocks prior to when the data is ready
000 = Early interrupt is set and an interrupt is generated 1 TADCORE clock prior to when the data is ready

bit 9-8 **RES<1:0>:** ADC Core x Resolution Selection bits

11 = 12-bit resolution
10 = 10-bit resolution
01 = 8-bit resolution
00 = 6-bit resolution

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

bit 6-0 **ADCS<6:0>:** ADC Core x Input Clock Divider bits

These bits determine the number of Source Clock Periods (TCORESRC) for one Core Clock Period (TADCORE).
1111111 = 254 Source Clock Periods
•
•
•
0000011 = 6 Source Clock Periods
0000010 = 4 Source Clock Periods
0000001 = 2 Source Clock Periods
0000000 = 2 Source Clock Periods

**Note 1:** For the 6-bit ADC core resolution (RES<1:0> = 00), the EISEL<2:0> bits settings, from '100' to '111', are not valid and should not be used. For the 8-bit ADC core resolution (RES<1:0> = 01), the EISEL<2:0> bits settings, '110' and '111', are not valid and should not be used.

**REGISTER 22-13: ADLVLTRGL: ADC LEVEL-SENSITIVE TRIGGER CONTROL REGISTER LOW**

| R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| LVLEN<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| LVLEN<7:0> | | | | | | | |
| 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 15-0 **LVLEN<15:0>:** Level Trigger for Corresponding Analog Input Enable bits
1 = Input trigger is level-sensitive
0 = Input trigger is edge-sensitive

**REGISTER 22-14: ADLVLTRGH: ADC LEVEL-SENSITIVE TRIGGER CONTROL REGISTER HIGH**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | LVLEN<21:16> | | | | | |
| 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 5-0 **LVLEN<21:16>:** Level Trigger for Corresponding Analog Input Enable bits
1 = Input trigger is level-sensitive
0 = Input trigger is edge-sensitive


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**REGISTER 22-15: ADEIEL: ADC EARLY INTERRUPT ENABLE REGISTER LOW**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| EIEN<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| EIEN<7:0> | | | | | | | |
| 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 15-0 **EIEN<15:0>:** Early Interrupt Enable for Corresponding Analog Inputs bits
1 = Early interrupt is enabled for the channel
0 = Early interrupt is disabled for the channel

**REGISTER 22-16: ADEIEH: ADC EARLY INTERRUPT ENABLE REGISTER HIGH**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | EIEN<21:16> | | | | | |
| 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 5-0 **EIEN<21:16>:** Early Interrupt Enable for Corresponding Analog Inputs bits
1 = Early interrupt is enabled for the channel
0 = Early interrupt is disabled for the channel

**REGISTER 22-17: ADEISTATL: ADC EARLY INTERRUPT STATUS REGISTER LOW**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| EISTAT<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| EISTAT<7:0> | | | | | | | |
| 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 15-0 **EISTAT<15:0>:** Early Interrupt Status for Corresponding Analog Inputs bits
1 = Early interrupt was generated
0 = Early interrupt was not generated since the last ADCBUFx read

**REGISTER 22-18: ADEISTATH: ADC EARLY INTERRUPT STATUS REGISTER HIGH**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | EISTAT<21:16> | | | | | |
| 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 5-0 **EISTAT<21:16>:** Early Interrupt Status for Corresponding Analog Inputs bits
1 = Early interrupt was generated
0 = Early interrupt was not generated since the last ADCBUFx read


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**REGISTER 22-19: ADMOD0L: ADC INPUT MODE CONTROL REGISTER 0 LOW**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| DIFF7 | SIGN7 | DIFF6 | SIGN6 | DIFF5 | SIGN5 | DIFF4 | SIGN4 |
| 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 |
|---|---|---|---|---|---|---|---|
| DIFF3 | SIGN3 | DIFF2 | SIGN2 | DIFF1 | SIGN1 | DIFF0 | SIGN0 |
| 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(odd) **DIFF<7:0>:** Differential-Mode for Corresponding Analog Inputs bits
1 = Channel is differential
0 = Channel is single-ended

bit 14-0 (even) **SIGN<7:0>:** Output Data Sign for Corresponding Analog Inputs bits
1 = Channel output data is signed
0 = Channel output data is unsigned

**REGISTER 22-20: ADMOD0H: ADC INPUT MODE CONTROL REGISTER 0 HIGH**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| DIFF15 | SIGN15 | DIFF14 | SIGN14 | DIFF13 | SIGN13 | DIFF12 | SIGN12 |
| 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 |
|---|---|---|---|---|---|---|---|
| DIFF11 | SIGN11 | DIFF10 | SIGN10 | DIFF9 | SIGN9 | DIFF8 | SIGN8 |
| 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(odd) **DIFF<15:8>:** Differential-Mode for Corresponding Analog Inputs bits
1 = Channel is differential
0 = Channel is single-ended

bit 14-0 (even) **SIGN<15:8>:** Output Data Sign for Corresponding Analog Inputs bits
1 = Channel output data is signed
0 = Channel output data is unsigned

**REGISTER 22-21: ADMOD1L: ADC INPUT MODE CONTROL REGISTER 1 LOW**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | DIFF21 | SIGN21 | DIFF20 | SIGN20 |
| 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 |
|---|---|---|---|---|---|---|---|
| DIFF19 | SIGN19 | DIFF18 | SIGN18 | DIFF17 | SIGN17 | DIFF16 | SIGN16 |
| 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 15-12 **Unimplemented:** Read as ‘0’

bit 11-1(odd) **DIFF<21:16>:** Differential-Mode for Corresponding Analog Inputs bits
1 = Channel is differential
0 = Channel is single-ended

bit 10-0 (even) **SIGN<21:16>:** Output Data Sign for Corresponding Analog Inputs bits
1 = Channel output data is signed
0 = Channel output data is unsigned


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**REGISTER 22-22: ADIEL: ADC INTERRUPT ENABLE REGISTER LOW**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| IE<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| IE<7:0> | | | | | | | |
| 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 15-0 **IE<15:0>:** Common Interrupt Enable bits
1 = Common and individual interrupts are enabled for the corresponding channel
0 = Common and individual interrupts are disabled for the corresponding channel

**REGISTER 22-23: ADIEH: ADC INTERRUPT ENABLE REGISTER HIGH**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | IE<21:16> | | | | | |
| 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 5-0 **IE<21:16>:** Common Interrupt Enable bits
1 = Common and individual interrupts are enabled for the corresponding channel
0 = Common and individual interrupts are disabled for the corresponding channel

**REGISTER 22-24: ADSTATL: ADC DATA READY STATUS REGISTER LOW**

| R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| AN<15:8>RDY | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| AN<7:0>RDY | | | | | | | |
| bit 7 | | | | | | | bit 0 |

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

bit 15-0 **AN<15:0>RDY:** Common Interrupt Enable for Corresponding Analog Inputs bits
1 = Channel conversion result is ready in the corresponding ADCBUFx register
0 = Channel conversion result is not ready

**REGISTER 22-25: ADSTATH: ADC DATA READY STATUS REGISTER HIGH**

| 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-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| — | — | AN<21:16>RDY | | | | | |
| bit 7 | | | | | | | bit 0 |

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

bit 15-6 **Unimplemented:** Read as '0'

bit 5-0 **AN<21:16>RDY:** Common Interrupt Enable for Corresponding Analog Inputs bits
1 = Channel conversion result is ready in the corresponding ADCBUFx register
0 = Channel conversion result is not ready


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**REGISTER 22-26: ADTRIGxL: ADC CHANNEL TRIGGER x SELECTION REGISTER LOW (x = 0 to 5)**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | TRGSRC(4x+1)<4:0> | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | TRGSRC(4x)<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 15-13 **Unimplemented:** Read as '0'

bit 12-8 **TRGSRC(4x+1)<4:0>:** Trigger Source Selection for Corresponding Analog Inputs bits

11111 = ADTRG31
11110 = PTG Trigger Output 12
11101 = PWM Generator 6 current-limit trigger
11100 = PWM Generator 5 current-limit trigger
11011 = PWM Generator 4 current-limit trigger
11010 = PWM Generator 3 current-limit trigger
11001 = PWM Generator 2 current-limit trigger
11000 = PWM Generator 1 current-limit trigger
10111 = Output Compare 2 trigger
10110 = Output Compare 1 trigger
10101 = CLC2 output
10100 = PWM Generator 6 secondary trigger
10011 = PWM Generator 5 secondary trigger
10010 = PWM Generator 4 secondary trigger
10001 = PWM Generator 3 secondary trigger
10000 = PWM Generator 2 secondary trigger
01111 = PWM Generator 1 secondary trigger
01110 = PWM secondary Special Event Trigger
01101 = Timer2 period match
01100 = Timer1 period match
01011 = CLC1 output
01010 = PWM Generator 6 primary trigger
01001 = PWM Generator 5 primary trigger
01000 = PWM Generator 4 primary trigger
00111 = PWM Generator 3 primary trigger
00110 = PWM Generator 2 primary trigger
00101 = PWM Generator 1 primary trigger
00100 = PWM Special Event Trigger
00011 = Reserved
00010 = Level software trigger
00001 = Common software trigger
00000 = No trigger is enabled

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

**REGISTER 22-26: ADTRIGxL: ADC CHANNEL TRIGGER x SELECTION REGISTER LOW (x = 0 to 5) (CONTINUED)**

bit 4-0 **TRGSRC(4x)<4:0>:** Trigger Source Selection for Corresponding Analog Inputs bits

11111 = ADTRG31
11110 = PTG Trigger Output 30
11101 = PWM Generator 6 current-limit trigger
11100 = PWM Generator 5 current-limit trigger
11011 = PWM Generator 4 current-limit trigger
11010 = PWM Generator 3 current-limit trigger
11001 = PWM Generator 2 current-limit trigger
11000 = PWM Generator 1 current-limit trigger
10111 = Output Compare 2 trigger
10110 = Output Compare 1 trigger
10101 = CLC2 output
10100 = PWM Generator 6 secondary trigger
10011 = PWM Generator 5 secondary trigger
10010 = PWM Generator 4 secondary trigger
10001 = PWM Generator 3 secondary trigger
10000 = PWM Generator 2 secondary trigger
01111 = PWM Generator 1 secondary trigger
01110 = PWM secondary Special Event Trigger
01101 = Timer2 period match
01100 = Timer1 period match
01011 = CLC1 output
01010 = PWM Generator 6 primary trigger
01001 = PWM Generator 5 primary trigger
01000 = PWM Generator 4 primary trigger
00111 = PWM Generator 3 primary trigger
00110 = PWM Generator 2 primary trigger
00101 = PWM Generator 1 primary trigger
00100 = PWM Special Event Trigger
00011 = Reserved
00010 = Level software trigger
00001 = Common software trigger
00000 = No trigger is enabled


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**REGISTER 22-27: ADTRIGxH: ADC CHANNEL TRIGGER x SELECTION REGISTER HIGH (x = 0 to 5)**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | TRGSRC(4x+3)<4:0> | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | TRGSRC(4x+2)<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 15-13 **Unimplemented:** Read as '0'

bit 12-8 **TRGSRC(4x+3)<4:0>:** Trigger Source Selection for Corresponding Analog Inputs bits

11111 = ADTRG31
11110 = PTG Trigger Output 30
11101 = PWM Generator 6 current-limit trigger
11100 = PWM Generator 5 current-limit trigger
11011 = PWM Generator 4 current-limit trigger
11010 = PWM Generator 3 current-limit trigger
11001 = PWM Generator 2 current-limit trigger
11000 = PWM Generator 1 current-limit trigger
10111 = Output Compare 2 trigger
10110 = Output Compare 1 trigger
10101 = CLC2 output
10100 = PWM Generator 6 secondary trigger
10011 = PWM Generator 5 secondary trigger
10010 = PWM Generator 4 secondary trigger
10001 = PWM Generator 3 secondary trigger
10000 = PWM Generator 2 secondary trigger
01111 = PWM Generator 1 secondary trigger
01110 = PWM secondary Special Event Trigger
01101 = Timer2 period match
01100 = Timer1 period match
01011 = CLC1 output
01010 = PWM Generator 6 primary trigger
01001 = PWM Generator 5 primary trigger
01000 = PWM Generator 4 primary trigger
00111 = PWM Generator 3 primary trigger
00110 = PWM Generator 2 primary trigger
00101 = PWM Generator 1 primary trigger
00100 = PWM Special Event Trigger
00011 = Reserved
00010 = Level software trigger
00001 = Common software trigger
00000 = No trigger is enabled

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

**REGISTER 22-27: ADTRIGxH: ADC CHANNEL TRIGGER x SELECTION REGISTER HIGH (x = 0 to 5) (CONTINUED)**

bit 4-0 **TRGSRC(4x+2)<4:0>:** Trigger Source Selection for Corresponding Analog Inputs bits

11111 = ADTRG31
11110 = PTG Trigger Output 30
11101 = PWM Generator 6 current-limit trigger
11100 = PWM Generator 5 current-limit trigger
11011 = PWM Generator 4 current-limit trigger
11010 = PWM Generator 3 current-limit trigger
11001 = PWM Generator 2 current-limit trigger
11000 = PWM Generator 1 current-limit trigger
10111 = Output Compare 2 trigger
10110 = Output Compare 1 trigger
10101 = CLC2 output
10100 = PWM Generator 6 secondary trigger
10011 = PWM Generator 5 secondary trigger
10010 = PWM Generator 4 secondary trigger
10001 = PWM Generator 3 secondary trigger
10000 = PWM Generator 2 secondary trigger
01111 = PWM Generator 1 secondary trigger
01110 = PWM secondary Special Event Trigger
01101 = Timer2 period match
01100 = Timer1 period match
01011 = CLC1 output
01010 = PWM Generator 6 primary trigger
01001 = PWM Generator 5 primary trigger
01000 = PWM Generator 4 primary trigger
00111 = PWM Generator 3 primary trigger
00110 = PWM Generator 2 primary trigger
00101 = PWM Generator 1 primary trigger
00100 = PWM Special Event Trigger
00011 = Reserved
00010 = Level software trigger
00001 = Common software trigger
00000 = No trigger is enabled


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**REGISTER 22-28: ADCAL0L: ADC CALIBRATION REGISTER 0 LOW**

| R-0, HSC | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CAL1RDY | — | — | — | CAL1SKIP | CAL1DIFF | CAL1EN | CAL1RUN |
| bit 15 | | | | | | | bit 8 |

| R-0, HSC | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CAL0RDY | — | — | — | CAL0SKIP | CAL0DIFF | CAL0EN | CAL0RUN |
| bit 7 | | | | | | | bit 0 |

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

bit 15 **CAL1RDY:** Dedicated ADC Core 1 Calibration Status Flag bit
1 = Dedicated ADC Core 1 calibration is finished
0 = Dedicated ADC Core 1 calibration is in progress

bit 14-12 **Unimplemented:** Read as '0'

bit 11 **CAL1SKIP:** Dedicated ADC Core 1 Calibration Bypass bit
1 = After power-up, the dedicated ADC Core 1 will not be calibrated
0 = After power-up, the dedicated ADC Core 1 will be calibrated

bit 10 **CAL1DIFF:** Dedicated ADC Core 1 Differential-Mode Calibration bit
1 = Dedicated ADC Core 1 will be calibrated in Differential Input mode
0 = Dedicated ADC Core 1 will be calibrated in Single-Ended Input mode

bit 9 **CAL1EN:** Dedicated ADC Core 1 Calibration Enable bit
1 = Dedicated ADC Core 1 calibration bits (CALxRDY, CALxSKIP, CALxDIFF and CALxRUN) can be accessed by software
0 = Dedicated ADC Core 1 calibration bits are disabled

bit 8 **CAL1RUN:** Dedicated ADC Core 1 Calibration Start bit
1 = If this bit is set by software, the dedicated ADC Core 1 calibration cycle is started; this bit is automatically cleared by hardware
0 = Software can start the next calibration cycle

bit 7 **CAL0RDY:** Dedicated ADC Core 0 Calibration Status Flag bit
1 = Dedicated ADC Core 0 calibration is finished
0 = Dedicated ADC Core 0 calibration is in progress

bit 6-4 **Unimplemented:** Read as '0'

bit 3 **CAL0SKIP:** Dedicated ADC Core 0 Calibration Bypass bit
1 = After power-up, the dedicated ADC Core 0 will not be calibrated
0 = After power-up, the dedicated ADC Core 0 will be calibrated

bit 2 **CAL0DIFF:** Dedicated ADC Core 0 Differential-Mode Calibration bit
1 = Dedicated ADC Core 0 will be calibrated in Differential Input mode
0 = Dedicated ADC Core 0 will be calibrated in Single-Ended Input mode

bit 1 **CAL0EN:** Dedicated ADC Core 0 Calibration Enable bit
1 = Dedicated ADC Core 0 calibration bits (CALxRDY, CALxSKIP, CALxDIFF and CALxRUN) can be accessed by software
0 = Dedicated ADC Core 0 calibration bits are disabled

bit 0 **CAL0RUN:** Dedicated ADC Core 0 Calibration Start bit
1 = If this bit is set by software, the dedicated ADC Core 0 calibration cycle is started; this bit is automatically cleared by hardware
0 = Software can start the next calibration cycle

**REGISTER 22-29: ADCAL0H: ADC CALIBRATION REGISTER 0 HIGH**

| R-0, HSC | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CAL3RDY | — | — | — | CAL3SKIP | CAL3DIFF | CAL3EN | CAL3RUN |
| bit 15 | | | | | | | bit 8 |

| R-0, HSC | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CAL2RDY | — | — | — | CAL2SKIP | CAL2DIFF | CAL2EN | CAL2RUN |
| bit 7 | | | | | | | bit 0 |

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

bit 15 **CAL3RDY:** Dedicated ADC Core 3 Calibration Status Flag bit
1 = Dedicated ADC Core 3 calibration is finished
0 = Dedicated ADC Core 3 calibration is in progress

bit 14-12 **Unimplemented:** Read as '0'

bit 11 **CAL3SKIP:** Dedicated ADC Core 3 Calibration Bypass bit
1 = After power-up, the dedicated ADC Core 3 will not be calibrated
0 = After power-up, the dedicated ADC Core 3 will be calibrated

bit 10 **CAL3DIFF:** Dedicated ADC Core 3 Differential-Mode Calibration bit
1 = Dedicated ADC Core 3 will be calibrated in Differential Input mode
0 = Dedicated ADC Core 3 will be calibrated in Single-Ended Input mode

bit 9 **CAL3EN:** Dedicated ADC Core 3 Calibration Enable bit
1 = Dedicated ADC Core 3 calibration bits (CALxRDY, CALxSKIP, CALxDIFF and CALxRUN) can be accessed by software
0 = Dedicated ADC Core 3 calibration bits are disabled

bit 8 **CAL3RUN:** Dedicated ADC Core 3 Calibration Start bit
1 = If this bit is set by software, the dedicated ADC Core 3 calibration cycle is started; this bit is automatically cleared by hardware
0 = Software can start the next calibration cycle

bit 7 **CAL2RDY:** Dedicated ADC Core 2 Calibration Status Flag bit
1 = Dedicated ADC Core 2 calibration is finished
0 = Dedicated ADC Core 2 calibration is in progress

bit 6-4 **Unimplemented:** Read as '0'

bit 3 **CAL2SKIP:** Dedicated ADC Core 2 Calibration Bypass bit
1 = After power-up, the dedicated ADC Core 2 will not be calibrated
0 = After power-up, the dedicated ADC Core 2 will be calibrated

bit 2 **CAL2DIFF:** Dedicated ADC Core 2 Differential-Mode Calibration bit
1 = Dedicated ADC Core 2 will be calibrated in Differential Input mode
0 = Dedicated ADC Core 2 will be calibrated in Single-Ended Input mode

bit 1 **CAL2EN:** Dedicated ADC Core 2 Calibration Enable bit
1 = Dedicated ADC Core 2 calibration bits (CALxRDY, CALxSKIP, CALxDIFF and CALxRUN) can be accessed by software
0 = Dedicated ADC Core 2 calibration bits are disabled

bit 0 **CAL2RUN:** Dedicated ADC Core 2 Calibration Start bit
1 = If this bit is set by software, the dedicated ADC Core 2 calibration cycle is started; this bit is automatically cleared by hardware
0 = Software can start the next calibration cycle


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**REGISTER 22-30: ADCAL1H: ADC CALIBRATION REGISTER 1 HIGH**

| R/W-0, HS | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CSHRRDY | — | — | — | CSHRSKIP | CSHRDIFF | CSHREN | CSHRRUN |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable 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 **CSHRRDY:** Shared ADC Core Calibration Status Flag bit
1 = Shared ADC core calibration is finished
0 = Shared ADC core calibration is in progress

bit 14-12 **Unimplemented:** Read as '0'

bit 11 **CSHRSKIP:** Shared ADC Core Calibration Bypass bit
1 = After power-up, the shared ADC core will not be calibrated
0 = After power-up, the shared ADC core will be calibrated

bit 10 **CSHRDIFF:** Shared ADC Core Differential-Mode Calibration bit
1 = Shared ADC core will be calibrated in Differential Input mode
0 = Shared ADC core will be calibrated in Single-Ended Input mode

bit 9 **CSHREN:** Shared ADC Core Calibration Enable bit
1 = Shared ADC core calibration bits (CSHRRDY, CSHRSKIP, CSHRDIFF and CSHRRUN) can be accessed by software
0 = Shared ADC core calibration bits are disabled

bit 8 **CSHRRUN:** Shared ADC Core Calibration Start bit
1 = If this bit is set by software, the shared ADC core calibration cycle is started; this bit is cleared automatically by hardware
0 = Software can start the next calibration cycle

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

**REGISTER 22-31: ADCMPxCON: ADC DIGITAL COMPARATOR x CONTROL REGISTER (x = 0 or 1)**

| U-0 | U-0 | U-0 | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC | R-0, HSC |
|---|---|---|---|---|---|---|---|
| — | — | — | CHNL4 | CHNL3 | CHNL2 | CHNL1 | CHNL0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R-0, HC, HS | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CMPEN | IE | STAT | BTWN | HIHI | HILO | LOHI | LOLO |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware Clearable bit | U = Unimplemented bit, read as '0' | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | HSC = Hardware Settable/Clearable bit | |
| -n = Value at POR | '1' = Bit is set | '0' = Bit is cleared | HS = Hardware Settable bit |

bit 15-13 **Unimplemented:** Read as '0'

bit 12-8 **CHNL<4:0>:** Input Channel Number bits

If the comparator has detected an event for a channel, this channel number is written to these bits.
11111 = Reserved
•
•
10110 = Reserved
10101 = AN21
10100 = AN20
•
•
00001 = AN1
00000 = AN0

bit 7 **CMPEN:** Comparator Enable bit

1 = Comparator is enabled
0 = Comparator is disabled and the STAT status bit is cleared

bit 6 **IE:** Comparator Common ADC Interrupt Enable bit

1 = Common ADC interrupt will be generated if the comparator detects a comparison event
0 = Common ADC interrupt will not be generated for the comparator

bit 5 **STAT:** Comparator Event Status bit

This bit is cleared by hardware when the channel number is read from the CHNL<4:0> bits.
1 = A comparison event has been detected since the last read of the CHNL<4:0> bits
0 = A comparison event has not been detected since the last read of the CHNL<4:0> bits

bit 4 **BTWN:** Between Low/High Comparator Event bit

1 = Generates a comparator event when ADCMPxLO ≤ ADCBUFx < ADCMPxHI
0 = Does not generate a digital comparator event when ADCMPxLO ≤ ADCBUFx < ADCMPxHI

bit 3 **HIHI:** High/High Comparator Event bit

1 = Generates a digital comparator event when ADCBUFx ≥ ADCMPxHI
0 = Does not generate a digital comparator event when ADCBUFx ≥ ADCMPxHI

bit 2 **HILO:** High/Low Comparator Event bit

1 = Generates a digital comparator event when ADCBUFx < ADCMPxHI
0 = Does not generate a digital comparator event when ADCBUFx < ADCMPxHI

bit 1 **LOHI:** Low/High Comparator Event bit

1 = Generates a digital comparator event when ADCBUFx ≥ ADCMPxLO
0 = Does not generate a digital comparator event when ADCBUFx ≥ ADCMPxLO

bit 0 **LOLO:** Low/Low Comparator Event bit

1 = Generates a digital comparator event when ADCBUFx < ADCMPxLO
0 = Does not generate a digital comparator event when ADCBUFx < ADCMPxLO


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**REGISTER 22-32: ADCMPxENL: ADC DIGITAL COMPARATOR x CHANNEL ENABLE REGISTER LOW (x = 0 or 1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CMPEN<15:8> | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| CMPEN<7:0> | | | | | | | |
| 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 15-0 **CMPEN<15:0>:** Comparator Enable for Corresponding Input Channels bits
1 = Conversion result for corresponding channel is used by the comparator
0 = Conversion result for corresponding channel is not used by the comparator

**REGISTER 22-33: ADCMPxENH: ADC DIGITAL COMPARATOR x CHANNEL ENABLE REGISTER HIGH (x = 0 or 1)**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-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 |
|---|---|---|---|---|---|---|---|
| — | — | CMPEN<21:16> | | | | | |
| 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 5-0 **CMPEN<21:16>:** Comparator Enable for Corresponding Input Channels bits
1 = Conversion result for corresponding channel is used by the comparator
0 = Conversion result for corresponding channel is not used by the comparator

**REGISTER 22-34: ADFLxCON: ADC DIGITAL FILTER x CONTROL REGISTER (x = 0 or 1)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-0, HSC |
|---|---|---|---|---|---|---|---|
| FLEN | MODE1 | MODE0 | OVRSAM2 | OVRSAM1 | OVRSAM0 | IE | RDY |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | FLCHSEL4 | FLCHSEL3 | FLCHSEL2 | FLCHSEL1 | FLCHSEL0 |
| bit 7 | | | | | | | bit 0 |

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

bit 15 **FLEN:** Filter Enable bit
1 = Filter is enabled
0 = Filter is disabled and the RDY bit is cleared

bit 14-13 **MODE<1:0>:** Filter Mode bits
11 = Averaging mode
10 = Reserved
01 = Reserved
00 = Oversampling mode

bit 12-10 **OVRSAM<2:0>:** Filter Averaging/Oversampling Ratio bits
If MODE<1:0> = 00:
111 = 128x (16-bit result in the ADFLxDAT register is in 12.4 format)
110 = 32x (15-bit result in the ADFLxDAT register is in 12.3 format)
101 = 8x (14-bit result in the ADFLxDAT register is in 12.2 format)
100 = 2x (13-bit result in the ADFLxDAT register is in 12.1 format)
011 = 256x (16-bit result in the ADFLxDAT register is in 12.4 format)
010 = 64x (15-bit result in the ADFLxDAT register is in 12.3 format)
001 = 16x (14-bit result in the ADFLxDAT register is in 12.2 format)
000 = 4x (13-bit result in the ADFLxDAT register is in 12.1 format)
If MODE<1:0> = 11 (12-bit result in the ADFLxDAT register in all instances):
111 = 256x
110 = 128x
101 = 64x
100 = 32x
011 = 16x
010 = 8x
001 = 4x
000 = 2x

bit 9 **IE:** Filter Common ADC Interrupt Enable bit
1 = Common ADC interrupt will be generated when the filter result will be ready
0 = Common ADC interrupt will not be generated for the filter

bit 8 **RDY:** Oversampling Filter Data Ready Flag bit
This bit is cleared by hardware when the result is read from the ADFLxDAT register.
1 = Data in the ADFLxDAT register is ready
0 = The ADFLxDAT register has been read and new data in the ADFLxDAT register is not ready

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


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**REGISTER 22-34: ADFLxCON: ADC DIGITAL FILTER x CONTROL REGISTER (x = 0 or 1) (CONTINUED)**

bit 4-0 **FLCHSEL<4:0>:** Oversampling Filter Input Channel Selection bits

11111 = Reserved
•
•
•
10110 = Reserved
10101 = AN21
10100 = AN20
•
•
•
00001 = AN1
00000 = AN0

**NOTES:**


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## 23.0 CONTROLLER AREA NETWORK (CAN) MODULE (dsPIC33EPXXXGS80X DEVICES ONLY)

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Enhanced Controller Area Network (ECAN™)"** (DS70353) in the *"dsPIC33/PIC24 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.

### 23.1 Overview

The Controller Area Network (CAN) module is a serial interface, useful for communicating with other CAN modules or microcontroller devices. This interface/protocol was designed to allow communications within noisy environments. The dsPIC33EPXXXGS80X devices contain two CAN modules.

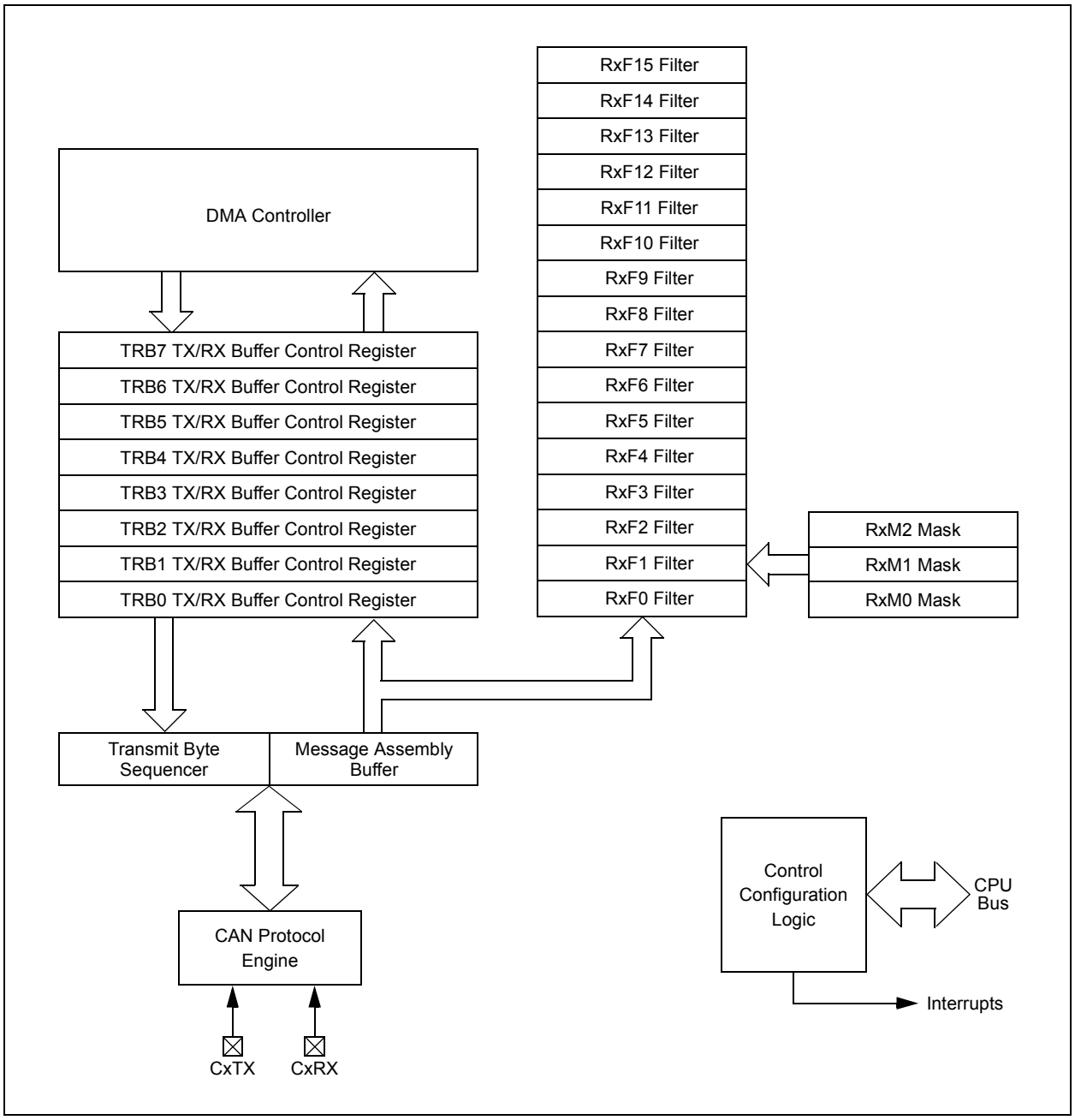
The CAN module is a communication controller, implementing the CAN 2.0 A/B protocol, as defined in the BOSCH CAN specification. The module supports CAN 1.2, CAN 2.0A, CAN 2.0B Passive and CAN 2.0B Active versions of the protocol. The module implementation is a full CAN system. The CAN specification is not covered within this data sheet. The reader can refer to the BOSCH CAN specification for further details.

The CAN module features are as follows:

- Implementation of the CAN Protocol, CAN 1.2, CAN 2.0A and CAN 2.0B
- Standard and Extended Data Frames
- 0-8 Bytes of Data Length
- Programmable Bit Rate, up to 1 Mbit/sec
- Automatic Response to Remote Transmission Requests
- Up to 8 Transmit Buffers with Application Specified Prioritization and Abort Capability (each buffer can contain up to 8 bytes of data)
- Up to 32 Receive Buffers (each buffer can contain up to 8 bytes of data)
- Up to 16 Full (Standard/Extended Identifier) Acceptance Filters
- Three Full Acceptance Filter Masks
- DeviceNet™ Addressing Support
- Programmable Wake-up Functionality with Integrated Low-Pass Filter
- Programmable Loopback mode supports Self-Test Operation
- Signaling via Interrupt Capabilities for All CAN Receiver and Transmitter Error States
- Programmable Clock Source
- Programmable Link to Input Capture 2 (IC2) module for Timestamping and Network Synchronization
- Low-Power Sleep and Idle modes

The CAN bus module consists of a protocol engine and message buffering/control. The CAN protocol engine handles all functions for receiving and transmitting messages on the CAN bus. Messages are transmitted by first loading the appropriate data registers. Status and errors can be checked by reading the appropriate registers. Any message detected on the CAN bus is checked for errors and then matched against filters to see if it should be received and stored in one of the receive registers.

**FIGURE 23-1: CANx MODULE BLOCK DIAGRAM**




## 23.2 Modes of Operation

The CANx module can operate in one of several operation modes selected by the user. These modes include:

- Initialization mode
- Disable mode
- Normal Operation mode
- Listen Only mode
- Listen All Messages mode
- Loopback mode

Modes are requested by setting the REQOP<2:0> bits (CxCTRL1<10:8>). Entry into a mode is Acknowledged by monitoring the OPMODE<2:0> bits (CxCTRL1<7:5>). The module does not change the mode and the OPMODEx bits until a change in mode is acceptable, generally during bus Idle time, which is defined as at least 11 consecutive recessive bits.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## 23.3 CAN Control Registers

**REGISTER 23-1: CxCTRL1: CANx CONTROL REGISTER 1**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-1 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | CSIDL | ABAT | CANCKS | REQOP2 | REQOP1 | REQOP0 |
| bit 15 | | | | | | | bit 8 |

| R-1 | R-0 | R-0 | U-0 | R/W-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| OPMODE2 | OPMODE1 | OPMODE0 | — | CANCAP | — | — | WIN |
| 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 **CSIDL:** CANx Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **ABAT:** Abort All Pending Transmissions bit
1 = Signals all transmit buffers to abort transmission
0 = Module will clear this bit when all transmissions are aborted

bit 11 **CANCKS:** CANx Module Clock (FCAN) Source Select bit
1 = FCAN is equal to 2 * FP
0 = FCAN is equal to FP

bit 10-8 **REQOP<2:0>:** Request Operation Mode bits
111 = Set Listen All Messages mode
110 = Reserved
101 = Reserved
100 = Set Configuration mode
011 = Set Listen Only mode
010 = Set Loopback mode
001 = Set Disable mode
000 = Set Normal Operation mode

bit 7-5 **OPMODE<2:0>**: Operation Mode bits
111 = Module is in Listen All Messages mode
110 = Reserved
101 = Reserved
100 = Module is in Configuration mode
011 = Module is in Listen Only mode
010 = Module is in Loopback mode
001 = Module is in Disable mode
000 = Module is in Normal Operation mode

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

bit 3 **CANCAP:** CANx Message Receive Timer Capture Event Enable bit
1 = Enables input capture based on CAN message receive
0 = Disables CAN capture

bit 2-1 **Unimplemented:** Read as '0'

bit 0 **WIN:** SFR Map Window Select bit
1 = Uses filter window
0 = Uses buffer window

**REGISTER 23-2: CxCTRL2: CANx CONTROL REGISTER 2**

| 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-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | DNCNT<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 **DNCNT<4:0>:** DeviceNet™ Filter Bit Number bits

10010-11111 = Invalid selection
10001 = Compare up to Data Byte 3, bit 6 with EID<17>
•
•
•
00001 = Compare up to Data Byte 1, bit 7 with EID<0>
00000 = Do not compare data bytes


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**REGISTER 23-3: CxVEC: CANx INTERRUPT CODE REGISTER**

| U-0 | U-0 | U-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | FILHIT4 | FILHIT3 | FILHIT2 | FILHIT1 | FILHIT0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | R-1 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | ICODE6 | ICODE5 | ICODE4 | ICODE3 | ICODE2 | ICODE1 | ICODE0 |
| 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 **Unimplemented:** Read as '0'

bit 12-8 **FILHIT<4:0>:** Filter Hit Number bits

10000-11111 = Reserved
01111 = Filter 15
•
•
•
00001 = Filter 1
00000 = Filter 0

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

bit 6-0 **ICODE<6:0>:** Interrupt Flag Code bits

1000101-1111111 = Reserved
1000100 = FIFO almost full interrupt
1000011 = Receiver overflow interrupt
1000010 = Wake-up interrupt
1000001 = Error interrupt
1000000 = No interrupt
•
•
•
0010000-0111111 = Reserved
0001111 = RB15 buffer interrupt
•
•
•
0001001 = RB9 buffer interrupt
0001000 = RB8 buffer interrupt
0000111 = TRB7 buffer interrupt
0000110 = TRB6 buffer interrupt
0000101 = TRB5 buffer interrupt
0000100 = TRB4 buffer interrupt
0000011 = TRB3 buffer interrupt
0000010 = TRB2 buffer interrupt
0000001 = TRB1 buffer interrupt
0000000 = TRB0 buffer interrupt

**REGISTER 23-4: CxFCTRL: CANx FIFO CONTROL REGISTER**

| R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| DMABS2 | DMABS1 | DMABS0 | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | FSA4 | FSA3 | FSA2 | FSA1 | FSA0 |
| 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 **DMABS<2:0>:** DMA Buffer Size bits
111 = Reserved
110 = 32 buffers in RAM
101 = 24 buffers in RAM
100 = 16 buffers in RAM
011 = 12 buffers in RAM
010 = 8 buffers in RAM
001 = 6 buffers in RAM
000 = 4 buffers in RAM

bit 12-5 **Unimplemented:** Read as '0'

bit 4-0 **FSA<4:0>:** FIFO Area Starts with Buffer bits
11111 = Receive Buffer RB31
11110 = Receive Buffer RB30
•
•
•
00001 = Transmit/Receive Buffer TRB1
00000 = Transmit/Receive Buffer TRB0


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**REGISTER 23-5: CxFIFO: CANx FIFO STATUS REGISTER**

| U-0 | U-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | FBP5 | FBP4 | FBP3 | FBP2 | FBP1 | FBP0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | FNRB5 | FNRB4 | FNRB3 | FNRB2 | FNRB1 | FNRB0 |
| 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 **FBP<5:0>:** FIFO Buffer Pointer bits

011111 = RB31 buffer
011110 = RB30 buffer
•
•
•
000001 = TRB1 buffer
000000 = TRB0 buffer

bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-0 **FNRB<5:0>:** FIFO Next Read Buffer Pointer bits

011111 = RB31 buffer
011110 = RB30 buffer
•
•
•
000001 = TRB1 buffer
000000 = TRB0 buffer

**REGISTER 23-6: CxINTF: CANx INTERRUPT FLAG REGISTER**

| U-0 | U-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | TXBO | TXBP | RXBP | TXWAR | RXWAR | EWARN |
| bit 15 | | | | | | | bit 8 |

| R/C-0 | R/C-0 | R/C-0 | U-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| IVRIF | WAKIF | ERRIF | — | FIFOIF | RBOVIF | RBIF | TBIF |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Writable bit, but only '0' can be Written to Clear 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 15-14 **Unimplemented:** Read as '0'

bit 13 **TXBO:** Transmitter in Error State Bus Off bit
1 = Transmitter is in Bus Off state
0 = Transmitter is not in Bus Off state

bit 12 **TXBP:** Transmitter in Error State Bus Passive bit
1 = Transmitter is in Bus Passive state
0 = Transmitter is not in Bus Passive state

bit 11 **RXBP:** Receiver in Error State Bus Passive bit
1 = Receiver is in Bus Passive state
0 = Receiver is not in Bus Passive state

bit 10 **TXWAR:** Transmitter in Error State Warning bit
1 = Transmitter is in Error Warning state
0 = Transmitter is not in Error Warning state

bit 9 **RXWAR:** Receiver in Error State Warning bit
1 = Receiver is in Error Warning state
0 = Receiver is not in Error Warning state

bit 8 **EWARN:** Transmitter or Receiver in Error State Warning bit
1 = Transmitter or receiver is in Error Warning state
0 = Transmitter or receiver is not in Error Warning state

bit 7 **IVRIF:** Invalid Message Interrupt Flag bit
1 = Interrupt request has occurred
0 = Interrupt request has not occurred

bit 6 **WAKIF:** Bus Wake-up Activity Interrupt Flag bit
1 = Interrupt request has occurred
0 = Interrupt request has not occurred

bit 5 **ERRIF:** Error Interrupt Flag bit (multiple sources in CxINTF<13:8> register)
1 = Interrupt request has occurred
0 = Interrupt request has not occurred

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

bit 3 **FIFOIF:** FIFO Almost Full Interrupt Flag bit
1 = Interrupt request has occurred
0 = Interrupt request has not occurred

bit 2 **RBOVIF:** RX Buffer Overflow Interrupt Flag bit
1 = Interrupt request has occurred
0 = Interrupt request has not occurred


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**REGISTER 23-6: CxINTF: CANx INTERRUPT FLAG REGISTER (CONTINUED)**

bit 1 **RBIF:** RX Buffer Interrupt Flag bit
1 = Interrupt request has occurred
0 = Interrupt request has not occurred

bit 0 **TBIF:** TX Buffer Interrupt Flag bit
1 = Interrupt request has occurred
0 = Interrupt request has not occurred

**REGISTER 23-7: CxINTE: CANx INTERRUPT ENABLE REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 | R/W-0 |
|---|---|---|---|---|---|---|---|
| IVRIE | WAKIE | ERRIE | — | FIFOIE | RBOVIE | RBIE | TBIE |
| 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 **Unimplemented:** Read as ‘0’

bit 7 **IVRIE:** Invalid Message Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

bit 6 **WAKIE:** Bus Wake-up Activity Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

bit 5 **ERRIE:** Error Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

bit 4 **Unimplemented:** Read as ‘0’

bit 3 **FIFOIE:** FIFO Almost Full Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

bit 2 **RBOVIE:** RX Buffer Overflow Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

bit 1 **RBIE:** RX Buffer Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

bit 0 **TBIE:** TX Buffer Interrupt Enable bit
1 = Interrupt request is enabled
0 = Interrupt request is not enabled

**REGISTER 23-8: CxEC: CANx TRANSMIT/RECEIVE ERROR COUNT REGISTER**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| TERRCNT7 | TERRCNT6 | TERRCNT5 | TERRCNT4 | TERRCNT3 | TERRCNT2 | TERRCNT1 | TERRCNT0 |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| RERRCNT7 | RERRCNT6 | RERRCNT5 | RERRCNT4 | RERRCNT3 | RERRCNT2 | RERRCNT1 | RERRCNT0 |
| 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 **TERRCNT<7:0>:** Transmit Error Count bits

bit 7-0 **RERRCNT<7:0>:** Receive Error Count bits

**REGISTER 23-9: CxCFG1: CANx BAUD RATE CONFIGURATION REGISTER 1**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| SJW1 | SJW0 | BRP5 | BRP4 | BRP3 | BRP2 | BRP1 | BRP0 |
| 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 **Unimplemented:** Read as '0'

bit 7-6 **SJW<1:0>:** Synchronization Jump Width bits

11 = Length is 4 x TQ
10 = Length is 3 x TQ
01 = Length is 2 x TQ
00 = Length is 1 x TQ

bit 5-0 **BRP<5:0>:** Baud Rate Prescaler bits

11 1111 = TQ = 2 x 64 x 1/FCAN
•
•
•
00 0010 = TQ = 2 x 3 x 1/FCAN
00 0001 = TQ = 2 x 2 x 1/FCAN
00 0000 = TQ = 2 x 1 x 1/FCAN


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**REGISTER 23-10: CxCFG2: CANx BAUD RATE CONFIGURATION REGISTER 2**

| U-0 | R/W-x | U-0 | U-0 | U-0 | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| — | WAKFIL | — | — | — | SEG2PH2 | SEG2PH1 | SEG2PH0 |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| SEG2PHTS | SAM | SEG1PH2 | SEG1PH1 | SEG1PH0 | PRSEG2 | PRSEG1 | PRSEG0 |
| 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 **WAKFIL:** Select CAN Bus Line Filter for Wake-up bit
1 = Uses CAN bus line filter for wake-up
0 = CAN bus line filter is not used for wake-up

bit 13-11 **Unimplemented:** Read as '0'

bit 10-8 **SEG2PH<2:0>:** Phase Segment 2 bits
111 = Length is 8 x TQ
•
•
•
000 = Length is 1 x TQ

bit 7 **SEG2PHTS:** Phase Segment 2 Time Select bit
1 = Freely programmable
0 = Maximum of SEG1PHx bits or Information Processing Time (IPT), whichever is greater

bit 6 **SAM:** Sample of the CAN Bus Line bit
1 = Bus line is sampled three times at the sample point
0 = Bus line is sampled once at the sample point

bit 5-3 **SEG1PH<2:0>:** Phase Segment 1 bits
111 = Length is 8 x TQ
•
•
•
000 = Length is 1 x TQ

bit 2-0 **PRSEG<2:0>:** Propagation Time Segment bits
111 = Length is 8 x TQ
•
•
•
000 = Length is 1 x TQ

**REGISTER 23-11: CxFEN1: CANx ACCEPTANCE FILTER ENABLE REGISTER 1**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| FLTEN<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| FLTEN<7:0> | | | | | | | |
| 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 15-0 **FLTEN<15:0>:** Enable Filter n to Accept Messages bits
1 = Enables Filter n
0 = Disables Filter n

**REGISTER 23-12: CxBUFPNT1: CANx FILTERS 0-3 BUFFER POINTER REGISTER 1**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| F3BP3 | F3BP2 | F3BP1 | F3BP0 | F2BP3 | F2BP2 | F2BP1 | F2BP0 |
| 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 |
|---|---|---|---|---|---|---|---|
| F1BP3 | F1BP2 | F1BP1 | F1BP0 | F0BP3 | F0BP2 | F0BP1 | F0BP0 |
| 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 15-12 **F3BP<3:0>:** RX Buffer Mask for Filter 3 bits
1111 = Filter hits received in RX FIFO buffer
1110 = Filter hits received in RX Buffer 14
•
•
•
0001 = Filter hits received in RX Buffer 1
0000 = Filter hits received in RX Buffer 0

bit 11-8 **F2BP<3:0>:** RX Buffer Mask for Filter 2 bits (same values as bits 15-12)

bit 7-4 **F1BP<3:0>:** RX Buffer Mask for Filter 1 bits (same values as bits 15-12)

bit 3-0 **F0BP<3:0>:** RX Buffer Mask for Filter 0 bits (same values as bits 15-12)


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**REGISTER 23-13: CxBUFPNT2: CANx FILTERS 4-7 BUFFER POINTER REGISTER 2**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| F7BP3 | F7BP2 | F7BP1 | F7BP0 | F6BP3 | F6BP2 | F6BP1 | F6BP0 |
| 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 |
|---|---|---|---|---|---|---|---|
| F5BP3 | F5BP2 | F5BP1 | F5BP0 | F4BP3 | F4BP2 | F4BP1 | F4BP0 |
| 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 15-12 **F7BP<3:0>:** RX Buffer Mask for Filter 7 bits
1111 = Filter hits received in RX FIFO buffer
1110 = Filter hits received in RX Buffer 14
•
•
•
0001 = Filter hits received in RX Buffer 1
0000 = Filter hits received in RX Buffer 0

bit 11-8 **F6BP<3:0>:** RX Buffer Mask for Filter 6 bits (same values as bits 15-12)

bit 7-4 **F5BP<3:0>:** RX Buffer Mask for Filter 5 bits (same values as bits 15-12)

bit 3-0 **F4BP<3:0>:** RX Buffer Mask for Filter 4 bits (same values as bits 15-12)

**REGISTER 23-14: CxBUFPNT3: CANx FILTERS 8-11 BUFFER POINTER REGISTER 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 |
|---|---|---|---|---|---|---|---|
| F11BP3 | F11BP2 | F11BP1 | F11BP0 | F10BP3 | F10BP2 | F10BP1 | F10BP0 |
| 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 |
|---|---|---|---|---|---|---|---|
| F9BP3 | F9BP2 | F9BP1 | F9BP0 | F8BP3 | F8BP2 | F8BP1 | F8BP0 |
| 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 15-12 **F11BP<3:0>:** RX Buffer Mask for Filter 11 bits
1111 = Filter hits received in RX FIFO buffer
1110 = Filter hits received in RX Buffer 14
•
•
•
0001 = Filter hits received in RX Buffer 1
0000 = Filter hits received in RX Buffer 0

bit 11-8 **F10BP<3:0>:** RX Buffer Mask for Filter 10 bits (same values as bits 15-12)

bit 7-4 **F9BP<3:0>:** RX Buffer Mask for Filter 9 bits (same values as bits 15-12)

bit 3-0 **F8BP<3:0>:** RX Buffer Mask for Filter 8 bits (same values as bits 15-12)

**REGISTER 23-15: CxBUFPNT4: CANx FILTERS 12-15 BUFFER POINTER REGISTER 4**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| F15BP3 | F15BP2 | F15BP1 | F15BP0 | F14BP3 | F14BP2 | F14BP1 | F14BP0 |
| 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 |
|---|---|---|---|---|---|---|---|
| F13BP3 | F13BP2 | F13BP1 | F13BP0 | F12BP3 | F12BP2 | F12BP1 | F12BP0 |
| 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 15-12 **F15BP<3:0>:** RX Buffer Mask for Filter 15 bits
1111 = Filter hits received in RX FIFO buffer
1110 = Filter hits received in RX Buffer 14
•
•
•
0001 = Filter hits received in RX Buffer 1
0000 = Filter hits received in RX Buffer 0

bit 11-8 **F14BP<3:0>:** RX Buffer Mask for Filter 14 bits (same values as bits 15-12)

bit 7-4 **F13BP<3:0>:** RX Buffer Mask for Filter 13 bits (same values as bits 15-12)

bit 3-0 **F12BP<3:0>:** RX Buffer Mask for Filter 12 bits (same values as bits 15-12)


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**REGISTER 23-16: CxRXFnSID: CANx ACCEPTANCE FILTER n STANDARD IDENTIFIER REGISTER (n = 0-15)**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| SID10 | SID9 | SID8 | SID7 | SID6 | SID5 | SID4 | SID3 |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | U-0 | R/W-x | U-0 | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| SID2 | SID1 | SID0 | — | EXIDE | — | EID17 | EID16 |
| 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 **SID<10:0>:** Standard Identifier bits
1 = Message address bit, SIDx, must be '1' to match filter
0 = Message address bit, SIDx, must be '0' to match filter

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

bit 3 **EXIDE:** Extended Identifier Enable bit
If MIDE = 1:
1 = Matches only messages with Extended Identifier addresses
0 = Matches only messages with Standard Identifier addresses
If MIDE = 0:
Ignores EXIDE bit.

bit 2 **Unimplemented:** Read as '0'

bit 1-0 **EID<17:16>:** Extended Identifier bits
1 = Message address bit, EIDx, must be '1' to match filter
0 = Message address bit, EIDx, must be '0' to match filter

**REGISTER 23-17: CxRXFnEID: CANx ACCEPTANCE FILTER n EXTENDED IDENTIFIER REGISTER (n = 0-15)**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| EID<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| EID<7:0> | | | | | | | |
| 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 15-0 **EID<15:0>:** Extended Identifier bits
1 = Message address bit, EIDx, must be '1' to match filter
0 = Message address bit, EIDx, must be '0' to match filter

**REGISTER 23-18: CxFMSKSEL1: CANx FILTERS 7-0 MASK SELECTION REGISTER 1**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| F7MSK1 | F7MSK0 | F6MSK1 | F6MSK0 | F5MSK1 | F5MSK0 | F4MSK1 | F4MSK0 |
| 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 |
|---|---|---|---|---|---|---|---|
| F3MSK1 | F3MSK0 | F2MSK1 | F2MSK0 | F1MSK1 | F1MSK0 | F0MSK1 | F0MSK0 |
| 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 **F7MSK<1:0>:** Mask Source for Filter 7 bits
11 = Reserved
10 = Acceptance Mask 2 registers contain mask
01 = Acceptance Mask 1 registers contain mask
00 = Acceptance Mask 0 registers contain mask

bit 13-12 **F6MSK<1:0>:** Mask Source for Filter 6 bits (same values as bits 15-14)

bit 11-10 **F5MSK<1:0>:** Mask Source for Filter 5 bits (same values as bits 15-14)

bit 9-8 **F4MSK<1:0>:** Mask Source for Filter 4 bits (same values as bits 15-14)

bit 7-6 **F3MSK<1:0>:** Mask Source for Filter 3 bits (same values as bits 15-14)

bit 5-4 **F2MSK<1:0>:** Mask Source for Filter 2 bits (same values as bits 15-14)

bit 3-2 **F1MSK<1:0>:** Mask Source for Filter 1 bits (same values as bits 15-14)

bit 1-0 **F0MSK<1:0>:** Mask Source for Filter 0 bits (same values as bits 15-14)


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**REGISTER 23-19: CxFMSKSEL2: CANx FILTERS 15-8 MASK SELECTION REGISTER 2**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| F15MSK1 | F15MSK0 | F14MSK1 | F14MSK0 | F13MSK1 | F13MSK0 | F12MSK1 | F12MSK0 |
| 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 |
|---|---|---|---|---|---|---|---|
| F11MSK1 | F11MSK0 | F10MSK1 | F10MSK0 | F9MSK1 | F9MSK0 | F8MSK1 | F8MSK0 |
| 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 **F15MSK<1:0>:** Mask Source for Filter 15 bits
11 = Reserved
10 = Acceptance Mask 2 registers contain mask
01 = Acceptance Mask 1 registers contain mask
00 = Acceptance Mask 0 registers contain mask

bit 13-12 **F14MSK<1:0>:** Mask Source for Filter 14 bits (same values as bits 15-14)

bit 11-10 **F13MSK<1:0>:** Mask Source for Filter 13 bits (same values as bits 15-14)

bit 9-8 **F12MSK<1:0>:** Mask Source for Filter 12 bits (same values as bits 15-14)

bit 7-6 **F11MSK<1:0>:** Mask Source for Filter 11 bits (same values as bits 15-14)

bit 5-4 **F10MSK<1:0>:** Mask Source for Filter 10 bits (same values as bits 15-14)

bit 3-2 **F9MSK<1:0>:** Mask Source for Filter 9 bits (same values as bits 15-14)

bit 1-0 **F8MSK<1:0>:** Mask Source for Filter 8 bits (same values as bits 15-14)

**REGISTER 23-20: CxRXMnSID: CANx ACCEPTANCE FILTER MASK n STANDARD IDENTIFIER REGISTER (n = 0-2)**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| SID10 | SID9 | SID8 | SID7 | SID6 | SID5 | SID4 | SID3 |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | U-0 | R/W-x | U-0 | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| SID2 | SID1 | SID0 | — | MIDE | — | EID17 | EID16 |
| 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 **SID<10:0>:** Standard Identifier bits
1 = Includes bit, SIDx, in filter comparison
0 = Bit, SIDx, is a don't care in filter comparison

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

bit 3 **MIDE:** Identifier Receive Mode bit
1 = Matches only message types (standard or extended address) that correspond to the EXIDE bit in the filter
0 = Matches either standard or extended address message if filters match (i.e., if (Filter SIDx) = (Message SIDx) or if (Filter SIDx/EIDx) = (Message SIDx/EIDx))

bit 2 **Unimplemented:** Read as '0'

bit 1-0 **EID<17:16>:** Extended Identifier bits
1 = Includes bit, EIDx, in filter comparison
0 = Bit, EIDx, is a don't care in filter comparison

**REGISTER 23-21: CxRXMnEID: CANx ACCEPTANCE FILTER MASK n EXTENDED IDENTIFIER REGISTER (n = 0-2)**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| EID<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| EID<7:0> | | | | | | | |
| 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 15-0 **EID<15:0>:** Extended Identifier bits
1 = Includes bit, EIDx, in filter comparison
0 = Bit, EIDx, is a don't care in filter comparison


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**REGISTER 23-22: CxRXFUL1: CANx RECEIVE BUFFER FULL REGISTER 1**

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXFUL<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXFUL<7:0> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Writable bit, but only ‘0’ can be Written to Clear 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 15-0 **RXFUL<15:0>:** Receive Buffer n Full bits
1 = Buffer is full (set by module)
0 = Buffer is empty (cleared by user software)

**REGISTER 23-23: CxRXFUL2: CANx RECEIVE BUFFER FULL REGISTER 2**

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXFUL<31:24> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXFUL<23:16> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Writable bit, but only ‘0’ can be Written to Clear 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 15-0 **RXFUL<31:16>:** Receive Buffer n Full bits
1 = Buffer is full (set by module)
0 = Buffer is empty (cleared by user software)

**REGISTER 23-24: CxRXOVF1: CANx RECEIVE BUFFER OVERFLOW REGISTER 1**

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXOVF<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXOVF<7:0> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Writable bit, but only '0' can be Written to Clear 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 15-0 **RXOVF<15:0>:** Receive Buffer n Overflow bits
1 = Module attempted to write to a full buffer (set by module)
0 = No overflow condition (cleared by user software)

**REGISTER 23-25: CxRXOVF2: CANx RECEIVE BUFFER OVERFLOW REGISTER 2**

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXOVF<31:24> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| RXOVF<23:16> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Writable bit, but only '0' can be Written to Clear 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 15-0 **RXOVF<31:16>:** Receive Buffer n Overflow bits
1 = Module attempted to write to a full buffer (set by module)
0 = No overflow condition (cleared by user software)


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**REGISTER 23-26: CxTRmnCON: CANx TX/RX BUFFER mn CONTROL REGISTER (m = 0,2,4,6; n = 1,3,5,7)**

| R/W-0 | R-0 | R-0 | R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TXENn | TXABTn | TXLARBn | TXERRn | TXREQn | RTRENn | TXnPRI1 | TXnPRI0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R-0 | R-0 | R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TXENm | TXABTm(1) | TXLARBm(1) | TXERRm(1) | TXREQm | RTRENm | TXmPRI1 | TXmPRI0 |
| 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 See Definition for bits 7-0, controls Buffer n.

bit 7 **TXENm:** TX/RX Buffer m Selection bit
1 = Buffer, TRBm, is a transmit buffer
0 = Buffer, TRBm, is a receive buffer

bit 6 **TXABTm:** Message Aborted bit(1)
1 = Message was aborted
0 = Message completed transmission successfully

bit 5 **TXLARBm:** Message Lost Arbitration bit(1)
1 = Message lost arbitration while being sent
0 = Message did not lose arbitration while being sent

bit 4 **TXERRm:** Error Detected During Transmission bit(1)
1 = A bus error occurred while the message was being sent
0 = A bus error did not occur while the message was being sent

bit 3 **TXREQm:** Message Send Request bit
1 = Requests that a message be sent; the bit automatically clears when the message is successfully sent
0 = Clearing the bit to '0' while set requests a message abort

bit 2 **RTRENm:** Auto-Remote Transmit Enable bit
1 = When a remote transmit is received, TXREQx will be set
0 = When a remote transmit is received, TXREQx will be unaffected

bit 1-0 **TXmPRI<1:0>:** Message Transmission Priority bits
11 = Highest message priority
10 = High intermediate message priority
01 = Low intermediate message priority
00 = Lowest message priority

**Note 1:** This bit is cleared when TXREQmn is set.

**Note:** The buffers, SIDx, EIDx, DLCx, Data Field and Receive Status registers, are located in DMA RAM.

## 23.4 CAN Message Buffers

CAN Message Buffers are part of RAM memory. They are not CAN Special Function Registers. The user application must directly write into the RAM area that is configured for CAN Message Buffers. The location and size of the buffer area is defined by the user application.

**BUFFER 21-1: CANx MESSAGE BUFFER WORD 0**

| U-0 | U-0 | U-0 | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| — | — | — | SID10 | SID9 | SID8 | SID7 | SID6 |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| SID5 | SID4 | SID3 | SID2 | SID1 | SID0 | SRR | IDE |
| 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 **Unimplemented:** Read as ‘0’

bit 12-2 **SID<10:0>:** Standard Identifier bits

bit 1 **SRR:** Substitute Remote Request bit

When IDE = 0:
1 = Message will request remote transmission
0 = Normal message

When IDE = 1:
The SRR bit must be set to ‘1’.

bit 0 **IDE:** Extended Identifier bit

1 = Message will transmit an Extended Identifier
0 = Message will transmit a Standard Identifier

**BUFFER 21-2: CANx MESSAGE BUFFER WORD 1**

| U-0 | U-0 | U-0 | U-0 | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| — | — | — | — | EID<17:14> | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| EID<13:6> | | | | | | | |
| 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 15-12 **Unimplemented:** Read as ‘0’

bit 11-0 **EID<17:6>:** Extended Identifier bits


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**BUFFER 21-3: CANx MESSAGE BUFFER WORD 2**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| EID5 | EID4 | EID3 | EID2 | EID1 | EID0 | RTR | RB1 |
| bit 15 | | | | | | | bit 8 |

| U-x | U-x | U-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| — | — | — | RB0 | DLC3 | DLC2 | DLC1 | DLC0 |
| 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 15-10 **EID<5:0>:** Extended Identifier bits

bit 9 **RTR:** Remote Transmission Request bit
When IDE = 1:
1 = Message will request remote transmission
0 = Normal message
When IDE = 0:
The RTR bit is ignored.

bit 8 **RB1:** Reserved Bit 1
User must set this bit to '0' per CAN protocol.

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

bit 4 **RB0:** Reserved Bit 0
User must set this bit to '0' per CAN protocol.

bit 3-0 **DLC<3:0>:** Data Length Code bits

**BUFFER 21-4: CANx MESSAGE BUFFER WORD 3**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 1<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 0<7:0> | | | | | | | |
| 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 15-8 **Byte 1<15:8>:** CANx Message Byte 1 bits

bit 7-0 **Byte 0<7:0>:** CANx Message Byte 0 bits

**BUFFER 21-5: CANx MESSAGE BUFFER WORD 4**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 3<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 2<7:0> | | | | | | | |
| 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 15-8 **Byte 3<15:8>:** CANx Message Byte 3 bits

bit 7-0 **Byte 2<7:0>:** CANx Message Byte 2 bits

**BUFFER 21-6: CANx MESSAGE BUFFER WORD 5**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 5<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 4<7:0> | | | | | | | |
| 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 15-8 **Byte 5<15:8>:** CANx Message Byte 5 bits

bit 7-0 **Byte 4<7:0>:** CANx Message Byte 4 bits


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**BUFFER 21-7: CANx MESSAGE BUFFER WORD 6**

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 7<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| Byte 6<7:0> | | | | | | | |
| 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 15-8 **Byte 7<15:8>:** CANx Message Byte 7 bits

bit 7-0 **Byte 6<7:0>:** CANx Message Byte 6 bits

**BUFFER 21-8: CANx MESSAGE BUFFER WORD 7**

| U-0 | U-0 | U-0 | R/W-x | R/W-x | R/W-x | R/W-x | R/W-x |
|---|---|---|---|---|---|---|---|
| — | — | — | FILHIT<4:0>(1) | | | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-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 15-13 **Unimplemented:** Read as '0'

bit 12-8 **FILHIT<4:0>:** Filter Hit Code bits(1)
Encodes number of filter that resulted in writing this buffer.

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

**Note 1:** Only written by module for receive buffers, unused for transmit buffers.

**NOTES:**


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## 24.0 HIGH-SPEED ANALOG COMPARATOR

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"High-Speed Analog Comparator Module"** (DS70005128) in the *"dsPIC33/PIC24 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 high-speed analog comparator module monitors current and/or voltage transients that may be too fast for the CPU and ADC to capture.

### 24.1 Features Overview

The Switch Mode Power Supply (SMPS) comparator module offers the following major features:

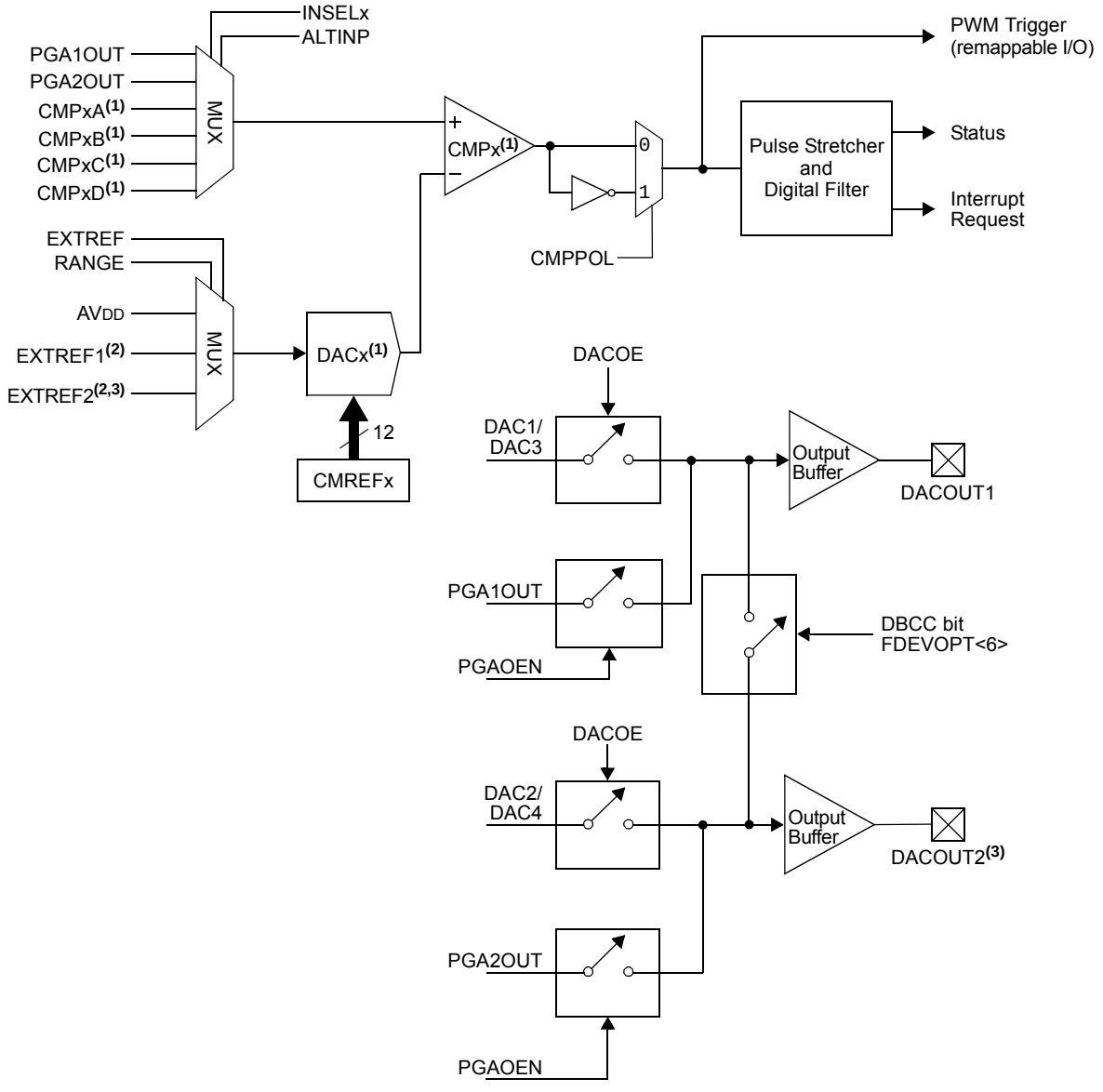
- Four Rail-to-Rail Analog Comparators
- Dedicated 12-Bit DAC for each Analog Comparator
- Up to Six Selectable Input Sources per Comparator:
  - Four external inputs
  - Two internal inputs from the PGAx module
- Programmable Comparator Hysteresis
- Programmable Output Polarity
- Up to Two DAC Outputs to Device Pins
- Multiple Voltage References for the DAC:
  - External References (EXTREF1 or EXTREF2)
  - $AV_{DD}$
- Interrupt Generation Capability
- Functional Support for PWMx:
  - PWMx duty cycle control
  - PWMx period control
  - PWMx Fault detected

## 24.2 Module Description

Figure 24-1 shows a functional block diagram of one analog comparator from the high-speed analog comparator module. The analog comparator provides high-speed operation with a typical delay of 15 ns. The negative input of the comparator is always connected to the DACx circuit. The positive input of the comparator is connected to an analog multiplexer that selects the desired source pin.

The analog comparator input pins are typically shared with pins used by the Analog-to-Digital Converter (ADC) module. Both the comparator and the ADC can use the same pins at the same time. This capability enables a user to measure an input voltage with the ADC and detect voltage transients with the comparator.

**FIGURE 24-1: HIGH-SPEED ANALOG COMPARATOR x MODULE BLOCK DIAGRAM**




**Note 1:** x = 1-4

**2:** EXTREF1 is connected to DAC1/DAC3. EXTREF2 is connected to DAC2/DAC4.

**3:** Not available on all devices.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## 24.3 Module Applications

This module provides a means for the SMPS dsPIC® DSC devices to monitor voltage and currents in a power conversion application. The ability to detect transient conditions and stimulate the dsPIC DSC processor and/or peripherals, without requiring the processor and ADC to constantly monitor voltages or currents, frees the dsPIC DSC to perform other tasks.

The comparator module has a high-speed comparator and an associated 12-bit DAC that provides a programmable reference voltage to the inverting input of the comparator. The polarity of the comparator output is user-programmable. The output of the module can be used in the following modes:

- Generate an Interrupt
- Trigger an ADC Sample and Convert Process
- Truncate the PWMx Signal (current limit)
- Truncate the PWMx Period (current minimum)
- Disable the PWMx Outputs (Fault latch)

The output of the comparator module may be used in multiple modes at the same time, such as: 1) generate an interrupt, 2) have the ADC take a sample and convert it, and 3) truncate the PWMx output in response to a voltage being detected beyond its expected value.

The comparator module can also be used to wake-up the system from Sleep or Idle mode when the analog input voltage exceeds the programmed threshold voltage.

## 24.4 Digital-to-Analog Comparator (DAC)

Each analog comparator has a dedicated 12-bit DAC that is used to program the comparator threshold voltage via the CMPxDAC register. The DAC voltage reference source is selected using the EXTREF and RANGE bits in the CMPxCON register.

The EXTREF bit selects either the external voltage reference, EXTREFx, or an internal source as the voltage reference source. The EXTREFx input enables users to connect to a voltage reference that better suits their application. The RANGE bit enables $AV_{DD}$ as the voltage reference source for the DAC when an internal voltage reference is selected.

**Note:** EXTREF2 is not available on all devices.

Each DACx has an output enable bit, DACOE, in the CMPxCON register that enables the DACx reference voltage to be routed to an external output pin (DACOUTx). Refer to Figure 24-1 for connecting the DACx output voltage to the DACOUTx pins.

**Note 1:** Ensure that multiple DACOE bits are not set in software. The output on the DACOUTx pin will be indeterminate if multiple comparators enable the DACx output.

**2:** DACOUT2 is not available on all devices.

## 24.5 Pulse Stretcher and Digital Logic

The analog comparator can respond to very fast transient signals. After the comparator output is given the desired polarity, the signal is passed to a pulse stretching circuit. The pulse stretching circuit has an asynchronous set function and a delay circuit that ensures the minimum pulse width is three system clock cycles wide to allow the attached circuitry to properly respond to a narrow pulse event.

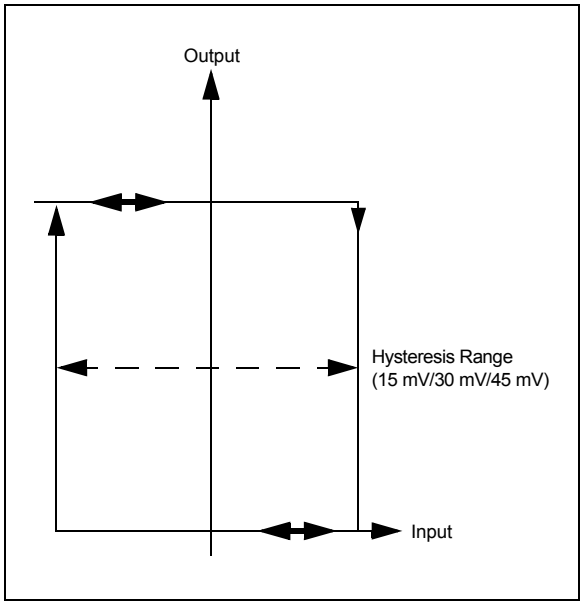
The pulse stretcher circuit is followed by a digital filter. The digital filter is enabled via the FLTREN bit in the CMPxCON register. The digital filter operates with the clock specified via the FCLKSEL bit in the CMPxCON register. The comparator signal must be stable in a high or low state, for at least three of the selected clock cycles, for it to pass through the digital filter.

## 24.6 Hysteresis

An additional feature of the module is hysteresis control. Hysteresis can be enabled or disabled and its amplitude can be controlled by the HYSSEL<1:0> bits in the CMPxCON register. Three different values are available: 15 mV, 30 mV and 45 mV. It is also possible to select the edge (rising or falling) to which hysteresis is to be applied.

Hysteresis control prevents the comparator output from continuously changing state because of small perturbations (noise) at the input (see Figure 24-2).

**FIGURE 24-2: HYSTERESIS CONTROL**




## 24.7 Analog Comparator 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 contains the latest updates and additional information.

### 24.7.1 KEY RESOURCES

- **"High-Speed Analog Comparator Module"** (DS70005128) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools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**REGISTER 24-1: CMPxCON: COMPARATOR x CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CMPON | — | CMPSIDL | HYSSEL1 | HYSSEL0 | FLTREN | FCLKSEL | DACOE |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | HC-0, HS | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| INSEL1 | INSEL0 | EXTREF | HYSPOL | CMPSTAT | ALTINP | CMPPOL | RANGE |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware Clearable bit | HS = Hardware Settable 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 **CMPON:** Comparator Operating Mode bit
1 = Comparator module is enabled
0 = Comparator module is disabled (reduces power consumption)

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

bit 13 **CMPSIDL:** Comparator Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode.
0 = Continues module operation in Idle mode
If a device has multiple comparators, any CMPSIDL bit set to '1' disables all comparators while in Idle mode.

bit 12-11 **HYSSEL<1:0>:** Comparator Hysteresis Select bits
11 = 45 mV hysteresis
10 = 30 mV hysteresis
01 = 15 mV hysteresis
00 = No hysteresis is selected

bit 10 **FLTREN:** Digital Filter Enable bit
1 = Digital filter is enabled
0 = Digital filter is disabled

bit 9 **FCLKSEL:** Digital Filter and Pulse Stretcher Clock Select bit
1 = Digital filter and pulse stretcher operate with the PWM clock
0 = Digital filter and pulse stretcher operate with the system clock

bit 8 **DACOE:** DACx Output Enable bit
1 = DACx analog voltage is connected to the DACOUTx pin(1)
0 = DACx analog voltage is not connected to the DACOUTx pin

bit 7-6 **INSEL<1:0>:** Input Source Select for Comparator bits
If ALTINP = 0, Select from Comparator Inputs:
11 = Selects CMPxD input pin
10 = Selects CMPxC input pin
01 = Selects CMPxB input pin
00 = Selects CMPxA input pin
If ALTINP = 1, Select from Alternate Inputs:
11 = Reserved
10 = Reserved
01 = Selects PGA2 output
00 = Selects PGA1 output

**Note 1:** DACOUTx can be associated only with a single comparator at any given time. The software must ensure that multiple comparators do not enable the DACx output by setting their respective DACOE bit.

**REGISTER 24-1: CMPxCON: COMPARATOR x CONTROL REGISTER (CONTINUED)**

bit 5 **EXTREF:** Enable External Reference bit
1 = External source provides reference to DACx (maximum DAC voltage is determined by the external voltage source)
0 = AVDD provides reference to DACx (maximum DAC voltage is AVDD)

bit 4 **HYSPOL:** Comparator Hysteresis Polarity Select bit
1 = Hysteresis is applied to the falling edge of the comparator output
0 = Hysteresis is applied to the rising edge of the comparator output

bit 3 **CMPSTAT:** Comparator Current State bit
Reflects the current output state of Comparator x, including the setting of the CMPPOL bit.

bit 2 **ALTINP:** Alternate Input Select bit
1 = INSEL<1:0> bits select alternate inputs
0 = INSEL<1:0> bits select comparator inputs

bit 1 **CMPPOL:** Comparator Output Polarity Control bit
1 = Output is inverted
0 = Output is non-inverted

bit 0 **RANGE:** DACx Output Voltage Range Select bit
1 = AVDD is the maximum DACx output voltage
0 = Unimplemented, do not use

**Note 1:** DACOUTx can be associated only with a single comparator at any given time. The software must ensure that multiple comparators do not enable the DACx output by setting their respective DACOE bit.


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**REGISTER 24-2: CMPxDAC: COMPARATOR x DAC CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | CMREF<11:8> | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| CMREF<7:0> | | | | | | | |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11-0 **CMREF<11:0>:** Comparator Reference Voltage Select bits

111111111111
•
•
•  = ([CMREF<11:0>] * (AVDD)/4096) volts (EXTREF = 0)
•  or ([CMREF<11:0>] * (EXTREF)/4096) volts (EXTREF = 1)
•
•
000000000000

**NOTES:**


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## 25.0 PROGRAMMABLE GAIN AMPLIFIER (PGA)

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Programmable Gain Amplifier (PGA)"** (DS70005146) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

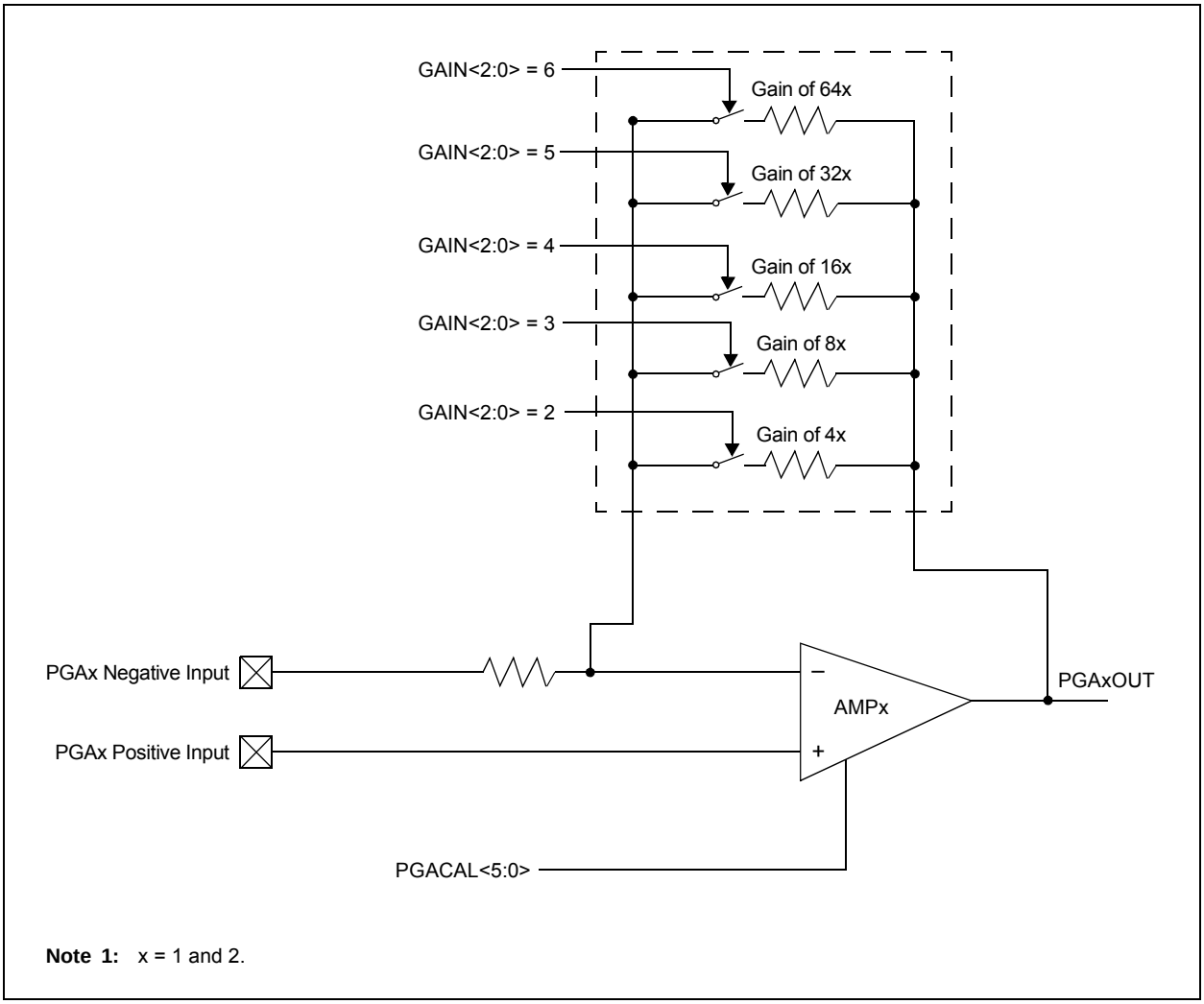
**2:** Some registers and associated bits described in this section may not be available on all devices. Refer to **Section 4.0 "Memory Organization"** in this data sheet for device-specific register and bit information.

The dsPIC33EPXXXGS70X/80X family devices have two Programmable Gain Amplifiers (PGA1, PGA2). The PGA is an op amp-based, non-inverting amplifier with user-programmable gains. The output of the PGA can be connected to a number of dedicated Sample-and-Hold inputs of the Analog-to-Digital Converter and/or to the high-speed analog comparator module. The PGA has five selectable gains and may be used as a ground referenced amplifier (single-ended) or used with an independent ground reference point.

Key features of the PGA module include:

- Single-Ended or Independent Ground Reference
- Selectable Gains: 4x, 8x, 16x, 32x and 64x
- High Gain Bandwidth
- Rail-to-Rail Output Voltage
- Wide Input Voltage Range

**FIGURE 25-1: PGAx MODULE BLOCK DIAGRAM**




**Note 1:** x = 1 and 2.

## 25.1 Module Description

The Programmable Gain Amplifiers are used to amplify small voltages (i.e., voltages across burden/shunt resistors) to improve the signal-to-noise ratio of the measured signal. The PGAx output voltage can be read by any of the four dedicated Sample-and-Hold circuits on the ADC module. The output voltage can also be fed to the comparator module for overcurrent/voltage protection. Figure 25-2 shows a functional block diagram of the PGAx module. Refer to **Section 22.0 "High-Speed, 12-Bit Analog-to-Digital Converter (ADC)"** and **Section 24.0 "High-Speed Analog Comparator"** for more interconnection details.

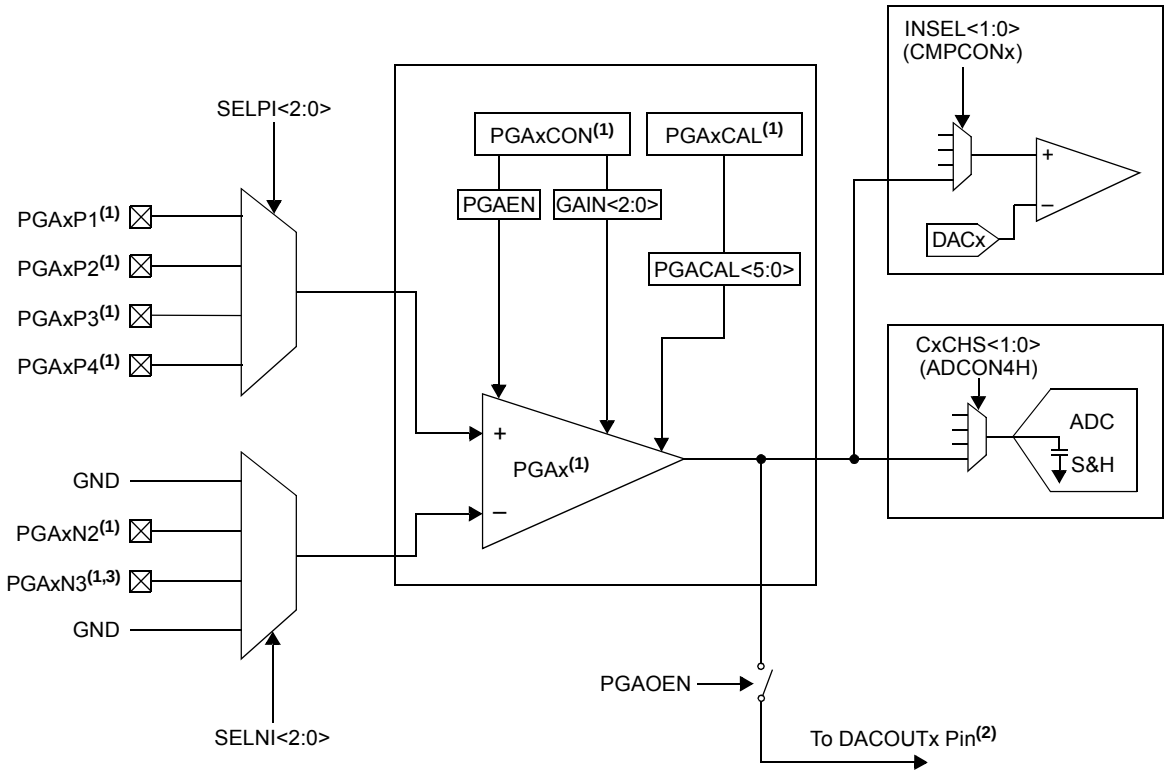
The gain of the PGAx module is selectable via the GAIN<2:0> bits in the PGAxCON register. There are five selectable gains, ranging from 4x to 64x. The SELPI<2:0> and SELNI<2:0> bits in the PGAxCON register select one of four positive/negative inputs to the PGAx module. For single-ended applications, the SELNI<2:0> bits will select the ground as the negative input source. To provide an independent ground reference, the PGAxN2 and PGAxN3 pins are available as the negative input source to the PGAx module.

**Note 1:** Not all PGA positive/negative inputs are available on all devices. Refer to the specific device pinout for available input source pins.

The output voltage of the PGAx module can be connected to the DACOUTx pin by setting the PGAOEN bit in the PGAxCON register. When the PGAOEN bit is enabled, the output voltage of PGA1 is connected to DACOUT1 and PGA2 is connected to DACOUT2. For devices with a single DACOUTx pin, the output voltage of PGA2 can be connected to DACOUT1 by configuring the DBCC Configuration bit in the FDEVOPT register (FDEVOPT<6>).

If both the DACx output voltage and PGAx output voltage are connected to the DACOUTx pin, the resulting output voltage would be a combination of signals. There is no assigned priority between the PGAx module and the DACx module.

**FIGURE 25-2: PGAx FUNCTIONAL BLOCK DIAGRAM**




**Note 1:** x = 1 and 2.
**2:** The DACOUT2 device pin is only available on 64-pin devices.
**3:** The PGAxN3 input is not available on 28-pin devices.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## 25.2 PGA Resources

Many useful resources are provided on the main product page of the Microchip website for the devices listed in this data sheet. This product page contains the latest updates and additional information.

### 25.2.1 KEY RESOURCES

- **"Programmable Gain Amplifier (PGA)"** (DS70005146) in the *"dsPIC33/PIC24 Family Reference Manual"*
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- All Related *"dsPIC33/PIC24 Family Reference Manual"* Sections
- Development Tools

**REGISTER 25-1: PGAxCON: PGAx CONTROL REGISTER**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PGAEN | PGAOEN | SELPI2 | SELPI1 | SELPI0 | SELNI2 | SELNI1 | SELNI0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | GAIN2 | GAIN1 | GAIN0 |
| 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 **PGAEN:** PGAx Enable bit
1 = PGAx module is enabled
0 = PGAx module is disabled (reduces power consumption)

bit 14 **PGAOEN:** PGAx Output Enable bit
1 = PGAx output is connected to the DACOUTx pin
0 = PGAx output is not connected to the DACOUTx pin

bit 13-11 **SELPI<2:0>:** PGAx Positive Input Selection bits
111 = Reserved
110 = Reserved
101 = Reserved
100 = Reserved
011 = PGAxP4
010 = PGAxP3
001 = PGAxP2
000 = PGAxP1

bit 10-8 **SELNI<2:0>:** PGAx Negative Input Selection bits
111 = Reserved
110 = Reserved
101 = Reserved
100 = Reserved
011 = Ground (Single-Ended mode)
010 = PGAxN3
001 = PGAxN2
000 = Ground (Single-Ended mode)

bit 7-3 **Unimplemented:** Read as '0'

**REGISTER 25-1: PGAxCON: PGAx CONTROL REGISTER (CONTINUED)**

bit 2-0 **GAIN<2:0>:** PGAx Gain Selection bits
111 = Reserved
110 = Gain of 64x
101 = Gain of 32x
100 = Gain of 16x
011 = Gain of 8x
010 = Gain of 4x
001 = Reserved
000 = Reserved

**REGISTER 25-2: PGAxCAL: PGAx CALIBRATION REGISTER**

| 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | PGACAL<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 15-6 **Unimplemented:** Read as ‘0’

bit 5-0 **PGACAL<5:0>:** PGAx Offset Calibration bits
The calibration values for PGA1 and PGA2 must be copied from Flash addresses, 0x800E48 and 0x800E4C, respectively, into these bits before the module is enabled. Refer to the calibration data address table (Table 27-3) in **Section 27.0 “Special Features”** for more information.


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## 26.0 CONSTANT-CURRENT SOURCE

**Note 1:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to the *"dsPIC33/PIC24 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 constant-current source module is a precision current generator and is used in conjunction with the ADC module to measure the resistance of external resistors connected to device pins.

### 26.1 Features Overview

The constant-current source module offers the following major features:

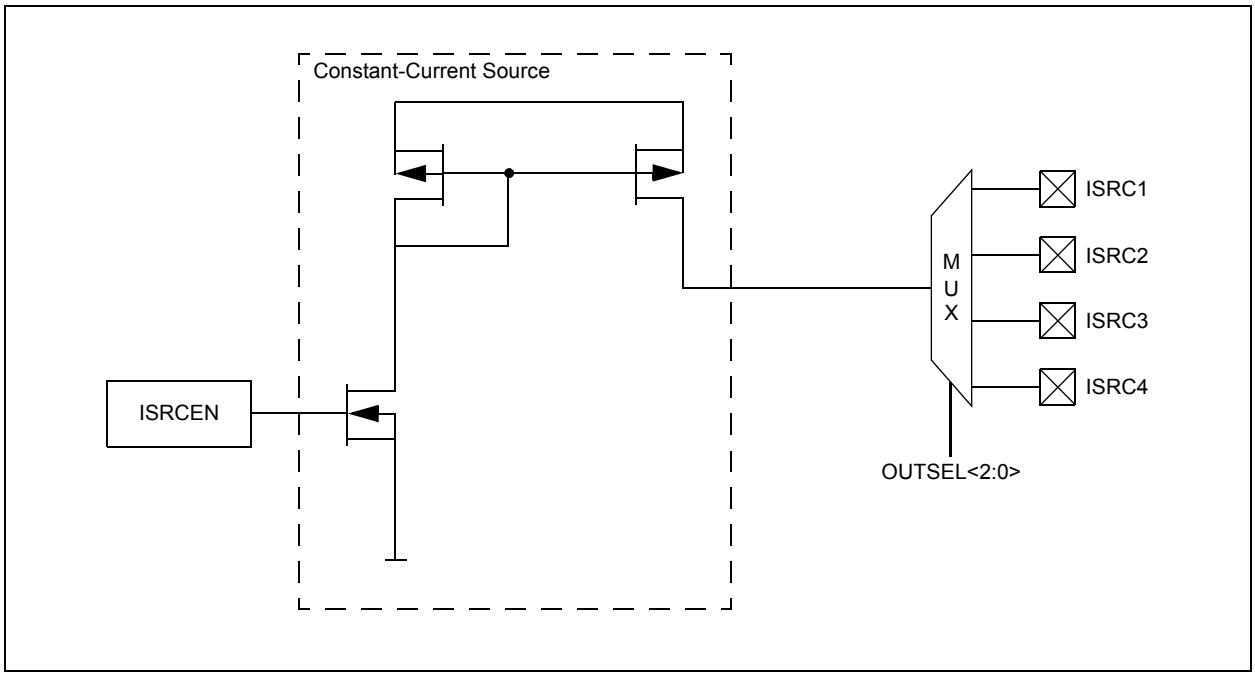
- Constant-Current Generator (10 µA nominal)
- Internal Selectable Connection to One of Four Pins
- Enable/Disable bit

### 26.2 Module Description

Figure 26-1 shows a functional block diagram of the constant-current source module. It consists of a precision current generator with a nominal value of 10 µA. The module can be enabled and disabled using the ISRCEN bit in the ISRCCON register. The output of the current generator is internally connected to a device pin. The dsPIC33EPXXXGS70X/80X family can have up to 4 selectable current source pins. The OUTSEL<2:0> bits in the ISRCCON register allow selection of the target pin.

The current source is calibrated during testing.

**FIGURE 26-1: CONSTANT-CURRENT SOURCE MODULE BLOCK DIAGRAM**



## 26.3 Current Source Control Register

**REGISTER 26-1: ISRCCON: CONSTANT-CURRENT SOURCE CONTROL REGISTER**

| R/W-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ISRCEN | — | — | — | — | OUTSEL2 | OUTSEL1 | OUTSEL0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | ISRCCAL5 | ISRCCAL4 | ISRCCAL3 | ISRCCAL2 | ISRCCAL1 | ISRCCAL0 |
| 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 **ISRCEN:** Constant-Current Source Enable bit
1 = Current source is enabled
0 = Current source is disabled

bit 14-11 **Unimplemented:** Read as ‘0’

bit 10-8 **OUTSEL<2:0>:** Output Constant-Current Select bits
111 = Reserved
110 = Reserved
101 = Reserved
100 = Input pin, ISRC4 (AN4)
011 = Input pin, ISRC3 (AN5)
010 = Input pin, ISRC2 (AN6)
001 = Input pin, ISRC1 (AN12)
000 = No output is selected

bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-0 **ISRCCAL<5:0>:** Constant-Current Source Calibration bits
The calibration value must be copied from Flash address, 0x800E78, into these bits before the module is enabled. Refer to the calibration data address table (Table 27-3) in **Section 27.0 “Special Features”** for more information.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## 27.0 SPECIAL FEATURES

**Note:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Device Configuration"** (DS70000618), **"Watchdog Timer and Power-Saving Modes"** (DS70615) and **"CodeGuard™ Intermediate Security"** (DS70005182) in the *"dsPIC33/PIC24 Family Reference Manual"*, which is available from the Microchip web site (www.microchip.com).

The dsPIC33EPXXXGS70X/80X family devices include several features intended to maximize application flexibility and reliability, and minimize cost through elimination of external components. These are:

- Flexible Configuration
- Watchdog Timer (WDT)
- Code Protection and CodeGuard™ Security
- JTAG Boundary Scan Interface
- In-Circuit Serial Programming™ (ICSP™)
- In-Circuit Emulation
- Brown-out Reset (BOR)

### 27.1 Configuration Bits

In dsPIC33EPXXXGS70X/80X family devices, the Configuration Words are implemented as volatile memory. This means that configuration data must be programmed each time the device is powered up. Configuration data is stored at the end of the on-chip program memory space, known as the Flash Configuration Words. Their specific locations are shown in Table 27-1 with detailed descriptions in Table 27-2. The configuration data is automatically loaded from the Flash Configuration Words to the proper Configuration Shadow registers during device Resets.

For devices operating in Dual Partition Flash modes, the BSEQx bits (FBTSEQ<11:0>) determine which panel is the Active Partition at start-up and the Configuration Words from that panel are loaded into the Configuration Shadow registers.

**Note:** Configuration data is reloaded on all types of device Resets.

When creating applications for these devices, users should always specifically allocate the location of the Flash Configuration Words for configuration data in their code for the compiler. This is to make certain that program code is not stored in this address when the code is compiled. Program code executing out of configuration space will cause a device Reset.

**Note:** Performing a page erase operation on the last page of program memory clears the Flash Configuration Words.

**TABLE 27-1: CONFIGURATION REGISTER MAP(3)**

| Name | Address | Device Memory Size (Kbytes) | Bits 23-16 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FSEC | 00AF80 | 64 | — | AIVTDIS | — | — | — | CSS<2:0> | | | CWRP | GSS<1:0> | | GWRP | — | BSEN | BSS<1:0> | | BWRP |
| | 015780 | 128 | | | | | | | | | | | | | | | | | |
| FBSLIM | 00AF90 | 64 | — | — | — | — | BSLIM<12:0> | | | | | | | | | | | | |
| | 015790 | 128 | | | | | | | | | | | | | | | | | |
| FSIGN | 00AF90 | 64 | — | Reserved(2) | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 015794 | 128 | | | | | | | | | | | | | | | | | |
| FOSCSEL | 00AF98 | 64 | — | — | — | — | — | — | — | — | — | IESO | — | — | — | — | FNOSC<2:0> | | |
| | 015798 | 128 | | | | | | | | | | | | | | | | | |
| FOSC | 00AF9C | 64 | — | — | — | — | — | — | — | — | PLLKEN | FCKSM<1:0> | | IOL1WAY | — | — | OSCIOFNC | POSCMD<1:0> | |
| | 01579C | 128 | | | | | | | | | | | | | | | | | |
| FWDT | 00AFA0 | 64 | — | — | — | — | — | — | — | WDTWIN<1:0> | | WINDIS | WDTEN<1:0> | | WDTPRE | WDTPOST<3:0> | | | |
| | 0157A0 | 128 | | | | | | | | | | | | | | | | | |
| FPOR | 00AFA4 | 64 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | Reserved(1) |
| | 0157A4 | 128 | | | | | | | | | | | | | | | | | |
| FICD | 00AFA8 | 64 | — | BTSWP | — | — | — | — | — | — | — | Reserved(1) | — | JTAGEN | — | — | — | ICS<1:0> | |
| | 0157A8 | 128 | | | | | | | | | | | | | | | | | |
| FDEVOPT | 00AFAC | 64 | — | — | — | — | — | — | — | — | — | — | DBCC | — | ALTI2C2 | ALTI2C1 | Reserved(1) | — | PWMLOCK |
| | 0157AC | 128 | | | | | | | | | | | | | | | | | |
| FALTREG | 00AFB0 | 64 | — | — | CTXT4<2:0> | | | — | CTXT3<3:0> | | | — | CTXT2 <2:0> | | | — | CTXT1 <2:0> | | |
| | 0157B0 | 128 | | | | | | | | | | | | | | | | | |
| FBTSEQ | 00AFFC | 64 | IBSEQ<11:0> | | | | | BSEQ<11:0> | | | | | | | | | | | |
| | 0157FC | 128 | | | | | | | | | | | | | | | | | |
| FBOOT(4) | 801000 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | BTMODE<1:0> | |

**Note 1:** These bits are reserved and must be programmed as '1'.

**2:** This bit is reserved and must be programmed as '0'.

**3:** When operating in Dual Partition Flash mode, each partition will have dedicated Configuration registers. On a device Reset, the configuration values of the Active Partition are read at start-up, but during a soft swap condition, the configuration settings of the newly Active Partition are ignored.

**4:** FBOOT resides in configuration memory space.



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**TABLE 27-2: CONFIGURATION BITS DESCRIPTION**

| Bit Field | Description |
|---|---|
| BSS<1:0> | Boot Segment Code-Protect Level bits<br>11 = Boot Segment is not code-protected other than BWRP<br>10 = Standard security<br>0x = High security |
| BSEN | Boot Segment Control bit<br>1 = No Boot Segment is enabled<br>0 = Boot Segment size is determined by the BSLIM<12:0> bits |
| BWRP | Boot Segment Write-Protect bit<br>1 = Boot Segment can be written<br>0 = Boot Segment is write-protected |
| BSLIM<12:0> | Boot Segment Flash Page Address Limit bits<br>Contains the last active Boot Segment page. The value to be programmed is the inverted page address, such that programming additional '0's can only increase the Boot Segment size (i.e., 0x1FFD = 2 Pages or 1024 IW). |
| GSS<1:0> | General Segment Code-Protect Level bits<br>11 = User program memory is not code-protected<br>10 = Standard security<br>0x = High security |
| GWRP | General Segment Write-Protect bit<br>1 = User program memory is not write-protected<br>0 = User program memory is write-protected |
| CWRP | Configuration Segment Write-Protect bit<br>1 = Configuration data is not write-protected<br>0 = Configuration data is write-protected |
| CSS<2:0> | Configuration Segment Code-Protect Level bits<br>111 = Configuration data is not code-protected<br>110 = Standard security<br>10x = Enhanced security<br>0xx = High security |
| BTSWP | BOOTSWP Instruction Enable/Disable bit<br>1 = BOOTSWP instruction is disabled<br>0 = BOOTSWP instruction is enabled |
| BSEQ<11:0> | Boot Sequence Number bits (Dual Partition modes only)<br>Relative value defining which partition will be active after device Reset; the partition containing a lower boot number will be active. |
| IBSEQ<11:0> | Inverse Boot Sequence Number bits (Dual Partition modes only)<br>The one's complement of BSEQ<11:0>; must be calculated by the user and written for device programming. If BSEQx and IBSEQx are not complements of each other, the Boot Sequence Number is considered to be invalid. |
| AIVTDIS(1) | Alternate Interrupt Vector Table bit<br>1 = Alternate Interrupt Vector Table is disabled<br>0 = Alternate Interrupt Vector Table is enabled if INTCON2<8> = 1 |
| IESO | Two-Speed Oscillator Start-up Enable bit<br>1 = Starts up device with FRC, then automatically switches to the user-selected oscillator source when ready<br>0 = Starts up device with the user-selected oscillator source |
| PWMLOCK | PWMx Lock Enable bit<br>1 = Certain PWMx registers may only be written after a key sequence<br>0 = PWMx registers may be written without a key sequence |

**Note 1:** The Boot Segment must be present to use the Alternate Interrupt Vector Table.

**TABLE 27-2: CONFIGURATION BITS DESCRIPTION (CONTINUED)**

| Bit Field | Description |
|---|---|
| FNOSC<2:0> | Oscillator Selection bits<br>111 = Fast RC Oscillator with Divide-by-N (FRCDIVN)<br>110 = Fast RC Oscillator with Divide-by-16<br>101 = Low-Power RC Oscillator (LPRC)<br>100 = Reserved; do not use<br>011 = Primary Oscillator with PLL module (XT+PLL, HS+PLL, EC+PLL)<br>010 = Primary Oscillator (XT, HS, EC)<br>001 = Fast RC Oscillator with Divide-by-N with PLL module (FRCPLL)<br>000 = Fast RC Oscillator (FRC) |
| FCKSM<1:0> | 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 |
| IOL1WAY | Peripheral Pin Select Configuration bit<br>1 = Allows only one reconfiguration<br>0 = Allows multiple reconfigurations |
| OSCIOFNC | OSC2 Pin Function bit (except in XT and HS modes)<br>1 = OSC2 is the clock output<br>0 = OSC2 is a general purpose digital I/O pin |
| POSCMD<1:0> | Primary Oscillator Mode Select bits<br>11 = Primary Oscillator is disabled<br>10 = HS Crystal Oscillator mode<br>01 = XT Crystal Oscillator mode<br>00 = EC (External Clock) mode |
| WDTEN<1:0> | Watchdog Timer Enable bits<br>11 = Watchdog Timer is always enabled (LPRC oscillator cannot be disabled; clearing the SWDTEN bit in the RCON register will have no effect)<br>10 = Watchdog Timer is enabled/disabled by user software (LPRC can be disabled by clearing the SWDTEN bit in the RCON register)<br>01 = Watchdog Timer is enabled only while device is active and is disabled while in Sleep mode; software control is disabled in this mode<br>00 = Watchdog Timer and SWDTEN bit are disabled |
| WINDIS | Watchdog Timer Window Enable bit<br>1 = Watchdog Timer is in Non-Window mode<br>0 = Watchdog Timer is in Window mode |
| PLLKEN | PLL Lock Enable bit<br>1 = PLL lock is enabled<br>0 = PLL lock is disabled |
| WDTPRE | Watchdog Timer Prescaler bit<br>1 = 1:128<br>0 = 1:32 |
| WDTPOST<3:0> | 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 |

**Note 1:** The Boot Segment must be present to use the Alternate Interrupt Vector Table.


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**TABLE 27-2: CONFIGURATION BITS DESCRIPTION (CONTINUED)**

| Bit Field | Description |
|---|---|
| WDTWIN<1:0> | Watchdog Timer Window Select bits<br>11 = WDT window is 25% of the WDT period<br>10 = WDT window is 37.5% of the WDT period<br>01 = WDT window is 50% of the WDT period<br>00 = WDT window is 75% of the WDT period |
| ALTI2C1 | Alternate I2C1 Pin bit<br>1 = I2C1 is mapped to the SDA1/SCL1 pins<br>0 = I2C1 is mapped to the ASDA1/ASCL1 pins |
| ALTI2C2 | Alternate I2C2 Pin bit<br>1 = I2C2 is mapped to the SDA2/SCL2 pins<br>0 = I2C2 is mapped to the ASDA2/ASCL2 pins |
| JTAGEN | JTAG Enable bit<br>1 = JTAG is enabled<br>0 = JTAG is disabled |
| ICS<1:0> | ICD Communication Channel Select bits<br>11 = Communicates on PGEC1 and PGED1<br>10 = Communicates on PGEC2 and PGED2<br>01 = Communicates on PGEC3 and PGED3<br>00 = Reserved, do not use |
| DBCC | DACx Output Cross Connection Select bit<br>1 = No cross connection between DAC outputs<br>0 = Interconnects DACOUT1 and DACOUT2 |
| CTXT1<2:0> | Alternate Working Register Set 1 Interrupt Priority Level (IPL) Select bits<br>111 = Reserved<br>110 = Assigned to IPL of 7<br>101 = Assigned to IPL of 6<br>100 = Assigned to IPL of 5<br>011 = Assigned to IPL of 4<br>010 = Assigned to IPL of 3<br>001 = Assigned to IPL of 2<br>000 = Assigned to IPL of 1 |
| CTXT2<2:0> | Alternate Working Register Set 2 Interrupt Priority Level (IPL) Select bits<br>111 = Reserved<br>110 = Assigned to IPL of 7<br>101 = Assigned to IPL of 6<br>100 = Assigned to IPL of 5<br>011 = Assigned to IPL of 4<br>010 = Assigned to IPL of 3<br>001 = Assigned to IPL of 2<br>000 = Assigned to IPL of 1 |
| CTXT3<2:0> | Alternate Working Register Set 3 Interrupt Priority Level (IPL) Select bits<br>111 = Reserved<br>110 = Assigned to IPL of 7<br>101 = Assigned to IPL of 6<br>100 = Assigned to IPL of 5<br>011 = Assigned to IPL of 4<br>010 = Assigned to IPL of 3<br>001 = Assigned to IPL of 2<br>000 = Assigned to IPL of 1 |

**Note 1:** The Boot Segment must be present to use the Alternate Interrupt Vector Table.

**TABLE 27-2: CONFIGURATION BITS DESCRIPTION (CONTINUED)**

| Bit Field | Description |
|---|---|
| CTXT4<2:0> | Alternate Working Register Set 4 Interrupt Priority Level (IPL) Select bits<br>111 = Reserved<br>110 = Assigned to IPL of 7<br>101 = Assigned to IPL of 6<br>100 = Assigned to IPL of 5<br>011 = Assigned to IPL of 4<br>010 = Assigned to IPL of 3<br>001 = Assigned to IPL of 2<br>000 = Assigned to IPL of 1 |
| BTMODE<1:0> | Boot Mode Configuration bits<br>11 = Single Partition mode<br>10 = Dual Partition mode<br>01 = Protected Dual Partition mode<br>00 = Privileged Dual Partition mode |

**Note 1:** The Boot Segment must be present to use the Alternate Interrupt Vector Table.


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## 27.2 Device Calibration and Identification

The PGAx and current source modules on the dsPIC33EPXXXGS70X/80X family devices require Calibration Data registers to improve performance of the module over a wide operating range. These Calibration registers are read-only and are stored in configuration memory space. Prior to enabling the module, the calibration data must be read (TBLPAG and Table Read instruction) and loaded into its respective SFR registers. The device calibration addresses are shown in Table 27-3.

The dsPIC33EPXXXGS70X/80X devices have two Identification registers near the end of configuration memory space that store the Device ID (DEVID) and Device Revision (DEVREV). These registers are used to determine the mask, variant and manufacturing information about the device. These registers are read-only and are shown in Register 27-1 and Register 27-2.

**TABLE 27-3: DEVICE CALIBRATION ADDRESSES(1)**

| Calibration Name | Address | Bits 23-16 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PGA1CAL | 800E48 | — | — | — | — | — | — | — | — | — | — | — | PGA1 Calibration Data | | | | | |
| PGA2CAL | 800E4C | — | — | — | — | — | — | — | — | — | — | — | PGA2 Calibration Data | | | | | |
| ISRCCAL | 800E78 | — | — | — | — | — | — | — | — | — | — | — | Current Source Calibration Data | | | | | |

**Note 1:** The calibration data must be copied into its respective SFR registers prior to enabling the module.

**REGISTER 27-1: DEVID: DEVICE ID REGISTER**

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEVID<23:16> | | | | | | | |
| bit 23 | | | | | | | bit 16 |

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEVID<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEVID<7:0> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** R = Read-Only bit | U = Unimplemented bit |
|---|---|

bit 23-0 **DEVID<23:0>:** Device Identifier bits

**REGISTER 27-2: DEVREV: DEVICE REVISION REGISTER**

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEVREV<23:16> | | | | | | | |
| bit 23 | | | | | | | bit 16 |

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEVREV<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEVREV<7:0> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** R = Read-only bit | U = Unimplemented bit |
|---|---|

bit 23-0 **DEVREV<23:0>:** Device Revision bits


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## 27.3 User OTP Memory

The dsPIC33EPXXXGS70X/80X family devices contain 64 words of user One-Time-Programmable (OTP) memory, located at addresses, 0x800F80 through 0x800FFC. The user OTP Words can be used for storing checksum, code revisions, product information, such as serial numbers, system manufacturing dates, manufacturing lot numbers and other application-specific information. These words can only be written once at program time and not at run time; they can be read at run time.

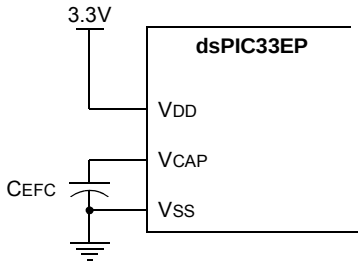
## 27.4 On-Chip Voltage Regulator

All the dsPIC33EPXXXGS70X/80X family devices power their core digital logic at a nominal 1.8V. This can create a conflict for designs that are required to operate at a higher typical voltage, such as 3.3V. To simplify system design, all devices in the dsPIC33EPXXXGS70X/80X family incorporate an on-chip regulator that allows the device to run its core logic from VDD.

The regulator provides power to the core from the other VDD pins. A low-ESR (less than 1 Ohm) capacitor (such as tantalum or ceramic) must be connected to the VCAP pin (Figure 27-1). This helps to maintain the stability of the regulator. The recommended value for the filter capacitor is provided in Table 30-5, located in **Section 30.0 "Electrical Characteristics"**.

| | |
|---|---|
| **Note:** | It is important for the low-ESR capacitor to be placed as close as possible to the VCAP pin. |

**FIGURE 27-1: CONNECTIONS FOR THE ON-CHIP VOLTAGE REGULATOR(1,2,3)**




**Note 1:** These are typical operating voltages. Refer to Table 30-5 located in **Section 30.0 "Electrical Characteristics"** for the full operating ranges of VDD and VCAP.

**2:** It is important for the low-ESR capacitor to be placed as close as possible to the VCAP pin.

**3:** Typical VCAP pin voltage = 1.8V when VDD ≥ VDDMIN.

## 27.5 Brown-out Reset (BOR)

The Brown-out Reset (BOR) module is based on an internal voltage reference circuit that monitors the regulated supply voltage, VCAP. The main purpose of the BOR module is to generate a device Reset when a brown-out condition occurs. Brown-out conditions are generally caused by glitches on the AC mains (for example, missing portions of the AC cycle waveform due to bad power transmission lines or voltage sags due to excessive current draw when a large inductive load is turned on).

A BOR generates a Reset pulse which resets the device. The BOR selects the clock source based on the device Configuration bit values (FNOSC<2:0> and POSCMD<1:0>).

If an Oscillator mode is selected, the BOR activates the Oscillator Start-up Timer (OST). The system clock is held until OST expires. If the PLL is used, the clock is held until the LOCK bit (OSCCON<5>) is '1'.

Concurrently, the Power-up Timer (PWRT) Time-out (TPWRT) is applied before the internal Reset is released. If TPWRT = 0 and a crystal oscillator is being used, then a nominal delay of TFSCM is applied. The total delay in this case is TFSCM. Refer to Parameter SY35 in Table 30-23 of **Section 30.0 "Electrical Characteristics"** for specific TFSCM values.

The BOR status bit (RCON<1>) is set to indicate that a BOR has occurred. The BOR circuit continues to operate while in Sleep or Idle modes and resets the device should VDD fall below the BOR threshold voltage.

## 27.6 Watchdog Timer (WDT)

For dsPIC33EPXXXGS70X/80X family devices, the WDT is driven by the LPRC oscillator. When the WDT is enabled, the clock source is also enabled.

### 27.6.1 PRESCALER/POSTSCALER

The nominal WDT clock source from LPRC is 32 kHz. This feeds a prescaler that can be configured for either 5-bit (divide-by-32) or 7-bit (divide-by-128) operation. The prescaler is set by the WDTPRE Configuration bit. With a 32 kHz input, the prescaler yields a WDT Time-out Period (TWDT), as shown in Parameter SY12 in Table 30-23.

A variable postscaler divides down the WDT prescaler output and allows for a wide range of time-out periods. The postscaler is controlled by the WDTPOST<3:0> Configuration bits (FWDT<3:0>), which allow the selection of 16 settings, from 1:1 to 1:32,768. Using the prescaler and postscaler time-out periods, ranges from 1 ms to 131 seconds can be achieved.

The WDT, prescaler and postscaler are reset:

- On any device Reset
- On the completion of a clock switch, whether invoked by software (i.e., setting the OSWEN bit after changing the NOSCx bits) or by hardware (i.e., Fail-Safe Clock Monitor)
- When a PWRSAV instruction is executed (i.e., Sleep or Idle mode is entered)
- When the device exits Sleep or Idle mode to resume normal operation
- By a CLRWDT instruction during normal execution

**Note:** The CLRWDT and PWRSAV instructions clear the prescaler and postscaler counts when executed.

### 27.6.2 SLEEP AND IDLE MODES

If the WDT is enabled, it continues to run during Sleep or Idle modes. When the WDT time-out occurs, the device wakes and code execution continues from where the PWRSAV instruction was executed. The corresponding SLEEP or IDLE bit (RCON<3:2>) needs to be cleared in software after the device wakes up.

### 27.6.3 ENABLING WDT

The WDT is enabled or disabled by the WDTEN<1:0> Configuration bits in the FWDT Configuration register. When the WDTEN<1:0> Configuration bits have been programmed to '0b11', the WDT is always enabled.

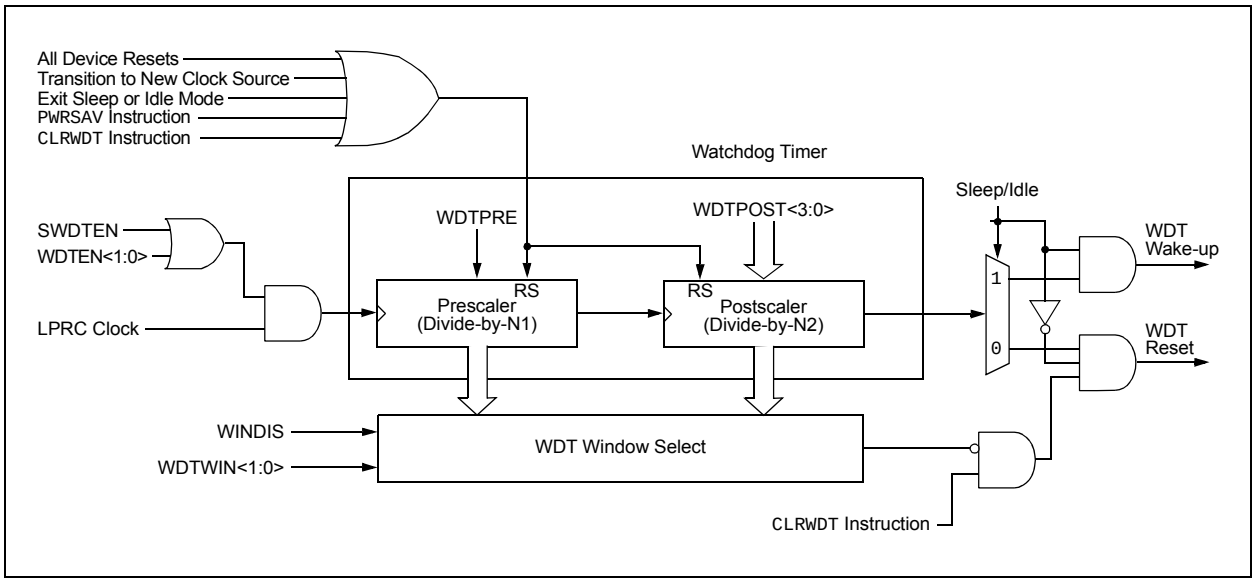
The WDT can be optionally controlled in software when the WDTEN<1:0> Configuration bits have been programmed to '0b10'. The WDT is enabled in software by setting the SWDTEN control bit (RCON<5>). The SWDTEN control bit is cleared on any device Reset. The software WDT option allows the user application to enable the WDT for critical code segments and disables the WDT during non-critical segments for maximum power savings.

The WDT Time-out flag bit, WDTO (RCON<4>), is not automatically cleared following a WDT time-out. To detect subsequent WDT events, the flag must be cleared in software.

### 27.6.4 WDT WINDOW

The Watchdog Timer has an optional Windowed mode, enabled by programming the WINDIS bit in the WDT Configuration register (FWDT<7>). In the Windowed mode (WINDIS = 0), the WDT should be cleared based on the settings in the programmable Watchdog Timer Window select bits (WDTWIN<1:0>).

**FIGURE 27-2: WDT BLOCK DIAGRAM**





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## 27.7 JTAG Interface

The dsPIC33EPXXXGS70X/80X family devices implement a JTAG interface, which supports boundary scan device testing. Detailed information on this interface is provided in future revisions of the document.

**Note:** Refer to **"Programming and Diagnostics"** (DS70608) in the *"dsPIC33/PIC24 Family Reference Manual"* for further information on usage, configuration and operation of the JTAG interface.

## 27.8 In-Circuit Serial Programming™ (ICSP™)

The dsPIC33EPXXXGS70X/80X family devices can be serially programmed while in the end application circuit. This is done with two lines for clock and data, and three other lines for power, ground and the programming sequence. Serial programming allows customers to manufacture boards with unprogrammed devices and then program the device just before shipping the product. Serial programming also allows the most recent firmware or a custom firmware to be programmed. Refer to the *"dsPIC33E/PIC24E Flash Programming Specification for Devices with Volatile Configuration Bits"* (DS70663) for details about In-Circuit Serial Programming™ (ICSP™).

Any of the three pairs of programming clock/data pins can be used:

- PGEC1 and PGED1
- PGEC2 and PGED2
- PGEC3 and PGED3

## 27.9 In-Circuit Debugger

When MPLAB® ICD 3 or REAL ICE™ emulator is selected as a debugger, the in-circuit debugging functionality is enabled. This function allows simple debugging functions when used with MPLAB IDE. Debugging functionality is controlled through the PGECx (Emulation/Debug Clock) and PGEDx (Emulation/Debug Data) pin functions.

Any of the three pairs of debugging clock/data pins can be used:

- PGEC1 and PGED1
- PGEC2 and PGED2
- PGEC3 and PGED3

To use the in-circuit debugger function of the device, the design must implement ICSP connections to $\overline{MCLR}$, $V_{DD}$, $V_{SS}$ and the PGECx/PGEDx pin pair. In addition, when the feature is enabled, some of the resources are not available for general use. These resources include the first 80 bytes of data RAM and two I/O pins (PGECx and PGEDx).

## 27.10 Code Protection and CodeGuard™ Security

dsPIC33EPXXXGS70X/80X devices offer multiple levels of security for protecting individual intellectual property. The program Flash protection can be broken up into three segments: Boot Segment (BS), General Segment (GS) and Configuration Segment (CS). Boot Segment has the highest security privilege and can be thought to have limited restrictions when accessing other segments. General Segment has the least security and is intended for the end user system code. Configuration Segment contains only the device user configuration data which is located at the end of the program memory space.

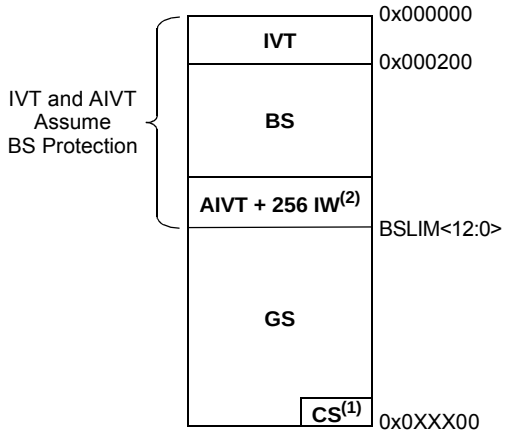
The code protection features are controlled by the Configuration registers, FSEC and FBSLIM. The FSEC register controls the code-protect level for each segment and if that segment is write-protected. The size of BS and GS will depend on the BSLIM<12:0> bits setting and if the Alternate Interrupt Vector Table (AIVT) is enabled. The BSLIM<12:0> bits define the number of pages for BS with each page containing 512 IW. The smallest BS size is one page, which will consist of the Interrupt Vector Table (IVT) and 256 IW of code protection.

If the AIVT is enabled, the last page of BS will contain the AIVT and will not contain any BS code. With AIVT enabled, the smallest BS size is now two pages (1024 IW), with one page for the IVT and BS code, and the other page for the AIVT. Write protection of the BS does not cover the AIVT. The last page of BS can always be programmed or erased by BS code. The General Segment will start at the next page and will consume the rest of program Flash except for the Flash Configuration Words. The IVT will assume GS security only if BS is not enabled. The IVT is protected from being programmed or page erased when either security segment has enabled write protection.

**Note:** Refer to **"CodeGuard™ Intermediate Security"** (DS70005182) in the *"dsPIC33/PIC24 Family Reference Manual"* for further information on usage, configuration and operation of CodeGuard Security.

The different device security segments are shown in Figure 27-3. Here, all three segments are shown but are not required. If only basic code protection is required, then GS can be enabled independently or combined with CS, if desired.

**FIGURE 27-3: SECURITY SEGMENTS EXAMPLE FOR dsPIC33EPXXXGS70X/80X DEVICES**




**Note 1:** If CS is write-protected, the last page (GS + CS) of program memory will be protected from an erase condition.

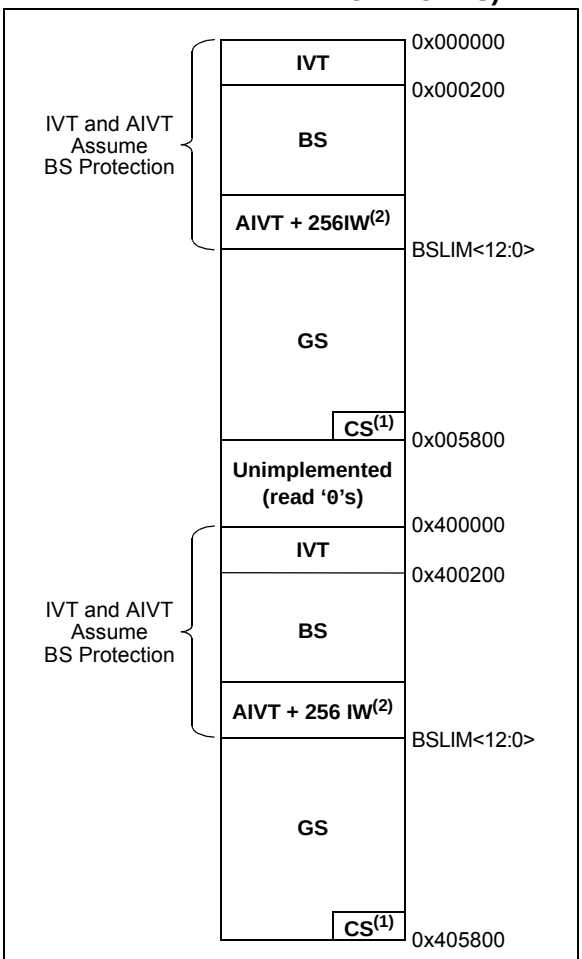
**2:** The last half (256 IW) of the last page of BS is unusable program memory.

dsPIC33EPXXXGS70X/80X family devices can be operated in Dual Partition mode, where security is required for each partition. When operating in Dual Partition mode, the Active and Inactive Partitions both contain unique copies of the Reset vector, Interrupt Vector Tables (IVT and AIVT, if enabled) and the Flash Configuration Words. Both partitions have the three security segments described previously. Code may not be executed from the Inactive Partition, but it may be programmed by, and read from, the Active Partition, subject to defined code protection. Figure 27-4 and Figure 27-5 show the different security segments for devices operating in Dual Partition mode.

The device may also operate in a Protected Dual Partition mode or in Privileged Dual Partition mode. In Protected Dual Partition mode, Partition 1 is permanently erase/write-protected. This implementation allows for a “Factory Default” mode, which provides a fail-safe backup image to be stored in Partition 1. For example, a fail-safe bootloader can be placed in Partition 1, along with a fail-safe backup code image, which can be used or rewritten into Partition 2 in the event of a failed Flash update to Partition 2.

Privileged Dual Partition mode performs the same function as Protected Dual Partition mode, except additional constraints are applied in an effort to prevent code in the Boot Segment and General Segment from being used against each other.

**FIGURE 27-4: SECURITY SEGMENTS EXAMPLE FOR dsPIC33EP64GS70X/80X DEVICES (DUAL PARTITION MODES)**




**Note 1:** If CS is write-protected, the last page (GS + CS) of program memory will be protected from an erase condition.

**2:** The last half (256 IW) of the last page of BS is unusable program memory.


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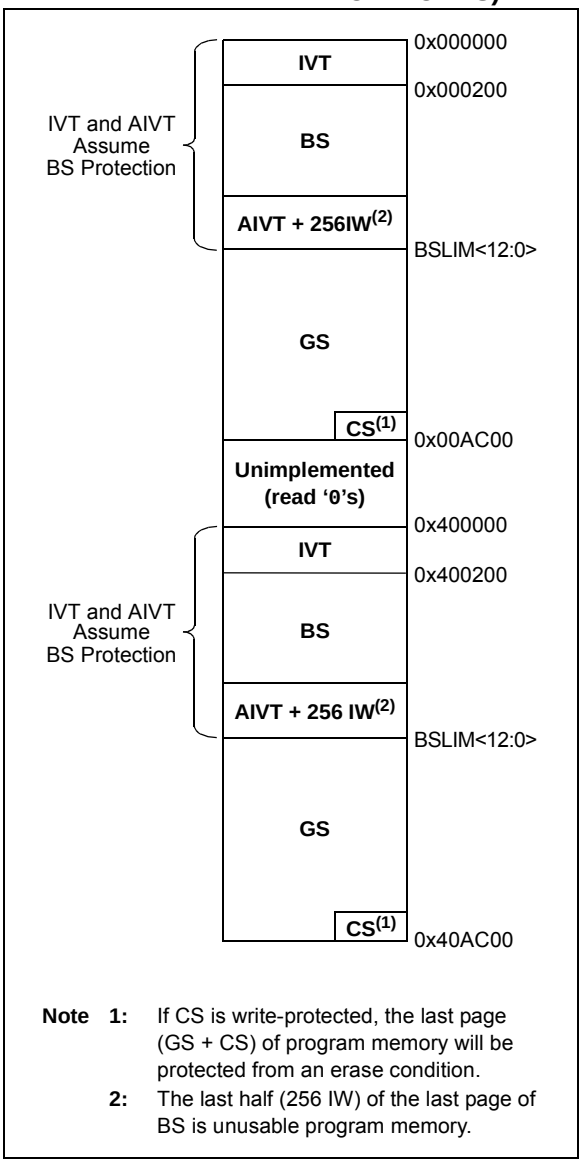
**FIGURE 27-5: SECURITY SEGMENTS EXAMPLE FOR dsPIC33EP128GS70X/80X DEVICES (DUAL PARTITION MODES)**




**Note 1:** If CS is write-protected, the last page (GS + CS) of program memory will be protected from an erase condition.

**2:** The last half (256 IW) of the last page of BS is unusable program memory.

**NOTES:**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## 28.0 INSTRUCTION SET SUMMARY

**Note:** This data sheet summarizes the features of the dsPIC33EPXXXGS70X/80X family of devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to the related section of the "*dsPIC33/PIC24 Family Reference Manual*", which is available from the Microchip web site (www.microchip.com).

The dsPIC33EP instruction set is almost identical to that of the dsPIC30F and dsPIC33F.

Most instructions are a single program memory word (24 bits). Only three instructions require two program memory locations.

Each single-word instruction is a 24-bit word, divided into an 8-bit opcode, which specifies the instruction type and one or more operands, which further specify the operation of the instruction.

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

- Word or byte-oriented operations
- Bit-oriented operations
- Literal operations
- DSP operations
- Control operations

Table 28-1 lists the general symbols used in describing the instructions.

The dsPIC33E instruction set summary in Table 28-2 lists all the instructions, along with the status flags affected by each instruction.

Most word or byte-oriented W register instructions (including barrel shift instructions) have three operands:

- The first source operand, which is typically a register 'Wb' without any address modifier
- The second source operand, which is typically a register 'Ws' with or without an address modifier
- The destination of the result, which is typically a register 'Wd' with or without an address modifier

However, word or byte-oriented file register instructions have two operands:

- The file register specified by the value 'f'
- The destination, which could be either the file register 'f' or the W0 register, which is denoted as 'WREG'

Most bit-oriented instructions (including simple rotate/shift instructions) have two operands:

- The W register (with or without an address modifier) or file register (specified by the value of 'Ws' or 'f')
- The bit in the W register or file register (specified by a literal value or indirectly by the contents of register 'Wb')

The literal instructions that involve data movement can use some of the following operands:

- A literal value to be loaded into a W register or file register (specified by 'k')
- The W register or file register where the literal value is to be loaded (specified by 'Wb' or 'f')

However, literal instructions that involve arithmetic or logical operations use some of the following operands:

- The first source operand, which is a register 'Wb' without any address modifier
- The second source operand, which is a literal value
- The destination of the result (only if not the same as the first source operand), which is typically a register 'Wd' with or without an address modifier

The MAC class of DSP instructions can use some of the following operands:

- The accumulator (A or B) to be used (required operand)
- The W registers to be used as the two operands
- The X and Y address space prefetch operations
- The X and Y address space prefetch destinations
- The accumulator write back destination

The other DSP instructions do not involve any multiplication and can include:

- The accumulator to be used (required)
- The source or destination operand (designated as Wso or Wdo, respectively) with or without an address modifier
- The amount of shift specified by a W register 'Wn' or a literal value

The control instructions can use some of the following operands:

- A program memory address
- The mode of the Table Read and Table Write instructions

Most instructions are a single word. Certain double-word instructions are designed to provide all the required information in these 48 bits. In the second word, the 8 MSbs are '0's. If this second word is executed as an instruction (by itself), it executes as a NOP.

The double-word instructions execute in two instruction cycles.

Most single-word instructions are executed in a single instruction cycle, unless a conditional test is true or the Program Counter is changed as a result of the instruction, or a PSV or Table Read is performed. In these cases, the execution takes multiple instruction cycles, with the additional instruction cycle(s) executed as a NOP. Certain instructions that involve skipping over the subsequent instruction require either two or three cycles if the skip is performed, depending on whether the instruction being skipped is a single-word or two-word instruction. Moreover, double-word moves require two cycles.

| **Note:** | For more details on the instruction set, refer to the *"16-bit MCU and DSC Programmer's Reference Manual"* (DS70157). |
|---|---|

**TABLE 28-1: SYMBOLS USED IN OPCODE DESCRIPTIONS**

| Field | Description |
|---|---|
| #text | Means literal defined by "text" |
| (text) | Means "content of text" |
| [text] | Means "the location addressed by text" |
| { } | Optional field or operation |
| a ∈ {b, c, d} | a is selected from the set of values b, c, d |
| <n:m> | Register bit field |
| .b | Byte mode selection |
| .d | Double-Word mode selection |
| .S | Shadow register select |
| .w | Word mode selection (default) |
| Acc | One of two accumulators {A, B} |
| AWB | Accumulator Write-Back Destination Address register ∈ {W13, [W13]+ = 2} |
| bit4 | 4-bit bit selection field (used in word addressed instructions) ∈ {0...15} |
| C, DC, N, OV, Z | MCU Status bits: Carry, Digit Carry, Negative, Overflow, Sticky Zero |
| Expr | Absolute address, label or expression (resolved by the linker) |
| f | File register address ∈ {0x0000...0x1FFF} |
| lit1 | 1-bit unsigned literal ∈ {0,1} |
| lit4 | 4-bit unsigned literal ∈ {0...15} |
| lit5 | 5-bit unsigned literal ∈ {0...31} |
| lit8 | 8-bit unsigned literal ∈ {0...255} |
| lit10 | 10-bit unsigned literal ∈ {0...255} for Byte mode, {0:1023} for Word mode |
| lit14 | 14-bit unsigned literal ∈ {0...16384} |
| lit16 | 16-bit unsigned literal ∈ {0...65535} |
| lit23 | 23-bit unsigned literal ∈ {0...8388608}; LSb must be '0' |
| None | Field does not require an entry, can be blank |
| OA, OB, SA, SB | DSP Status bits: ACCA Overflow, ACCB Overflow, ACCA Saturate, ACCB Saturate |
| PC | Program Counter |
| Slit10 | 10-bit signed literal ∈ {-512...511} |
| Slit16 | 16-bit signed literal ∈ {-32768...32767} |
| Slit6 | 6-bit signed literal ∈ {-16...16} |
| Wb | Base W register ∈ {W0...W15} |
| Wd | Destination W register ∈ { Wd, [Wd], [Wd++], [Wd--], [++Wd], [--Wd] } |
| Wdo | Destination W register ∈<br>{ Wnd, [Wnd], [Wnd++], [Wnd--], [++Wnd], [--Wnd], [Wnd+Wb] } |
| Wm,Wn | Dividend, Divisor Working register pair (Direct Addressing) |


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**TABLE 28-1: SYMBOLS USED IN OPCODE DESCRIPTIONS (CONTINUED)**

| Field | Description |
|---|---|
| Wm*Wm | Multiplicand and Multiplier Working register pair for Square instructions ∈ {W4 * W4,W5 * W5,W6 * W6,W7 * W7} |
| Wm*Wn | Multiplicand and Multiplier Working register pair for DSP instructions ∈ {W4 * W5,W4 * W6,W4 * W7,W5 * W6,W5 * W7,W6 * W7} |
| Wn | One of 16 Working registers ∈ {W0...W15} |
| Wnd | One of 16 Destination Working registers ∈ {W0...W15} |
| Wns | One of 16 Source Working registers ∈ {W0...W15} |
| WREG | W0 (Working register used in file register instructions) |
| Ws | Source W register ∈ { Ws, [Ws], [Ws++], [Ws--], [++Ws], [--Ws] } |
| Wso | Source W register ∈ { Wns, [Wns], [Wns++], [Wns--], [++Wns], [--Wns], [Wns+Wb] } |
| Wx | X Data Space Prefetch Address register for DSP instructions ∈ {[W8] + = 6, [W8] + = 4, [W8] + = 2, [W8], [W8] - = 6, [W8] - = 4, [W8] - = 2, [W9] + = 6, [W9] + = 4, [W9] + = 2, [W9], [W9] - = 6, [W9] - = 4, [W9] - = 2, [W9 + W12], none} |
| Wxd | X Data Space Prefetch Destination register for DSP instructions ∈ {W4...W7} |
| Wy | Y Data Space Prefetch Address register for DSP instructions ∈ {[W10] + = 6, [W10] + = 4, [W10] + = 2, [W10], [W10] - = 6, [W10] - = 4, [W10] - = 2, [W11] + = 6, [W11] + = 4, [W11] + = 2, [W11], [W11] - = 6, [W11] - = 4, [W11] - = 2, [W11 + W12], none} |
| Wyd | Y Data Space Prefetch Destination register for DSP instructions ∈ {W4...W7} |

**TABLE 28-2: INSTRUCTION SET OVERVIEW**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 1 | ADD | ADD | Acc | Add Accumulators | 1 | 1 | OA,OB,SA,SB |
| | | ADD | f | f = f + WREG | 1 | 1 | C,DC,N,OV,Z |
| | | ADD | f,WREG | WREG = f + WREG | 1 | 1 | C,DC,N,OV,Z |
| | | ADD | #lit10,Wn | Wd = lit10 + Wd | 1 | 1 | C,DC,N,OV,Z |
| | | ADD | Wb,Ws,Wd | Wd = Wb + Ws | 1 | 1 | C,DC,N,OV,Z |
| | | ADD | Wb,#lit5,Wd | Wd = Wb + lit5 | 1 | 1 | C,DC,N,OV,Z |
| | | ADD | Wso,#Slit4,Acc | 16-bit Signed Add to Accumulator | 1 | 1 | OA,OB,SA,SB |
| 2 | ADDC | ADDC | f | f = f + WREG + (C) | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC | f,WREG | WREG = f + WREG + (C) | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC | #lit10,Wn | Wd = lit10 + Wd + (C) | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC | Wb,Ws,Wd | Wd = Wb + Ws + (C) | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC | Wb,#lit5,Wd | Wd = Wb + lit5 + (C) | 1 | 1 | C,DC,N,OV,Z |
| 3 | AND | AND | f | f = f .AND. WREG | 1 | 1 | N,Z |
| | | AND | f,WREG | WREG = f .AND. WREG | 1 | 1 | N,Z |
| | | AND | #lit10,Wn | Wd = lit10 .AND. Wd | 1 | 1 | N,Z |
| | | AND | Wb,Ws,Wd | Wd = Wb .AND. Ws | 1 | 1 | N,Z |
| | | AND | Wb,#lit5,Wd | Wd = Wb .AND. lit5 | 1 | 1 | N,Z |
| 4 | ASR | ASR | f | f = Arithmetic Right Shift f | 1 | 1 | C,N,OV,Z |
| | | ASR | f,WREG | WREG = Arithmetic Right Shift f | 1 | 1 | C,N,OV,Z |
| | | ASR | Ws,Wd | Wd = Arithmetic Right Shift Ws | 1 | 1 | C,N,OV,Z |
| | | ASR | Wb,Wns,Wnd | Wnd = Arithmetic Right Shift Wb by Wns | 1 | 1 | N,Z |
| | | ASR | Wb,#lit5,Wnd | Wnd = Arithmetic Right Shift Wb by lit5 | 1 | 1 | N,Z |
| 5 | BCLR | BCLR | f,#bit4 | Bit Clear f | 1 | 1 | None |
| | | BCLR | Ws,#bit4 | Bit Clear Ws | 1 | 1 | None |
| 6 | BOOTSWP | BOOTSWP | | Swap the active and inactive program Flash Space | 1 | 2 | None |
| 7 | BRA | BRA | C,Expr | Branch if Carry | 1 | 1 (4) | None |
| | | BRA | GE,Expr | Branch if greater than or equal | 1 | 1 (4) | None |
| | | BRA | GEU,Expr | Branch if unsigned greater than or equal | 1 | 1 (4) | None |
| | | BRA | GT,Expr | Branch if greater than | 1 | 1 (4) | None |
| | | BRA | GTU,Expr | Branch if unsigned greater than | 1 | 1 (4) | None |
| | | BRA | LE,Expr | Branch if less than or equal | 1 | 1 (4) | None |
| | | BRA | LEU,Expr | Branch if unsigned less than or equal | 1 | 1 (4) | None |
| | | BRA | LT,Expr | Branch if less than | 1 | 1 (4) | None |
| | | BRA | LTU,Expr | Branch if unsigned less than | 1 | 1 (4) | None |
| | | BRA | N,Expr | Branch if Negative | 1 | 1 (4) | None |
| | | BRA | NC,Expr | Branch if Not Carry | 1 | 1 (4) | None |
| | | BRA | NN,Expr | Branch if Not Negative | 1 | 1 (4) | None |
| | | BRA | NOV,Expr | Branch if Not Overflow | 1 | 1 (4) | None |
| | | BRA | NZ,Expr | Branch if Not Zero | 1 | 1 (4) | None |
| | | BRA | OA,Expr | Branch if Accumulator A overflow | 1 | 1 (4) | None |
| | | BRA | OB,Expr | Branch if Accumulator B overflow | 1 | 1 (4) | None |
| | | BRA | OV,Expr | Branch if Overflow | 1 | 1 (4) | None |
| | | BRA | SA,Expr | Branch if Accumulator A saturated | 1 | 1 (4) | None |
| | | BRA | SB,Expr | Branch if Accumulator B saturated | 1 | 1 (4) | None |
| | | BRA | Expr | Branch Unconditionally | 1 | 4 | None |
| | | BRA | Z,Expr | Branch if Zero | 1 | 1 (4) | None |
| | | BRA | Wn | Computed Branch | 1 | 4 | None |
| 8 | BSET | BSET | f,#bit4 | Bit Set f | 1 | 1 | None |
| | | BSET | Ws,#bit4 | Bit Set Ws | 1 | 1 | None |

**Note 1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.


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

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 9 | BSW | BSW.C | Ws,Wb | Write C bit to Ws<Wb> | 1 | 1 | None |
| | | BSW.Z | Ws,Wb | Write Z bit to Ws<Wb> | 1 | 1 | None |
| 10 | BTG | BTG | f,#bit4 | Bit Toggle f | 1 | 1 | None |
| | | BTG | Ws,#bit4 | Bit Toggle Ws | 1 | 1 | None |
| 11 | BTSC | BTSC | f,#bit4 | Bit Test f, Skip if Clear | 1 | 1 (2 or 3) | None |
| | | BTSC | Ws,#bit4 | Bit Test Ws, Skip if Clear | 1 | 1 (2 or 3) | None |
| 12 | BTSS | BTSS | f,#bit4 | Bit Test f, Skip if Set | 1 | 1 (2 or 3) | None |
| | | BTSS | Ws,#bit4 | Bit Test Ws, Skip if Set | 1 | 1 (2 or 3) | None |
| 13 | BTST | BTST | f,#bit4 | Bit Test f | 1 | 1 | Z |
| | | BTST.C | Ws,#bit4 | Bit Test Ws to C | 1 | 1 | C |
| | | BTST.Z | Ws,#bit4 | Bit Test Ws to Z | 1 | 1 | Z |
| | | BTST.C | Ws,Wb | Bit Test Ws<Wb> to C | 1 | 1 | C |
| | | BTST.Z | Ws,Wb | Bit Test Ws<Wb> to Z | 1 | 1 | Z |
| 14 | BTSTS | BTSTS | f,#bit4 | Bit Test then Set f | 1 | 1 | Z |
| | | BTSTS.C | Ws,#bit4 | Bit Test Ws to C, then Set | 1 | 1 | C |
| | | BTSTS.Z | Ws,#bit4 | Bit Test Ws to Z, then Set | 1 | 1 | Z |
| 15 | CALL | CALL | lit23 | Call subroutine | 2 | 4 | SFA |
| | | CALL | Wn | Call indirect subroutine | 1 | 4 | SFA |
| | | CALL.L | Wn | Call indirect subroutine (long address) | 1 | 4 | SFA |
| 16 | CLR | CLR | f | f = 0x0000 | 1 | 1 | None |
| | | CLR | WREG | WREG = 0x0000 | 1 | 1 | None |
| | | CLR | Ws | Ws = 0x0000 | 1 | 1 | None |
| | | CLR | Acc,Wx,Wxd,Wy,Wyd,AWB | Clear Accumulator | 1 | 1 | OA,OB,SA,SB |
| 17 | CLRWDT | CLRWDT | | Clear Watchdog Timer | 1 | 1 | WDTO,Sleep |
| 18 | COM | COM | f | $f = \overline{f}$ | 1 | 1 | N,Z |
| | | COM | f,WREG | $WREG = \overline{f}$ | 1 | 1 | N,Z |
| | | COM | Ws,Wd | $Wd = \overline{Ws}$ | 1 | 1 | N,Z |
| 19 | CP | CP | f | Compare f with WREG | 1 | 1 | C,DC,N,OV,Z |
| | | CP | Wb,#lit8 | Compare Wb with lit8 | 1 | 1 | C,DC,N,OV,Z |
| | | CP | Wb,Ws | Compare Wb with Ws (Wb – Ws) | 1 | 1 | C,DC,N,OV,Z |
| 20 | CP0 | CP0 | f | Compare f with 0x0000 | 1 | 1 | C,DC,N,OV,Z |
| | | CP0 | Ws | Compare Ws with 0x0000 | 1 | 1 | C,DC,N,OV,Z |
| 21 | CPB | CPB | f | Compare f with WREG, with Borrow | 1 | 1 | C,DC,N,OV,Z |
| | | CPB | Wb,#lit8 | Compare Wb with lit8, with Borrow | 1 | 1 | C,DC,N,OV,Z |
| | | CPB | Wb,Ws | Compare Wb with Ws, with Borrow ($Wb – Ws – \overline{C}$) | 1 | 1 | C,DC,N,OV,Z |
| 22 | CPSEQ | CPSEQ | Wb,Wn | Compare Wb with Wn, skip if = | 1 | 1 (2 or 3) | None |
| | CPBEQ | CPBEQ | Wb,Wn,Expr | Compare Wb with Wn, branch if = | 1 | 1 (5) | None |
| 23 | CPSGT | CPSGT | Wb,Wn | Compare Wb with Wn, skip if > | 1 | 1 (2 or 3) | None |
| | CPBGT | CPBGT | Wb,Wn,Expr | Compare Wb with Wn, branch if > | 1 | 1 (5) | None |
| 24 | CPSLT | CPSLT | Wb,Wn | Compare Wb with Wn, skip if < | 1 | 1 (2 or 3) | None |
| | CPBLT | CPBLT | Wb,Wn,Expr | Compare Wb with Wn, branch if < | 1 | 1 (5) | None |
| 25 | CPSNE | CPSNE | Wb,Wn | Compare Wb with Wn, skip if ≠ | 1 | 1 (2 or 3) | None |
| | CPBNE | CPBNE | Wb,Wn,Expr | Compare Wb with Wn, branch if ≠ | 1 | 1 (5) | None |

**Note 1:** 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(1) | Status Flags Affected |
|---|---|---|---|---|---|---|
| 26 | CTXTSWP | CTXTSWP #1it3 | Switch CPU register context to context defined by lit3 | 1 | 2 | None |
| | | CTXTSWP Wn | Switch CPU register context to context defined by Wn | 1 | 2 | None |
| 27 | DAW | DAW Wn | Wn = decimal adjust Wn | 1 | 1 | C |
| 28 | 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 |
| 29 | 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 |
| 30 | DISI | DISI #lit14 | Disable Interrupts for k instruction cycles | 1 | 1 | None |
| 31 | 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 |
| 32 | DIVF | DIVF Wm,Wn | Signed 16/16-bit Fractional Divide | 1 | 18 | N,Z,C,OV |
| 33 | DO | DO #lit15,Expr | Do code to PC + Expr, lit15 + 1 times | 2 | 2 | None |
| | | DO Wn,Expr | Do code to PC + Expr, (Wn) + 1 times | 2 | 2 | None |
| 34 | ED | ED Wm*Wm,Acc,Wx,Wy,Wxd | Euclidean Distance (no accumulate) | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 35 | EDAC | EDAC Wm*Wm,Acc,Wx,Wy,Wxd | Euclidean Distance | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 36 | EXCH | EXCH Wns,Wnd | Swap Wns with Wnd | 1 | 1 | None |
| 37 | FBCL | FBCL Ws,Wnd | Find Bit Change from Left (MSb) Side | 1 | 1 | C |
| 38 | FF1L | FF1L Ws,Wnd | Find First One from Left (MSb) Side | 1 | 1 | C |
| 39 | FF1R | FF1R Ws,Wnd | Find First One from Right (LSb) Side | 1 | 1 | C |
| 40 | 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 |
| 41 | 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 |
| 42 | 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 |
| 43 | 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 |
| 44 | LAC | LAC Wso,#Slit4,Acc | Load Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 45 | LNK | LNK #lit14 | Link Frame Pointer | 1 | 1 | SFA |
| 46 | 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 |
| 47 | MAC | MAC Wm*Wn,Acc,Wx,Wxd,Wy,Wyd,AWB | Multiply and Accumulate | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | MAC Wm*Wm,Acc,Wx,Wxd,Wy,Wyd | Square and Accumulate | 1 | 1 | OA,OB,OAB, SA,SB,SAB |

**Note 1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.


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

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|
| 48 | MOV | MOV f,Wn | Move f to Wn | 1 | 1 | None |
| | | MOV f | Move f to f | 1 | 1 | None |
| | | MOV f,WREG | Move f to WREG | 1 | 1 | None |
| | | MOV #lit16,Wn | Move 16-bit literal to Wn | 1 | 1 | None |
| | | MOV.b #lit8,Wn | Move 8-bit literal to Wn | 1 | 1 | None |
| | | MOV Wn,f | Move Wn to f | 1 | 1 | None |
| | | MOV Wso,Wdo | Move Ws to Wd | 1 | 1 | None |
| | | MOV WREG,f | Move WREG to f | 1 | 1 | None |
| | | MOV.D Wns,Wd | Move Double from W(ns):W(ns + 1) to Wd | 1 | 2 | None |
| | | MOV.D Ws,Wnd | Move Double from Ws to W(nd + 1):W(nd) | 1 | 2 | None |
| 49 | MOVPAG | MOVPAG #lit10,DSRPAG | Move 10-bit literal to DSRPAG | 1 | 1 | None |
| | | MOVPAG #lit8,TBLPAG | Move 8-bit literal to TBLPAG | 1 | 1 | None |
| | | MOVPAGW Ws, DSRPAG | Move Ws<9:0> to DSRPAG | 1 | 1 | None |
| | | MOVPAGW Ws, TBLPAG | Move Ws<7:0> to TBLPAG | 1 | 1 | None |
| 50 | MOVSAC | MOVSAC Acc,Wx,Wxd,Wy,Wyd,AWB | Prefetch and store accumulator | 1 | 1 | None |
| 51 | MPY | MPY Wm*Wn,Acc,Wx,Wxd,Wy,Wyd | Multiply Wm by Wn to Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | MPY Wm*Wm,Acc,Wx,Wxd,Wy,Wyd | Square Wm to Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 52 | MPY.N | MPY.N Wm*Wn,Acc,Wx,Wxd,Wy,Wyd | -(Multiply Wm by Wn) to Accumulator | 1 | 1 | None |
| 53 | MSC | MSC Wm*Wm,Acc,Wx,Wxd,Wy,Wyd,AWB | Multiply and Subtract from Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 54 | MUL | MUL.SS Wb,Ws,Wnd | {Wnd + 1, Wnd} = signed(Wb) * signed(Ws) | 1 | 1 | None |
| | | MUL.SS Wb,Ws,Acc | 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 | Accumulator = signed(Wb) * unsigned(Ws) | 1 | 1 | None |
| | | MUL.SU Wb,#lit5,Acc | 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 | 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 | Accumulator = unsigned(Wb) * unsigned(lit5) | 1 | 1 | None |
| | | MUL.UU Wb,Ws,Acc | 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:** 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(1) | Status Flags Affected |
|---|---|---|---|---|---|---|
| 55 | NEG | NEG Acc | Negate Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | NEG f | f = $\overline{f}$ + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | NEG f,WREG | WREG = $\overline{f}$ + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | NEG Ws,Wd | Wd = $\overline{Ws}$ + 1 | 1 | 1 | C,DC,N,OV,Z |
| 56 | NOP | NOP | No Operation | 1 | 1 | None |
| | | NOPR | No Operation | 1 | 1 | None |
| 57 | POP | POP f | Pop f from Top-of-Stack (TOS) | 1 | 1 | None |
| | | POP Wdo | Pop from Top-of-Stack (TOS) to Wdo | 1 | 1 | None |
| | | POP.D Wnd | Pop from Top-of-Stack (TOS) to W(nd):W(nd + 1) | 1 | 2 | None |
| | | POP.S | Pop Shadow Registers | 1 | 1 | All |
| 58 | PUSH | PUSH f | Push f to Top-of-Stack (TOS) | 1 | 1 | None |
| | | PUSH Wso | Push Wso to Top-of-Stack (TOS) | 1 | 1 | None |
| | | PUSH.D Wns | Push W(ns):W(ns + 1) to Top-of-Stack (TOS) | 1 | 2 | None |
| | | PUSH.S | Push Shadow Registers | 1 | 1 | None |
| 59 | PWRSAV | PWRSAV #lit1 | Go into Sleep or Idle mode | 1 | 1 | WDTO,Sleep |
| 60 | RCALL | RCALL Expr | Relative Call | 1 | 4 | SFA |
| | | RCALL Wn | Computed Call | 1 | 4 | SFA |
| 61 | REPEAT | REPEAT #lit15 | Repeat Next Instruction lit15 + 1 times | 1 | 1 | None |
| | | REPEAT Wn | Repeat Next Instruction (Wn) + 1 times | 1 | 1 | None |
| 62 | RESET | RESET | Software device Reset | 1 | 1 | None |
| 63 | RETFIE | RETFIE | Return from interrupt | 1 | 6 (5) | SFA |
| 64 | RETLW | RETLW #lit10,Wn | Return with literal in Wn | 1 | 6 (5) | SFA |
| 65 | RETURN | RETURN | Return from Subroutine | 1 | 6 (5) | SFA |
| 66 | RLC | RLC f | f = Rotate Left through Carry f | 1 | 1 | C,N,Z |
| | | RLC f,WREG | WREG = Rotate Left through Carry f | 1 | 1 | C,N,Z |
| | | RLC Ws,Wd | Wd = Rotate Left through Carry Ws | 1 | 1 | C,N,Z |
| 67 | RLNC | RLNC f | f = Rotate Left (No Carry) f | 1 | 1 | N,Z |
| | | RLNC f,WREG | WREG = Rotate Left (No Carry) f | 1 | 1 | N,Z |
| | | RLNC Ws,Wd | Wd = Rotate Left (No Carry) Ws | 1 | 1 | N,Z |
| 68 | RRC | RRC f | f = Rotate Right through Carry f | 1 | 1 | C,N,Z |
| | | RRC f,WREG | WREG = Rotate Right through Carry f | 1 | 1 | C,N,Z |
| | | RRC Ws,Wd | Wd = Rotate Right through Carry Ws | 1 | 1 | C,N,Z |
| 69 | RRNC | RRNC f | f = Rotate Right (No Carry) f | 1 | 1 | N,Z |
| | | RRNC f,WREG | WREG = Rotate Right (No Carry) f | 1 | 1 | N,Z |
| | | RRNC Ws,Wd | Wd = Rotate Right (No Carry) Ws | 1 | 1 | N,Z |
| 70 | SAC | SAC Acc,#Slit4,Wdo | Store Accumulator | 1 | 1 | None |
| | | SAC.R Acc,#Slit4,Wdo | Store Rounded Accumulator | 1 | 1 | None |
| 71 | SE | SE Ws,Wnd | Wnd = sign-extended Ws | 1 | 1 | C,N,Z |
| 72 | SETM | SETM f | f = 0xFFFF | 1 | 1 | None |
| | | SETM WREG | WREG = 0xFFFF | 1 | 1 | None |
| | | SETM Ws | Ws = 0xFFFF | 1 | 1 | None |
| 73 | SFTAC | SFTAC Acc,Wn | Arithmetic Shift Accumulator by (Wn) | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | SFTAC Acc,#Slit6 | Arithmetic Shift Accumulator by Slit6 | 1 | 1 | OA,OB,OAB, SA,SB,SAB |

**Note 1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.


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

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 74 | 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 |
| 75 | SUB | SUB | Acc | 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 |
| 76 | 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 |
| 77 | 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 |
| 78 | 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 |
| 79 | SWAP | SWAP.b | Wn | Wn = nibble swap Wn | 1 | 1 | None |
| | | SWAP | Wn | Wn = byte swap Wn | 1 | 1 | None |
| 80 | TBLRDH | TBLRDH | Ws,Wd | Read Prog<23:16> to Wd<7:0> | 1 | 5 | None |
| 81 | TBLRDL | TBLRDL | Ws,Wd | Read Prog<15:0> to Wd | 1 | 5 | None |
| 82 | TBLWTH | TBLWTH | Ws,Wd | Write Ws<7:0> to Prog<23:16> | 1 | 2 | None |
| 83 | TBLWTL | TBLWTL | Ws,Wd | Write Ws to Prog<15:0> | 1 | 2 | None |
| 84 | ULNK | ULNK | | Unlink Frame Pointer | 1 | 1 | SFA |
| 85 | 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 |
| 86 | ZE | ZE | Ws,Wnd | Wnd = Zero-extend Ws | 1 | 1 | C,Z,N |

**Note 1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.

**NOTES:**


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## 29.0 DEVELOPMENT SUPPORT

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

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

### 29.1 MPLAB X Integrated Development Environment Software

The MPLAB X IDE is a single, unified graphical user interface for Microchip and third-party software, and hardware development tool that runs on Windows®, Linux and Mac OS® X. Based on the NetBeans IDE, MPLAB X IDE is an entirely new IDE with a host of free software components and plug-ins for high-performance application development and debugging. Moving between tools and upgrading from software simulators to hardware debugging and programming tools is simple with the seamless user interface.

With complete project management, visual call graphs, a configurable watch window and a feature-rich editor that includes code completion and context menus, MPLAB X IDE is flexible and friendly enough for new users. With the ability to support multiple tools on multiple projects with simultaneous debugging, MPLAB X IDE is also suitable for the needs of experienced users.

Feature-Rich Editor:

- Color syntax highlighting
- Smart code completion makes suggestions and provides hints as you type
- Automatic code formatting based on user-defined rules
- Live parsing

User-Friendly, Customizable Interface:

- Fully customizable interface: toolbars, toolbar buttons, windows, window placement, etc.
- Call graph window

Project-Based Workspaces:

- Multiple projects
- Multiple tools
- Multiple configurations
- Simultaneous debugging sessions

File History and Bug Tracking:

- Local file history feature
- Built-in support for Bugzilla issue tracker

## 29.2 MPLAB XC Compilers

The MPLAB XC Compilers are complete ANSI C compilers for all of Microchip's 8, 16 and 32-bit MCU and DSC devices. These compilers provide powerful integration capabilities, superior code optimization and ease of use. MPLAB XC Compilers run on Windows, Linux or MAC OS X.

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

The free MPLAB XC Compiler editions support all devices and commands, with no time or memory restrictions, and offer sufficient code optimization for most applications.

MPLAB XC Compilers include an assembler, linker and utilities. The assembler generates relocatable object files that can then be archived or linked with other relocatable object files and archives to create an executable file. MPLAB XC Compiler uses the assembler to produce its object file. Notable features of the assembler include:

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

## 29.3 MPASM Assembler

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

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

The MPASM Assembler features include:

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

## 29.4 MPLINK Object Linker/ MPLIB Object Librarian

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

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

The object linker/library features include:

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

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

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

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


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## 29.6 MPLAB X SIM Software Simulator

The MPLAB X 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 X SIM Software Simulator fully supports symbolic debugging using the MPLAB XC 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.

## 29.7 MPLAB REAL ICE In-Circuit Emulator System

The 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 all 8, 16 and 32-bit MCU, and DSC devices with the easy-to-use, powerful graphical user interface of the MPLAB X IDE.

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 (RJ-11) 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 X IDE. MPLAB REAL ICE offers significant advantages over competitive emulators including full-speed emulation, run-time variable watches, trace analysis, complex breakpoints, logic probes, a ruggedized probe interface and long (up to three meters) interconnection cables.

## 29.8 MPLAB ICD 3 In-Circuit Debugger System

The MPLAB ICD 3 In-Circuit Debugger System is Microchip's most cost-effective, high-speed hardware debugger/programmer for Microchip Flash DSC and MCU devices. It debugs and programs PIC Flash microcontrollers and dsPIC DSCs with the powerful, yet easy-to-use graphical user interface of the MPLAB 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.

## 29.9 PICkit 3 In-Circuit Debugger/ Programmer

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 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 a 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™ (ICSP™).

## 29.10 MPLAB PM3 Device Programmer

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

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

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

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

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

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

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

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

## 29.12 Third-Party Development Tools

Microchip also offers a great collection of tools from third-party vendors. These tools are carefully selected to offer good value and unique functionality.

- Device Programmers and Gang Programmers from companies, such as SoftLog and CCS
- Software Tools from companies, such as Gimpel and Trace Systems
- Protocol Analyzers from companies, such as Saleae and Total Phase
- Demonstration Boards from companies, such as MikroElektronika, Digilent® and Olimex
- Embedded Ethernet Solutions from companies, such as EZ Web Lynx, WIZnet and IPLogika®


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## 30.0 ELECTRICAL CHARACTERISTICS

This section provides an overview of the dsPIC33EPXXXGS70X/80X family electrical characteristics. Additional information will be provided in future revisions of this document as it becomes available.

Absolute maximum ratings for the dsPIC33EPXXXGS70X/80X 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(1)

Ambient temperature under bias ..... -40°C to +125°C
Storage temperature ..... -65°C to +150°C
Voltage on $V_{DD}$ with respect to $V_{SS}$ ..... -0.3V to +4.0V
Voltage on any pin that is not 5V tolerant with respect to $V_{SS}$(3) ..... -0.3V to ($V_{DD}$ + 0.3V)
Voltage on any 5V tolerant pin with respect to $V_{SS}$ when $V_{DD} \geq 3.0V$(3) ..... -0.3V to +5.5V
Voltage on any 5V tolerant pin with respect to Vss when $V_{DD} < 3.0V$(3) ..... -0.3V to +3.6V
Maximum current out of $V_{SS}$ pin ..... 300 mA
Maximum current into $V_{DD}$ pin(2) ..... 300 mA
Maximum current sunk/sourced by any 4x I/O pin ..... 15 mA
Maximum current sunk/sourced by any 8x I/O pin ..... 25 mA
Maximum current sunk by all ports(2) ..... 200 mA

**Note 1:** 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.

**2:** Maximum allowable current is a function of device maximum power dissipation (see Table 30-2).

**3:** See the **“Pin Diagrams”** section for the 5V tolerant pins.

## 30.1 DC Characteristics

**TABLE 30-1: OPERATING MIPS vs. VOLTAGE**

| Characteristic | VDD Range (in Volts) | Temperature Range (in °C) | Maximum MIPS |
|---|---|---|---|
| | | | dsPIC33EPXXXGS70X/80X Family |
| — | 3.0V to 3.6V(1) | -40°C to +85°C | 70 |
| — | 3.0V to 3.6V(1) | -40°C to +125°C | 60 |

**Note 1:** Device is functional at VBORMIN < VDD < VDDMIN. Analog modules (ADC, PGAs and comparators) may have degraded performance. Device functionality is tested but not characterized. Refer to Parameter BO10 in Table 30-13 for the minimum and maximum BOR values.

**TABLE 30-2: THERMAL OPERATING CONDITIONS**

| Rating | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Industrial Temperature Devices | | | | | |
| Operating Junction Temperature Range | TJ | -40 | — | +125 | °C |
| Operating Ambient Temperature Range | TA | -40 | — | +85 | °C |
| Extended Temperature Devices | | | | | |
| Operating Junction Temperature Range | TJ | -40 | — | +140 | °C |
| Operating Ambient Temperature Range | TA | -40 | — | +125 | °C |
| Power Dissipation:<br>Internal Chip Power Dissipation:<br>PINT = VDD x (IDD – Σ IOH)<br>I/O Pin Power Dissipation:<br>I/O = Σ ({VDD – VOH} x IOH) + Σ (VOL x IOL) | PD | PINT + PI/O | | | W |
| Maximum Allowed Power Dissipation | PDMAX | (TJ – TA)/θJA | | | W |

**TABLE 30-3: THERMAL PACKAGING CHARACTERISTICS**

| Characteristic | Symbol | Typ. | Max. | Unit | Notes |
|---|---|---|---|---|---|
| Package Thermal Resistance, 80-Pin TQFP 12x12x1 mm | θJA | 53.0 | — | °C/W | 1 |
| Package Thermal Resistance, 64-Pin TQFP 10x10x1 mm | θJA | 49.0 | — | °C/W | 1 |
| Package Thermal Resistance, 48-Pin TQFP 7x7x1 mm | θJA | 63.0 | — | °C/W | 1 |
| Package Thermal Resistance, 44-Pin QFN 8x8 mm | θJA | 29.0 | — | °C/W | 1 |
| Package Thermal Resistance, 44-Pin TQFP 10x10x1 mm | θJA | 50.0 | — | °C/W | 1 |
| Package Thermal Resistance, 28-Pin QFN-S 6x6x0.9 mm | θJA | 30.0 | — | °C/W | 1 |
| Package Thermal Resistance, 28-Pin UQFN 6x6x0.55 mm | θJA | 26.0 | — | °C/W | 1 |
| Package Thermal Resistance, 28-Pin SOIC 7.50 mm | θJA | 70.0 | — | °C/W | 1 |

**Note 1:** Junction to ambient thermal resistance, Theta-JA (θJA) numbers are achieved by package simulations.


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**TABLE 30-4: DC TEMPERATURE AND VOLTAGE SPECIFICATIONS**

| DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[1]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| **Operating Voltage** | | | | | | | |
| DC10 | VDD | **Supply Voltage** | 3.0 | — | 3.6 | V | |
| DC12 | VDR | **RAM Retention Voltage**[2] | — | — | 1.95 | V | +25°C, +85°C, +125°C |
| | | | — | — | 2.0 | V | -40°C |
| DC16 | VPOR | **VDD Start Voltage** to Ensure Internal Power-on Reset Signal | — | — | VSS | V | |
| DC17 | SVDD | **VDD Rise Rate** to Ensure Internal Power-on Reset Signal | 1.0 | — | — | V/ms | 0V-3V in 3 ms |

**Note 1:** Device is functional at VBORMIN < VDD < VDDMIN. Analog modules (ADC, PGAs and comparators) may have degraded performance. Device functionality is tested but not characterized. Refer to Parameter BO10 in Table 30-13 for the minimum and maximum BOR values.

**2:** This is the limit to which VDD may be lowered and the RAM contents will always be retained.

**TABLE 30-5: FILTER CAPACITOR (CEFC) SPECIFICATIONS**

| **Standard Operating Conditions (unless otherwise stated):**<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| | CEFC | External Filter Capacitor Value[1] | 4.7 | — | 10 | μF | Capacitor must have a low series resistance (<1 Ohm) |

**Note 1:** Typical VCAP Voltage = 1.8 volts when VDD ≥ VDDMIN.

**TABLE 30-6: DC CHARACTERISTICS: OPERATING CURRENT (IDD)**

| 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 | | | |
|---|---|---|---|---|---|---|
| **Parameter No.** | **Typ.** | **Max.** | **Units** | **Conditions** | | |
| **Operating Current (IDD)(1)** | | | | | | |
| DC20d | 8 | 13 | mA | -40°C | 3.3V | 10 MIPS |
| DC20a | 8 | 13 | mA | +25°C | | |
| DC20b | 8 | 13 | mA | +85°C | | |
| DC20c | 8 | 13 | mA | +125°C | | |
| DC22d | 12 | 20 | mA | -40°C | 3.3V | 20 MIPS |
| DC22a | 12 | 20 | mA | +25°C | | |
| DC22b | 12 | 20 | mA | +85°C | | |
| DC22c | 12 | 20 | mA | +125°C | | |
| DC24d | 19 | 30 | mA | -40°C | 3.3V | 40 MIPS |
| DC24a | 19 | 30 | mA | +25°C | | |
| DC24b | 19 | 30 | mA | +85°C | | |
| DC24c | 19 | 30 | mA | +125°C | | |
| DC25d | 27 | 42 | mA | -40°C | 3.3V | 60 MIPS |
| DC25a | 27 | 42 | mA | +25°C | | |
| DC25b | 27 | 42 | mA | +85°C | | |
| DC25c | 27 | 42 | mA | +125°C | | |
| DC26d | 30 | 46 | mA | -40°C | 3.3V | 70 MIPS |
| DC26a | 30 | 46 | mA | +25°C | | |
| DC26b | 30 | 46 | mA | +85°C | | |
| DC27d | 57 | 75 | mA | -40°C | 3.3V | 70 MIPS (Note 2) |
| DC27a | 57 | 75 | mA | +25°C | | |
| DC27b | 57 | 75 | mA | +85°C | | |

**Note 1:** IDD is primarily a function of the operating voltage and frequency. Other factors, such as I/O pin loading and switching rate, oscillator type, internal code execution pattern and temperature, also have an impact on the current consumption. The test conditions for all IDD measurements are as follows:

- Oscillator is configured in EC mode with PLL, OSC1 is driven with external square wave from rail-to-rail (EC clock overshoot/undershoot < 250 mV required)
- CLKO is configured as an I/O input pin in the Configuration Word
- All I/O pins are configured as inputs and pulled to VSS
- $\overline{MCLR}$ = VDD, WDT and FSCM are disabled
- CPU, SRAM, program memory and data memory are operational
- No peripheral modules are operating or being clocked (all defined PMDx bits are set)
- CPU is executing `while(1)` statement
- JTAG is disabled

**2:** For this specification, the following test conditions apply:

- APLL clock is enabled
- All 8 PWMs enabled and operating at maximum speed (PTCON2<2:0> = `000`), PTPER = 1000h, 50% duty cycle
- All other peripherals are disabled (corresponding PMDx bits are set)


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**TABLE 30-7: DC CHARACTERISTICS: IDLE CURRENT (IIDLE)**

| 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 | | | |
|---|---|---|---|---|---|---|
| **Parameter No.** | **Typ.** | **Max.** | **Units** | **Conditions** | | |
| **Idle Current (IIDLE)(1)** | | | | | | |
| DC40d | 2 | 4 | mA | -40°C | 3.3V | 10 MIPS |
| DC40a | 2 | 4 | mA | +25°C | | |
| DC40b | 2 | 4 | mA | +85°C | | |
| DC40c | 2 | 4 | mA | +125°C | | |
| DC42d | 3 | 6 | mA | -40°C | 3.3V | 20 MIPS |
| DC42a | 3 | 6 | mA | +25°C | | |
| DC42b | 4 | 7 | mA | +85°C | | |
| DC42c | 4 | 7 | mA | +125°C | | |
| DC44d | 6 | 12 | mA | -40°C | 3.3V | 40 MIPS |
| DC44a | 6 | 12 | mA | +25°C | | |
| DC44b | 6 | 12 | mA | +85°C | | |
| DC44c | 6 | 12 | mA | +125°C | | |
| DC45d | 9 | 17 | mA | -40°C | 3.3V | 60 MIPS |
| DC45a | 9 | 17 | mA | +25°C | | |
| DC45b | 9 | 17 | mA | +85°C | | |
| DC45c | 9 | 17 | mA | +125°C | | |
| DC46d | 10 | 20 | mA | -40°C | 3.3V | 70 MIPS |
| DC46a | 10 | 20 | mA | +25°C | | |
| DC46b | 10 | 20 | mA | +85°C | | |

**Note 1:** Base Idle current (IIDLE) is measured as follows:

- CPU core is off, oscillator is configured in EC mode and external clock is active; OSC1 is driven with external square wave from rail-to-rail (EC clock overshoot/undershoot < 250 mV required)
- CLKO is configured as an I/O input pin in the Configuration Word
- All I/O pins are configured as inputs and pulled to VSS
- $\overline{\text{MCLR}}$ = VDD, WDT and FSCM are disabled
- No peripheral modules are operating or being clocked (all defined PMDx bits are set)
- The NVMSIDL bit (NVMCON<12>) = 1 (i.e., Flash regulator is set to standby while the device is in Idle mode)
- The VREGSF bit (RCON<11>) = 0 (i.e., Flash regulator is set to standby while the device is in Sleep mode)
- JTAG is disabled

**TABLE 30-8: DC CHARACTERISTICS: POWER-DOWN CURRENT ($I_{PD}$)**

| 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 | | |
|---|---|---|---|---|---|
| **Parameter No.** | **Typ.** | **Max.** | **Units** | **Conditions** | |
| **Power-Down Current ($I_{PD}$)(1)** | | | | | |
| DC60d | 15 | 110 | µA | -40°C | 3.3V |
| DC60a | 20 | 150 | µA | +25°C | |
| DC60b | 150 | 500 | µA | +85°C | |
| DC60c | 500 | 1200 | µA | +125°C | |

**Note 1:** $I_{PD}$ (Sleep) current is measured as follows:

- CPU core is off, oscillator is configured in EC mode and external clock is active; OSC1 is driven with external square wave from rail-to-rail (EC clock overshoot/undershoot < 250 mV required)
- CLKO is configured as an I/O input pin in the Configuration Word
- All I/O pins are configured as inputs and pulled to $V_{SS}$
- $\overline{MCLR}$ = $V_{DD}$, WDT and FSCM are disabled
- All peripheral modules are disabled (PMDx bits are all set)
- The VREGS bit (RCON<8>) = 0 (i.e., core regulator is set to standby while the device is in Sleep mode)
- The VREGSF bit (RCON<11>) = 0 (i.e., Flash regulator is set to standby while the device is in Sleep mode)
- JTAG is disabled

**TABLE 30-9: DC CHARACTERISTICS: WATCHDOG TIMER DELTA CURRENT ($\Delta I_{WDT}$)(1)**

| 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 | | |
|---|---|---|---|---|---|
| **Parameter No.** | **Typ.** | **Max.** | **Units** | **Conditions** | |
| DC61d | 1 | 10 | µA | -40°C | 3.3V |
| DC61a | 1 | 10 | µA | +25°C | |
| DC61b | 2 | 17 | µA | +85°C | |
| DC61c | 2 | 20 | µA | +125°C | |

**Note 1:** The $\Delta I_{WDT}$ current is the additional current consumed when the module is enabled. This current should be added to the base $I_{PD}$ current. All parameters are characterized but not tested during manufacturing.


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**TABLE 30-10: DC CHARACTERISTICS: DOZE CURRENT (IDOZE)**

| 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 | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter No.** | **Typ.** | **Max.** | **Doze Ratio** | **Units** | **Conditions** | | |
| **Doze Current (IDOZE)(1)** | | | | | | | |
| DC73a(2) | 20 | 40 | 1:2 | mA | -40°C | 3.3V | FOSC = 140 MHz |
| DC73g | 10 | 22 | 1:128 | mA | | | |
| DC70a(2) | 20 | 40 | 1:2 | mA | +25°C | 3.3V | FOSC = 140 MHz |
| DC70g | 10 | 22 | 1:128 | mA | | | |
| DC71a(2) | 20 | 40 | 1:2 | mA | +85°C | 3.3V | FOSC = 140 MHz |
| DC71g | 10 | 22 | 1:128 | mA | | | |
| DC72a(2) | 20 | 40 | 1:2 | mA | +125°C | 3.3V | FOSC = 120 MHz |
| DC72g | 10 | 22 | 1:128 | mA | | | |

**Note 1:** IDOZE is primarily a function of the operating voltage and frequency. Other factors, such as I/O pin loading and switching rate, oscillator type, internal code execution pattern and temperature, also have an impact on the current consumption. The test conditions for all IDOZE measurements are as follows:

- Oscillator is configured in EC mode and external clock is active, OSC1 is driven with external square wave from rail-to-rail (EC clock overshoot/undershoot < 250 mV required)
- CLKO is configured as an I/O input pin in the Configuration Word
- All I/O pins are configured as inputs and pulled to VSS
- $\overline{MCLR}$ = VDD, WDT and FSCM are disabled
- CPU, SRAM, program memory and data memory are operational
- No peripheral modules are operating or being clocked (all defined PMDx bits are set)
- CPU is executing `while(1)` statement
- JTAG is disabled

**2:** These parameter are characterized but not tested in manufacturing.

**TABLE 30-11: DC CHARACTERISTICS: I/O PIN INPUT SPECIFICATIONS**

| 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** |
| | VIL | **Input Low Voltage** | | | | | |
| DI10 | | Any I/O Pin and $\overline{MCLR}$ | VSS | — | 0.2 VDD | V | |
| DI18 | | I/O Pins with SDAx, SCLx | VSS | — | 0.3 VDD | V | SMBus disabled |
| DI19 | | I/O Pins with SDAx, SCLx | VSS | — | 0.8 | V | SMBus enabled |
| | VIH | **Input High Voltage** | | | | | |
| DI20 | | I/O Pins Not 5V Tolerant(4) | 0.8 VDD | — | VDD | V | |
| | | I/O Pins 5V Tolerant and $\overline{MCLR}$(4) | 0.8 VDD | — | 5.5 | V | |
| | | 5V Tolerant I/O Pins with SDAx, SCLx(4) | 0.8 VDD | — | 5.5 | V | SMBus disabled |
| | | 5V Tolerant I/O Pins with SDAx, SCLx(4) | 2.1 | — | 5.5 | V | SMBus enabled |
| | | I/O Pins with SDAx, SCLx Not 5V Tolerant(4) | 0.8 VDD | — | VDD | V | SMBus disabled |
| | | I/O Pins with SDAx, SCLx Not 5V Tolerant(4) | 2.1 | — | VDD | V | SMBus enabled |
| DI30 | ICNPU | **Input Change Notification Pull-up Current** | 100 | 230 | 550 | µA | VDD = 3.3V, VPIN = VSS |
| DI31 | ICNPD | **Input Change Notification Pull-Down Current(5)** | 100 | 230 | 400 | µA | VDD = 3.3V, VPIN = VDD |

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

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

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

**4:** See the **"Pin Diagrams"** section for the 5V tolerant I/O pins.

**5:** VIL Source < (VSS – 0.3). Characterized but not tested.

**6:** VIH Source > (VDD + 0.3) for pins that are not 5V tolerant only.

**7:** Digital 5V tolerant pins do not have internal high-side diodes to VDD and cannot tolerate any "positive" input injection current.

**8:** Injection Currents > | 0 | can affect the ADC results by approximately 4-6 counts.

**9:** Any number and/or combination of I/O pins not excluded under IICL or IICH conditions are permitted provided the mathematical "absolute instantaneous" sum of the input injection currents from all pins do not exceed the specified limit. Characterized but not tested.


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**TABLE 30-11: DC CHARACTERISTICS: I/O PIN INPUT SPECIFICATIONS (CONTINUED)**

| 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** |
| | IIL | **Input Leakage Current(2,3)** | | | | | |
| DI50 | | I/O Pins 5V Tolerant(4) | -1 | — | +1 | µA | VSS ≤ VPIN ≤ VDD, pin at high-impedance |
| DI51 | | I/O Pins Not 5V Tolerant(4) | -1 | — | +1 | µA | VSS ≤ VPIN ≤ VDD, pin at high-impedance, -40°C ≤ TA ≤ +85°C |
| DI51a | | I/O Pins Not 5V Tolerant(4) | -1 | — | +1 | µA | Analog pins shared with external reference pins, -40°C ≤ TA ≤ +85°C |
| DI51b | | I/O Pins Not 5V Tolerant(4) | -1 | — | +1 | µA | VSS ≤ VPIN ≤ VDD, pin at high-impedance, -40°C ≤ TA ≤ +125°C |
| DI51c | | I/O Pins Not 5V Tolerant(4) | -1 | — | +1 | µA | Analog pins shared with external reference pins, -40°C ≤ TA ≤ +125°C |
| DI55 | | $\overline{\text{MCLR}}$ | -5 | — | +5 | µA | VSS ≤ VPIN ≤ VDD |
| DI56 | | OSC1 | -5 | — | +5 | µA | VSS ≤ VPIN ≤ VDD, XT and HS modes |

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

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

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

**4:** See the **“Pin Diagrams”** section for the 5V tolerant I/O pins.

**5:** VIL Source < (VSS – 0.3). Characterized but not tested.

**6:** VIH Source > (VDD + 0.3) for pins that are not 5V tolerant only.

**7:** Digital 5V tolerant pins do not have internal high-side diodes to VDD and cannot tolerate any “positive” input injection current.

**8:** Injection Currents > | 0 | can affect the ADC results by approximately 4-6 counts.

**9:** Any number and/or combination of I/O pins not excluded under IICL or IICH conditions are permitted provided the mathematical “absolute instantaneous” sum of the input injection currents from all pins do not exceed the specified limit. Characterized but not tested.

**TABLE 30-11: DC CHARACTERISTICS: I/O PIN INPUT SPECIFICATIONS (CONTINUED)**

| 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** |
| DI60a | IICL | **Input Low Injection Current** | 0 | — | -5(5,8) | mA | All pins except VDD, VSS, AVDD, AVSS, MCLR, VCAP and RB7 |
| DI60b | IICH | **Input High Injection Current** | 0 | — | +5(6,7,8) | mA | All pins except VDD, VSS, AVDD, AVSS, MCLR, VCAP, RB7 and all 5V tolerant pins(7) |
| DI60c | ∑IICT | **Total Input Injection Current (sum of all I/O and control pins)** | -20(9) | — | +20(9) | mA | Absolute instantaneous sum of all ± input injection currents from all I/O pins ( \| IICL \| + \| IICH \| ) ≤ ∑IICT |

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

**2:** The leakage current on the MCLR pin is strongly dependent on the applied voltage level. The specified levels represent normal operating conditions. Higher leakage current can be measured at different input voltages.

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

**4:** See the **"Pin Diagrams"** section for the 5V tolerant I/O pins.

**5:** VIL Source < (VSS – 0.3). Characterized but not tested.

**6:** VIH Source > (VDD + 0.3) for pins that are not 5V tolerant only.

**7:** Digital 5V tolerant pins do not have internal high-side diodes to VDD and cannot tolerate any "positive" input injection current.

**8:** Injection Currents > | 0 | can affect the ADC results by approximately 4-6 counts.

**9:** Any number and/or combination of I/O pins not excluded under IICL or IICH conditions are permitted provided the mathematical "absolute instantaneous" sum of the input injection currents from all pins do not exceed the specified limit. Characterized but not tested.


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**TABLE 30-12: DC CHARACTERISTICS: I/O PIN OUTPUT SPECIFICATIONS**

| 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** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| DO10 | VOL | **Output Low Voltage**<br>4x Sink Driver Pins(2) | — | — | 0.4 | V | VDD = 3.3V,<br>IOL ≤ 6 mA, -40°C ≤ TA ≤ +85°C,<br>IOL ≤ 5 mA, +85°C < TA ≤ +125°C |
| | | **Output Low Voltage**<br>8x Sink Driver Pins(3) | — | — | 0.4 | V | VDD = 3.3V,<br>IOL ≤ 12 mA, -40°C ≤ TA ≤ +85°C,<br>IOL ≤ 8 mA, +85°C < TA ≤ +125°C |
| DO20 | VOH | **Output High Voltage**<br>4x Source Driver Pins(2) | 2.4 | — | — | V | IOH ≥ -10 mA, VDD = 3.3V |
| | | **Output High Voltage**<br>8x Source Driver Pins(3) | 2.4 | — | — | V | IOH ≥ -15 mA, VDD = 3.3V |
| DO20A | VOH1 | **Output High Voltage**<br>4x Source Driver Pins(2) | 1.5(1) | — | — | V | IOH ≥ -14 mA, VDD = 3.3V |
| | | | 2.0(1) | — | — | | IOH ≥ -12 mA, VDD = 3.3V |
| | | | 3.0(1) | — | — | | IOH ≥ -7 mA, VDD = 3.3V |
| | | **Output High Voltage**<br>8x Source Driver Pins(3) | 1.5(1) | — | — | V | IOH ≥ -22 mA, VDD = 3.3V |
| | | | 2.0(1) | — | — | | IOH ≥ -18 mA, VDD = 3.3V |
| | | | 3.0(1) | — | — | | IOH ≥ -10 mA, VDD = 3.3V |

**Note 1:** Parameters are characterized but not tested.

**2:** Includes RA0-RA2, RB0-RB1, RB9, RC1-RC2, RC9-RC10, RC12, RD7, RD8, RE4-RE5, RE8-RE9 and RE12-RE13 pins.

**3:** Includes all I/O pins that are not 4x driver pins (see **Note 2**).

**TABLE 30-13: ELECTRICAL CHARACTERISTICS: BOR**

| DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)(1)<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.(2)** | **Typ.** | **Max.** | **Units** | **Conditions** |
| BO10 | VBOR | BOR Event on VDD Transition High-to-Low | 2.65 | — | 2.95 | V | VDD (**Notes 2** and **3**) |

**Note 1:** Device is functional at VBORMIN < VDD < VDDMIN, but will have degraded performance. Device functionality is tested, but not characterized. Analog modules (ADC, PGAs and comparators) may have degraded performance.

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

**3:** The VBOR specification is relative to VDD.

**TABLE 30-14: 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 | -40°C to +125°C |
| D131 | VPR | VDD for Read | 3.0 | — | 3.6 | V | |
| D132b | VPEW | VDD for Self-Timed Write | 3.0 | — | 3.6 | V | |
| D134 | TRETD | Characteristic Retention | 20 | — | — | Year | Provided no other specifications are violated, -40°C to +125°C |
| D135 | IDDP | Supply Current during Programming(2) | — | 10 | — | mA | |
| D136 | IPEAK | Instantaneous Peak Current During Start-up | — | — | 150 | mA | |
| D137a | TPE | Page Erase Time | 19.7 | — | 20.1 | ms | TPE = 146893 FRC cycles, TA = +85°C **(Note 3)** |
| D137b | TPE | Page Erase Time | 19.5 | — | 20.3 | ms | TPE = 146893 FRC cycles, TA = +125°C **(Note 3)** |
| D138a | TWW | Word Write Cycle Time | 46.5 | — | 47.3 | µs | TWW = 346 FRC cycles, TA = +85°C **(Note 3)** |
| D138b | TWW | Word Write Cycle Time | 46.0 | — | 47.9 | µs | TWW = 346 FRC cycles, TA = +125°C **(Note 3)** |
| D139a | TRW | Row Write Time | 667 | — | 679 | µs | TRW = 4965 FRC cycles, TA = +85°C **(Note 3)** |
| D139b | TRW | Row Write Time | 660 | — | 687 | µs | TRW = 4965 FRC cycles, TA = +125°C **(Note 3)** |

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

**2:** Parameter characterized but not tested in manufacturing.

**3:** Other conditions: FRC = 7.37 MHz, TUN<5:0> = `011111` (for Minimum), TUN<5:0> = `100000` (for Maximum). This parameter depends on the FRC accuracy (see Table 30-20) 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”**.


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## 30.2 AC Characteristics and Timing Parameters

This section defines the dsPIC33EPXXXGS70X/80X family AC characteristics and timing parameters.

**TABLE 30-15: TEMPERATURE AND VOLTAGE SPECIFICATIONS – AC**

| 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<br>Operating voltage VDD range as described in **Section 30.1 "DC Characteristics"**. |
|---|---|

**FIGURE 30-1: LOAD CONDITIONS FOR DEVICE TIMING SPECIFICATIONS**

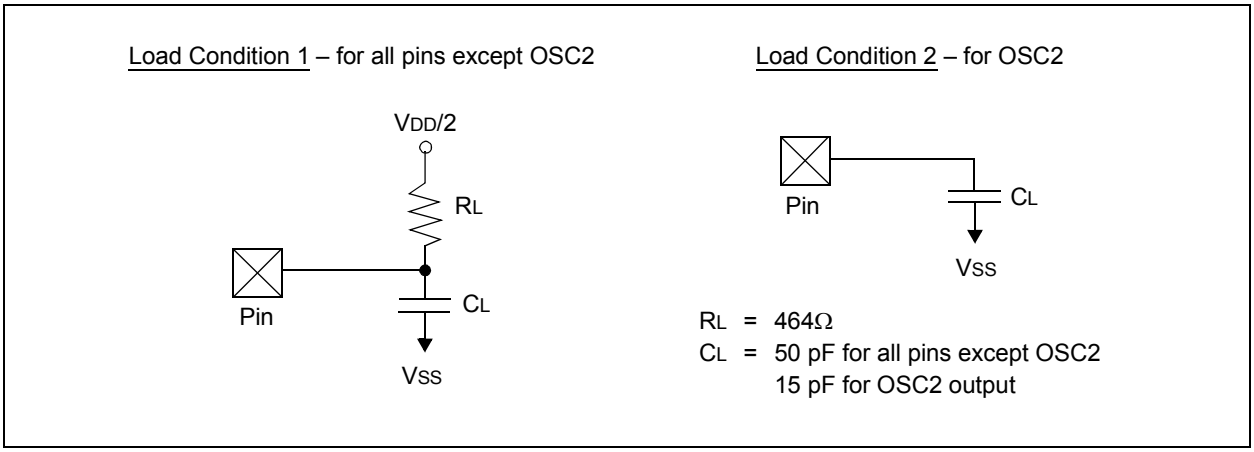


**TABLE 30-16: CAPACITIVE LOADING REQUIREMENTS ON OUTPUT PINS**

| Param No. | Symbol | Characteristic | Min. | Typ. | Max. | Units | Conditions |
|---|---|---|---|---|---|---|---|
| DO50 | COSCO | OSC2 Pin | — | — | 15 | pF | In XT and HS modes, when external clock is used to drive OSC1 |
| DO56 | CIO | All I/O Pins and OSC2 | — | — | 50 | pF | EC mode |
| DO58 | CB | SCLx, SDAx | — | — | 400 | pF | In $I^2C$ mode |

**FIGURE 30-2: EXTERNAL CLOCK TIMING**

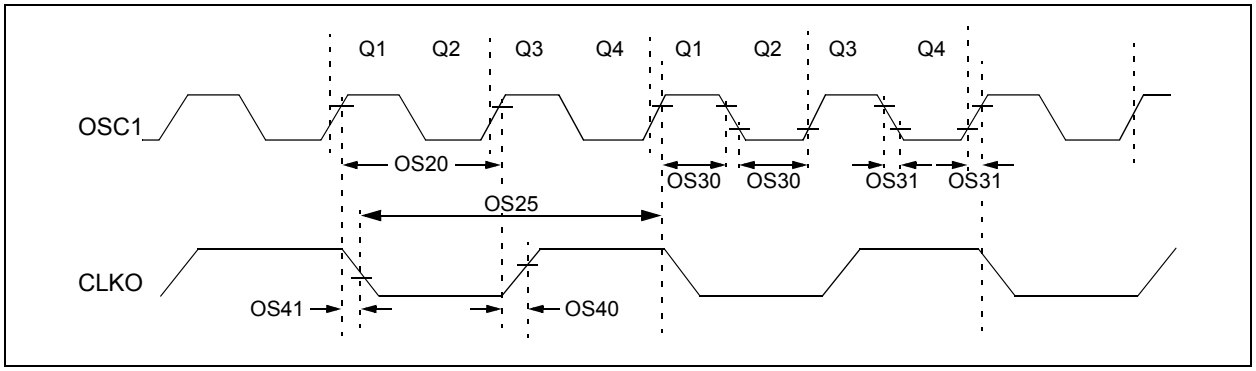


**TABLE 30-17: EXTERNAL CLOCK TIMING REQUIREMENTS**

| 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.** | **Sym** | **Characteristic** | **Min.** | **Typ.(1)** | **Max.** | **Units** | **Conditions** |
| OS10 | FIN | External CLKI Frequency (External clocks allowed only in EC and ECPLL modes) | DC | — | 60 | MHz | EC |
| | | Oscillator Crystal Frequency | 3.5<br>10 | —<br>— | 10<br>40 | MHz<br>MHz | XT<br>HS |
| OS20 | TOSC | TOSC = 1/FOSC | 8.33 | — | DC | ns | +125°C |
| | | TOSC = 1/FOSC | 7.14 | — | DC | ns | +85°C |
| OS25 | TCY | Instruction Cycle Time(2) | 16.67 | — | DC | ns | +125°C |
| | | Instruction Cycle Time(2) | 14.28 | — | DC | ns | +85°C |
| OS30 | TosL, TosH | External Clock in (OSC1) High or Low Time | 0.45 x TOSC | — | 0.55 x TOSC | ns | EC |
| OS31 | TosR, TosF | External Clock in (OSC1) Rise or Fall Time | — | — | 20 | ns | EC |
| OS40 | TckR | CLKO Rise Time(3,4) | — | 5.2 | — | ns | |
| OS41 | TckF | CLKO Fall Time(3,4) | — | 5.2 | — | ns | |
| OS42 | GM | External Oscillator Transconductance(4) | — | 12 | — | mA/V | HS, VDD = 3.3V, TA = +25°C |
| | | | — | 6 | — | mA/V | XT, VDD = 3.3V, TA = +25°C |

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

**2:** Instruction cycle period (TCY) equals two times the input oscillator time base period. All specified values are based on characterization data for that particular oscillator type, under standard operating conditions, with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at “Minimum” values with an external clock applied to the OSC1 pin. When an external clock input is used, the “Maximum” cycle time limit is “DC” (no clock) for all devices.

**3:** Measurements are taken in EC mode. The CLKO signal is measured on the OSC2 pin.

**4:** This parameter is characterized but not tested in manufacturing.


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**TABLE 30-18: PLL CLOCK TIMING SPECIFICATIONS**

| 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** | **Min.** | **Typ.(1)** | **Max.** | **Units** | **Conditions** |
| OS50 | FPLLI | PLL Voltage Controlled Oscillator (VCO) Input Frequency Range | 0.8 | — | 8.0 | MHz | ECPLL, XTPLL modes |
| OS51 | FVCO | On-Chip VCO System Frequency | 120 | — | 340 | MHz | |
| OS52 | TLOCK | PLL Start-up Time (Lock Time) | 0.9 | 1.5 | 3.1 | ms | |
| OS53 | DCLK | CLKO Stability (Jitter)(2) | -3 | 0.5 | 3 | % | |

**Note 1:** Data in "Typ." column is at 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

**2:** This jitter specification is based on clock cycle-by-clock cycle measurements. To get the effective jitter for individual time bases, or communication clocks used by the application, use the following formula:

$$\text{Effective Jitter} = \frac{DCLK}{\sqrt{\frac{FOSC}{\text{Time Base or Communication Clock}}}}$$

For example, if FOSC = 120 MHz and the SPIx bit rate = 10 MHz, the effective jitter is as follows:

$$\text{Effective Jitter} = \frac{DCLK}{\sqrt{\frac{120}{10}}} = \frac{DCLK}{\sqrt{12}} = \frac{DCLK}{3.464}$$

**TABLE 30-19: AUXILIARY PLL CLOCK TIMING SPECIFICATIONS**

| 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** | **Min** | **Typ(1)** | **Max** | **Units** | **Conditions** |
| OS56 | FHPOUT | On-Chip 16x PLL CCO Frequency | 112 | 118 | 120 | MHz | |
| OS57 | FHPIN | On-Chip 16x PLL Phase Detector Input Frequency | 7.0 | 7.37 | 7.5 | MHz | |
| OS58 | TSU | Frequency Generator Lock Time | — | — | 10 | µs | |

**Note 1:** Data in "Typ" column is at 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested in manufacturing.

**TABLE 30-20: INTERNAL FRC ACCURACY**

| 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** | |
| **Internal FRC Accuracy @ FRC Frequency = 7.37 MHz(1)** | | | | | | | |
| F20a | FRC | -2 | 0.5 | +2 | % | -40°C ≤ TA ≤ -10°C | VDD = 3.0-3.6V |
| | | -0.9 | 0.5 | +0.9 | % | -10°C ≤ TA ≤ +85°C | VDD = 3.0-3.6V |
| F20b | FRC | -2 | 1 | +2 | % | +85°C ≤ TA ≤ +125°C | VDD = 3.0-3.6V |

**Note 1:** Frequency is calibrated at +25°C and 3.3V. TUNx bits can be used to compensate for temperature drift.

**TABLE 30-21: INTERNAL LPRC ACCURACY**

| 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** | |
| **LPRC @ 32.768 kHz(1)** | | | | | | | |
| F21a | LPRC | -30 | — | +30 | % | -40°C ≤ TA ≤ -10°C | VDD = 3.0-3.6V |
| | | -20 | — | +20 | % | -10°C ≤ TA ≤ +85°C | VDD = 3.0-3.6V |
| F21b | LPRC | -30 | — | +30 | % | +85°C ≤ TA ≤ +125°C | VDD = 3.0-3.6V |

**Note 1:** This is the change of the LPRC frequency as VDD changes.


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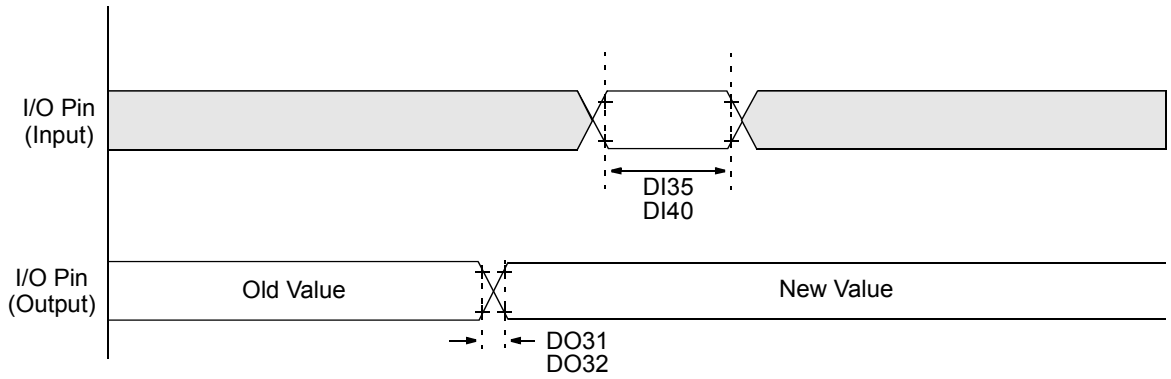
**FIGURE 30-3: I/O TIMING CHARACTERISTICS**




**Note:** Refer to Figure 30-1 for load conditions.

**TABLE 30-22: I/O 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** | **Min.** | **Typ.(1)** | **Max.** | **Units** | **Conditions** |
| DO31 | TIOR | Port Output Rise Time | — | 5 | 10 | ns | |
| DO32 | TIOF | Port Output Fall Time | — | 5 | 10 | ns | |
| DI35 | TINP | INTx Pin High or Low Time (input) | 20 | — | — | ns | |
| DI40 | TRBP | CNx High or Low Time (input) | 2 | — | — | TCY | |

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

**FIGURE 30-4: BOR AND MASTER CLEAR RESET TIMING CHARACTERISTICS**

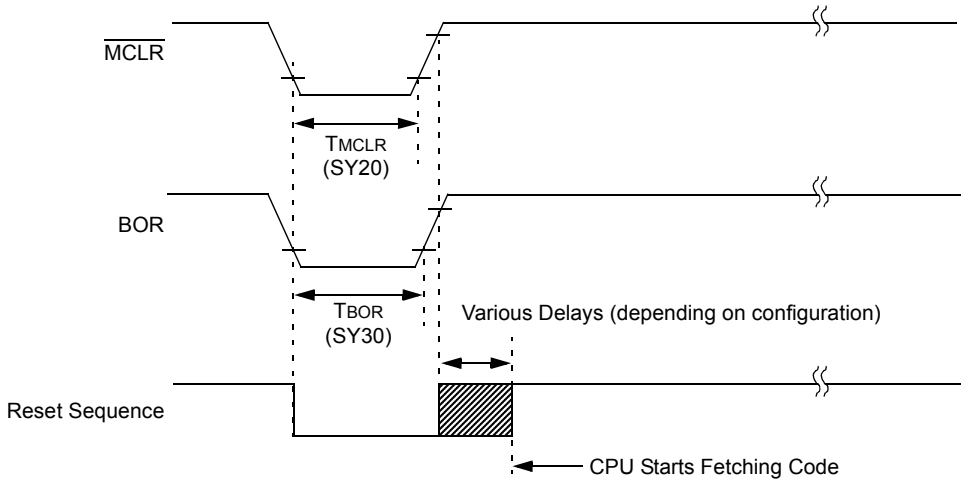


**TABLE 30-23: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER, POWER-UP TIMER TIMING REQUIREMENTS**

| 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** |
| SY00 | TPU | Power-up Period | — | 400 | 600 | μs | |
| SY10 | TOST | Oscillator Start-up Time | — | 1024 TOSC | — | — | TOSC = OSC1 period |
| SY12 | TWDT | Watchdog Timer Time-out Period | 0.81 | — | 1.22 | ms | WDTPRE = 0, WDTPOST<3:0> = 0000, using LPRC tolerances indicated in F21 (see Table 30-21) at +85°C |
| | | | 3.25 | — | 4.88 | ms | WDTPRE = 1, WDTPOST<3:0> = 0000, using LPRC tolerances indicated in F21 (see Table 30-21) at +85°C |
| SY13 | TIOZ | I/O High-Impedance from $\overline{\text{MCLR}}$ Low or Watchdog Timer Reset | 0.68 | 0.72 | 1.2 | μs | |
| SY20 | TMCLR | $\overline{\text{MCLR}}$ Pulse Width (low) | 2 | — | — | μs | |
| SY30 | TBOR | BOR Pulse Width (low) | 1 | — | — | μs | |
| SY35 | TFSCM | Fail-Safe Clock Monitor Delay | — | 500 | 900 | μs | -40°C to +85°C |
| SY36 | TVREG | Voltage Regulator Standby-to-Active mode Transition Time | — | — | 30 | μs | |
| SY37 | TOSCDFRC | FRC Oscillator Start-up Delay | — | 48 | — | μs | |
| SY38 | TOSCDLPRC | LPRC Oscillator Start-up Delay | — | — | 70 | μs | |

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

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


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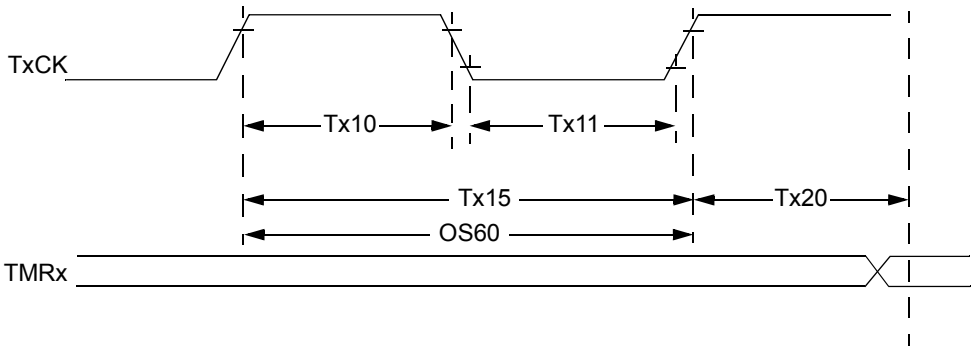
**FIGURE 30-5: TIMER1-TIMER5 EXTERNAL CLOCK TIMING CHARACTERISTICS**




**Note:** Refer to Figure 30-1 for load conditions.

**TABLE 30-24: TIMER1 EXTERNAL CLOCK TIMING REQUIREMENTS(1)**

| 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(2)** | | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| TA10 | TTXH | T1CK High Time | Synchronous mode | Greater of: 20 or (TCY + 20)/N | — | — | ns | Must also meet Parameter TA15, N = Prescale Value (1, 8, 64, 256) |
| | | | Asynchronous mode | 35 | — | — | ns | |
| TA11 | TTXL | T1CK Low Time | Synchronous mode | Greater of: 20 or (TCY + 20)/N | — | — | ns | Must also meet Parameter TA15, N = Prescale Value (1, 8, 64, 256) |
| | | | Asynchronous mode | 10 | — | — | ns | |
| TA15 | TTXP | T1CK Input Period | Synchronous mode | Greater of: 40 or (2 TCY + 40)/N | — | — | ns | N = Prescale Value (1, 8, 64, 256) |
| OS60 | Ft1 | T1CK Oscillator Input Frequency Range (oscillator enabled by setting bit, TCS (T1CON<1>)) | | DC | — | 50 | kHz | |
| TA20 | TCKEXTMRL | Delay from External T1CK Clock Edge to Timer Increment | | 0.75 TCY + 40 | — | 1.75 TCY + 40 | ns | |

**Note 1:** Timer1 is a Type A timer.

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

**TABLE 30-25: TIMER2 AND TIMER4 (TYPE B TIMER) EXTERNAL CLOCK 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.** | **Max.** | **Units** | **Conditions** |
| TB10 | TtxH | TxCK High Time | Synchronous mode | Greater of: 20 or (TCY + 20)/N | — | — | ns | Must also meet Parameter TB15, N = Prescale Value (1, 8, 64, 256) |
| TB11 | TtxL | TxCK Low Time | Synchronous mode | Greater of: 20 or (TCY + 20)/N | — | — | ns | Must also meet Parameter TB15, N = Prescale Value (1, 8, 64, 256) |
| TB15 | TtxP | TxCK Input Period | Synchronous mode | Greater of: 40 or (2 TCY + 40)/N | — | — | ns | N = Prescale Value (1, 8, 64, 256) |
| TB20 | TCKEXTMRL | Delay from External TxCK Clock Edge to Timer Increment | | 0.75 TCY + 40 | — | 1.75 TCY + 40 | ns | |

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

**TABLE 30-26: TIMER3 AND TIMER5 (TYPE C TIMER) EXTERNAL CLOCK 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.** | **Max.** | **Units** | **Conditions** |
| TC10 | TtxH | TxCK High Time | Synchronous | TCY + 20 | — | — | ns | Must also meet Parameter TC15 |
| TC11 | TtxL | TxCK Low Time | Synchronous | TCY + 20 | — | — | ns | Must also meet Parameter TC15 |
| TC15 | TtxP | TxCK Input Period | Synchronous with Prescaler | 2 TCY + 40 | — | — | ns | N = Prescale Value (1, 8, 64, 256) |
| TC20 | TCKEXTMRL | Delay from External TxCK Clock Edge to Timer Increment | | 0.75 TCY + 40 | — | 1.75 TCY + 40 | ns | |

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


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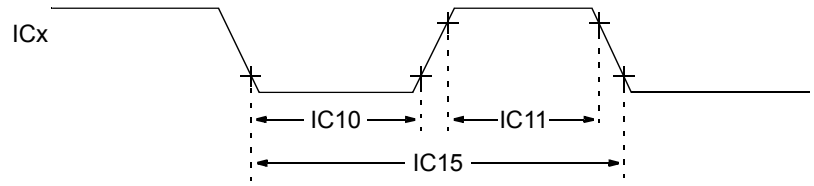
**FIGURE 30-6: INPUT CAPTURE x (ICx) TIMING CHARACTERISTICS**



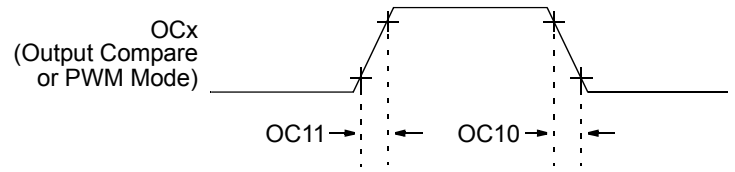

**Note:** Refer to Figure 30-1 for load conditions.

**TABLE 30-27: INPUT CAPTURE x MODULE 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** | **Characteristics(1)** | **Min.** | **Max.** | **Units** | **Conditions** | |
| IC10 | TccL | ICx Input Low Time | Greater of:<br>12.5 + 25 or<br>(0.5 TCY/N) + 25 | — | ns | Must also meet Parameter IC15 | N = Prescale Value (1, 4, 16) |
| IC11 | TccH | ICx Input High Time | Greater of:<br>12.5 + 25 or<br>(0.5 TCY/N) + 25 | — | ns | Must also meet Parameter IC15 | |
| IC15 | TccP | ICx Input Period | Greater of:<br>25 + 50 or<br>(1 TCY/N) + 50 | — | ns | | |

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

**FIGURE 30-7: OUTPUT COMPARE x MODULE (OCx) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 30-1 for load conditions.

**TABLE 30-28: OUTPUT COMPARE x MODULE 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.** | **Max.** | **Units** | **Conditions** |
| OC10 | TccF | OCx Output Fall Time | — | — | — | ns | See Parameter DO32 |
| OC11 | TccR | OCx Output Rise Time | — | — | — | ns | See Parameter DO31 |

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

**FIGURE 30-8: OCx/PWMx MODULE TIMING CHARACTERISTICS**

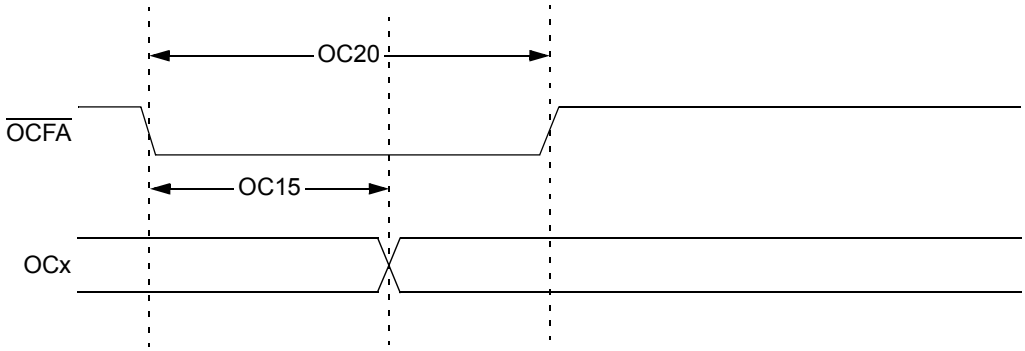



**TABLE 30-29: OCx/PWMx MODULE TIMING REQUIREMENTS**

| 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.** | **Max.** | **Units** | **Conditions** |
| OC15 | TFD | Fault Input to PWMx I/O Change | — | — | TCY + 20 | ns | |
| OC20 | TFLT | Fault Input Pulse Width | TCY + 20 | — | — | ns | |

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


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**FIGURE 30-9: HIGH-SPEED PWMx MODULE FAULT TIMING CHARACTERISTICS**

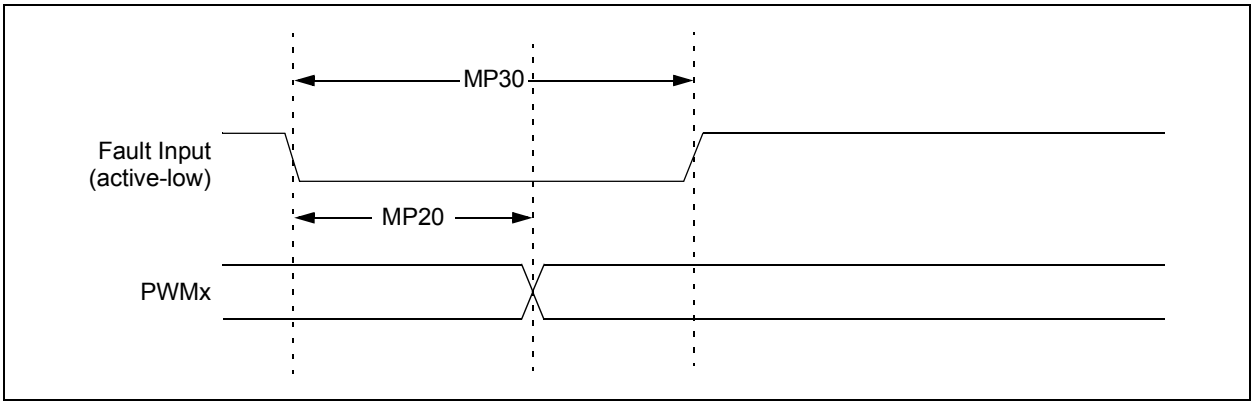
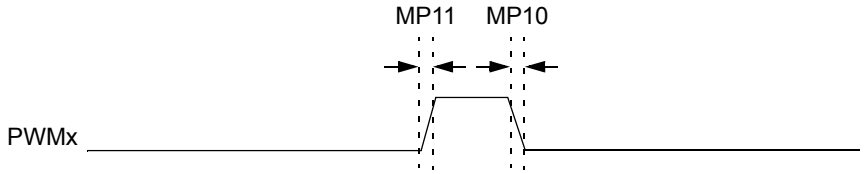



**FIGURE 30-10: HIGH-SPEED PWMx MODULE TIMING CHARACTERISTICS**




**Note:** Refer to Figure 30-1 for load conditions.

**TABLE 30-30: HIGH-SPEED PWMx MODULE 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.** | **Max.** | **Units** | **Conditions** |
| MP10 | TFPWM | PWMx Output Fall Time | — | — | — | ns | See Parameter DO32 |
| MP11 | TRPWM | PWMx Output Rise Time | — | — | — | ns | See Parameter DO31 |
| MP20 | TFD | Fault Input ↓ to PWMx I/O Change | — | — | 15 | ns | |
| MP30 | TFH | Fault Input Pulse Width | 15 | — | — | ns | |

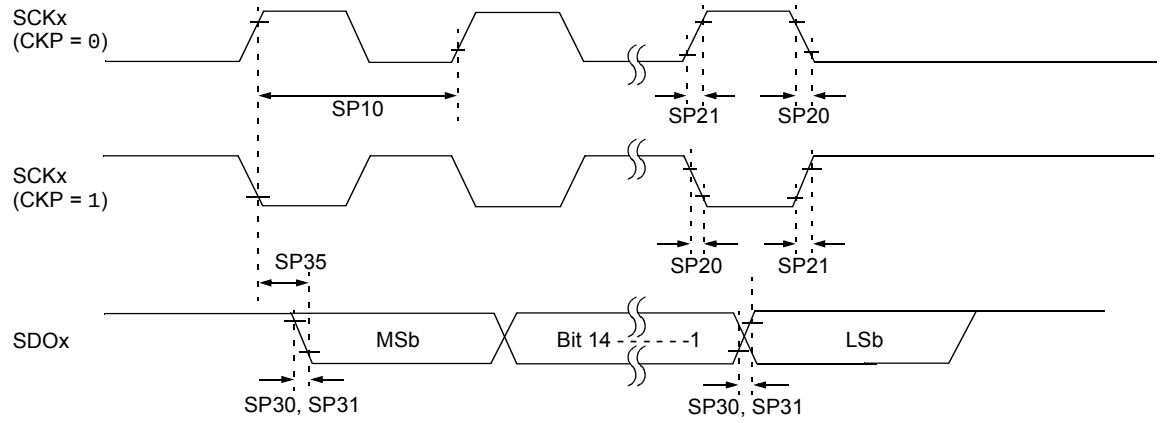
**Note 1:** These parameters are characterized but not tested in manufacturing.

**TABLE 30-31: SPI1, SPI2 AND SPI3 MAXIMUM DATA/CLOCK RATE SUMMARY(1)**

| 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 | | | |
|---|---|---|---|---|---|---|
| **Maximum Data Rate** | **Master Transmit Only (Half-Duplex)** | **Master Transmit/Receive (Full-Duplex)** | **Slave Transmit/Receive (Full-Duplex)** | **CKE** | **CKP** | **SMP** |
| 15 MHz | Table 30-32 | — | — | 0,1 | 0,1 | 0,1 |
| 9 MHz | — | Table 30-33 | — | 1 | 0,1 | 1 |
| 9 MHz | — | Table 30-34 | — | 0 | 0,1 | 1 |
| 15 MHz | — | — | Table 30-35 | 1 | 0 | 0 |
| 11 MHz | — | — | Table 30-36 | 1 | 1 | 0 |
| 15 MHz | — | — | Table 30-37 | 0 | 1 | 0 |
| 11 MHz | — | — | Table 30-38 | 0 | 0 | 0 |

**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**FIGURE 30-11: SPI1, SPI2 AND SPI3 MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY, CKE = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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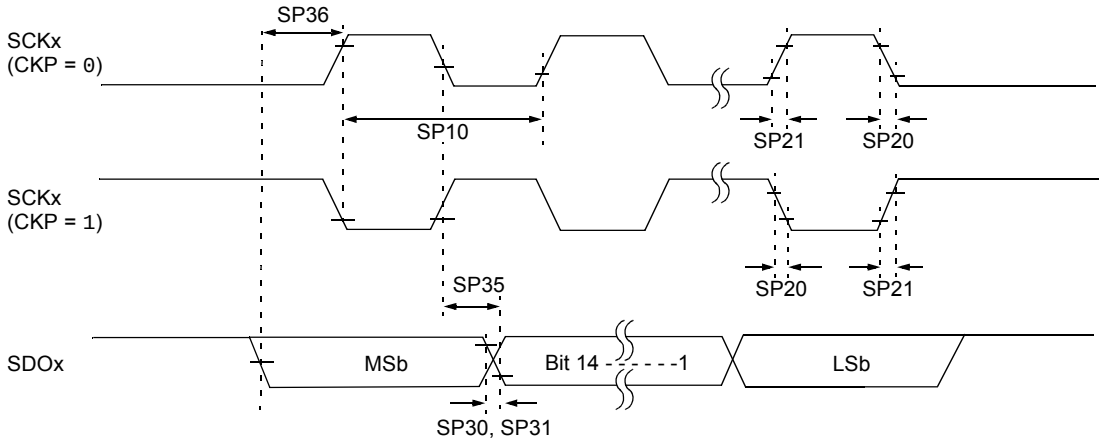
**FIGURE 30-12: SPI1, SPI2 AND SPI3 MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY, CKE = 1) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.

**TABLE 30-32: SPI1, SPI2 AND SPI3 MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Frequency | — | — | 15 | MHz | **(Note 3)** |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(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.

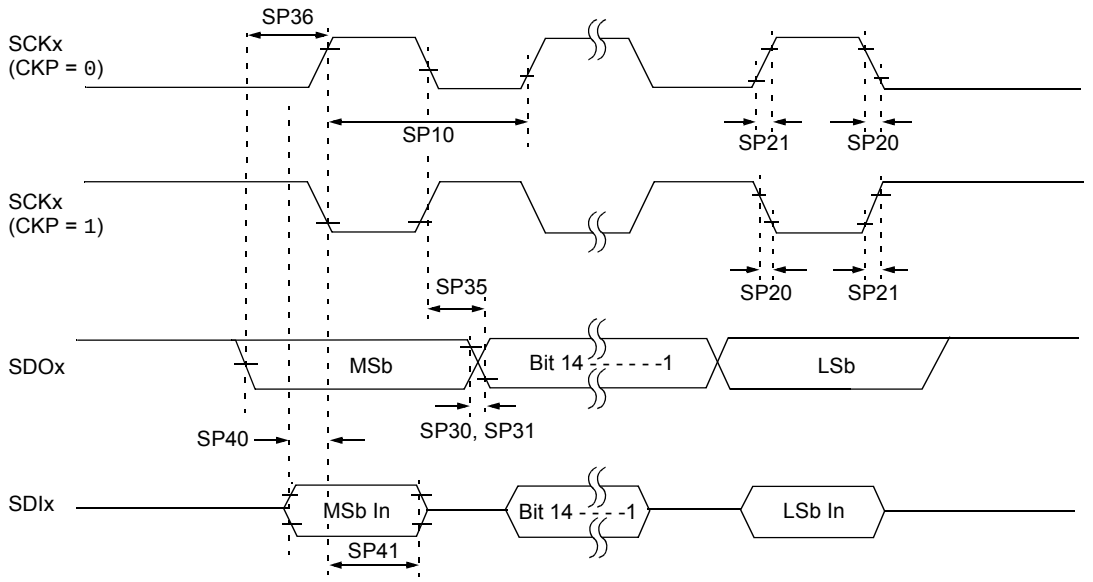
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**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.

**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**FIGURE 30-13: SPI1, SPI2 AND SPI3 MASTER MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 1) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.

**TABLE 30-33: SPI1, SPI2 AND SPI3 MASTER MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 1) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Frequency | — | — | 9 | MHz | **(Note 3)** |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2sc, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |

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

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

**3:** The minimum clock period for SCKx is 111 ns. The clock generated in Master mode must not violate this specification.

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

**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.


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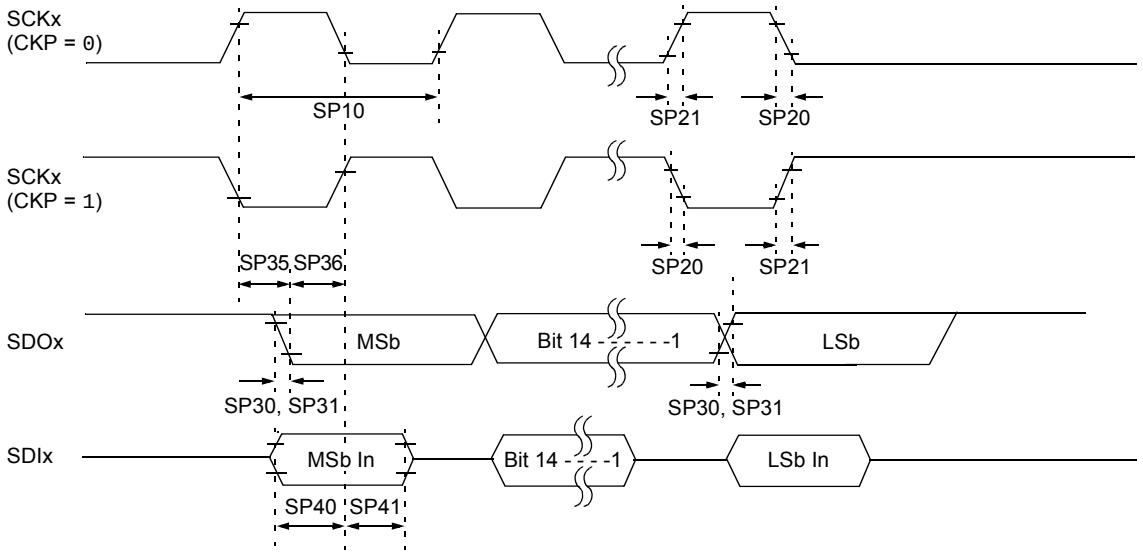
**FIGURE 30-14: SPI1, SPI2 AND SPI3 MASTER MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 1) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.

**TABLE 30-34: SPI1, SPI2 AND SPI3 MASTER MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 1) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Frequency | — | — | 9 | MHz | -40ºC to +125ºC **(Note 3)** |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |

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

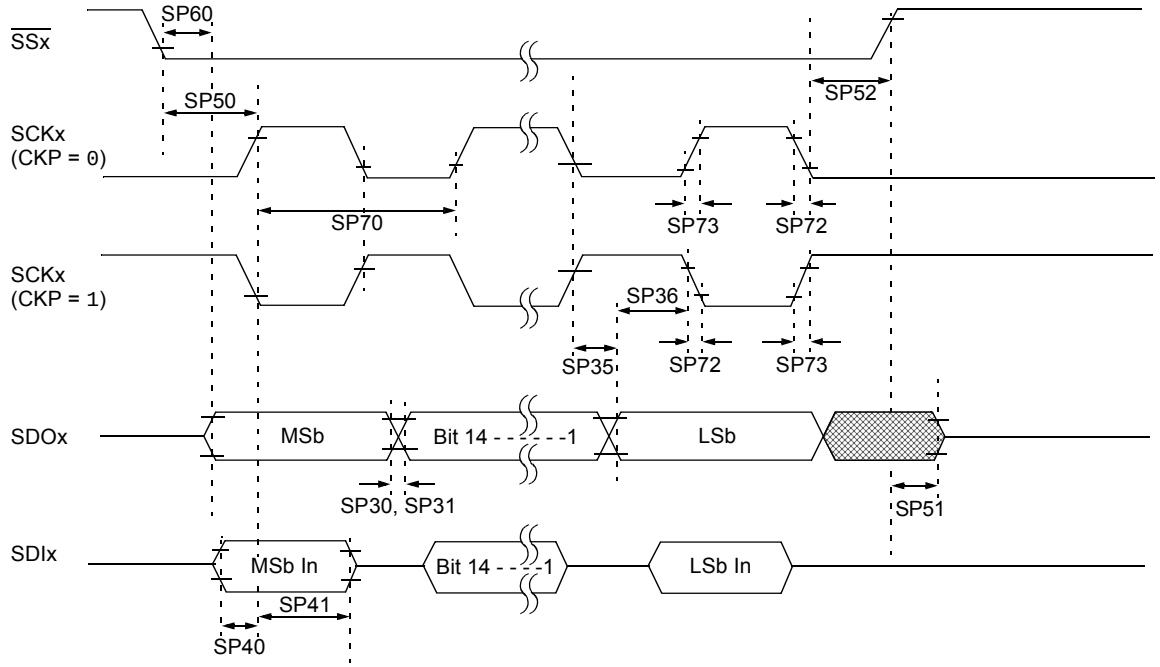
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCKx is 111 ns. The clock generated in Master mode must not violate this specification.

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

**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**FIGURE 30-15: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 0, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-35: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 0, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCKx Input Frequency | — | — | 15 | MHz | **(Note 3)** |
| SP72 | TscF | SCKx Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCKx Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SSx}$ ↓ to SCKx ↑ or SCKx ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SSx}$ ↑ to SDOx Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH TscL2ssH | $\overline{SSx}$ ↑ after SCKx Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |
| SP60 | TssL2doV | $\overline{SDOx}$ Data Output Valid after $\overline{SSx}$ Edge | — | — | 50 | ns | |

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

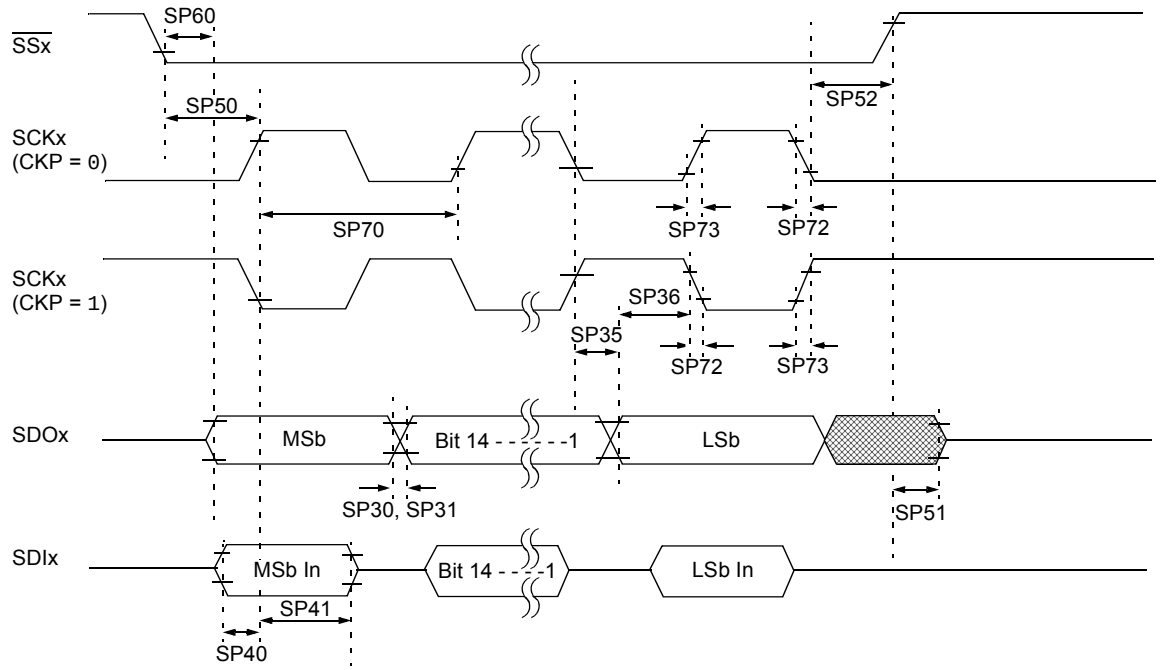
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

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

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

**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**FIGURE 30-16: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 1, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-36: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 1, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCKx Input Frequency | — | — | 11 | MHz | **(Note 3)** |
| SP72 | TscF | SCKx Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCKx Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SSx}$ ↓ to SCKx ↑ or SCKx ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SSx}$ ↑ to SDOx Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH TscL2ssH | $\overline{SSx}$ ↑ after SCKx Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |
| SP60 | TssL2doV | SDOx Data Output Valid after $\overline{SSx}$ Edge | — | — | 50 | ns | |

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

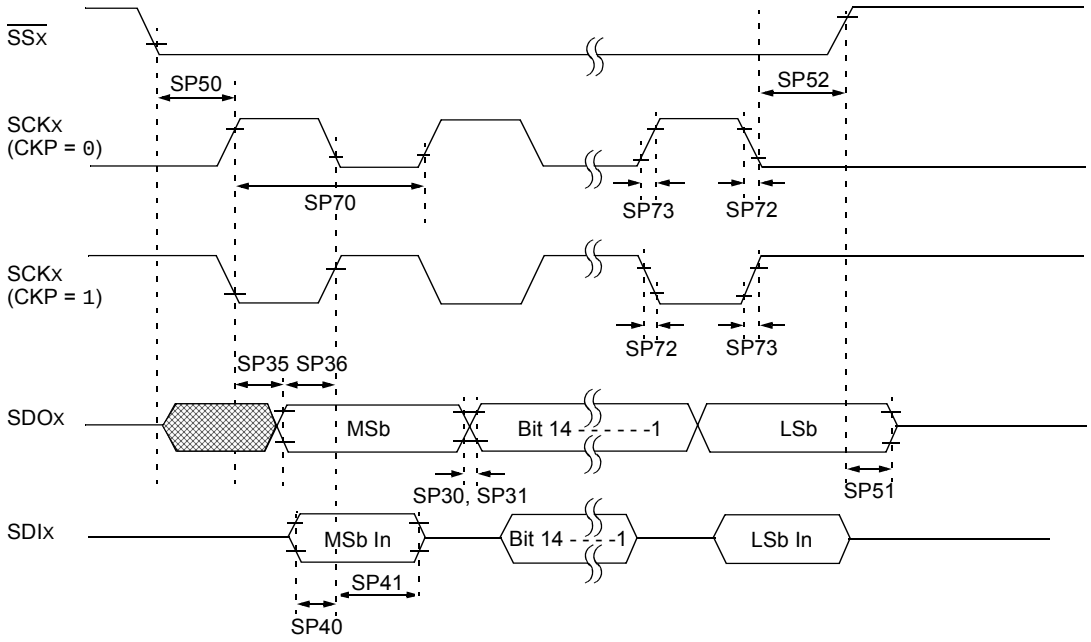
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCKx is 91 ns. Therefore, the SCKx clock generated by the master must not violate this specification.

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

**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**FIGURE 30-17: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 1, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-37: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 1, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCKx Input Frequency | — | — | 15 | MHz | **(Note 3)** |
| SP72 | TscF | SCKx Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCKx Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SSx}$ ↓ to SCKx ↑ or SCKx ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SSx}$ ↑ to SDOx Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH TscL2ssH | $\overline{SSx}$ ↑ after SCKx Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |

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

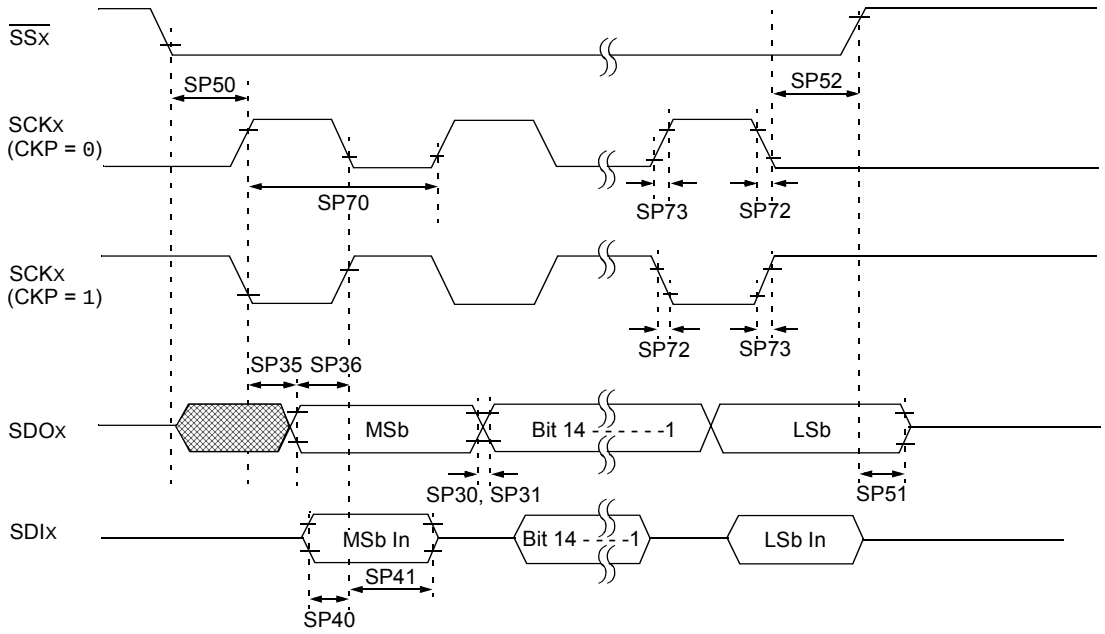
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

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

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

**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**FIGURE 30-18: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 0, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-38: SPI1, SPI2 AND SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 0, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCKx Input Frequency | — | — | 11 | MHz | **(Note 3)** |
| SP72 | TscF | SCKx Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCKx Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDOx Data Output Setup to First SCKx Edge | 30 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SSx}$ ↓ to SCKx ↑ or SCKx ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SSx}$ ↑ to SDOx Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH TscL2ssH | $\overline{SSx}$ ↑ after SCKx Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |

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

**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCKx is 91 ns. Therefore, the SCKx clock generated by the master must not violate this specification.

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

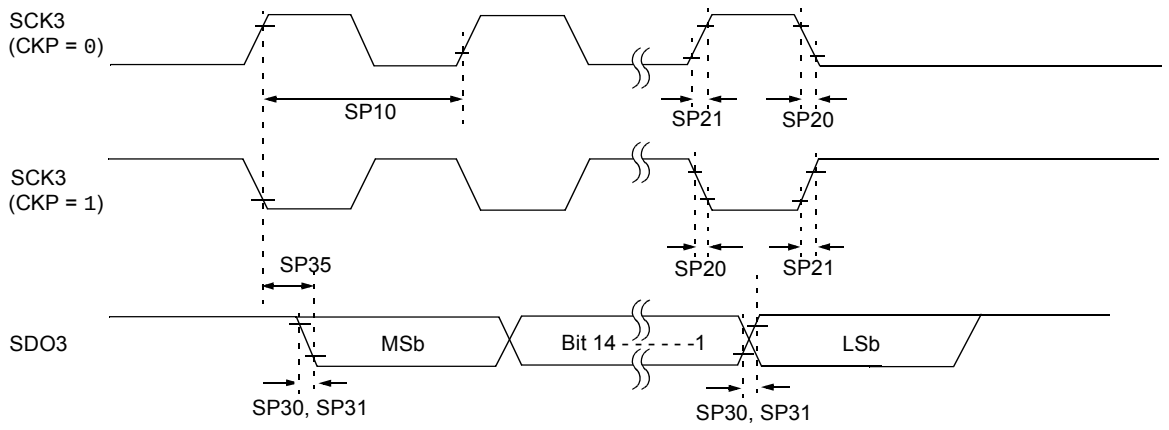
**5:** Pertaining to SPI3: dsPIC33EPXXXGS702, dsPIC33EPXXXGSX04 and dsPIC33EPXXXGSX05 devices with a remappable SCK3 pin.

**TABLE 30-39: SPI3 MAXIMUM DATA/CLOCK RATE SUMMARY(1)**

| 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 | | | |
|---|---|---|---|---|---|---|
| **Maximum Data Rate** | **Master Transmit Only (Half-Duplex)** | **Master Transmit/Receive (Full-Duplex)** | **Slave Transmit/Receive (Full-Duplex)** | **CKE** | **CKP** | **SMP** |
| 25 MHz | Table 30-40 | — | — | 0,1 | 0,1 | 0,1 |
| 25 MHz | — | Table 30-41 | — | 1 | 0,1 | 1 |
| 25 MHz | — | Table 30-42 | — | 0 | 0,1 | 1 |
| 25 MHz | — | — | Table 30-43 | 1 | 0 | 0 |
| 25 MHz | — | — | Table 30-44 | 1 | 1 | 0 |
| 25 MHz | — | — | Table 30-45 | 0 | 1 | 0 |
| 25 MHz | — | — | Table 30-46 | 0 | 0 | 0 |

**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-19: SPI3 MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY, CKE = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.
**2:** Refer to Figure 30-1 for load conditions.


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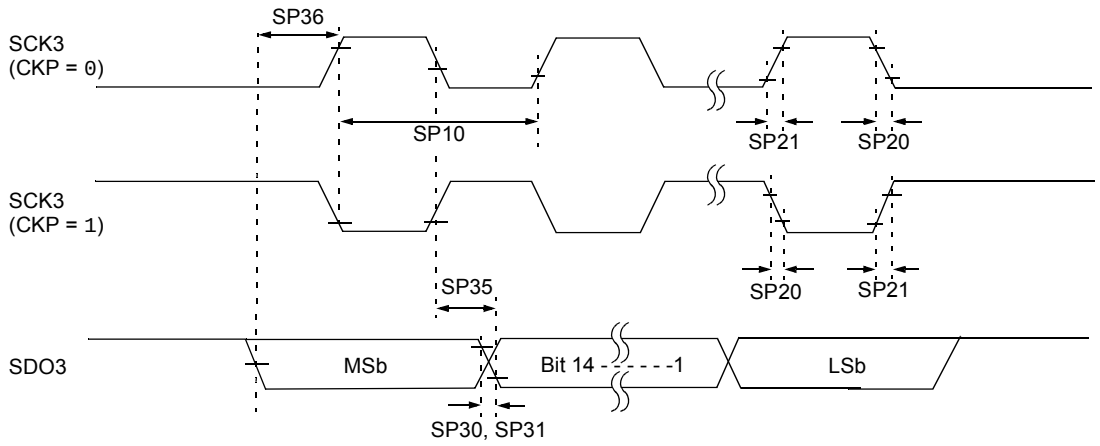
**FIGURE 30-20: SPI3 MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY, CKE = 1) TIMING CHARACTERISTICS(1,2)**



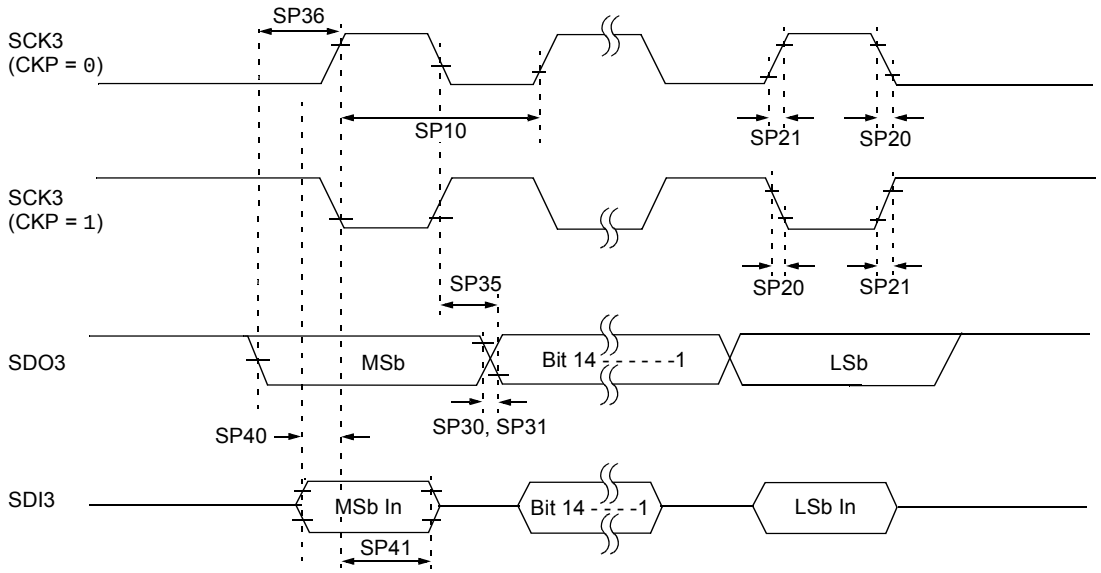

**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.
**2:** Refer to Figure 30-1 for load conditions.

**TABLE 30-40: SPI3 MASTER MODE (HALF-DUPLEX, TRANSMIT ONLY) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCK3 Frequency | — | — | 25 | MHz | **(Note 3)** |
| SP20 | TscF | SCK3 Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP21 | TscR | SCK3 Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdiV2scH, TdiV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |

**Note 1:** These parameters are characterized, but are not tested in manufacturing.
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.
**3:** The minimum clock period for SCK3 is 66.7 ns. Therefore, the clock generated in Master mode must not violate this specification.
**4:** Assumes 50 pF load on all SPI3 pins.
**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-21: SPI3 MASTER MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 1) TIMING CHARACTERISTICS(1,2)**




**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.

**TABLE 30-41: SPI3 MASTER MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 1) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCK3 Frequency | — | — | 25 | MHz | **(Note 3)** |
| SP20 | TscF | SCK3 Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP21 | TscR | SCK3 Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2sc, TdoV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDI3 Data Input to SCK3 Edge | 20 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDI3 Data Input to SCK3 Edge | 15 | — | — | ns | |

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

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

**3:** The minimum clock period for SCK3 is 100 ns. The clock generated in Master mode must not violate this specification.

**4:** Assumes 50 pF load on all SPI3 pins.

**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.


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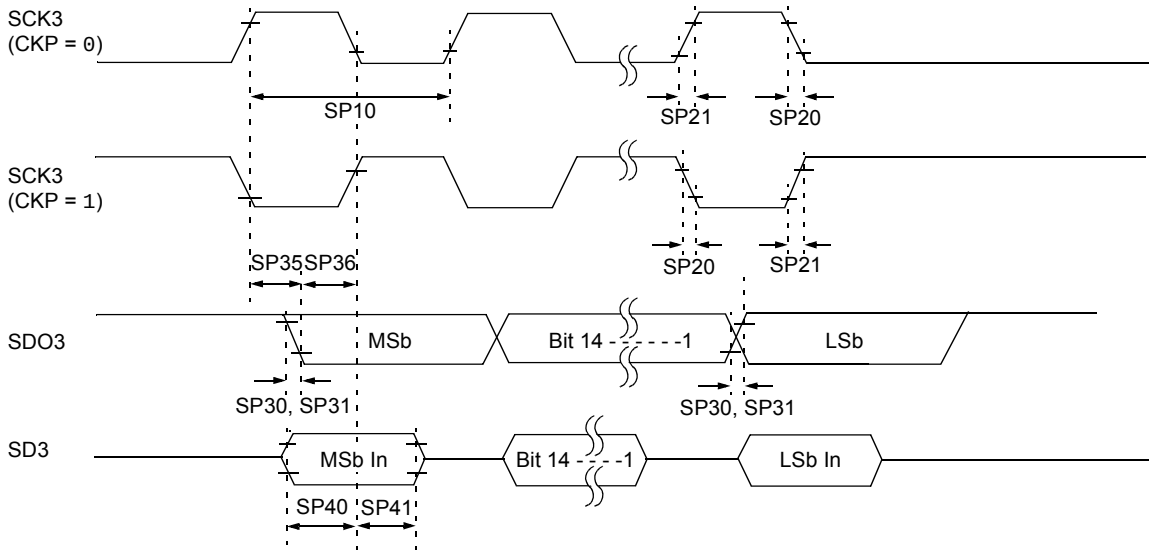
**FIGURE 30-22: SPI3 MASTER MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 1) TIMING CHARACTERISTICS(1,2)**



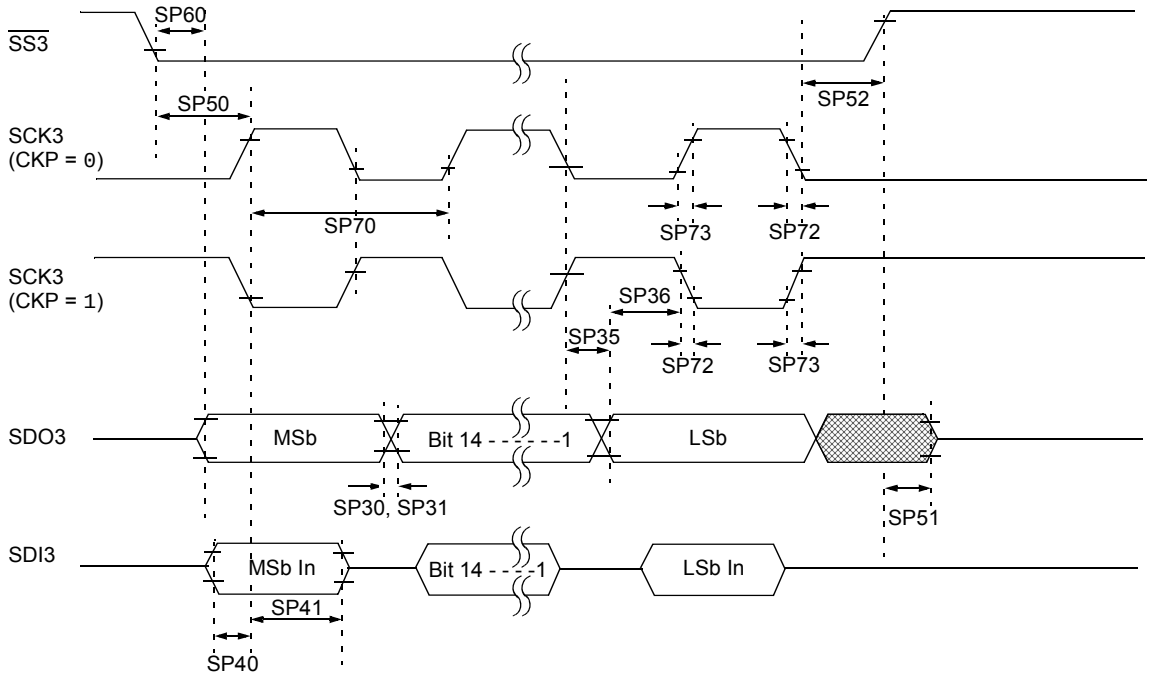

**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.
**2:** Refer to Figure 30-1 for load conditions.

**TABLE 30-42: SPI3 MASTER MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 1) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCK3 Frequency | — | — | 25 | MHz | -40ºC to +125ºC **(Note 3)** |
| SP20 | TscF | SCK3 Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP21 | TscR | SCK3 Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDI3 Data Input to SCK3 Edge | 20 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDI3 Data Input to SCK3Edge | 20 | — | — | ns | |

**Note 1:** These parameters are characterized, but are not tested in manufacturing.
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.
**3:** The minimum clock period for SCK3 is 100 ns. The clock generated in Master mode must not violate this specification.
**4:** Assumes 50 pF load on all SPI3 pins.
**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-23: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 0, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-43: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 0, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCK3 Input Frequency | — | — | 25 | MHz | **(Note 3)** |
| SP72 | TscF | SCK3 Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCK3 Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDI3 Data Input to SCK3 Edge | 20 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDI3 Data Input to SCK3 Edge | 15 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SS3}$ ↓ to SCK3 ↑ or SCK3 ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SS3}$ ↑ to SDO3 Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH TscL2ssH | $\overline{SS3}$ ↑ after SCK3 Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |
| SP60 | TssL2doV | SDO3 Data Output Valid after $\overline{SS3}$ Edge | — | — | 50 | ns | |

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

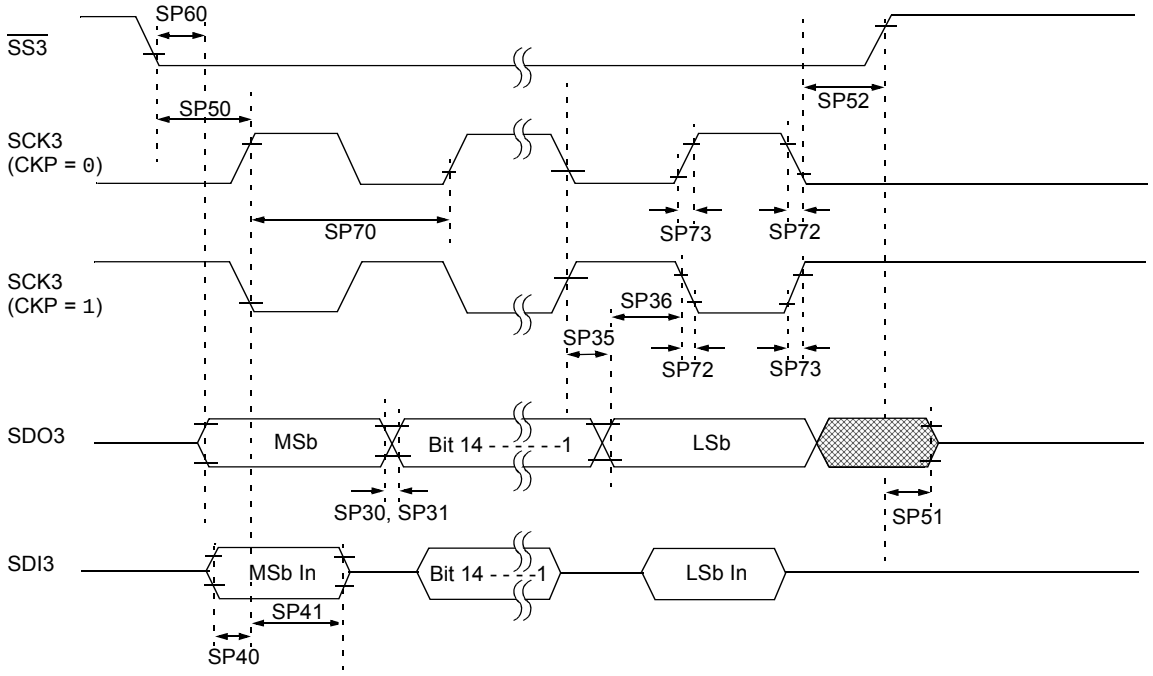
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCK3 is 66.7 ns. Therefore, the SCK3 clock generated by the master must not violate this specification.

**4:** Assumes 50 pF load on all SPI3 pins.

**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-24: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 1, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-44: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 1, CKP = 1, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCK3 Input Frequency | — | — | 25 | MHz | **(Note 3)** |
| SP72 | TscF | SCK3 Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCK3 Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDI3 Data Input to SCK3 Edge | 20 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDI3 Data Input to SCK3 Edge | 15 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SS3}$ ↓ to SCK3 ↑ or SCK3 ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SS3}$ ↑ to SDO3 Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH, TscL2ssH | $\overline{SS3}$ ↑ after SCK3 Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |
| SP60 | TssL2doV | SDO3 Data Output Valid after $\overline{SS3}$ Edge | — | — | 50 | ns | |

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

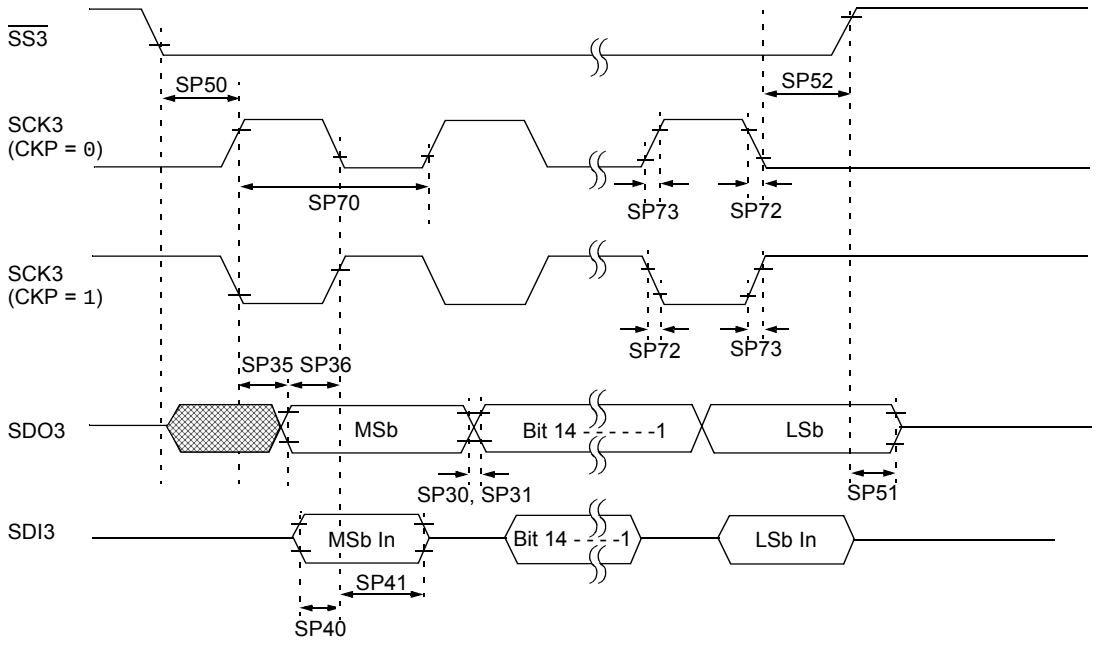
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCK3 is 91 ns. Therefore, the SCK3 clock generated by the master must not violate this specification.

**4:** Assumes 50 pF load on all SPI3 pins.

**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-25: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 1, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.
**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-45: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 1, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCK3 Input Frequency | — | — | 25 | MHz | **(Note 3)** |
| SP72 | TscF | SCK3 Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCK3 Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDI3 Data Input to SCK3 Edge | 20 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDI3 Data Input to SCK3 Edge | 15 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SS3}$ ↓ to SCK3 ↑ or SCK3 ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SS3}$ ↑ to SDO3 Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH, TscL2ssH | $\overline{SS3}$ ↑ after SCK3 Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |

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

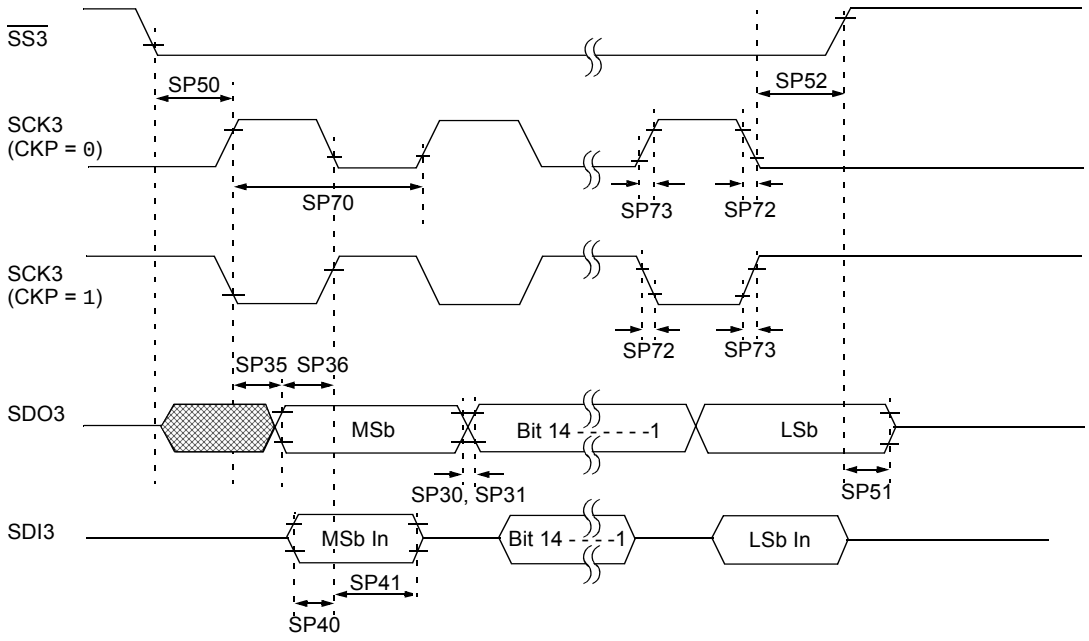
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCK3 is 66.7 ns. Therefore, the SCK3 clock generated by the master must not violate this specification.

**4:** Assumes 50 pF load on all SPI3 pins.

**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-26: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 0, SMP = 0) TIMING CHARACTERISTICS(1,2)**




**Note 1:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.
**2:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-46: SPI3 SLAVE MODE (FULL-DUPLEX, CKE = 0, CKP = 0, SMP = 0) TIMING REQUIREMENTS(5)**

| 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.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP70 | FscP | Maximum SCK3 Input Frequency | — | — | 25 | MHz | **(Note 3)** |
| SP72 | TscF | SCK3 Input Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP73 | TscR | SCK3 Input Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP30 | TdoF | SDO3 Data Output Fall Time | — | — | — | ns | See Parameter DO32 **(Note 4)** |
| SP31 | TdoR | SDO3 Data Output Rise Time | — | — | — | ns | See Parameter DO31 **(Note 4)** |
| SP35 | TscH2doV, TscL2doV | SDO3 Data Output Valid after SCK3 Edge | — | 6 | 20 | ns | |
| SP36 | TdoV2scH, TdoV2scL | SDO3 Data Output Setup to First SCK3 Edge | 20 | — | — | ns | |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDI3 Data Input to SCK3 Edge | 20 | — | — | ns | |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDI3 Data Input to SCK3 Edge | 15 | — | — | ns | |
| SP50 | TssL2scH, TssL2scL | $\overline{SS3}$ ↓ to SCK3 ↑ or SCK3 ↓ Input | 120 | — | — | ns | |
| SP51 | TssH2doZ | $\overline{SS3}$ ↑ to SDO3 Output High-Impedance | 10 | — | 50 | ns | **(Note 4)** |
| SP52 | TscH2ssH, TscL2ssH | $\overline{SS3}$ ↑ after SCK1 Edge | 1.5 TCY + 40 | — | — | ns | **(Note 4)** |

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

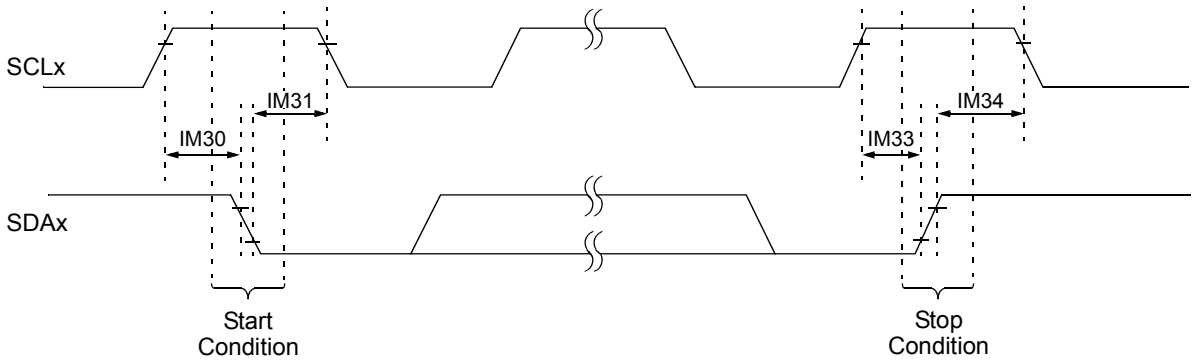
**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated.

**3:** The minimum clock period for SCK3 is 91 ns. Therefore, the SCK3 clock generated by the master must not violate this specification.

**4:** Assumes 50 pF load on all SPI3 pins.

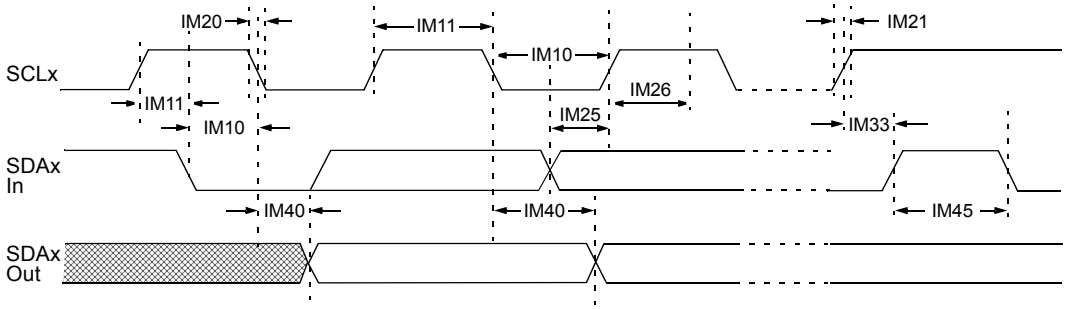
**5:** For dsPIC33EPXXXGSX06 and dsPIC33EPXXXGSX08 devices with a fixed SCK3 pin.

**FIGURE 30-27: I2Cx BUS START/STOP BITS TIMING CHARACTERISTICS (MASTER MODE)**




**Note:** Refer to Figure 30-1 for load conditions.

**FIGURE 30-28: I2Cx BUS DATA TIMING CHARACTERISTICS (MASTER MODE)**




**Note:** Refer to Figure 30-1 for load conditions.


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**TABLE 30-47: I2Cx BUS DATA TIMING REQUIREMENTS (MASTER MODE)**

| 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(4)** | | **Min.(1)** | **Max.** | **Units** | **Conditions** |
| IM10 | TLO:SCL | Clock Low Time | 100 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 400 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 1 MHz mode(2) | TCY/2 (BRG + 2) | — | µs | |
| IM11 | THI:SCL | Clock High Time | 100 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 400 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 1 MHz mode(2) | TCY/2 (BRG + 2) | — | µs | |
| IM20 | TF:SCL | SDAx and SCLx Fall Time | 100 kHz mode | — | 300 | ns | CB is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 CB | 300 | ns | |
| | | | 1 MHz mode(2) | — | 100 | ns | |
| IM21 | TR:SCL | SDAx and SCLx Rise Time | 100 kHz mode | — | 1000 | ns | CB is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 CB | 300 | ns | |
| | | | 1 MHz mode(2) | — | 300 | ns | |
| IM25 | TSU:DAT | Data Input Setup Time | 100 kHz mode | 250 | — | ns | |
| | | | 400 kHz mode | 100 | — | ns | |
| | | | 1 MHz mode(2) | 40 | — | ns | |
| IM26 | THD:DAT | Data Input Hold Time | 100 kHz mode | 0 | — | µs | |
| | | | 400 kHz mode | 0 | 0.9 | µs | |
| | | | 1 MHz mode(2) | 0.2 | — | µs | |
| IM30 | TSU:STA | Start Condition Setup Time | 100 kHz mode | TCY/2 (BRG + 2) | — | µs | Only relevant for Repeated Start condition |
| | | | 400 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 1 MHz mode(2) | TCY/2 (BRG + 2) | — | µs | |
| IM31 | THD:STA | Start Condition Hold Time | 100 kHz mode | TCY/2 (BRG + 2) | — | µs | After this period, the first clock pulse is generated |
| | | | 400 kHz mode | TCY/2 (BRG +2) | — | µs | |
| | | | 1 MHz mode(2) | TCY/2 (BRG + 2) | — | µs | |
| IM33 | TSU:STO | Stop Condition Setup Time | 100 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 400 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 1 MHz mode(2) | TCY/2 (BRG + 2) | — | µs | |
| IM34 | THD:STO | Stop Condition Hold Time | 100 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 400 kHz mode | TCY/2 (BRG + 2) | — | µs | |
| | | | 1 MHz mode(2) | TCY/2 (BRG + 2) | — | µs | |
| IM40 | TAA:SCL | Output Valid from Clock | 100 kHz mode | — | 3500 | ns | |
| | | | 400 kHz mode | — | 1000 | ns | |
| | | | 1 MHz mode(2) | — | 400 | ns | |
| IM45 | TBF:SDA | Bus Free Time | 100 kHz mode | 4.7 | — | µs | Time the bus must be free before a new transmission can start |
| | | | 400 kHz mode | 1.3 | — | µs | |
| | | | 1 MHz mode(2) | 0.5 | — | µs | |
| IM50 | CB | Bus Capacitive Loading | | — | 400 | pF | |
| IM51 | TPGD | Pulse Gobbler Delay | | 65 | 390 | ns | **(Note 3)** |

**Note 1:** BRG is the value of the $I^2C$ Baud Rate Generator.

**2:** Maximum Pin Capacitance = 10 pF for all I2Cx pins (for 1 MHz mode only).

**3:** Typical value for this parameter is 130 ns.

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

**FIGURE 30-29: I2Cx BUS START/STOP BITS TIMING CHARACTERISTICS (SLAVE MODE)**

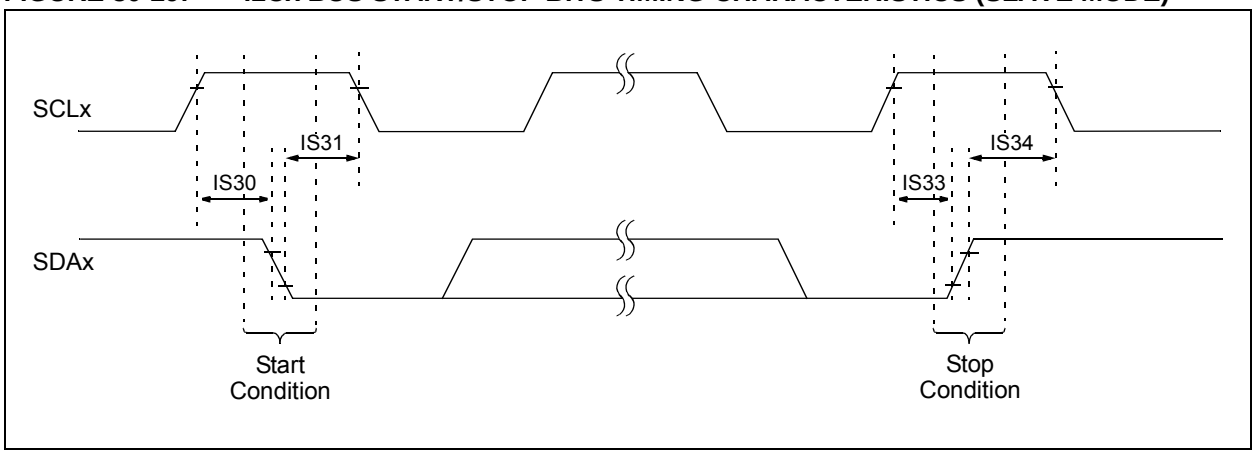


**FIGURE 30-30: I2Cx BUS DATA TIMING CHARACTERISTICS (SLAVE MODE)**

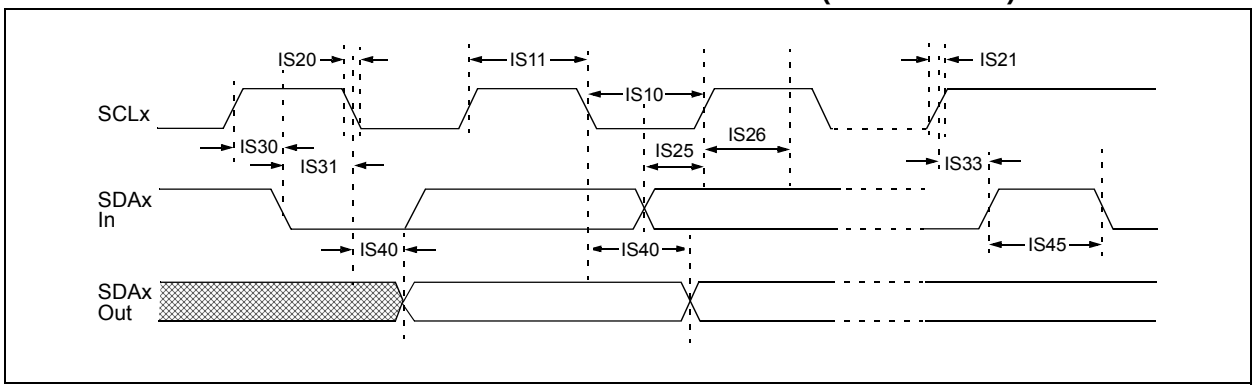



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**TABLE 30-48: I2Cx BUS DATA TIMING REQUIREMENTS (SLAVE MODE)**

| 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(3)** | | **Min.** | **Max.** | **Units** | **Conditions** |
| IS10 | TLO:SCL | Clock Low Time | 100 kHz mode | 4.7 | — | µs | |
| | | | 400 kHz mode | 1.3 | — | µs | |
| | | | 1 MHz mode(1) | 0.5 | — | µs | |
| IS11 | THI:SCL | Clock High Time | 100 kHz mode | 4.0 | — | µs | Device must operate at a minimum of 1.5 MHz |
| | | | 400 kHz mode | 0.6 | — | µs | Device must operate at a minimum of 10 MHz |
| | | | 1 MHz mode(1) | 0.5 | — | µs | |
| IS20 | TF:SCL | SDAx and SCLx Fall Time | 100 kHz mode | — | 300 | ns | CB is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 CB | 300 | ns | |
| | | | 1 MHz mode(1) | — | 100 | ns | |
| IS21 | TR:SCL | SDAx and SCLx Rise Time | 100 kHz mode | — | 1000 | ns | CB is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 CB | 300 | ns | |
| | | | 1 MHz mode(1) | — | 300 | ns | |
| IS25 | TSU:DAT | Data Input Setup Time | 100 kHz mode | 250 | — | ns | |
| | | | 400 kHz mode | 100 | — | ns | |
| | | | 1 MHz mode(1) | 100 | — | ns | |
| IS26 | THD:DAT | Data Input Hold Time | 100 kHz mode | 0 | — | µs | |
| | | | 400 kHz mode | 0 | 0.9 | µs | |
| | | | 1 MHz mode(1) | 0 | 0.3 | µs | |
| IS30 | TSU:STA | Start Condition Setup Time | 100 kHz mode | 4.7 | — | µs | Only relevant for Repeated Start condition |
| | | | 400 kHz mode | 0.6 | — | µs | |
| | | | 1 MHz mode(1) | 0.25 | — | µs | |
| IS31 | THD:STA | Start Condition Hold Time | 100 kHz mode | 4.0 | — | µs | After this period, the first clock pulse is generated |
| | | | 400 kHz mode | 0.6 | — | µs | |
| | | | 1 MHz mode(1) | 0.25 | — | µs | |
| IS33 | TSU:STO | Stop Condition Setup Time | 100 kHz mode | 4.7 | — | µs | |
| | | | 400 kHz mode | 0.6 | — | µs | |
| | | | 1 MHz mode(1) | 0.6 | — | µs | |
| IS34 | THD:STO | Stop Condition Hold Time | 100 kHz mode | 4 | — | µs | |
| | | | 400 kHz mode | 0.6 | — | µs | |
| | | | 1 MHz mode(1) | 0.25 | | µs | |
| IS40 | TAA:SCL | Output Valid from Clock | 100 kHz mode | 0 | 3500 | ns | |
| | | | 400 kHz mode | 0 | 1000 | ns | |
| | | | 1 MHz mode(1) | 0 | 350 | ns | |
| IS45 | TBF:SDA | Bus Free Time | 100 kHz mode | 4.7 | — | µs | Time the bus must be free before a new transmission can start |
| | | | 400 kHz mode | 1.3 | — | µs | |
| | | | 1 MHz mode(1) | 0.5 | — | µs | |
| IS50 | CB | Bus Capacitive Loading | | — | 400 | pF | |
| IS51 | TPGD | Pulse Gobbler Delay | | 65 | 390 | ns | **(Note 2)** |

**Note 1:** Maximum Pin Capacitance = 10 pF for all I2Cx pins (for 1 MHz mode only).

**2:** Typical value for this parameter is 130 ns.

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

**FIGURE 30-31: CANx MODULE I/O TIMING CHARACTERISTICS**

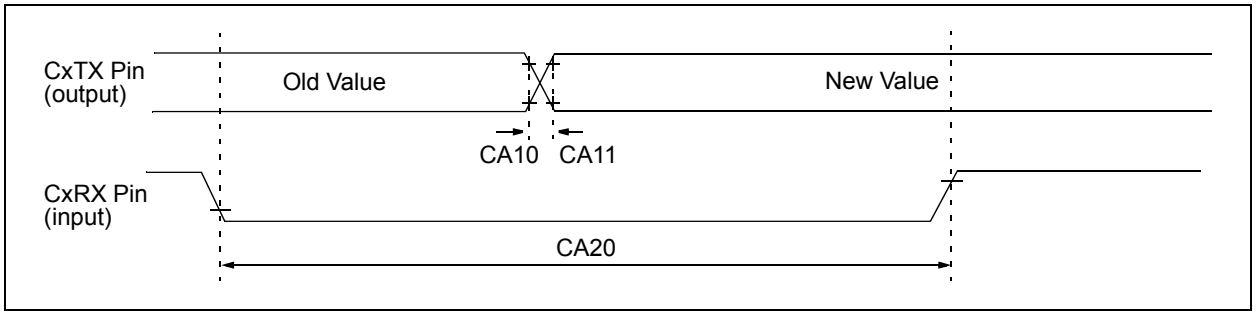


**TABLE 30-49: CANx MODULE I/O TIMING REQUIREMENTS**

| 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** |
| CA10 | TIOF | Port Output Fall Time | — | — | — | ns | See Parameter DO32 |
| CA11 | TIOR | Port Output Rise Time | — | — | — | ns | See Parameter DO31 |
| CA20 | TCWF | Pulse Width to Trigger CAN Wake-up Filter | 120 | — | — | ns | |

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

**2:** Data in "Typical" column is at 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested.


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**FIGURE 30-32: UARTx MODULE I/O TIMING CHARACTERISTICS**

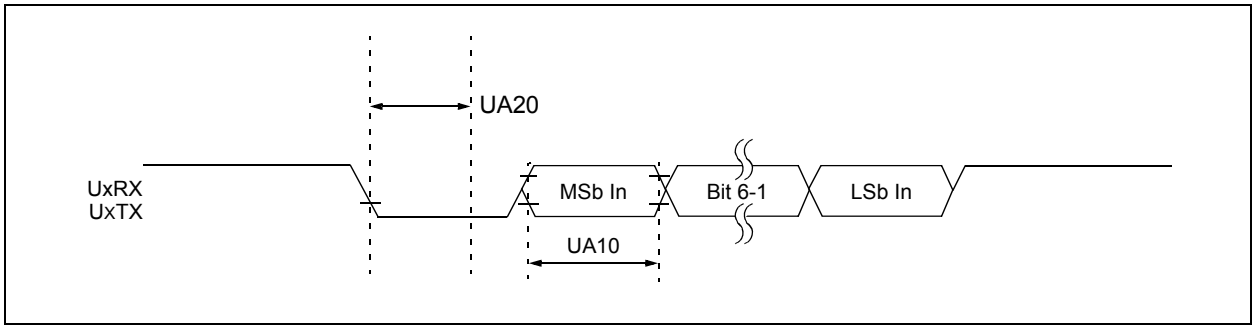


**TABLE 30-50: UARTx MODULE I/O TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +125°C | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| UA10 | TUABAUD | UARTx Baud Time | 66.67 | — | — | ns | |
| UA11 | FBAUD | UARTx Baud Frequency | — | — | 15 | Mbps | |
| UA20 | TCWF | Start Bit Pulse Width to Trigger UARTx Wake-up | 500 | — | — | ns | |

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

**2:** Data in "Typ." column is at 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

**TABLE 30-51: ANALOG CURRENT SPECIFICATIONS**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)<br>Operating temperature -40°C ≤ TA ≤ +125°C | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| AVD01 | IDD | Analog Modules Current Consumption | — | 9 | — | mA | Characterized data with the following modules enabled: APLL, 5 ADC Cores, 2 PGAs and 4 Analog Comparators |

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

**2:** Data in "Typ." column is at 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

**TABLE 30-52: ADC MODULE SPECIFICATIONS**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[5]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | **Min.** | **Typical** | **Max.** | **Units** | **Conditions** |
| **Device Supply** | | | | | | | |
| AD01 | AVDD | Module VDD Supply | Greater of: VDD – 0.3 or 3.0 | — | Lesser of: VDD + 0.3 or 3.6 | V | Within 300 mV of VDD at all times, including device power-up |
| AD02 | AVSS | Module VSS Supply | VSS | — | VSS + 0.3 | V | |
| **Reference Inputs** | | | | | | | |
| AD06 | VREFL | Reference Voltage Low | — | AVSS | — | V | **(Note 1)** |
| AD07 | VREF | Absolute Reference Voltage (VREFH – VREFL) | 2.7 | — | AVDD | V | **(Note 3)** |
| AD08 | IREF | Reference Input Current | — | 5 | 10 | μA | ADC operating or in standby |
| **Analog Input** | | | | | | | |
| AD12 | VINH-VINL | Full-Scale Input Span | AVSS | — | AVDD | V | |
| AD14 | VIN | Absolute Input Voltage | AVSS – 0.3 | — | AVDD + 0.3 | V | |
| AD17 | RIN | Recommended Impedance of Analog Voltage Source | — | 100 | — | Ω | For minimum sampling time **(Note 1)** |
| AD66 | VBG | Internal Voltage Reference Source | — | 1.2 | — | V | |
| **ADC Accuracy: Pseudodifferential Input** | | | | | | | |
| AD20a | Nr | Resolution | 12 | | | bits | |
| AD21a | INL | Integral Nonlinearity | > -3 | — | < 3 | LSb | AVSS = 0V, AVDD = 3.3V |
| AD22a | DNL | Differential Nonlinearity | > -1 | — | < 1 | LSb | AVSS = 0V, AVDD = 3.3V **(Note 2)** |
| AD23a | GERR | Gain Error (Dedicated Core) | > 0 | 8 | < 15 | LSb | AVSS = 0V, AVDD = 3.3V |
| | | Gain Error (Shared Core) | > 5 | 15 | < 22 | LSb | |
| AD24a | EOFF | Offset Error (Dedicated Core) | > 0 | 5 | < 10 | LSb | AVSS = 0V, AVDD = 3.3V |
| | | Offset Error (Shared Core) | > 2 | 8 | < 13 | LSb | |
| AD25a | — | Monotonicity | — | — | — | — | Guaranteed |

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

**2:** No missing codes, limits based on characterization results.

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

**4:** Characterized with a 15 kHz sine wave.

**5:** The ADC module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is ensured, but not characterized.


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**TABLE 30-52: ADC MODULE SPECIFICATIONS (CONTINUED)**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[5]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | **Min.** | **Typical** | **Max.** | **Units** | **Conditions** |
| **ADC Accuracy: Single-Ended Input** | | | | | | | |
| AD20b | Nr | Resolution | 12 | | | bits | |
| AD21b | INL | Integral Nonlinearity | > 5 | — | < 5 | LSb | AVSS = 0V, AVDD = 3.3V |
| AD22b | DNL | Differential Nonlinearity | > -1 | — | < 1 | LSb | AVSS = 0V, AVDD = 3.3V **(Note 2)** |
| AD23b | GERR | Gain Error (Dedicated Core) | > 0 | 8 | < 15 | LSb | AVSS = 0V, AVDD = 3.3V |
| | | Gain Error (Shared Core) | > 5 | 15 | < 22 | LSb | |
| AD24b | EOFF | Offset Error (Dedicated Core) | > 2 | 9 | < 15 | LSb | AVSS = 0V, AVDD = 3.3V |
| | | Offset Error (Shared Core) | > 5 | 17 | < 22 | LSb | |
| AD25b | — | Monotonicity | — | — | — | — | Guaranteed |
| **Dynamic Performance** | | | | | | | |
| AD31b | SINAD | Signal-to-Noise and Distortion | 63 | — | > 65 | dB | **(Notes 3, 4)** |
| AD34b | ENOB | Effective Number of Bits | 10.3 | — | — | bits | **(Notes 3, 4)** |

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

**2:** No missing codes, limits based on characterization results.

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

**4:** Characterized with a 15 kHz sine wave.

**5:** The ADC module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is ensured, but not characterized.

**TABLE 30-53: ANALOG-TO-DIGITAL CONVERSION TIMING REQUIREMENTS**

| AC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[2]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | **Min.** | **Typ.[1]** | **Max.** | **Units** | **Conditions** |
| **Clock Parameters** | | | | | | | |
| AD50 | TAD | ADC Clock Period | 14.28 | — | — | ns | |
| **Throughput Rate** | | | | | | | |
| AD51 | FTP | SH0-SH3 | — | — | 3.25 | Msps | 70 MHz ADC clock, 12 bits, no pending conversion at time of trigger |
| | | SH4 | — | — | 3.25 | Msps | |

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

**2:** The ADC module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is ensured, but not characterized.

**TABLE 30-54: HIGH-SPEED ANALOG COMPARATOR MODULE SPECIFICATIONS**

| AC/DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[2]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| CM10 | VIOFF | Input Offset Voltage | -35 | ±5 | 35 | mV | |
| CM11 | VICM | Input Common-Mode Voltage Range[1] | 0 | — | AVDD | V | |
| CM13 | CMRR | Common-Mode Rejection Ratio | 60 | — | — | dB | |
| CM14 | TRESP | Large Signal Response | — | 15 | — | ns | V+ input step of 100 mV while V- input is held at AVDD/2. Delay measured from analog input pin to PWMx output pin. |
| CM15 | VHYST | Input Hysteresis | 5 | 10 | 20 | mV | Depends on HYSSEL<1:0> |
| CM16 | TON | Comparator Enabled to Valid Output | — | — | 1 | µs | |

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

**2:** The comparator module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is tested, but not characterized.


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**TABLE 30-55: DACx MODULE SPECIFICATIONS**

| AC/DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[2]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| DA01 | EXTREF | External Voltage Reference[1] | 1 | — | AVDD | V | |
| DA02 | CVRES | Resolution | 12 | | | bits | |
| DA03 | INL | Integral Nonlinearity Error | -16 | -12 | 0 | LSB | |
| DA04 | DNL | Differential Nonlinearity Error | -1.8 | ±1 | 1.8 | LSB | |
| DA05 | EOFF | Offset Error | -8 | 3 | 15 | LSB | |
| DA06 | EG | Gain Error | -1.2 | -0.5 | 0 | % | |
| DA07 | TSET | Settling Time[1] | — | 700 | — | ns | Output with 2% of desired output voltage with a 10-90% or 90-10% step |

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

**2:** The DACx module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is tested, but not characterized.

**TABLE 30-56: DACx OUTPUT (DACOUTx PIN) SPECIFICATIONS**

| DC CHARACTERISTICS | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[1]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| DA11 | RLOAD | Resistive Output Load Impedance | 10K | — | — | Ohm | |
| DA11a | CLOAD | Output Load Capacitance | — | — | 35 | pF | Including output pin capacitance |
| DA12 | IOUT | Output Current Drive Strength | — | 300 | — | µA | Sink and source |
| DA13 | VRANGE | Output Drive Voltage Range at Current Drive of 300 µA | AVSS + 250 mV | — | AVDD – 900 mV | V | |
| DA14 | VLRANGE | Output Drive Voltage Range at Reduced Current Drive of 50 µA | AVSS + 50 mV | — | AVDD – 500 mV | V | |
| DA15 | IDD | Current Consumed when Module is Enabled | — | — | 1.3 x IOUT | µA | Module will always consume this current, even if no load is connected to the output |
| DA30 | VOFFSET | Input Offset Voltage | — | ±5 | — | mV | |

**Note 1:** The DACx module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is tested, but not characterized.

**TABLE 30-57: PGAx MODULE SPECIFICATIONS**

| AC/DC CHARACTERISTICS | | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[1]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| PA01 | VIN | Input Voltage Range | | AVSS – 0.3 | — | AVDD + 0.3 | V | |
| PA02 | VCM | Common-Mode Input Voltage Range | | AVSS | — | AVDD – 1.6 | V | |
| PA03 | VOS | Input Offset Voltage | | -10 | — | 10 | mV | |
| PA04 | VOS | Input Offset Voltage Drift with Temperature | | — | ±15 | — | µV/°C | |
| PA05 | RIN+ | Input Impedance of Positive Input | | — | >1M \|\| 7 pF | — | Ω\|\| pF | |
| PA06 | RIN- | Input Impedance of Negative Input | | — | 10K \|\| 7 pF | — | Ω\|\| pF | |
| PA07 | GERR | Gain Error | | -2 | — | 2 | % | Gain = 4x, 8x |
| | | | | -3 | — | 3 | % | Gain = 16x |
| | | | | -4 | — | 4 | % | Gain = 32x, 64x |
| PA08 | LERR | Gain Nonlinearity Error | | — | — | 0.5 | % | % of full scale, Gain = 16x |
| PA09 | IDD | Current Consumption | | — | 2.0 | — | mA | Module is enabled with a 2-volt P-P output voltage swing |
| PA10a | BW | Small Signal Bandwidth (-3 dB) | G = 4x | — | 10 | — | MHz | |
| PA10b | | | G = 8x | — | 5 | — | MHz | |
| PA10c | | | G = 16x | — | 2.5 | — | MHz | |
| PA10d | | | G = 32x | — | 1.25 | — | MHz | |
| PA10e | | | G = 64x | — | 0.625 | — | MHz | |
| PA11 | OST | Output Settling Time to 1% of Final Value | | — | 0.4 | — | µs | Gain = 16x, 100 mV input step change |
| PA12 | SR | Output Slew Rate | | — | 40 | — | V/µs | Gain = 16x |
| PA13 | TGSEL | Gain Selection Time | | — | 1 | — | µs | |
| PA14 | TON | Module Turn On/Setting Time | | — | — | 10 | µs | |

**Note 1:** The PGAx module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is tested, but not characterized.


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**TABLE 30-58: CONSTANT-CURRENT SOURCE SPECIFICATIONS**

| DC CHARACTERISTICS | | | | Standard Operating Conditions: 3.0V to 3.6V (unless otherwise stated)[1]<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| CC01 | IDD | Current Consumption | — | 30 | — | µA | |
| CC02 | IREG | Regulation of Current with Voltage On | — | ±3 | — | % | |
| CC03 | IOUT | Current Output at Terminal | — | 10 | — | µA | |

**Note 1:** The constant-current source module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is tested, but not characterized.

**TABLE 30-59: DMA MODULE 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.[1]** | **Max.** | **Units** | **Conditions** |
| DM1 | DMA Byte/Word Transfer Latency | 1 TCY[2] | — | — | ns | |

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

**2:** Because DMA transfers use the CPU data bus, this time is dependent on other functions on the bus.

**NOTES:**


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## 31.0 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 31-1: VOH – 4x DRIVER PINS**

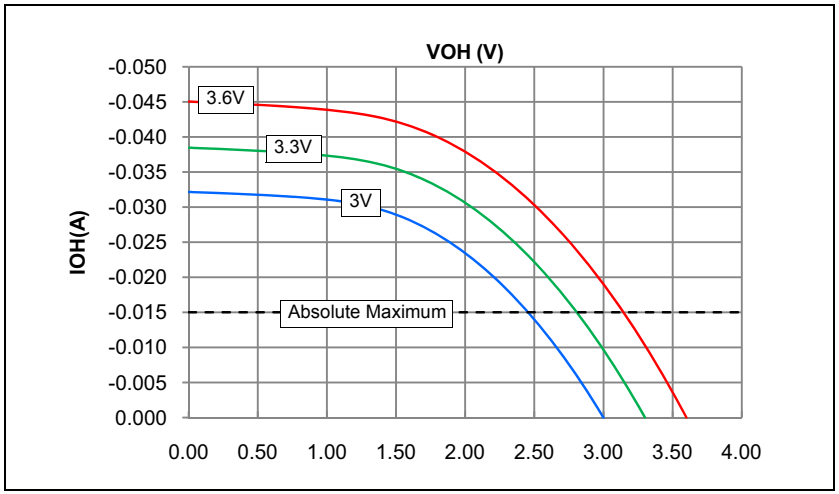


**FIGURE 31-2: VOH – 8x DRIVER PINS**

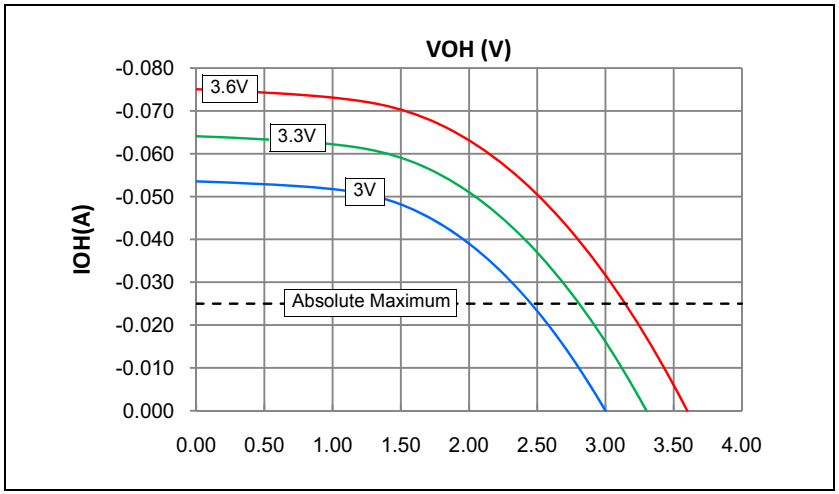


**FIGURE 31-3: VOL – 4x DRIVER PINS**

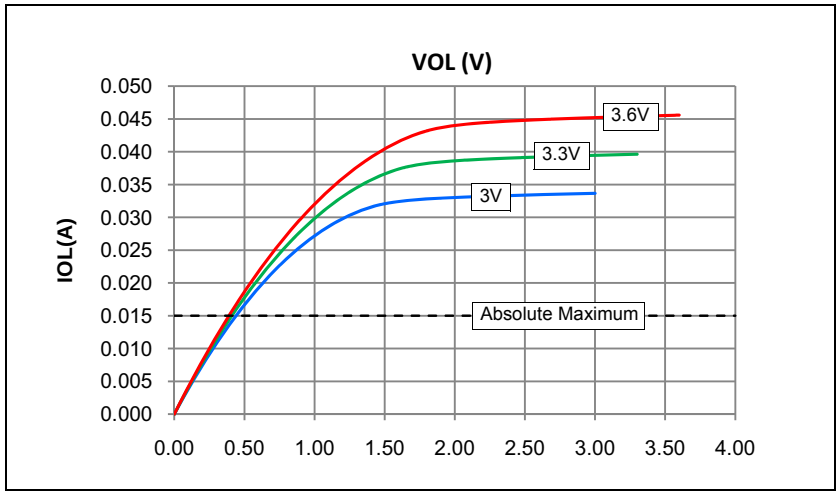


**FIGURE 31-4: VOL – 8x DRIVER PINS**

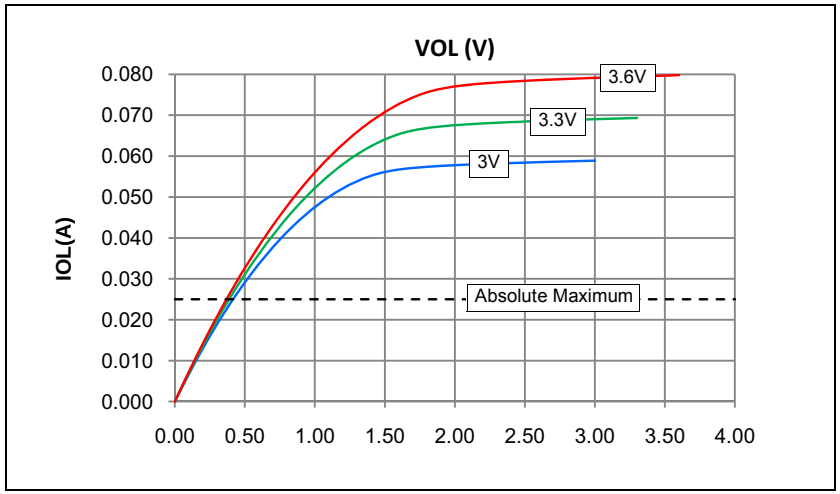


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**FIGURE 31-5: TYPICAL IPD CURRENT @ VDD = 3.3V**

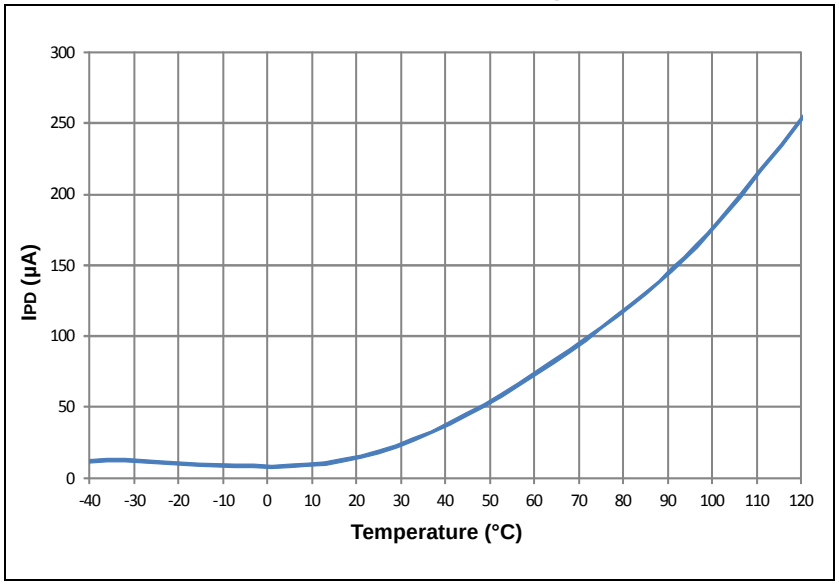



**FIGURE 31-6: TYPICAL IDD CURRENT @ VDD = 3.3V, +25°C**

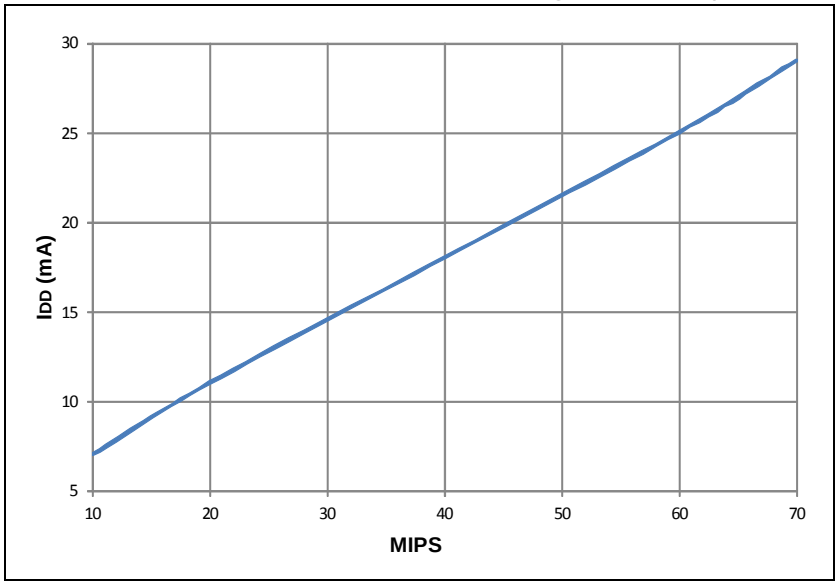



**FIGURE 31-7: TYPICAL IDOZE CURRENT @ VDD = 3.3V, +25°C**

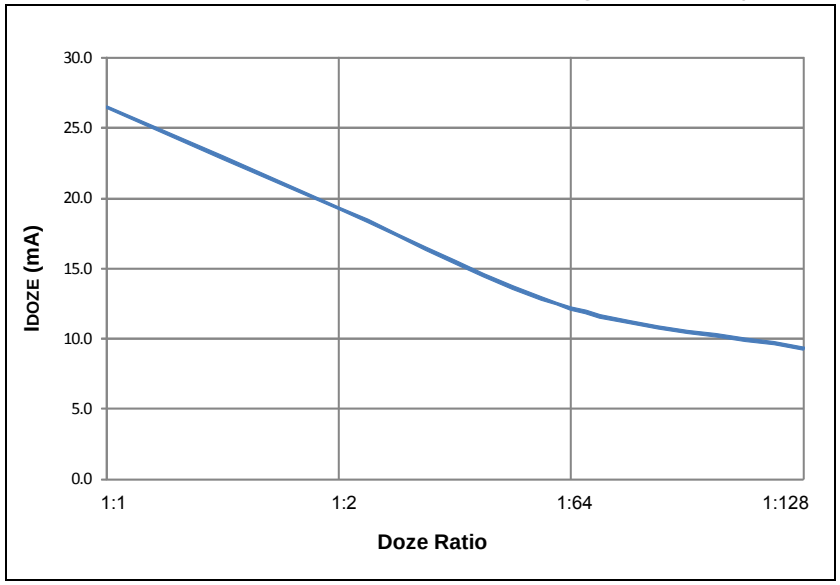
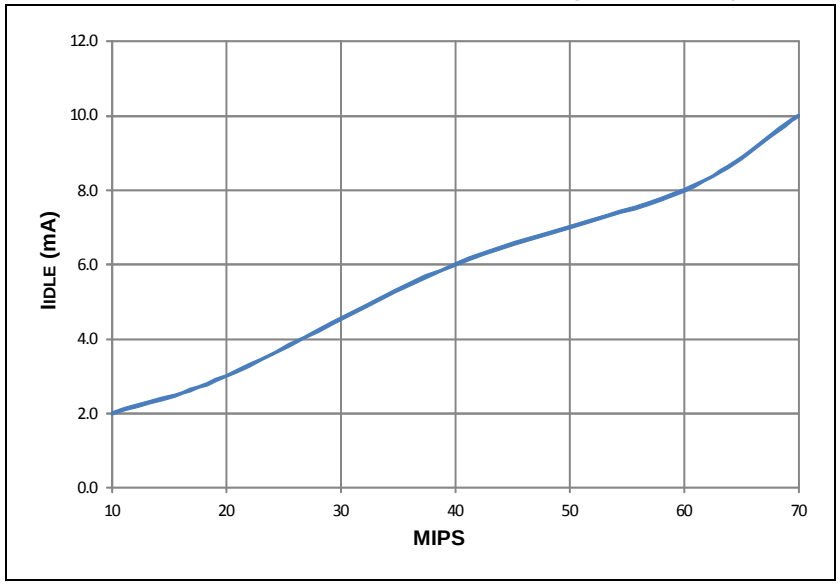



**FIGURE 31-8: TYPICAL IIDLE CURRENT @ VDD = 3.3V, +25°C**



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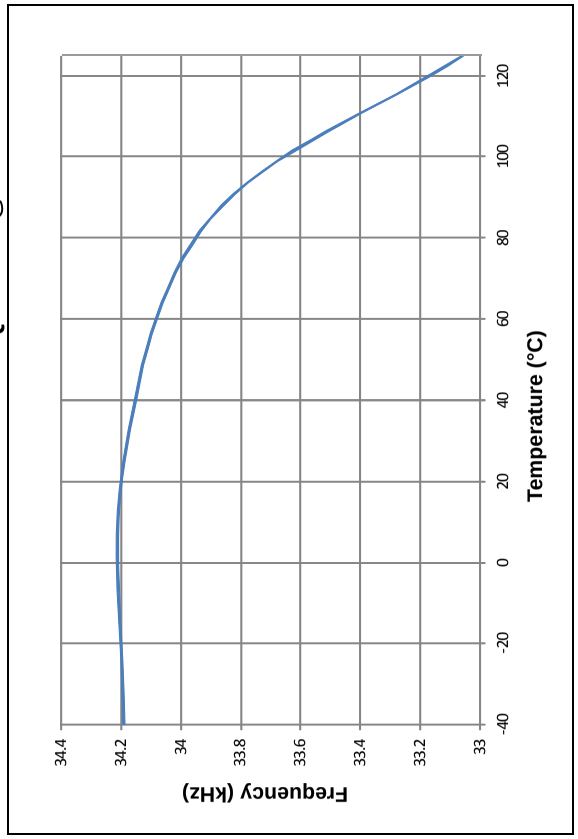


**FIGURE 31-10: TYPICAL LPRC FREQUENCY @ VDD = 3.3V**

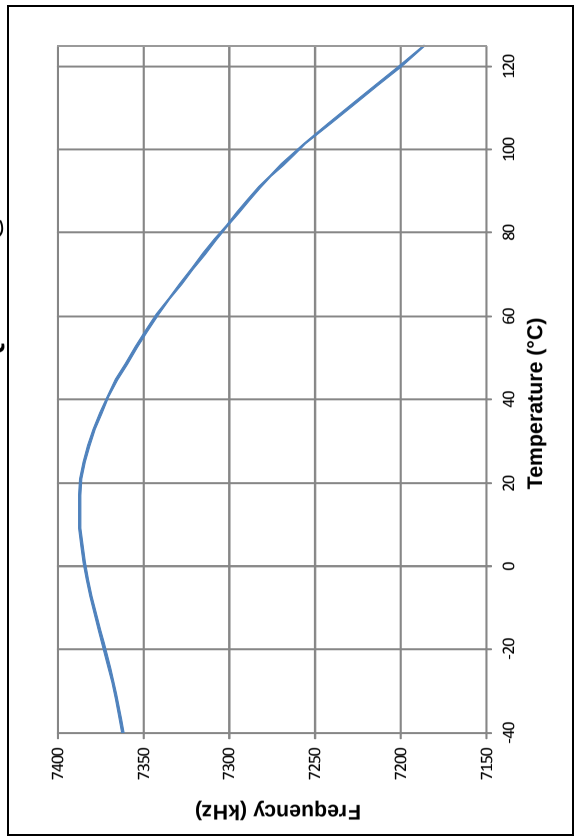


**FIGURE 31-9: TYPICAL FRC FREQUENCY @ VDD = 3.3V**

**NOTES:**


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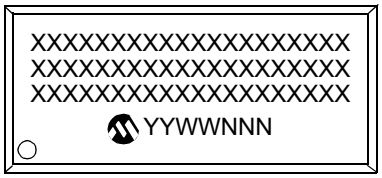
## 32.0 PACKAGING INFORMATION

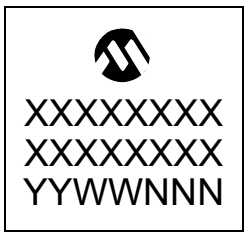
### 32.1 Package Marking Information

28-Lead SOIC (7.50 mm)



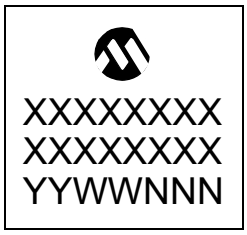

Example

28-Lead UQFN (6x6x0.55 mm)



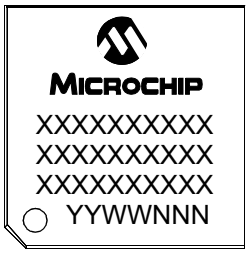

Example

28-Lead QFN-S (6x6x0.9 mm)




Example

44-Lead TQFP (10x10x1 mm)



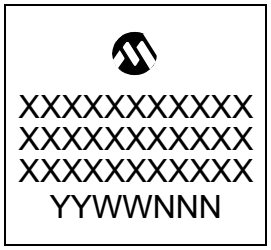

Example

| | | |
|---|---|---|
| **Legend:** | XX...X | Customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week ‘01’) |
| | NNN | Alphanumeric traceability code |

**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.

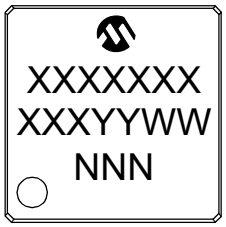
### 32.1 Package Marking Information (Continued)

44-Lead QFN (8x8 mm)



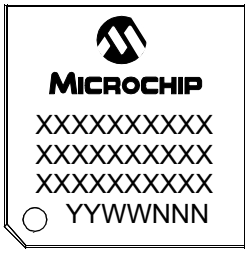

Example

48-Lead TQFP (7x7x1.0 mm)

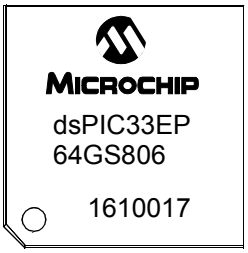



Example

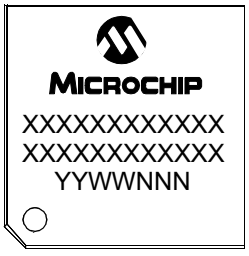
64-Lead TQFP (10x10x1 mm)




Example




80-Lead TQFP (12x12x1 mm)




Example

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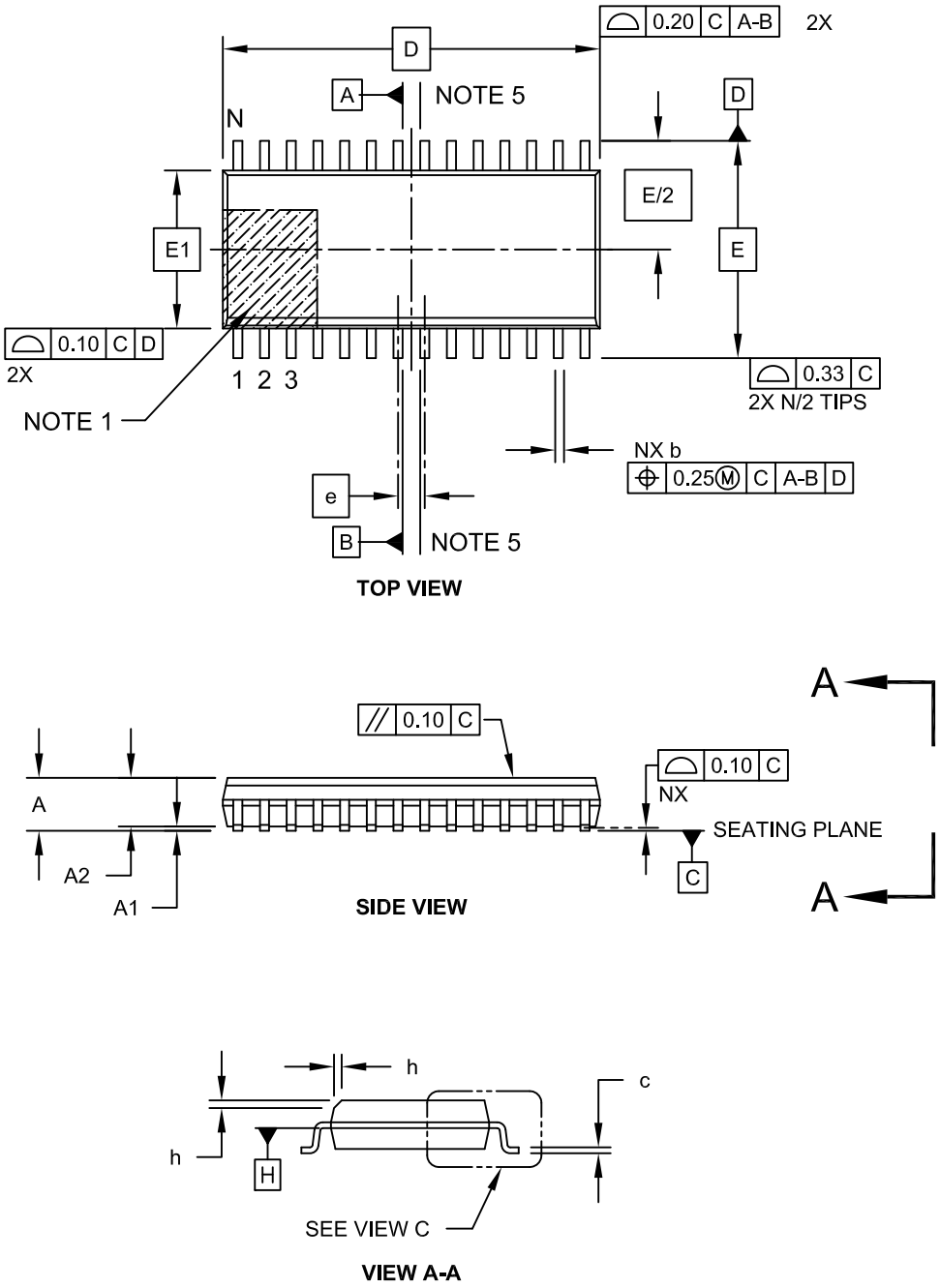
## 32.2 Package Details

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

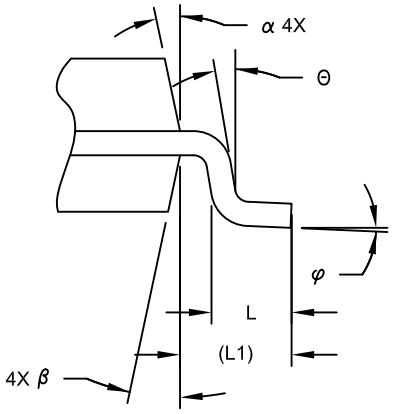
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



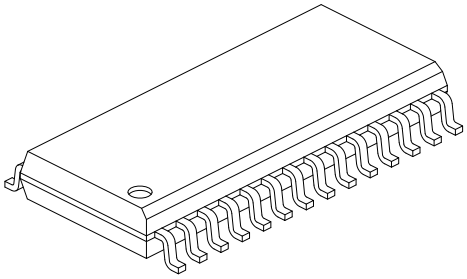

Microchip Technology Drawing C04-052C Sheet 1 of 2

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

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




VIEW C



| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | | 28 | |
| Pitch | e | | 1.27 BSC | |
| Overall Height | A | - | - | 2.65 |
| Molded Package Thickness | A2 | 2.05 | - | - |
| Standoff § | A1 | 0.10 | - | 0.30 |
| Overall Width | E | | 10.30 BSC | |
| Molded Package Width | E1 | | 7.50 BSC | |
| Overall Length | D | | 17.90 BSC | |
| Chamfer (Optional) | h | 0.25 | - | 0.75 |
| Foot Length | L | 0.40 | - | 1.27 |
| Footprint | L1 | | 1.40 REF | |
| Lead Angle | Θ | 0° | - | - |
| Foot Angle | φ | 0° | - | 8° |
| Lead Thickness | c | 0.18 | - | 0.33 |
| Lead Width | b | 0.31 | - | 0.51 |
| Mold Draft Angle Top | α | 5° | - | 15° |
| Mold Draft Angle Bottom | β | 5° | - | 15° |

**Notes:**

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

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

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

Microchip Technology Drawing C04-052C Sheet 2 of 2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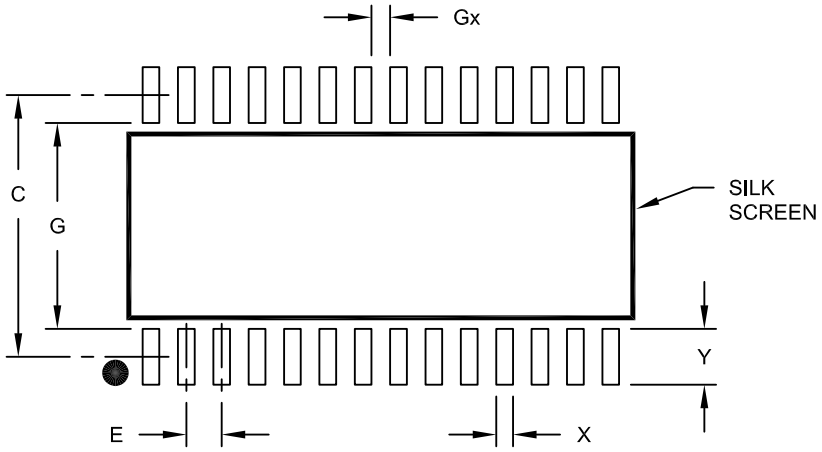
28-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

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




RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | 1.27 BSC | | |
| Contact Pad Spacing | C | | 9.40 | |
| Contact Pad Width (X28) | X | | | 0.60 |
| Contact Pad Length (X28) | Y | | | 2.00 |
| Distance Between Pads | Gx | 0.67 | | |
| Distance Between Pads | G | 7.40 | | |

Notes:

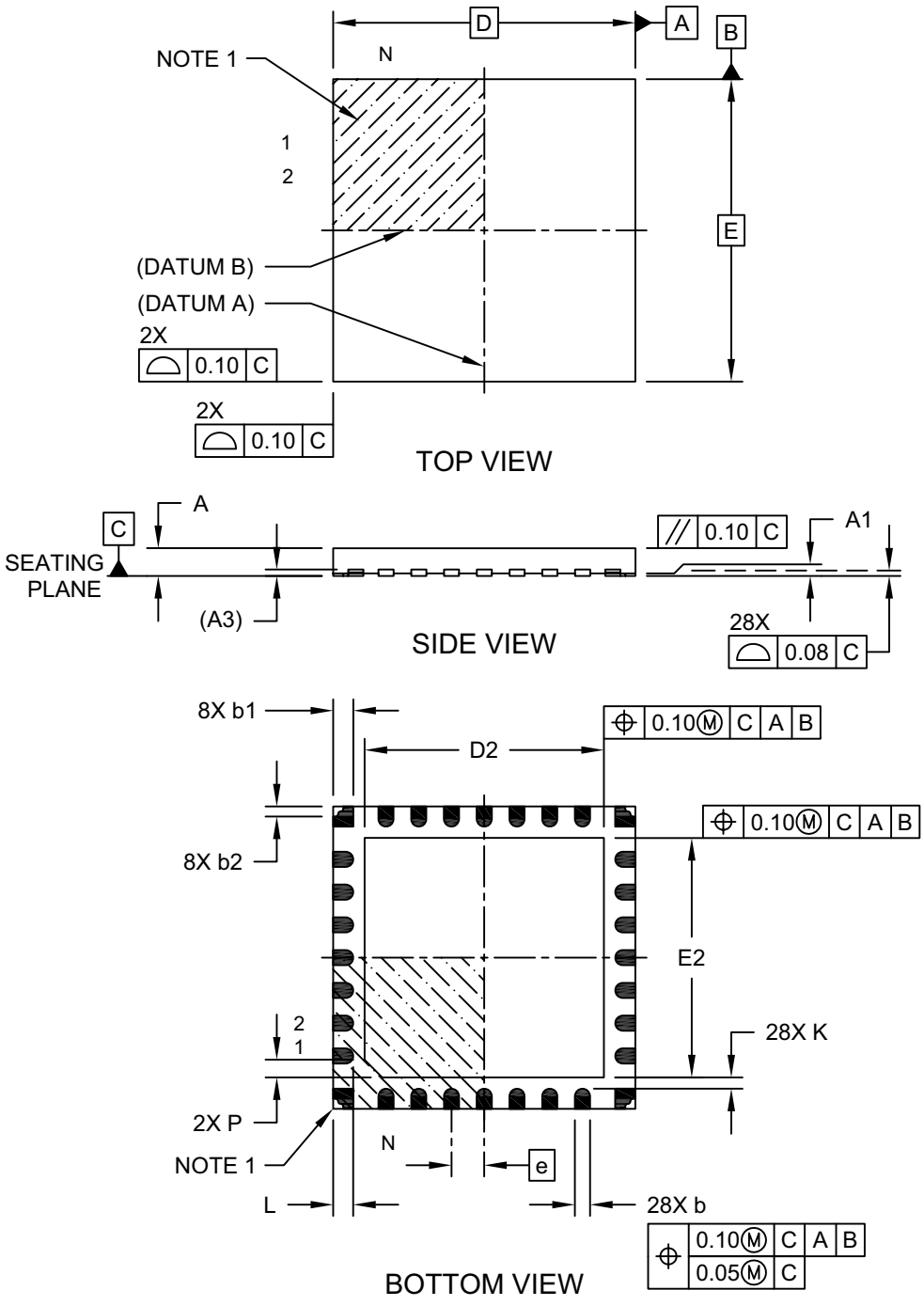
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2052A

**28-Lead Ultra Thin Plastic Quad Flat, No Lead Package (2N) - 6x6x0.55 mm Body [UQFN] With 4.65x4.65 mm Exposed Pad and Corner Anchors**

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




Microchip Technology Drawing C04-385B Sheet 1 of 2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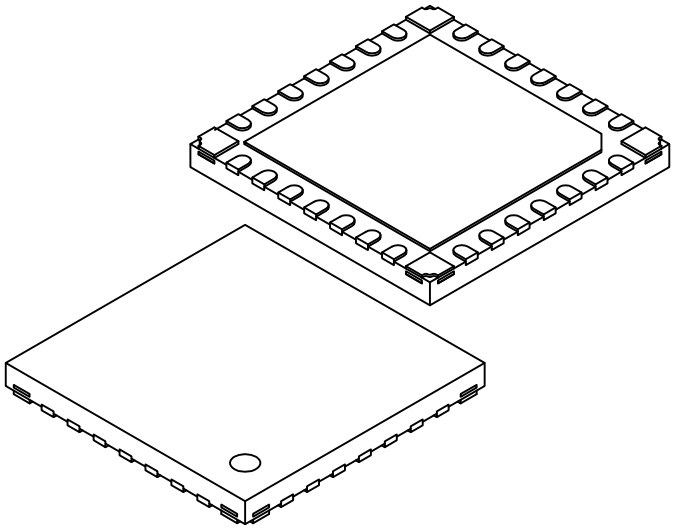
**28-Lead Ultra Thin Plastic Quad Flat, No Lead Package (2N) - 6x6x0.55 mm Body [UQFN] With 4.65x4.65 mm Exposed Pad and Corner Anchors**

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



| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Terminals | N | | 28 | |
| Pitch | e | | 0.65 BSC | |
| Overall Height | A | 0.45 | 0.50 | 0.55 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Terminal Thickness | A3 | | 0.127 REF | |
| Overall Width | E | | 6.00 BSC | |
| Exposed Pad Width | E2 | 4.55 | 4.65 | 4.75 |
| Overall Length | D | | 6.00 BSC | |
| Exposed Pad Length | D2 | 4.55 | 4.65 | 4.75 |
| Exposed Pad Corner Chamfer | P | - | 0.35 | - |
| Terminal Width | b | 0.25 | 0.30 | 0.35 |
| Corner Anchor Pad | b1 | 0.35 | 0.40 | 0.43 |
| Corner Pad, Metal Free Zone | b2 | 0.15 | 0.20 | 0.25 |
| Terminal Length | L | 0.30 | 0.40 | 0.50 |
| Terminal-to-Exposed-Pad | K | 0.20 | - | - |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

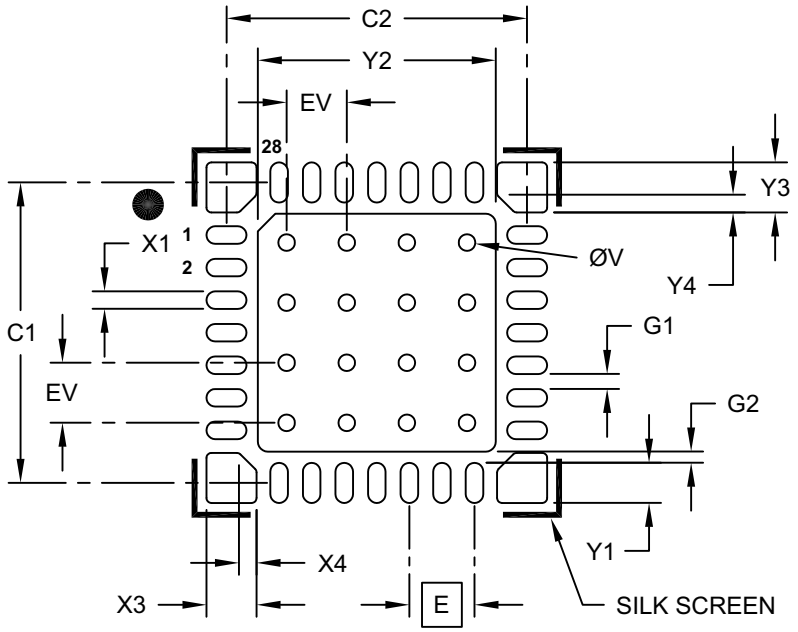
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing C04-385B Sheet 2 of 2

**28-Lead Ultra Thin Plastic Quad Flat, No Lead Package (2N) - 6x6x0.55 mm Body [UQFN] With 4.65x4.65 mm Exposed Pad and Corner Anchors**

**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 | X2 | | | 4.75 |
| Optional Center Pad Length | Y2 | | | 4.75 |
| Contact Pad Spacing | C1 | | 6.00 | |
| Contact Pad Spacing | C2 | | 6.00 | |
| Contact Pad Width (X28) | X1 | | | 0.35 |
| Contact Pad Length (X28) | Y1 | | | 0.80 |
| Corner Anchor (X4) | X3 | | | 1.00 |
| Corner Anchor (X4) | Y3 | | | 1.00 |
| Corner Anchor Chamfer (X4) | X4 | | | 0.35 |
| Corner Anchor Chamfer (X4) | Y4 | | | 0.35 |
| Contact Pad to Pad (X28) | G1 | 0.20 | | |
| Contact Pad to Center Pad (X28) | G2 | 0.20 | | |
| Thermal Via Diameter | V | | 0.33 | |
| Thermal Via Pitch | EV | | 1.20 | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-2385B

**Note:** Corner anchor pads are not connected internally and are designed as mechanical features when the package is soldered to the PCB.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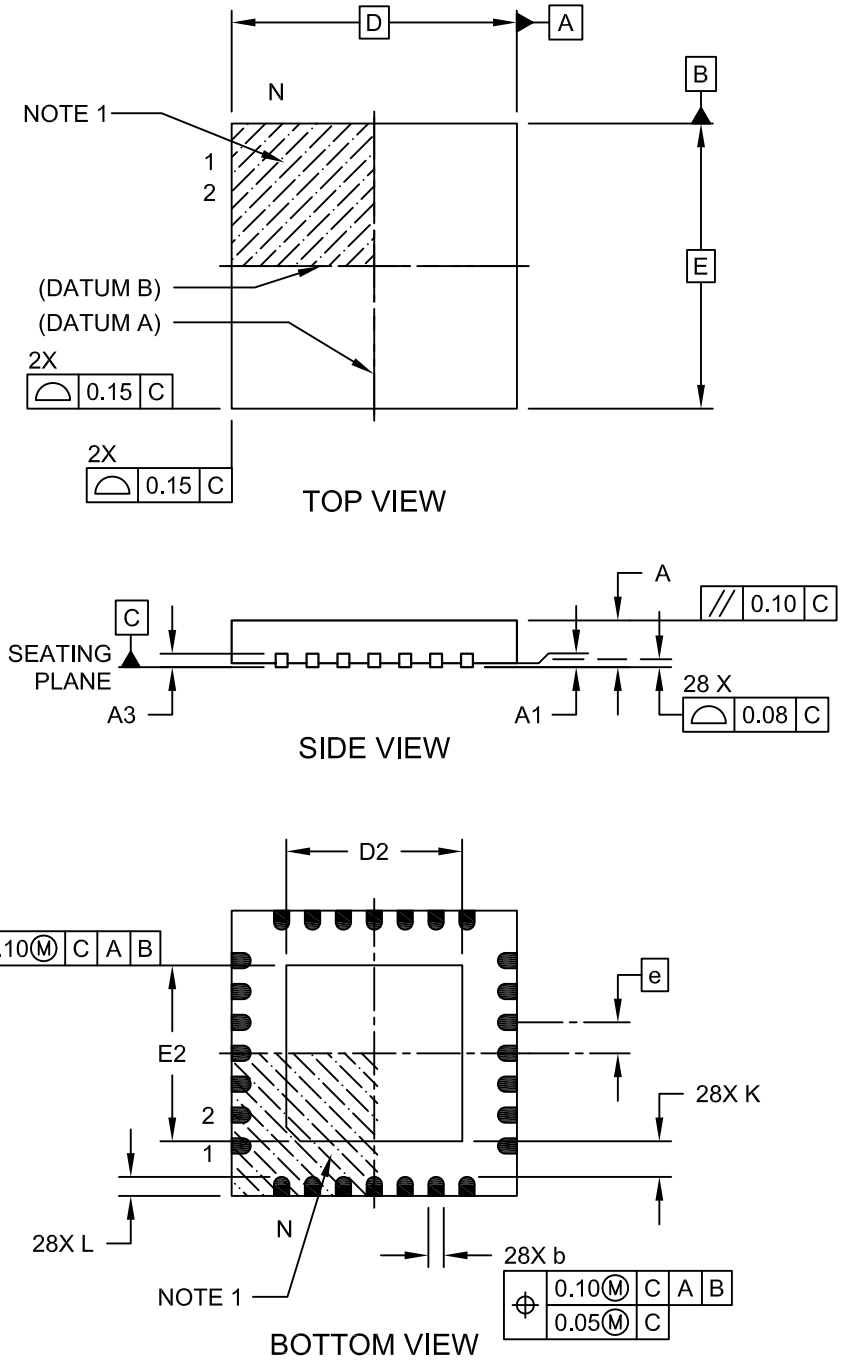
**28-Lead Plastic Quad Flat, No Lead Package (MM) - 6x6x0.9mm Body [QFN-S]**
**With 0.40 mm Terminal Length**

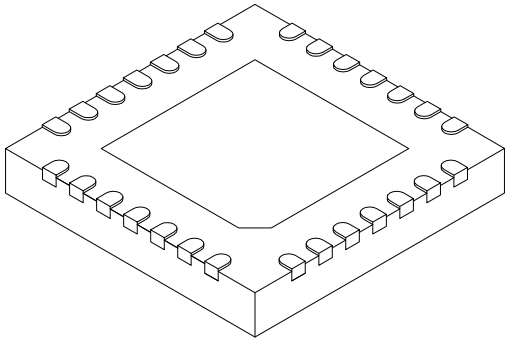
| **Note:** | For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging |
|---|---|




Microchip Technology Drawing C04-124C Sheet 1 of 2

**28-Lead Plastic Quad Flat, No Lead Package (MM) - 6x6x0.9mm Body [QFN-S]**
**With 0.40 mm Terminal Length**

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



| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | | 28 | |
| Pitch | e | | 0.65 BSC | |
| Overall Height | A | 0.80 | 0.90 | 1.00 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Terminal Thickness | A3 | | 0.20 REF | |
| Overall Width | E | | 6.00 BSC | |
| Exposed Pad Width | E2 | 3.65 | 3.70 | 4.70 |
| Overall Length | D | | 6.00 BSC | |
| Exposed Pad Length | D2 | 3.65 | 3.70 | 4.70 |
| Terminal Width | b | 0.23 | 0.30 | 0.35 |
| Terminal Length | L | 0.30 | 0.40 | 0.50 |
| Terminal-to-Exposed Pad | K | 0.20 | - | - |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-124C Sheet 2 of 2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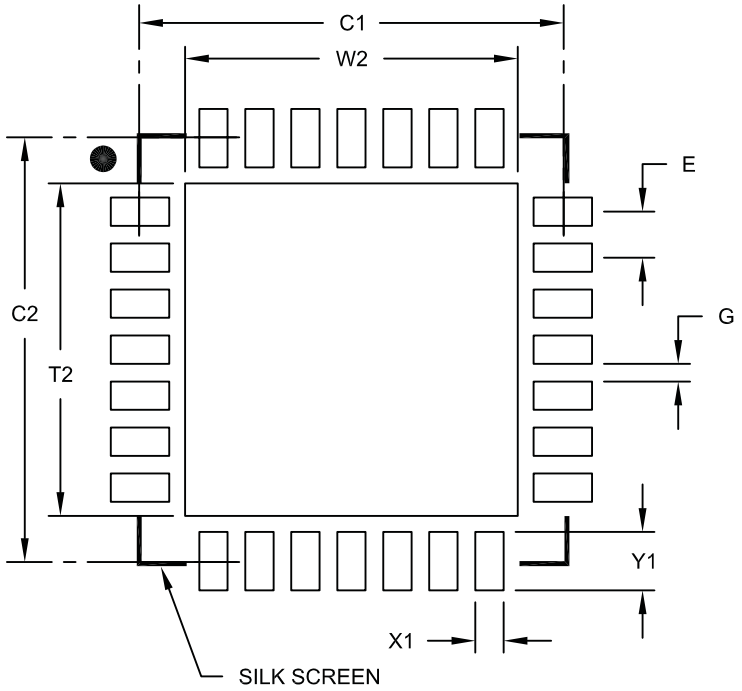
**28-Lead Plastic Quad Flat, No Lead Package (MM) – 6x6x0.9 mm Body [QFN-S] with 0.40 mm Contact Length**

**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:

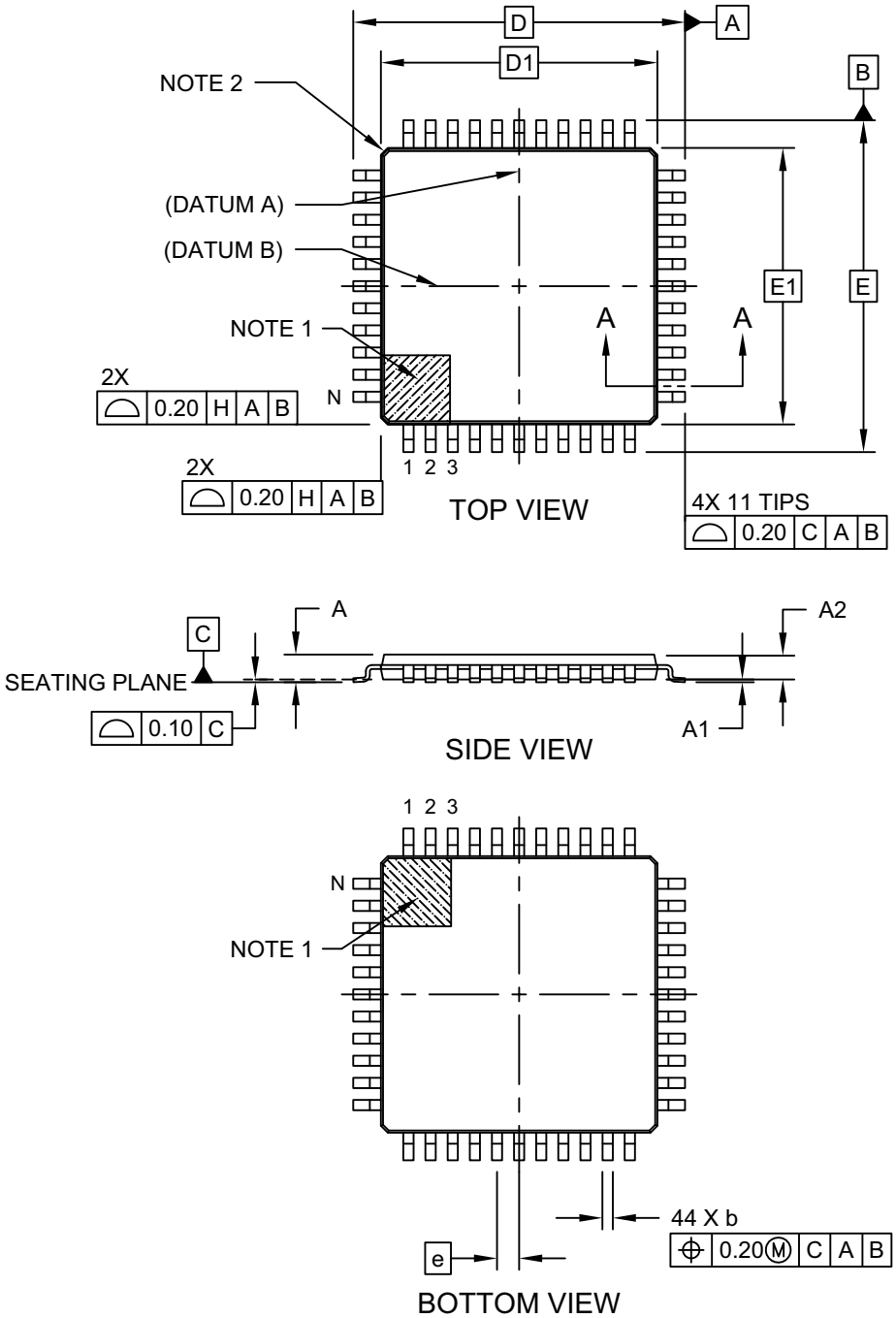
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2124A

**44-Lead Plastic Thin Quad Flatpack (PT) - 10x10x1.0 mm Body [TQFP]**

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




Microchip Technology Drawing C04-076C Sheet 1 of 2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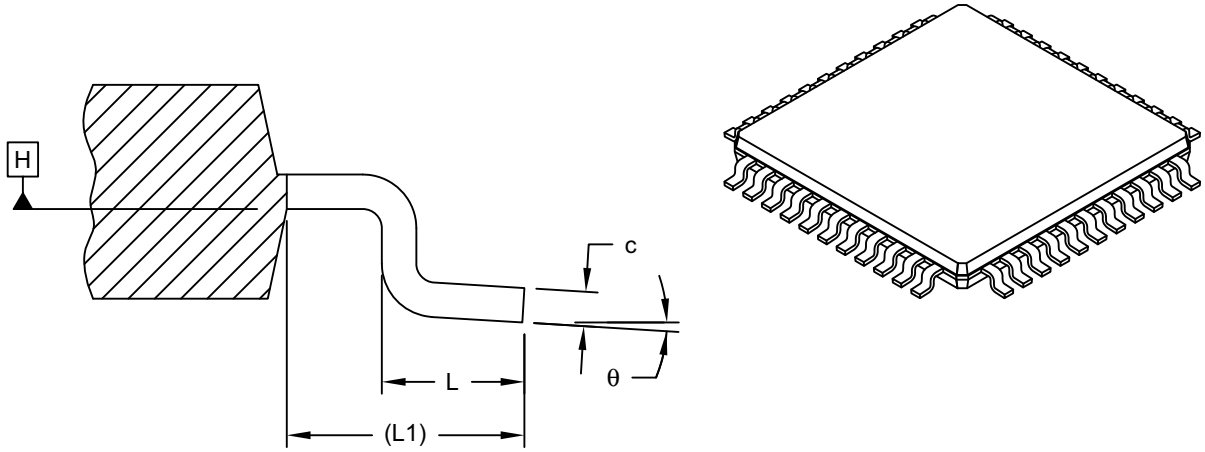
### 44-Lead Plastic Thin Quad Flatpack (PT) - 10x10x1.0 mm Body [TQFP]

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




SECTION A-A

| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Leads | N | | 44 | |
| Lead Pitch | e | | 0.80 BSC | |
| Overall Height | A | - | - | 1.20 |
| Standoff | A1 | 0.05 | - | 0.15 |
| Molded Package Thickness | A2 | 0.95 | 1.00 | 1.05 |
| Overall Width | E | | 12.00 BSC | |
| Molded Package Width | E1 | | 10.00 BSC | |
| Overall Length | D | | 12.00 BSC | |
| Molded Package Length | D1 | | 10.00 BSC | |
| Lead Width | b | 0.30 | 0.37 | 0.45 |
| Lead Thickness | c | 0.09 | - | 0.20 |
| Lead Length | L | 0.45 | 0.60 | 0.75 |
| Footprint | L1 | | 1.00 REF | |
| Foot Angle | θ | 0° | 3.5° | 7° |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Exact shape of each corner is optional.
3. Dimensioning and tolerancing per ASME Y14.5M

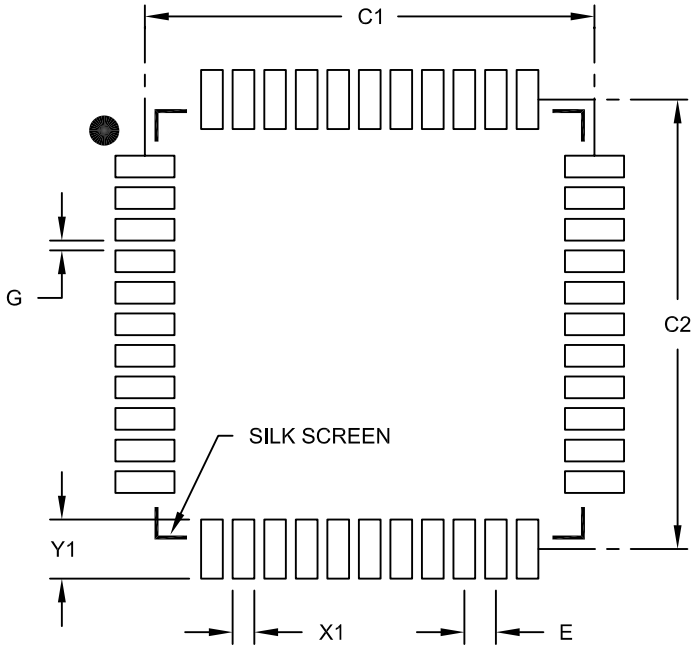
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing C04-076C Sheet 2 of 2

44-Lead Plastic Thin Quad Flatpack (PT) 10X10X1 mm Body, 2.00 mm Footprint [TQFP]

**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 | 0.80 BSC | | |
| Contact Pad Spacing | C1 | | 11.40 | |
| Contact Pad Spacing | C2 | | 11.40 | |
| Contact Pad Width (X44) | X1 | | | 0.55 |
| Contact Pad Length (X44) | Y1 | | | 1.50 |
| 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. C04-2076B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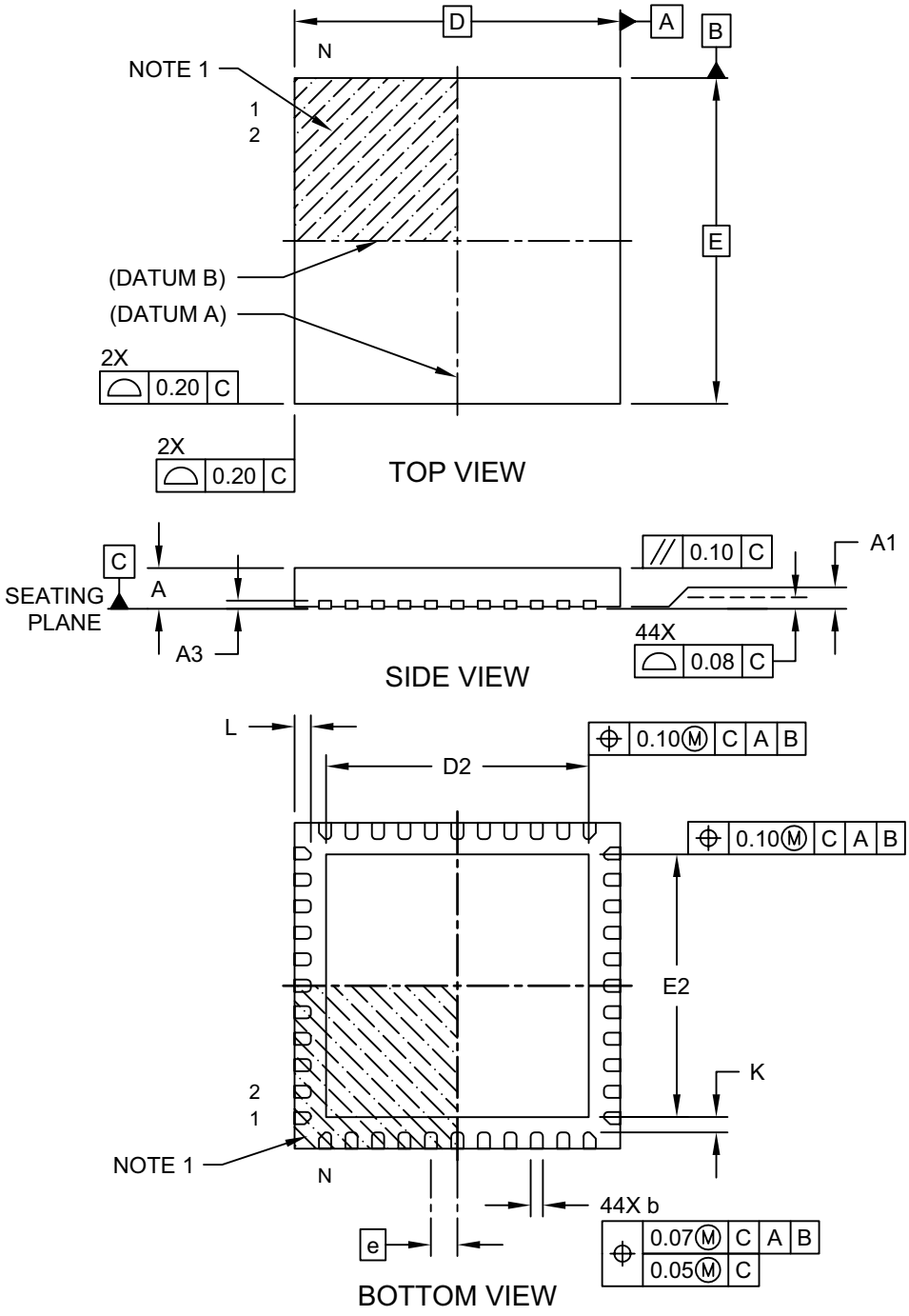
**44-Lead Plastic Quad Flat, No Lead Package (ML) - 8x8 mm Body [QFN or VQFN]**

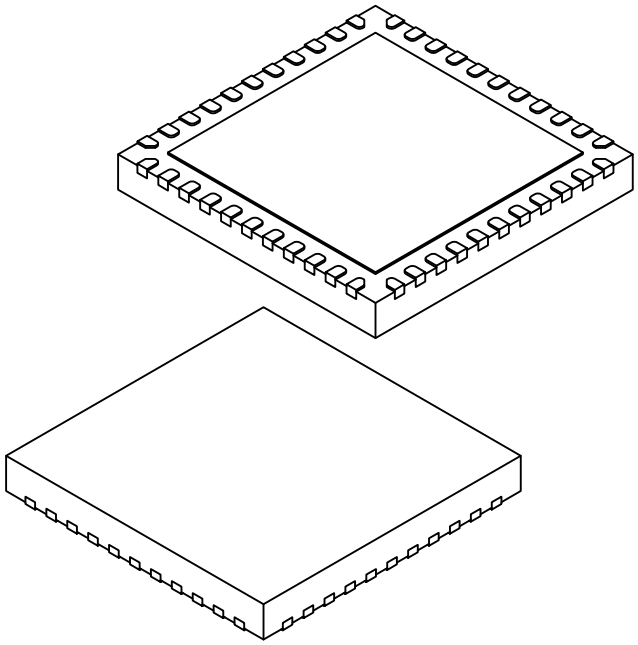
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




Microchip Technology Drawing C04-103D Sheet 1 of 2

### 44-Lead Plastic Quad Flat, No Lead Package (ML) - 8x8 mm Body [QFN or VQFN]

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



| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | | 44 | |
| Pitch | e | | 0.65 BSC | |
| Overall Height | A | 0.80 | 0.90 | 1.00 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Terminal Thickness | A3 | | 0.20 REF | |
| Overall Width | E | | 8.00 BSC | |
| Exposed Pad Width | E2 | 6.25 | 6.45 | 6.60 |
| Overall Length | D | | 8.00 BSC | |
| Exposed Pad Length | D2 | 6.25 | 6.45 | 6.60 |
| Terminal Width | b | 0.20 | 0.30 | 0.35 |
| Terminal Length | L | 0.30 | 0.40 | 0.50 |
| Terminal-to-Exposed-Pad | K | 0.20 | - | - |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-103D Sheet 2 of 2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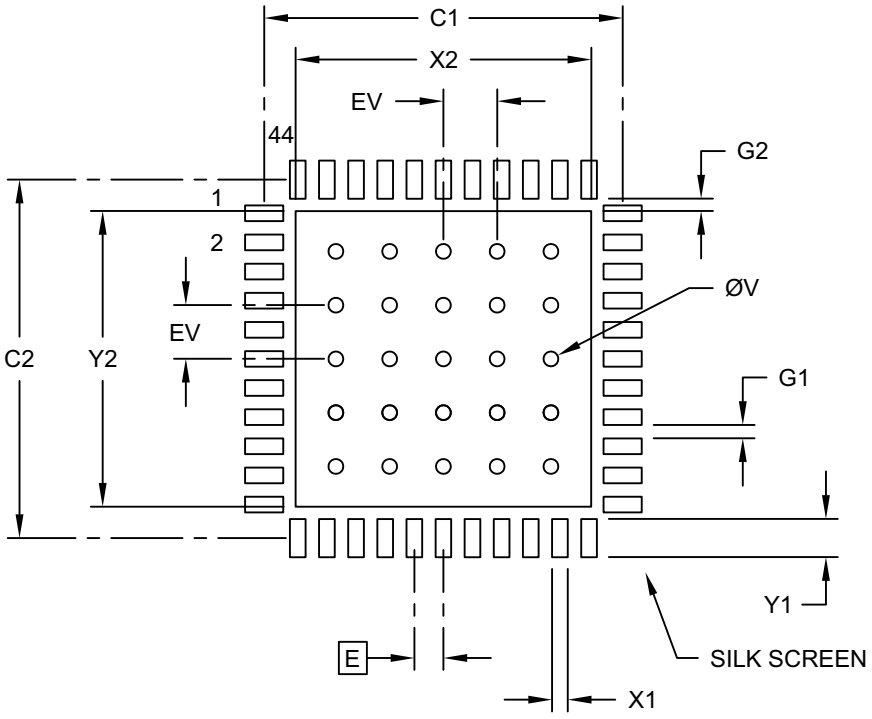
### 44-Lead Plastic Quad Flat, No Lead Package (ML) - 8x8 mm Body [QFN or VQFN]

**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 | X2 | | | 6.60 |
| Optional Center Pad Length | Y2 | | | 6.60 |
| Contact Pad Spacing | C1 | | 8.00 | |
| Contact Pad Spacing | C2 | | 8.00 | |
| Contact Pad Width (X44) | X1 | | | 0.35 |
| Contact Pad Length (X44) | Y1 | | | 0.85 |
| Contact Pad to Contact Pad (X40) | G1 | 0.30 | | |
| Contact Pad to Center Pad (X44) | G2 | 0.28 | | |
| Thermal Via Diameter | V | | 0.33 | |
| Thermal Via Pitch | EV | | 1.20 | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

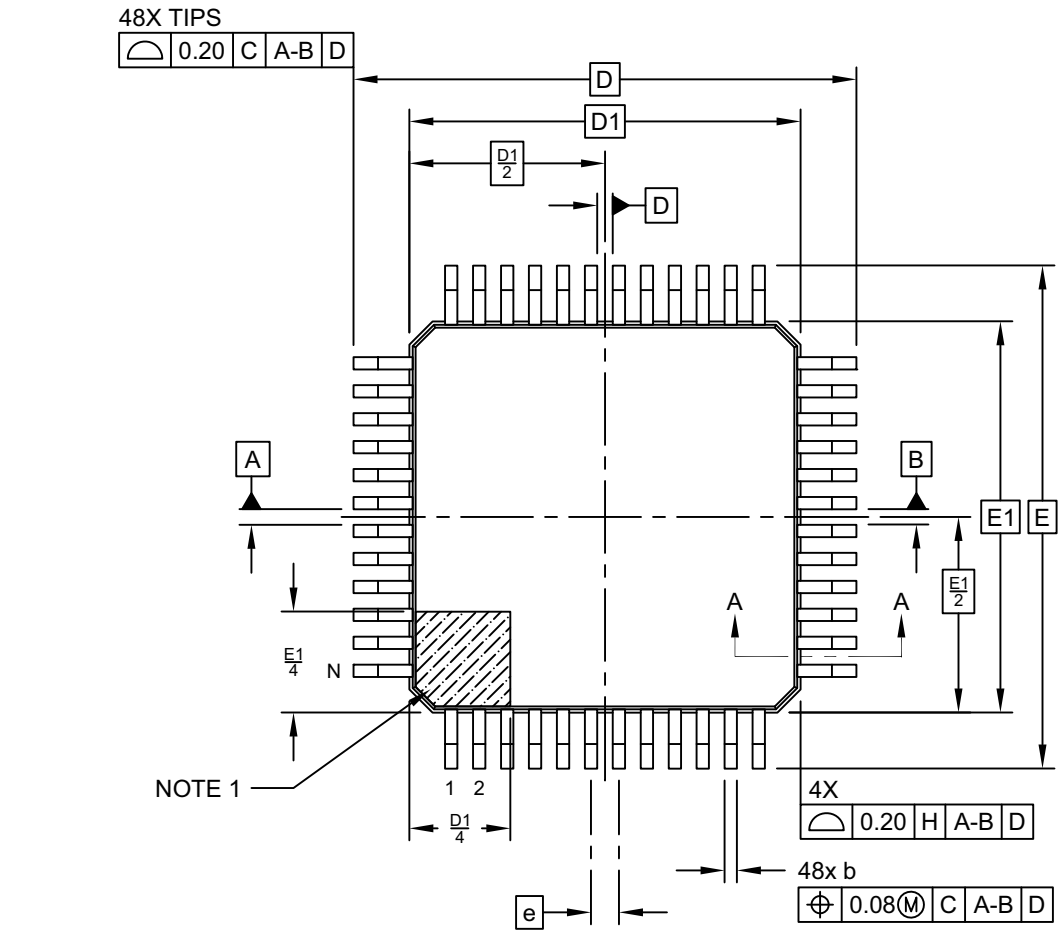
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

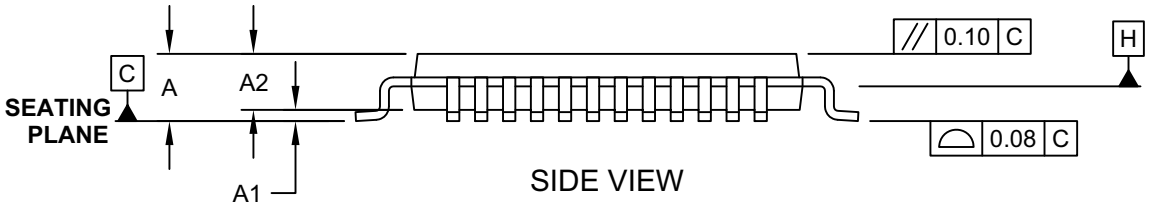
Microchip Technology Drawing No. C04-2103C

**48-Lead Thin Quad Flatpack (PT) - 7x7x1.0 mm Body [TQFP]**

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




TOP VIEW




SIDE VIEW

Microchip Technology Drawing C04-300-PT Rev A Sheet 1 of 2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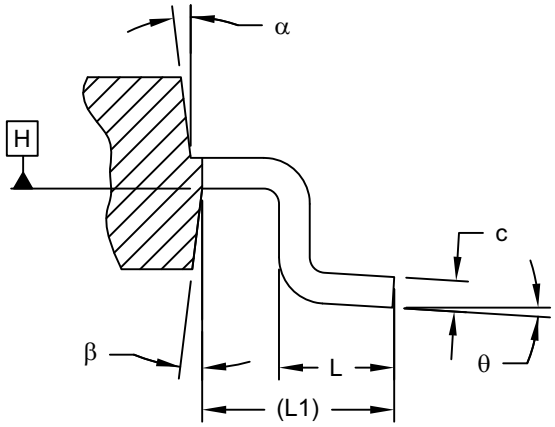
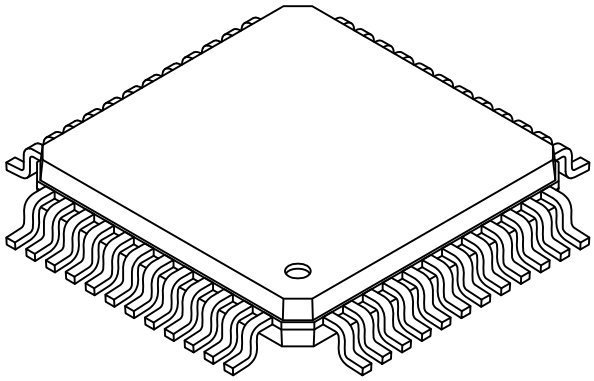
### 48-Lead Thin Quad Flatpack (PT) - 7x7x1.0 mm Body [TQFP]

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



SECTION A-A

| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Leads | N | | 48 | |
| Lead Pitch | e | | 0.50 BSC | |
| Overall Height | A | - | - | 1.20 |
| Standoff | A1 | 0.05 | - | 0.15 |
| Molded Package Thickness | A2 | 0.95 | 1.00 | 1.05 |
| Foot Length | L | 0.45 | 0.60 | 0.75 |
| Footprint | L1 | | 1.00 REF | |
| Foot Angle | ϕ | 0° | 3.5° | 7° |
| Overall Width | E | | 9.00 BSC | |
| Overall Length | D | | 9.00 BSC | |
| Molded Package Width | E1 | | 7.00 BSC | |
| Molded Package Length | D1 | | 7.00 BSC | |
| Lead Thickness | c | 0.09 | - | 0.16 |
| Lead Width | b | 0.17 | 0.22 | 0.27 |
| Mold Draft Angle Top | α | 11° | 12° | 13° |
| Mold Draft Angle Bottom | β | 11° | 12° | 13° |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Chamfers at corners are optional; size may vary.
3. Dimensions D1 and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

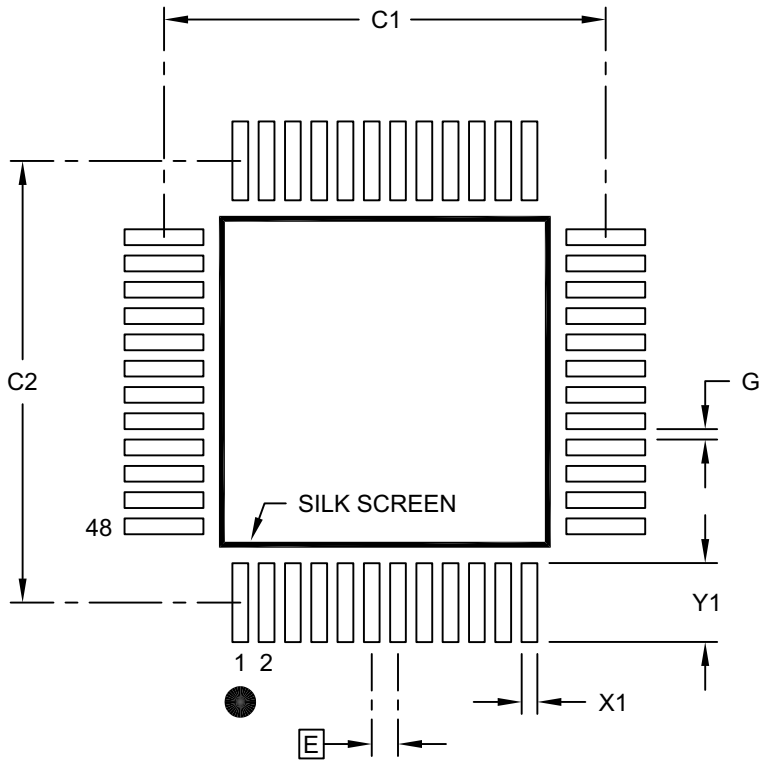
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.
5. Datums A-B and D to be determined at center line between leads where leads exit plastic body at datum plane H

Microchip Technology Drawing C04-300-PT Rev A Sheet 2 of 2

### 48-Lead Thin Quad Flatpack (PT) - 7x7x1.0 mm Body [TQFP]

**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 | |
| Contact Pad Spacing | C1 | | 8.40 | |
| Contact Pad Spacing | C2 | | 8.40 | |
| Contact Pad Width (X48) | X1 | | | 0.30 |
| Contact Pad Length (X48) | Y1 | | | 1.50 |
| Distance Between Pads | G | 0.20 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-2300-PT Rev A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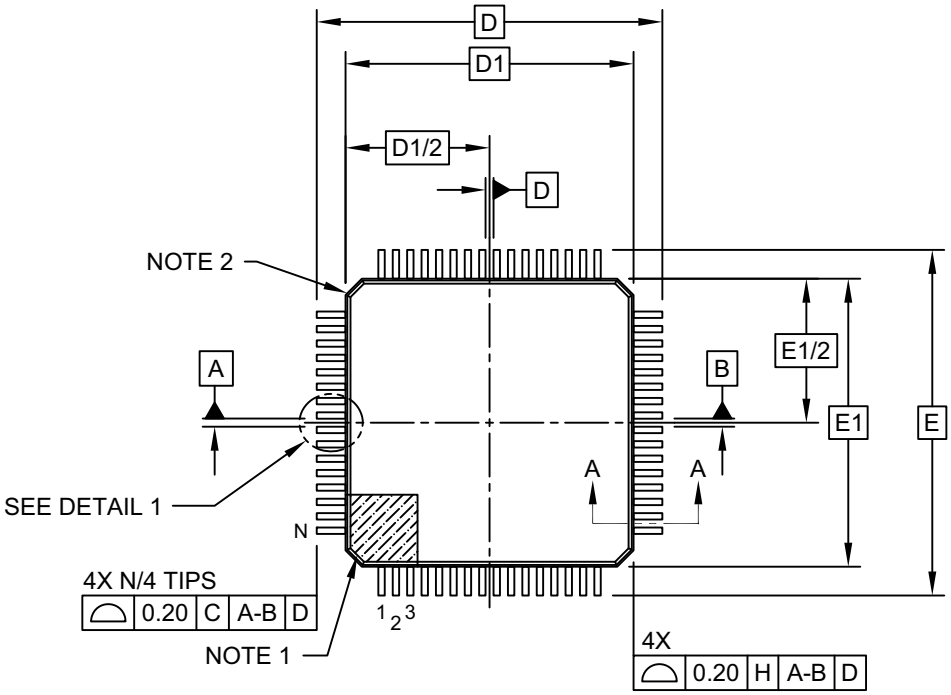
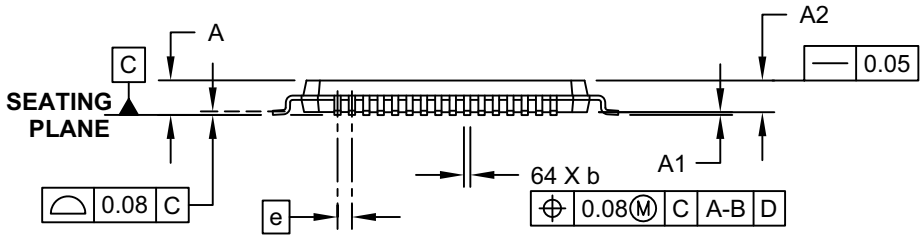
**64-Lead Plastic Thin Quad Flatpack (PT)-10x10x1 mm Body, 2.00 mm Footprint [TQFP]**

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




TOP VIEW

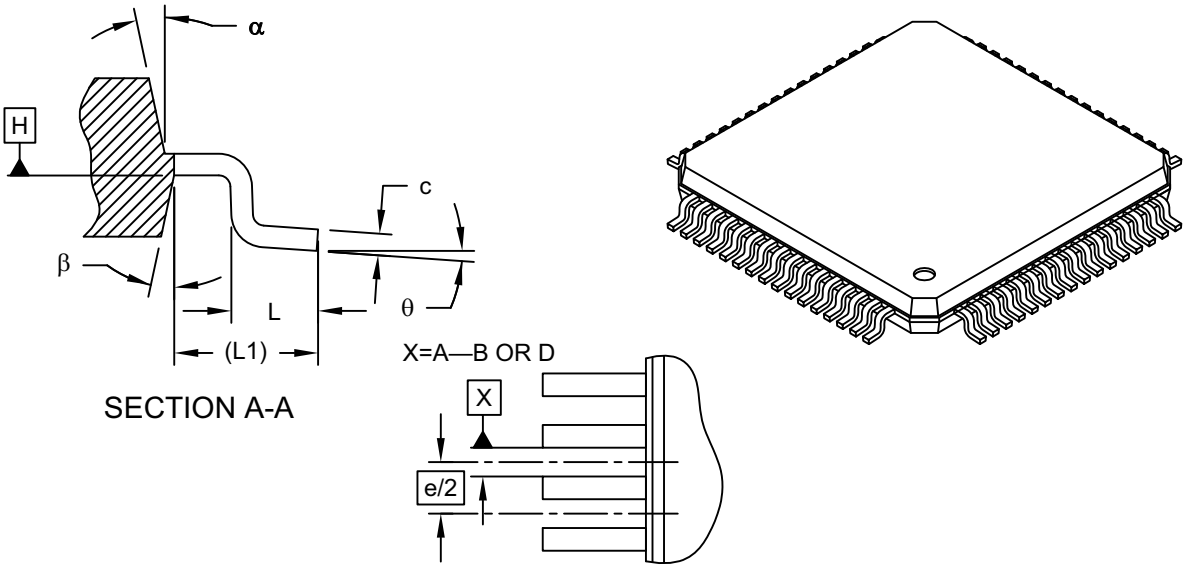



SIDE VIEW

Microchip Technology Drawing C04-085C Sheet 1 of 2

### 64-Lead Plastic Thin Quad Flatpack (PT)-10x10x1 mm Body, 2.00 mm Footprint [TQFP]

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




| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Leads | N | | 64 | |
| Lead Pitch | e | | 0.50 BSC | |
| Overall Height | A | - | - | 1.20 |
| Molded Package Thickness | A2 | 0.95 | 1.00 | 1.05 |
| Standoff | A1 | 0.05 | - | 0.15 |
| Foot Length | L | 0.45 | 0.60 | 0.75 |
| Footprint | L1 | | 1.00 REF | |
| Foot Angle | ϕ | 0° | 3.5° | 7° |
| Overall Width | E | | 12.00 BSC | |
| Overall Length | D | | 12.00 BSC | |
| Molded Package Width | E1 | | 10.00 BSC | |
| Molded Package Length | D1 | | 10.00 BSC | |
| Lead Thickness | c | 0.09 | - | 0.20 |
| Lead Width | b | 0.17 | 0.22 | 0.27 |
| Mold Draft Angle Top | α | 11° | 12° | 13° |
| Mold Draft Angle Bottom | β | 11° | 12° | 13° |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Chamfers at corners are optional; size may vary.
3. Dimensions D1 and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-085C Sheet 2 of 2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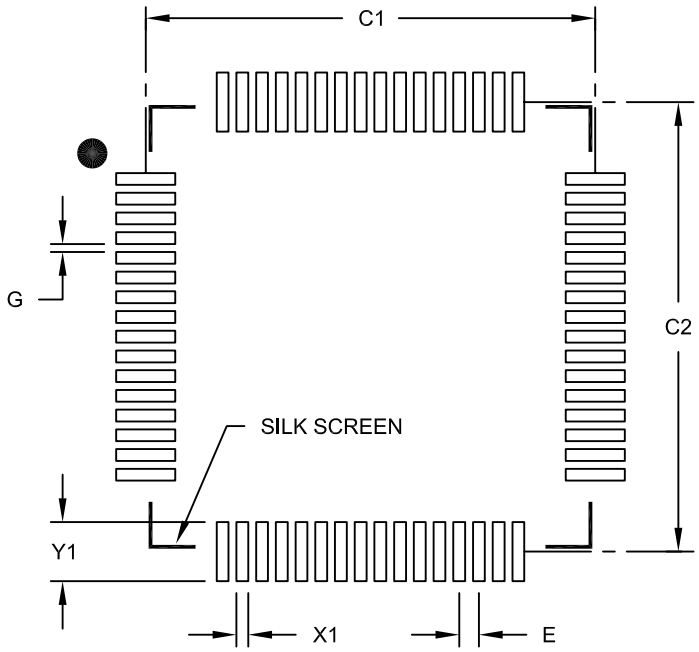
64-Lead Plastic Thin Quad Flatpack (PT) 10x10x1 mm Body, 2.00 mm Footprint [TQFP]

**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 | |
| Contact Pad Spacing | C1 | | 11.40 | |
| Contact Pad Spacing | C2 | | 11.40 | |
| Contact Pad Width (X64) | X1 | | | 0.30 |
| Contact Pad Length (X64) | Y1 | | | 1.50 |
| Distance Between Pads | G | 0.20 | | |

Notes:

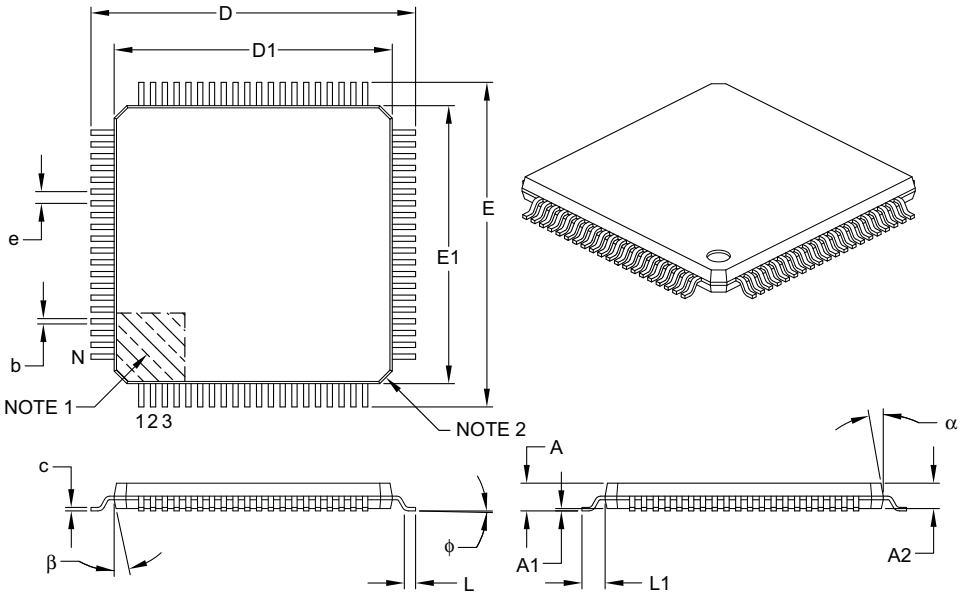
1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2085B

### 80-Lead Plastic Thin Quad Flatpack (PT) – 12x12x1 mm Body, 2.00 mm [TQFP]

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




| Units | | MILLIMETERS | | |
|---|---|---|---|---|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Leads | N | | 80 | |
| Lead Pitch | e | | 0.50 BSC | |
| Overall Height | A | – | – | 1.20 |
| Molded Package Thickness | A2 | 0.95 | 1.00 | 1.05 |
| Standoff | A1 | 0.05 | – | 0.15 |
| Foot Length | L | 0.45 | 0.60 | 0.75 |
| Footprint | L1 | | 1.00 REF | |
| Foot Angle | ϕ | 0° | 3.5° | 7° |
| Overall Width | E | | 14.00 BSC | |
| Overall Length | D | | 14.00 BSC | |
| Molded Package Width | E1 | | 12.00 BSC | |
| Molded Package Length | D1 | | 12.00 BSC | |
| Lead Thickness | c | 0.09 | – | 0.20 |
| Lead Width | b | 0.17 | 0.22 | 0.27 |
| Mold Draft Angle Top | α | 11° | 12° | 13° |
| Mold Draft Angle Bottom | β | 11° | 12° | 13° |

**Notes:**

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Chamfers at corners are optional; size may vary.
3. Dimensions D1 and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-092B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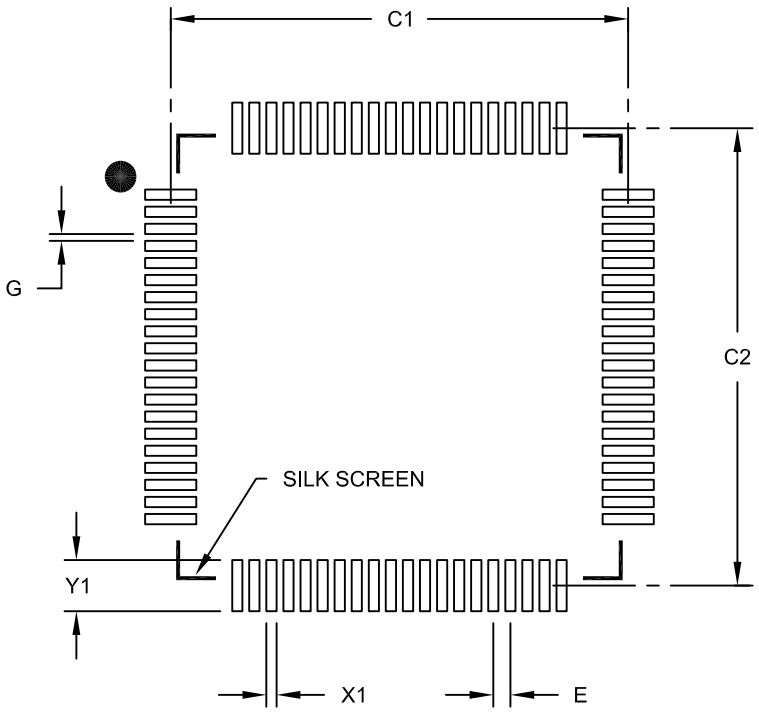
80-Lead Plastic Thin Quad Flatpack (PT) - 12x12x1mm Body, 2.00 mm Footprint [TQFP]

**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 | |
| Contact Pad Spacing | C1 | | 13.40 | |
| Contact Pad Spacing | C2 | | 13.40 | |
| Contact Pad Width (X80) | X1 | | | 0.30 |
| Contact Pad Length (X80) | Y1 | | | 1.50 |
| 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. C04-2092B

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

## Revision A (May 2016)

This is the initial version of the document.

## Revision B (January 2017)

- Sections:
  - Updates Note 1 in **Section 5.0 "Flash Program Memory"**.
- Tables:
  - Updates the device description table on page 2.
  - Updates Table 1-1, Table 4-2, Table 4-11, Table 7-1, Table 8-1, Table 11-11, Table 11-13, Table 17-1, Table 30-3, Table 30-4, Table 30-6, Table 30-7, Table 30-8, Table 30-9, Table 30-10, Table 30-11, Table 30-52, Table 30-54 and Table 30-55.
  - Adds Table 11-6, Table 11-7, Table 11-8, Table 11-9 and Table 11-10.
- Figures:
  - Updates the Pin Function tables in the Pin Diagram figures on pages 5 through 8.
  - Updates Figure 4-1, Figure 17-1, Figure 18-1 and Figure 18-2.
- Registers:
  - Updates Register 3-3, Register 16-5, Register 17-11, Register 18-1 and Register 19-2.
  - Adds Register 11-1, Register 11-2, Register 11-3, Register 11-4, Register 11-5, Register 11-6, Register 11-7 and Register 11-8.

**NOTES:**


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## INDEX

### A


Absolute Maximum Ratings ..... 375
AC Characteristics ..... 387
  ADC Specifications ..... 428
  Analog Current Specifications ..... 427
  Analog-to-Digital Conversion Requirements ..... 430
  Auxiliary PLL Clock ..... 389
  CANx I/O Requirements ..... 426
  Capacitive Loading Requirements on Output Pins ..... 387
  DMA Module Requirements ..... 433
  External Clock Requirements ..... 388
  High-Speed PWMx Requirements ..... 397
  I/O Requirements ..... 391
  I2Cx Bus Data Requirements (Master Mode) ..... 423
  I2Cx Bus Data Requirements (Slave Mode) ..... 425
  Input Capture x Requirements ..... 395
  Internal FRC Accuracy ..... 390
  Internal LPRC Accuracy ..... 390
  Load Conditions ..... 387
  OCx/PWMx Module Requirements ..... 396
  Output Compare x Requirements ..... 396
  PLL Clock ..... 389
  Reset, WDT, OST, PWRT Requirements ..... 392
  SPI1, SPI2 and SPI3 Master Mode (Full-Duplex, CKE = 0, CKP = x, SMP = 1) Requirements ..... 401
  SPI1, SPI2 and SPI3 Master Mode (Full-Duplex, CKE = 1, CKP = x, SMP = 1) Requirements ..... 400
  SPI1, SPI2 and SPI3 Master Mode (Half-Duplex, Transmit Only) Requirements ..... 399
  SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 0, SMP = 0) Requirements ..... 409
  SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 1, SMP = 0) Requirements ..... 407
  SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 0, SMP = 0) Requirements ..... 403
  SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 1, SMP = 0) Requirements ..... 405
  SPI3 Master Mode (Full-Duplex, CKE = 0, CKP = x, SMP = 1) Requirements ..... 413
  SPI3 Master Mode (Full-Duplex, CKE = 1, CKP = x, SMP = 1) Requirements ..... 412
  SPI3 Master Mode (Half-Duplex, Transmit Only) Requirements ..... 411
  SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 0, SMP = 0) Requirements ..... 421
  SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 1, SMP = 0) Requirements ..... 419
  SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 0, SMP = 0) Requirements ..... 415
  SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 1, SMP = 0) Requirements ..... 417
  Temperature and Voltage Specifications ..... 387
  Timer1 External Clock Requirements ..... 393
  Timer2/Timer4 External Clock Requirements ..... 394
  Timer3/Timer5 External Clock Requirements ..... 394
  UARTx I/O Requirements ..... 427
AC/DC Characteristics
  DACx Specifications ..... 431
  High-Speed Analog Comparator Specifications ..... 430
  PGAx Specifications ..... 432
Analog-to-Digital Converter. *See* ADC.
Arithmetic Logic Unit (ALU) ..... 30
Assembler
  MPASM Assembler ..... 372
  MPLAB Assembler, Linker, Librarian ..... 372


### B


Bit-Reversed Addressing ..... 56
  Example ..... 57
  Implementation ..... 56
  Sequence Table (16-Entry) ..... 57
Block Diagrams
  16-Bit Timer1 Module ..... 169
  ADC Module ..... 274
  Addressing for Table Registers ..... 61
  CALL Stack Frame ..... 52
  CANx Module ..... 308
  CLCx Input Source Selection ..... 261
  CLCx Logic Function Combinatorial Options ..... 260
  CLCx Module ..... 259
  Connections for On-Chip Voltage Regulator ..... 355
  Constant-Current Source ..... 345
  CPU Core ..... 22
  Data Access from Program Space Address Generation ..... 58
  Dedicated ADC Cores 0-3 ..... 275
  DMA Controller ..... 91
  dsPIC33EPXXGS70X/80X Family ..... 11
  High-Speed Analog Comparator x ..... 334
  High-Speed PWM Architecture ..... 189
  Hysteresis Control ..... 336
  I2Cx Module ..... 246
  Input Capture x ..... 177
  Interleaved PFC ..... 18
  MCLR Pin Connections ..... 16
  Multiplexing Remappable Outputs for RPn ..... 138
  Off-Line UPS ..... 20
  Oscillator System ..... 104
  Output Compare x Module ..... 181
  Peripheral to DMA Controller ..... 89
  PGAx Functions ..... 342
  PGAx Module ..... 341
  Phase-Shifted Full-Bridge Converter ..... 19
  PLL Module ..... 105
  Programmer's Model ..... 24
  PSV Read Address Generation ..... 49
  PTG Module ..... 214
  Recommended Minimum Connection ..... 16
  Remappable Input for U1RX ..... 136
  Reset System ..... 69
  Security Segments for dsPIC33EP128GS70X/80X (Dual Partition Modes) ..... 359
  Security Segments for dsPIC33EP64GS70X/80X (Dual Partition Modes) ..... 358
  Security Segments for dsPIC33EPXXXGS70X/80X ..... 358
  Shared ADC Core ..... 275
  Shared Port Structure ..... 125
  Simplified Conceptual of High-Speed PWM ..... 190
  SPIx Master, Frame Master Connection ..... 243
  SPIx Master, Frame Slave Connection ..... 244
  SPIx Master/Slave Connection (Enhanced Buffer Modes) ..... 243
  SPIx Master/Slave Connection (Standard Mode) ..... 242
  SPIx Module (Enhanced Mode) ..... 231
  SPIx Module (Standard Mode) ..... 230

SPIx Slave, Frame Master Connection ..... 244
SPIx Slave, Frame Slave Connection ..... 244
Suggested Oscillator Circuit Placement ..... 17
Timerx (x = 2 through 5) ..... 174
Type B/Type C Timer Pair (32-Bit Timer) ..... 174
UARTx Module ..... 253
Watchdog Timer (WDT) ..... 356
Brown-out Reset (BOR) ..... 347, 355

**C**

C Compilers
MPLAB XC ..... 372
CAN Module
Control Registers ..... 309
Message Buffers ..... 328
Word 0 ..... 328
Word 1 ..... 328
Word 2 ..... 329
Word 3 ..... 329
Word 4 ..... 330
Word 5 ..... 330
Word 6 ..... 331
Word 7 ..... 331
Modes of Operation ..... 308
Overview ..... 307
CAN Module (CAN) ..... 307
CLC
Control Registers ..... 262
Code Examples
Port Write/Read ..... 130
PWM Write-Protected Register Unlock Sequence ..... 188
PWRSAV Instruction Syntax ..... 115
Code Protection ..... 347, 357
CodeGuard Security ..... 347, 357
Configurable Logic Cell (CLC) ..... 259
Configurable Logic Cell. *See* CLC.
Configuration Bits ..... 347
Description ..... 349
Configuration Register Map ..... 348
Constant-Current Source ..... 345
Control Register ..... 346
Description ..... 345
Features Overview ..... 345
Controller Area Network. *See* CAN.
CPU
Addressing Modes ..... 21
Clocking System Options ..... 105
Fast RC (FRC) Oscillator ..... 105
FRC Oscillator with PLL (FRCPLL) ..... 105
FRC Oscillator with Postscaler ..... 105
Low-Power RC (LPRC) Oscillator ..... 105
Primary (XT, HS, EC) Oscillator ..... 105
Primary Oscillator with PLL (XTPLL, HSPLL, ECPLL) ..... 105
Control Registers ..... 26
Data Space Addressing ..... 21
Instruction Set ..... 21
Registers ..... 21
Resources ..... 25
Customer Change Notification Service ..... 474
Customer Notification Service ..... 474
Customer Support ..... 474

**D**

Data Address Space ..... 37
Memory Map for dsPIC33EP64GS70X/80X Devices ..... 38
Near Data Space ..... 37
Organization, Alignment ..... 37
SFR Space ..... 37
Width ..... 37
Data Space
Extended X ..... 52
Paged Data Memory Space (figure) ..... 50
Paged Memory Scheme ..... 49
DC Characteristics
Brown-out Reset (BOR) ..... 385
Constant-Current Source Specifications ..... 433
DACx Output (DACOUTx Pin) Specifications ..... 431
Doze Current (IDOZE) ..... 381
I/O Pin Input Specifications ..... 382
I/O Pin Output Specifications ..... 385
Idle Current (IIDLE) ..... 379
Operating Current (IDD) ..... 378
Operating MIPS vs. Voltage ..... 376
Power-Down Current (IPD) ..... 380
Program Memory ..... 386
Temperature and Voltage Specifications ..... 377
Watchdog Timer Delta Current (ΔIWDT) ..... 380
DC/AC Characteristics
Graphs and Tables ..... 435
Demo/Development Boards, Evaluation and Starter Kits ..... 374
Development Support ..... 371
Device Calibration ..... 353
Addresses ..... 353
and Identification ..... 353
Device Programmer
MPLAB PM3 ..... 373
Direct Memory Access. *See* DMA.
DMA Controller
Channel to Peripheral Associations ..... 90
Control Registers ..... 92
DMAxCNT ..... 92
DMAxCON ..... 92
DMAxPAD ..... 92
DMAxREQ ..... 92
DMAxSTAL/H ..... 92
DMAxSTBL/H ..... 92
Supported Peripherals ..... 89
Doze Mode ..... 117
DSP Engine ..... 30

**E**

Electrical Characteristics ..... 375
AC ..... 387
Equations
Device Operating Frequency ..... 105
FPLLO Calculation ..... 105
FVCO Calculation ..... 105
Relationship Between Device and SPIx Clock Speed ..... 244
Errata ..... 10



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**F**

Filter Capacitor (CEFC) Specifications ..... 377
Flash Program Memory ..... 61
  and Table Instructions ..... 61
  Control Registers ..... 64
  Dual Partition Flash Configuration ..... 63
  Operations ..... 62
  Resources ..... 63
  RTSP Operation ..... 62
Flexible Configuration ..... 347

**G**

Getting Started Guidelines ..... 15
  Connection Requirements ..... 15
  CPU Logic Filter Capacitor Connection (VCAP) ..... 16
  Decoupling Capacitors ..... 15
  External Oscillator Pins ..... 17
  ICSP Pins ..... 17
  Master Clear ($\overline{MCLR}$) Pin ..... 16
  Oscillator Value Conditions on Start-up ..... 18
  Targeted Applications ..... 18
  Unused I/Os ..... 18

**H**

High-Speed Analog Comparator
  Applications ..... 335
  Description ..... 334
  Digital-to-Analog Comparator (DAC) ..... 335
  Features Overview ..... 333
  Hysteresis ..... 336
  Pulse Stretcher and Digital Logic ..... 335
  Resources ..... 336
High-Speed PWM
  Features ..... 187
  Resources ..... 188
  Write-Protected Registers ..... 188
High-Speed, 12-Bit Analog-to-Digital Converter (ADC) ..... 273
  Control Registers ..... 276
  Features Overview ..... 273
  Resources ..... 276

**I**

I/O Ports ..... 125
  Configuring Analog/Digital Port Pins ..... 130
  Control Registers ..... 131
  Helpful Tips ..... 140
  Open-Drain Configuration ..... 130
  Parallel I/O (PIO) ..... 125
  Register Maps ..... 127
    PORTA ..... 127
    PORTB ..... 127
    PORTC ..... 128
    PORTD ..... 128
    PORTE ..... 129
  Resources ..... 141
  Write/Read Timing ..... 130
In-Circuit Debugger ..... 357
  MPLAB ICD 3 ..... 373
  PICkit 3 Programmer ..... 373
In-Circuit Emulation ..... 347
In-Circuit Serial Programming (ICSP) ..... 347, 357
Input Capture ..... 177
  Control Registers ..... 178
  Resources ..... 177
Input Change Notification (ICN) ..... 130
Instruction Addressing Modes ..... 53
  File Register Instructions ..... 53
  Fundamental Modes Supported ..... 53
  MAC Instructions ..... 54
  MCU Instructions ..... 53
  Move and Accumulator Instructions ..... 54
  Other Instructions ..... 54
Instruction Set Summary ..... 361
  Overview ..... 364
  Symbols Used in Opcode Descriptions ..... 362
Instruction-Based Power-Saving Modes ..... 115
  Idle ..... 116
  Sleep ..... 116
Inter-Integrated Circuit ($I^2C$) ..... 245
  Control Registers ..... 247
  Resources ..... 245
Inter-Integrated Circuit. *See* $I^2C$.
Internet Address ..... 474
Interrupt Controller
  Alternate Interrupt Vector Table (AIVT) ..... 73
  Control and Status Registers ..... 81
    INTCON1 ..... 81
    INTCON2 ..... 81
    INTCON3 ..... 81
    INTCON4 ..... 81
    INTTREG ..... 81
  Interrupt Vector Details ..... 76
  Interrupt Vector Table (IVT) ..... 73
  Reset Sequence ..... 73
  Resources ..... 81
Interrupts Coincident with Power Save Instructions ..... 116

**J**

JTAG Boundary Scan Interface ..... 347
JTAG Interface ..... 357

**L**

Leading-Edge Blanking (LEB) ..... 187
LPRC Oscillator
  Use with WDT ..... 356

**M**

Memory Organization ..... 31
  Resources ..... 39
  Special Function Register Maps ..... 40
Microchip Internet Web Site ..... 474
Modulo Addressing ..... 55
  Applicability ..... 56
  Operation Example ..... 55
  Start and End Address ..... 55
  W Address Register Selection ..... 55
MPLAB REAL ICE In-Circuit Emulator System ..... 373
MPLAB X Integrated Development
  Environment Software ..... 371
MPLINK Object Linker/MPLIB Object Librarian ..... 372
Multiplexer Input Sources
  CLC1 ..... 265
  CLC2 ..... 266
  CLC3 ..... 267
  CLC4 ..... 268

**O**

Oscillator
- Control Registers ..... 107
- Resources ..... 106

Oscillator Configuration ..... 103

Output Compare ..... 181
- Control Registers ..... 182
- Resources ..... 181

**P**

Packaging ..... 439
- Details ..... 441
- Marking ..... 439

Peripheral Module Disable (PMD) ..... 117

Peripheral Pin Select (PPS) ..... 135
- Available Peripherals ..... 135
- Available Pins ..... 135
- Control ..... 135
- Control Registers ..... 142
- Input Mapping ..... 136
- Output Mapping ..... 138
- Output Selection for Remappable Pins ..... 139
- Selectable Input Sources ..... 137

Peripheral Trigger Generator (PTG) Module ..... 213

Peripheral Trigger Generator. *See* PTG.

Pinout I/O Descriptions (table) ..... 12

Power-Saving Features ..... 115
- Clock Frequency and Switching ..... 115
- Resources ..... 117

Program Address Space ..... 31
- Construction ..... 58
- Data Access from Program Memory Using Table Instructions ..... 59
- Memory Map (dsPIC33EP128GS70X/80X Devices, Dual Partition) ..... 35
- Memory Map (dsPIC33EP128GS70X/80X Devices) ..... 33
- Memory Map (dsPIC33EP64GS70X/80X Devices, Dual Partition) ..... 34
- Memory Map (dsPIC33EP64GS70X/80X Devices) ..... 32
- Table Read High Instructions (TBLRDH) ..... 59
- Table Read Low Instructions (TBLRDL) ..... 59

Program Memory
- Interfacing with Data Memory Spaces ..... 58
- Organization ..... 36
- Reset Vector ..... 36

Programmable Gain Amplifier (PGA) ..... 341
- Description ..... 342
- Resources ..... 343

Programmable Gain Amplifier. *See* PGA.

Programmer's Model ..... 23
- Register Descriptions ..... 23

PTG
- Control Registers ..... 215
- Introduction ..... 213
- Output Descriptions ..... 228
- Step Commands and Format ..... 225

Pulse-Width Modulator. *See PWM.*

**R**

Registers
- ACLKCON (Auxiliary Clock Divisor Control) ..... 112
- ADCAL0L (ADC Calibration 0 High) ..... 300
- ADCAL0L (ADC Calibration 0 Low) ..... 299
- ADCAL1H (ADC Calibration 1 High) ..... 301
- ADCMPxCON (ADC Digital Comparator x Control) ..... 302
- ADCMPxENH (ADC Digital Comparator x Channel Enable High) ..... 303
- ADCMPxENL (ADC Digital Comparator x Channel Enable Low) ..... 303
- ADCON1H (ADC Control 1 High) ..... 277
- ADCON1L (ADC Control 1 Low) ..... 276
- ADCON2H (ADC Control 2 High) ..... 279
- ADCON2L (ADC Control 2 Low) ..... 278
- ADCON3H (ADC Control 3 High) ..... 281
- ADCON3L (ADC Control 3 Low) ..... 280
- ADCON4H (ADC Control 4 High) ..... 283
- ADCON4L (ADC Control 4 Low) ..... 282
- ADCON5H (ADC Control 5 High) ..... 285
- ADCON5L (ADC Control 5 Low) ..... 284
- ADCORExH (Dedicated ADC Core x Control High) ..... 287
- ADCORExL (Dedicated ADC Core x Control Low) ..... 286
- ADEIEH (ADC Early Interrupt Enable High) ..... 289
- ADEIEL (ADC Early Interrupt Enable Low) ..... 289
- ADEISTATH (ADC Early Interrupt Status High) ..... 290
- ADEISTATL (ADC Early Interrupt Status Low) ..... 290
- ADFLxCON (ADC Digital Filter x Control) ..... 304
- ADIEH (ADC Interrupt Enable High) ..... 293
- ADIEL (ADC Interrupt Enable Low) ..... 293
- ADLVLTRGH (ADC Level-Sensitive Trigger Control High) ..... 288
- ADLVLTRGL (ADC Level-Sensitive Trigger Control Low) ..... 288
- ADMOD0H (ADC Input Mode Control 0 High) ..... 291
- ADMOD0L (ADC Input Mode Control 0 Low) ..... 291
- ADMOD1L (ADC Input Mode Control 1 Low) ..... 292
- ADSTATH (ADC Data Ready Status High) ..... 294
- ADSTATL (ADC Data Ready Status Low) ..... 294
- ADTRIGxH (ADC Channel Trigger x Selection High) ..... 297
- ADTRIGxL (ADC Channel Trigger x Selection Low) ..... 295
- ALTDTRx (PWMx Alternate Dead-Time) ..... 203
- ANSELx (Analog Select Control x) ..... 134
- AUXCONx (PWMx Auxiliary Control) ..... 211
- CHOP (PWMx Chop Clock Generator) ..... 196
- CLCxCONH (CLCx Control High) ..... 263
- CLCxCONL (CLCx Control Low) ..... 262
- CLCxGLSH (CLCx Gate Logic Input Select High) ..... 271
- CLCxGLSL (CLCx Gate Logic Input Select Low) ..... 269
- CLCxSEL (CLCx Input MUX Select) ..... 264
- CLKDIV (Clock Divisor) ..... 109
- CMPxCON (Comparator x Control) ..... 337
- CMPxDAC (Comparator x DAC Control) ..... 339
- CNENx (Input Change Notification Interrupt Enable x) ..... 133



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CNPDx (Input Change Notification Pull-Down Enable x) ..... 134
CNPUx (Input Change Notification Pull-up Enable x) ..... 133
CORCON (Core Control) ..... 28, 83
CTXTSTAT (CPU W Register Context Status) ..... 29
CxBUFPNT1 (CANx Filters 0-3 Buffer Pointer 1) ..... 318
CxBUFPNT2 (CANx Filters 4-7 Buffer Pointer 2) ..... 319
CxBUFPNT3 (CANx Filters 8-11 Buffer Pointer 3) ..... 319
CxBUFPNT4 (CANx Filters 12-15 Buffer Pointer 4) ..... 320
CxCFG1 (CANx Baud Rate Configuration 1) ..... 316
CxCFG2 (CANx Baud Rate Configuration 2) ..... 317
CxCTRL1 (CANx Control 1) ..... 309
CxCTRL2 (CANx Control 2) ..... 310
CxEC (CANx Transmit/Receive Error Count) ..... 316
CxFCTRL (CANx FIFO Control) ..... 312
CxFEN1 (CANx Acceptance Filter Enable 1) ..... 318
CxFIFO (CANx FIFO Status) ..... 313
CxFMSKSEL1 (CANx Filters 7-0 Mask Selection 1) ..... 322
CxFMSKSEL2 (CANx Filters 15-8 Mask Selection 2) ..... 323
CxINTE (CANx Interrupt Enable) ..... 315
CxINTF (CANx Interrupt Flag) ..... 314
CxRXFnEID (CANx Acceptance Filter n Extended Identifier) ..... 321
CxRXFnSID (CANx Acceptance Filter n Standard Identifier) ..... 321
CxRXFUL1 (CANx Receive Buffer Full 1) ..... 325
CxRXFUL2 (CANx Receive Buffer Full 2) ..... 325
CxRXMnEID (CANx Acceptance Filter Mask n Extended Identifier) ..... 324
CxRXMnSID (CANx Acceptance Filter Mask n Standard Identifier) ..... 324
CxRXOVF1 (CANx Receive Buffer Overflow 1) ..... 326
CxRXOVF2 (CANx Receive Buffer Overflow 2) ..... 326
CxTRmnCON (CANx TX/RX Buffer mn Control) ..... 327
CxVEC (CANx Interrupt Code) ..... 311
DEVID (Device ID) ..... 354
DEVREV (Device Revision) ..... 354
DMALCA (DMA Last Channel Active Status) ..... 100
DMAPPS (DMA Ping-Pong Status) ..... 101
DMAPWC (DMA Peripheral Write Collision Status) ..... 98
DMARQC (DMA Request Collision Status) ..... 99
DMAxCNT (DMA Channel x Transfer Count) ..... 96
DMAxCON (DMA Channel x Control) ..... 92
DMAxPAD (DMA Channel x Peripheral Address) ..... 96
DMAxREQ (DMA Channel x IRQ Select) ..... 93
DMAxSTAH (DMA Channel x Start Address A, High) ..... 94
DMAxSTAL (DMA Channel x Start Address A, Low) ..... 94
DMAxSTBH (DMA Channel x Start Address B, High) ..... 95
DMAxSTBL (DMA Channel x Start Address B, Low) ..... 95
DSADRH (DMA Most Recent RAM High Address) ..... 97
DSADRL (DMA Most Recent RAM Low Address) ..... 97
DTRx (PWMx Dead-Time) ..... 203
FCLCONx (PWMx Fault Current-Limit Control) ..... 207
I2CxCONH (I2Cx Control High) ..... 249
I2CxCONL (I2Cx Control Low) ..... 247
I2CxMSK (I2Cx Slave Mode Address Mask) ..... 252
I2CxSTAT (I2Cx Status) ..... 250
ICxCON1 (Input Capture x Control 1) ..... 178
ICxCON2 (Input Capture x Control 2) ..... 179
INTCON1 (Interrupt Control 1) ..... 84
INTCON2 (Interrupt Control 2) ..... 86
INTCON3 (Interrupt Control 3) ..... 87
INTCON4 (Interrupt Control 4) ..... 87
INTTREG (Interrupt Control and Status) ..... 88
IOCONx (PWMx I/O Control) ..... 205
ISRCCON (Constant-Current Source Control) ..... 346
LATx (PORTx Data Latch) ..... 132
LEBCONx (PWMx Leading-Edge Blanking Control) ..... 209
LEBDLYx (PWMx Leading-Edge Blanking Delay) ..... 210
LFSR (Linear Feedback Shift) ..... 114
MDC (PWMx Master Duty Cycle) ..... 197
NVMADR (Nonvolatile Memory Lower Address) ..... 67
NVMADRU (Nonvolatile Memory Upper Address) ..... 67
NVMCON (Nonvolatile Memory (NVM) Control) ..... 65
NVMKEY (Nonvolatile Memory Key) ..... 68
NVMSRCADR (NVM Source Data Address) ..... 68
OCxCON1 (Output Compare x Control 1) ..... 182
OCxCON2 (Output Compare x Control 2) ..... 184
ODCx (PORTx Open-Drain Control) ..... 132
OSCCON (Oscillator Control) ..... 107
OSCTUN (FRC Oscillator Tuning) ..... 111
PDCx (PWMx Generator Duty Cycle) ..... 200
PGAxCAL (PGAx Calibration) ..... 344
PGAxCON (PGAx Control) ..... 343
PHASEx (PWMx Primary Phase-Shift) ..... 201
PLLFBD (PLL Feedback Divisor) ..... 110
PMD1 (Peripheral Module Disable Control 1) ..... 118
PMD2 (Peripheral Module Disable Control 2) ..... 120
PMD3 (Peripheral Module Disable Control 3) ..... 121
PMD4 (Peripheral Module Disable Control 4) ..... 121
PMD6 (Peripheral Module Disable Control 6) ..... 122
PMD7 (Peripheral Module Disable Control 7) ..... 123
PMD8 (Peripheral Module Disable Control 8) ..... 124
PORTx (I/O PORTx) ..... 131
PTCON (PWMx Time Base Control) ..... 191
PTCON2 (PWMx Clock Divider Select) ..... 192
PTGADJ (PTG Adjust) ..... 223
PTGBTE (PTG Broadcast Trigger Enable) ..... 218
PTGC0LIM (PTG Counter 0 Limit) ..... 221
PTGC1LIM (PTG Counter 1 Limit) ..... 222
PTGCON (PTG Control) ..... 217
PTGCST (PTG Control/Status) ..... 215
PTGHOLD (PTG Hold) ..... 222
PTGL0 (PTG Literal 0) ..... 223
PTGQPTR (PTG Step Queue Pointer) ..... 224
PTGQUEx (PTG Step Queue x) ..... 224
PTGSDLIM (PTG Step Delay Limit) ..... 221
PTGT0LIM (PTG Timer0 Limit) ..... 220
PTGT1LIM (PTG Timer1 Limit) ..... 220
PTPER (PWMx Primary Master Time Base Period) ..... 193
PWMCAPx (PWMx Primary Time Base Capture) ..... 212
PWMCONx (PWMx Control) ..... 198
PWMKEY (PWMx Protection Lock/Unlock Key) ..... 197
RCON (Reset Control) ..... 71
REFOCON (Reference Oscillator Control) ..... 113
RPINR0 (Peripheral Pin Select Input 0) ..... 142
RPINR1 (Peripheral Pin Select Input 1) ..... 142

RPINR11 (Peripheral Pin Select Input 11) ..... 145
RPINR12 (Peripheral Pin Select Input 12) ..... 145
RPINR13 (Peripheral Pin Select Input 13) ..... 146
RPINR18 (Peripheral Pin Select Input 18) ..... 146
RPINR19 (Peripheral Pin Select Input 19) ..... 147
RPINR2 (Peripheral Pin Select Input 2) ..... 143
RPINR20 (Peripheral Pin Select Input 20) ..... 147
RPINR21 (Peripheral Pin Select Input 21) ..... 148
RPINR22 (Peripheral Pin Select Input 22) ..... 148
RPINR23 (Peripheral Pin Select Input 23) ..... 149
RPINR26 (Peripheral Pin Select Input 26) ..... 149
RPINR29 (Peripheral Pin Select Input 29) ..... 150
RPINR3 (Peripheral Pin Select Input 3) ..... 143
RPINR30 (Peripheral Pin Select Input 30) ..... 150
RPINR37 (Peripheral Pin Select Input 37) ..... 151
RPINR38 (Peripheral Pin Select Input 38) ..... 151
RPINR42 (Peripheral Pin Select Input 42) ..... 152
RPINR43 (Peripheral Pin Select Input 43) ..... 152
RPINR45 (Peripheral Pin Select Input 45) ..... 153
RPINR46 (Peripheral Pin Select Input 46) ..... 153
RPINR7 (Peripheral Pin Select Input 7) ..... 144
RPINR8 (Peripheral Pin Select Input 8) ..... 144
RPOR0 (Peripheral Pin Select Output 0) ..... 154
RPOR1 (Peripheral Pin Select Output 1) ..... 154
RPOR10 (Peripheral Pin Select Output 10) ..... 159
RPOR11 (Peripheral Pin Select Output 11) ..... 159
RPOR12 (Peripheral Pin Select Output 12) ..... 160
RPOR13 (Peripheral Pin Select Output 13) ..... 160
RPOR14 (Peripheral Pin Select Output 14) ..... 161
RPOR15 (Peripheral Pin Select Output 15) ..... 161
RPOR16 (Peripheral Pin Select Output 16) ..... 162
RPOR17 (Peripheral Pin Select Output 17) ..... 162
RPOR18 (Peripheral Pin Select Output 18) ..... 163
RPOR19 (Peripheral Pin Select Output 19) ..... 163
RPOR2 (Peripheral Pin Select Output 2) ..... 155
RPOR20 (Peripheral Pin Select Output 20) ..... 164
RPOR21 (Peripheral Pin Select Output 21) ..... 164
RPOR22 (Peripheral Pin Select Output 22) ..... 165
RPOR23 (Peripheral Pin Select Output 23) ..... 165
RPOR24 (Peripheral Pin Select Output 24) ..... 166
RPOR25 (Peripheral Pin Select Output 25) ..... 166
RPOR26 (Peripheral Pin Select Output 26) ..... 167
RPOR3 (Peripheral Pin Select Output 3) ..... 155
RPOR4 (Peripheral Pin Select Output 4) ..... 156
RPOR5 (Peripheral Pin Select Output 5) ..... 156
RPOR6 (Peripheral Pin Select Output 6) ..... 157
RPOR7 (Peripheral Pin Select Output 7) ..... 157
RPOR8 (Peripheral Pin Select Output 8) ..... 158
RPOR9 (Peripheral Pin Select Output 9) ..... 158
SDCx (PWMx Secondary Duty Cycle) ..... 200
SEVTCMP (PWMx Special Event Compare) ..... 193
SPHASEx (PWMx Secondary Phase-Shift) ..... 202
SPIxCON1H (SPIx Control 1 High) ..... 234
SPIxCON1L (SPIx Control 1 Low) ..... 232
SPIxCON2L (SPIx Control 2 Low) ..... 236
SPIxIMSKH (SPIx Interrupt Mask High) ..... 241
SPIxIMSKL (SPIx Interrupt Mask Low) ..... 240
SPIxSTATH (SPIx Status High) ..... 239
SPIxSTATL (SPIx Status Low) ..... 237
SR (CPU STATUS) ..... 26, 82
SSEVTCMP (PWMx Secondary Special Event Compare) ..... 196
STCON (PWMx Secondary Master Time Base Control) ..... 194
STCON2 (PWMx Secondary Clock Divider Select) ..... 195
STPER (PWMx Secondary Master Time Base Period) ..... 195
STRIGx (PWMx Secondary Trigger Compare Value) ..... 208
T1CON (Timer1 Control) ..... 171
TRGCONx (PWMx Trigger Control) ..... 204
TRIGx (PWMx Primary Trigger Compare Value) ..... 206
TRISx (PORTx Data Direction Control) ..... 131
TxCON (Timer2/4 Control) ..... 175
TyCON (Timer3/5 Control) ..... 176
UxMODE (UARTx Mode) ..... 255
UxSTA (UARTx Status and Control) ..... 257
Resets ..... 69
Brown-out Reset (BOR) ..... 69
Configuration Mismatch Reset (CM) ..... 69
Illegal Condition Reset (IOPUWR) ..... 69
Illegal Opcode ..... 69
Security ..... 69
Uninitialized W Register ..... 69
Master Clear ($\overline{MCLR}$) Pin Reset ..... 69
Power-on Reset (POR) ..... 69
RESET Instruction (SWR) ..... 69
Resources ..... 70
Trap Conflict Reset (TRAPR) ..... 69
Watchdog Timer Time-out Reset (WDTO) ..... 69
Revision History ..... 465

## S

Serial Peripheral Interface (SPI) ..... 229
Serial Peripheral Interface. *See* SPI.
SFR Blocks
000h ..... 40
100h ..... 40
200h ..... 41
300h ..... 41
400h ..... 42
500h ..... 42
600h ..... 43
700h ..... 44
800h ..... 45
900h ..... 45
A00h ..... 46
B00h ..... 46
C00h-D00h ..... 47
E00h-F00h ..... 48
Software Simulator
MPLAB X SIM ..... 373
Special Features of the CPU ..... 347

## T

Thermal Operating Conditions ..... 376
Thermal Packaging Characteristics ..... 376
Third-Party Development Tools ..... 374
Timer1 ..... 169
Control Register ..... 171
Mode Settings ..... 169
Resources ..... 170
Timer2/3 and Timer4/5 ..... 173
Control Registers ..... 175
Resources ..... 173


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Timing Diagrams
BOR and Master Clear Reset Characteristics ..... 391
CANx I/O ..... 426
External Clock ..... 388
High-Speed PWMx Fault Characteristics ..... 397
High-Speed PWMx Module Characteristics ..... 397
I/O Characteristics ..... 391
I2Cx Bus Data (Master Mode) ..... 422
I2Cx Bus Data (Slave Mode) ..... 424
I2Cx Bus Start/Stop Bits (Master Mode) ..... 422
I2Cx Bus Start/Stop Bits (Slave Mode) ..... 424
Input Capture x (ICx) Characteristics ..... 395
OCx/PWMx Characteristics ..... 396
Output Compare x (OCx) Characteristics ..... 396
SPI1, SPI2 and SPI3 Master Mode (Full-Duplex, CKE = 0, CKP = x, SMP = 1) ..... 401
SPI1, SPI2 and SPI3 Master Mode (Full-Duplex, CKE = 1, CKP = x, SMP = 1) ..... 400
SPI1, SPI2 and SPI3 Master Mode (Half-Duplex, Transmit Only, CKE = 0) ..... 398
SPI1, SPI2 and SPI3 Master Mode (Half-Duplex, Transmit Only, CKE = 1) ..... 399
SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 0, SMP = 0) ..... 408
SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 1, SMP = 0) ..... 406
SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 0, SMP = 0) ..... 402
SPI1, SPI2 and SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 1, SMP = 0) ..... 404
SPI3 Master Mode (Full-Duplex, CKE = 0, CKP = x, SMP = 1) ..... 413
SPI3 Master Mode (Full-Duplex, CKE = 1, CKP = x, SMP = 1) ..... 412
SPI3 Master Mode (Half-Duplex, Transmit Only, CKE = 0) ..... 410
SPI3 Master Mode (Half-Duplex, Transmit Only, CKE = 1) ..... 411
SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 0, SMP = 0) ..... 420
SPI3 Slave Mode (Full-Duplex, CKE = 0, CKP = 1, SMP = 0) ..... 418
SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 0, SMP = 0) ..... 414
SPI3 Slave Mode (Full-Duplex, CKE = 1, CKP = 1, SMP = 0) ..... 416
Timer1-Timer5 External Clock Characteristics ..... 393
UARTx I/O Characteristics ..... 427

**U**

UART
Unique Device Identifier (UDID) ..... 32
Universal Asynchronous Receiver
Transmitter (UART) ..... 253
Control Registers ..... 255
Helpful Tips ..... 254
Resources ..... 254
Universal Asynchronous Receiver Transmitter. *See* UART.
User OTP Memory ..... 355

**V**

Voltage Regulator (On-Chip) ..... 355

**W**

Watchdog Timer (WDT) ..... 347, 356
Programming Considerations ..... 356
WWW Address ..... 474
WWW, On-Line Support ..... 10

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## PRODUCT IDENTIFICATION SYSTEM

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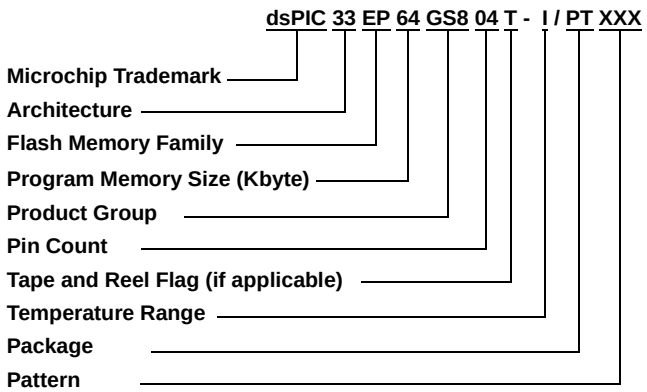


| | | | |
|---|---|---|---|
| **Architecture:** | 33 | = | 16-Bit Digital Signal Controller |
| **Flash Memory Family:** | EP | = | Enhanced Performance |
| **Product Group:** | GS | = | SMPS Family |
| **Pin Count:** | 02 | = | 28-pin |
| | 04 | = | 44-pin |
| | 05 | = | 48-pin |
| | 06 | = | 64-pin |
| | 08 | = | 80-pin |
| **Temperature Range:** | I | = | -40°C to +85°C (Industrial) |
| | E | = | -40°C to +125°C (Extended) |
| **Package:** | ML | = | Plastic Quad, No Lead Package – (44-pin) 8x8 mm body (QFN) |
| | MM | = | Plastic Quad, No Lead Package – (28-pin) 6x6 mm body (QFN-S) |
| | 2N | = | Plastic Quad Flat, No Lead Package – (28-pin) 6x6 mm body (UQFN) |
| | PT | = | Plastic Thin Quad Flatpack – (44-pin) 10x10 mm body (TQFP) |
| | PT | = | Plastic Thin Quad Flatpack – (48-pin) 7x7 mm body (TQFP) |
| | PT | = | Plastic Thin Quad Flatpack – (64-pin) 10x10 mm body (TQFP) |
| | PT | = | Plastic Thin Quad Flatpack – (80-pin) 12x12 mm body (TQFP) |
| | SO | = | Plastic Small Outline, Wide – (28-pin) 7.50 mm body (SOIC) |

**Examples:**

dsPIC33EP64GS804-I/PT:
dsPIC33, Enhanced Performance, 64-Kbyte Program Memory, SMPS, 44-Pin, Industrial Temperature, TQFP Package.

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