# dsPIC33CDVL64MC106 FAMILY

## 16-Bit Digital Signal Controllers with High-Resolution PWM, Op Amps, Advanced Analog, MOSFET Driver and LIN Transceiver

### Operating Conditions

- 3.0V to 3.6V: -40°C to +125°C, DC to 100 MIPS
- 3.0V to 3.6V: -40°C to +150°C, DC to 70 MIPS

### Host dsPIC DSC Features

- Based on dsPIC33CK64MC105
- 16-Bit Wide Data Path
- Code Efficient (C and Assembly) Architecture
- 40-Bit Wide Accumulators
- Single-Cycle (MAC/MPY) with Dual Data Fetch
- Single-Cycle, Mixed-Sign Multiply:
  - 32-bit multiply support
- Fast Six-Cycle Divide
- Zero Overhead Looping

### High-Resolution PWM

- Four PWM Pairs
- Up to 2 ns PWM Resolution
- Dead Time for Rising and Falling Edges
- Dead-Time Compensation
- Clock Chopping for High-Frequency Operation
- PWM Support for:
  - DC/DC, AC/DC, inverters, PFC, lighting
  - BLDC, PMSM, ACIM, SRM motors
- Fault and Current Limit Inputs
- Flexible Trigger Configuration for ADC Triggering

### High-Speed Analog-to-Digital Converter

- Up to 15 A/D inputs
- 12-Bit Resolution
- One Shared SAR ADC Core
- Up to 3.5 Msps Conversion Rate per Core
- Dedicated Result Buffer for Each Analog Channel
- Flexible and Independent ADC Trigger Sources
- Four Digital Comparators
- Four Oversampling Filters

### Microcontroller Features

- High-Current I/O Sink/Source
- Edge or Level Change Notification Interrupt on I/O Pins
- Peripheral Pin Select (PPS) Remappable Pins
- Up to 64 Kbytes Flash Memory:
  - Ten thousand erase/write cycle endurance
  - Twenty years minimum data retention
  - Self-programmable under software control
  - Programmable code protection
  - Error Code Correction (ECC)
  - Flash OTP by ICSP™ Write Inhibit
- Eight Kbytes SRAM Memory:
  - SRAM Memory Built-In Self-Test (MBIST)
- Multiple Interrupt Vectors with Individually Programmable Priority
- Four Sets of Interrupt Context Saving Registers which Include Accumulator and STATUS for Fast Reserved Interrupt Handling
- Four External Interrupt Pins
- Watchdog Timer (WDT)
- Windowed Deadman Timer (DMT)
- Fail-Safe Clock Monitor (FSCM) with Dedicated Oscillator
- Selectable Oscillator Options Including:
  - High-precision, 8 MHz internal Fast RC (FRC) Oscillator
  - Primary high-speed, crystal/resonator oscillator or external clock
  - Primary PLL, which can be clocked from FRC or crystal oscillator
- Low-Power Management Modes (Sleep and Idle)
- Power-on Reset and Brown-out Reset
- On-Board Capacitorless Regulator
- Three Hundred Eighty-Four Bytes of One-Time-Programmable (OTP) Memory

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## Peripheral Features

- Two Four-Wire SPI Modules (up to 50 Mbps):
  - 16-byte FIFO
  - Variable width
  - I2S mode
- One I2C Host and Client w/Address Masking and IPMI Support
- Three Protocol UARTs with Automated Handling Support for:
  - LIN 2.2
  - DMX
  - Smart card (ISO 7816)
- One SENT module
- Timers/Counters:
  - One dedicated 16-bit timer/counter
- Four Single Output Capture/Compare/PWM/Timer (SCCP) Modules:
  - Flexible configuration as PWM, input capture, output compare or timers
  - Two 16-bit timers or one 32-bit timer in each module
  - PWM resolution down to 2.5 ns
  - Single PWM output
- One Quadrature Encoder Interface (QEI):
  - Four inputs: Phase A, Phase B, Home and Index
  - One 32-bit timer/counter (in QEI module, available if encoder is not used)
- Reference Clock Output (REFCLKO)
- Four Configurable Logic Cells (CLC) with Internal Connections to Select Peripherals and PPS
- Four-Channel Hardware DMA
- 32-Bit CRC Calculation Module
- Peripheral Trigger Generator (PTG):
  - Sixteen possible trigger sources to other peripheral modules
  - CPU-independent state machine-based instruction sequencer
  - Two 16-bit general purpose timers

## Analog Features

- One Fast Analog Comparator with Input Multiplexing
- Three Operational Amplifiers
- One 12-Bit PDM DAC with Slope Compensation
- One Output DAC Buffer

## Debug Features

- Three Programming and Debugging Interfaces:
  - Two-wire ICSP™ interface with non-intrusive access and real-time data exchange with application
- Three Complex, Five Simple Breakpoints
- IEEE Standard 1149.2 Compatible (JTAG) Boundary Scan

## Safety Features

- Backup Fast RC Oscillator (BFRC)
- Brown-out Reset (BOR)
- Capless Internal Voltage Regulator
- Clock Monitor System with Backup Oscillator
- CodeGuard™ Security
- Cyclic Redundancy Check (CRC)
- Dual Watchdog Timer (WDT)
- Fail-Safe Clock Monitoring (FSCM)
- Flash Error Correcting Code (ECC)
- Flash OTP by ICSP™ Write Inhibit
- RAM Memory Built-In Self-Test (MBIST)
- Two-Speed Start-up
- Virtual Pins for Redundancy and Monitoring
- Windowed Deadman Timer (DMT)

## MOSFET Gate Driver Module (Based on MCP8021 Device)

- Three Half-Bridge Drivers Configured to Drive External High-Side NMOS and Low-Side NMOS MOSFETs:
  - Peak output current: 0.5A @ 12V
  - Shoot-through protection
  - Overcurrent and short-circuit protection
- Fixed Output Linear Regulator:
  - 3.3V @ 70 mA
  - True current foldback
- Protection Features:
  - Gate drive undervoltage lockout: 4.5V
  - Supply voltage undervoltage shutdown: 4.5V
  - Supply voltage Undervoltage Lockout (UVLO): 6.25V
  - Overvoltage Lockout (OVLO): 32V
  - Transient (100 ms) Voltage Tolerance: 40V
  - Power Module Thermal Shutdown


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### LIN Transceiver Module (Based on ATA663211 Device) (dsPIC33CDVL64MC106 Only)

- LIN_BUS Voltage Up to 40V
- LIN_$V_{DD}$ Voltage = 5V to 28V
- Very Low Supply Current:
  - Sleep mode: typically 9 µA
  - Fail-Safe mode: typically 80 µA
  - Normal mode: typically 250 µA
- Fully Compatible with 3.3V and 5V Devices
- LIN Physical Layer According to LIN 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2
- Wake-up Capability via LIN_BUS Activity (100 µs dominant)
- External Wake-up via LIN_WKIN Pin (100 µs low level)

### Functional Safety Readiness – ISO 26262 / IEC 61508 / IEC 60730

To learn about the functional safety readiness of this device family and various functional safety standards that an application can target using this device family, visit www.microchip.com/dsPIC33-Functional-Safety.

### Qualification

- AEC-Q100 REV G (Grade 1: -40°C to +125°C)
- AEC-Q100 REV G (Grade 0: -40°C to +150°C)

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## dsPIC33CDVL64MC106

The dsPIC33CDVL64MC106 family device features are listed in Table 1.

**TABLE 1: dsPIC33CDVL64MC106 DEVICE FEATURES**

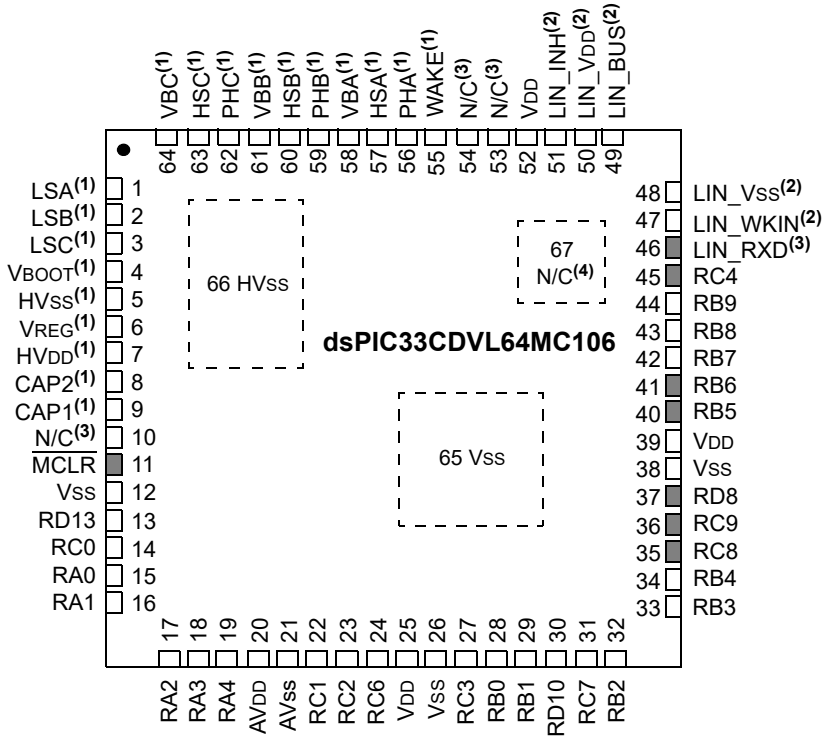
| Device | Pins | Flash (Kbytes) | SRAM (Kbytes) | DMA # of Ch | GPIO/PPS | LIN Transceiver | MOSFET Gate Driver | 16-Bit Timer | SCCP | UART | SPI | $I^2C$ | SENT | MC PWM | PWM Res (ns) | QEI | 12-Bit ADC Module | ADC Channels | Op Amp | Analog Comp w/12-Bit DAC | PTG | CLC | REFO | CRC | WDT/DMT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dsPIC33CDVL64MC106 | 64 | 64 | 8 | 4 | 27/22 | 1 | 1 | 1 | 4 | 3 | 2 | 1 | 1 | 4x2 | 2 | 1 | 1 | 15 | 3 | 1 | 1 | 4 | 1 | 1 | 1/1 |
| dsPIC33CDV64MC106 | 64 | 64 | 8 | 4 | 30/25 | 0 | 1 | 1 | 4 | 3 | 2 | 1 | 1 | 4x2 | 2 | 1 | 1 | 15 | 3 | 1 | 1 | 4 | 1 | 1 | 1/1 |


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## Pin Diagrams

**64-Pin VGQFN**

■ = 5.5 VDC Tolerant




**Note 1:** These pins are specific to the MOSFET gate driver module.

**2:** These pins are specific to the LIN transceiver module.

**3:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**4:** Pin has no electrical connection to the device but is recommended to be connected to VSS/LIN_VSS in the PCB design to improve thermal dissipation.

**TABLE 2: dsPIC33CDVL64MC106 COMPLETE PIN FUNCTIONS**

| Pin | Function | Pin | Function |
|---|---|---|---|
| 1 | LSA | 35 | **RP56**/ASDA1/SCK2/RC8 |
| 2 | LSB | 36 | **RP57**/ASCL1/SDI2/RC9 |
| 3 | LSC | 37 | **RP72**/PCI19/SDO2/RD8 |
| 4 | VBOOT | 38 | VSS |
| 5 | HVSS | 39 | VDD |
| 6 | VREG | 40 | PGD3/**RP37**/RB5 |
| 7 | HVDD | 41 | PGC3/**RP38**/RB6 |
| 8 | CAP2 | 42 | AN2/**RP39**/RB7 |
| 9 | CAP1 | 43 | PGD1/AN10/**RP40**/SCL1/RB8 |
| 10 | N/C(1) | 44 | PGC1/AN11/**RP41**/SDA1/RB9 |
| 11 | $\overline{\text{MCLR}}$ | 45 | **RP52**/RC4 |
| 12 | Vss | 46 | LIN_RXD(1) |
| 13 | ANN0/**RP77**/RD13 | 47 | LIN_WKIN |
| 14 | AN12/**RP48**/RC0 | 48 | LIN_Vss |
| 15 | OA1OUT/AN0/CMP1A/IBIAS0/RA0 | 49 | LIN_BUS |
| 16 | OA1IN-/RA1 | 50 | LIN_VDD |
| 17 | OA1IN+/AN9/RA2 | 51 | LIN_INH |
| 18 | DACOUT/AN3/CMP1C/RA3 | 52 | VDD |
| 19 | OA3OUT/AN4/IBIAS3/RA4 | 53 | N/C(1) |
| 20 | AVDD | 54 | N/C(1) |
| 21 | AVSS | 55 | WAKE |
| 22 | OA3IN-/AN13/CMP1B/ISRC0/**RP49**/RC1 | 56 | PHA |
| 23 | OA3IN+/AN14/ISRC1/**RP50**/RC2 | 57 | HSA |
| 24 | IBIAS1/**RP54**/RC6 | 58 | VBA |
| 25 | VDD | 59 | PHB |
| 26 | VSS | 60 | HSB |
| 27 | AN15/IBIAS2/**RP51**/RC3 | 61 | VBB |
| 28 | OSCI/CLKI/AN5/**RP32**/RB0 | 62 | PHC |
| 29 | OSCO/CLKO/AN6/**RP33**/RB1 | 63 | HSC |
| 30 | ISRC3/**RP74**/RD10 | 64 | VBC |
| 31 | ISRC2/**RP55**/RC7 | 65 | VSS(2) |
| 32 | OA2OUT/AN1/AN7/CMP1D/**RP34**/INT0/RB2 | 66 | HVSS(2) |
| 33 | PGD2/OA2IN-/AN8/**RP35**/RB3 | 67 | N/C(3) |
| 34 | PGC2/OA2IN+/**RP36**/RB4 | | |

**Legend:** **RPn** represents remappable pins for the Peripheral Pin Select (PPS) function.

**Note 1:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**2:** Pin is connected to a device exposed pad.

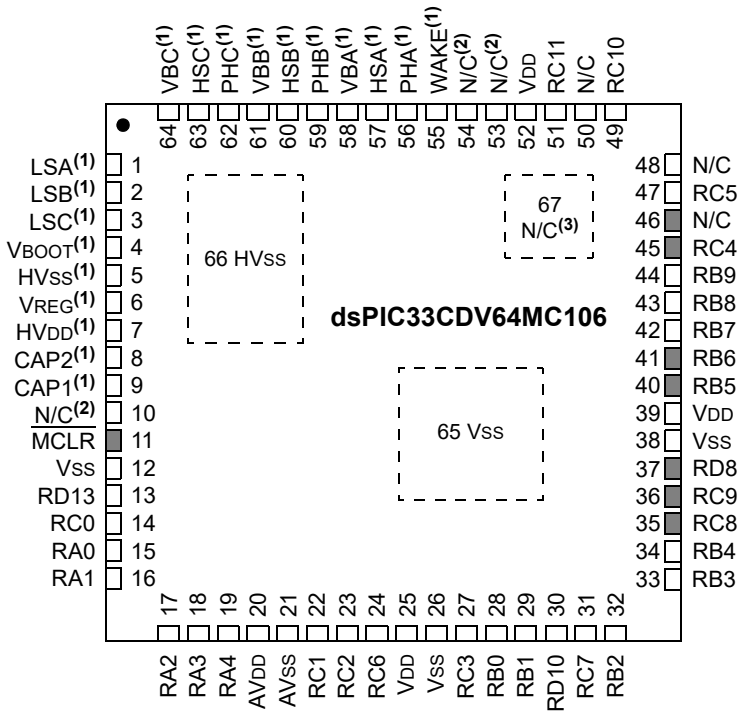
**3:** Pin has no electrical connection to the device, but is recommended to be connected to VSS in the PCB design to improve thermal dissipation.


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## Pin Diagrams (Continued)

**64-Pin VGQFN**

■ = 5.5 VDC Tolerant




**Note 1:** These pins are specific to the MOSFET gate driver module.

**2:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**3:** Pin has no electrical connection to the device, but is recommended to be connected to Vss in the PCB design to improve thermal dissipation.

**TABLE 3: dsPIC33CDV64MC106 COMPLETE PIN FUNCTIONS**

| Pin | Function | Pin | Function |
|---|---|---|---|
| 1 | LSA | 35 | **RP56**/ASDA1/SCK2/RC8 |
| 2 | LSB | 36 | **RP57**/ASCL1/SDI2/RC9 |
| 3 | LSC | 37 | **RP72**/PCI19/SDO2/RD8 |
| 4 | VBOOT | 38 | VSS |
| 5 | HVSS | 39 | VDD |
| 6 | VREG | 40 | PGD3/**RP37**/RB5 |
| 7 | HVDD | 41 | PGC3/**RP38**/RB6 |
| 8 | CAP2 | 42 | AN2/**RP39**/RB7 |
| 9 | CAP1 | 43 | PGD1/AN10/**RP40**/SCL1/RB8 |
| 10 | N/C(1) | 44 | PGC1/AN11/**RP41**/SDA1/RB9 |
| 11 | $\overline{\text{MCLR}}$ | 45 | **RP52**/RC4 |
| 12 | VSS | 46 | N/C |
| 13 | ANN0/**RP77**/RD13 | 47 | **RP53**/RC5 |
| 14 | AN12/**RP48**/RC0 | 48 | N/C |
| 15 | OA1OUT/AN0/CMP1A/IBIAS0/RA0 | 49 | **RP58**/RC10 |
| 16 | OA1IN-/RA1 | 50 | N/C |
| 17 | OA1IN+/AN9/RA2 | 51 | **RP59**/RC11 |
| 18 | DACOUT/AN3/CMP1C/RA3 | 52 | VDD |
| 19 | OA3OUT/AN4/IBIAS3/RA4 | 53 | N/C(1) |
| 20 | AVDD | 54 | N/C(1) |
| 21 | AVSS | 55 | WAKE |
| 22 | OA3IN-/AN13/CMP1B/ISRC0/**RP49**/RC1 | 56 | PHA |
| 23 | OA3IN+/AN14/ISRC1/**RP50**/RC2 | 57 | HSA |
| 24 | IBIAS1/**RP54**/RC6 | 58 | VBA |
| 25 | VDD | 59 | PHB |
| 26 | VSS | 60 | HSB |
| 27 | AN15/IBIAS2/**RP51**/RC3 | 61 | VBB |
| 28 | OSCI/CLKI/AN5/**RP32**/RB0 | 62 | PHC |
| 29 | OSCO/CLKO/AN6/**RP33**/RB1 | 63 | HSC |
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| 31 | ISRC2/**RP55**/RC7 | 65 | VSS(2) |
| 32 | OA2OUT/AN1/AN7/CMP1D/**RP34**/INT0/RB2 | 66 | HVSS(2) |
| 33 | PGD2/OA2IN-/AN8/**RP35**/RB3 | 67 | N/C(3) |
| 34 | PGC2/OA2IN+/**RP36**/RB4 | | |

**Legend:** **RPn** represents remappable pins for the Peripheral Pin Select (PPS) function.

**Note 1:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**2:** Pin is connected to a device exposed pad.

**3:** Pin has no electrical connection to the device, but is recommended to be connected to VSS in the PCB design to improve thermal dissipation.


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## Table of Contents

1.0 Device Overview ..... 13
2.0 Guidelines for Getting Started with 16-Bit Digital Signal Controllers ..... 21
3.0 CPU ..... 26
4.0 Memory Organization ..... 37
5.0 Flash Program Memory ..... 63
6.0 Resets ..... 77
7.0 Interrupt Controller ..... 81
8.0 I/O Ports ..... 99
9.0 Oscillator with High-Frequency PLL ..... 150
10.0 Direct Memory Access (DMA) Controller ..... 169
11.0 High-Resolution PWM with Fine Edge Placement ..... 179
12.0 MOSFET Gate Driver Module ..... 211
13.0 High-Speed, 12-Bit Analog-to-Digital Converter (ADC) ..... 244
14.0 High-Speed Analog Comparator with Slope Compensation DAC ..... 270
15.0 Quadrature Encoder Interface (QEI) ..... 282
16.0 Universal Asynchronous Receiver Transmitter (UART) ..... 302
17.0 LIN Transceiver Module ..... 324
18.0 Serial Peripheral Interface (SPI) ..... 336
19.0 Inter-Integrated Circuit ($I^2C$) ..... 354
20.0 Single-Edge Nibble Transmission (SENT) ..... 364
21.0 Timer1 ..... 374
22.0 Capture/Compare/PWM/Timer Modules (SCCP) ..... 378
23.0 Configurable Logic Cell (CLC) ..... 394
24.0 Peripheral Trigger Generator (PTG) ..... 406
25.0 Current Bias Generator (CBG) ..... 422
26.0 Operational Amplifier ..... 428
27.0 Deadman Timer (DMT) ..... 432
28.0 32-Bit Programmable Cyclic Redundancy Check (CRC) Generator ..... 440
29.0 Power-Saving Features ..... 444
30.0 Special Features ..... 457
31.0 Instruction Set Summary ..... 483
32.0 Development Support ..... 493
33.0 Electrical Characteristics ..... 495
34.0 High-Temperature Electrical Characteristics ..... 530
35.0 MOSFET Gate Driver Electrical Characteristics ..... 538
36.0 LIN Transceiver Electrical Characteristics ..... 544
37.0 Packaging Information ..... 550
Appendix A: Revision History ..... 554
Index ..... 557
Product Identification System ..... 565

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## Referenced Sources

This device data sheet is based on the following individual chapters of the *"dsPIC33/PIC24 Family Reference Manual"*. These documents should be considered as the general reference for the operation of a particular module or device feature.

**Note:** To access the documents listed below, browse to the documentation section of the dsPIC33CDVL64MC106 product page of the Microchip website (www.microchip.com) or select a family reference manual section from the following list.

In addition to parameters, features and other documentation, the resulting page provides links to the related family reference manual sections.

- **"Introduction"** (www.microchip.com/DS70000573)
- **"Enhanced CPU"** (www.microchip.com/DS70005158)
- **"Data Memory"** (www.microchip.com/DS70000595)
- **"dsPIC33/PIC24 Program Memory"** (www.microchip.com/DS70000613)
- **"Reset"** (www.microchip.com/DS70000602)
- **"Interrupts"** (www.microchip.com/DS70000600)
- **"I/O Ports with Edge Detect"** (www.microchip.com/DS70005322)
- **"Oscillator Module with High-Speed PLL"** (www.microchip.com/DS70005255)
- **"Direct Memory Access Controller (DMA)"** (www.microchip.com/DS30009742)
- **"High-Resolution PWM with Fine Edge Placement"** (www.microchip.com/DS70005320)
- **"12-Bit High-Speed, Multiple SARs A/D Converter (ADC)"** (www.microchip.com/DS70005213)
- **"High-Speed Analog Comparator with Slope Compensation DAC"** (www.microchip.com/DS70005280)
- **"Quadrature Encoder Interface (QEI)"** (www.microchip.com/DS70000601)
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- **"Timer1 Module"** (www.microchip.com/DS70005279)
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- **"Configurable Logic Cell (CLC)"** (www.microchip.com/DS70005298)
- **"Peripheral Trigger Generator (PTG)"** (www.microchip.com/DS70000669)
- **"Current Bias Generator (CBG)"** (www.microchip.com/DS70005253)
- **"Deadman Timer (DMT)"** (www.microchip.com/DS70005155)
- **"32-Bit Programmable Cyclic Redundancy Check (CRC)"** (www.microchip.com/DS30009729)
- **"Dual Watchdog Timer"** (www.microchip.com/DS70005250)
- **"Watchdog Timer and Power-Saving Modes"** (www.microchip.com/DS70000615)
- **"Programming and Diagnostics"** (www.microchip.com/DS70000608)
- **"CodeGuard™ Intermediate Security"** (www.microchip.com/DS70005182)
- **"Flash Programming"** (www.microchip.com/DS70000609)

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## Terminology Cross Reference

Table 4 provides updated terminology for depreciated naming conventions. Register and bit names remain unchanged, however, descriptions and usage guidance may have been updated

**TABLE 4: TERMINOLOGY CROSS REFERENCES**

| Use Case | Depreciated Term | New Term |
|---|---|---|
| CPU | Master | Initiator |
| DMA | Master | Initiator |
| $I^2C$ | Master | Host |
| | Slave | Client |
| SPI | Master | Host |
| | Slave | Client |
| UART, LIN Mode | Master | Commander |
| | Slave | Responder |
| PWM | Master | Host |
| | Slave | Client |


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## 1.0 DEVICE OVERVIEW

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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 website (www.microchip.com).

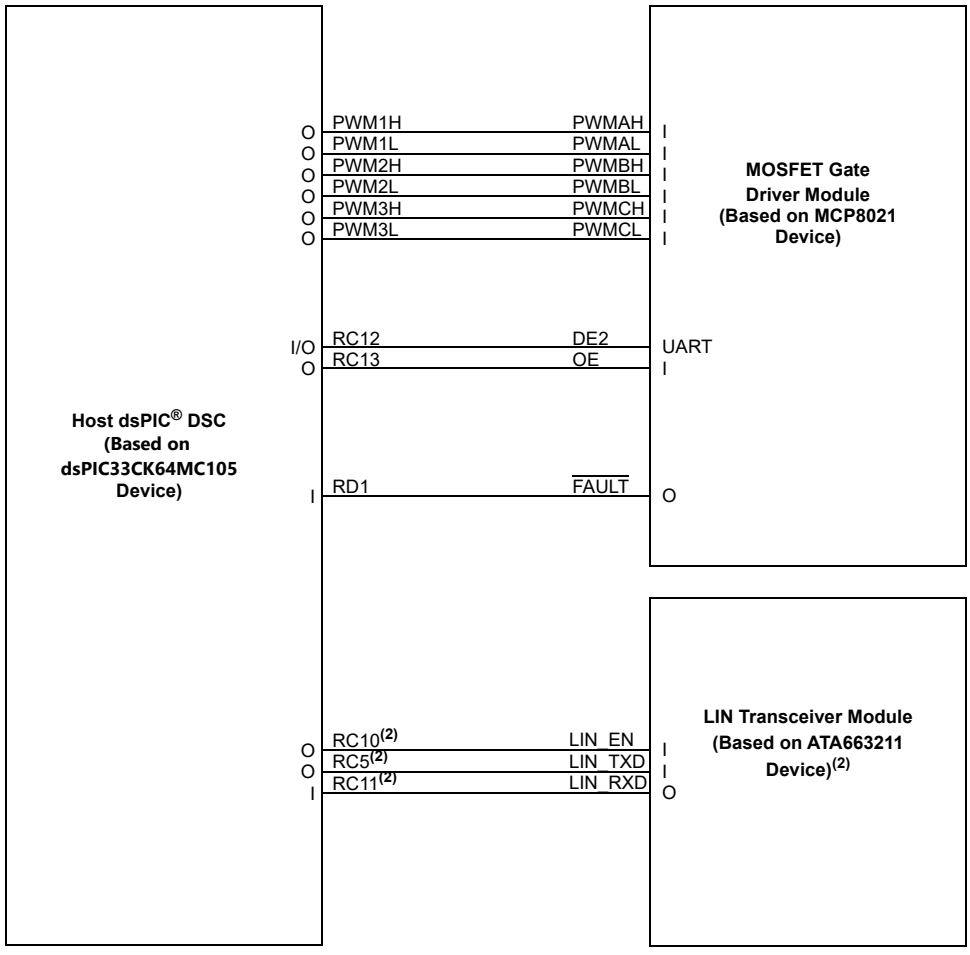
**2:** Some registers and associated bits described in this section may not be available on all devices. Refer to **Section 4.0 "Memory Organization"** in this data sheet for device-specific register and bit information.

This document contains device-specific information for the dsPIC33CDVL64MC106 Digital Signal Controller (DSC) and Microcontroller (MCU) devices.

The dsPIC33CDVL64MC106 devices contain extensive Digital Signal Processor (DSP) functionality with a high-performance, 16-bit MCU architecture.

Figure 1-2 shows a general block diagram of the core and peripheral modules of the dsPIC33CDVL64MC106 family. Table 1-2 lists the functions of the various pins shown in the pinout diagrams.

**FIGURE 1-1: dsPIC33CDVL64MC106 FAMILY INTERNAL CONNECTIONS BLOCK DIAGRAM**




**Note 1:** Device Interconnections are shown in Table 1-1.
**2:** Only applies to devices with the LIN transceiver module. Please see Table 1 for more information.

**TABLE 1-1: dsPIC33CDVL64MC106 FAMILY INTERCONNECTIONS(1)**

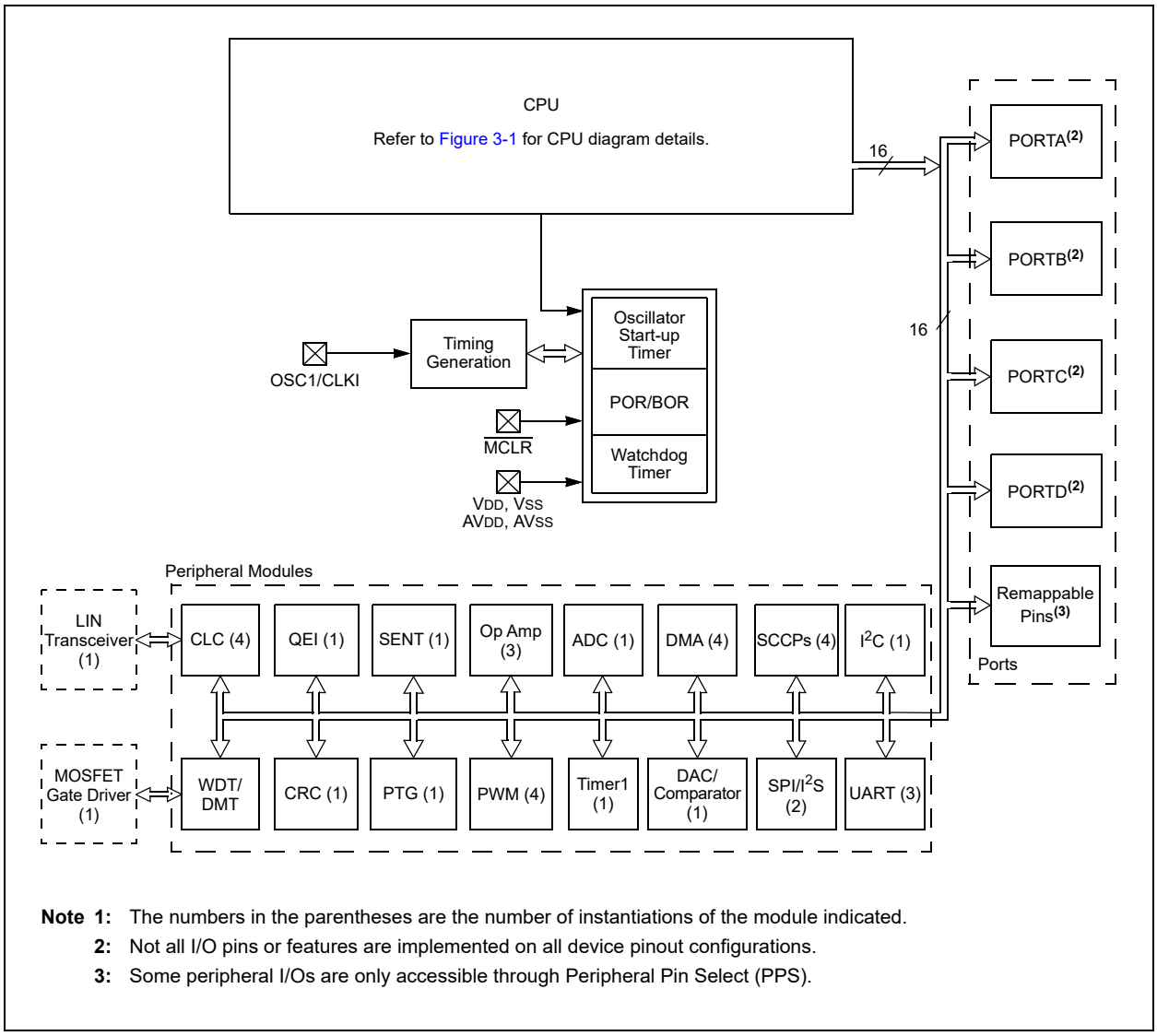
| Host dsPIC® DSC Connection | MOSFET Gate Driver Connection | External Pin |
|---|---|---|
| RB14/PWM1H | PWMAH | 10 |
| RB15/PWM1L | PWMAL | No |
| RB12/PWM2H | PWMBH | 54 |
| RB13/PWM2L | PWMBL | No |
| RB10/PWM3H | PWMCH | 53 |
| RB11/PWM3L | PWMCL | No |
| RD1 | FAULT | No |
| RC12/RP60 | DE2 | No |
| RC13 | OE | No |
| **Host dsPIC DSC Connection** | **LIN Transceiver Connection(2)** | **External Pin** |
| RC10 | LIN_EN | No |
| RC5/RP53 | LIN_TXD | No |
| RC11/RP59 | LIN_RXD | 46 |

**Note 1:** Interconnect is also bonded to an external device pin.

**2:** Only applies to devices with LIN Transceiver module.


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**FIGURE 1-2: dsPIC33CDVL64MC106 FAMILY BLOCK DIAGRAM(1)**




**Note 1:** The numbers in the parentheses are the number of instantiations of the module indicated.
**2:** Not all I/O pins or features are implemented on all device pinout configurations.
**3:** Some peripheral I/Os are only accessible through Peripheral Pin Select (PPS).

**TABLE 1-2: PINOUT I/O DESCRIPTIONS**

| Pin Name(1) | Pin Type | Buffer Type | PPS | Description |
|---|---|---|---|---|
| **dsPIC® DSC Functions** | | | | |
| AN0-AN15 | I | Analog | No | Analog input channels |
| ANN0 | I | Analog | No | Analog negative input |
| CLKI | I | ST | No | External Clock (EC) source input. Always associated with OSCI pin function. |
| CLKO | O | — | No | In Configuration bits, it can be set to output the CPU clock. Always associated with OSCO pin function. |
| OSCI | I | CMOS | No | Oscillator crystal input. Connects to crystal or resonator in Crystal Oscillator mode. |
| OSCO | I/O | — | No | Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. |
| REFCLKI | I | ST | Yes | Reference clock input |
| REFCLKO | O | — | Yes | Reference clock output |
| INT0 | I | ST | No | External Interrupt 0 |
| INT1 | I | ST | Yes | External Interrupt 1 |
| INT2 | I | ST | Yes | External Interrupt 2 |
| INT3 | I | ST | Yes | External Interrupt 3 |
| IOCA[4:0] | I | ST | No | Interrupt-on-Change input for PORTA |
| IOCB[15:0] | I | ST | No | Interrupt-on-Change input for PORTB |
| IOCC[13:0] | I | ST | No | Interrupt-on-Change input for PORTC |
| IOCD1, IOCD8, IOCD10 IOCD13 | I | ST | No | Interrupt-on-Change input for PORTD |
| QEIAx | I | ST | Yes | QEIx Input A |
| QEIBx | I | ST | Yes | QEIx Input B |
| QEINDXx | I | ST | Yes | QEIx Index input |
| QEIHOMx | I | ST | Yes | QEIx Home input |
| QEICMPx | O | — | Yes | QEIx comparator output |
| RP32-RP61, RP65, RP72, RP77 | I/O | ST | Yes | Remappable I/O ports |
| 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-RC13 | I/O | ST | No | PORTC is a bidirectional I/O port. |
| RD1, RD8, RD10, RD13 | I/O | ST | No | PORTD is a bidirectional I/O port. |
| T1CK | I | ST | Yes | Timer1 external clock input |
| $\overline{U1CTS}$ | I | ST | Yes | UART1 Clear-to-Send |
| $\overline{U1RTS}$ | O | — | Yes | UART1 Request-to-Send |
| U1RX | I | ST | Yes | UART1 Receive |
| U1TX | O | — | Yes | UART1 Transmit |
| $\overline{U1DSR}$ | I | ST | Yes | UART1 Data-Set-Ready |
| $\overline{U1DTR}$ | O | — | Yes | UART1 Data-Terminal-Ready |

**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

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

**2:** PWM4L and PWM4H pins are available on PPS.

**3:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**4:** A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.


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**TABLE 1-2: 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 Request-to-Send |
| U2RX | I | ST | Yes | UART2 Receive |
| U2TX | O | — | Yes | UART2 Transmit |
| U2DSR | I | ST | Yes | UART2 Data-Set-Ready |
| U2DTR | O | — | Yes | UART2 Data-Terminal-Ready |
| U3CTS | I | ST | Yes | UART3 Clear-to-Send |
| U3RTS | O | — | Yes | UART3 Request-to-Send |
| U3RX | I | ST | Yes | UART3 Receive |
| U3TX | O | — | Yes | UART3 Transmit |
| U3DSR | I | ST | Yes | UART3 Data-Set-Ready |
| U3DTR | O | — | Yes | UART3 Data-Terminal-Ready |
| SENT1 | I | ST | Yes | SENT1 input |
| SENT1OUT | O | — | Yes | SENT1 output |
| PTGTRG24 | O | — | Yes | PTG Trigger Output 24 |
| PTGTRG25 | O | — | Yes | PTG Trigger Output 25 |
| TCKI1-TCKI4 | I | ST | Yes | SCCP timer inputs |
| ICM1-ICM4 | I | ST | Yes | SCCP capture inputs |
| OCFA-OCFB | I | ST | Yes | SCCP Fault inputs |
| OCM1x-OCM4x | O | — | Yes | SCCP compare outputs |
| 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 |
| 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 |
| PCI8-PCI18 | I | ST | Yes | PWM Inputs 8 through 18 |
| PCI19 | I | ST | No | PWM Input 19 |
| PWMEA-PWMED | O | — | Yes | PWM Event Outputs A through D |
| PWM1L-PWM4L[2] | O | — | No | PWM Low Outputs 1 through 4 |
| PWM1H-PWM4H[2] | O | — | No | PWM High Outputs 1 through 4 |
| CLCINA-CLCIND | I | ST | Yes | CLC Inputs A through D |
| CLCxOUT | O | — | Yes | CLCx Output |
| CMP1A | I | Analog | No | Comparator Channel 1A |
| CMP1B | I | Analog | No | Comparator Channel 1B |
| CMP1C | I | Analog | No | Comparator Channel 1C |
| CMP1D | I | Analog | No | Comparator Channel 1D |

**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

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

**2:** PWM4L and PWM4H pins are available on PPS.

**3:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**4:** A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.

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**TABLE 1-2: PINOUT I/O DESCRIPTIONS (CONTINUED)**

| Pin Name(1) | Pin Type | Buffer Type | PPS | Description |
|---|---|---|---|---|
| DACOUT | O | — | No | DAC output voltage |
| IBIAS0-IBIAS3<br>ISRC0-ISRC3 | O<br>O | Analog<br>Analog | No<br>No | 50 µA Constant-Current Outputs 0 through 3<br>10 µA Constant-Current Outputs 0 through 3 |
| OA1IN+<br>OA1IN-<br>OA1OUT<br>OA2IN+<br>OA2IN-<br>OA2OUT<br>OA3IN+<br>OA3IN-<br>OA3OUT | I<br>I<br>O<br>I<br>I<br>O<br>I<br>I<br>O | —<br>—<br>—<br>—<br>—<br>—<br>—<br>—<br>— | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Op Amp 1+ input<br>Op Amp 1- input<br>Op Amp 1 output<br>Op Amp 2+ input<br>Op Amp 2- input<br>Op Amp 2 output<br>Op Amp 3+ input<br>Op Amp 3- input<br>Op Amp 3 output |
| ADTRG31 | I | ST | No | External ADC trigger source |
| PGD1<br>PGC1<br><br>PGD2<br>PGC2<br><br>PGD3<br>PGC3 | I/O<br>I<br><br>I/O<br>I<br><br>I/O<br>I | ST<br>ST<br><br>ST<br>ST<br><br>ST<br>ST | No<br>No<br><br>No<br>No<br><br>No<br>No | Data I/O pin for Programming/Debugging Communication Channel 1<br>Clock input pin for Programming/Debugging Communication Channel 1<br>Data I/O pin for Programming/Debugging Communication Channel 2<br>Clock input pin for Programming/Debugging Communication Channel 2<br>Data I/O pin for Programming/Debugging Communication Channel 3<br>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. |
| AVDD | P | P | No | Positive supply for analog modules. This pin must be connected at all times. |
| AVSS | P | P | No | Ground reference for analog modules. This pin must be connected at all times. |
| VDD | P | P | No | Positive supply for peripheral logic and I/O pins |
| VSS | P | 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

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

**2:** PWM4L and PWM4H pins are available on PPS.

**3:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**4:** A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.


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**TABLE 1-2: PINOUT I/O DESCRIPTIONS (CONTINUED)**

| Pin Name[1] | Pin Type | Buffer Type | PPS | Description |
|---|---|---|---|---|
| **MOSFET Gate Driver Module Functions** | | | | |
| WAKE | I | | | HV digital level-sensitive input, device wake-up from Sleep with internal pull-down resistor |
| PHA | I/O | | | Phase A high-side MOSFET Driver reference, back-EMF sense input |
| HSA | O | | | Phase A high-side N-channel MOSFET Driver, active-high |
| VBA | P | | | Phase A high-side MOSFET Driver bias |
| PHB | I/O | | | Phase B high-side MOSFET Driver reference, back-EMF sense input |
| HSB | O | | | Phase B high-side N-channel MOSFET Driver, active-high |
| VBB | P | | | Phase B high-side MOSFET Driver bias |
| PHC | I/O | | | Phase C high-side MOSFET Driver reference, back-EMF sense input |
| HSC | O | | | Phase C high-side N-channel MOSFET Driver, active-high |
| VBC | P | | | Phase C high-side MOSFET driver bias |
| LSA | O | | | Phase A low-side N-channel MOSFET Driver, active-high |
| LSB | O | | | Phase B low-side N-channel MOSFET Driver, active-high |
| LSC | O | | | Phase C low-side N-channel MOSFET Driver, active-high |
| VBOOT | P | | | External bootstrap circuit supply voltage output |
| CAP1[4] | P | | | Charge Pump Flying Capacitor Input 1 |
| CAP2 | P | | | Charge Pump Flying Capacitor Input 2 |
| HVDD | P | | | Input supply |
| VREG | P | | | Linear Regulator Output: 3.3V |
| HVSS | P | | | MOSFET Driver Ground Reference |
| PWMAH [3] | I | | | Phase A high-side control, internal 51 kΩ pull-down |
| PWMAL[3] | I | | | Phase A low-side control, internal 51 kΩ pull-down |
| PWMBH[3] | I | | | Phase B high-side control, internal 51 kΩ pull-down |
| PWMBL[3] | I | | | Phase B low-side control, internal 51 kΩ pull-down |
| PWMCH[3] | I | | | Phase C high-side control, internal 51 kΩ pull-down |
| PWMCL[3] | I | | | Phase C low-side control, internal 51 kΩ pull-down |
| FAULT[3] | O | | | Digital output, active-low Fault, open-drain |
| DE2[3] | UART | | | Digital communications port, open-drain |
| OE[3] | I | | | Digital input, output enable, Fault clearing, internal 51 kΩ pull-down |
| **LIN Transceiver Module Functions (dsPIC33CDVL64MC106 Only)** | | | | |
| LIN_INH | I | | | LIN Transceiver Inhibit, active high |
| LIN_BUS | I/O | | | LIN Communications Bus |
| LIN_WKin | I | | | LIN Wake Input |
| LIN_VDD[3] | P | | | LIN Transceiver Input Supply |
| LIN_VSS[3] | P | | | LIN Transceiver Ground Reference |
| LIN_EN[3] | I | | | Digital input, enable signal |
| LIN_TXD[3] | I | | | Transmit data input from microcontroller |
| LIN_RXD[3] | O | | | Receive data output to microcontroller, use 4.7 kΩ external pull-up and 20 pF load capacitor |

**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

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

**2:** PWM4L and PWM4H pins are available on PPS.

**3:** Pin is connected to a device interconnect; see Table 1-1 for more information.

**4:** A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.

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**NOTES:**


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

## 2.1 Basic Connection Requirements

Getting started with the dsPIC33CDVL64MC106 family devices 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 the ADC module is not used (see **Section 2.2 “Decoupling Capacitors”**).
- $\overline{\text{MCLR}}$ pin
  (see **Section 2.3 “Master Clear (MCLR) Pin”**)
- PGCx/PGDx pins
  used for In-Circuit Serial Programming™ (ICSP™) and debugging purposes (see **Section 2.4 “ICSP Pins”**).
- OSCI and OSCO pins
  when an external oscillator source is used (see **Section 2.5 “External Oscillator Pins”**).

## 2.2 Decoupling Capacitors

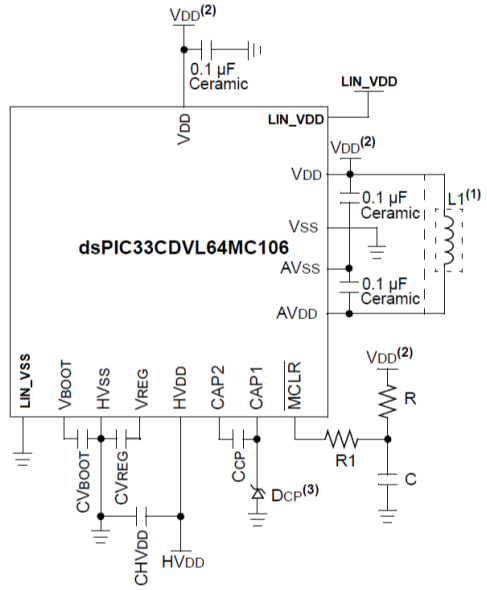
The use of decoupling capacitors on every pair of power supply pins, such as VDD, VSS, AVDD and AVSS is required.

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.

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**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.

**2:** VDD/AVDD pins may be powered by either an external power supply or by the 3.3V VREG output.

**3:** A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.

Where:

$$f = \frac{FCNV}{2}$$ (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 BULK CAPACITORS

On boards with power traces running longer than six inches in length, it is suggested to use a bulk capacitor for integrated circuits, including DSCs, to supply a local power source. The value of the bulk 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 bulk capacitor so that it meets the acceptable voltage sag at the device. Typical values range from 4.7 µF to 47 µF.

## 2.3 Master Clear ($\overline{MCLR}$) Pin

The $\overline{MCLR}$ pin provides two specific device functions:

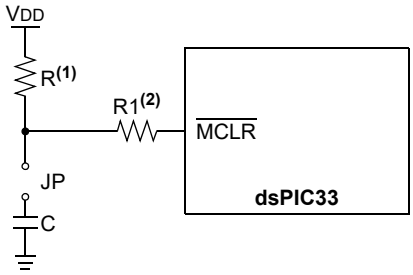
- Device Reset
- Device Programming and Debugging

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 $\overline{MCLR}$ 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 $\overline{MCLR}$ pin during programming and debugging operations.

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

**FIGURE 2-2: EXAMPLE OF $\overline{MCLR}$ PIN CONNECTIONS**




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

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


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## 2.4 ICSP Pins

The PGCx and PGDx 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 PGCx and PGDx 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., PGCx/PGDx pins) programmed into the device matches the physical connections for the ICSP to the MPLAB® debugger tool.

For more information on the MPLAB programmer/debugger connection requirements, refer to the Microchip website (www.microchip.com).

## 2.5 External Oscillator Pins

When the Primary Oscillator (POSC) circuit is used to connect a crystal oscillator, special care and consideration are required to ensure proper operation. The POSC circuit should be tested across the environmental conditions that the end product is intended to be used. The load capacitors specified in the crystal oscillator data sheet can be used as a starting point, however, the parasitic capacitance from the PCB traces can affect the circuit and the values may need to be altered to ensure proper start-up and operation.

Excessive trace length and other physical interaction can lead to poor signal quality. Poorly tuned oscillator circuits can have reduced amplitude, incorrect frequency (runt pulses), distorted waveforms and long start-up times that may result in unpredictable application behavior, such as instruction misexecution, illegal op code fetch, etc. Ensure that the crystal oscillator circuit is at full amplitude and correct frequency before the system begins to execute code. In planning the application's routing and I/O assignments, ensure that adjacent port pins and other signals in close proximity to the oscillator do not have high frequencies, short rise and fall times and other similar noise. For further information on the Primary Oscillator, see **Section 9.4 "Internal Fast RC (FRC) Oscillator"**.

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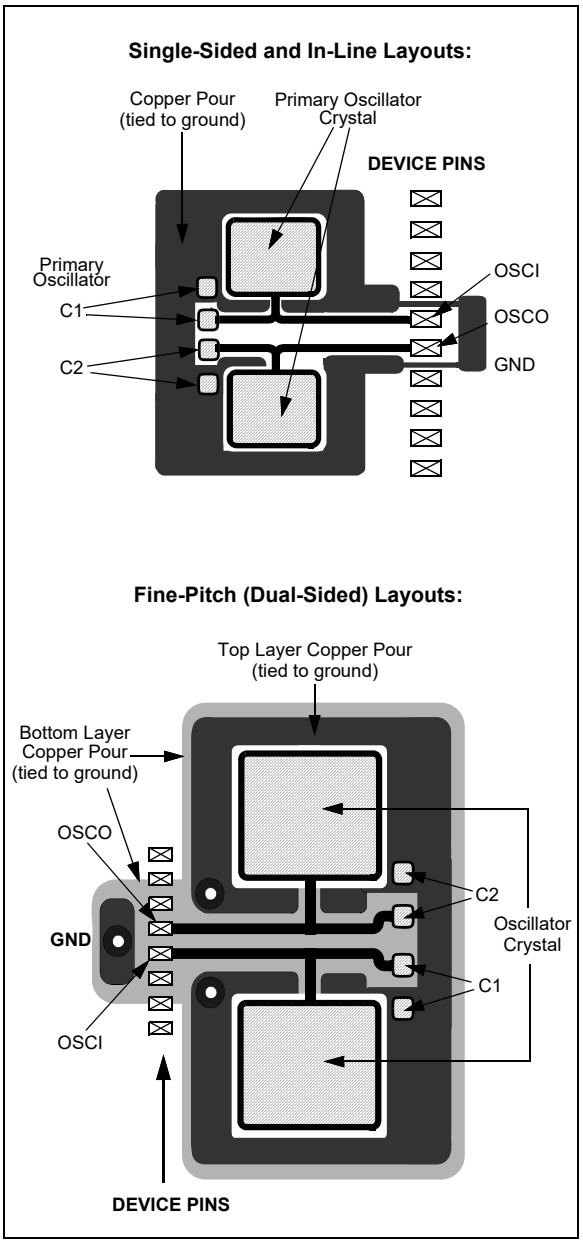
## 2.6 External Oscillator Layout Guidance

Use best practices during PCB layout to ensure a robust start-up and operation. 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 a 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 it 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. 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.

For additional information and design guidance on oscillator circuits, please refer to these Microchip Application Notes, available at the Microchip website (www.microchip.com):

- *AN943, Practical PICmicro® Oscillator Analysis and Design* (**DS00943**)
- *AN949, Making Your Oscillator Work* (DS00949)
- *AN1798, Crystal Selection for Low-Power Secondary Oscillator* (DS00001798)

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





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## 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 a certain frequency (see **Section 9.0 "Oscillator with High-Frequency PLL"**) 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.

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## 3.0 CPU

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Enhanced CPU"** (www.microchip.com/DS70005158).

**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 dsPIC33CDVL64MC106 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 dsPIC33CDVL64MC106 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 sixteenth Working register (W15) operates as a Software Stack Pointer (SSP) for interrupts and calls.

In addition, the dsPIC33CDVL64MC106 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 IPL6) 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 the dsPIC33CDVL64MC106 family 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 split 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"** (www.microchip.com/DS70000595) for more details on PSV and table accesses.

On the dsPIC33CDVL64MC106 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

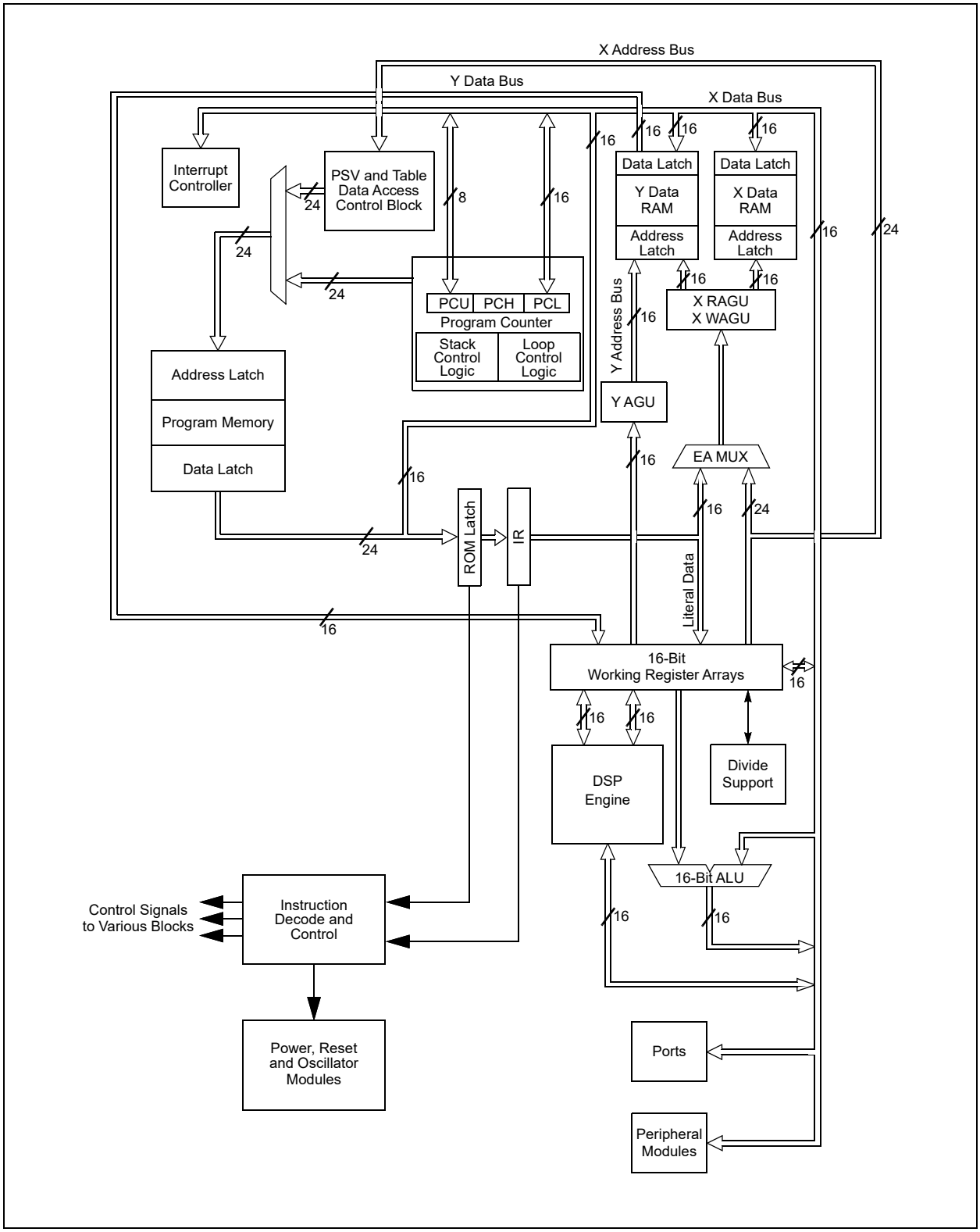
The CPU supports these addressing modes:

- 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.


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**FIGURE 3-1: dsPIC33CDVL64MC106 FAMILY CPU BLOCK DIAGRAM**



### 3.4.1 PROGRAMMER'S MODEL

The programmer's model for the dsPIC33CDVL64MC106 devices 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 dsPIC33CDVL64MC106 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 Figure 3-2.

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

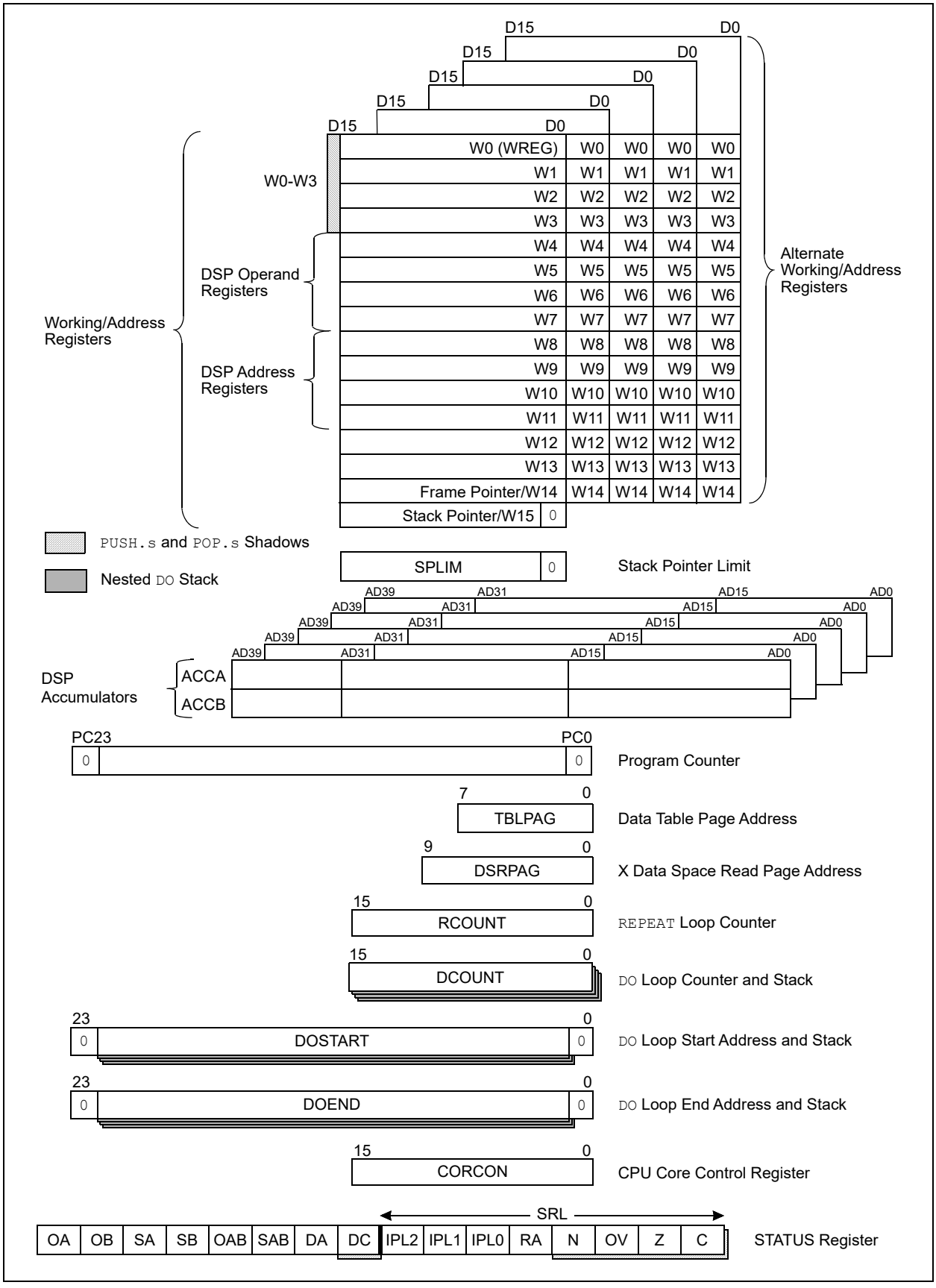
| Register(s) Name | Description |
|---|---|
| W0 through W15(1) | Working register array |
| W0 through W14(1) | Alternate Working register array 1 |
| W0 through W14(1) | Alternate Working register array 2 |
| W0 through W14(1) | Alternate Working register array 3 |
| W0 through W14(1) | Alternate Working register array 4 |
| ACCA, ACCB | 40-Bit DSP accumulators (additional four alternate 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, 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.


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



### 3.4.2 CPU 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.

#### 3.4.2.1 Key Resources

- **"Enhanced CPU"** (www.microchip.com/DS70005158)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools


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### 3.4.3 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.

**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 (two'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.


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**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 the current loop iteration.
0 = No effect

bit 10-8 **DL[2:0]:** DO Loop Nesting Level Status bits
111 = Seven DO loops are active.
...
001 = One DO loop is active.
000 = Zero 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.

**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 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | CCTXI[2:0] | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | MCTXI[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 15-11 **Unimplemented:** Read as '0'

bit 10-8 **CCTXI[2:0]:** Current (W Register) Context Identifier bits
111 = 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 Working 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
...
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 Working Register set was most recently manually selected.


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**REGISTER 3-4: MSTRPR: EDS BUS INITIATOR PRIORITY CONTROL 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 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | DMAPR | — | — | — | — | NVMPR |
| 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 **DMAPR:** Modify DMA Controller Bus Initiator Priority Relative to CPU bit
1 = Raises DMA Controller bus Initiator priority to above that of the CPU.
0 = No change to DMA Controller bus Initiator priority

bit 4-1 **Unimplemented:** Read as '0'

bit 0 **NVMPR:** Modify NVM Controller Bus Initiator Priority Relative to CPU bit
1 = Raises NVM Controller bus Initiator priority to above that of the CPU.
0 = No change to NVM Controller bus Initiator priority

### 3.4.4 ARITHMETIC LOGIC UNIT (ALU)

The dsPIC33CDVL64MC106 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***" (www.microchip.com/DS70000157) 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.

#### 3.4.4.1 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

#### 3.4.4.2 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 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. There are additional instructions: `DIV2` and `DIVF2`. Divide instructions will complete in six cycles.

### 3.4.5 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`, `NEG`, `MIN` and `MAX`.

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 | $A = A + (x \bullet y)$ | Yes |
| MAC | $A = A + x^2$ | No |
| MOVSAC | No change in A | Yes |
| MPY | $A = x \bullet y$ | No |
| MPY | $A = x^2$ | No |
| MPY.N | $A = -x \bullet y$ | No |
| MSC | $A = A - x \bullet y$ | Yes |


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## 4.0 MEMORY ORGANIZATION

**Note:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"dsPIC33/PIC24 Program Memory"** (www.microchip.com/DS70000613).

The dsPIC33CDVL64MC106 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.

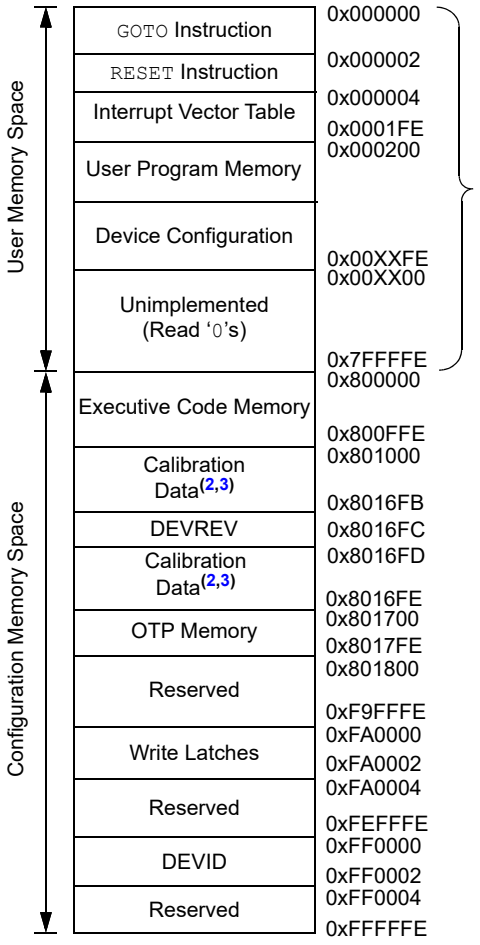
### 4.1 Program Address Space

The program address memory space of the dsPIC33CDVL64MC106 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 4.5.5 "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 code memory map for the dsPIC33CDVL64MC106 devices is shown in Figure 4-1.

**FIGURE 4-1: CODE MEMORY MAP FOR dsPIC33CDVL64MC106 DEVICES(1)**




**Note 1:** Memory areas are not shown to scale.
**2:** Calibration data area must be maintained during programming.
**3:** Calibration data area includes UDID and ICSP™ Write Inhibit registers locations.

### 4.1.1 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 4-2).

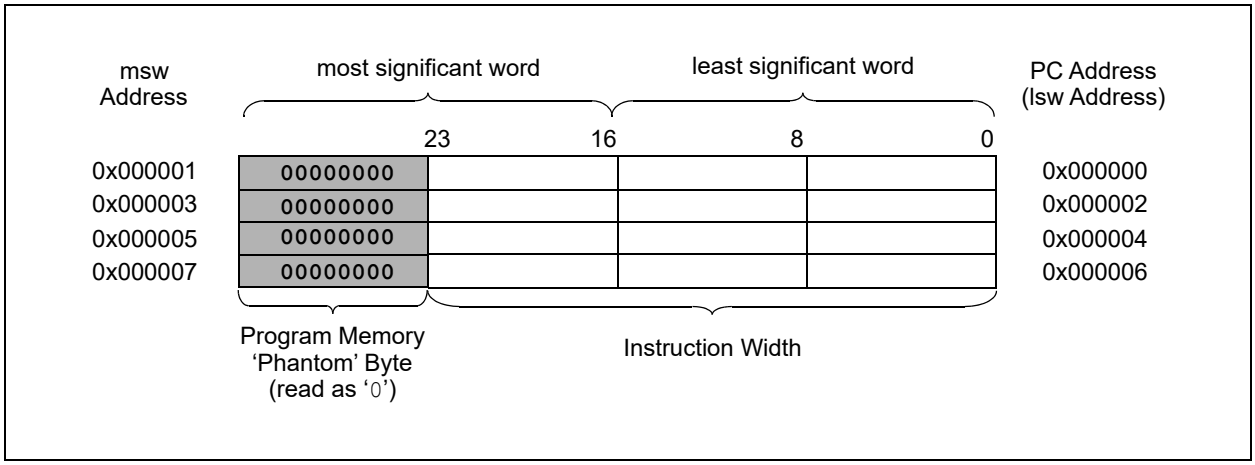
Program memory addresses are always word-aligned on the lower word, and addresses are incremented or decremented, by two, during code execution. This arrangement provides compatibility with data memory space addressing and makes data in the program memory space accessible.

### 4.1.2 INTERRUPT AND TRAP VECTORS

The dsPIC33CDVL64MC106 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 7.0 "Interrupt Controller"**.

**FIGURE 4-2: PROGRAM MEMORY ORGANIZATION**





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### 4.1.3 UNIQUE DEVICE IDENTIFIER (UDID)

The dsPIC33CDVL64MC106 family is individually encoded during final manufacturing with a Unique Device Identifier or UDID. The UDID cannot be erased by a bulk erase command or any other user-accessible means. 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 0x801200 and 0x801208 in the device configuration space. Table 4-1 lists the addresses of the identifier words and shows their contents.

**TABLE 4-1: UDID ADDRESSES**

| UDID | Address | Description |
|---|---|---|
| UDID1 | 0x801200 | UDID Word 1 |
| UDID2 | 0x801202 | UDID Word 2 |
| UDID3 | 0x801204 | UDID Word 3 |
| UDID4 | 0x801206 | UDID Word 4 |
| UDID5 | 0x801208 | UDID Word 5 |

## 4.2 Data Address Space

The dsPIC33CDVL64MC106 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 4-3.

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).

The dsPIC33CDVL64MC106 devices implement up to 16 Kbytes of data memory. If an EA points to a location outside of this area, an all-zero word or byte is returned.

### 4.2.1 DATA SPACE WIDTH

The data memory space is organized in byte-addressable, 16-bit wide blocks. Data are 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.

### 4.2.2 DATA MEMORY ORGANIZATION AND ALIGNMENT

To maintain backward compatibility with PIC® MCU devices and improve Data Space memory usage efficiency, the dsPIC33CDVL64MC106 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.

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### 4.2.3 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 dsPIC33CDVL64MC106 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'.

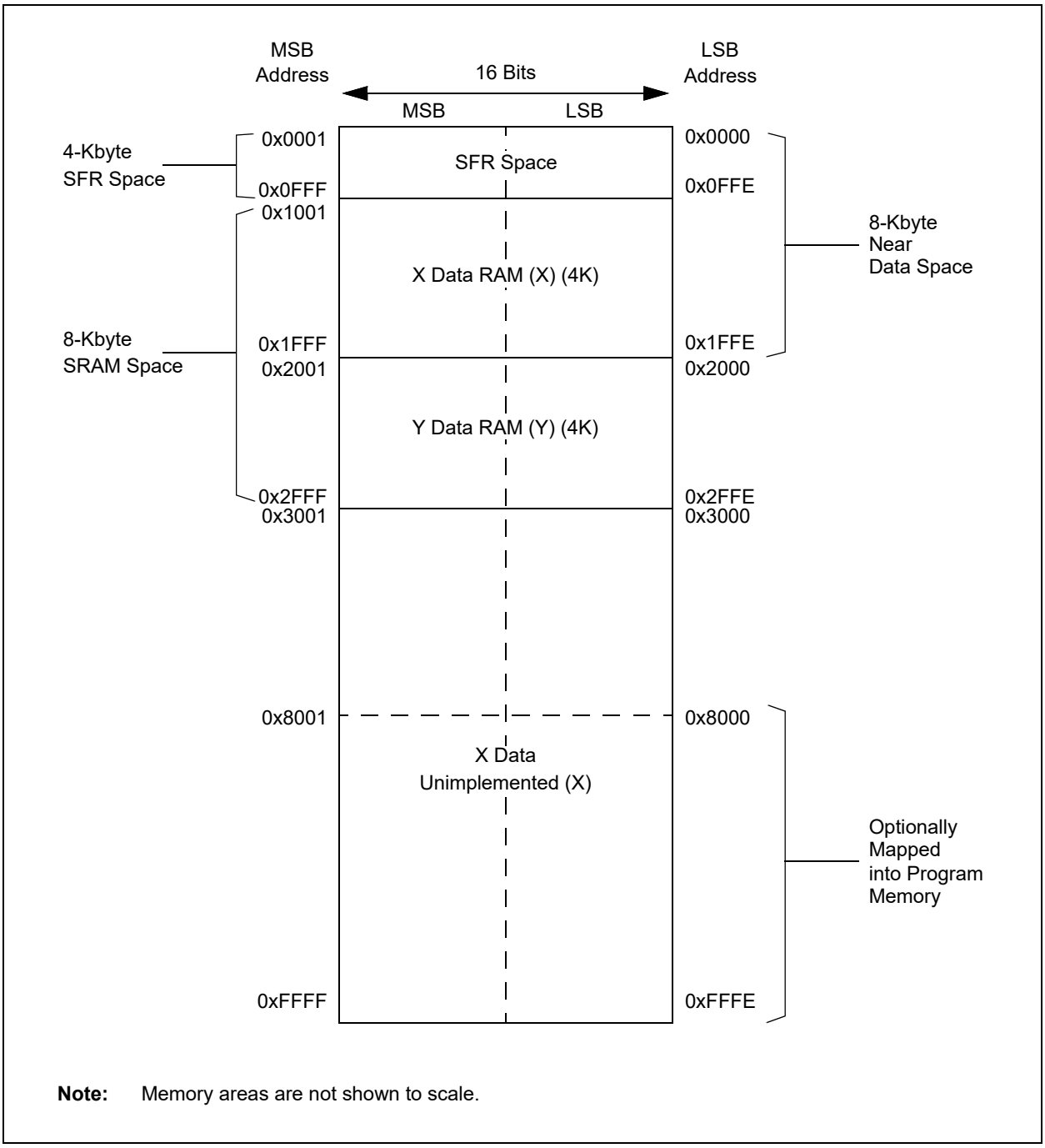
| | |
|---|---|
| **Note:** | The actual set of peripheral features and interrupts varies by the device. Refer to the corresponding device tables and pinout diagrams for device-specific information. |

### 4.2.4 NEAR DATA SPACE

The 8-Kbyte area, between 0x0000 and 0x1FFF, is referred to as the Near Data Space. Locations in this space are directly addressable 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.


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**FIGURE 4-3: DATA MEMORY MAP FOR dsPIC33CDVL64MC106 FAMILY**




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

### 4.2.5 X AND Y DATA SPACES

The dsPIC33CDVL64MC106 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.

## 4.3 BIST Overview

The dsPIC33CDVL64MC106 devices feature a data memory Built-In Self-Test (BIST) that has the option to be run at start-up or run time. The memory test checks that all memory locations are functional and provides a pass/fail status of the RAM that can be used by software to take action if needed. If a failure is reported, the specific location(s) are not identified.

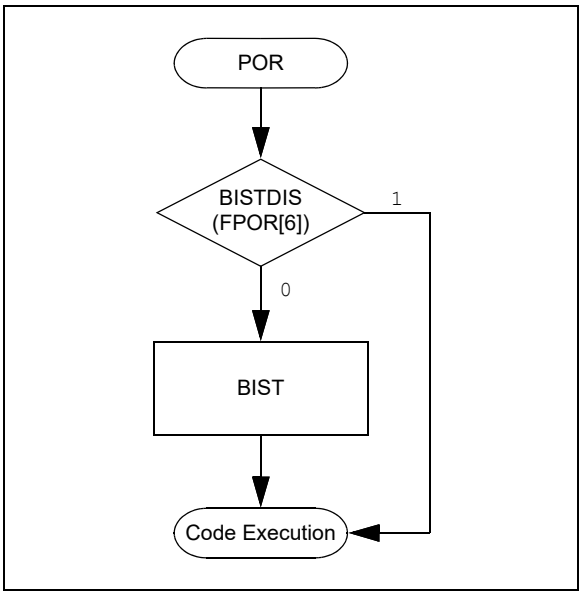
The MBISTCON register (Register 4-1) contains control and status bits for BIST operation. The MBISTDONE bit (MBISTCON[7]) indicates if a BIST was run since the last Reset, and the MBISTSTAT bit (MBISTCON[4]) provides the pass/fail result.

The BIST feature operates with a clock of FRC+PLL with PLL settings forced by hardware to result in a 125 MHz clock rate, at both start-up and run time.

### 4.3.1 BIST AT START-UP

The BIST can be configured to automatically run on a POR-type Reset, as shown in Figure 4-4. By default, when BISTDIS (FPOR[6]) = `1`, the BIST is disabled and will not be part of device start-up. If the BISTDIS bit is cleared during device programming, the BIST will run after all Configuration registers have been loaded and before code execution begins.

**FIGURE 4-4: BIST FLOWCHART**




### 4.3.2 BIST AT RUN TIME

A BIST test can be requested to run on subsequent device Resets at any time.

A BIST will corrupt all of the RAM contents, including the Stack Pointer, and requires a subsequent Reset. The system should be prepared for a Reset before a BIST is performed. The BIST is invoked by setting the MBISTEN bit (MBISTCON[0]) and executing a Reset. The MBISTCON register is protected against accidental writes and requires an unlock sequence prior to writing. Only one bit can be set per unlock sequence. The procedure for a run-time BIST is as follows:

1. Execute the unlock sequence by consecutively writing 0x55 and 0xAA to the NVMKEY register.
2. Write 0x0001 to the MBISTCON SFR.
3. Execute a software `RESET` command.
4. Verify a software Reset has occurred by reading SWR (RCON[6]) (optional).
5. Verify that the MBISTDONE bit is set.
6. Take action depending on test result indicated by MBISTSTAT.


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### 4.3.3 FAULT SIMULATION

A mechanism is available to simulate a BIST failure to allow testing of Fault handling software. When the FLTINJ bit is set during a run-time BIST, the MBISTSTAT bit will be set regardless of the test result. The procedure for a BIST Fault simulation is as follows:

1. Execute the unlock sequence by consecutively writing 0x55 and 0xAA to the NVMKEY register.
2. Set the MBISTEN bit (MBISTCON[0]).
3. Execute a second unlock sequence by consecutively writing 0x55 and 0xAA to the NVMKEY register.
4. Set the FLTINJ bit (MBISTCON[8]).
5. Execute a software `RESET` command.
6. Verify the MBISTDONE, MBISTSTAT and FLTINJ bits are all set.

**REGISTER 4-1: MBISTCON: MBIST CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0(1) |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | FLTINJ |
| bit 15 | | | | | | | bit 8 |

| R/W/HS-0(1) | U-0 | U-0 | R-0 | U-0 | U-0 | U-0 | R/W/HC-0(2) |
|---|---|---|---|---|---|---|---|
| MBISTDONE | — | — | MBISTSTAT | — | — | — | MBISTEN |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable 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 15-9 **Unimplemented:** Read as '0'

bit 8 **FLTINJ:** MBIST Fault Inject Control bit(1)
- 1 = The MBIST test will complete and sets MBISTSTAT = 1, simulating an SRAM test failure.
- 0 = The MBIST test will execute normally.

bit 7 **MBISTDONE:** MBIST Done Status bit(1)
- 1 = An MBIST operation has been executed.
- 0 = No MBIST operation has occurred on the last Reset sequence.

bit 6-5 **Unimplemented:** Read as '0'

bit 4 **MBISTSTAT:** MBIST Status bit
- 1 = The last MBIST failed.
- 0 = The last MBIST passed.

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

bit 0 **MBISTEN:** MBIST Enable bit(2)
- 1 = MBIST test is armed; an MBIST test will execute at the next device Reset.
- 0 = MBIST test is disarmed.

**Note 1:** HW resets only on a true POR Reset.
**2:** This bit will self-clear when the MBIST test is complete.

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## 4.4 Memory 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.

### 4.4.1 KEY RESOURCES

- **"dsPIC33/PIC24 Program Memory"** (www.microchip.com/DS70000613)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools

## 4.5 SFR Maps

The following tables show the dsPIC33CDVL64MC106 SFR names, addresses and Reset values. These tables contain all registers applicable to the dsPIC33CDVL64MC106 devices. Not all registers are present on all device variants. Refer to Table 1, Table 2 and Table 3 for peripheral availability. Table 8-1 details port availability for the different package options.

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

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Core** | | | CORCON | 044 | 0-00000000100000 | CRCXORL | 0B4 | 000000000000000- |
| WREG0 | 000 | 0000000000000000 | MODCON | 046 | 00--0000000000000 | CRCXORH | 0B6 | 0000000000000000 |
| WREG1 | 002 | 0000000000000000 | XMODSRT | 048 | 0000000000000000 | CRCDATL | 0B8 | 0000000000000000 |
| WREG2 | 004 | 0000000000000000 | XMODEND | 04A | 0000000000000001 | CRCDATH | 0BA | 0000000000000000 |
| WREG3 | 006 | 0000000000000000 | YMODSRT | 04C | 0000000000000000 | CRCWDATL | 0BC | 0000000000000000 |
| WREG4 | 008 | 0000000000000000 | YMODEND | 04E | 0000000000000001 | CRCWDATH | 0BE | 0000000000000000 |
| WREG5 | 00A | 0000000000000000 | XBREV | 050 | 0000000000000000 | **CLC** | | |
| WREG6 | 00C | 0000000000000000 | DISICNT | 052 | --00000000000000 | CLC1CONL | 0C0 | 0---00--000--000 |
| WREG7 | 00E | 0000000000000000 | TBLPAG | 054 | --------00000000 | CLC1CONH | 0C2 | ------------0000 |
| WREG8 | 010 | 0000000000000000 | YPAG | 056 | --------00000001 | CLC1SEL | 0C4 | -000-000-000-000 |
| WREG9 | 012 | 0000000000000000 | MSTRPR | 058 | ----------0----0 | CLC1GLSL | 0C8 | 0000000000000000 |
| WREG10 | 014 | 0000000000000000 | CTXTSTAT | 05A | -----000-----000 | CLC1GLSH | 0CA | 0000000000000000 |
| WREG11 | 016 | 0000000000000000 | **DMT** | | | CLC2CONL | 0CC | 0---00--000--000 |
| WREG12 | 018 | 0000000000000000 | DMTCON | 05C | 0--------------- | CLC2CONH | 0CE | ------------0000 |
| WREG13 | 01A | 0000000000000000 | DMTPRECLR | 060 | 00000000-------- | CLC2SEL | 0D0 | -000-000-000-000 |
| WREG14 | 01C | 0000000000000000 | DMTCLR | 064 | --------00000000 | CLC2GLSL | 0D4 | 0000000000000000 |
| WREG15 | 01E | 0000000000000000 | DMTSTAT | 068 | --------000----0 | CLC2GLSH | 0D6 | 0000000000000000 |
| SPLIM | 020 | 0000000000000000 | DMTCNTL | 06C | 0000000000000000 | CLC3CONL | 0D8 | 0---00--000--000 |
| ACCAL | 022 | 0000000000000000 | DMTCNTH | 06E | 0000000000000000 | CLC3CONH | 0DA | ------------0000 |
| ACCAH | 024 | 0000000000000000 | DMTHOLDREG | 070 | 0000000000000000 | CLC3SEL | 0DC | -000-000-000-000 |
| ACCAU | 026 | 0000000000000000 | DMTPSCNTL | 074 | 0000000000000000 | CLC3GLSL | 0E0 | 0000000000000000 |
| ACCBL | 028 | 0000000000000000 | DMTPSCNTH | 076 | 0000000000000000 | CLC3GLSH | 0E2 | 0000000000000000 |
| ACCBH | 02A | 0000000000000000 | DMTPSINTVL | 078 | 0000000000000000 | CLC4CONL | 0E4 | 0---00--000--000 |
| ACCBU | 02C | 0000000000000000 | DMTPSINTVH | 07A | 0000000000000000 | CLC4CONH | 0E6 | ------------0000 |
| PCL | 02E | 0000000000000000 | **SENT** | | | CLC4SEL | 0E8 | -000-000-000-000 |
| PCH | 030 | --------00000000 | SENT1CON1 | 080 | 0-0-000000-0-000 | CLC4GLSL | 0EC | 0000000000000000 |
| DSRPAG | 032 | ------0000000001 | SENT1CON2 | 084 | 0000000000000000 | CLC4GLSH | 0EE | 0000000000000000 |
| DSWPAG | 034 | -------000000001 | SENT1CON3 | 088 | 0000000000000000 | **ECC** | | |
| RCOUNT | 036 | 0000000000000000 | SENT1STAT | 08C | --------00000000 | ECCCONL | 0F0 | ---------------0 |
| DCOUNT | 038 | 0000000000000000 | SENT1SYNC | 090 | 0000000000000000 | ECCCONH | 0F2 | 0000000000000000 |
| DOSTARTL | 03A | 0000000000000000 | SENT1DATL | 094 | 0000000000000000 | ECCADDRL | 0F4 | 0000000000000000 |
| DOSTARTH | 03C | ----------0000000 | SENT1DATH | 096 | 0000000000000000 | ECCADDRH | 0F6 | --------00000000 |
| DOENDL | 03E | 0000000000000000 | **CRC** | | | ECCSTATL | 0F8 | 0000000000000000 |
| DOENDH | 040 | ----------0000000 | CRCCONL | 0B0 | 0-000000010000-- | ECCSTATH | 0FA | ------0000000000 |
| SR | 042 | 0000000000000000 | CRCCONH | 0B2 | ---00000---00000 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.


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

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Timers** | | | POS1CNTH | 14E | 0000000000000000 | INT1HLDH | 162 | 0000000000000000 |
| T1CON | 100 | 0-0000000-00-00- | POS1HLDL | 150 | 0000000000000000 | INDX1CNTL | 164 | 0000000000000000 |
| TMR1 | 104 | 0000000000000000 | POS1HLD | 152 | 0000000000000000 | INDX1CNTH | 166 | 0000000000000000 |
| PR1 | 108 | 0000000000000000 | VEL1CNT | 154 | 0000000000000000 | INDX1HLDL | 168 | 0000000000000000 |
| **QEI** | | | VEL1CNTH | 156 | 0000000000000000 | INDX1HLD | 16A | 0000000000000000 |
| QEI1CON | 140 | 0-000000-0000000 | VEL1HLDL | 158 | 0000000000000000 | QEI1GECL/ QEI1ICL | 16C | 0000000000000000 |
| QEI1IOC | 144 | 00000000000xxxx | VEL1HLD | 15A | 0000000000000000 | QEI1GECH/ QEI1ICH | 16E | 0000000000000000 |
| QEI1IOCH | 146 | ---------------0 | INT1TMRL | 15C | 0000000000000000 | QEI1LECL | 170 | 0000000000000000 |
| QEI1STAT | 148 | --00000000000000 | INT1TMRH | 15E | 0000000000000000 | QEI1LECH | 172 | 0000000000000000 |
| POS1CNTL | 14C | 0000000000000000 | INT1HLDL | 160 | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

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

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **I2C1** | | | U1SCCON | 258 | ----------00000- | SPI1STATL | 2B4 | ---00--0001-1-00 |
| I2C1CONL | 200 | 0-01000000000000 | U1SCINT | 25A | --00-000--00-000 | SPI1STATH | 2B6 | --000000--000000 |
| I2C1CONH | 202 | ---------0000000 | U1INT | 25C | --------00---0-- | SPI1BUFL | 2B8 | 0000000000000000 |
| I2C1STAT | 204 | 000--0000000000 | U2MODE | 260 | 0-000-0000000000 | SPI1BUFH | 2BA | 0000000000000000 |
| I2C1ADD | 208 | ------0000000000 | U2MODEH | 262 | 00--000000000000 | SPI1BRGL | 2BC | ---xxxxxxxxxxxx |
| I2C1MSK | 20C | ------0000000000 | U2STA | 264 | 0000000010000000 | SPI1IMSKL | 2C0 | ---00--0000-0-00 |
| I2C1BRG | 210 | 0000000000000000 | U2STAH | 266 | -000-00000101110 | SPI1IMSKH | 2C2 | 0-0000000-000000 |
| I2C1TRN | 214 | --------11111111 | U2BRG | 268 | 0000000000000000 | SPI1URDTL | 2C4 | 0000000000000000 |
| I2C1RCV | 218 | --------00000000 | U2BRGH | 26A | ------------0000 | SPI1URDTH | 2C6 | 0000000000000000 |
| **UART1 and UART2** | | | U2RXREG | 26C | --------xxxxxxxx | SPI2CON1L | 2C8 | 0-00000000000000 |
| U1MODE | 238 | 0-000-0000000000 | U2TXREG | 270 | x-------xxxxxxxx | SPI2CON1H | 2CA | 0000000000000000 |
| U1MODEH | 23A | 00--000000000000 | U2P1 | 274 | -------000000000 | SPI2CON2L | 2CC | -----------00000 |
| U1STA | 23C | 0000000010000000 | U2P2 | 276 | -------000000000 | SPI2STATL | 2D0 | ---00--0001-1-00 |
| U1STAH | 23E | -000-00000101110 | U2P3 | 278 | 0000000000000000 | SPI2STATH | 2D2 | --000000--000000 |
| U1BRG | 240 | 0000000000000000 | U2P3H | 27A | --------00000000 | SPI2BUFL | 2D4 | 0000000000000000 |
| U1BRGH | 242 | ------------0000 | U2TXCHK | 27C | --------00000000 | SPI2BUFH | 2D6 | 0000000000000000 |
| U1RXREG | 244 | --------xxxxxxxx | U2RXCHK | 27E | --------00000000 | SPI2BRGL | 2D8 | ---xxxxxxxxxxxx |
| U1TXREG | 248 | x-------xxxxxxxx | U2SCCON | 280 | ----------00000- | SPI2IMSKL | 2DC | ---00--0000-0-00 |
| U1P1 | 24C | -------000000000 | U2SCINT | 282 | --00-000--00-000 | SPI2IMSKH | 2DE | 0-0000000-000000 |
| U1P2 | 24E | -------000000000 | U2INT | 284 | --------00---0-- | SPI2URDTL | 2E0 | 0000000000000000 |
| U1P3 | 250 | 0000000000000000 | **SPI** | | | SPI2URDTH | 2E2 | 0000000000000000 |
| U1P3H | 252 | --------00000000 | SPI1CON1L | 2AC | 0-00000000000000 | | | |
| U1TXCHK | 254 | --------00000000 | SPI1CON1H | 2AE | 0000000000000000 | | | |
| U1RXCHK | 256 | --------00000000 | SPI1CON2L | 2B0 | -----------00000 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-5: SFR BLOCK 300h-400h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **High-Speed PWM** | | | PG1TRIGB | 356 | 0000000000000000 | PG3FFPCIH | 3AE | 0000-00000000000 |
| PCLKCON | 300 | -------0--00--00 | PG1TRIGC | 358 | 0000000000000000 | PG3SPCIL | 3B0 | 0000000000000000 |
| FSCL | 302 | 0000000000000000 | PG1DTL | 35A | -----00000000000 | PG3SPCIH | 3B2 | 0000-00000000000 |
| FSMINPER | 304 | 0000000000000000 | PG1DTH | 35C | -----00000000000 | PG3LEBL | 3B4 | 0000000000000--- |
| MPHASE | 306 | 0000000000000000 | PG1CAP | 35E | 0000000000000000 | PG3LEBH | 3B6 | -----000----0000 |
| MDC | 308 | 0000000000000000 | PG2CONL | 360 | 0----000---00000 | PG3PHASE | 3B8 | 0000000000000000 |
| MPER | 30A | 0000000000000000 | PG2CONH | 362 | 000-000000--0000 | PG3DC | 3BA | 0000000000000000 |
| LFSR | 30C | -000000000000000 | PG2STAT | 364 | 0000000000000000 | PG3DCA | 3BC | --------00000000 |
| CMBTRIGL | 30E | --------00000000 | PG2IOCONL | 366 | 0000000000000000 | PG3PER | 3BE | 0000000000000000 |
| CMBTRIGH | 310 | --------00000000 | PG2IOCONH | 368 | -000---0--000000 | PG3TRIGA | 3C0 | 0000000000000000 |
| LOGCONA | 312 | 000000000000-000 | PG2EVTL | 36A | 00000000---00000 | PG3TRIGB | 3C2 | 0000000000000000 |
| LOGCONB | 314 | 000000000000-000 | PG2EVTH | 36C | 0000--0000000000 | PG3TRIGC | 3C4 | 0000000000000000 |
| LOGCONC | 316 | 000000000000-000 | PG2FPCIL | 36E | 0000000000000000 | PG3DTL | 3C6 | -----00000000000 |
| LOGCOND | 318 | 000000000000-000 | PG2FPCIH | 370 | 0000-00000000000 | PG3DTH | 3C8 | -----00000000000 |
| LOGCONE | 31A | 000000000000-000 | PG2CLPCIL | 372 | 0000000000000000 | PG3CAP | 3CA | 0000000000000000 |
| LOGCONF | 31C | 000000000000-000 | PG2CLPCIH | 374 | 0000-00000000000 | PG4CONL | 3CC | 0----000---00000 |
| PWMEVTA | 31E | 0000----0000-000 | PG2FFPCIL | 376 | 0000000000000000 | PG4CONH | 3CE | 000-000000--0000 |
| PWMEVTB | 320 | 0000----0000-000 | PG2FFPCIH | 378 | 0000-00000000000 | PG4STAT | 3D0 | 0000000000000000 |
| PWMEVTC | 322 | 0000----0000-000 | PG2SPCIL | 37A | 0000000000000000 | PG4IOCONL | 3D2 | 0000000000000000 |
| PWMEVTD | 324 | 0000----0000-000 | PG2SPCIH | 37C | 0000-00000000000 | PG4IOCONH | 3D4 | -000---0--000000 |
| PWMEVTE | 326 | 0000----0000-000 | PG2LEBL | 37E | 0000000000000--- | PG4EVTL | 3D6 | 00000000---00000 |
| PWMEVTF | 328 | 0000----0000-000 | PG2LEBH | 380 | -----000----0000 | PG4EVTH | 3D8 | 0000--0000000000 |
| PG1CONL | 32A | 0----000---00000 | PG2PHASE | 382 | 0000000000000000 | PG4FPCIL | 3DA | 0000000000000000 |
| PG1CONH | 32C | 000-000000--0000 | PG2DC | 384 | 0000000000000000 | PG4FPCIH | 3DC | 0000-00000000000 |
| PG1STAT | 32E | 0000000000000000 | PG2DCA | 386 | --------00000000 | PG4CLPCIL | 3DE | 0000000000000000 |
| PG1IOCONL | 330 | 0000000000000000 | PG2PER | 388 | 0000000000000000 | PG4CLPCIH | 3E0 | 0000-00000000000 |
| PG1IOCONH | 332 | -000---0--000000 | PG2TRIGA | 38A | 0000000000000000 | PG4FFPCIL | 3E2 | 0000000000000000 |
| PG1EVTL | 334 | 00000000---00000 | PG2TRIGB | 38C | 0000000000000000 | PG4FFPCIH | 3E4 | 0000-00000000000 |
| PG1EVTH | 336 | 0000--0000000000 | PG2TRIGC | 38E | 0000000000000000 | PG4SPCIL | 3E6 | 0000000000000000 |
| PG1FPCIL | 338 | 0000000000000000 | PG2DTL | 390 | -----00000000000 | PG4SPCIH | 3E8 | 0000-00000000--- |
| PG1FPCIH | 33A | 0000-00000000000 | PG2DTH | 392 | -----00000000000 | PG4LEBL | 3EA | 0000000000000--- |
| PG1CLPCIL | 33C | 0000000000000000 | PG2CAP | 394 | 0000000000000000 | PG4LEBH | 3EC | -----000----0000 |
| PG1CLPCIH | 33E | 0000-00000000000 | PG3CONL | 396 | 0----000---00000 | PG4PHASE | 3EE | 0000000000000000 |
| PG1FFPCIL | 340 | 0000000000000000 | PG3CONH | 398 | 000-000000--0000 | PG4DC | 3F0 | 0000000000000000 |
| PG1FFPCIH | 342 | 0000-00000000000 | PG3STAT | 39A | 0000000000000000 | PG4DCA | 3F2 | --------00000000 |
| PG1SPCIL | 344 | 0000000000000000 | PG3IOCONL | 39C | 0000000000000000 | PG4PER | 3F4 | 0000000000000000 |
| PG1SPCIH | 346 | 0000-00000000000 | PG3IOCONH | 39E | -000---0--000000 | PG4TRIGA | 3F6 | 0000000000000000 |
| PG1LEBL | 348 | 0000000000000--- | PG3EVTL | 3A0 | 00000000---00000 | PG4TRIGB | 3F8 | 0000000000000000 |
| PG1LEBH | 34A | -----000----0000 | PG3EVTH | 3A2 | 0000--0000000000 | PG4TRIGC | 3FA | 0000000000000000 |
| PG1PHASE | 34C | 0000000000000000 | PG3FPCIL | 3A4 | 0000000000000000 | PG4DTL | 3FC | -----00000000000 |
| PG1DC | 34E | 0000000000000000 | PG3FPCIH | 3A6 | 0000-00000000000 | PG4DTH | 3FE | -----00000000000 |
| PG1DCA | 350 | --------00000000 | PG3CLPCIL | 3A8 | 0000000000000000 | PG4CAP | 400 | 0000000000000000 |
| PG1PER | 352 | 0000000000000000 | PG3CLPCIH | 3AA | 0000-00000000000 | | | |
| PG1TRIGA | 354 | 0000000000000000 | PG3FFPCIL | 3AC | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-6: SFR BLOCK 800h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **Interrupts** | | | IPC5 | 84A | -100-----100-100 | IPC42 | 894 | -100-100-100---- |
| IFS0 | 800 | 0000000000-00000 | IPC6 | 84C | -100-100-----100 | IPC43 | 896 | -100-100-100-100 |
| IFS1 | 802 | -00000-00-000000 | IPC7 | 84E | -----100-100-100 | IPC44 | 898 | -100-100-100-100 |
| IFS2 | 804 | --0---00---00--- | IPC8 | 850 | -100---------- | IPC45 | 89A | ----------100 |
| IFS3 | 806 | 0----000----0000 | IPC9 | 852 | ----------100 | IPC47 | 89E | -100-100-100---- |
| IFS4 | 808 | --0-0----0000--0 | IPC10 | 854 | ---------100-100 | INTCON1 | 8C0 | 0000000000-0000- |
| IFS5 | 80A | 000000--0000000- | IPC11 | 856 | ---------100---- | INTCON2 | 8C2 | 100----0----0000 |
| IFS6 | 80C | ---0000000000000 | IPC12 | 858 | -100-100-100-100 | INTCON3 | 8C4 | 0------0---0---- |
| IFS7 | 80E | 0000000000000--- | IPC14 | 85C | -----100-100-100 | INTCON4 | 8C6 | ----------00 |
| IFS10 | 814 | 0000000--------- | IPC15 | 85E | -100---------- | INTTREG | 8C8 | --0-000000000000 |
| IFS11 | 816 | 000--------00000 | IPC16 | 860 | -100---------100 | **Flash** | | |
| IEC0 | 820 | 0000000000-00000 | IPC17 | 862 | -----100-100-100 | NVMCON | 8D0 | 0000--00----0000 |
| IEC1 | 822 | -00000-00-000000 | IPC18 | 864 | -100---------- | NVMADR | 8D2 | xxxxxxxxxxxxxxxx |
| IEC2 | 824 | --0---00---00--- | IPC19 | 866 | ---------100---- | NVMADRU | 8D4 | --------xxxxxxxx |
| IEC3 | 826 | 0----000----0000 | IPC20 | 868 | -100-100-100---- | NVMKEY | 8D6 | --------00000000 |
| IEC4 | 828 | --0-0----0000--0 | IPC21 | 86A | -100-100-100-100 | NVMSRCADRL | 8D8 | 0000000000000000 |
| IEC5 | 82A | 000000--0000000- | IPC22 | 86C | -100-100-------- | NVMSRCADRH | 8DA | --------00000000 |
| IEC6 | 82C | ---0000000000000 | IPC23 | 86E | -100-100-100-100 | **Op Amp** | | |
| IEC7 | 82E | 0000000000000--- | IPC24 | 870 | -100-100-100-100 | AMPCON1L | 8DC | 0----------000 |
| IEC10 | 834 | 0000000--------- | IPC25 | 872 | -100-100-100-100 | AMPCON1H | 8DE | ----------000 |
| IEC11 | 836 | 000--------00000 | IPC26 | 874 | -100-100-100-100 | **CBG** | | |
| IPC0 | 840 | -100-100-100-100 | IPC27 | 876 | ----------100 | BIASCON | 8F0 | 0----------0000 |
| IPC1 | 842 | -100-100-----100 | IPC28 | 878 | -100---------- | IBIASCONL | 8F4 | --000000--000000 |
| IPC2 | 844 | -100-100-100-100 | IPC29 | 87A | -100-100-100-100 | IBIASCONH | 8F6 | --000000--000000 |
| IPC3 | 846 | -100-100-100-100 | IPC30 | 87C | -100-100-100-100 | | | |
| IPC4 | 848 | -100-100-100-100 | IPC31 | 87E | -100-100-100-100 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-7: SFR BLOCK 900h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **PTG** | | | **CCP** | | | CCP2BUFH | 996 | 0000000000000000 |
| PTGCST | 900 | 0-00-000000---00 | CCP1CON1L | 950 | 0-00000000000000 | CCP3CON1L | 998 | 0-00000000000000 |
| PTGCON | 902 | 000000000000-000 | CCP1CON1H | 952 | 00--000000000000 | CCP3CON1H | 99A | 00--000000000000 |
| PTGBTE | 904 | 0000000000000000 | CCP1CON2L | 954 | 00-0----00000000 | CCP3CON2L | 99C | 00-0----00000000 |
| PTGBTEH | 906 | 0000000000000000 | CCP1CON2H | 956 | 0-------00-00000 | CCP3CON2H | 99E | 0-------00-00000 |
| PTGHOLD | 908 | 0000000000000000 | CCP1CON3L | 958 | ----------000000 | CCP3CON3H | 9A2 | 0000------0-00-- |
| PTGT0LIM | 90C | 0000000000000000 | CCP1CON3H | 95A | 0000------0-00-- | CCP3STATL | 9A4 | -----0--01100000 |
| PTGT1LIM | 910 | 0000000000000000 | CCP1STATL | 95C | -----0--01100000 | CCP3STATH | 9A6 | -----------00000 |
| PTGSDLIM | 914 | 0000000000000000 | CCP1STATH | 95E | -----------00000 | CCP3TMRL | 9A8 | 0000000000000000 |
| PTGC0LIM | 918 | 0000000000000000 | CCP1TMRL | 960 | 0000000000000000 | CCP3TMRH | 9AA | 0000000000000000 |
| PTGC1LIM | 91C | 0000000000000000 | CCP1TMRH | 962 | 0000000000000000 | CCP3PRL | 9AC | 1111111111111111 |
| PTGADJ | 920 | 0000000000000000 | CCP1PRL | 964 | 1111111111111111 | CCP3PRH | 9AE | 1111111111111111 |
| PTGL0 | 924 | 0000000000000000 | CCP1PRH | 966 | 1111111111111111 | CCP3RA | 9B0 | 0000000000000000 |
| PTGQPTR | 928 | -----------00000 | CCP1RA | 968 | 0000000000000000 | CCP3RB | 9B4 | 0000000000000000 |
| PTGQUE0 | 930 | 0000000000000000 | CCP1RB | 96C | 0000000000000000 | CCP3BUFL | 9B8 | 0000000000000000 |
| PTGQUE1 | 932 | 0000000000000000 | CCP1BUFL | 970 | 0000000000000000 | CCP3BUFH | 9BA | 0000000000000000 |
| PTGQUE2 | 934 | 0000000000000000 | CCP1BUFH | 972 | 0000000000000000 | CCP4CON1L | 9BC | 0-00000000000000 |
| PTGQUE3 | 936 | 0000000000000000 | CCP2CON1L | 974 | 0-00000000000000 | CCP4CON1H | 9BE | 00--000000000000 |
| PTGQUE4 | 938 | 0000000000000000 | CCP2CON1H | 976 | 00--000000000000 | CCP4CON2L | 9C0 | 00-0----00000000 |
| PTGQUE5 | 93A | 0000000000000000 | CCP2CON2L | 978 | 00-0----00000000 | CCP4CON2H | 9C2 | 0-------00-00000 |
| PTGQUE6 | 93C | 0000000000000000 | CCP2CON2H | 97A | 0-------00-00000 | CCP4CON3H | 9C6 | 0000------0-00-- |
| PTGQUE7 | 93E | 0000000000000000 | CCP2CON3H | 97E | 0000------0-00-- | CCP4STATL | 9C8 | -----0--01100000 |
| PTGQUE8 | 940 | 0000000000000000 | CCP2STATL | 980 | -----0--01100000 | CCP4STATH | 9CA | -----------00000 |
| PTGQUE9 | 942 | 0000000000000000 | CCP2STATH | 982 | -----------00000 | CCP4TMRL | 9CC | 0000000000000000 |
| PTGQUE10 | 944 | 0000000000000000 | CCP2TMRL | 984 | 0000000000000000 | CCP4TMRH | 9CE | 0000000000000000 |
| PTGQUE11 | 946 | 0000000000000000 | CCP2TMRH | 986 | 0000000000000000 | CCP4PRL | 9D0 | 1111111111111111 |
| PTGQUE12 | 948 | 0000000000000000 | CCP2PRL | 988 | 1111111111111111 | CCP4PRH | 9D2 | 1111111111111111 |
| PTGQUE13 | 94A | 0000000000000000 | CCP2PRH | 98A | 1111111111111111 | CCP4RA | 9D4 | 0000000000000000 |
| PTGQUE14 | 94C | 0000000000000000 | CCP2RA | 98C | 0000000000000000 | CCP4RB | 9D8 | 0000000000000000 |
| PTGQUE15 | 94E | 0000000000000000 | CCP2RB | 990 | 0000000000000000 | CCP4BUFL | 9DC | 0000000000000000 |
| | | | CCP2BUFL | 994 | 0000000000000000 | CCP4BUFH | 9DE | 0000000000000000 |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-8: SFR BLOCK A00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **DMA** | | | DMACNT0 | ACC | 0000000000000001 | DMADST2 | ADE | 0000000000000000 |
| DMACON | ABC | 0-0----------0 | DMACH1 | ACE | -----00000000000 | DMACNT2 | AE0 | 0000000000000001 |
| DMABUF | ABE | 0000000000000000 | DMAINT1 | AD0 | 0000000000000--0 | DMACH3 | AE2 | -----00000000000 |
| DMAL | AC0 | 0000000000000000 | DMASRC1 | AD2 | 0000000000000000 | DMAINT3 | AE4 | 0000000000000--0 |
| DMAH | AC2 | 0000000000000000 | DMADST1 | AD4 | 0000000000000000 | DMASRC3 | AE6 | 0000000000000000 |
| DMACH0 | AC4 | -----00000000000 | DMACNT1 | AD6 | 0000000000000001 | DMADST3 | AE8 | 0000000000000000 |
| DMAINT0 | AC6 | 0000000000000--0 | DMACH2 | AD8 | -----00000000000 | DMACNT3 | AEA | 0000000000000001 |
| DMASRC0 | AC8 | 0000000000000000 | DMAINT2 | ADA | 0000000000000--0 | | | |
| DMADST0 | ACA | 0000000000000000 | DMASRC2 | ADC | 0000000000000000 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-9: SFR BLOCK B00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **ADC** | | | ADCMP1ENL | B40 | 0000000000000000 | ADTRIG0L | B80 | ---00000---00000 |
| ADCON1L | B00 | 0-0---------- | ADCMP1ENH | B42 | --------------00 | ADTRIG0H | B82 | ---00000---00000 |
| ADCON1H | B02 | --------011----- | ADCMP1LO | B44 | 0000000000000000 | ADTRIG1L | B84 | ---00000---00000 |
| ADCON2L | B04 | 00-0-000-0000000 | ADCMP1HI | B46 | 0000000000000000 | ADTRIG1H | B86 | ---00000---00000 |
| ADCON2H | B06 | 00----0000000000 | ADCMP2ENL | B48 | 0000000000000000 | ADTRIG2L | B88 | ---00000---00000 |
| ADCON3L | B08 | 0000000000000000 | ADCMP2ENH | B4A | --------------00 | ADTRIG2H | B8A | ---00000---00000 |
| ADCON3H | B0A | 000000000------- | ADCMP2LO | B4C | 0000000000000000 | ADTRIG3L | B8C | ---00000---00000 |
| ADMOD0L | B10 | 0000000000000000 | ADCMP2HI | B4E | 0000000000000000 | ADTRIG3H | B8E | ---00000---00000 |
| ADMOD0H | B12 | 0000000000000000 | ADCMP3ENL | B50 | 0000000000000000 | ADTRIG4L | B90 | ---00000---00000 |
| ADMOD1L | B14 | ------------0000 | ADCMP3ENH | B52 | --------------00 | ADCMP0CON | BA0 | ---0000000000000 |
| ADIEL | B20 | 0000000000000000 | ADCMP3LO | B54 | 0000000000000000 | ADCMP1CON | BA4 | ---0000000000000 |
| ADIEH | B22 | --------------00 | ADCMP3HI | B56 | 0000000000000000 | ADCMP2CON | BA8 | ---0000000000000 |
| ADCSSL | B28 | 0000000000000000 | ADFL0DAT | B68 | 0000000000000000 | ADCMP3CON | BAC | ---0000000000000 |
| ADCSSH | B2A | 0000000000000000 | ADFL0CON | B6A | 00000000---00000 | ADLVLTRGL | BD0 | 0000000000000000 |
| ADSTATL | B30 | 0000000000000000 | ADFL1DAT | B6C | 0000000000000000 | ADLVLTRGH | BD2 | --------------00 |
| ADSTATH | B32 | --------------00 | ADFL1CON | B6E | 00000000---00000 | ADEIEL | BF0 | 0000000000000000 |
| ADCMP0ENL | B38 | 0000000000000000 | ADFL2DAT | B70 | 0000000000000000 | ADEIEH | BF2 | --------------00 |
| ADCMP0ENH | B3A | --------------00 | ADFL2CON | B72 | 00000000---00000 | ADEISTATL | BF8 | 0000000000000000 |
| ADCMP0LO | B3C | 0000000000000000 | ADFL3DAT | B74 | 0000000000000000 | ADEISTATH | BFA | --------------00 |
| ADCMP0HI | B3E | 0000000000000000 | ADFL3CON | B76 | 00000000---00000 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-10: SFR BLOCK C00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **ADC (Continued)** | | | ADCBUF9 | C1E | 0000000000000000 | DACCTRL2H | C86 | ------0010001010 |
| ADCON5L | C00 | 0-------0------- | ADCBUF10 | C20 | 0000000000000000 | DAC1CONL | C88 | 000--000x0000000 |
| ADCON5H | C02 | ----xxxx0------- | ADCBUF11 | C22 | 0000000000000000 | DAC1CONH | C8A | ------0000000000 |
| ADCBUF0 | C0C | 0000000000000000 | ADCBUF12 | C24 | 0000000000000000 | DAC1DATL | C8C | ----000000000000 |
| ADCBUF1 | C0E | 0000000000000000 | ADCBUF13 | C26 | 0000000000000000 | DAC1DATH | C8E | ----000000000000 |
| ADCBUF2 | C10 | 0000000000000000 | ADCBUF14 | C28 | 0000000000000000 | SLP1CONL | C90 | 0000000000000000 |
| ADCBUF3 | C12 | 0000000000000000 | ADCBUF15 | C2A | 0000000000000000 | SLP1CONH | C92 | 0---000--------- |
| ADCBUF4 | C14 | 0000000000000000 | ADCBUF16 | C2C | 0000000000000000 | SLP1DAT | C94 | 0000000000000000 |
| ADCBUF5 | C16 | 0000000000000000 | ADCBUF17 | C2E | 0000000000000000 | VREGCON | CFC | 0--------------00 |
| ADCBUF6 | C18 | 0000000000000000 | **DAC** | | | | | |
| ADCBUF7 | C1A | 0000000000000000 | DACCTRL1L | C80 | 0-0-----0000-000 | | | |
| ADCBUF8 | C1C | 0000000000000000 | DACCTRL2L | C84 | ------0001010101 | | | |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-11: SFR BLOCK D00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **PPS** | | | RPINR21 | D2E | 0000000000000000 | RPOR3 | D86 | --000000--000000 |
| RPCON | D00 | ----0---------- | RPINR22 | D30 | 0000000000000000 | RPOR4 | D88 | --000000--000000 |
| RPINR0 | D04 | 00000000-------- | RPINR23 | D32 | --------00000000 | RPOR5 | D8A | --000000--000000 |
| RPINR1 | D06 | 0000000000000000 | RPINR27 | D3A | 0000000000000000 | RPOR6 | D8C | --000000--000000 |
| RPINR2 | D08 | 00000000-------- | RPINR37 | D4E | 0000000000000000 | RPOR7 | D8E | --000000--000000 |
| RPINR3 | D0A | 0000000000000000 | RPINR38 | D50 | --------00000000 | RPOR8 | D90 | --000000--000000 |
| RPINR4 | D0C | 0000000000000000 | RPINR42 | D58 | 0000000000000000 | RPOR9 | D92 | --000000--000000 |
| RPINR5 | D0E | 0000000000000000 | RPINR43 | D5A | 0000000000000000 | RPOR10 | D94 | --000000--000000 |
| RPINR6 | D10 | 0000000000000000 | RPINR44 | D5C | 0000000000000000 | RPOR11 | D96 | --000000--000000 |
| RPINR11 | D1A | 0000000000000000 | RPINR45 | D5E | 00000000-------- | RPOR12 | D98 | --000000--000000 |
| RPINR12 | D1C | 0000000000000000 | RPINR46 | D60 | 0000000000000000 | RPOR13 | D9A | --000000--000000 |
| RPINR13 | D1E | 0000000000000000 | RPINR47 | D62 | 0000000000000000 | RPOR14 | D9C | --000000--000000 |
| RPINR14 | D20 | 0000000000000000 | RPINR48 | D64 | 0000000000000000 | RPOR16 | DA0 | --000000-------- |
| RPINR15 | D22 | 0000000000000000 | RPINR49 | D66 | 0000000000000000 | RPOR17 | DA2 | --000000--000000 |
| RPINR18 | D28 | 0000000000000000 | RPOR0 | D80 | --000000--000000 | RPOR18 | DA4 | --000000--000000 |
| RPINR19 | D2A | 0000000000000000 | RPOR1 | D82 | --000000--000000 | RPOR19 | DA6 | --000000--000000 |
| RPINR20 | D2C | 0000000000000000 | RPOR2 | D84 | --000000--000000 | | | |

**Legend:** x = unknown or indeterminate value; "–" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.

**TABLE 4-12: SFR BLOCK E00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **I/O Ports** | | | ODCB | E24 | 0000000000000000 | CNSTATC | E4A | --00000000000000 |
| ANSELA | E00 | ----------11111 | CNPUB | E26 | 0000000000000000 | CNEN1C | E4C | --00000000000000 |
| TRISA | E02 | ----------11111 | CNPDB | E28 | 0000000000000000 | CNFC | E4E | --00000000000000 |
| PORTA | E04 | ----------00000 | CNCONB | E2A | 0---0---------- | ANSELD | E54 | --1--1---------- |
| LATA | E06 | ----------xxxxx | CNEN0B | E2C | 0000000000000000 | TRISD | E56 | --1--1-1------1- |
| ODCA | E08 | ----------00000 | CNSTATB | E2E | 0000000000000000 | PORTD | E58 | --0--0-0------0- |
| CNPUA | E0A | ----------00000 | CNEN1B | E30 | 0000000000000000 | LATD | E5A | --x--x-x------x- |
| CNPDA | E0C | ----------00000 | CNFB | E32 | 0000000000000000 | ODCD | E5C | --0--0-0------0- |
| CNCONA | E0E | 0---0---------- | ANSELC | E38 | --------11--1111 | CNPUD | E5E | --0--0-0------0- |
| CNEN0A | E10 | ----------00000 | TRISC | E3A | --11111111111111 | CNPDD | E60 | 0000000000000000 |
| CNSTATA | E12 | ----------00000 | PORTC | E3C | --00000000000000 | CNCOND | E62 | 0---0---------- |
| CNEN1A | E14 | ----------00000 | LATC | E3E | --xxxxxxxxxxxxxx | CNEN0D | E64 | --0--0-0------0- |
| CNFA | E16 | ----------00000 | ODCC | E40 | --00000000000000 | CNSTATD | E66 | --0--0-0------0- |
| ANSELB | E1C | ------111--11111 | CNPUC | E42 | --00000000000000 | CNEN1D | E68 | --0--0-0------0- |
| TRISB | E1E | 1111111111111111 | CNPDC | E44 | --00000000000000 | CNFD | E6A | --0--0-0------0- |
| PORTB | E20 | 0000000000000000 | CNCONC | E46 | 0---0---------- | **Memory BIST** | | |
| LATB | E22 | xxxxxxxxxxxxxxxx | CNEN0C | E48 | --00000000000000 | MBISTCON | EFC | -------00--0---0 |

**Legend:** x = unknown or indeterminate value; "-" = unimplemented bits. Address values are in hexadecimal. Reset values are in binary.


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**TABLE 4-13: SFR BLOCK F00h**

| Register | Address | All Resets | Register | Address | All Resets | Register | Address | All Resets |
|---|---|---|---|---|---|---|---|---|
| **UART3** | | | U3SCINT | F22 | --00-000--00-000 | PMD4 | FAA | ----------0--- |
| U3MODE | F00 | 0-000-0000000000 | U3INT | F24 | --------00---0-- | PMD6 | FAE | ----0000-------- |
| U3MODEH | F02 | 00--000000000000 | **Reset and Oscillator** | | | PMD7 | FB0 | -------0----0--- |
| U3STA | F04 | 0000000010000000 | RCON | F80 | 00----0000-00011 | PMD8 | FB2 | --0-0--0--00000- |
| U3STAH | F06 | -000-00000101110 | OSCCON | F84 | -000-yyy0-0-0--0 | **WDT** | | |
| U3BRG | F08 | 0000000000000000 | CLKDIV | F86 | 00110000--000001 | WDTCONL | FB4 | 0--0000000000000 |
| U3BRGH | F0A | ----------0000 | PLLFBD | F88 | ----000010010110 | WDTCONH | FB6 | 0000000000000000 |
| U3RXREG | F0C | --------xxxxxxxx | PLLDIV | F8A | ------00-011-001 | **Reference Clock Output** | | |
| U3TXREG | F10 | x-------xxxxxxxx | OSCTUN | F8C | ----------000000 | REFOCONL | FB8 | 0-000-00----0000 |
| U3P1 | F14 | -------000000000 | DCOTUN | F9C | ----------000000 | REFOCONH | FBA | -000000000000000 |
| U3P2 | F16 | -------000000000 | DCOCON | F9E | --0-xxxx-------- | REFOTRIMH | FBE | 000000000------- |
| U3P3 | F18 | 0000000000000000 | **PMD** | | | **Programmer/Debugger** | | |
| U3P3H | F1A | --------00000000 | PMDCON | FA0 | ----0---------- | VISI | FCC | 0000000000000000 |
| U3TXCHK | F1C | --------00000000 | PMD1 | FA4 | ----000-00000--0 | APPO | FD2 | 0000000000000000 |
| U3RXCHK | F1E | --------00000000 | PMD2 | FA6 | ----------0000 | APPI | FD4 | 0000000000000000 |
| U3SCCON | F20 | ----------00000- | PMD3 | FA8 | --------0---0--- | APPS | FD6 | ----------00000 |

**Legend:** x = unknown or indeterminate value; "-" =unimplemented bits; y = value set by Configuration bits. Address values are in hexadecimal. Reset values are in binary.

### 4.5.1 PAGED MEMORY SCHEME

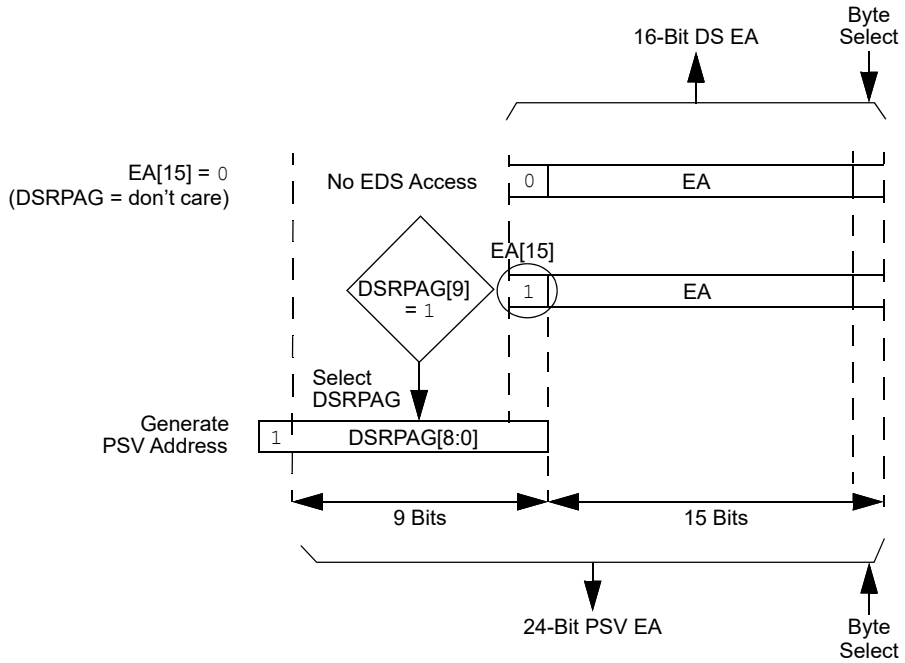
The dsPIC33CDVL64MC106 architecture extends the available Data Space through a paging scheme, which allows the available Data Space to be accessed using MOV instructions in a linear fashion for pre- and post-modified Effective Addresses (EAs). The upper half of the base Data Space address is used in 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 4-5. 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 4-6.

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

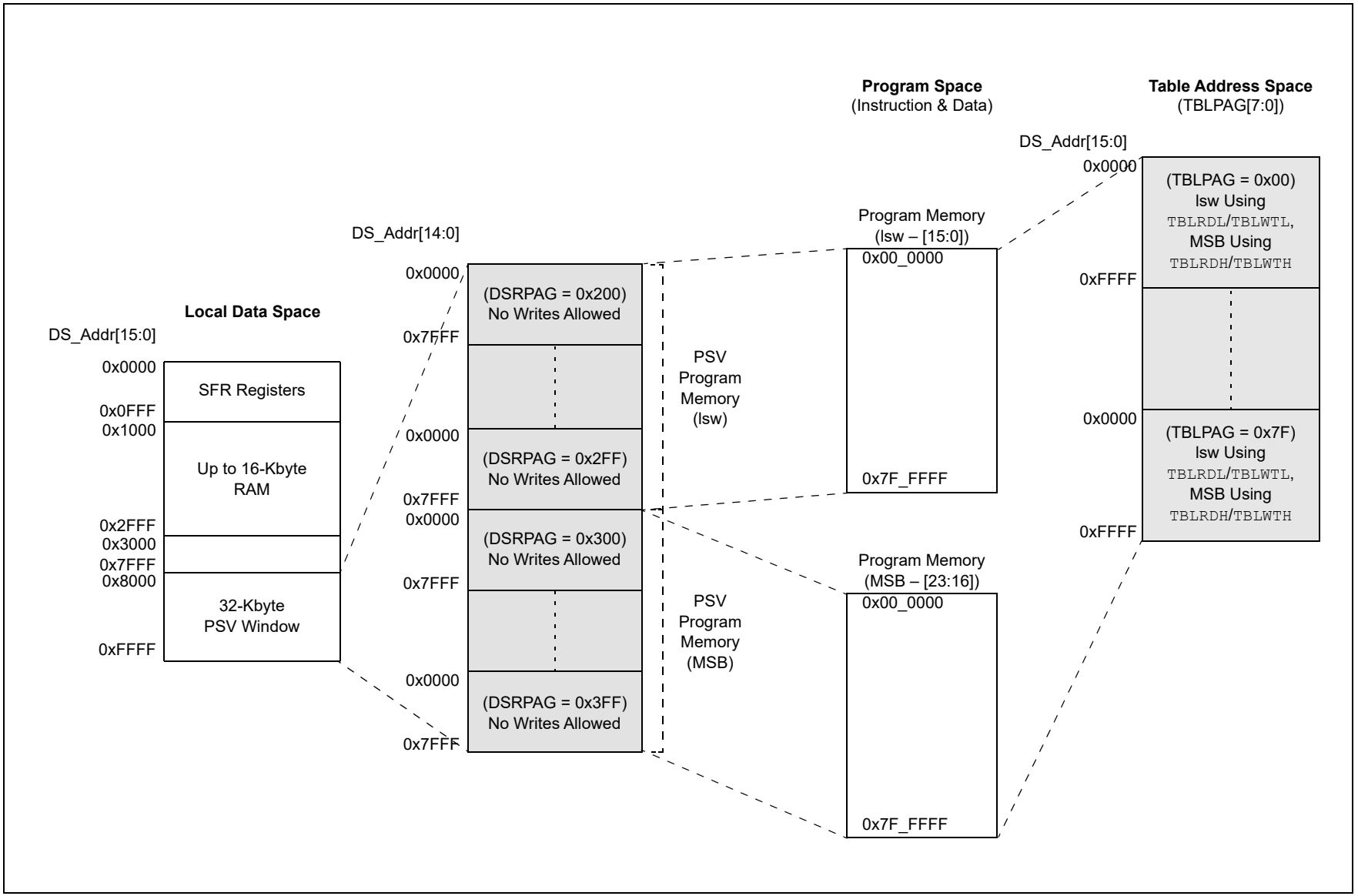
**FIGURE 4-5: PROGRAM SPACE VISIBILITY (PSV) READ ADDRESS GENERATION**




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


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**FIGURE 4-6: 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 4-14 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 4-14: OVERFLOW AND UNDERFLOW SCENARIOS AT PAGE 0 AND PSV SPACE BOUNDARIES(2,3,4)**

| O/U, R/W | Operation | Before | | | After | | |
|---|---|---|---|---|---|---|---|
| | | DSRPAG | DS EA[15] | Page Description | DSRPAG | DS EA[15] | Page Description |
| O, R | [++Wn] or [Wn++] | DSRPAG = 0x2FF | 1 | PSV: Last lsw page | DSRPAG = 0x300 | 1 | PSV: First MSB page |
| O, R | | DSRPAG = 0x3FF | 1 | PSV: Last MSB page | DSRPAG = 0x3FF | 0 | See **Note 1** |
| U, R | [--Wn] or [Wn--] | DSRPAG = 0x001 | 1 | PSV page | DSRPAG = 0x001 | 0 | See **Note 1** |
| U, R | | DSRPAG = 0x200 | 1 | PSV: First lsw page | DSRPAG = 0x200 | 0 | See **Note 1** |
| U, R | | 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 (0x0000-0x8000).

**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.


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#### 4.5.1.1 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 = 0x000. 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 the base address bit, EA[15] = 1.

#### 4.5.1.2 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 the dsPIC33CDVL64MC106 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.

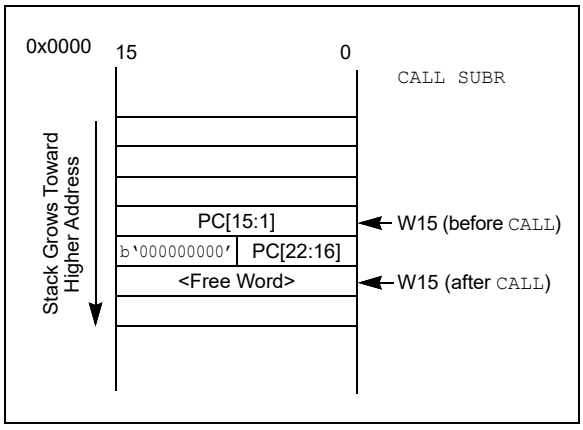
The Software Stack Pointer always points to the first available free word and fills the software stack, working from lower toward higher addresses. Figure 4-7 illustrates how it pre-decrements for a stack pop (read) and post-increments for a stack push (writes).

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 4-7. During exception processing, the MSB of the PC is concatenated with the lower eight 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 4-7: CALL STACK FRAME**



### 4.5.2 INSTRUCTION ADDRESSING MODES

The addressing modes shown in Table 4-15 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.

#### 4.5.2.1 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.

#### 4.5.2.2 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 4-15: 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. |


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#### 4.5.2.3 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. |

#### 4.5.2.4 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)

#### 4.5.2.5 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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### 4.5.3 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).

#### 4.5.3.1 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).

#### 4.5.3.2 W Address Register Selection

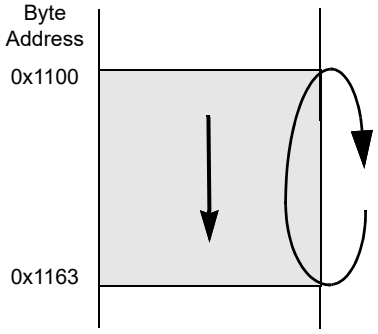
The Modulo and Bit-Reversed Addressing Control register, MODCON[15:0], contains enable flags as well as a W register field to specify the W Address registers. The XWM and YWM fields select the registers that operate with Modulo Addressing:

- 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 4-8: 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
```


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#### 4.5.3.3 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. |

### 4.5.4 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.

#### 4.5.4.1 Bit-Reversed Addressing Implementation

Bit-Reversed Addressing mode is enabled in any of these situations:

- 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 are 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 4-9: BIT-REVERSED ADDRESSING EXAMPLE**

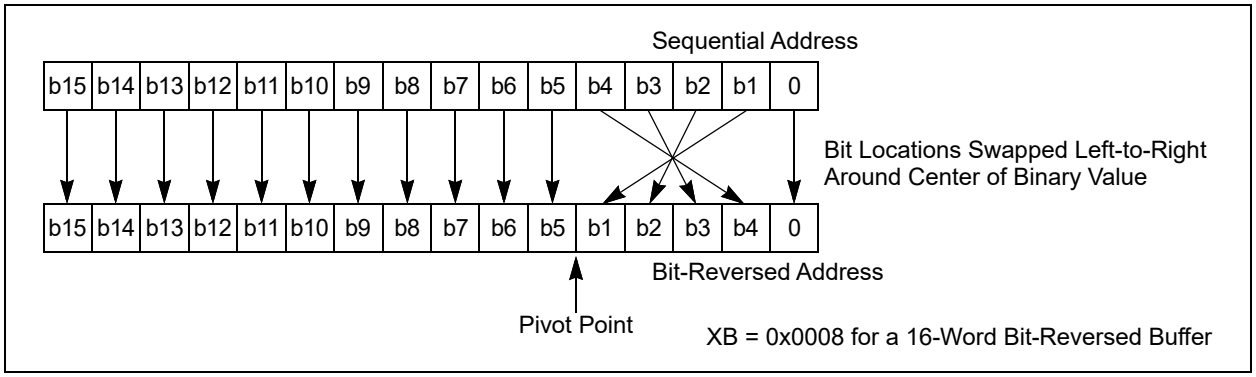



**TABLE 4-16: BIT-REVERSED ADDRESSING SEQUENCE (16-ENTRY)**

| 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 |


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### 4.5.5 INTERFACING PROGRAM AND DATA MEMORY SPACES

The dsPIC33CDVL64MC106 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 these data successfully, they must be accessed in a way that preserves the alignment of information in both spaces.

Aside from normal execution, the architecture of the dsPIC33CDVL64MC106 devices provides two methods by which Program Space can be accessed during operation:

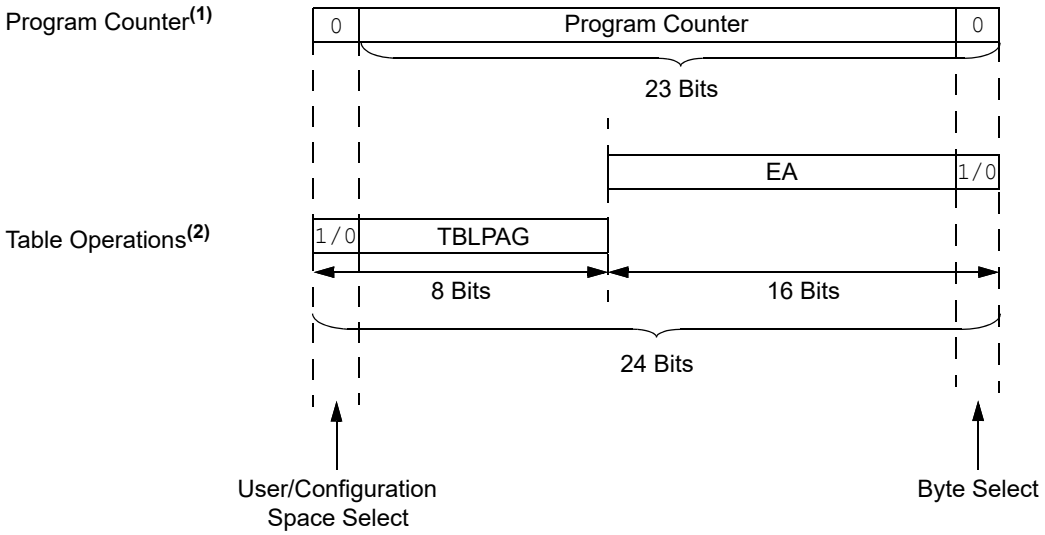
- Using table instructions to access individual bytes or words anywhere in the Program Space.
- Remapping a portion of the Program Space into the Data Space (Program Space Visibility).

Table instructions allow an application to read 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 4-17: 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 (Byte/Word Read) | 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 4-10: 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.

#### 4.5.5.1 Data Access from Program Memory Using Table Instructions

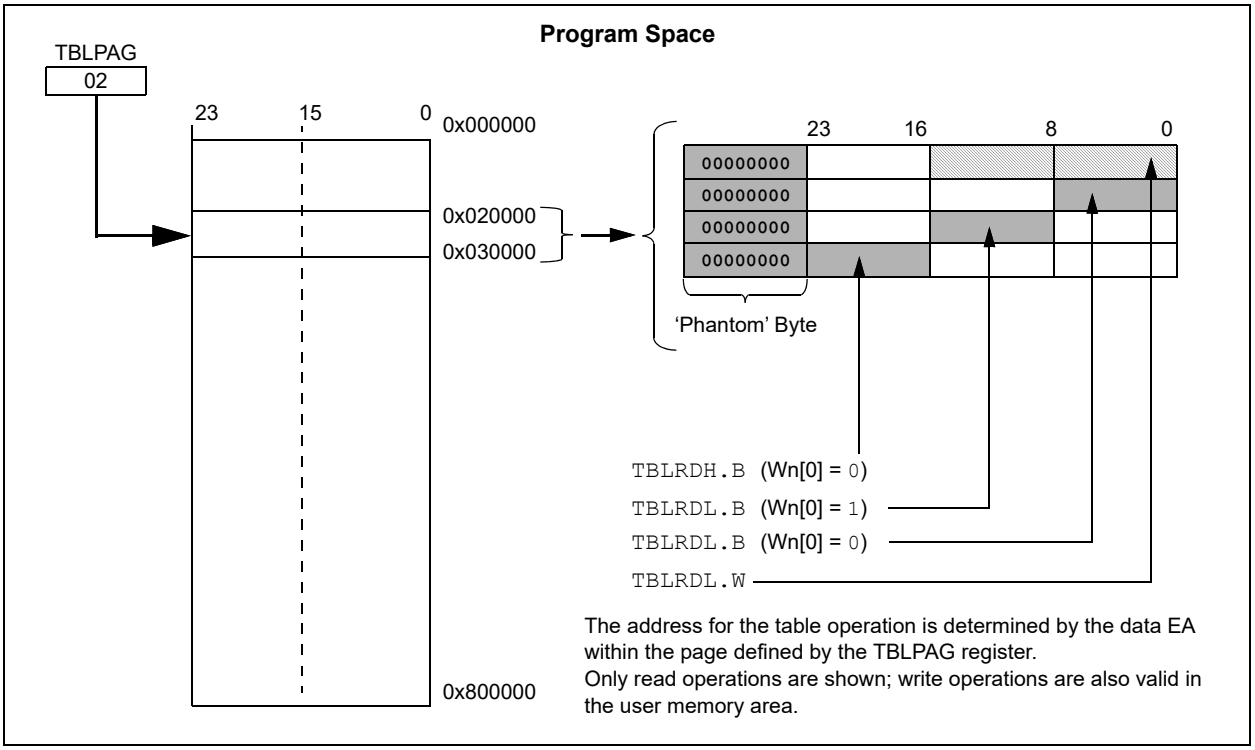
The TBLRDL instruction offers a direct method of reading the lower word of any address within the Program Space without going through Data Space. The TBLRDH instruction is the only method to read the upper eight bits of a Program Space word as data.

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 accesses the space that contains the least significant data word. TBLRDH accesses the space that contains the upper data byte.

Two table instructions are provided to read byte or word-sized (16-bit) data 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 are always '0' when the upper 'phantom' byte is selected (Byte Select = 1).

**FIGURE 4-11: ACCESSING PROGRAM MEMORY WITH TABLE INSTRUCTIONS**





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## 5.0 FLASH PROGRAM MEMORY

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Flash Programming"** (www.microchip.com/DS70000609).

The dsPIC33CDVL64MC106 devices contain internal Flash program memory for storing and executing application code. The memory is readable, writable and erasable during a 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 dsPIC33CDVL64MC106 device to be serially programmed while in the end application circuit. This is done with a Programming Clock and Programming Data (PGCx/PGDx) 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.

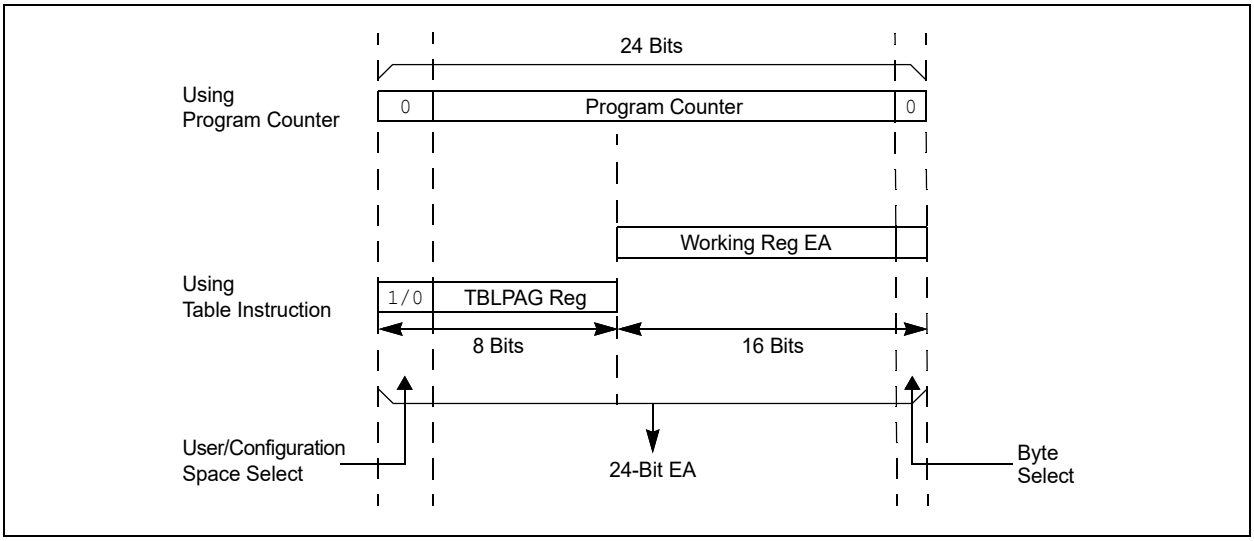
Enhanced In-Circuit Serial Programming uses an on-board bootloader, known as the programming executive, to manage the programming process. Using an SPI data frame format, the programming executive can erase, program and verify program memory. For more information on Enhanced ICSP, see the device programming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

RTSP is accomplished using TBLRD (Table Read) and TBLWT (Table Write) instructions. With RTSP, the user application can write program memory data by double program memory words or by blocks ('rows') of 128 instructions (256 addressable bytes). RTSP can erase program memory in blocks or 'pages' of 1024 instructions (2048 addressable 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 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 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 dsPIC33CDVL64MC106 Flash program memory array is organized into rows of 128 instructions or 384 bytes. RTSP allows the user application to erase a single page (eight rows or 1024 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.

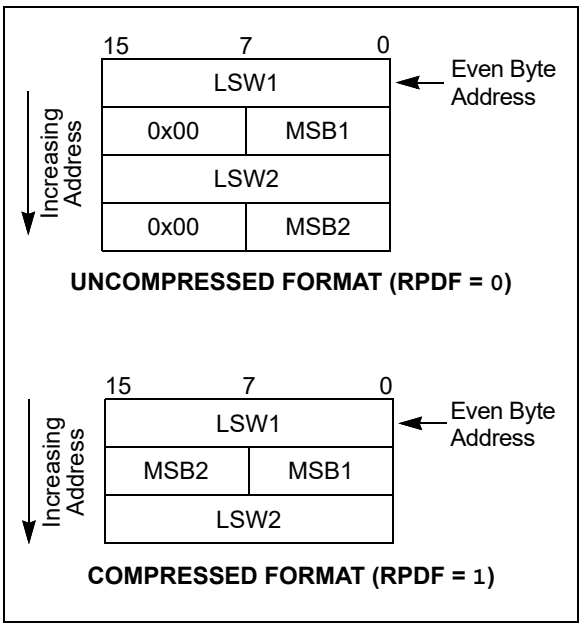
The page erase and single row write blocks are edge-aligned, from the beginning of program memory, on boundaries of 3072 bytes and 384 bytes, respectively. Table 33-17 in **Section 33.0 "Electrical Characteristics"** lists the typical erase and programming times. To write into the Flash memory, it is necessary to erase the page that contains the desired address of the location the user wants to change.

Row programming is performed by loading 384 bytes into data memory and then loading the address of the first byte in that row into the NVMSRCADRL/H register pair. Once the write has been initiated, the device will automatically load the write latches and increment the NVMSRCADRL/H 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 help 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 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.

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




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. The WR bit is protected against an accidental write. To set this bit, 0x55 and 0xAA values must be written sequentially into the NVMKEY register. After the programming command (WR bit = `1`) has been executed, the user application must wait until programming is complete (WR bit = `0`). The two instructions following the start of the programming sequence should be `NOP`s.

**Note:** MPLAB® XC16 provides a built-in C language function, including the unlocking sequence to set the WR bit in the NVMCON register:

```
__builtin_write_NVM()
```


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## 5.3 Program Flash Memory Control Registers

Six SFRs are used to write and erase the Program Flash Memory: NVMCON, NVMKEY, NVMADR/U and NVMSRCADRL/H.

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

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 eight 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 are written into the data memory space (RAM) at an address defined by the NVMSRCADRL/H register pair (the location of first element in row programming data).

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

| R/SO-0(1,6) | R/W-0(1) | R/W-0(1) | R/W-0 | U-0 | U-0 | R/W-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| WR | WREN | WRERR | NVMSIDL(2) | — | — | 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) |
|---|---|---|---|---|---|---|---|
| — | — | — | — | NVMOP[3:0](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(1,6)
- 1 = Initiates a Flash memory program 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 11-10 **Unimplemented:** Read as '0'

bit 9 **RPDF:** Row Programming Data Format bit
- 1 = Row data to be stored in RAM are in compressed format.
- 0 = Row data to be stored in RAM are 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, there will be minimal power savings ($I_{IDLE}$), 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:** An unlock sequence is required to write to this bit (see **Section 5.2 "RTSP Operation"**).


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**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
1110 = User memory bulk erase operation
1101 = Reserved
1100 = Reserved
1011 = Reserved
1010 = Reserved
1001 = Reserved
1000 = Reserved
0111 = Reserved
0101 = Reserved
0100 = Reserved
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, there will be minimal power savings (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:** An unlock sequence is required to write to this bit (see **Section 5.2 "RTSP Operation"**).

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


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**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)

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**REGISTER 5-5: NVMSRCADRL: NVM SOURCE DATA ADDRESS 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 |
|---|---|---|---|---|---|---|---|
| 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.

**REGISTER 5-6: NVMSRCADRH: NVM SOURCE DATA ADDRESS REGISTER 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 |
|---|---|---|---|---|---|---|---|
| NVMSRCADR[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 **NVMSRCADR[23:16]:** 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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## 5.4 Error Correcting Code (ECC)

In order to improve program memory performance and durability, these devices include Error Correcting Code (ECC) functionality as an integral part of the Flash memory controller. ECC can determine the presence of single-bit errors in program data, including which bit is in error, and correct the data automatically without user intervention. ECC cannot be disabled.

When data are written to program memory, ECC generates a 7-bit Hamming code parity value for every two (24-bit) instruction words. The data are stored in blocks of 48 data bits and seven parity bits; parity data are not memory-mapped and are inaccessible. When the data are read back, the ECC calculates the parity on them and compares it to the previously stored parity value. If a parity mismatch occurs, there are two possible outcomes:

- A single-bit error has occurred and has been automatically corrected on readback.
- A double-bit error has occurred and the read data are not changed.

Single-bit error occurrence can be identified by the state of the ECCSBEIF (IFS0[13]) bit. An interrupt can be generated when the corresponding interrupt enable bit is set, ECCSBEIE (IEC0[13]). The ECCSTATL register contains the parity information for single-bit errors. The SECOUT[7:0] bit field contains the expected calculated SEC parity, and the SECIN[7:0] bits contain the actual value from a Flash read operation. The SECSYNDx bits (ECCSTATH[7:0]) indicate the bit position of the single-bit error within the 48-bit pair of instruction words. When no error is present, SECINx equals SECOUTx and SECSYNDx is zero. The ECCSTATL and ECCSTATH registers will only update and be valid when an error has occurred, or when the included Fault injection is enabled, and an ECCADDR match occurs.

Double-bit errors result in a generic hard trap. The ECCDBE bit (INTCON4[1]) bit will be set to identify the source of the hard trap. If no Interrupt Service Routine is implemented for the hard trap, a device Reset will also occur. The ECCSTATH register contains double-bit error status information. The DEDOUT bit is the expected calculated DED parity, and DEDIN is the actual value from a Flash read operation. When no error is present, DEDIN equals DEDOUT.

### 5.4.1 ECC FAULT INJECTION

To test Fault handling, an EEC error can be generated. Both single and double-bit errors can be generated in both the read and write data paths. A read path Fault injection first reads the Flash data and then modifies them prior to entering the ECC logic. A write path Fault injection modifies the actual data prior to them being written into the target Flash and will cause an EEC error on a subsequent Flash read. The following procedure is used to inject a Fault:

1. Load the Flash target address into the ECCADDR register.
2. Select the first Fault bit determined by FLT1PTRx (ECCCONH[7:0]). The target bit is inverted to create the Fault.
3. If a double Fault is desired, select the second Fault bit determined by FLT2PTRx (ECCCONH[15:8]), otherwise set to all '1's.
4. Write the NVMKEY unlock sequence (see **Section 5.3 "Program Flash Memory Control Registers"**).
5. Enable the ECC Fault injection logic by setting the FLTINJ bit (ECCCONL[0]).
6. Perform a read or write to the Flash target address.

5.4.2 ECC CONTROL REGISTERS

**REGISTER 5-7: ECCCONL: ECC FAULT INJECTION CONFIGURATION REGISTER 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 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | FLTINJ |
| 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 **FLTINJ:** Fault Injection Sequence Enable bit
1 = Enabled
0 = Disabled

**REGISTER 5-8: ECCCONH: ECC FAULT INJECTION CONFIGURATION REGISTER 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 |
|---|---|---|---|---|---|---|---|
| FLT2PTR[7:0] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| FLT1PTR[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 **FLT2PTR[7:0]:** ECC Fault Injection Bit Pointer 2 bits
11111111-00111000 = No Fault injection occurs.
00110111 = Fault injection (bit inversion) occurs on bit 55 of ECC bit order.
•
•
•
00000001 = Fault injection (bit inversion) occurs on bit 1 of ECC bit order.
00000000 = Fault injection (bit inversion) occurs on bit 0 of ECC bit order.

bit 7-0 **FLT1PTR[7:0]:** ECC Fault Injection Bit Pointer 1 bits
11111111-00111000 = No Fault injection occurs.
00110111 = Fault injection occurs on bit 55 of ECC bit order.
•
•
•
00000001 = Fault injection occurs on bit 1 of ECC bit order.
00000000 = Fault injection occurs on bit 0 of ECC bit order.


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**REGISTER 5-9: ECCADDRL: ECC FAULT INJECT ADDRESS COMPARE 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 |
|---|---|---|---|---|---|---|---|
| ECCADDR[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 |
|---|---|---|---|---|---|---|---|
| ECCADDR[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 **ECCADDR[15:0]:** ECC Fault Injection NVM Address Match Compare bits

**REGISTER 5-10: ECCADDRH: ECC FAULT INJECT ADDRESS COMPARE REGISTER 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 |
|---|---|---|---|---|---|---|---|
| ECCADDR[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 **ECCADDR[23:16]:** ECC Fault Injection NVM Address Match Compare bits

**REGISTER 5-11: ECCSTATL: ECC SYSTEM STATUS DISPLAY REGISTER LOW**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| SECOUT[7:0] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| SECIN[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 **SECOUT[7:0]:** Calculated Single Error Correction Parity Value bits

bit 7-0 **SECIN[7:0]:** Read Single Error Correction Parity Value bits
SECIN[7:0] bits are the actual parity value of a Flash read operation.

**REGISTER 5-12: ECCSTATH: ECC SYSTEM STATUS DISPLAY REGISTER HIGH**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | DEDOUT | DEDIN |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| SECSYND[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 **DEDOUT:** Calculated Dual Bit Error Detection Parity bit

bit 8 **DEDIN:** Read Dual Bit Error Detection Parity bit
DEDIN is the actual parity value of a Flash read operation.

bit 7-0 **SECSYND[7:0]:** Calculated ECC Syndrome Value bits
Indicates the bit location that contains the error.


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## 5.5 Flash OTP by ICSP™ Write Inhibit

ICSP Write Inhibit is an access restriction feature that, when activated, restricts all of Flash memory. Once activated, ICSP Write Inhibit permanently prevents ICSP Flash programming and erase operations and cannot be deactivated. This feature is intended to prevent alteration of Flash memory contents with behavior similar to One-Time-Programmable (OTP) devices.

RTSP, including erase and programming operations, is not restricted when ICSP Write Inhibit is activated; however, code to perform these actions must be programmed into the device before ICSP Write Inhibit is activated. This allows for a bootloader-type application to alter Flash contents with ICSP Write Inhibit activated.

Entry into ICSP and Enhanced ICSP modes is not affected by ICSP Write Inhibit. In these modes, it will continue to be possible to read configuration memory space and any user memory space regions which are not code-protected. With ICSP writes inhibited, an attempt to set WR (NVMCON[15]) = 1 will maintain WR = 0, and instead, set WRERR (NVMCON[13]) = 1. All Enhanced ICSP erase and programming commands will have no effect with self-checked programming commands returning a FAIL response opcode (PASS if the destination already exactly matched the requested programming data).

Once ICSP Write Inhibit is activated, it is not possible for a device executing in Debug mode to erase/write Flash, nor can a debug tool switch the device to Production mode. ICSP Write Inhibit should therefore only be activated on devices programmed for production.

### 5.5.1 ACTIVATING FLASH OTP BY ICSP WRITE INHIBIT

| **Note:** | It is not possible to deactivate ICSP Write Inhibit. |
|---|---|

ICSP Write Inhibit is activated by executing a pair of NVMCON double-word programming commands to save two 16-bit activation values in the configuration memory space. The target NVM addresses and values required for activation are shown in Table 5-1. Once both addresses contain their activation values, ICSP Write Inhibit will take permanent effect on the next device Reset.

Only the lower 16 data bits stored at the activation addresses are evaluated; the upper eight bits and second 24-bit word written by the double-word programming should be written as '0's. The addresses can be programmed in any order and also during separate ICSP/Enhanced ICSP/RTSP sessions, but any attempt to program an incorrect 16-bit value or use a row programming operation to program the values will be aborted without altering the existing data.

**TABLE 5-1: ICSP™ WRITE INHIBIT ACTIVATION ADDRESSES AND DATA**

| | Configuration Memory Address | ICSP™ Write Inhibit Activation Value |
|---|---|---|
| Write Lock 1 | 0x801028 | 0x006D63 |
| Write Lock 2 | 0x80102C | 0x006870 |

**NOTES:**


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## 6.0 RESETS

| | |
|---|---|
| **Note 1:** | This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Reset"** (www.microchip.com/DS70000602). |
| **2:** | Some registers and associated bits described in this section may not be available on all devices. |

The Reset module combines all Reset sources and controls the device Master Reset Signal, $\overline{SYSRST}$. The following is a list of device Reset sources:

- POR: Power-on Reset
- BOR: Brown-out Reset
- $\overline{MCLR}$: 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 $\overline{SYSRST}$ 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"** for register Reset states. |

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

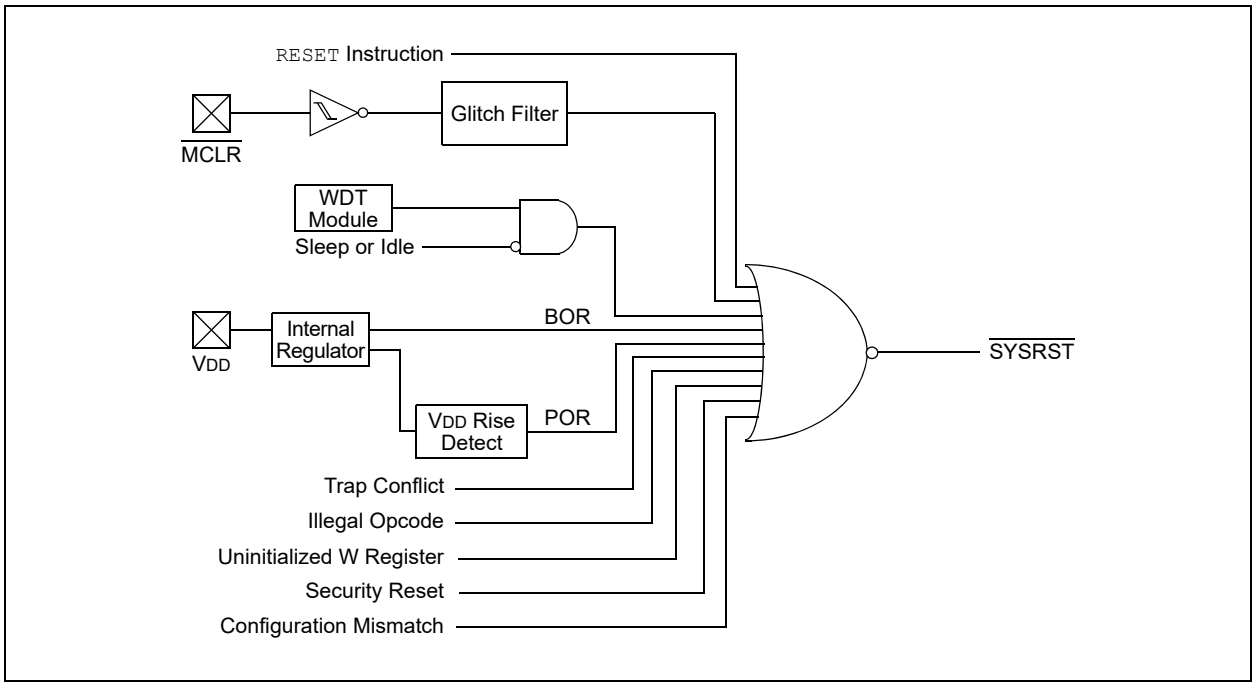
A POR clears all the bits, except for the BOR and POR bits (RCON[1:0]) that are set. The user application can set or clear any bit, at any time, during code execution. The RCON bits only serve as status bits. Setting a particular Reset status bit in software does not cause a device Reset to occur.

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 website for the devices listed in this data sheet. This product page contains the latest updates and additional information.

### 6.1.1 KEY RESOURCES

- **"Reset"** (www.microchip.com/DS70000602)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools


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

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

| R/W-0 | R/W-0 | r-0 | R/W-0 | R/W-0 | R/W-0 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| EXTR | SWR | — | WDTO | SLEEP | IDLE | BOR | POR |
| 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 **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 13-10 **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 **Reserved:** Read as '0'

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

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.

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**NOTES:**


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# 7.0 INTERRUPT CONTROLLER

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Interrupts"** (www.microchip.com/DS70000600).

**2:** Some registers and associated bits described in this section may not be available on all devices.

The dsPIC33CDVL64MC106 interrupt controller reduces the numerous peripheral interrupt request signals to a single interrupt request signal to the dsPIC33CDVL64MC106 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 dsPIC33CDVL64MC106 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 (BS) is defined and the AIVT has been enabled. To enable the AIVT, the Configuration bits, BSEN and 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 two 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.

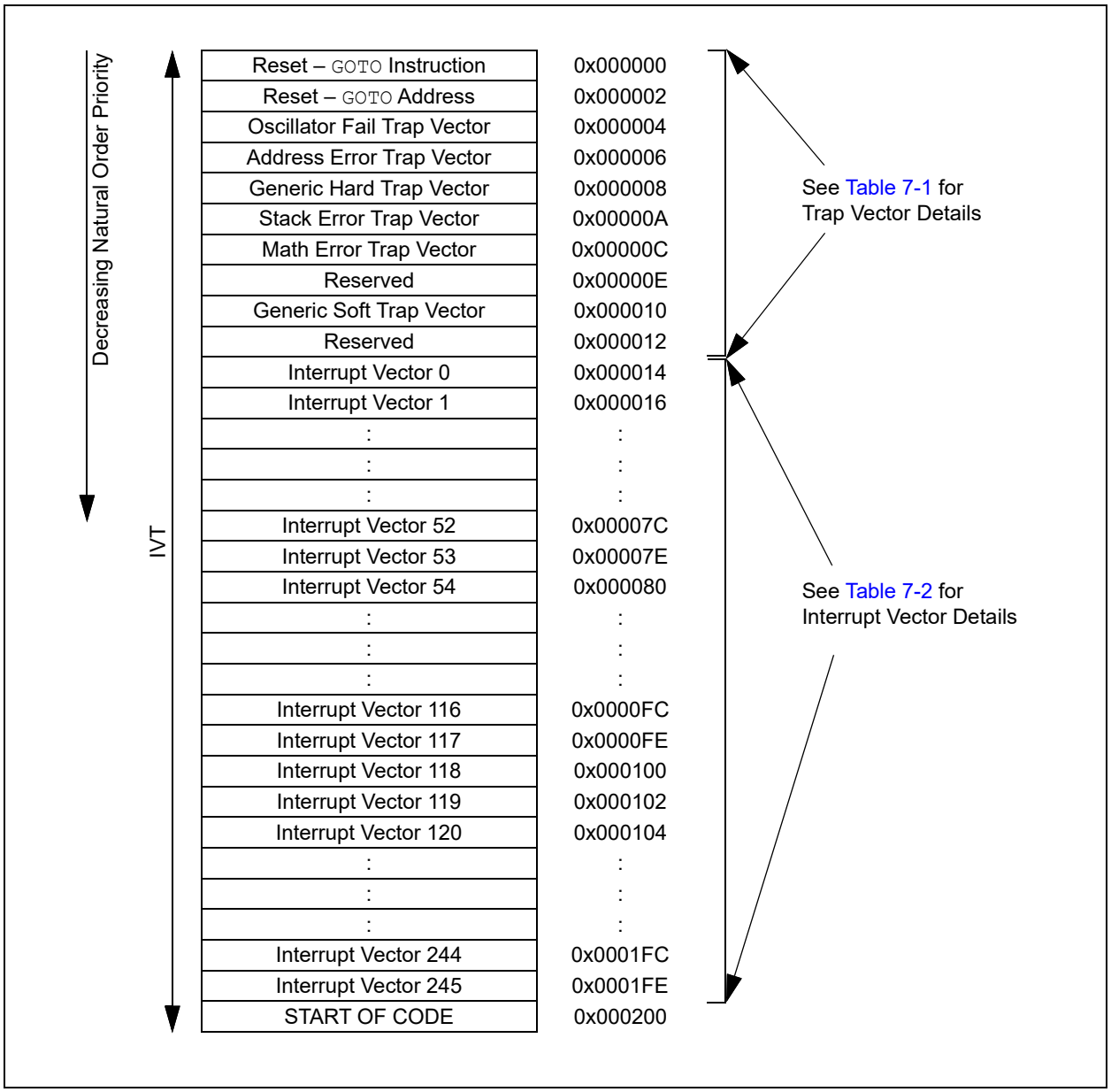
## 7.2 Reset Sequence

A device Reset is not a true exception because the interrupt controller is not involved in the Reset process. The dsPIC33CDVL64MC106 family clears its 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.

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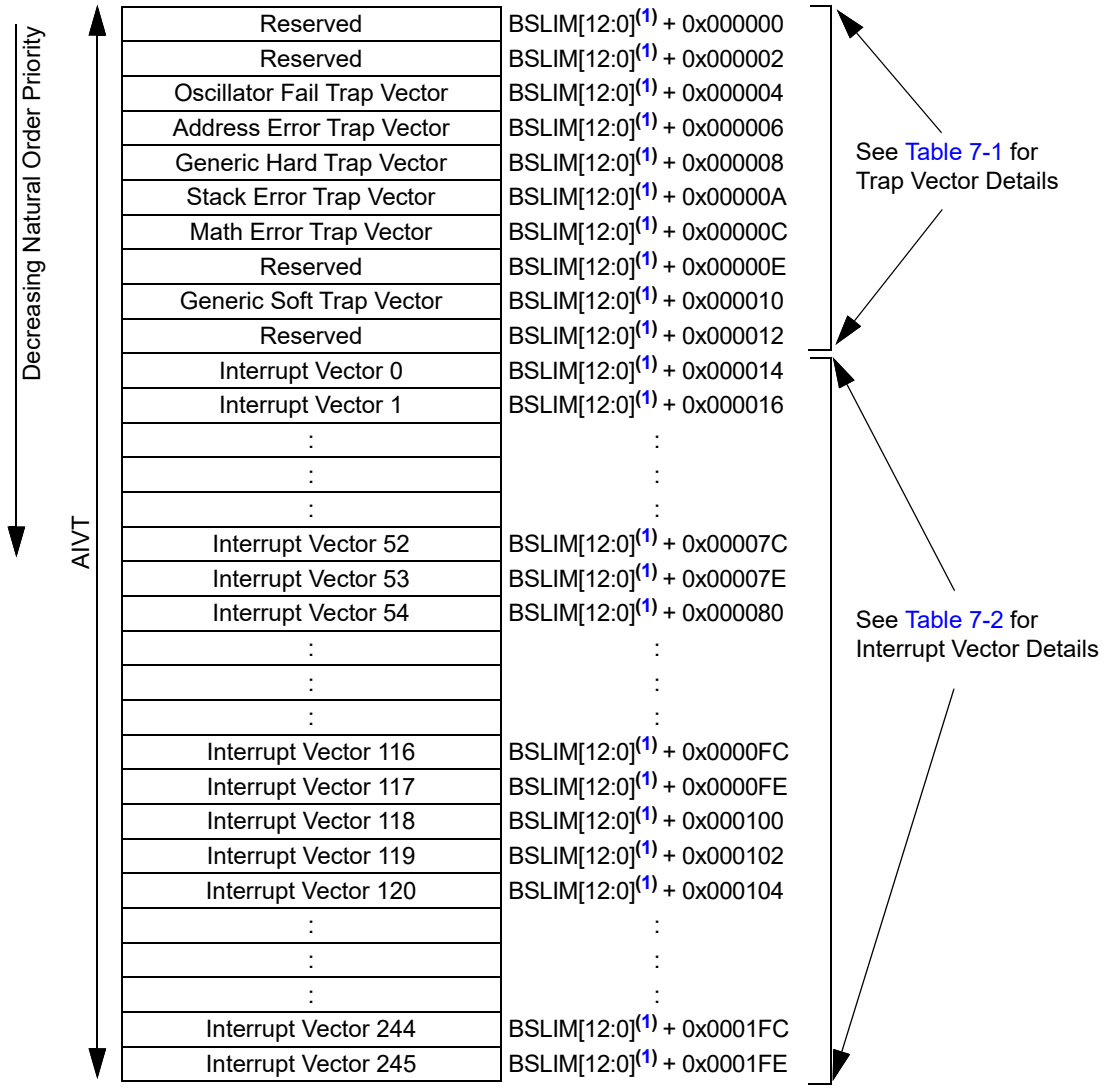
**FIGURE 7-1: dsPIC33CDVL64MC106 FAMILY INTERRUPT VECTOR TABLE**





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**FIGURE 7-2: dsPIC33CDVL64MC106 FAMILY ALTERNATE INTERRUPT VECTOR TABLE**




**Note 1:** The address depends on the size of the Boot Segment defined by BSLIM[12:0]: [(BSLIM[12:0] – 1) x 0x800] + Offset.

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

| Trap Description | MPLAB® XC16 Trap ISR Name | IVT Address | Trap Bit Location | | | Priority |
|---|---|---|---|---|---|---|
| | | | Interrupt Flag | Type | Enable | |
| Oscillator Failure | _OscillatorFail | 0x000004 | INTCON1[1] | — | — | 15 |
| Address Error | _AddressError | 0x000006 | INTCON1[3] | — | — | 14 |
| ECC Double-Bit Error | _HardTrapError | 0x000008 | INTCON4[1] | — | — | 13 |
| Software Generated Trap | _HardTrapError | 0x000008 | INTCON4[0] | — | INTCON2[13] | 13 |
| Stack Error | _StackError | 0x00000A | INTCON1[2] | — | — | 12 |
| Overflow Accumulator A | _MathError | 0x00000C | INTCON1[4] | INTCON1[14] | INTCON1[10] | 11 |
| Overflow Accumulator B | _MathError | 0x00000C | INTCON1[4] | INTCON1[13] | INTCON1[9] | 11 |
| Catastrophic Overflow Accumulator A | _MathError | 0x00000C | INTCON1[4] | INTCON1[12] | INTCON1[8] | 11 |
| Catastrophic Overflow Accumulator B | _MathError | 0x00000C | INTCON1[4] | INTCON1[11] | INTCON1[8] | 11 |
| Shift Accumulator Error | _MathError | 0x00000C | INTCON1[4] | INTCON1[7] | INTCON1[8] | 11 |
| Divide-by-Zero Error | _MathError | 0x00000C | INTCON1[4] | INTCON1[6] | INTCON1[8] | 11 |
| Reserved | Reserved | 0x00000E | — | — | — | — |
| NVM Address Error | _SoftTrapError | 0x000010 | INTCON3[8] | — | — | 9 |
| DMA Address Error | _SoftTrapError | 0x000010 | INTCON3[5] | — | — | 9 |
| DO Stack Overflow | _SoftTrapError | 0x000010 | INTCON3[4] | — | — | 9 |
| Reserved | Reserved | 0x000012 | — | — | — | — |


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**TABLE 7-2: INTERRUPT VECTOR DETAILS**

| Interrupt Source | MPLAB® XC16 ISR Name | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|---|
| | | | | | Flag | Enable | Priority |
| External Interrupt 0 | _INT0Interrupt | 8 | 0 | 0x000014 | IFS0[0] | IEC0[0] | IPC0[2:0] |
| Timer1 | _T1Interrupt | 9 | 1 | 0x000016 | IFS0[1] | IEC0[1] | IPC0[6:4] |
| Change Notice Interrupt A | _CNAInterrupt | 10 | 2 | 0x000018 | IFS0[2] | IEC0[2] | IPC0[10:8] |
| Change Notice Interrupt B | _CNBInterrupt | 11 | 3 | 0x00001A | IFS0[3] | IEC0[3] | IPC0[14:12] |
| DMA Channel 0 | _DMA0Interrupt | 12 | 4 | 0x00001C | IFS0[4] | IEC0[4] | IPC1[2:0] |
| Reserved | Reserved | 13 | 5 | 0x00001E | — | — | — |
| Input Capture/Output Compare 1 | _CCP1Interrupt | 14 | 6 | 0x000020 | IFS0[6] | IEC0[6] | IPC1[10:8] |
| CCP1 Timer | _CCT1Interrupt | 15 | 7 | 0x000022 | IFS0[7] | IEC0[7] | IPC1[14:12] |
| DMA Channel 1 | _DMA1Interrupt | 16 | 8 | 0x000024 | IFS0[8] | IEC0[8] | IPC2[2:0] |
| SPI1 Receiver | _SPI1RXInterrupt | 17 | 9 | 0x000026 | IFS0[9] | IEC0[9] | IPC2[6:4] |
| SPI1 Transmitter | _SPI1TXInterrupt | 18 | 10 | 0x000028 | IFS0[10] | IEC0[10] | IPC2[10:8] |
| UART1 Receiver | _U1RXInterrupt | 19 | 11 | 0x00002A | IFS0[11] | IEC0[11] | IPC2[14:12] |
| UART1 Transmitter | _U1TXInterrupt | 20 | 12 | 0x00002C | IFS0[12] | IEC0[12] | IPC3[2:0] |
| ECC Single-Bit Error | _ECCSBEInterrupt | 21 | 13 | 0x00002E | IFS0[13] | IEC0[13] | IPC3[6:4] |
| NVM Write Complete | _NVMInterrupt | 22 | 14 | 0x000030 | IFS0[14] | IEC0[14] | IPC3[10:8] |
| External Interrupt 1 | _INT1Interrupt | 23 | 15 | 0x000032 | IFS0[15] | IEC0[15] | IPC3[14:12] |
| I2C1 Slave Event | _SI2C1Interrupt | 24 | 16 | 0x000034 | IFS1[0] | IEC1[0] | IPC4[2:0] |
| I2C1 Master Event | _MI2C1Interrupt | 25 | 17 | 0x000036 | IFS1[1] | IEC1[1] | IPC4[6:4] |
| DMA Channel 2 | _DMA2Interrupt | 26 | 18 | 0x000038 | IFS1[2] | IEC1[2] | IPC4[10:8] |
| Change Notice Interrupt C | _CNCInterrupt | 27 | 19 | 0x00003A | IFS1[3] | IEC1[3] | IPC4[14:12] |
| External Interrupt 2 | _INT2Interrupt | 28 | 20 | 0x00003C | IFS1[4] | IEC1[4] | IPC5[2:0] |
| DMA Channel 3 | _DMA3Interrupt | 29 | 21 | 0x00003E | IFS1[5] | IEC1[5] | IPC5[6:4] |
| Reserved | Reserved | 30 | 22 | 0x000040 | — | — | — |
| Input Capture/Output Compare 2 | _CCP2Interrupt | 31 | 23 | 0x000042 | IFS1[7] | IEC1[7] | IPC5[14:12] |
| CCP2 Timer | _CCT2Interrupt | 32 | 24 | 0x000044 | IFS1[8] | IEC1[8] | IPC6[2:0] |
| Reserved | Reserved | 33 | 25 | 0x000046 | — | — | — |
| External Interrupt 3 | _INT3Interrupt | 34 | 26 | 0x000048 | IFS1[10] | IEC1[10] | IPC6[10:8] |
| U2RX – UART2 Receiver | _U2RXInterrupt | 35 | 27 | 0x00004A | IFS1[11] | IEC1[11] | IPC6[14:12] |
| U2TX – UART2 Transmitter | _U2TXInterrupt | 36 | 28 | 0x00004C | IFS1[12] | IEC1[12] | IPC7[2:0] |
| SPI2 Receiver | _SPI2RXInterrupt | 37 | 29 | 0x00004E | IFS1[13] | IEC1[13] | IPC7[6:4] |
| SPI2 Transmitter | _SPI2TXInterrupt | 38 | 30 | 0x000050 | IFS1[14] | IEC1[14] | IPC7[10:8] |
| Reserved | Reserved | 39-42 | 31-34 | 0x000052-0x000058 | — | — | — |
| Input Capture/Output Compare 3 | _CCP3Interrupt | 43 | 35 | 0x00005A | IFS2[3] | IEC2[3] | IPC8[14:12] |
| CCP3 Timer | _CCT3Interrupt | 44 | 36 | 0x00005C | IFS2[4] | IEC2[4] | IPC9[2:0] |
| Reserved | Reserved | 45-47 | 37-39 | 0x00005E-0x000062 | — | — | — |
| Input Capture/Output Compare 4 | _CCP4Interrupt | 48 | 40 | 0x000064 | IFS2[8] | IEC2[8] | IPC10[2:0] |
| CCP4 Timer | _CCT4Interrupt | 49 | 41 | 0x000066 | IFS2[9] | IEC2[9] | IPC10[6:4] |
| Reserved | Reserved | 50-52 | 42-44 | 0x000068-0x00006C | — | — | — |
| Deadman Timer | _DMTInterrupt | 53 | 45 | 0x00006E | IFS2[13] | IEC2[13] | IPC11[6:4] |
| Reserved | Reserved | 54-55 | 46-47 | 0x000070-0x000072 | — | — | — |
| QEI Position Counter Compare | _QEI1Interrupt | 56 | 48 | 0x000074 | IFS3[0] | IEC3[0] | IPC12[2:0] |
| UART1 Error | _U1EInterrupt | 57 | 49 | 0x000076 | IFS3[1] | IEC3[1] | IPC12[6:4] |
| UART2 Error | _U2EInterrupt | 58 | 50 | 0x000078 | IFS3[2] | IEC3[2] | IPC12[10:8] |
| CRC Generator | _CRCInterrupt | 59 | 51 | 0x00007A | IFS3[3] | IEC3[3] | IPC12[14:12] |
| Reserved | Reserved | 60-63 | 52-55 | 0x00007C-0x000082 | — | — | — |
| UART3 Error | _U3EInterrupt | 64 | 56 | 0x000084 | IFS3[8] | IEC3[8] | IPC14[2:0] |
| UART3 Receiver | _U3RXInterrupt | 65 | 57 | 0x000086 | IFS3[9] | IEC3[9] | IPC14[6:4] |

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**TABLE 7-2: INTERRUPT VECTOR DETAILS (CONTINUED)**

| Interrupt Source | MPLAB® XC16 ISR Name | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|---|
| | | | | | Flag | Enable | Priority |
| UART3 Transmitter | _U3TXInterrupt | 66 | 58 | 0x000088 | IFS3[10] | IEC3[10] | IPC14[10:8] |
| Reserved | Reserved | 67-68 | 59-60 | 0x00008A-0x00008C | — | — | — |
| In-Circuit Debugger | _ICDInterrupt | 69 | 61 | 0x00008E | IFS3[13] | IEC3[13] | IPC15[6:4] |
| Reserved | Reserved | 70 | 62 | 0x000090 | — | — | — |
| PTG Step | _PTGSTEPInterrupt | 71 | 63 | 0x000092 | IFS3[15] | IEC3[15] | IPC15[14:12] |
| I2C1 Bus Collision | _I2C1BCInterrupt | 72 | 64 | 0x000094 | IFS4[0] | IEC4[0] | IPC16[2:0] |
| Reserved | Reserved | 73-74 | 65-66 | 0x000096-0x000098 | — | — | — |
| PWM Generator 1 | _PWM1Interrupt | 75 | 67 | 0x00009A | IFS4[3] | IEC4[3] | IPC16[14:12] |
| PWM Generator 2 | _PWM2Interrupt | 76 | 68 | 0x00009C | IFS4[4] | IEC4[4] | IPC17[2:0] |
| PWM Generator 3 | _PWM3Interrupt | 77 | 69 | 0x00009E | IFS4[5] | IEC4[5] | IPC17[6:4] |
| PWM Generator 4 | _PWM4Interrupt | 78 | 70 | 0x0000A0 | IFS4[6] | IEC4[6] | IPC17[10:8] |
| Reserved | Reserved | 79-82 | 71-74 | 0x0000A2-0x0000A8 | — | — | — |
| Change Notice D | _CNDInterrupt | 83 | 75 | 0x0000AA | IFS4[11] | IEC4[11] | IPC18[14:12] |
| Reserved | Reserved | 84 | 76 | 0x0000AC | — | — | — |
| Comparator 1 | _CMP1Interrupt | 85 | 77 | 0x0000AE | IFS4[13] | IEC4[13] | IPC19[6:4] |
| Reserved | Reserved | 86-88 | 78-80 | 0x0000B0-0x0000B4 | — | — | — |
| PTG Watchdog Timer Time-out | _PTGWDTInterrupt | 89 | 81 | 0x0000B6 | IFS5[1] | IEC5[1] | IPC20[6:4] |
| PTG Trigger 0 | _PTG0Interrupt | 90 | 82 | 0x0000B8 | IFS5[2] | IEC5[2] | IPC20[10:8] |
| PTG Trigger 1 | _PTG1Interrupt | 91 | 83 | 0x0000BA | IFS5[3] | IEC5[3] | IPC20[14:12] |
| PTG Trigger 2 | _PTG2Interrupt | 92 | 84 | 0x0000BC | IFS5[4] | IEC5[4] | IPC21[2:0] |
| PTG Trigger 3 | _PTG3Interrupt | 93 | 85 | 0x0000BE | IFS5[5] | IEC5[6] | IPC21[6:4] |
| SENT1 TX/RX | _SENT1Interrupt | 94 | 86 | 0x0000C0 | IFS5[6] | IEC5[6] | IPC21[10:8] |
| SENT1 Error | _SENT1EInterrupt | 95 | 87 | 0x0000C2 | IFS5[7] | IEC5[7] | IPC21[14:12] |
| Reserved | Reserved | 96-97 | 88-89 | 0x0000C4-0x0000C6 | — | — | — |
| ADC Global Interrupt | _ADCInterrupt | 98 | 90 | 0x0000C8 | IFS5[10] | IEC5[10] | IPC22[10:8] |
| ADC AN0 Interrupt | _ADCAN0Interrupt | 99 | 91 | 0x0000CA | IFS5[11] | IEC5[11] | IPC22[14:12] |
| ADC AN1 Interrupt | _ADCAN1Interrupt | 100 | 92 | 0x0000CC | IFS5[12] | IEC5[12] | IPC23[2:0] |
| ADC AN2 Interrupt | _ADCAN2Interrupt | 101 | 93 | 0x0000CE | IFS5[13] | IEC5[13] | IPC23[6:4] |
| ADC AN3 Interrupt | _ADCAN3Interrupt | 102 | 94 | 0x0000D0 | IFS5[14] | IEC5[14] | IPC23[10:8] |
| ADC AN4 Interrupt | _ADCAN4Interrupt | 103 | 95 | 0x0000D2 | IFS5[15] | IEC5[15] | IPC23[14:12] |
| ADC AN5 Interrupt | _ADCAN5Interrupt | 104 | 96 | 0x0000D4 | IFS6[0] | IEC6[0] | IPC24[2:0] |
| ADC AN6 Interrupt | _ADCAN6Interrupt | 105 | 97 | 0x0000D6 | IFS6[1] | IEC6[1] | IPC24[6:4] |
| ADC AN7 Interrupt | _ADCAN7Interrupt | 106 | 98 | 0x0000D8 | IFS6[2] | IEC6[2] | IPC24[10:8] |
| ADC AN8 Interrupt | _ADCAN8Interrupt | 107 | 99 | 0x0000DA | IFS6[3] | IEC6[3] | IPC24[14:12] |
| ADC AN9 Interrupt | _ADCAN9Interrupt | 108 | 100 | 0x0000DC | IFS6[4] | IEC6[4] | IPC25[2:0] |
| ADC AN10 Interrupt | _ADCAN10Interrupt | 109 | 101 | 0x0000DE | IFS6[5] | IEC6[5] | IPC25[6:4] |
| ADC AN11 Interrupt | _ADCAN11Interrupt | 110 | 102 | 0x0000E0 | IFS6[6] | IEC6[6] | IPC25[10:8] |
| ADC AN12 Interrupt | _ADCAN12Interrupt | 111 | 103 | 0x0000E2 | IFS6[7] | IEC6[7] | IPC25[14:12] |
| ADC AN13 Interrupt | _ADCAN13Interrupt | 112 | 104 | 0x0000E4 | IFS6[8] | IEC6[8] | IPC26[2:0] |
| ADC AN14 Interrupt | _ADCAN14Interrupt | 113 | 105 | 0x0000E6 | IFS6[9] | IEC6[9] | IPC26[6:4] |
| ADC AN15 Interrupt | _ADCAN15Interrupt | 114 | 106 | 0x0000E8 | IFS6[10] | IEC6[10] | IPC26[10:8] |
| Reserved | Reserved | 109-114 | 101-106 | 0x0000DE-0x0000E8 | — | — | — |
| ADC AN16 Interrupt | _ADCAN16Interrupt | 115 | 107 | 0x0000EA | IFS6[11] | IEC6[11] | IPC26[14:12] |
| ADC AN17 Interrupt | _ADCAN17Interrupt | 116 | 108 | 0x0000EC | IFS6[12] | IEC6[12] | IPC27[2:0] |
| Reserved | Reserved | 117-123 | 109-115 | 0x0000EE-0x0000FA | — | — | — |
| ADC Digital Comparator 0 | _ADCMP0Interrupt | 124 | 116 | 0x0000FC | IFS7[4] | IEC7[4] | IPC29[2:0] |
| ADC Digital Comparator 1 | _ADCMP1Interrupt | 125 | 117 | 0x0000FE | IFS7[5] | IEC7[5] | IPC29[6:4] |
| ADC Digital Comparator 2 | _ADCMP2Interrupt | 126 | 118 | 0x000100 | IFS7[6] | IEC7[6] | IPC29[10:8] |


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**TABLE 7-2: INTERRUPT VECTOR DETAILS (CONTINUED)**

| Interrupt Source | MPLAB® XC16 ISR Name | Vector # | IRQ # | IVT Address | Interrupt Bit Location | | |
|---|---|---|---|---|---|---|---|
| | | | | | Flag | Enable | Priority |
| ADC Digital Comparator 3 | _ADCMP3Interrupt | 127 | 119 | 0x000102 | IFS7[7] | IEC7[7] | IPC29[14:12] |
| ADC Oversample Filter 0 | _ADFLTR0Interrupt | 128 | 120 | 0x000104 | IFS7[8] | IEC7[8] | IPC30[2:0] |
| ADC Oversample Filter 1 | _ADFLTR1Interrupt | 129 | 121 | 0x000106 | IFS7[9] | IEC7[9] | IPC30[6:4] |
| ADC Oversample Filter 2 | _ADFLTR2Interrupt | 130 | 122 | 0x000108 | IFS7[10] | IEC7[10] | IPC30[10:8] |
| ADC Oversample Filter 3 | _ADFLTR3Interrupt | 131 | 123 | 0x00010A | IFS7[11] | IEC7[11] | IPC30[14:12] |
| CLC1 Positive Edge | _CLC1PInterrupt | 132 | 124 | 0x00010C | IFS7[12] | IEC7[12] | IPC31[2:0] |
| CLC2 Positive Edge | _CLC2PInterrupt | 133 | 125 | 0x00010E | IFS7[13] | IEC7[13] | IPC31[6:4] |
| SPI1 Error | _SPI1Interrupt | 134 | 126 | 0x000110 | IFS7[14] | IEC7[14] | IPC31[10:8] |
| SPI2 Error | _SPI2Interrupt | 135 | 127 | 0x000112 | IFS7[15] | IEC7[15] | IPC31[14:12] |
| Reserved | Reserved | 136-176 | 128-168 | 0x000114-0x000164 | — | — | — |
| PEVTA – PWM Event A | _PEVTAInterrupt | 177 | 169 | 0x000166 | IFS10[9] | IEC10[9] | IPC42[6:4] |
| PEVTB – PWM Event B | _PEVTBInterrupt | 178 | 170 | 0x000168 | IFS10[10] | IEC10[10] | IPC42[10:8] |
| PEVTC – PWM Event C | _PEVTCInterrupt | 179 | 171 | 0x00016A | IFS10[11] | IEC10[11] | IPC42[14:12] |
| PEVTD – PWM Event D | _PEVTDInterrupt | 180 | 172 | 0x00016C | IFS10[12] | IEC10[12] | IPC43[2:0] |
| PEVTE – PWM Event E | _PEVTEInterrupt | 181 | 173 | 0x00016E | IFS10[13] | IEC10[13] | IPC43[6:4] |
| PEVTF – PWM Event F | _PEVTFInterrupt | 182 | 174 | 0x000170 | IFS10[14] | IEC10[14] | IPC43[10:8] |
| CLC3 Positive Edge | _CLC3PInterrupt | 183 | 175 | 0x000172 | IFS10[15] | IEC10[15] | IPC43[14:12] |
| CLC4 Positive Edge | _CLC4PInterrupt | 184 | 176 | 0x000174 | IFS11[0] | IEC11[0] | IPC44[2:0] |
| CLC1 Negative Edge | _CLC1NInterrupt | 185 | 177 | 0x000176 | IFS11[1] | IEC11[1] | IPC44[6:4] |
| CLC2 Negative Edge | _CLC2NInterrupt | 186 | 178 | 0x000178 | IFS11[2] | IEC11[2] | IPC44[10:8] |
| CLC3 Negative Edge | _CLC3NInterrupt | 187 | 179 | 0x00017A | IFS11[3] | IEC11[3] | IPC44[14:]12] |
| CLC4 Negative Edge | _CLC4NInterrupt | 188 | 180 | 0x00017C | IFS11[4] | IEC11[4] | IPC45[2:0] |
| Reserved | Reserved | 189-196 | 181-188 | 0x0017E-0x0018C | — | — | — |
| UART1 Event | _U1EVTInterrupt | 197 | 189 | 0x00018E | IFS11[13] | IEC11[13] | IPC47[6:4] |
| UART2 Event | _U2EVTInterrupt | 198 | 190 | 0x000190 | IFS11[14] | IEC11[14] | IPC47[12:8] |
| UART3 Event | _U3EVTInterrupt | 199 | 191 | 0x000192 | IFS11[15] | IEC11[15] | IPC47[14:12] |
| Reserved | Reserved | 200-255 | 192-247 | 0x000194-0x0001FE | — | — | — |

**TABLE 7-3: INTERRUPT FLAG REGISTERS**

| Register | Address | Bit 15 | Bit14 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IFS0 | 800h | INT1IF | NVMIF | ECCSBEIF | U1TXIF | U1RXIF | SPI1TXIF | SPI1RXIF | DMA1IF | CCT1IF | CCP1IF | — | DMA0IF | CNBIF | CNAIF | T1IF | INT0IF |
| IFS1 | 802h | — | SPI2TXIF | SPI2RXIF | U2TXIF | U2RXIF | INT3IF | — | CCT2IF | CCP2IF | — | DMA3IF | INT2IF | CNCIF | DMA2IF | MI2C1IF | SI2C1IF |
| IFS2 | 804h | — | — | DMTIF | — | — | — | CCT4IF | CCP4IF | — | — | — | CCT3IF | CCP3IF | — | — | — |
| IFS3 | 806h | PTGSTEPIF | — | ICDIF | — | — | U3TXIF | U3RXIF | U3EIF | — | — | — | — | CRCIF | U2EIF | U1EIF | QEI1IF |
| IFS4 | 808h | — | — | CMP1IF | — | CNDIF | — | — | — | — | PWM4IF | PWM3IF | PWM2IF | PWM1IF | — | — | I2C1BCIF |
| IFS5 | 80Ah | ADCAN4IF | ADCAN3IF | ADCAN2IF | ADCAN1IF | ADCAN0IF | ADCIF | — | — | SENT1EIF | SENT1IF | PTG3IF | PTG2IF | PTG1IF | PTG0IF | PTGWDTIF | — |
| IFS6 | 80Ch | — | — | — | ADCAN17IF | ADCAN16IF | ADCAN15IF | ADCAN14IF | ADCAN13IF | ADCAN12IF | ADCAN11IF | ADCAN10IF | ADCAN9IF | ADCAN8IF | ADCAN7IF | ADCAN6IF | ADCAN5IF |
| IFS7 | 80Eh | SPI2GIF | SPI1GIF | CLC2PIF | CLC1PIF | ADFLTR3IF | ADFLTR2IF | ADFLTR1IF | ADFLTR0IF | ADCMP3IF | ADCMP2IF | ADCMP1IF | ADCMP0IF | — | — | — | — |
| IFS10 | 814h | CLC3PIF | PEVTFIF | PEVTEIF | PEVTDIF | PEVTCIF | PEVTBIF | PEVTAIF | — | — | — | — | — | — | — | — | — |
| IFS11 | 816h | U3EVTIF | U2EVTIF | U1EVTIF | — | — | — | — | — | — | — | — | CLC4NIF | CLC3NIF | CLC2NIF | CLC1NIF | CLC4PIF |

**Legend:** — = Unimplemented.

**TABLE 7-4: INTERRUPT ENABLE REGISTERS**

| Register | Address | Bit 15 | Bit14 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IEC0 | 820h | INT1IE | NVMIE | ECCSBEIE | U1TXIE | U1RXIE | SPI1TXIE | SPI1RXIE | DMA1IE | CCT1IE | CCP1IE | — | DMA0IE | CNBIE | CNAIE | T1IE | INT0IE |
| IEC1 | 822h | — | SPI2TXIE | SPI2RXIE | U2TXIE | U2RXIE | INT3IE | — | CCT2IE | CCP2IE | — | DMA3IE | INT2IE | CNCIE | DMA2IE | MI2C1IE | SI2C1IE |
| IEC2 | 824h | — | — | DMTIE | — | — | — | CCT4IE | CCP4IE | — | — | — | CCT3IE | CCP3IE | — | — | — |
| IEC3 | 826h | PTGSTEPIE | — | ICDIE | — | — | U3TXIE | U3RXIE | U3EIE | — | — | — | — | CRCIE | U2EIE | U1EIE | QEI1IE |
| IEC4 | 828h | — | — | CMP1IE | — | CNDIE | — | — | — | — | PWM4IE | PWM3IE | PWM2IE | PWM1IE | — | — | I2C1BCIE |
| IEC5 | 82Ah | ADCAN4IE | ADCAN3IE | ADCAN2IE | ADCAN1IE | ADCAN0IE | ADCIE | — | — | SENT1EIE | SENT1IE | PTG3IE | PTG2IE | PTG1IE | PTG0IE | PTGWDTIE | — |
| IEC6 | 82Ch | — | — | — | ADCAN17IE | ADCAN16IE | ADCAN15IE | ADCAN14IE | ADCAN13IE | ADCAN12IE | ADCAN11IE | ADCAN10IE | ADCAN9IE | ADCAN8IE | ADCAN7IE | ADCAN6IE | ADCAN5IE |
| IEC7 | 82Eh | SPI2GIE | SPI1GIE | CLC2PIE | CLC1PIE | ADFLTR3IE | ADFLTR2IE | ADFLTR1IE | ADFLTR0IE | ADCMP3IE | ADCMP2IE | ADCMP1IE | ADCMP0IE | — | — | — | — |
| IEC10 | 834h | CLC3PIE | PEVTFIE | PEVTEIE | PEVTDIE | PEVTCIE | PEVTBIE | PEVTAIE | — | — | — | — | — | — | — | — | — |
| IEC11 | 836h | U3EVTIE | U2EVTIE | U1EVTIE | — | — | — | — | — | — | — | — | CLC4NIE | CLC3NIE | CLC2NIE | CLC1NIE | CLC4PIE |

**Legend:** — = Unimplemented.



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**TABLE 7-5: INTERRUPT PRIORITY REGISTERS**

| Register | Address | Bit 15 | Bit14 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IPC0 | 840h | — | CNBIP2 | CNBIP1 | CNBIP0 | — | CNAIP2 | CNAIP1 | CNAIP0 | — | T1IP2 | T1IP1 | T1IP0 | — | INT0IP2 | INT0IP1 | INT0IP0 |
| IPC1 | 842h | — | CCT1IP2 | CCT1IP1 | CCT1IP0 | — | CCP1IP2 | CCP1IP1 | CCP1IP0 | — | — | — | — | — | DMA0IP2 | DMA0IP1 | DMA0IP0 |
| IPC2 | 844h | — | U1RXIP2 | U1RXIP1 | U1RXIP0 | — | SPI1TXIP2 | SPI1TXIP1 | SPI1TXIP0 | — | SPI1RXIP2 | SPI1RXIP1 | SPI1RXIP0 | — | DMA1IP2 | DMA1IP1 | DMA1IP0 |
| IPC3 | 846h | — | INT1IP2 | INT1IP1 | INT1IP0 | — | NVMIP2 | NVMIP1 | NVMIP0 | — | ECCSBEIP2 | ECCSBEIP1 | ECCSBEIP0 | — | U1TXIP2 | U1TXIP1 | U1TXIP0 |
| IPC4 | 848h | — | CNCIP2 | CNCIP1 | CNCIP0 | — | DMA2IP2 | DMA2IP1 | DMA2IP0 | — | MI2C1IP2 | MI2C1IP1 | MI2C1IP0 | — | SI2C1IP2 | SI2C1IP1 | SI2C1IP0 |
| IPC5 | 84Ah | — | CCP2IP2 | CCP2IP1 | CCP2IP0 | — | — | — | — | — | DMA3IP2 | DMA3IP1 | DMA3IP20 | — | INT2IP2 | INT2IP1 | INT2IP0 |
| IPC6 | 84Ch | — | U2RXIP2 | U2RXIP1 | U2RXIP0 | — | INT3IP2 | INT3IP1 | INT3IP0 | — | — | — | — | — | CCT2IP2 | CCT2IP1 | CCT2IP0 |
| IPC7 | 84Eh | — | — | — | — | — | SPI2TXIP2 | SPI2TXIP1 | SPI2TXIP0 | — | SPI2RXIP2 | SPI2RXIP1 | SPI2RXIP0 | — | U2TXIP2 | U2TXIP1 | U2TXIP0 |
| IPC8 | 850h | — | CCP3IP2 | CCP3IP1 | CCP3IP0 | — | — | — | — | — | — | — | — | — | — | — | — |
| IPC9 | 852h | — | — | — | — | — | — | — | — | — | — | — | — | — | CCT3IP2 | CCT3IP1 | CCT3IP0 |
| IPC10 | 854h | — | CCP5IP2 | CCP5IP1 | CCP5IP0 | — | — | — | — | — | CCT4IP2 | CCT4IP1 | CCT4IP0 | — | CCP4IP2 | CCP4IP1 | CCP4IP0 |
| IPC11 | 856h | — | — | — | — | — | — | — | — | — | DMTIP2 | DMTIP1 | DMTIP0 | — | — | — | — |
| IPC12 | 858h | — | CRCIP2 | CRCIP1 | CRCIP0 | — | U2EIP2 | U2EIP1 | U2EIP0 | — | U1EIP2 | U1EIP1 | U1EIP0 | — | QEI1IP2 | QEI1IP1 | QEI1IP0 |
| IPC14 | 85Ch | — | — | — | — | — | U3TXIP2 | U3TXIP1 | U3TXIP1 | — | U3RXIP2 | U3RXIP1 | U3RXIP0 | — | U3EIP2 | U3EIP1 | U3EIP0 |
| IPC15 | 85Eh | — | PTGSTEPIP2 | PTGSTEPIP1 | PTGSTEPIP0 | — | — | — | — | — | ICDIP2 | ICDIP1 | ICDIP0 | — | — | — | — |
| IPC16 | 860h | — | PWM1IP2 | PWM1IP1 | PWM1IP0 | — | — | — | — | — | — | — | — | — | I2C1BCIP2 | I2C1BCIP1 | I2C1BCIP0 |
| IPC17 | 862h | — | — | — | — | — | PWM4IP2 | PWM4IP1 | PWM4IP0 | — | PWM3IP2 | PWM3IP1 | PWM3IP0 | — | PWM2IP2 | PWM2IP1 | PWM2IP0 |
| IPC18 | 864h | — | CNDIP2 | CNDIP1 | CNDIP0 | — | — | — | — | — | — | — | — | — | — | — | — |
| IPC19 | 866h | — | — | — | — | — | — | — | — | — | CMP1IP2 | CMP1IP1 | CMP1IP0 | — | — | — | — |
| IPC20 | 868h | — | PTG1IP2 | PTG1IP1 | PTG1IP0 | — | PTG0IP2 | PTG0IP1 | PTG0IP0 | — | PTGWDTIP2 | PTGWDTIP1 | PTGWDTIP0 | — | — | — | — |
| IPC21 | 86Ah | — | SENT1EIP2 | SENT1EIP1 | SENT1EIP0 | — | SENT1IP2 | SENT1IP1 | SENT1IP0 | — | PTG3IP2 | PTG3IP1 | PTG3IP0 | — | PTG2IP2 | PTG2IP1 | PTG2IP0 |
| IPC22 | 86Ch | — | ADCAN0IP2 | ADCAN0IP1 | ADCAN0IP0 | — | ADCIP2 | ADCIP1 | ADCIP0 | — | — | — | — | — | — | — | — |
| IPC23 | 86Eh | — | ADCAN4IP2 | ADCAN4IP1 | ADCAN4IP0 | — | ADCAN3IP2 | ADCAN3IP1 | ADCAN3IP0 | — | ADCAN2IP2 | ADCAN2IP1 | ADCAN2IP0 | — | ADCAN1IP2 | ADCAN1IP1 | ADCAN1IP0 |
| IPC24 | 870h | — | ADCAN8IP2 | ADCAN8IP1 | ADCAN8IP0 | — | ADCAN7IP2 | ADCAN7IP1 | ADCAN7IP0 | — | ADCAN6IP2 | ADCAN6IP1 | ADCAN6IP0 | — | ADCAN5IP2 | ADCAN5IP1 | ADCAN5IP0 |
| IPC25 | 872h | — | ADCAN12IP2 | ADCAN12IP1 | ADCAN12IP0 | — | ADCAN11IP2 | ADCAN11IP1 | ADCAN11IP0 | — | ADCAN10IP2 | ADCAN10IP1 | ADCAN10IP0 | — | ADCAN9IP2 | ADCAN9IP1 | ADCAN9IP0 |
| IPC26 | 874h | — | ADCAN16IP2 | ADCAN16IP2 | ADCAN16IP2 | — | ADCAN15IP2 | ADCAN15IP1 | ADCAN15IP0 | — | ADCAN14IP2 | ADCAN14IP1 | ADCAN14IP0 | — | ADCAN13IP2 | ADCAN13IP1 | ADCAN13IP0 |
| IPC27 | 876h | — | — | — | — | — | — | — | — | — | — | — | — | — | ADCAN17IP2 | ADCAN17IP1 | ADCAN17IP0 |
| IPC29 | 87Ah | — | ADCMP3IP2 | ADCMP3IP1 | ADCMP3IP0 | — | ADCMP2IP2 | ADCMP2IP1 | ADCMP2IP0 | — | ADCMP1IP2 | ADCMP1IP1 | ADCMP1IP0 | — | ADCMP0IP2 | ADCMP0IP1 | ADCMP0IP0 |
| IPC30 | 87Ch | — | ADFLTR3IP2 | ADFLTR3IP1 | ADFLTR3IP0 | — | ADFLTR2IP2 | ADFLTR2IP1 | ADFLTR2IP0 | — | ADFLTR1IP2 | ADFLTR1IP1 | ADFLTR1IP0 | — | ADFLTR0IP2 | ADFLTR0IP1 | ADFLTR0IP0 |
| IPC31 | 87Eh | — | SPI2GIP0 | SPI2GIP1 | SPI2GIP0 | — | SPI1GIP2 | SPI1GIP1 | SPI1GIP0 | — | CLC2PIP2 | CLC2PIP1 | CLC2PIP0 | — | CLC1PIP2 | CLC1PIP1 | CLC1PIP0 |
| IPC42 | 894h | — | PEVTCIP2 | PEVTCIP1 | PEVTCIP0 | — | PEVTBIP2 | PEVTBIP1 | PEVTBIP0 | — | PEVTAIP2 | PEVTAIP1 | PEVTAIP0 | — | — | — | — |
| IPC43 | 896h | — | CLC3PIP2 | CLC3PIP1 | CLC3PIP0 | — | PEVTFIP2 | PEVTFIP1 | PEVTFIP0 | — | PEVTEIP2 | PEVTEIP1 | PEVTEIP0 | — | PEVTDIP2 | PEVTDIP1 | PEVTDIP0 |
| IPC44 | 898h | — | CLC3NIP2 | CLC3NIP1 | CLC3NIP0 | — | CLC2NIP2 | CLC2NIP1 | CLC2NIP0 | — | CLC1NIP2 | CLC1NIP1 | CLC1NIP0 | — | CLC4PIP2 | CLC4PIP1 | CLC4PIP0 |
| IPC45 | 89Ah | — | — | — | — | — | — | — | — | — | — | — | — | — | CLC4NIP2 | CLC4NIP1 | CLC4NIP0 |
| IPC47 | 89Eh | — | U3EVTIP2 | U3EVTIP1 | U3EVTIP0 | — | U2EVTIP2 | U2EVTIP1 | U2EVTIP0 | — | U1EVTIP2 | U1EVTIP1 | U1EVTIP0 | — | — | — | — |

**Legend:** — = Unimplemented.

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## 7.3 Interrupt 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.

### 7.3.1 KEY RESOURCES

- **"Interrupts"** (www.microchip.com/DS70000600)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools

## 7.4 Interrupt Control and Status Registers

The dsPIC33CDVL64MC106 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 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 (VECNUM[7:0]) and Interrupt 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 7-2. For example, 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 **"Enhanced CPU"** (www.microchip.com/DS70005158).

- 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.


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

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

| R/W-0(3) | R/W-0(3) | R/W-0(3) | R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| 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 latency is enabled.
0 = Fixed exception processing latency 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.


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**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 an overflow of Accumulator A.
0 = Trap was not caused by an overflow of Accumulator A.

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

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

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

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

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

bit 8 **COVTE:** Catastrophic Overflow Trap Enable bit
1 = Trap 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'


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**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 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | INT3EP | 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 bit
1 = Uses Alternate Interrupt Vector Table.
0 = Uses standard Interrupt Vector Table.

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

bit 3 **INT3EP:** External Interrupt 3 Edge Detect Polarity Select bit
1 = Interrupt on negative edge.
0 = Interrupt on positive edge.

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 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | DAE | DOOVR | — | — | — | — |
| bit 7 | | | | | | | bit 0 |

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

bit 15-9 **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 7-6 **Unimplemented:** Read as '0'

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

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

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


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**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 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | ECCDBE | 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 15-2 **Unimplemented:** Read as ‘0’

bit 1 **ECCDBE:** ECC Double-Bit Error Trap bit
1 = ECC double-bit error trap has occurred.
0 = ECC double-bit error trap has not occurred.

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

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

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

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| VECNUM[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 **VHOLD:** Vector Number Capture Enable bit
1 = VECNUM[7:0] bits read current value of vector number encoding tree (i.e., highest priority pending interrupt).
0 = Vector number latched into VECNUM[7:0] at Interrupt Acknowledge and retained until next IACK.

bit 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, T1 – Timer1 interrupt
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 I/O PORTS

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"I/O Ports with Edge Detect"** (www.microchip.com/DS70005322).

**2:** Some registers and associated bits described in this section may not be available on all devices.

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. The PORT registers are located in the SFR.

Some of the key features of the I/O ports are:

- Individual Output Pin Open-Drain Enable/Disable
- Individual Input Pin Weak Pull-up and Pull-Down
- Monitor Selective Inputs and Generate Interrupt when Change in Pin State is Detected
- Operation during Sleep and Idle Modes

### 8.1 Parallel I/O (PIO) Ports

All port pins have 12 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.

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. Table 8-1 shows the pin availability. Table 8-2 shows the 5V input tolerant pins across this device.

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**TABLE 8-1: PIN AND ANSELx AVAILABILITY**

| Device | Rx15 | Rx14 | Rx13 | Rx12 | Rx11 | Rx10 | Rx9 | Rx8 | Rx7 | Rx6 | Rx5 | Rx4 | Rx3 | Rx2 | Rx1 | Rx0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PORTA** | | | | | | | | | | | | | | | | |
| dsPIC33CDV64MC106 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| dsPIC33CDVL64MC106 | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| ANSELA | — | — | — | — | — | — | — | — | — | — | — | X | X | X | X | X |
| **PORTB** | | | | | | | | | | | | | | | | |
| dsPIC33CDV64MC106 | X(1) | X(1) | X(1) | X(1) | X(1) | X(1) | X | X | X | X | X | X | X | X | X | X |
| dsPIC33CDVL64MC106 | X(1) | X(1) | X(1) | X(1) | X(1) | X(1) | X | X | X | X | X | X | X | X | X | X |
| ANSELB | — | — | — | — | — | — | X | X | X | — | — | X | X | X | X | X |
| **PORTC** | | | | | | | | | | | | | | | | |
| dsPIC33CDV64MC106 | — | — | X(1) | X(1) | X | X | X | X | X | X | X | X | X | X | X | X |
| dsPIC33CDVL64MC106 | — | — | X(1) | X(1) | X(1) | X(1) | X | X | X | X | X(1) | X | X | X | X | X |
| ANSELC | — | — | — | — | — | — | — | — | X | X | — | — | X | X | X | X |
| **PORTD** | | | | | | | | | | | | | | | | |
| dsPIC33CDV64MC106 | — | — | X | — | — | X | — | X | — | — | — | — | — | — | X(1) | — |
| dsPIC33CDVL64MC106 | — | — | X | — | — | X | — | X | — | — | — | — | — | — | X(1) | — |
| ANSELD | — | — | X | — | — | X | — | — | — | — | — | — | — | — | — | — |

**Note 1:** Pin is connected to device interconnect and may not be externally available. See Table 1 for more information.

**TABLE 8-2: 5V INPUT TOLERANT PORTS**

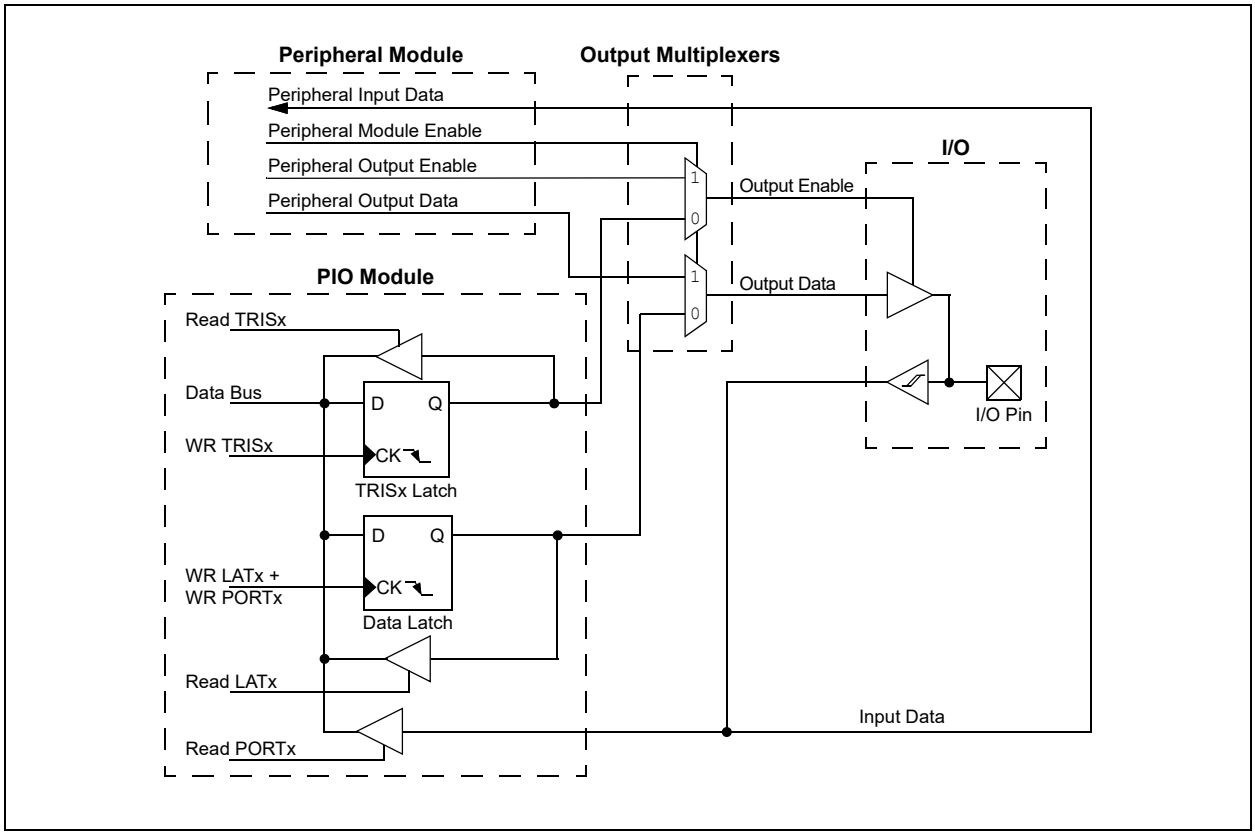
| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PORTA | — | — | — | — | — | — | — | — | — | — | — | RA4 | RA3 | RA2 | RA1 | RA0 |
| PORTB | RB15 | RB14 | RB13 | RB12 | RB11 | RB10(1) | RB9 | RB8 | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0 |
| PORTC | — | — | RC13 | RC12 | RC11 | RC10 | RC9 | RC8 | RC7 | RC6 | RC5 | RC4 | RC3 | RC2 | RC1 | RC0 |
| PORTD | — | — | RD13 | — | — | RD10 | — | RD8 | — | — | — | — | — | — | RD1 | — |

**Legend:** Shaded pins are up to 5.5 VDC input tolerant.

**Note 1:** A pull-up resistor is connected to this pin during programming or when JTAG is enabled in the Configuration bits; this limits the maximum voltage on this pin to 3.6V. If JTAG is disabled, the maximum voltage on this pin can reach 5.5V.


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**FIGURE 8-1: BLOCK DIAGRAM OF A TYPICAL SHARED PORT STRUCTURE**



### 8.1.1 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 Enable for PORTx 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.

## 8.2 Configuring Analog and Digital Port Pins

The ANSELx registers control the operation of the analog port pins. The port pins that are to function as analog inputs 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 registers have 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).

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.

### 8.2.1 I/O PORT WRITE/READ TIMING

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

## 8.3 Control Registers

The following registers are in the PORT module:

- Register 8-1: ANSELx (one per port)
- Register 8-2: TRISx (one per port)
- Register 8-3: PORTx (one per port)
- Register 8-4: LATx (one per port)
- Register 8-5: ODCx (one per port)
- Register 8-6: CNPUx (one per port)
- Register 8-7: CNPDx (one per port)
- Register 8-8: CNCONx (one per port – optional)
- Register 8-9: CNEN0x (one per port)
- Register 8-10: CNSTATx (one per port – optional)
- Register 8-11: CNEN1x (one per port)
- Register 8-12: CNFx (one per port)

**REGISTER 8-1: ANSELx: ANALOG SELECT FOR PORTx REGISTER**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| ANSELx[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 |
|---|---|---|---|---|---|---|---|
| ANSELx[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 **ANSELx[15:0]:** Analog Select for PORTx bits

1 = The analog input is enabled, and the digital input is disabled on the PORTx[n] pin.
0 = The analog input is disabled, and the digital input is enabled on the PORTx[n] pin.


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**REGISTER 8-2: TRISx: OUTPUT ENABLE FOR PORTx REGISTER**

| 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 15-0 **TRISx[15:0]:** Output Enable for PORTx bits

1 = LATx[n] is not driven on the PORTx[n] pin.

0 = LATx[n] is driven on the PORTx[n] pin.

**REGISTER 8-3: PORTx: INPUT DATA FOR PORTx REGISTER**

| R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 | R/W-1 |
|---|---|---|---|---|---|---|---|
| PORTx[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 |
|---|---|---|---|---|---|---|---|
| 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 15-0 **PORTx[15:0]:** PORTx Data Input Value bits

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**REGISTER 8-4: LATx: OUTPUT DATA FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| LATx[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 |
|---|---|---|---|---|---|---|---|
| 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 15-0 **LATx[15:0]:** PORTx Data Output Value bits

**REGISTER 8-5: ODCx: OPEN-DRAIN ENABLE FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| 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 15-0 **ODCx[15:0]:** PORTx Open-Drain Enable bits
1 = Open-drain is enabled on the PORTx pin.
0 = Open-drain is disabled on the PORTx pin.


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**REGISTER 8-6: CNPUx: CHANGE NOTIFICATION PULL-UP ENABLE FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| 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 15-0 **CNPUx[15:0]:** Change Notification Pull-up Enable for PORTx bits

1 = The pull-up for PORTx[n] is enabled – takes precedence over the pull-down selection.

0 = The pull-up for PORTx[n] is disabled.

**REGISTER 8-7: CNPDx: CHANGE NOTIFICATION PULL-DOWN ENABLE FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| 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 15-0 **CNPDx[15:0]:** Change Notification Pull-Down Enable for PORTx bits

1 = The pull-down for PORTx[n] is enabled (if the pull-up for PORTx[n] is not enabled).

0 = The pull-down for PORTx[n] is disabled.

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**REGISTER 8-8: CNCONx: CHANGE NOTIFICATION CONTROL FOR PORTx REGISTER**

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| ON | — | — | — | CNSTYLE | — | — | — |
| 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 **ON:** Change Notification (CN) Control for PORTx On bit
1 = CN is enabled.
0 = CN is disabled.

bit 14-12 **Unimplemented:** Read as '0'

bit 11 **CNSTYLE:** Change Notification Style Selection bit
1 = Edge style (detects edge transitions, CNFx[15:0] bits are used for a Change Notification event)
0 = Mismatch style (detects change from last port read, CNSTATx[15:0] bits are used for a Change Notification event)

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

**REGISTER 8-9: CNEN0x: CHANGE NOTIFICATION INTERRUPT ENABLE FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| CNEN0x[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 |
|---|---|---|---|---|---|---|---|
| CNEN0x[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 **CNEN0x[15:0]:** Change Notification Interrupt Enable for PORTx bits
1 = Interrupt-on-change (from the last read value) is enabled for PORTx[n].
0 = Interrupt-on-change is disabled for PORTx[n].


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**REGISTER 8-10: CNSTATx: CHANGE NOTIFICATION INTERRUPT STATUS FOR PORTx REGISTER**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| CNSTATx[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| CNSTATx[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 **CNSTATx[15:0]:** Change Notification Interrupt Status for PORTx bits
When CNSTYLE (CNCONx[11]) = 0:
1 = Change occurred on PORTx[n] since last read of PORTx[n].
0 = Change did not occur on PORTx[n] since last read of PORTx[n].

**REGISTER 8-11: CNEN1x: CHANGE NOTIFICATION INTERRUPT EDGE SELECT FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| CNEN1x[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 |
|---|---|---|---|---|---|---|---|
| CNEN1x[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 **CNEN1x[15:0]:** Change Notification Interrupt Edge Select for PORTx bits

**REGISTER 8-12: CNFx: CHANGE NOTIFICATION INTERRUPT FLAG FOR PORTx 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 |
|---|---|---|---|---|---|---|---|
| CNFx[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 |
|---|---|---|---|---|---|---|---|
| CNFx[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 **CNFx[15:0]:** Change Notification Interrupt Flag for PORTx bits

When CNSTYLE (CNCONx[11]) = 1:

1 = An enabled edge event occurred on the PORTx[n] pin.

0 = An enabled edge event did not occur on the PORTx[n] pin.


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## 8.4 Input Change Notification (ICN)

The Input Change Notification function of the I/O ports allows the dsPIC33CDVL64MC106 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. Five control registers are associated with the Change Notification (CN) functionality of each I/O port. To enable the Change Notification feature for the port, the ON bit (CNCONx[15]) must be set.

The CNEN0x and CNEN1x registers contain the CN interrupt enable control bits for each of the input pins. The setting of these bits enables a CN interrupt for the corresponding pins. Also, these bits, in combination with the CNSTYLE bit (CNCONx[11]), define a type of transition when the interrupt is generated. Possible CN event options are listed in Table 8-3.

**TABLE 8-3: CHANGE NOTIFICATION EVENT OPTIONS**

| CNSTYLE Bit (CNCONx[11]) | CNEN1x Bit | CNEN0x Bit | Change Notification Event Description |
|---|---|---|---|
| 0 | Does not matter | 0 | Disabled |
| 0 | Does not matter | 1 | Detects a mismatch between the last read state and the current state of the pin. |
| 1 | 0 | 0 | Disabled |
| 1 | 0 | 1 | Detects a positive transition only (from '0' to '1'). |
| 1 | 1 | 0 | Detects a negative transition only (from '1' to '0'). |
| 1 | 1 | 1 | Detects both positive and negative transitions. |

The CNSTATx register indicates whether a change occurred on the corresponding pin since the last read of the PORTx bit. In addition to the CNSTATx register, the CNFx register is implemented for each port. This register contains flags for Change Notification events. These flags are set if the valid transition edge, selected in the CNEN0x and CNEN1x registers, is detected. CNFx stores the occurrence of the event. CNFx bits must be cleared in software to get the next Change Notification interrupt. The CN interrupt is generated only for the I/Os configured as inputs (corresponding TRISx bits must be set).

**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.

## 8.5 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.

### 8.5.1 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.

### 8.5.2 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 A/D Converter (ADC).

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.

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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.

### 8.5.3 CONTROLLING CONFIGURATION CHANGES

Because peripheral mapping can be changed during run time, some restrictions on peripheral remapping are needed to prevent accidental configuration changes. The dsPIC33CDVL64MC106 devices have implemented the control register lock sequence.

After a Reset, writes to the RPINRx and RPORx registers are allowed, but they can be disabled by setting the IOLOCK bit (RPCON[11]). Attempted writes with the IOLOCK bit set will appear to execute normally, but the contents of the registers will remain unchanged. Setting IOLOCK prevents writes to the control registers; clearing IOLOCK allows writes. To set or clear IOLOCK, the NVMKEY unlock sequence must be executed:

1. Write 0x55 to NVMKEY.
2. Write 0xAA to NVMKEY.
3. Clear (or set) IOLOCK as a single operation.

**Note:** MPLAB® XC16 compiler provides a built-in C language function for unlocking and modifying the RPCON register: `__builtin_write_RPCON(value)`. For more information, see the XC16 compiler help files.

### 8.5.4 INPUT MAPPING

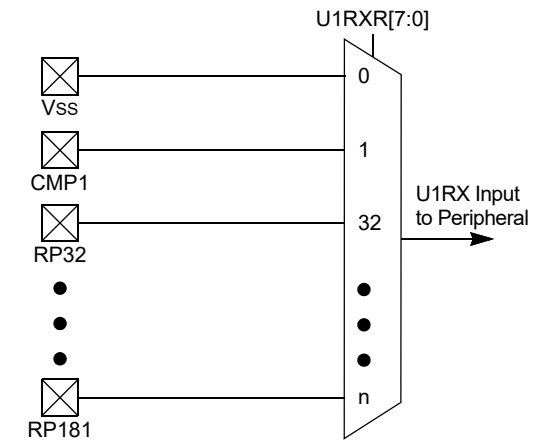
The inputs of the Peripheral Pin Select options are mapped on the basis of the peripheral. That is, a control register associated with a peripheral dictates the pin it will be mapped to. The RPINRx registers are used to configure peripheral input mapping. Each register contains sets of 8-bit fields, 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 8-4 for a list of available inputs.

For example, Figure 8-2 illustrates remappable pin selection for the U1RX input.

**EXAMPLE 8-1: CONFIGURING UART1 INPUT AND OUTPUT FUNCTIONS**

```
//
****************************************
// Unlock Registers
//****************************************
__builtin_write_RPCON(0x0000);
//****************************************
// Configure Input Functions (See Table 8-5)
// Assign U1Rx To Pin RP35
//**************************
_U1RXR = 35;
// Assign U1CTS To Pin RP36
//**************************
_U1CTSR = 36;
//****************************************
// Configure Output Functions (See Table 8-7)
//****************************************
// Assign U1Tx To Pin RP37
//**************************
_RP37R = 1;
//**************************
// Assign U1RTS To Pin RP38
//**************************
_RP38R = 2;
//****************************************
// Lock Registers
//****************************************
__builtin_write_RPCON(0x0800);
```

**FIGURE 8-2: 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'). Physical connection to a pin can be made through RP32 through RP77. There are internal signals and virtual pins that can be connected to an input. Table 8-4 shows the details of the input assignment.


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**TABLE 8-4: REMAPPABLE PIN INPUTS**

| RPINRx[15:8] or RPINRx[7:0] | Function | Available on Ports |
|---|---|---|
| 0 | Vss | Internal |
| 1 | Comparator 1 | Internal |
| 2 | Comparator 2 | Internal |
| 3 | Comparator 3 | Internal |
| 4-5 | RP4-RP5 | Reserved |
| 6 | PTG Trigger 26 | Internal |
| 7 | PTG Trigger 27 | Internal |
| 8-10 | RP8-RP10 | Reserved |
| 11 | PWM Event Out C | Internal |
| 12 | PWM Event Out D | Internal |
| 13 | PWM Event Out E | Internal |
| 14-31 | RP14-RP31 | Reserved |
| 32 | RP32 | Port Pin RB0 |
| 33 | RP33 | Port Pin RB1 |
| 34 | RP34 | Port Pin RB2 |
| 35 | RP35 | Port Pin RB3 |
| 36 | RP36 | Port Pin RB4 |
| 37 | RP37 | Port Pin RB5 |
| 38 | RP38 | Port Pin RB6 |
| 39 | RP39 | Port Pin RB7 |
| 40 | RP40 | Port Pin RB8 |
| 41 | RP41 | Port Pin RB9 |
| 42 | RP42 | Port Pin RB10 |
| 43 | RP43 | Port Pin RB11 |
| 44 | RP44 | Port Pin RB12 |
| 45 | RP45 | Port Pin RB13 |
| 46 | RP46 | Port Pin RB14 |
| 47 | RP47 | Port Pin RB15 |
| 48 | RP48 | Port Pin RC0 |
| 49 | RP49 | Port Pin RC1 |
| 50 | RP50 | Port Pin RC2 |
| 51 | RP51 | Port Pin RC3 |
| 52 | RP52 | Port Pin RC4 |
| 53 | RP53 | Port Pin RC5 |
| 54 | RP54 | Port Pin RC6 |
| 55 | RP55 | Port Pin RC7 |
| 56 | RP56 | Port Pin RC8 |
| 57 | RP57 | Port Pin RC9 |
| 58 | RP58 | Port Pin RC10 |
| 59 | RP59 | Port Pin RC11 |
| 60 | RP60 | Port Pin RC12 |
| 61 | RP61 | Port Pin RC13 |

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**TABLE 8-4: REMAPPABLE PIN INPUTS (CONTINUED)**

| RPINRx[15:8] or RPINRx[7:0] | Function | Available on Ports |
|---|---|---|
| 62-64 | RP62-RP64 | Reserved |
| 65 | RP65 | Port Pin RD1 |
| 66-71 | RP66-RP71 | Reserved |
| 72 | RP72 | Port Pin RD8 |
| 73 | RP73 | Reserved |
| 74 | RP74 | Port Pin RD10 |
| 75-76 | RP75-RP76 | Reserved |
| 77 | RP77 | Port Pin RD13 |
| 78-167 | RP78-RP167 | Reserved |
| 168 | DAC pwm_req_on | Internal |
| 169 | DAC1 pwm_req_off | Internal |
| 170-175 | RP170-175 | Reserved |
| 176 | RP176 | Virtual RPV0 |
| 177 | RP177 | Virtual RPV1 |
| 178 | RP178 | Virtual RPV2 |
| 179 | RP179 | Virtual RPV3 |
| 180 | RP180 | Virtual RPV4 |
| 181 | RP181 | Virtual RPV5 |

### 8.5.5 VIRTUAL CONNECTIONS

The dsPIC33CDVL64MC106 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.


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**TABLE 8-5: SELECTABLE INPUT SOURCES (MAPS INPUT TO FUNCTION)**

| Input Name[1] | Function Name | Register | Register Bits |
|---|---|---|---|
| External Interrupt 1 | INT1 | RPINR0 | INT1R[7:0] |
| External Interrupt 2 | INT2 | RPINR1 | INT2R[7:0] |
| External Interrupt 3 | INT3 | RPINR1 | INT3R[7:0] |
| Timer1 External Clock | T1CK | RPINR2 | T1CK[7:0] |
| SCCP Timer1 | TCKI1 | RPINR3 | TCKI1R[7:0] |
| SCCP Capture 1 | ICM1 | RPINR3 | ICM1R[7:0] |
| SCCP Timer2 | TCKI2 | RPINR4 | TCKI2R[7:0] |
| SCCP Capture 2 | ICM2 | RPINR4 | ICM2R[7:0] |
| SCCP Timer3 | TCKI3 | RPINR5 | TCKI3R[7:0] |
| SCCP Capture 3 | ICM3 | RPINR5 | ICM3R[7:0] |
| SCCP Timer4 | TCKI4 | RPINR6 | TCKI4R[7:0] |
| SCCP Capture 4 | ICM4 | RPINR6 | ICM4R[7:0] |
| SCCP Fault A | OCFA | RPINR11 | OCFAR[7:0] |
| SCCP Fault B | OCFB | RPINR11 | OCFBR[7:0] |
| PWM PCI Input 8 | PCI8 | RPINR12 | PCI8R[7:0] |
| PWM PCI Input 9 | PCI9 | RPINR12 | PCI9R[7:0] |
| PWM PCI Input 10 | PCI10 | RPINR13 | PCI10R[7:0] |
| PWM PCI Input 11 | PCI11 | RPINR13 | PCI11R[7:0] |
| QEI1 Input A | QEIA1 | RPINR14 | QEIA1R[7:0] |
| QEI1 Input B | QEIB1 | RPINR14 | QEIB1R[7:0] |
| QEI1 Index 1 Input | QEINDX1 | RPINR15 | QEINDX1R[7:0] |
| QEI1 Home 1 Input | QEIHOM1 | RPINR15 | QEIHOM1R[7:0] |
| UART1 Receive | U1RX | RPINR18 | U1RXR[7:0] |
| UART1 Data-Set-Ready | $\overline{\text{U1DSR}}$ | RPINR18 | U1DSRR[7:0] |
| UART2 Receive | U2RX | RPINR19 | U2RXR[7:0] |
| UART2 Data-Set-Ready | $\overline{\text{U2DSR}}$ | RPINR19 | U2DSRR[7:0] |
| SPI1 Data Input | SDI1 | RPINR20 | SDI1R[7:0] |
| SPI1 Clock Input | SCK1IN | RPINR20 | SCK1R[7:0] |
| SPI1 Slave Select | $\overline{\text{SS1}}$ | RPINR21 | SS1R[7:0] |
| Reference Clock Input | REFCLKI | RPINR21 | REFOIR[7:0] |
| SPI2 Data Input | SDI2 | RPINR22 | SDI2R[7:0] |
| SPI2 Clock Input | SCK2IN | RPINR22 | SCK2R[7:0] |
| SPI2 Slave Select | $\overline{\text{SS2}}$ | RPINR23 | SS2R[7:0] |
| UART3 Receive | U3RX | RPINR27 | U3RXR[7:0] |
| UART3 Data-Set-Ready | $\overline{\text{U3DSR}}$ | RPINR27 | U3DSRR[7:0] |
| SCCP Fault C | OCFC | RPINR37 | OCFCR[7:0] |
| PWM PCI Input 17 | PCI17 | RPINR37 | PCI17R[7:0] |
| PWM PCI Input 18 | PCI18 | RPINR38 | PCI18R[7:0] |
| PWM PCI Input 12 | PCI12 | RPINR42 | PCI12R[7:0] |
| PWM PCI Input 13 | PCI13 | RPINR42 | PCI13R[7:0] |
| PWM PCI Input 14 | PCI14 | RPINR43 | PCI14R[7:0] |
| PWM PCI Input 15 | PCI15 | RPINR43 | PCI15R[7:0] |
| PWM PCI Input 16 | PCI16 | RPINR44 | PCI16R[7:0] |

**Note 1:** Unless otherwise noted, all inputs use the Schmitt Trigger input buffers.

**TABLE 8-5: SELECTABLE INPUT SOURCES (MAPS INPUT TO FUNCTION) (CONTINUED)**

| Input Name[1] | Function Name | Register | Register Bits |
|---|---|---|---|
| SENT1 Input | SENT1 | RPINR44 | SENT1R[7:0] |
| CLC Input A | CLCINA | RPINR45 | CLCINAR[7:0] |
| CLC Input B | CLCINB | RPINR46 | CLCINBR[7:0] |
| CLC Input C | CLCINC | RPINR46 | CLCINCR[7:0] |
| CLC Input D | CLCIND | RPINR47 | CLCINDR[7:0] |
| ADC Trigger Input (ADTRIG31) | ADCTRG | RPINR47 | ADCTRGR[7:0] |
| SCCP Fault D | OCFD | RPINR48 | OCFDR[7:0] |
| UART1 Clear-to-Send | $\overline{\text{U1CTS}}$ | RPINR48 | U1CTSR[7:0] |
| UART2 Clear-to-Send | $\overline{\text{U2CTS}}$ | RPINR49 | U2CTSR[7:0] |
| UART3 Clear-to-Send | $\overline{\text{U3CTS}}$ | RPINR49 | U3CTSR[7:0] |

**Note 1:** Unless otherwise noted, all inputs use the Schmitt Trigger input buffers.

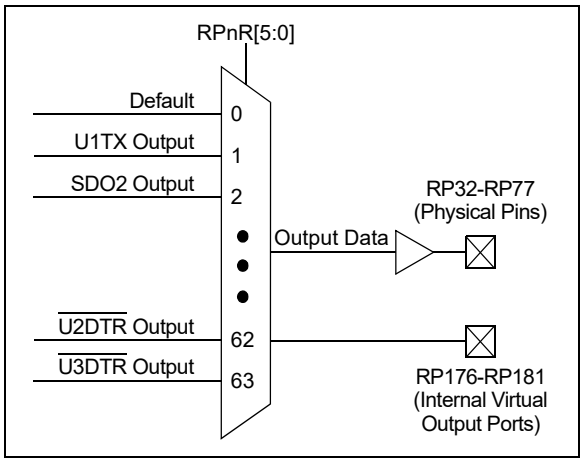

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### 8.5.6 OUTPUT MAPPING

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 8-43 through Register 8-62). The value of the bit field corresponds to one of the peripherals and that peripheral's output is mapped to the pin (see Table 8-7 and Figure 8-3).

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 8-3: MULTIPLEXING REMAPPABLE OUTPUTS FOR RPn**




**Note 1:** There are six virtual output ports which are not connected to any I/O ports (RP176-RP181). These virtual ports can be accessed by RPOR17, RPOR18 and RPOR19.

### 8.5.7 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 (see Table 8-6).

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**TABLE 8-6: REMAPPABLE OUTPUT PIN REGISTERS**

| Register | RP Pin | I/O Port |
|---|---|---|
| RPOR0[5:0] | RP32 | Port Pin RB0 |
| RPOR0[13:8] | RP33 | Port Pin RB1 |
| RPOR1[5:0] | RP34 | Port Pin RB2 |
| RPOR1[13:8] | RP35 | Port Pin RB3 |
| RPOR2[5:0] | RP36 | Port Pin RB4 |
| RPOR2[13:8] | RP37 | Port Pin RB5 |
| RPOR3[5:0] | RP38 | Port Pin RB6 |
| RPOR3[13:8] | RP39 | Port Pin RB7 |
| RPOR4[5:0] | RP40 | Port Pin RB8 |
| RPOR4[13:8] | RP41 | Port Pin RB9 |
| RPOR5[5:0] | RP42 | Port Pin RB10 |
| RPOR5[13:8] | RP43 | Port Pin RB11 |
| RPOR6[5:0] | RP44 | Port Pin RB12 |
| RPOR6[13:8] | RP45 | Port Pin RB13 |
| RPOR7[5:0] | RP46 | Port Pin RB14 |
| RPOR7[13:8] | RP47 | Port Pin RB15 |
| RPOR8[5:0] | RP48 | Port Pin RC0 |
| RPOR8[13:8] | RP49 | Port Pin RC1 |
| RPOR9[5:0] | RP50 | Port Pin RC2 |
| RPOR9[13:8] | RP51 | Port Pin RC3 |
| RPOR10[5:0] | RP52 | Port Pin RC4 |
| RPOR10[13:8] | RP53 | Port Pin RC5 |
| RPOR11[5:0] | RP54 | Port Pin RC6 |
| RPOR11[13:8] | RP55 | Port Pin RC7 |
| RPOR12[5:0] | RP56 | Port Pin RC8 |
| RPOR12[13:8] | RP57 | Port Pin RC9 |
| RPOR13[5:0] | RP58 | Port Pin RC10 |
| RPOR13[13:8] | RP59 | Port Pin RC11 |
| RPOR14[5:0] | RP60 | Port Pin RC12 |
| RPOR14[13:8] | RP61 | Port Pin RC13 |
| RPOR15[5:0] | RP65 | Port Pin RD1 |
| RPOR15[13:8] | RP72 | Port Pin RD8 |
| RPOR16[5:0] | RP74 | Port Pin RD10 |
| RPOR16[13:8] | RP77 | Port Pin RD13 |
| RPOR17[5:0] | RP176 | Virtual Pin RPV0 |
| RPOR17[13:8] | RP177 | Virtual Pin RPV1 |
| RPOR18[5:0] | RP178 | Virtual Pin RPV2 |
| RPOR18[13:8] | RP179 | Virtual Pin RPV3 |
| RPOR19[5:0] | RP180 | Virtual Pin RPV4 |
| RPOR19[13:8] | RP181 | Virtual Pin RPV5 |


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**TABLE 8-7: OUTPUT SELECTION FOR REMAPPABLE PINS (RPn)**

| Function | RPnR[5:0] | Output Name |
|---|---|---|
| Not Connected | 0 | Not Connected |
| U1TX | 1 | RPn tied to UART1 Transmit |
| $\overline{\text{U1RTS}}$ | 2 | RPn tied to UART1 Request-to-Send |
| U2TX | 3 | RPn tied to UART2 Transmit |
| $\overline{\text{U2RTS}}$ | 4 | RPn tied to UART2 Request-to-Send |
| SDO1 | 5 | RPn tied to SPI1 Data Output |
| SCK1 | 6 | RPn tied to SPI1 Clock Output |
| $\overline{\text{SS1}}$ | 7 | RPn tied to SPI1 Slave Select |
| SDO2 | 8 | RPn tied to SPI2 Data Output |
| SCK2 | 9 | RPn tied to SPI2 Clock Output |
| $\overline{\text{SS2}}$ | 10 | RPn tied to SPI2 Slave Select |
| REFCLKO | 14 | RPn tied to Reference Clock Output |
| OCM1A | 15 | RPn tied to SCCP1 Output |
| OCM2A | 16 | RPn tied to SCCP2 Output |
| OCM3A | 17 | RPn tied to SCCP3 Output |
| OCM4A | 18 | RPn tied to SCCP4 Output |
| CMP1 | 23 | RPn tied to Comparator 1 Output |
| U3TX | 27 | RPn tied to UART3 Transmit |
| $\overline{\text{U3RTS}}$ | 28 | RPn tied to UART3 Request-to-Send |
| PWM4H | 34 | RPn tied to PWM4H Output |
| PWM4L | 35 | RPn tied to PWM4L Output |
| PWMEA | 36 | RPn tied to PWM Event A Output |
| PWMEB | 37 | RPn tied to PWM Event B Output |
| QEICMP1 | 38 | RPn tied to QEI1 Comparator Output |
| CLC1OUT | 40 | RPn tied to CLC1 Output |
| CLC2OUT | 41 | RPn tied to CLC2 Output |
| PWMEC | 44 | RPn tied to PWM Event C Output |
| PWMED | 45 | RPn tied to PWM Event D Output |
| PTGTRG24 | 46 | RPn tied to PTG Trigger Output 24 |
| PTGTRG25 | 47 | RPn tied to PTG Trigger Output 25 |
| SENT1OUT | 48 | RPn tied to SENT1 Output |
| CLC3OUT | 59 | RPn tied to CLC4 Output |
| CLC4OUT | 60 | RPn tied to CLC4 Output |
| $\overline{\text{U1DTR}}$ | 61 | RPn tied to UART1 DTR |
| $\overline{\text{U2DTR}}$ | 62 | RPn tied to UART2 DTR |
| $\overline{\text{U3DTR}}$ | 63 | RPn tied to UART3 DTR |

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### 8.5.8 I/O HELPFUL TIPS

1. In some cases, certain pins, as defined in Table 33-15 under “Injection Current”, have internal protection diodes to VDD and VSS. The term, injection current, is also referred to as a 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 lesser 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 Select for PORTx registers in the I/O ports module (i.e., ANSELx) 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 a 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 leftmost function name takes precedence over any function to its right in the naming convention. For example, AN16/T2CK/T7CK/RC1 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 specifications. 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 33.0 “Electrical Characteristics”**. 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.


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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 (BIST).
   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 Select for PORTx (ANSELx) registers control the digital input buffer, not the TRISx register. The user must disable the analog function on a pin using the Analog Select for PORTx registers in order to use any digital input(s) on a corresponding pin, no exceptions.

### 8.5.9 I/O PORTS 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.

#### 8.5.9.1 Key Resources

- **"I/O Ports with Edge Detect"** (www.microchip.com/DS70005322)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools

**TABLE 8-8: PORTA REGISTER SUMMARY**

| Register | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANSELA | — | — | — | — | — | — | — | — | — | — | — | ANSELA[4:0] | | | | |
| TRISA | — | — | — | — | — | — | — | — | — | — | — | TRISA[4:0] | | | | |
| PORTA | — | — | — | — | — | — | — | — | — | — | — | RA[4:0] | | | | |
| LATA | — | — | — | — | — | — | — | — | — | — | — | LATA[4:0] | | | | |
| ODCA | — | — | — | — | — | — | — | — | — | — | — | ODCA[4:0] | | | | |
| CNPUA | — | — | — | — | — | — | — | — | — | — | — | CNPUA[4:0] | | | | |
| CNPDA | — | — | — | — | — | — | — | — | — | — | — | CNPDA[4:0] | | | | |
| CNCONA | ON | — | — | — | CNSTYLE | — | — | — | — | — | — | — | — | — | — | — |
| CNEN0A | — | — | — | — | — | — | — | — | — | — | — | CNEN0A[4:0] | | | | |
| CNSTATA | — | — | — | — | — | — | — | — | — | — | — | CNSTATA[4:0] | | | | |
| CNEN1A | — | — | — | — | — | — | — | — | — | — | — | CNEN1A[4:0] | | | | |
| CNFA | — | — | — | — | — | — | — | — | — | — | — | CNFA[4:0] | | | | |

**TABLE 8-9: PORTB REGISTER SUMMARY**

| Register | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANSELB | — | — | — | — | — | — | ANSELB[9:7] | | | — | — | ANSELB[4:0] | | | | |
| TRISB | TRISB[15:0] | | | | | | | | | | | | | | | |
| PORTB | RB[15:0] | | | | | | | | | | | | | | | |
| LATB | LATB[15:0] | | | | | | | | | | | | | | | |
| ODCB | ODCB[15:0] | | | | | | | | | | | | | | | |
| CNPUB | CNPUB[15:0] | | | | | | | | | | | | | | | |
| CNPDB | CNPDB[15:0] | | | | | | | | | | | | | | | |
| CNCONB | ON | — | — | — | CNSTYLE | — | — | — | — | — | — | — | — | — | — | — |
| CNEN0B | CNEN0[15:0] | | | | | | | | | | | | | | | |
| CNSTATB | CNSTATB[15:0] | | | | | | | | | | | | | | | |
| CNEN1B | CNEN1B[15:0] | | | | | | | | | | | | | | | |
| CNFB | CNFB[15:0] | | | | | | | | | | | | | | | |



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**TABLE 8-10: PORTC REGISTER SUMMARY**

| Register | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANSELC | — | — | — | — | — | — | — | — | ANSELC[7:6] | | — | — | ANSELC[3:0] | | | |
| TRISC | — | — | TRISC[13:0] | | | | | | | | | | | | | |
| PORTC | — | — | RC[13:0] | | | | | | | | | | | | | |
| LATC | — | — | LATC[13:0] | | | | | | | | | | | | | |
| ODCC | — | — | ODCC[13:0] | | | | | | | | | | | | | |
| CNPUC | — | — | CNPUC[13:0] | | | | | | | | | | | | | |
| CNPDC | — | — | CNPDC[13:0] | | | | | | | | | | | | | |
| CNCONC | ON | — | — | — | CNSTYLE | — | — | — | — | — | — | — | — | — | — | — |
| CNEN0C | — | — | CNEN0C[13:0] | | | | | | | | | | | | | |
| CNSTATC | — | — | CNSTATC[13:0] | | | | | | | | | | | | | |
| CNEN1C | — | — | CNEN1C[13:0] | | | | | | | | | | | | | |
| CNFC | — | — | CNFC[13:0] | | | | | | | | | | | | | |

**TABLE 8-11: PORTD REGISTER SUMMARY**

| Register | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANSELD | — | — | ANSELD13 | — | — | ANSELD10 | — | — | — | — | — | — | — | — | — | — |
| TRISD | — | — | TRISD13 | — | — | TRISD10 | — | TRISD8 | — | — | — | — | — | — | TRISD1 | — |
| PORTD | — | — | RD13 | — | — | RD10 | — | RD8 | — | — | — | — | — | — | RD1 | — |
| LATD | — | — | LATD13 | — | — | LATD10 | — | LATD8 | — | — | — | — | — | — | LATD1 | — |
| ODCD | — | — | ODCD13 | — | — | ODCD10 | — | ODCD8 | — | — | — | — | — | — | ODCD1 | — |
| CNPUD | — | — | CNPUD13 | — | — | CNPUD10 | — | CNPUD8 | — | — | — | — | — | — | CNPUD1 | — |
| CNPDD | — | — | CNPDD13 | — | — | CNPDD10 | — | CNPDD8 | — | — | — | — | — | — | CNPDD1 | — |
| CNCOND | ON | — | — | — | CNSTYLE | — | — | — | — | — | — | — | — | — | — | — |
| CNEN0D | — | — | CNEN0D13 | — | — | CNEN0D10 | — | CNEN0D8 | — | — | — | — | — | — | CNEN0D1 | — |
| CNSTATD | — | — | CNSTATD13 | — | — | CNSTATD10 | — | CNSTATD8 | — | — | — | — | — | — | CNSTATD1 | — |
| CNEN1D | — | — | CNEN1D13 | — | — | CNEN1D10 | — | CNEN1D8 | — | — | — | — | — | — | CNEN1D1 | — |
| CNFD | — | — | CNFD13 | — | — | CNFD10 | — | CNFD8 | | | | | | | CNFD1 | — |

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### 8.5.10 PERIPHERAL PIN SELECT REGISTERS

**REGISTER 8-13: RPCON: PERIPHERAL REMAPPING CONFIGURATION REGISTER(1)**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | IOLOCK | — | — | — |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11 **IOLOCK:** Peripheral Remapping Register Lock bit
1 = All Peripheral Remapping registers are locked and cannot be written.
0 = All Peripheral Remapping registers are unlocked and can be written.

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

**Note 1:** Writing to this register needs an unlock sequence.

**REGISTER 8-14: 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 8-4.

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


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**REGISTER 8-15: RPINR1: PERIPHERAL PIN SELECT INPUT 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 |
|---|---|---|---|---|---|---|---|
| INT3R7 | INT3R6 | INT3R5 | INT3R4 | INT3R3 | INT3R2 | INT3R1 | INT3R0 |
| 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 **INT3R[7:0]:** Assign External Interrupt 3 (INT3) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **INT2R[7:0]:** Assign External Interrupt 2 (INT2) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-16: 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 8-4.

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

**REGISTER 8-17: 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 |
|---|---|---|---|---|---|---|---|
| ICM1R7 | ICM1R6 | ICM1R5 | ICM1R4 | ICM1R3 | ICM1R2 | ICM1R1 | ICM1R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| TCKI1R7 | TCKI1R6 | TCKI1R5 | TCKI1R4 | TCKI1R3 | TCKI1R2 | TCKI1R1 | TCKI1R0 |
| 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 **ICM1R[7:0]:** Assign SCCP Capture 1 (ICM1) Input to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **TCKI1[7:0]:** Assign SCCP Timer1 (TCKI1) Input to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-18: RPINR4: PERIPHERAL PIN SELECT INPUT 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 |
|---|---|---|---|---|---|---|---|
| ICM2R7 | ICM2R6 | ICM2R5 | ICM2R4 | ICM2R3 | ICM2R2 | ICM2R1 | ICM2R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| TCKI2R7 | TCKI2R6 | TCKI2R5 | TCKI2R4 | TCKI2R3 | TCKI2R2 | TCKI2R1 | TCKI2R0 |
| 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 **ICM2R[7:0]:** Assign SCCP Capture 2 (ICM2) Input to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **TCKI2R[7:0]:** Assign SCCP Timer2 (TCKI2) Input to the Corresponding RPn Pin bits
See Table 8-4.


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**REGISTER 8-19: RPINR5: PERIPHERAL PIN SELECT INPUT REGISTER 5**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ICM3R7 | ICM3R6 | ICM3R5 | ICM3R4 | ICM3R3 | ICM3R2 | ICM3R1 | ICM3R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| TCKI3R7 | TCKI3R6 | TCKI3R5 | TCKI3R4 | TCKI3R3 | TCKI3R2 | TCKI3R1 | TCKI3R0 |
| 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 **ICM3R[7:0]:** Assign SCCP Capture 3 (ICM3) Input to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **TCKI3R[7:0]:** Assign SCCP Timer3 (TCKI3) Input to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-20: RPINR6: PERIPHERAL PIN SELECT INPUT 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 |
|---|---|---|---|---|---|---|---|
| ICM4R7 | ICM4R6 | ICM4R5 | ICM4R4 | ICM4R3 | ICM4R2 | ICM4R1 | ICM4R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| TCKI4R7 | TCKI4R6 | TCKI4R5 | TCKI4R4 | TCKI4R3 | TCKI4R2 | TCKI4R1 | TCKI4R0 |
| 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 **ICM4R[7:0]:** Assign SCCP Capture 4 (ICM4) Input to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **TCKI4R[7:0]:** Assign SCCP Timer4 (TCKI4) Input to the Corresponding RPn Pin bits
See Table 8-4.

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**REGISTER 8-21: RPINR11: PERIPHERAL PIN SELECT INPUT REGISTER 11**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| OCFBR7 | OCFBR6 | OCFBR5 | OCFBR4 | OCFBR3 | OCFBR2 | OCFBR1 | OCFBR0 |
| 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 **OCFBR[7:0]:** Assign xCCP Fault B (OCFB) Input to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **OCFAR[7:0]:** Assign xCCP Fault A (OCFA) Input to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-22: 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 |
|---|---|---|---|---|---|---|---|
| PCI9R7 | PCI9R6 | PCI9R5 | PCI9R4 | PCI9R3 | PCI9R2 | PCI9R1 | PCI9R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| PCI8R7 | PCI8R6 | PCI8R5 | PCI8R4 | PCI8R3 | PCI8R2 | PCI8R1 | PCI8R0 |
| 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 **PCI9R[7:0]:** Assign PWM Input 9 (PCI9) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **PCI8R[7:0]:** Assign PWM Input 8 (PCI8) to the Corresponding RPn Pin bits
See Table 8-4.


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**REGISTER 8-23: 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 |
|---|---|---|---|---|---|---|---|
| PCI11R7 | PCI11R6 | PCI11R5 | PCI11R4 | PCI11R3 | PCI11R2 | PCI11R1 | PCI11R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| PCI10R7 | PCI10R6 | PCI10R5 | PCI10R4 | PCI10R3 | PCI10R2 | PCI10R1 | PCI10R0 |
| 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 **PCI11R[7:0]:** Assign PWM Input 11 (PCI11) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **PCI10R[7:0]:** Assign PWM Input 10 (PCI10) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-24: RPINR14: PERIPHERAL PIN SELECT INPUT REGISTER 14**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| QEIB1R7 | QEIB1R6 | QEIB1R5 | QEIB1R4 | QEIB1R3 | QEIB1R2 | QEIB1R1 | QEIB1R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| QEIA1R7 | QEIA1R6 | QEIA1R5 | QEIA1R4 | QEIA1R3 | QEIA1R2 | QEIA1R1 | QEIA1R0 |
| 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 **QEIB1R[7:0]:** Assign QEI1 Input B (QEIB1) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **QEIA1R[7:0]:** Assign QEI1 Input A (QEIA1) to the Corresponding RPn Pin bits
See Table 8-4.

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**REGISTER 8-25: RPINR15: PERIPHERAL PIN SELECT INPUT REGISTER 15**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| QEIHOM1R7 | QEIHOM1R6 | QEIHOM1R5 | QEIHOM1R4 | QEIHOM1R3 | QEIHOM1R2 | QEIHOM1R1 | QEIHOM1R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| QEINDX1R7 | QEINDX1R6 | QEINDX1R5 | QEINDX1R4 | QEINDX1R3 | QEINDX1R2 | QEINDX1R1 | QEINDX1R0 |
| 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 **QEIHOM1R[7:0]:** Assign QEI1 Home 1 Input (QEIHOM1) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **QEINDX1R[7:0]:** Assign QEI1 Index 1 Input (QEINDX1) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-26: 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 |
|---|---|---|---|---|---|---|---|
| U1DSRR7 | U1DSRR6 | U1DSRR5 | U1DSRR4 | U1DSRR3 | U1DSRR2 | U1DSRR1 | U1DSRR0 |
| 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 **U1DSRR[7:0]:** Assign UART1 Data-Set-Ready ($\overline{\text{U1DSR}}$) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **U1RXR[7:0]:** Assign UART1 Receive (U1RX) to the Corresponding RPn Pin bits
See Table 8-4.


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**REGISTER 8-27: 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 |
|---|---|---|---|---|---|---|---|
| U2DSRR7 | U2DSRR6 | U2DSRR5 | U2DSRR4 | U2DSRR3 | U2DSRR2 | U2DSRR1 | U2DSRR0 |
| 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 **U2DSRR[7:0]:** Assign UART2 Data-Set-Ready ($\overline{\text{U2DSR}}$) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **U2RXR[7:0]:** Assign UART2 Receive (U2RX) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-28: 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 |
|---|---|---|---|---|---|---|---|
| SCK1R7 | SCK1R6 | SCK1R5 | SCK1R4 | SCK1R3 | SCK1R2 | SCK1R1 | SCK1R0 |
| 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 **SCK1R[7:0]:** Assign SPI1 Clock Input (SCK1IN) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **SDI1R[7:0]:** Assign SPI1 Data Input (SDI1) to the Corresponding RPn Pin bits
See Table 8-4.

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**REGISTER 8-29: RPINR21: PERIPHERAL PIN SELECT INPUT REGISTER 21**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| REFOIR7 | REFOIR6 | REFOIR5 | REFOIR4 | REFOIR3 | REFOIR2 | REFOIR1 | REFOIR0 |
| 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 **REFOIR[7:0]:** Assign Reference Clock Input (REFCLKI) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **SS1R[7:0]:** Assign SPI1 Slave Select ($\overline{SS1}$) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-30: 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 |
|---|---|---|---|---|---|---|---|
| SCK2R7 | SCK2R6 | SCK2R5 | SCK2R4 | SCK2R3 | SCK2R2 | SCK2R1 | SCK2R0 |
| 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 **SCK2R[7:0]:** Assign SPI2 Clock Input (SCK2IN) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **SDI2R[7:0]:** Assign SPI2 Data Input (SDI2) to the Corresponding RPn Pin bits
See Table 8-4.


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**REGISTER 8-31: 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 8-4.

**REGISTER 8-32: RPINR27: PERIPHERAL PIN SELECT INPUT REGISTER 27**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| U3DSRR7 | U3DSRR6 | U3DSRR5 | U3DSRR4 | U3DSRR3 | U3DSRR2 | U3DSRR1 | U3DSRR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| U3RXR7 | U3RXR6 | U3RXR5 | U3RXR4 | U3RXR3 | U3RXR2 | U3RXR1 | U3RXR0 |
| 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 **U3DSRR[7:0]:** Assign UART3 Data-Set-Ready ($\overline{U3DSR}$) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **U3RXR[7:0]:** Assign UART3 Receive (U3RX) to the Corresponding RPn Pin bits
See Table 8-4.

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**REGISTER 8-33: 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 |
|---|---|---|---|---|---|---|---|
| PCI17R7 | PCI17R6 | PCI17R5 | PCI17R4 | PCI17R3 | PCI17R2 | PCI17R1 | PCI17R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| OCFCR7 | OCFCR6 | OCFCR5 | OCFCR4 | OCFCR3 | OCFCR2 | OCFCR1 | OCFCR0 |
| 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 **PCI17R[7:0]:** Assign PWM Input 17 (PCI17) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **OCFCR[7:0]:** Assign xCCP Fault C (OCFC) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-34: 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 |
|---|---|---|---|---|---|---|---|
| PCI18R7 | PCI18R6 | PCI18R5 | PCI18R4 | PCI18R3 | PCI18R2 | PCI18R1 | PCI18R0 |
| 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 **PCI18R[7:0]:** Assign PWM Input 18 (PCI18) to the Corresponding RPn Pin bits
See Table 8-4.


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**REGISTER 8-35: 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 |
|---|---|---|---|---|---|---|---|
| PCI13R7 | PCI13R6 | PCI13R5 | PCI13R4 | PCI13R3 | PCI13R2 | PCI13R1 | PCI13R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| PCI12R7 | PCI12R6 | PCI12R5 | PCI12R4 | PCI12R3 | PCI12R2 | PCI12R1 | PCI12R0 |
| 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 **PCI13R[7:0]:** Assign PWM Input 13 (PCI13) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **PCI12R[7:0]:** Assign PWM Input 12 (PCI12) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-36: 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 |
|---|---|---|---|---|---|---|---|
| PCI15R7 | PCI15R6 | PCI15R5 | PCI15R4 | PCI15R3 | PCI15R2 | PCI15R1 | PCI15R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| PCI14R7 | PCI14R6 | PCI14R5 | PCI14R4 | PCI14R3 | PCI14R2 | PCI14R1 | PCI14R0 |
| 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 **PCI15R[7:0]:** Assign PWM Input 15 (PCI15) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **PCI14R[7:0]:** Assign PWM Input 14 (PCI14) to the Corresponding RPn Pin bits
See Table 8-4.

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**REGISTER 8-37: RPINR44: PERIPHERAL PIN SELECT INPUT REGISTER 44**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SENT1R7 | SENT1R6 | SENT1R5 | SENT1R4 | SENT1R3 | SENT1R2 | SENT1R1 | SENT1R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| PCI16R7 | PCI16R6 | PCI16R5 | PCI16R4 | PCI16R3 | PCI16R2 | PCI16R1 | PCI16R0 |
| 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 **SENT1R[7:0]:** Assign SENT1 Input (SENT1) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **PCI16R[7:0]:** Assign PWM Input 16 (PCI16) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-38: 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 8-4.

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


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**REGISTER 8-39: RPINR46: PERIPHERAL PIN SELECT INPUT REGISTER 46**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CLCINCR7 | CLCINCR6 | CLCINCR5 | CLCINCR4 | CLCINCR3 | CLCINCR2 | CLCINCR1 | CLCINCR0 |
| 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 **CLCINCR[7:0]:** Assign CLC Input C (CLCINC) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **CLCINBR[7:0]:** Assign CLC Input B (CLCINB) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-40: RPINR47: PERIPHERAL PIN SELECT INPUT REGISTER 47**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ADCTRGR7 | ADCTRGR6 | ADCTRGR5 | ADCTRGR4 | ADCTRGR3 | ADCTRGR2 | ADCTRGR1 | ADCTRGR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| CLCINDR7 | CLCINDR6 | CLCINDR5 | CLCINDR4 | CLCINDR3 | CLCINDR2 | CLCINDR1 | CLCINDR0 |
| 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 **ADCTRGR[7:0]:** Assign ADC Trigger Input (ADCTRG) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **CLCINDR[7:0]:** Assign CLC Input D (CLCIND) to the Corresponding RPn Pin bits
See Table 8-4.

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**REGISTER 8-41: RPINR48: PERIPHERAL PIN SELECT INPUT REGISTER 48**

| 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 |
|---|---|---|---|---|---|---|---|
| OCFDR7 | OCFDR6 | OCFDR5 | OCFDR4 | OCFDR3 | OCFDR2 | OCFDR1 | OCFDR0 |
| 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 8-4.

bit 7-0 **OCFDR[7:0]:** Assign xCCP Fault D (OCFD) to the Corresponding RPn Pin bits
See Table 8-4.

**REGISTER 8-42: RPINR49: PERIPHERAL PIN SELECT INPUT REGISTER 49**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| U3CTSR7 | U3CTSR6 | U3CTSR5 | U3CTSR4 | U3CTSR3 | U3CTSR2 | U3CTSR1 | U3CTSR0 |
| 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 |
|---|---|---|---|---|---|---|---|
| U2CTSR7 | U2CTSR6 | U2CTSR5 | U2CTSR4 | U2CTSR3 | U2CTSR2 | U2CTSR1 | U2CTSR0 |
| 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 **U3CTSR[7:0]:** Assign UART3 Clear-to-Send ($\overline{\text{U3CTS}}$) to the Corresponding RPn Pin bits
See Table 8-4.

bit 7-0 **U2CTSR[7:0]:** Assign UART2 Clear-to-Send ($\overline{\text{U2CTS}}$) to the Corresponding RPn Pin bits
See Table 8-4.


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**REGISTER 8-43: RPOR0: PERIPHERAL PIN SELECT OUTPUT REGISTER 0**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP33R5 | RP33R4 | RP33R3 | RP33R2 | RP33R1 | RP33R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP32R5 | RP32R4 | RP32R3 | RP32R2 | RP32R1 | RP32R0 |
| 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 **RP33R[5:0]:** Peripheral Output Function is Assigned to RP33 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP32R[5:0]:** Peripheral Output Function is Assigned to RP32 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-44: RPOR1: PERIPHERAL PIN SELECT OUTPUT REGISTER 1**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP35R5 | RP35R4 | RP35R3 | RP35R2 | RP35R1 | RP35R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP34R5 | RP34R4 | RP34R3 | RP34R2 | RP34R1 | RP34R0 |
| 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 **RP35R[5:0]:** Peripheral Output Function is Assigned to RP35 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP34R[5:0]:** Peripheral Output Function is Assigned to RP34 Output Pin bits (see Table 8-7 for peripheral function numbers)

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**REGISTER 8-45: RPOR2: PERIPHERAL PIN SELECT OUTPUT REGISTER 2**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP37R5 | RP37R4 | RP37R3 | RP37R2 | RP37R1 | RP37R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP36R5 | RP36R4 | RP36R3 | RP36R2 | RP36R1 | RP36R0 |
| 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 **RP37R[5:0]:** Peripheral Output Function is Assigned to RP37 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP36R[5:0]:** Peripheral Output Function is Assigned to RP36 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-46: RPOR3: PERIPHERAL PIN SELECT OUTPUT REGISTER 3**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP39R5 | RP39R4 | RP39R3 | RP39R2 | RP39R1 | RP39R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP38R5 | RP38R5 | RP38R5 | RP38R5 | RP38R5 | RP38R5 |
| bit 7 | | | | | | | bit 0 |

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

bit 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP39R[5:0]:** Peripheral Output Function is Assigned to RP39 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP38R[5:0]:** Peripheral Output Function is Assigned to RP38 Output Pin bits (see Table 8-7 for peripheral function numbers)


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**REGISTER 8-47: RPOR4: PERIPHERAL PIN SELECT OUTPUT REGISTER 4**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP41R5 | RP41R4 | RP41R3 | RP41R2 | RP41R1 | RP41R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP40R5 | RP40R4 | RP40R3 | RP40R2 | RP40R1 | RP40R0 |
| bit 7 | | | | | | | bit 0 |

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

bit 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP41R[5:0]:** Peripheral Output Function is Assigned to RP41 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP40R[5:0]:** Peripheral Output Function is Assigned to RP40 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-48: RPOR5: PERIPHERAL PIN SELECT OUTPUT REGISTER 5**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP43R5 | RP43R4 | RP43R3 | RP43R2 | RP43R1 | RP43R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP42R5 | RP42R4 | RP42R3 | RP42R2 | RP42R1 | RP42R0 |
| 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 **RP43R[5:0]:** Peripheral Output Function is Assigned to RP43 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP42R[5:0]:** Peripheral Output Function is Assigned to RP42 Output Pin bits (see Table 8-7 for peripheral function numbers)

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**REGISTER 8-49: RPOR6: PERIPHERAL PIN SELECT OUTPUT REGISTER 6**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP45R5 | RP45R4 | RP45R3 | RP45R2 | RP45R1 | RP45R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP45R[5:0]:** Peripheral Output Function is Assigned to RP45 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP44R[5:0]:** Peripheral Output Function is Assigned to RP44 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-50: RPOR7: PERIPHERAL PIN SELECT OUTPUT REGISTER 7**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP47R5 | RP47R4 | RP47R3 | RP47R2 | RP47R1 | RP47R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP47R[5:0]:** Peripheral Output Function is Assigned to RP47 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP46R[5:0]:** Peripheral Output Function is Assigned to RP46 Output Pin bits (see Table 8-7 for peripheral function numbers)


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**REGISTER 8-51: RPOR8: PERIPHERAL PIN SELECT OUTPUT REGISTER 8**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP49R5 | RP49R4 | RP49R3 | RP49R2 | RP49R1 | RP49R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP49R[5:0]:** Peripheral Output Function is Assigned to RP49 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP48R[5:0]:** Peripheral Output Function is Assigned to RP48 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-52: RPOR9: PERIPHERAL PIN SELECT OUTPUT REGISTER 9**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP51R5 | RP51R4 | RP51R3 | RP51R2 | RP51R1 | RP51R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP51R[5:0]:** Peripheral Output Function is Assigned to RP51 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP50R[5:0]:** Peripheral Output Function is Assigned to RP50 Output Pin bits (see Table 8-7 for peripheral function numbers)

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**REGISTER 8-53: RPOR10: PERIPHERAL PIN SELECT OUTPUT REGISTER 10**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP53R5 | RP53R4 | RP53R3 | RP53R2 | RP53R1 | RP53R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP53[5:0]:** Peripheral Output Function is Assigned to RP53 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP52R[5:0]:** Peripheral Output Function is Assigned to RP52 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-54: RPOR11: PERIPHERAL PIN SELECT OUTPUT REGISTER 11**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP55R5 | RP55R4 | RP55R3 | RP55R2 | RP55R1 | RP55R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP55R[5:0]:** Peripheral Output Function is Assigned to RP55 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP54R[5:0]:** Peripheral Output Function is Assigned to RP54 Output Pin bits (see Table 8-7 for peripheral function numbers)


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**REGISTER 8-55: RPOR12: PERIPHERAL PIN SELECT OUTPUT REGISTER 12**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP57R5 | RP57R4 | RP57R3 | RP57R2 | RP57R1 | RP57R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP57R[5:0]:** Peripheral Output Function is Assigned to RP57 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP56R[5:0]:** Peripheral Output Function is Assigned to RP56 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-56: RPOR13: PERIPHERAL PIN SELECT OUTPUT REGISTER 13**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP59R5 | RP59R4 | RP59R3 | RP59R2 | RP59R1 | RP59R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP59R[5:0]:** Peripheral Output Function is Assigned to RP59 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP58R[5:0]:** Peripheral Output Function is Assigned to RP58 Output Pin bits (see Table 8-7 for peripheral function numbers)

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**REGISTER 8-57: RPOR14: PERIPHERAL PIN SELECT OUTPUT REGISTER 14**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP61R5 | RP61R4 | RP61R3 | RP61R2 | RP61R1 | RP61R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP60R5 | RP60R4 | RP60R3 | RP60R2 | RP60R1 | RP60R0 |
| 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 **RP61R[5:0]:** Peripheral Output Function is Assigned to RP61 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP60R[5:0]:** Peripheral Output Function is Assigned to RP60 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-58: RPOR15: PERIPHERAL PIN SELECT OUTPUT REGISTER 15**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP72R5 | RP72R4 | RP72R3 | RP72R2 | RP72R1 | RP72R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | 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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP72R[5:0]:** Peripheral Output Function is Assigned to RP72 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP65R[5:0]:** Peripheral Output Function is Assigned to RP65 Output Pin bits (see Table 8-7 for peripheral function numbers)


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**REGISTER 8-59: RPOR16: PERIPHERAL PIN SELECT OUTPUT REGISTER 16**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP77R5 | RP77R4 | RP77R3 | RP77R2 | RP77R1 | RP77R0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP74R5 | RP74R4 | RP74R3 | RP74R2 | RP74R1 | RP74R0 |
| 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 **RP77R[5:0]:** Peripheral Output Function is Assigned to RP77 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP74R[5:0]:** Peripheral Output Function is Assigned to RP74 Output Pin bits (see Table 8-7 for peripheral function numbers)

**REGISTER 8-60: RPOR17: PERIPHERAL PIN SELECT OUTPUT REGISTER 17**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP177R5(1) | RP177R4(1) | RP177R3(1) | RP177R2(1) | RP177R1(1) | RP177R0(1) |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP176R5(1) | RP176R4(1) | RP176R3(1) | RP176R2(1) | RP176R1(1) | RP176R0(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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP177R[5:0]:** Peripheral Output Function is Assigned to RP177 Output Pin bits(1) (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP176R[5:0]:** Peripheral Output Function is Assigned to RP176 Output Pin bits(1) (see Table 8-7 for peripheral function numbers)

**Note 1:** These are virtual output ports.

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**REGISTER 8-61: RPOR18: PERIPHERAL PIN SELECT OUTPUT REGISTER 18**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP179R5(1) | RP179R4(1) | RP179R3(1) | RP179R2(1) | RP179R1(1) | RP179R0(1) |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP178R5(1) | RP178R4(1) | RP178R3(1) | RP178R2(1) | RP178R1(1) | RP178R0(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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP179R[5:0]:** Peripheral Output Function is Assigned to RP179 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP178R[5:0]:** Peripheral Output Function is Assigned to RP178 Output Pin bits (see Table 8-7 for peripheral function numbers)

**Note 1:** These are virtual output ports.

**REGISTER 8-62: RPOR19: PERIPHERAL PIN SELECT OUTPUT REGISTER 19**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RP181R5(1) | RP181R4(1) | RP181R3(1) | RP181R2(1) | RP181R1(1) | RP181R0(1) |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | RP180R5(1) | RP180R4(1) | RP180R3(1) | RP180R2(1) | RP180R1(1) | RP180R0(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 15-14 **Unimplemented:** Read as '0'

bit 13-8 **RP181R[5:0]:** Peripheral Output Function is Assigned to RP181 Output Pin bits (see Table 8-7 for peripheral function numbers)

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

bit 5-0 **RP180R[5:0]:** Peripheral Output Function is Assigned to RP180 Output Pin bits (see Table 8-7 for peripheral function numbers)

**Note 1:** These are virtual output ports.


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**TABLE 8-12: PPS INPUT CONTROL REGISTERS**

| Register | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RPCON | — | — | — | — | IOLOCK | — | — | — | — | — | — | — | — | — | — | — |
| RPINR0 | INT1R7 | INT1R6 | INT1R5 | INT1R4 | INT1R3 | INT1R2 | INT1R1 | INT1R0 | — | — | — | — | — | — | — | — |
| RPINR1 | INT3R7 | INT3R6 | INT3R5 | INT3R4 | INT3R3 | INT3R2 | INT3R1 | INT3R0 | INT2R7 | INT2R6 | INT2R5 | INT2R4 | INT2R3 | INT2R2 | INT2R1 | INT2R0 |
| RPINR2 | T1CKR7 | T1CKR6 | T1CKR5 | T1CKR4 | T1CKR3 | T1CKR2 | T1CKR1 | T1CKR0 | — | — | — | — | — | — | — | — |
| RPINR3 | ICM1R7 | ICM1R6 | ICM1R5 | ICM1R4 | ICM1R3 | ICM1R2 | ICM1R1 | ICM1R0 | TCKI1R7 | TCKI1R6 | TCKI1R5 | TCKI1R4 | TCKI1R3 | TCKI1R2 | TCKI1R1 | TCKI1R0 |
| RPINR4 | ICM2R7 | ICM2R6 | ICM2R5 | ICM2R4 | ICM2R3 | ICM2R2 | ICM2R1 | ICM2R0 | TCKI2R7 | TCKI2R6 | TCKI2R5 | TCKI2R4 | TCKI2R3 | TCKI2R2 | TCKI2R1 | TCKI2R0 |
| RPINR5 | ICM3R7 | ICM3R6 | ICM3R5 | ICM3R4 | ICM3R3 | ICM3R2 | ICM3R1 | ICM3R0 | TCKI3R7 | TCKI3R6 | TCKI3R5 | TCKI3R4 | TCKI3R3 | TCKI3R2 | TCKI3R1 | TCKI3R0 |
| RPINR6 | ICM4R7 | ICM4R6 | ICM4R5 | ICM4R4 | ICM4R3 | ICM4R2 | ICM4R1 | ICM4R0 | TCKI4R7 | TCKI4R | TCKI4R5 | TCKI4R4 | TCKI4R3 | TCKI4R2 | TCKI4R1 | TCKI4R0 |
| RPINR11 | OCFBR7 | OCFBR6 | OCFBR5 | OCFBR4 | OCFBR3 | OCFBR2 | OCFBR1 | OCFBR0 | OCFAR7 | OCFAR6 | OCFAR5 | OCFAR4 | OCFAR3 | OCFAR2 | OCFAR1 | OCFAR0 |
| RPINR12 | PCI9R7 | PCI9R6 | PCI9R5 | PCI9R4 | PCI9R3 | PCI9R2 | PCI9R1 | PCI9R0 | PCI8R7 | PCI8R6 | PCI8R5 | PCI8R4 | PCI8R3 | PCI8R2 | PCI8R1 | PCI8R0 |
| RPINR13 | PCI11R7 | PCI11R6 | PCI11R5 | PCI11R4 | PCI11R3 | PCI11R2 | PCI11R1 | PCI11R0 | PCI10R7 | PCI10R6 | PCI10R5 | PCI10R4 | PCI10R3 | PCI10R2 | PCI10R1 | PCI10R0 |
| RPINR14 | QEIB1R7 | QEIB1R6 | QEIB1R5 | QEIB1R4 | QEIB1R3 | QEIB1R2 | QEIB1R1 | QEIB1R0 | QEIA1R7 | QEIA1R6 | QEIA1R5 | QEIA1R4 | QEIA1R3 | QEIA1R2 | QEIA1R1 | QEIA1R0 |
| RPINR15 | QEIHOM1R7 | QEIHOM1R6 | QEIHOM1R5 | QEIHOM1R4 | QEIHOM1R3 | QEIHOM1R2 | QEIHOM1R1 | QEIHOM1R0 | QEINDX1R7 | QEINDX1R6 | QEINDX1R5 | QEINDX1R4 | QEINDX1R3 | QEINDX1R2 | QEINDX1R1 | QEINDX1R0 |
| RPINR18 | U1DSRR7 | U1DSRR6 | U1DSRR5 | U1DSRR4 | U1DSRR3 | U1DSRR2 | U1DSRR1 | U1DSRR0 | U1RXR7 | U1RXR6 | U1RXR5 | U1RXR4 | U1RXR3 | U1RXR2 | U1RXR1 | U1RXR0 |
| RPINR19 | U2DSRR7 | U2DSRR6 | U2DSRR5 | U2DSRR4 | U2DSRR3 | U2DSRR2 | U2DSRR1 | U2DSRR0 | U2RXR7 | U2RXR6 | U2RXR5 | U2RXR4 | U2RXR3 | U2RXR2 | U2RXR1 | U2RXR0 |
| RPINR20 | SCK1R7 | SCK1R6 | SCK1R5 | SCK1R4 | SCK1R3 | SCK1R2 | SCK1R1 | SCK1R0 | SDI1R7 | SDI1R6 | SDI1R5 | SDI1R4 | SDI1R3 | SDI1R2 | SDI1R1 | SDI1R0 |
| RPINR21 | REFOIR7 | REFOIR6 | REFOIR5 | REFOIR4 | REFOIR3 | REFOIR2 | REFOIR1 | REFOIR0 | SS1R7 | SS1R6 | SS1R5 | SS1R4 | SS1R3 | SS1R2 | SS1R1 | SS1R0 |
| RPINR22 | SCK2R7 | SCK2R6 | SCK2R5 | SCK2R4 | SCK2R3 | SCK2R2 | SCK2R1 | SCK2R0 | SDI2R7 | SDI2R6 | SDI2R5 | SDI2R4 | SDI2R3 | SDI2R2 | SDI2R1 | SDI2R0 |
| RPINR23 | — | — | — | — | — | — | — | — | SS2R7 | SS2R6 | SS2R5 | SS2R4 | SS2R3 | SS2R2 | SS2R1 | SS2R0 |
| RPINR27 | U3DSRR7 | U3DSRR6 | U3DSRR5 | U3DSRR4 | U3DSRR3 | U3DSRR2 | U3DSRR1 | U3DSRR0 | U3RXR7 | U3RXR6 | U3RXR5 | U3RXR4 | U3RXR3 | U3RXR2 | U3RXR1 | U3RXR0 |
| RPINR37 | PCI17R7 | PCI17R6 | PCI17R5 | PCI17R4 | PCI17R3 | PCI17R2 | PCI17R1 | PCI17R0 | OCFCR7 | OCFCR6 | OCFCR5 | OCFCR4 | OCFCR3 | OCFCR2 | OCFCR1 | OCFCR0 |
| RPINR38 | — | — | — | — | — | — | — | — | PCI18R7 | PCI18R6 | PCI18R5 | PCI18R4 | PCI18R3 | PCI18R2 | PCI18R1 | PCI18R0 |
| RPINR42 | PCI13R7 | PCI13R6 | PCI13R5 | PCI13R4 | PCI13R3 | PCI13R2 | PCI13R1 | PCI13R0 | PCI12R7 | PCI12R6 | PCI12R5 | PCI12R4 | PCI12R3 | PCI12R2 | PCI12R1 | PCI12R0 |
| RPINR43 | PCI15R7 | PCI15R6 | PCI15R5 | PCI15R4 | PCI15R3 | PCI15R2 | PCI15R1 | PCI15R0 | PCI14R7 | PCI14R6 | PCI14R5 | PCI14R4 | PCI14R3 | PCI14R2 | PCI14R1 | PCI14R0 |
| RPINR44 | SENT1R7 | SENT1R6 | SENT1R5 | SENT1R4 | SENT1R3 | SENT1R2 | SENT1R1 | SENT1R0 | PCI16R7 | PCI16R6 | PCI16R5 | PCI16R4 | PCI16R3 | PCI16R2 | PCI16R1 | PCI16R0 |
| RPINR45 | CLCINAR7 | CLCINAR6 | CLCINAR5 | CLCINAR4 | CLCINAR3 | CLCINAR2 | CLCINAR1 | CLCINAR0 | — | — | — | — | — | — | — | — |
| RPINR46 | CLCINCR7 | CLCINCR6 | CLCINCR5 | CLCINCR4 | CLCINCR3 | CLCINCR2 | CLCINCR1 | CLCINCR0 | CLCINBR7 | CLCINBR6 | CLCINBR5 | CLCINBR4 | CLCINBR3 | CLCINBR2 | CLCINBR1 | CLCINBR0 |
| RPINR47 | ADCTRGR7 | ADCTRGR6 | ADCTRGR5 | ADCTRGR4 | ADCTRGR3 | ADCTRGR2 | ADCTRGR1 | ADCTRGR0 | CLCINDR7 | CLCINDR6 | CLCINDR5 | CLCINDR4 | CLCINDR3 | CLCINDR2 | CLCINDR1 | CLCINDR0 |
| RPINR48 | U1CTSR7 | U1CTSR6 | U1CTSR5 | U1CTSR4 | U1CTSR3 | U1CTSR2 | U1CTSR1 | U1CTSR0 | OCFDR7 | OCFDR6 | OCFDR5 | OCFDR4 | OCFDR3 | OCFDR2 | OCFDR1 | OCFDR0 |
| RPINR49 | U3CTSR7 | U3CTSR6 | U3CTSR5 | U3CTSR4 | U3CTSR3 | U3CTSR2 | U3CTSR1 | U3CTSR0 | U2CTSR7 | U2CTSR6 | U2CTSR5 | U2CTSR4 | U2CTSR3 | U2CTSR2 | U2CTSR1 | U2CTSR0 |

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**TABLE 8-13: PPS OUTPUT CONTROL REGISTERS**

| Register | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RPOR0 | — | — | RP33R5 | RP33R4 | RP33R3 | RP33R2 | RP33R1 | RP33R0 | — | — | RP32R5 | RP32R4 | RP32R3 | RP32R2 | RP32R1 | RP32R0 |
| RPOR1 | — | — | RP35R5 | RP35R4 | RP35R3 | RP35R2 | RP35R1 | RP35R0 | — | — | RP34R5 | RP34R4 | RP34R3 | RP34R2 | RP34R1 | RP34R0 |
| RPOR2 | — | — | RP37R5 | RP37R4 | RP37R3 | RP37R2 | RP37R1 | RP37R0 | — | — | RP36R5 | RP36R4 | RP36R3 | RP36R2 | RP36R1 | RP36R0 |
| RPOR3 | — | — | RP39R5 | RP39R4 | RP39R3 | RP39R2 | RP39R1 | RP39R0 | — | — | RP38R5 | RP38R4 | RP38R3 | RP38R2 | RP38R1 | RP38R0 |
| RPOR4 | — | — | RP41R5 | RP41R4 | RP41R3 | RP41R2 | RP41R1 | RP41R0 | — | — | RP40R5 | RP40R4 | RP40R3 | RP40R2 | RP40R1 | RP40R0 |
| RPOR5 | — | — | RP43R5 | RP43R4 | RP43R3 | RP43R2 | RP43R1 | RP43R0 | — | — | RP42R5 | RP42R4 | RP42R3 | RP42R2 | RP42R1 | RP42R0 |
| RPOR6 | — | — | RP45R5 | RP45R4 | RP45R3 | RP45R2 | RP45R1 | RP45R0 | — | — | RP44R5 | RP44R4 | RP44R3 | RP44R2 | RP44R1 | RP44R0 |
| RPOR7 | — | — | RP47R5 | RP47R4 | RP47R3 | RP47R2 | RP47R1 | RP47R0 | — | — | RP46R5 | RP46R4 | RP46R3 | RP46R2 | RP46R1 | RP46R0 |
| RPOR8 | — | — | RP49R5 | RP49R4 | RP49R3 | RP49R2 | RP49R1 | RP49R0 | — | — | RP48R5 | RP48R4 | RP48R3 | RP48R2 | RP48R1 | RP48R0 |
| RPOR9 | — | — | RP51R5 | RP51R4 | RP51R3 | RP51R2 | RP51R1 | RP51R0 | — | — | RP50R5 | RP50R4 | RP50R3 | RP50R2 | RP50R1 | RP50R0 |
| RPOR10 | — | — | RP53R5 | RP53R4 | RP53R3 | RP53R2 | RP53R1 | RP53R0 | — | — | RP52R5 | RP52R4 | RP52R3 | RP52R2 | RP52R1 | RP52R0 |
| RPOR11 | — | — | RP55R5 | RP55R4 | RP55R3 | RP55R2 | RP55R1 | RP55R0 | — | — | RP54R5 | RP54R4 | RP54R3 | RP54R2 | RP54R1 | RP54R0 |
| RPOR12 | — | — | RP57R5 | RP57R4 | RP57R3 | RP57R2 | RP57R1 | RP57R0 | — | — | RP56R5 | RP56R4 | RP56R3 | RP56R2 | RP56R1 | RP56R0 |
| RPOR13 | — | — | RP59R5 | RP59R4 | RP59R3 | RP59R2 | RP59R1 | RP59R0 | — | — | RP58R5 | RP58R4 | RP58R3 | RP58R2 | RP58R1 | RP58R0 |
| RPOR14 | — | — | RP61R5 | RP61R4 | RP61R3 | RP61R2 | RP61R1 | RP61R0 | — | — | RP60R5 | RP60R4 | RP60R3 | RP60R2 | RP60R1 | RP60R0 |
| RPOR15 | — | — | RP72R5 | RP72R4 | RP72R3 | RP72R2 | RP72R1 | RP72R0 | — | — | RP65R5 | RP65R4 | RP65R3 | RP65R2 | RP65R1 | RP65R0 |
| RPOR16 | — | — | RP77R5 | RP77R4 | RP77R3 | RP77R2 | RP77R1 | RP77R0 | — | — | RP74R5 | RP74R4 | RP74R3 | RP74R2 | RP74R1 | RP74R0 |
| RPOR17 | — | — | RP177R5 | RP177R4 | RP177R3 | RP177R2 | RP177R1 | RP177R0 | — | — | RP176R5 | RP176R4 | RP176R3 | RP176R2 | RP176R1 | RP176R0 |
| RPOR18 | — | — | RP179R5 | RP179R4 | RP179R3 | RP179R2 | RP179R1 | RP179R0 | — | — | RP178R5 | RP178R4 | RP178R3 | RP178R2 | RP178R1 | RP178R0 |
| RPOR19 | — | — | RP181R5 | RP181R4 | RP181R3 | RP181R2 | RP181R1 | RP181R0 | — | — | RP180R5 | RP180R4 | RP180R3 | RP180R2 | RP180R1 | RP180R0 |

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**NOTES:**


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## 9.0 OSCILLATOR WITH HIGH-FREQUENCY PLL

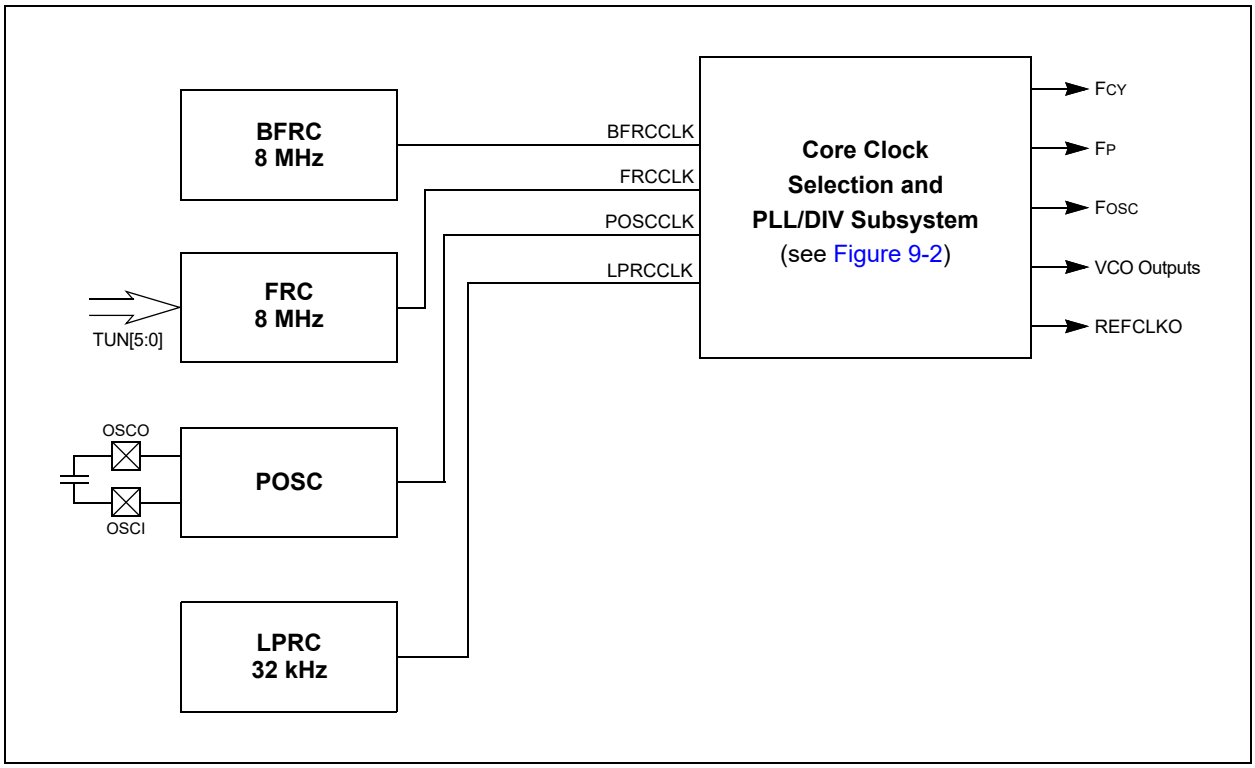
**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Oscillator Module with High-Speed PLL"**(www.microchip.com/DS70005255).

The dsPIC33CDVL64MC106 family oscillator with high-frequency PLL includes these characteristics:

- On-Chip Phase-Locked Loop (PLL) to Boost Internal Operating Frequency on Select Internal and External Oscillator Sources
- Doze Mode for System Power Savings
- Scalable Reference Clock Output (REFCLKO)
- On-the-Fly Clock Switching between Various Clock Sources
- Fail-Safe Clock Monitoring (FSCM) that Detects Clock Failure and Permits Safe Application Recovery or Shutdown

A block diagram of the dsPIC33CDVL64MC106 oscillator system is shown in Figure 9-1.

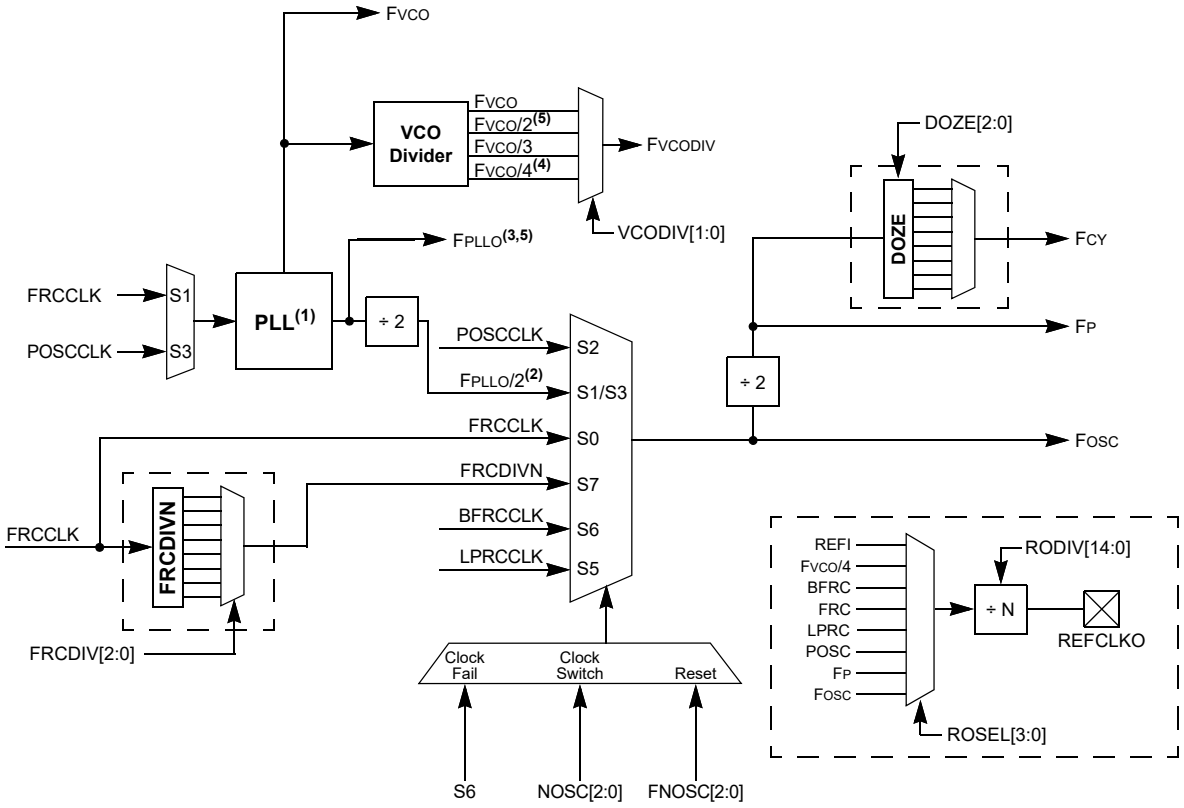
**FIGURE 9-1: dsPIC33CDVL64MC106 FAMILY CORE CLOCK SOURCES BLOCK DIAGRAM**





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**FIGURE 9-2: dsPIC33CDVL64MC106 FAMILY CORE OSCILLATOR SUBSYSTEM**




**Note 1:** See Figure 9-3 for details of the PLL module.
**2:** XTPLL, HSPLL, ECPLL, FRCPLL (FPLLO)
**3:** Clock option for PWM
**4:** Clock option for ADC
**5:** Clock option for DAC

## 9.1 Primary PLL

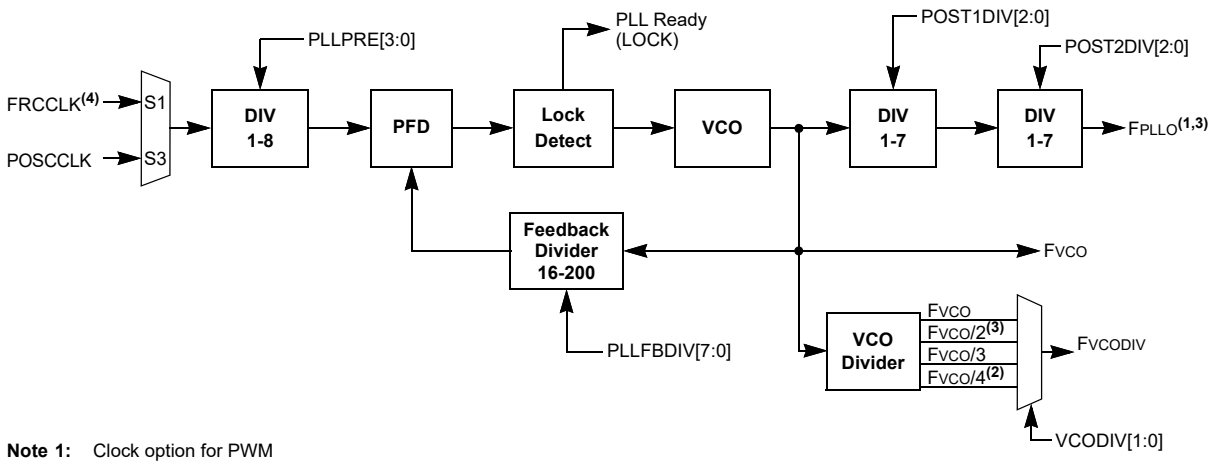
The primary oscillator and internal FRC oscillator sources can optionally use an on-chip PLL to obtain higher operating speeds. Figure 9-3 illustrates a block diagram of the PLL module.

For a PLL operation, the following requirements must be met at all times without exception:

- The PLL Input Frequency (FPLLI) must be in the range of 8 MHz to 64 MHz.
- The PFD Input Frequency (FPFD) must be in the range of 8 MHz to (FVCO/16) MHz.

The VCO Output Frequency (FVCO) must be in the range of 400 MHz to 1600 MHz.

**FIGURE 9-3: PLL AND VCO DETAIL**




**Note 1:** Clock option for PWM
**2:** Clock option for ADC
**3:** Clock option for DAC
**4:** PLL source is always FRC unless FNOSC is the Primary Oscillator with PLL.


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Equation 9-1 provides the relationship between the PLL Input Frequency (FPLLI) and VCO Output Frequency (FVCO).

**EQUATION 9-1: FVCO CALCULATION**

$$FVCO = FPLLI \times \left(\frac{M}{N1}\right) = FPLLI \times \left(\frac{PLLFBDIV[7:0]}{PLLPRE[3:0]}\right)$$

Equation 9-2 provides the relationship between the PLL Input Frequency (FPLLI) and PLL Output Frequency (FPLLO).

**EQUATION 9-2: FPLLO CALCULATION**

$$FPLLO = FPLLI \times \left(\frac{M}{N1 \times N2 \times N3}\right) = FPLLI \times \left(\frac{PLLFBDIV[7:0]}{PLLPRE[3:0] \times POST1DIV[2:0] \times POST2DIV[2:0]}\right)$$

Where:

$M$ = $PLLFBDIV$[7:0]
$N1$ = $PLLPRE$[3:0]
$N2$ = $POST1DIV$[2:0]
$N3$ = $POST2DIV$[2:0]

**Note:** The PLL Phase Detector Input Divider Select (PLLPREx) bits and the PLL Feedback Divider (PLLFBDIVx) bits should not be changed when operating in PLL mode. Therefore, the user must start in either a non-PLL mode or clock switch to a non-PLL mode (e.g., internal FRC Oscillator) to make any necessary changes and then clock switch to the desired PLL mode.

It is not permitted to directly clock switch from one PLL clock source to a different PLL clock source. The user would need to transition between PLL clock sources with a clock switch to a non-PLL clock source.

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Example 9-1 illustrates code for using the PLL (50 MIPS) with the primary oscillator.

**EXAMPLE 9-1: CODE EXAMPLE FOR USING PLL (50 MIPS) WITH PRIMARY OSCILLATOR (POSC)**

```
//code example for 50 MIPS system clock using POSC with 10 MHz external crystal

// Select Internal FRC at POR
_FOSCSEL(FNOSC_FRC & IESO_OFF);

// Enable Clock Switching and Configure POSC in XT mode
_FOSC(FCKSM_CSECMD & POSCMD_XT);

int main()
{
    // Configure PLL prescaler, both PLL postscalers, and PLL feedback divider
    CLKDIVbits.PLLPRE = 1;          // N1=1
    PLLFBDbits.PLLFBDIV = 100;      // M = 100
    PLLDIVbits.POST1DIV = 5;        // N2=5
    PLLDIVbits.POST2DIV = 1;        // N3=1

    // Initiate Clock Switch to Primary Oscillator with PLL (NOSC=0b011)
    __builtin_write_OSCCONH(0x03);
    __builtin_write_OSCCONL(OSCCON | 0x01);

    // Wait for Clock switch to occur
    while (OSCCONbits.OSWEN!= 0);

    // Wait for PLL to lock
    while (OSCCONbits.LOCK!= 1);
}
```

Example 9-2 illustrates code for using the PLL with an 8 MHz internal FRC.

**EXAMPLE 9-2: CODE EXAMPLE FOR USING PLL (50 MIPS) WITH 8 MHz INTERNAL FRC**

```
//code example for 50 MIPS system clock using 8MHz FRC

// Select Internal FRC at POR
_FOSCSEL(FNOSC_FRC & IESO_OFF);

// Enable Clock Switching
_FOSC(FCKSM_CSECMD);

int main()
{
    // Configure PLL prescaler, both PLL postscalers, and PLL feedback divider
    CLKDIVbits.PLLPRE = 1;          // N1=1
    PLLFBDbits.PLLFBDIV = 125;      // M = 125
    PLLDIVbits.POST1DIV = 5;        // N2=5
    PLLDIVbits.POST2DIV = 1;        // N3=1

    // Initiate Clock Switch to FRC with PLL (NOSC=0b001)
    __builtin_write_OSCCONH(0x01);
    __builtin_write_OSCCONL(OSCCON | 0x01);

    // Wait for Clock switch to occur
    while (OSCCONbits.OSWEN!= 0);

    // Wait for PLL to lock
    while (OSCCONbits.LOCK!= 1);
}
```


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## 9.2 CPU Clocking

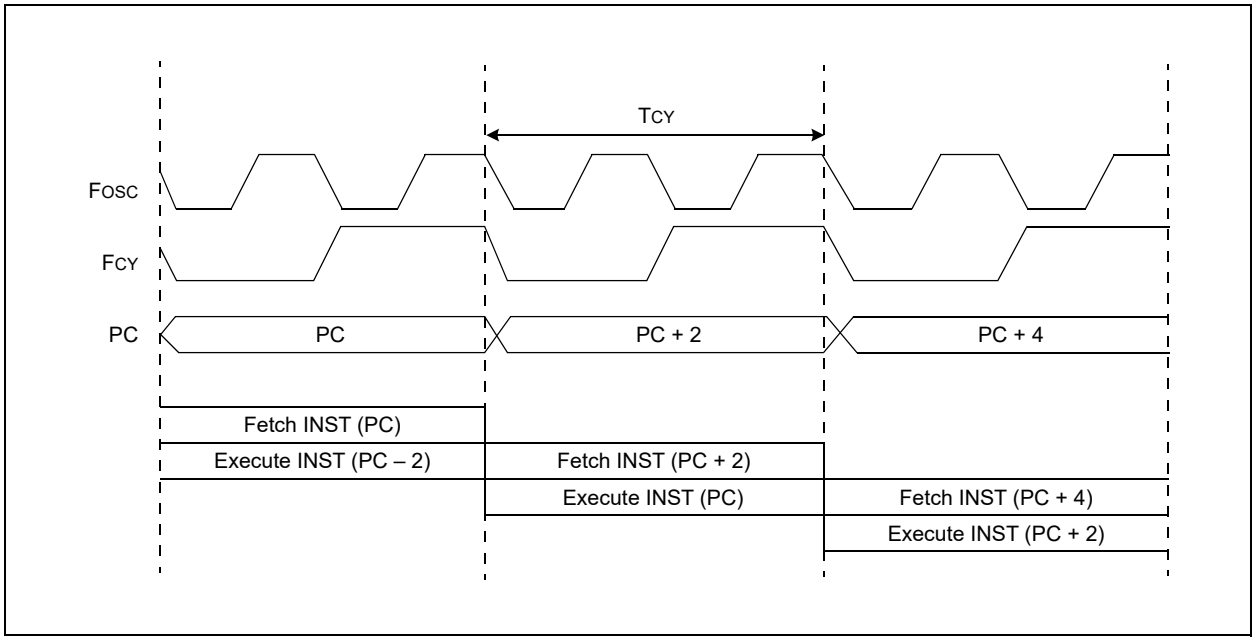
The dsPIC33CDVL64MC106 devices can be configured to use any of the following clock configurations:

- Primary Oscillator (POSC) on the OSCI and OSCO Pins
- Internal Fast RC Oscillator (FRC) with Optional Clock Divider
- Internal Low-Power RC Oscillator (LPRC)
- Primary Oscillator with PLL (ECPLL, HSPLL, XTPLL)
- Internal Fast RC Oscillator with PLL (FRCPLL)
- Internal Backup Fast RC Oscillator (BFRC)

The system clock source is divided by two to produce the internal instruction cycle clock. In this document, the instruction cycle clock is denoted by FCY. The timing diagram in Figure 9-4 illustrates the relationship between the system clock (FOSC), the instruction cycle clock (FCY) and the Program Counter (PC).

The internal instruction cycle clock (FCY) can be output on the OSCO I/O pin if the Primary Oscillator mode (POSCMD[1:0]) is not configured as HS/XT.

**FIGURE 9-4: CLOCK AND INSTRUCTION CYCLE TIMING**



## 9.3 Primary Oscillator (POSC)

The dsPIC33CDVL64MC106 family features a Primary Oscillator (POSC) and it is available on the OSCI and OSCO pins. This connection enables an external crystal (or ceramic resonator) to provide the clock to the device. The Primary Oscillator provides three modes of operation:

- Medium Speed Oscillator (XT mode):
  The XT mode is a Medium Gain, Medium Frequency mode used to work with crystal frequencies of 3.5 MHz to 10 MHz.
- High-Speed Oscillator (HS mode):
  The HS mode is a High-Gain, High-Frequency mode used to work with crystal frequencies of 10 MHz to 32 MHz.
- External Clock Source Operation (EC mode):
  If the on-chip oscillator is not used, the EC mode allows the internal oscillator to be bypassed. The device clocks are generated from an external source (0 MHz to up to 64 MHz) and input on the OSCI pin.

### 9.3.1 PRIMARY OSCILLATOR PIN FUNCTIONALITY

The Primary Oscillator pins (OSCI and OSCO) can be used for other functions when the primary oscillator is not being used. The POSCMD<1:0> Configuration bits in the Oscillator Configuration register (FOSC<1:0>) determine the oscillator pin function. The OSCIOFNC bit (FOSC<2>) determines the OSCO/CLKO pin function. By default, the CLKO function is active and the pin will output a clock frequency of Fcy. A clock signal is present on the OSCO/CLKO pin when the device is unprogrammed or during the programming sequence. Care should be taken when the OSCO/CLKO pin is used to drive other circuitry.

## 9.4 Internal Fast RC (FRC) Oscillator

The dsPIC33CDVL64MC106 devices contain one instance of the internal Fast RC (FRC) Oscillator and it provides a nominal 8 MHz clock without requiring an external crystal or ceramic resonator, which results in system cost savings for applications that do not require a precise clock reference.


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## 9.5 Low-Power RC (LPRC) Oscillator

The dsPIC33CDVL64MC106 family devices contain one instance of the Low-Power RC (LPRC) Oscillator, which provides a nominal clock frequency of 32 kHz and is the clock source for the Watchdog Timer (WDT) and Fail-Safe Clock Monitor (FSCM) circuits in the clock subsystem. The LPRC Oscillator is shut off in Sleep mode.

The LPRC Oscillator remains enabled under these conditions:

- The FSCM is enabled.
- The WDT is enabled.
- The LPRC Oscillator is selected as the system clock.

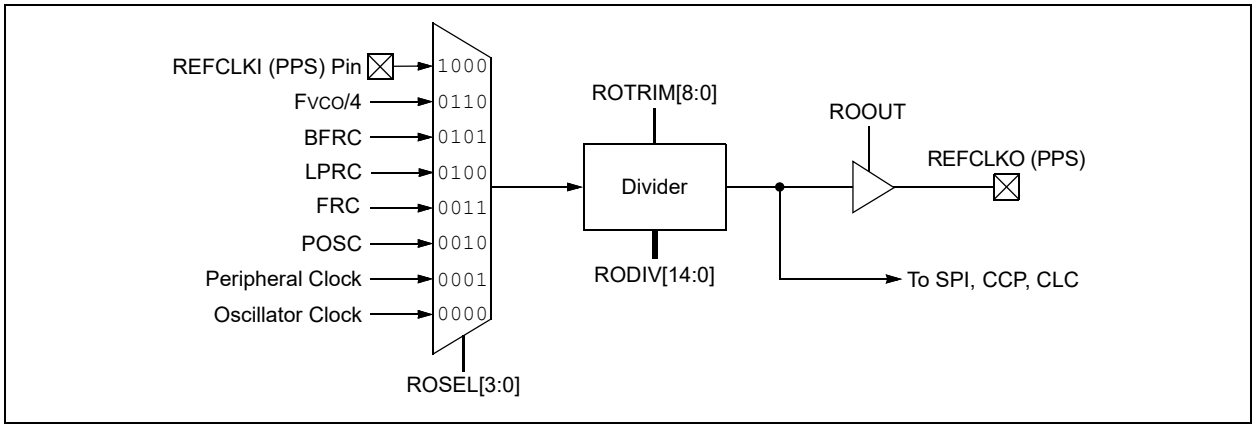
## 9.6 Backup Internal Fast RC (BFRC) Oscillator

The oscillator block provides a stable reference clock source for the Fail-Safe Clock Monitor (FSCM). When FSCM is enabled in the FCKSM[1:0] Configuration bits (FOSC[7:6]), it constantly monitors the main clock source against a reference signal from the 8 MHz Backup Internal Fast RC (BFRC) Oscillator. In case of a clock failure, the Fail-Safe Clock Monitor switches the clock to the BFRC Oscillator, allowing for continued low-speed operation or a safe application shutdown.

## 9.7 Reference Clock Output

In addition to the CLKO output (FOSC/2), the dsPIC33CDVL64MC106 devices can be configured to provide a reference clock output signal to a port pin. This feature is available in all oscillator configurations and allows the user to select a greater range of clock sub-multiples to drive external devices in the application. CLKO is enabled by Configuration bit, OSCIOFNC, and is independent of the REFCLKO reference clock. REFCLKO is mappable to any I/O pin that has mapped output capability. Refer to Table 8-7 for more information. The Reference Clock Output module block diagram is shown in Figure 9-5.

**FIGURE 9-5: REFERENCE CLOCK GENERATOR**



This reference clock output is controlled by the REFOCONL and REFOCONH registers. Setting the ROEN bit (REFOCONL[15]) makes the clock signal available on the REFCLKO pin. The RODIV[14:0] bits (REFOCONH[14:0]) and ROTRIM[8:0] bits (REFOTRIMH[15:7]) enable the selection of different clock divider options. The formula for determining the final frequency output is shown in Equation 9-3. The ROSWEN bit (REFOCONL[9]) indicates that the clock divider has been successfully switched. In order to switch the REFCLKO divider, the user should ensure that this bit reads as '0'. Write the updated values to the RODIV[14:0] or ROTRIM[8:0] bits, set the ROSWEN bit and then wait until it is cleared before assuming that the REFCLKO clock is valid.

**EQUATION 9-3: CALCULATING FREQUENCY OUTPUT**

$$FREFOUT = \frac{FREFIN}{2 \bullet (RODIV[14:0] + ROTRIM[8:0]/512)}$$

Where: $FREFOUT$ = Output Frequency
$FREFIN$ = Input Frequency
When $RODIV[14:0] = 0$, the output clock is the same as the input clock.

The ROSEL[3:0] bits (REFOCONL[3:0]) determine which clock source is used for the reference clock output. The ROSLP bit (REFOCONL[11]) determines if the reference source is available on REFCLKO when the device is in Sleep mode.

To use the reference clock output in Sleep mode, the ROSLP bit must be set and the clock selected by the ROSEL[3:0] bits must be enabled for operation during Sleep mode, if possible. Clearing the ROSEL[3:0] bits allows the reference output frequency to change, as the system clock changes during any clock switches. The ROOUT bit enables/disables the reference clock output on the REFCLKO pin.

The ROACTIV bit (REFOCONL[8]) indicates that the module is active; it can be cleared by disabling the module (setting ROEN to '0'). The user must not change the reference clock source, or adjust the divider when the ROACTIV bit indicates that the module is active. To avoid glitches, the user should not disable the module until the ROACTIV bit is '1'.


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## 9.8 Oscillator Configuration

The oscillator system has both Configuration registers and SFRs to configure, control and monitor the system. The FOSCSEL and FOSC Configuration registers (Register 30-4 and Register 30-5, respectively) are used for initial setup.

Table 9-1 lists the configuration settings that select the device's oscillator source and operating mode at a Power-on Reset (POR).

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

| Oscillator Source | Oscillator Mode | FNOSC[2:0] Value | POSCMD[1:0] Value |
|---|---|---|---|
| S0 | Fast RC Oscillator (FRC)(1) | 000 | xx |
| S1 | Fast RC Oscillator with PLL (FRCPLL)(1) | 001 | xx |
| S2 | Primary Oscillator (EC)(1) | 010 | 00 |
| S2 | Primary Oscillator (XT) | 010 | 01 |
| S2 | Primary Oscillator (HS) | 010 | 10 |
| S3 | Primary Oscillator with PLL (ECPLL)(1) | 011 | 00 |
| S3 | Primary Oscillator with PLL (XTPLL) | 011 | 01 |
| S3 | Primary Oscillator with PLL (HSPLL) | 011 | 10 |
| S4 | Reserved | 100 | xx |
| S5 | Low-Power RC Oscillator (LPRC)(1) | 101 | xx |
| S6 | Backup FRC (BFRC)(1) | 110 | xx |
| S7 | Fast RC Oscillator with ÷ N Divider (FRCDIVN)(1,2) | 111 | xx |

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

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

## 9.9 OSCCON Unlock Sequence

The OSCCON register is protected against unintended writes through a lock mechanism. The upper and lower bytes of OSCCON have their own unlock sequence, and both must be used when writing to both bytes of the register. Before OSCCON can be written to, the following unlock sequence must be used:

1. Execute the unlock sequence for the OSCCON high byte.
   In two back-to-back instructions:
   - Write 0x78 to OSCCON[15:8]
   - Write 0x9A to OSCCON[15:8]
2. In the instruction immediately following the unlock sequence, the OSCCON[15:8] bits can be modified.
3. Execute the unlock sequence for the OSCCON low byte.
   In two back-to-back instructions:
   - Write 0x46 to OSCCON[7:0]
   - Write 0x57 to OSCCON[7:0]
4. In the instruction immediately following the unlock sequence, the OSCCON[7:0] bits can be modified.

**Note:** MPLAB® XC16 provides a built-in C language function, including the unlocking sequence to modify high and low bytes in the OSCCON register:

```
__builtin_write_OSCCONH(value)
__builtin_write_OSCCONL(value)
```

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## 9.10 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 | U-0 | R-0 | U-0 | R-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CLKLOCK | — | 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 (FRCDIVN)
110 = Backup FRC (BFRC)
101 = Low-Power RC Oscillator (LPRC)
100 = Reserved – default to FRC
011 = Primary Oscillator (XT, HS, EC) with PLL (XTPLL, HSPLL, ECPLL)
010 = Primary Oscillator (XT, HS, EC)
001 = Fast RC Oscillator (FRC) with PLL (FRCPLL)
000 = Fast RC Oscillator (FRC)

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

bit 10-8 **NOSC[2:0]:** New Oscillator Selection bits
111 = Fast RC Oscillator (FRC) with Divide-by-n (FRCDIVN)
110 = Backup FRC (BFRC)
101 = Low-Power RC Oscillator (LPRC)
100 = Reserved – default to FRC
011 = Primary Oscillator (XT, HS, EC) with PLL (XTPLL, HSPLL, ECPLL)
010 = Primary Oscillator (XT, HS, EC)
001 = Fast RC Oscillator (FRC) with 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 **Unimplemented:** Read as '0'

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

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

**Note 1:** Writes to this register require an unlock sequence (see **Section 9.9 "OSCCON 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.


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

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 (see **Section 9.9 "OSCCON 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.

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**REGISTER 9-2: CLKDIV: CLOCK DIVIDER 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 |

| U-0 | U-0 | r-0 | r-0 | R/W-0 | R/W-0 | R/W-0 | R/W-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | PLLPRE[3:0](4) | | | |
| 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 **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
111 = FP divided by 128
110 = FP divided by 64
101 = FP divided by 32
100 = FP divided by 16
011 = FP divided by 8 (default)
010 = FP divided by 4
001 = FP divided by 2
000 = FP divided by 1

bit 11 **DOZEN:** Doze Mode Enable bit
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 **Unimplemented:** Read as '0'

bit 5-4 **Reserved:** 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.

**4:** PLLPRE[3:0] may be updated while the PLL is operating, but the VCO may overshoot.


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

bit 3-0 **PLLPRE[3:0]:** PLL Phase Detector Input Divider Select bits (also denoted as 'N1', PLL prescaler)
11111 = Reserved
...
1001 = Reserved
1000 = Input divided by 8
0111 = Input divided by 7
0110 = Input divided by 6
0101 = Input divided by 5
0100 = Input divided by 4
0011 = Input divided by 3
0010 = Input divided by 2
0001 = Input divided by 1 (power-on default selection)
0000 = Reserved

**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.

**4:** PLLPRE[3:0] may be updated while the PLL is operating, but the VCO may overshoot.

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

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

| R/W-1 | R/W-0 | R/W-0 | R/W-1 | R/W-0 | R/W-1 | R/W-1 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PLLFBDIV[7:0] | | | | | | | |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11-8 **Reserved:** Maintain as '0'

bit 7-0 **PLLFBDIV[7:0]:** PLL Feedback Divider bits (also denoted as 'M', PLL multiplier)

11111111 = Reserved
...
11001000 = 200 Maximum(1)
...
10010110 = 150 (default)
...
00010000 = 16 Minimum(1)
...
00000010 = Reserved
00000001 = Reserved
00000000 = Reserved

**Note 1:** The allowed range is 16-200 (decimal). The rest of the values are reserved and should be avoided. The default power-on feedback divider is 150 (decimal) with an 8 MHz FRC input clock. The VCO frequency is 1.2 GHz.


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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 +1.45%
011110 = Center frequency + 1.40%
. . .
000001 = Center frequency + 0.047%
000000 = Center frequency (8.00 MHz nominal)
111111 = Center frequency – 0.047%
. . .
100001 = Center frequency – 1.45%
100000 = Minimum frequency deviation of -1.50%

**REGISTER 9-5: PLLDIV: PLL OUTPUT DIVIDER REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | VCODIV[1:0] | |
| bit 15 | | | | | | | bit 8 |

| U-0 | R/W-0 | R/W-1 | R/W-1 | U-0 | R/W-0 | R/W-0 | R/W-1 |
|---|---|---|---|---|---|---|---|
| — | POST1DIV2(1,2) | POST1DIV1(1,2) | POST1DIV0(1,2) | — | POST2DIV2(1,2) | POST2DIV1(1,2) | POST2DIV0(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 15-10 **Unimplemented:** Read as '0'

bit 9-8 **VCODIV[1:0]:** PLL VCO Output Divider Select bits
11 = FVCO
10 = FVCO/2
01 = FVCO/3
00 = FVCO/4

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

bit 6-4 **POST1DIV[2:0]:** PLL Output Divider #1 Ratio bits
POST1DIV[2:0] can have a valid value, from 1 to 7 (the POST1DIVx value should be greater than or equal to the POST2DIVx value). The POST1DIVx divider is designed to operate at higher clock rates than the POST2DIVx divider.

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

bit 2-0 **POST2DIV[2:0]:** PLL Output Divider #2 Ratio bits
POST2DIV[2:0] can have a valid value, from 1 to 7 (the POST2DIVx value should be less than or equal to the POST1DIVx value). The POST1DIVx divider is designed to operate at higher clock rates than the POST2DIVx divider.

**Note 1:** The POST1DIVx and POST2DIVx divider values must not be changed while the PLL is operating.
**2:** The default values for POST1DIVx and POST2DIVx are 4 and 1, respectively, yielding a 150 MHz system source clock.


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**REGISTER 9-6: REFOCONL: REFERENCE CLOCK CONTROL LOW REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | HC/R/W-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| ROEN | — | ROSIDL | ROOUT | ROSLP | — | ROSWEN | ROACTIV |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | ROSEL[3:0] | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware Clearable bit | 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 **ROEN:** Reference Clock Enable bit
1 = Reference Oscillator is enabled on the REFCLKO pin
0 = Reference Oscillator is disabled

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

bit 13 **ROSIDL:** Reference Clock Stop in Idle bit
1 = Reference Oscillator is disabled in Idle mode
0 = Reference Oscillator continues to run in Idle mode

bit 12 **ROOUT:** Reference Clock Output Enable bit
1 = Reference clock external output is enabled and available on the REFCLKO pin
0 = Reference clock external output is disabled

bit 11 **ROSLP:** Reference Clock Stop in Sleep bit
1 = Reference Oscillator continues to run in Sleep modes
0 = Reference Oscillator is disabled in Sleep modes

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

bit 9 **ROSWEN:** Reference Clock Switch Request and Status bit
1 = Clock divider change (requested by changes to RODIVx) is requested or is in progress (set in software, cleared by hardware upon completion)
0 = Clock divider change has completed or is not pending

bit 8 **ROACTIV:** Reference Clock Status bit
1 = Reference clock is active; do not change clock source
0 = Reference clock is stopped; clock source and configuration may be safely changed

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

bit 3-0 **ROSEL[3:0]:** Reference Clock Source Select bits
1111 = Reserved
... = Reserved
1000 = Reserved
0111 = REFI pin
0110 = FVCO/4
0101 = BFRC
0100 = LPRC
0011 = FRC
0010 = Primary Oscillator
0001 = Peripheral Clock (FP)
0000 = System clock (FOSC)

**REGISTER 9-7: REFOCONH: REFERENCE CLOCK CONTROL HIGH REGISTER**

| U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | RODIV[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 |
|---|---|---|---|---|---|---|---|
| RODIV[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 **RODIV[14:0]:** Reference Clock Integer Divider Select bits
Divider for the selected input clock source is two times the selected value.
111 1111 1111 1111 = Base clock value divided by 65,534 (2 * 7FFFh)
111 1111 1111 1110 = Base clock value divided by 65,532 (2 * 7FFEh)
111 1111 1111 1101 = Base clock value divided by 65,530 (2 * 7FFDh)
...
000 0000 0000 0010 = Base clock value divided by 4 (2 * 2)
000 0000 0000 0001 = Base clock value divided by 2 (2 * 1)
000 0000 0000 0000 = Base clock value

**REGISTER 9-8: REFOTRIMH: REFERENCE OSCILLATOR TRIM 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 |
|---|---|---|---|---|---|---|---|
| ROTRIM[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| ROTRIM | — | — | — | — | — | — | — |
| 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 **ROTRIM[8:0]:** REFO Trim bits
These bits provide a fractional additive to the RODIV[14:0] value for the 1/2 period of the REFO clock.
000000000 = 0/512 (0.0 divisor added to the RODIV[14:0] value)
000000001 = 1/512 (0.001953125 divisor added to the RODIV[14:0] value)
000000010 = 2/512 (0.00390625 divisor added to the RODIV[14:0] value)
...
100000000 = 256/512 (0.5000 divisor added to the RODIV[14:0] value)
...
111111110 = 510/512 (0.99609375 divisor added to the RODIV[14:0] value)
111111111 = 511/512 (0.998046875 divisor added to the RODIV[14:0] value)

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


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## 10.0 DIRECT MEMORY ACCESS (DMA) CONTROLLER

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. For more information, refer to **"Direct Memory Access Controller (DMA)"** (www.microchip.com/DS30009742).

The Direct Memory Access Controller (DMA) is designed to service high data throughput peripherals operating on the SFR bus, allowing them to access data memory directly and alleviating the need for CPU-intensive management. By allowing these data-intensive peripherals to share their own data path, the main data bus is also offloaded, resulting in additional power savings.

The DMA Controller functions both as a peripheral and a direct extension of the CPU. It is located on the microcontroller data bus, between the CPU and DMA-enabled peripherals, with direct access to SRAM. This partitions the SFR bus into two buses, allowing the DMA Controller access to the DMA-capable peripherals located on the new DMA SFR bus. The controller serves as an Initiator device on the DMA SFR bus, controlling data flow from DMA-capable peripherals.

The controller also monitors CPU instruction processing directly, allowing it to be aware of when the CPU requires access to peripherals on the DMA bus and automatically relinquishing control to the CPU as needed. This increases the effective bandwidth for handling data without DMA operations causing a processor stall. This makes the controller essentially transparent to the user.

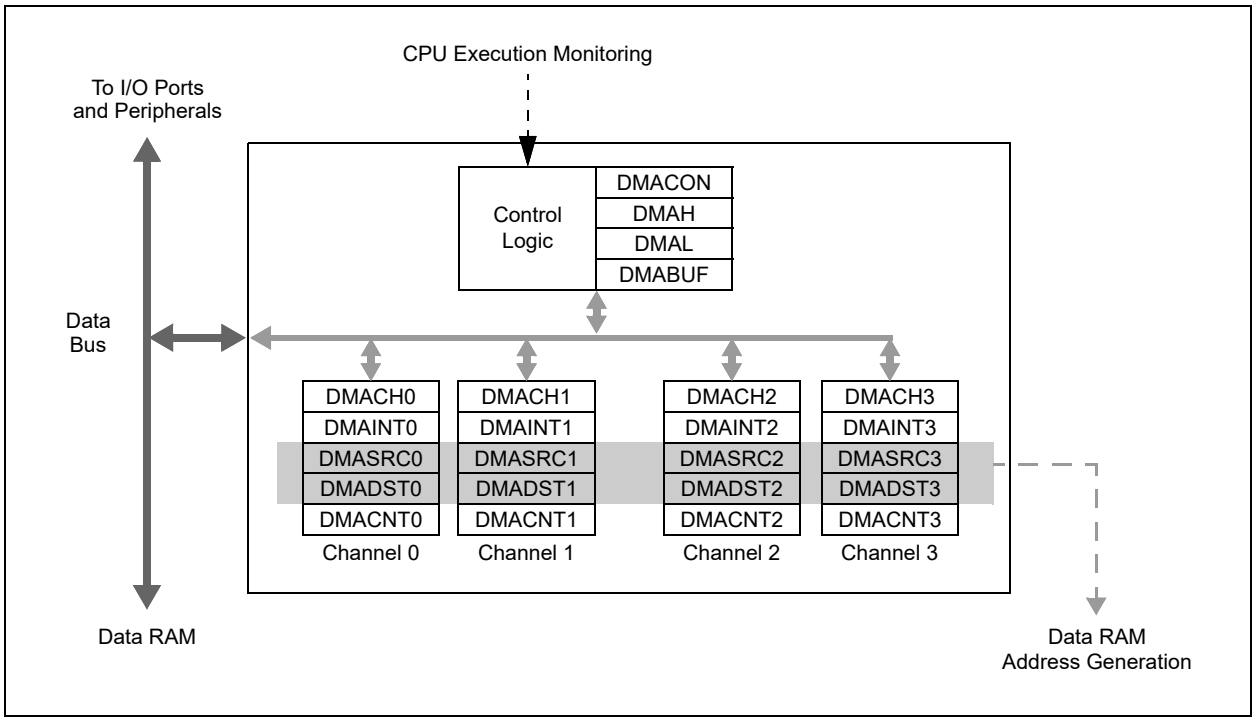
The DMA Controller has these features:

- Four Independently Programmable Channels
- Concurrent Operation with the CPU (no DMA caused Wait states)
- DMA Bus Arbitration
- Five Programmable Address Modes
- Four Programmable Transfer Modes
- Four Flexible Internal Data Transfer modes
- Byte or Word Support for Data Transfer
- 16-Bit Source and Destination Address Register for each Channel, Dynamically Updated and Reloadable
- 16-Bit Transaction Count Register, Dynamically Updated and Reloadable
- Upper and Lower Address Limit Registers
- Counter Half-Full Level Interrupt
- Software Triggered Transfer
- Null Write Mode for Symmetric Buffer Operations

A simplified block diagram of the DMA Controller is shown in Figure 10-1.

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**FIGURE 10-1: DMA FUNCTIONAL BLOCK DIAGRAM**





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## 10.1 Summary of DMA Operations

The DMA Controller is capable of moving data between addresses according to a number of different parameters. Each of these parameters can be independently configured for any transaction. In addition, any or all of the DMA channels can independently perform a different transaction at the same time. Transactions are classified by these parameters:

- Source and Destination (SFRs and data RAM)
- Data Size (byte or word)
- Trigger Source
- Transfer Mode (One-Shot, Repeated or Continuous)
- Addressing Modes (Fixed Address or Address Blocks with or without Address Increment/Decrement)

In addition, the DMA Controller provides channel priority arbitration for all channels.

### 10.1.1 SOURCE AND DESTINATION

Using the DMA Controller, data may be moved between any two addresses in the Data Space. The SFR space (0000h to 0FFFh) or the data RAM space (1000h to 2FFFh) can serve as either the source or the destination. Data can be moved between these areas in either direction or between addresses in either area. The four different combinations are shown in Figure 10-2.

If it is necessary to protect areas of data RAM, the DMA Controller allows the user to set upper and lower address boundaries for operations in the Data Space above the SFR space. The boundaries are set by the DMAH and DMAL Limit registers. If a DMA channel attempts an operation outside of the address boundaries, the transaction is terminated and an interrupt is generated.

### 10.1.2 DATA SIZE

The DMA Controller can handle both 8-bit and 16-bit transactions. Size is user-selectable using the SIZE bit (DMACHn[1]). By default, each channel is configured for word-sized transactions. When byte-sized transactions are chosen, the LSB of the source and/or destination address determines if the data represent the upper or lower byte of the data RAM location.

### 10.1.3 TRIGGER SOURCE

The DMA Controller can use 82 of the device's interrupt sources to initiate a transaction. The DMA trigger sources occur in reverse order from their natural interrupt priority and are shown in Table 10-1.

Since the source and destination addresses for any transaction can be programmed independently of the trigger source, the DMA Controller can use any trigger to perform an operation on any peripheral. This also allows DMA channels to be cascaded to perform more complex transfer operations.

### 10.1.4 TRANSFER MODE

The DMA Controller supports four types of data transfers, based on the volume of data to be moved for each trigger.

- One-Shot: A single transaction occurs for each trigger.
- Continuous: A series of back-to-back transactions occur for each trigger; the number of transactions is determined by the DMACNTn transaction counter.
- Repeated One-Shot: A single transaction is performed repeatedly, once per trigger, until the DMA channel is disabled.
- Repeated Continuous: A series of transactions are performed repeatedly, one cycle per trigger, until the DMA channel is disabled.

All transfer modes allow the option to have the source and destination addresses, and counter value automatically reloaded after the completion of a transaction.

### 10.1.5 ADDRESSING MODES

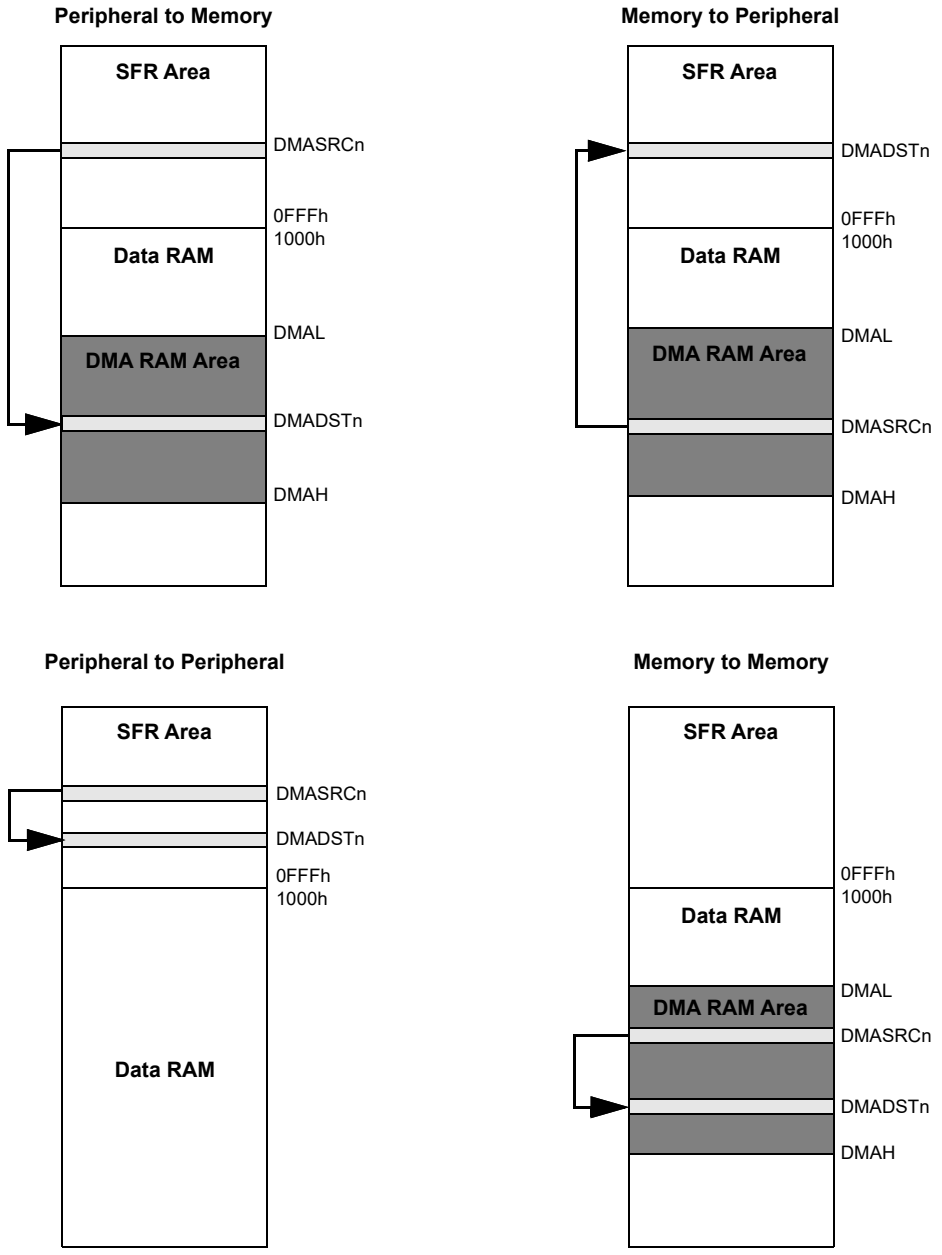
The DMA Controller also supports transfers between single addresses or address ranges. The four basic options are:

- Fixed-to-Fixed: Between two constant addresses
- Fixed-to-Block: From a constant source address to a range of destination addresses
- Block-to-Fixed: From a range of source addresses to a single, constant destination address
- Block-to-Block: From a range of source addresses to a range of destination addresses

The option to select auto-increment or auto-decrement of source and/or destination addresses is available for Block Addressing modes.

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**FIGURE 10-2: TYPES OF DMA DATA TRANSFERS**




**Note:** Relative sizes of memory areas are not shown to scale.


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#### 10.1.6 CHANNEL PRIORITY

Each DMA channel functions independently of the others, but also competes with the others for access to the data and DMA buses. When access collisions occur, the DMA Controller arbitrates between the channels using a user-selectable priority scheme. Two schemes are available:

- Round Robin: When two or more channels collide, the lower numbered channel receives priority on the first collision. On subsequent collisions, the higher numbered channels each receive priority based on their channel number.
- Fixed: When two or more channels collide, the lowest numbered channel always receives priority, regardless of past history; however, any channel being actively processed is not available for an immediate retrigger. If a higher priority channel is continually requesting service, it will be scheduled for service after the next lower priority channel with a pending request.

## 10.2 Typical Setup

To set up a DMA channel for a basic data transfer:

1. Enable the DMA Controller (DMAEN = 1) and select an appropriate channel priority scheme by setting or clearing PRSSEL.
2. Program DMAH and DMAL with appropriate upper and lower address boundaries for data RAM operations.
3. Select the DMA channel to be used and disable its operation (CHEN = 0).
4. Program the appropriate source and destination addresses for the transaction into the channel's DMASRCn and DMADSTn registers.
5. Program the DMACNTn register for the number of triggers per transfer (One-Shot or Continuous modes) or the number of words (bytes) to be transferred (Repeated modes).
6. Set or clear the SIZE bit to select the data size.
7. Program the TRMODE[1:0] bits to select the Data Transfer mode.
8. Program the SAMODE[1:0] and DAMODE[1:0] bits to select the Addressing mode.
9. Enable the DMA channel by setting CHEN.
10. Enable the trigger source interrupt.

## 10.3 Peripheral Module Disable

The channels of the DMA Controller can be individually powered down using the Peripheral Module Disable (PMD) registers.

## 10.4 Registers

The DMA Controller uses a number of registers to control its operation. The number of registers depend on the number of channels implemented for a particular device.

There are always four module-level registers (one control and three buffer/address):

- DMACON: DMA Engine Control register (Register 10-1)
- DMAH and DMAL: DMA High and Low Address Limit registers
- DMABUF: DMA Transfer Data buffer

Each of the DMA channels implements five registers (two control and three buffer/address):

- DMACHn: DMA Channel n Control register (Register 10-2)
- DMAINTn: DMA Channel n Interrupt register (Register 10-3)
- DMASRCn: DMA Data Source Address for Channel n register
- DMADSTn: DMA Data Destination Address for Channel n register
- DMACNTn: DMA Transaction Counter for Channel n register

For dsPIC33CDVL64MC106 devices, there are a total of 24 registers.

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**REGISTER 10-1: DMACON: DMA ENGINE CONTROL REGISTER**

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

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | PRSSEL |
| 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 **DMAEN:** DMA Module Enable bit
1 = Enables module
0 = Disables module and terminates all active DMA operation(s)

bit 14-1 **Unimplemented:** Read as '0'

bit 0 **PRSSEL:** Channel Priority Scheme Selection bit
1 = Round robin scheme
0 = Fixed priority scheme


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**REGISTER 10-2: DMACHn: DMA CHANNEL n CONTROL REGISTER**

| U-0 | U-0 | U-0 | r-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | NULLW | RELOAD(1) | CHREQ(3) |
| 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 |
|---|---|---|---|---|---|---|---|
| SAMODE1 | SAMODE0 | DAMODE1 | DAMODE0 | TRMODE1 | TRMODE0 | SIZE | CHEN |
| 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 15-13 **Unimplemented:** Read as '0'

bit 12 **Reserved:** Maintain as '0'

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

bit 10 **NULLW:** Null Write Mode bit
1 = A dummy write is initiated to DMASRCn for every write to DMADSTn
0 = No dummy write is initiated

bit 9 **RELOAD:** Address and Count Reload bit
1 = DMASRCn, DMADSTn and DMACNTn registers are reloaded to their previous values upon the start of the next operation
0 = DMASRCn, DMADSTn and DMACNTn are not reloaded on the start of the next operation(2)

bit 8 **CHREQ:** DMA Channel Software Request bit
1 = A DMA request is initiated by software; automatically cleared upon completion of a DMA transfer
0 = No DMA request is pending

bit 7-6 **SAMODE[1:0]:** Source Address Mode Selection bits
11 = Reserved
10 = DMASRCn is decremented based on the SIZE bit after a transfer completion
01 = DMASRCn is incremented based on the SIZE bit after a transfer completion
00 = DMASRCn remains unchanged after a transfer completion

bit 5-4 **DAMODE[1:0]:** Destination Address Mode Selection bits
11 = Reserved
10 = DMADSTn is decremented based on the SIZE bit after a transfer completion
01 = DMADSTn is incremented based on the SIZE bit after a transfer completion
00 = DMADSTn remains unchanged after a transfer completion

bit 3-2 **TRMODE[1:0]:** Transfer Mode Selection bits
11 = Repeated Continuous
10 = Continuous
01 = Repeated One-Shot
00 = One-Shot

bit 1 **SIZE:** Data Size Selection bit
1 = Byte (8-bit)
0 = Word (16-bit)

bit 0 **CHEN:** DMA Channel Enable bit
1 = The corresponding channel is enabled
0 = The corresponding channel is disabled

**Note 1:** Only the original DMACNTn is required to be stored to recover the original DMASRCn and DMADSTn values.
**2:** DMACNTn will always be reloaded in Repeated mode transfers, regardless of the state of the RELOAD bit.
**3:** The number of transfers executed while CHREQ is set depends on the configuration of TRMODE[1:0].

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**REGISTER 10-3: DMAINTn: DMA CHANNEL n INTERRUPT REGISTER**

| R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| DBUFWF(1) | CHSEL6 | CHSEL5 | CHSEL4 | CHSEL3 | CHSEL2 | CHSEL1 | CHSEL0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| HIGHIF(1,2) | LOWIF(1,2) | DONEIF(1) | HALFIF(1) | OVRUNIF(1) | — | — | HALFEN |
| 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 **DBUFWF:** DMA Buffered Data Write Flag bit
- 1 = The content of the DMA buffer has not been written to the location specified in DMADSTn or DMASRCn in Null Write mode
- 0 = The content of the DMA buffer has been written to the location specified in DMADSTn or DMASRCn in Null Write mode

bit 14-8 **CHSEL[6:0]:** DMA Channel Trigger Selection bits

See Table 10-1 for a complete list.

bit 7 **HIGHIF:** DMA High Address Limit Interrupt Flag bit
- 1 = The DMA channel has attempted to access an address higher than DMAH or the upper limit of the data RAM space
- 0 = The DMA channel has not invoked the high address limit interrupt

bit 6 **LOWIF:** DMA Low Address Limit Interrupt Flag bit
- 1 = The DMA channel has attempted to access the DMA SFR address lower than DMAL, but above the SFR range (07FFh)
- 0 = The DMA channel has not invoked the low address limit interrupt

bit 5 **DONEIF:** DMA Complete Operation Interrupt Flag bit

If CHEN = 1:
- 1 = The previous DMA session has ended with completion
- 0 = The current DMA session has not yet completed

If CHEN = 0:
- 1 = The previous DMA session has ended with completion
- 0 = The previous DMA session has ended without completion

bit 4 **HALFIF:** DMA 50% Watermark Level Interrupt Flag bit
- 1 = DMACNTn has reached the halfway point to 0000h
- 0 = DMACNTn has not reached the halfway point

bit 3 **OVRUNIF:** DMA Channel Overrun Flag bit
- 1 = The DMA channel is triggered while it is still completing the operation based on the previous trigger
- 0 = The overrun condition has not occurred

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

bit 0 **HALFEN:** Halfway Completion Watermark bit
- 1 = Interrupts are invoked when DMACNTn has reached its halfway point and at completion
- 0 = An interrupt is invoked only at the completion of the transfer

**Note 1:** Setting these flags in software does not generate an interrupt.

**2:** Testing for address limit violations (DMASRCn or DMADSTn is either greater than DMAH or less than DMAL) is NOT done before the actual access.


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**TABLE 10-1: DMA CHANNEL TRIGGER SOURCES**

| CHSEL[6:0] | | Trigger (Interrupt) | CHSEL[6:0] | | Trigger (Interrupt) | CHSEL[6:0] | | Trigger (Interrupt) |
|---|---|---|---|---|---|---|---|---|
| 0 | 00h | INT0 – External Interrupt 0 | 33 | 21h | (Reserved, do not use) | 66 | 42h | AD1FLTR3 – Oversample Filter 3 |
| 1 | 01h | SCCP1 IC/OC | 34 | 22h | | 67 | 43h | AD1FLTR4 – Oversample Filter 4 |
| 2 | 02h | SPI1 Receiver | 35 | 23h | | 68 | 44h | CLC1 Positive Edge Interrupt |
| 3 | 03h | SPI1 Transmitter | 36 | 24h | PWM Event C | 69 | 45h | CLC2 Positive Edge Interrupt |
| 4 | 04h | UART1 Receiver | 37 | 25h | SENT1 TX/RX | 70 | 46h | SPI1 – Fault Interrupt |
| 5 | 05h | UART1 Transmitter | 38 | 26h | (Reserved, do not use) | 71 | 47h | SPI2 – Fault Interrupt |
| 6 | 06h | ECC Single-Bit Error | 39 | 27h | ADC Common Interrupt | 72 | 48h | (Reserved, do not use) |
| 7 | 07h | NVM Write Complete | 40 | 28h | ADC Done AN0 | . . . | . . . | |
| 8 | 08h | INT1 – External Interrupt 1 | 41 | 29h | ADC Done AN1 | 86 | 56h | |
| 9 | 09h | SI2C1 – I2C1 Client Event | 42 | 2Ah | ADC Done AN2 | 87 | 57h | PWM Event D |
| 10 | 0Ah | MI2C1 – I2C1 Host Event | 43 | 2Bh | ADC Done AN3 | 88 | 58h | PWM Event E |
| 11 | 0Bh | INT2 – External Interrupt 2 | 44 | 2Ch | ADC Done AN4 | 89 | 59h | PWM Event F |
| 12 | 0Ch | SCCP2 Interrupt | 45 | 2Dh | ADC Done AN5 | 90 | 5Ah | (Reserved, do not use) |
| 13 | 0Dh | INT3 – External Interrupt 3 | 46 | 2Eh | ADC Done AN6 | 91 | 5Bh | |
| 14 | 0Eh | UART2 Receiver | 47 | 2Fh | ADC Done AN7 | 92 | 5Ch | |
| 15 | 0Fh | UART2 Transmitter | 48 | 30h | ADC Done AN8 | 93 | 5Dh | |
| 16 | 10h | SPI2 Receiver | 49 | 31h | ADC Done AN9 | 94 | 5Eh | |
| 17 | 11h | SPI2 Transmitter | 50 | 32h | ADC Done AN10 | 95 | 5Fh | |
| 18 | 12h | SCCP3 Interrupt | 51 | 33h | ADC Done AN11 | 96 | 60h | CLC3 Positive Edge Interrupt |
| 19 | 13h | (Reserved, do not use) | 52 | 34h | ADC Done AN12 | 97 | 61h | CLC4 Positive Edge Interrupt |
| 20 | 14h | | 53 | 35h | ADC Done AN13 | 98 | 62h | (Reserved, do not use) |
| 21 | 15h | SCCP4 Interrupt | 54 | 36h | ADC Done AN14 | 99 | 63h | |
| 22 | 16h | (Reserved, do not use) | 55 | 37h | ADC Done AN15 | 100 | 64h | |
| 23 | 17h | | 56 | 38h | ADC Done AN16 | 101 | 65h | |
| 24 | 18h | CRC Generator Interrupt | 57 | 39h | ADC Done AN17 | 102 | 66h | |
| 25 | 19h | PWM Event A | 58 | 3Ah | (Reserved, do not use) | 103 | 67h | |
| 26 | 1Ah | (Reserved, do not use) | 59 | 3Bh | | 104 | 68h | UART3 Receiver |
| 27 | 1Bh | PWM Event B | 60 | 3Ch | | 105 | 69h | UART3 Transmitter |
| 28 | 1Ch | PWM Generator 1 | 61 | 3Dh | | 106 | 6Ah | (Reserved, do not use) |
| 29 | 1Dh | PWM Generator 2 | 62 | 3Eh | | . . . | . . . | |
| 30 | 1Eh | PWM Generator 3 | 63 | 3Fh | | 127 | 7Fh | |
| 31 | 1Fh | PWM Generator 4 | 64 | 40h | AD1FLTR1 – Oversample Filter 1 | | | |
| 32 | 20h | (Reserved, do not use) | 65 | 41h | AD1FLTR2 – Oversample Filter 2 | | | |

**NOTES:**


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## 11.0 HIGH-RESOLUTION PWM WITH FINE EDGE PLACEMENT

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"High-Resolution PWM with Fine Edge Placement"** (www.microchip.com/DS70005320).

The High-Resolution PWM (HRPWM) module is a Pulse-Width Modulation (PWM) module to support both motor control and power supply applications. This flexible module provides features to support many types of Motor Control (MC) and Power Control (PC) applications, including:

- AC-to-DC Converters
- DC-to-DC Converters
- AC and DC Motors: BLDC, PMSM, ACIM, SRM, etc.
- Inverters
- Battery Chargers
- Digital Lighting
- Power Factor Correction (PFC)

**Note:** The Fine Edge Placement feature is not available in this family of devices.

### 11.1 Features

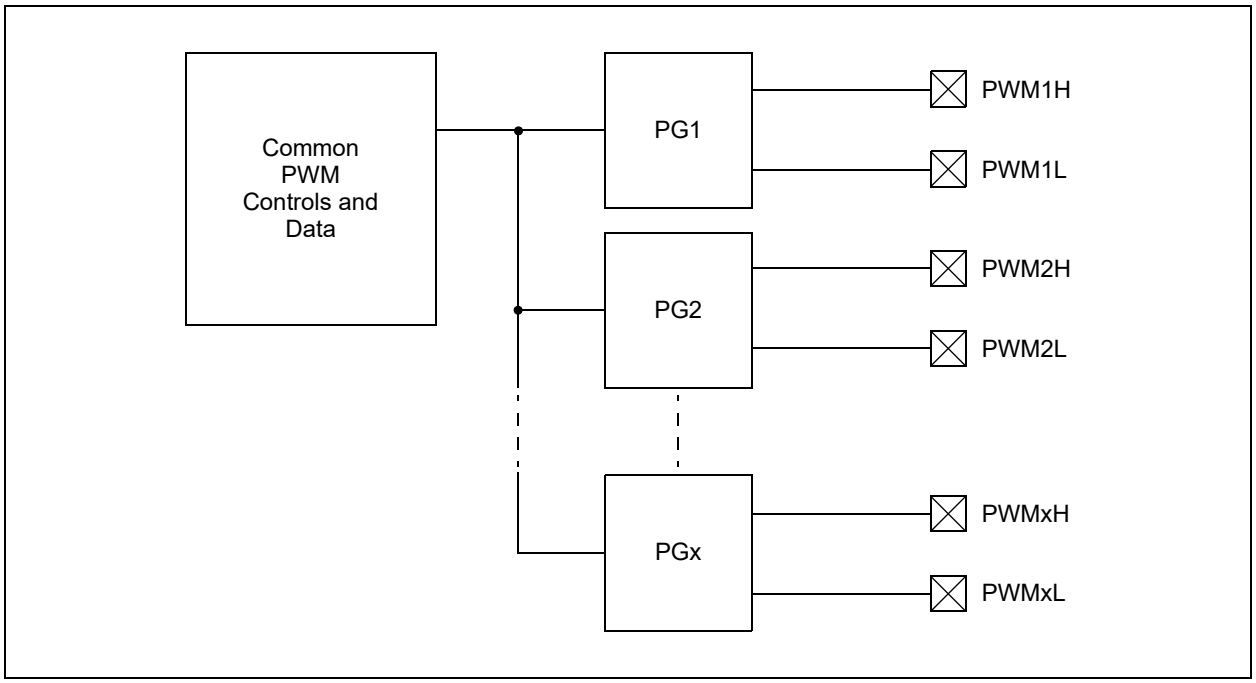
- Four Independent PWM Generators, each with Dual Outputs
- Operating Modes:
  - Independent Edge mode
  - Variable Phase PWM mode
  - Center-Aligned mode
  - Double Update Center-Aligned mode
  - Dual Edge Center-Aligned mode
  - Dual PWM mode
- Output Modes:
  - Complementary
  - Independent
  - Push-Pull
- Dead-Time Generator
- Leading-Edge Blanking (LEB)
- Output Override for Fault Handling
- Flexible Period/Duty Cycle Updating Options
- Programmable Control Inputs (PCI)
- Advanced Triggering Options
- Six Combinatorial Logic Outputs
- Six PWM Event Outputs

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## 11.2 Architecture Overview

The PWM module consists of a common set of controls and features and multiple instantiations of PWM Generators (PGs). Each PWM Generator can be independently configured or multiple PWM Generators can be used to achieve complex multiphase systems. PWM Generators can also be used to implement sophisticated triggering, protection and logic functions. A high-level block diagram is shown in Figure 11-1.

**FIGURE 11-1: PWM HIGH-LEVEL BLOCK DIAGRAM**




## 11.3 PWM4H Output on PPS

All devices support the capability to output a PWM4H signal via PPS on to any RPn pin. If PWM4H PPS output functions are used on 48-pin devices that also have a fixed RP65/PWM4H/RD1 pin, the output signal will be present on both the dedicated and RPn pins. The PWM4L/H Output Port Enable bits, PENH and PENL (PG4IOCONH[3:2]), control both dedicated and PPS pins together; it is not possible to disable the dedicated pin and use only PPS.

Given the natural priority of the RPn functions above that of the PWM, it is possible to use the PPS output functions on the dedicated RP65/PWM4H/RD1 pin while the PWM4H signal is routed to other pins via PPS.

## 11.4 Write Restrictions

The LOCK bit (PCLKCON[8]) may be set in software to block writes to certain registers. For more information, refer to **"High-Resolution PWM with Fine Edge Placement"** (www.microchip.com/DS70005320).

The following lock/unlock sequence is required to set or clear the LOCK bit:

1. Write 0x55 to NVMKEY.
2. Write 0xAA to NVMKEY.
3. Clear (or set) the LOCK bit (PCLKCON[8]) as a single operation.

In general, modifications to configuration controls should not be done while the module is running, as indicated by the ON bit (PGxCONL[15]) being set.


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## 11.5 Control Registers

There are two categories of Special Function Registers (SFRs) used to control the operation of the PWM module:

- Common, shared by all PWM Generators
- PWM Generator-specific

An ‘x’ in the register name denotes an instance of a PWM Generator.

A ‘y’ in the register name denotes an instance of the common function.

**REGISTER 11-1: PCLKCON: PWM CLOCK CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | LOCK(1) |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | DIVSEL1 | DIVSEL0 | — | — | MCLKSEL1(2) | MCLKSEL0(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 15-9 **Unimplemented:** Read as ‘0’

bit 8 **LOCK:** Lock bit
1 = Write-protected registers and bits are locked
0 = Write-protected registers and bits are unlocked

bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-4 **DIVSEL[1:0]:** PWM Clock Divider Selection bits
11 = Divide ratio is 1:16
10 = Divide ratio is 1:8
01 = Divide ratio is 1:4
00 = Divide ratio is 1:2

bit 3-2 **Unimplemented:** Read as ‘0’

bit 1-0 **MCLKSEL[1:0]:** PWM Host Clock Selection bits
11 = FVCO/3
10 = FPLLO – Primary PLL post-divider output
01 = FVCO/2
00 = FOSC

**Note 1:** The LOCK bit is protected against an accidental write. To set this bit, 0x55 and 0xAA values must be written sequentially into the NVMKEY register (see **Section 11.4 “Write Restrictions”**).

**2:** Changing the MCLKSEL[1:0] bits while ON (PGxCONL[15]) = 1 is not recommended.

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**REGISTER 11-2: FSCL: FREQUENCY SCALE 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 |
|---|---|---|---|---|---|---|---|
| FSCL[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 |
|---|---|---|---|---|---|---|---|
| FSCL[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 **FSCL[15:0]:** Frequency Scale Register bits
The value in this register is added to the frequency scaling accumulator at each PWM clock. When the accumulated value exceeds the value of FSMINPER, a clock pulse is produced.

**REGISTER 11-3: FSMINPER: FREQUENCY SCALING MINIMUM PERIOD 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 |
|---|---|---|---|---|---|---|---|
| FSMINPER[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 |
|---|---|---|---|---|---|---|---|
| FSMINPER[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 **FSMINPER[15:0]:** Frequency Scaling Minimum Period Register bits
This register holds the minimum clock period (maximum clock frequency) that can be produced by the frequency scaling circuit.


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**REGISTER 11-4: MPHASE: HOST PHASE 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 |
|---|---|---|---|---|---|---|---|
| MPHASE[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 |
|---|---|---|---|---|---|---|---|
| MPHASE[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 **MPHASE[15:0]:** Host Phase Register bits
This register holds the phase offset value that can be shared by multiple PWM Generators.

**REGISTER 11-5: MDC: HOST DUTY CYCLE 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 |
|---|---|---|---|---|---|---|---|
| MDC[15:8](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 |
|---|---|---|---|---|---|---|---|
| MDC[7:0](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 15-0 **MDC[15:0]:** Host Duty Cycle Register bits
This register holds the duty cycle value that can be shared by multiple PWM Generators.

**Note 1:** Duty cycle values less than '0x0008' should not be used.

**REGISTER 11-6: MPER: HOST PERIOD 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 |
|---|---|---|---|---|---|---|---|
| MPER[15:8](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 |
|---|---|---|---|---|---|---|---|
| MPER[7:0](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 15-0 **MPER[15:0]:** Host Period Register bits
This register holds the period value that can be shared by multiple PWM Generators.

**Note 1:** Period values less than '0x0010' should not be used.


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**REGISTER 11-7: CMBTRIGL: COMBINATIONAL TRIGGER REGISTER 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | CTA4EN | CTA3EN | CTA2EN | CTA1EN |
| 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 **CTA4EN:** Enable Trigger Output from PWM Generator #4 as Source for Combinational Trigger A bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger A signal
0 = Disables

bit 2 **CTA3EN:** Enable Trigger Output from PWM Generator #3 as Source for Combinational Trigger A bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger A signal
0 = Disables

bit 1 **CTA2EN:** Enable Trigger Output from PWM Generator #2 as Source for Combinational Trigger A bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger A signal
0 = Disables

bit 0 **CTA1EN:** Enable Trigger Output from PWM Generator #1 as Source for Combinational Trigger A bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger A signal
0 = Disables

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**REGISTER 11-8: CMBTRIGH: COMBINATIONAL TRIGGER 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | CTB4EN | CTB3EN | CTB2EN | CTB1EN |
| 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 **CTB4EN:** Enable Trigger Output from PWM Generator #4 as Source for Combinational Trigger B bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger B signal
0 = Disables

bit 2 **CTB3EN:** Enable Trigger Output from PWM Generator #3 as Source for Combinational Trigger B bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger B signal
0 = Disables

bit 1 **CTB2EN:** Enable Trigger Output from PWM Generator #2 as Source for Combinational Trigger B bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger B signal
0 = Disables

bit 0 **CTB1EN:** Enable Trigger Output from PWM Generator #1 as Source for Combinational Trigger B bit
1 = Enables specified trigger signal to be OR'd into the Combinatorial Trigger B signal
0 = Disables


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**REGISTER 11-9: LOGCONy: COMBINATORIAL PWM LOGIC CONTROL REGISTER y(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 |
|---|---|---|---|---|---|---|---|
| PWMS1y3(1) | PWMS1y2(1) | PWMS1y1(1) | PWMS1y0(1) | PWMS2y3(1) | PWMS2y2(1) | PWMS2y1(1) | PWMS2y0(1) |
| 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 |
|---|---|---|---|---|---|---|---|
| S1yPOL | S2yPOL | PWMLFy1 | PWMLFy0 | — | PWMLFyD2(3) | PWMLFyD1(3) | PWMLFyD0(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 15-12 **PWMS1y[3:0]:** Combinatorial PWM Logic Source #1 Selection bits
1111-1000 = Reserved
0111 = PWM4L
0110 = PWM4H
0101 = PWM3L
0100 = PWM3H
0011 = PWM2L
0010 = PWM2H
0001 = PWM1L
0000 = PWM1H

bit 11-8 **PWMS2y[3:0]:** Combinatorial PWM Logic Source #2 Selection bits
1111-1000 = Reserved
0111 = PWM4L
0110 = PWM4H
0101 = PWM3L
0100 = PWM3H
0011 = PWM2L
0010 = PWM2H
0001 = PWM1L
0000 = PWM1H

bit 7 **S1yPOL:** Combinatorial PWM Logic Source #1 Polarity bit
1 = Input is inverted
0 = Input is positive logic

bit 6 **S2yPOL:** Combinatorial PWM Logic Source #2 Polarity bit
1 = Input is inverted
0 = Input is positive logic

bit 5-4 **PWMLFy[1:0]:** Combinatorial PWM Logic Function Selection bits
11 = Reserved
10 = PWMS1y ^ PWMS2y (XOR)
01 = PWMS1y & PWMS2y (AND)
00 = PWMS1y | PWMS2y (OR)

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

**Note 1:** Logic function input will be connected to '0' if the PWM channel is not present.
**2:** 'y' denotes a common instance (A-F).
**3:** Instances of y = A, C, E of LOGCONy assign logic function output to the PWMxH pin. Instances of y = B, D, F of LOGCONy assign logic function to the PWMxL pin.

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**REGISTER 11-9: LOGCONy: COMBINATORIAL PWM LOGIC CONTROL REGISTER y(2) (CONTINUED)**

bit 2-0 **PWMLFyD[2:0]:** Combinatorial PWM Logic Destination Selection bits
111-100 = Reserved
011 = Logic function is assigned to PWM4H or PWM4L pin
010 = Logic function is assigned to PWM3H or PWM3L pin
001 = Logic function is assigned to PWM2H or PWM2L pin
000 = No assignment, combinatorial PWM logic function is disabled

**Note 1:** Logic function input will be connected to '0' if the PWM channel is not present.
**2:** 'y' denotes a common instance (A-F).
**3:** Instances of y = A, C, E of LOGCONy assign logic function output to the PWMxH pin. Instances of y = B, D, F of LOGCONy assign logic function to the PWMxL pin.


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**REGISTER 11-10: PWMEVTy: PWM EVENT OUTPUT CONTROL REGISTER y(5)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| EVTyOEN | EVTyPOL | EVTySTRD | EVTySYNC | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| EVTySEL3 | EVTySEL2 | EVTySEL1 | EVTySEL0 | — | EVTyPGS2(2) | EVTyPGS1(2) | EVTyPGS0(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 **EVTyOEN:** PWM Event Output Enable bit
1 = Event output signal is output on PWMEy pin
0 = Event output signal is internal only

bit 14 **EVTyPOL:** PWM Event Output Polarity bit
1 = Event output signal is active-low
0 = Event output signal is active-high

bit 13 **EVTySTRD:** PWM Event Output Stretch Disable bit
1 = Event output signal pulse width is not stretched
0 = Event output signal is stretched to eight PWM clock cycles minimum(1)

bit 12 **EVTySYNC:** PWM Event Output Sync bit
1 = Event output signal is synchronized to the system clock
0 = Event output is not synchronized to the system clock
Event output signal pulse will be two system clocks when this bit is set and EVTySTRD = 1.

bit 11-8 **Unimplemented:** Read as '0'

bit 7-4 **EVTySEL[3:0]:** PWM Event Selection bits
1111-1010 = Reserved
1001 = ADC Trigger 2 signal
1000 = ADC Trigger 1 signal
0111 = STEER signal (available in Push-Pull Output modes only)(4)
0110 = CAHALF signal (available in Center-Aligned modes only)(4)
0101 = PCI Fault active output signal
0100 = PCI current limit active output signal
0011 = PCI feed-forward active output signal
0010 = PCI Sync active output signal
0001 = PWM Generator output signal(3)
0000 = Source is selected by the PGTRGSEL[2:0] bits

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

**Note 1:** The event signal is stretched using peripheral_clk because different PWM Generators may be operating from different clock sources.
**2:** No event will be produced if the selected PWM Generator is not present.
**3:** This is the PWM Generator output signal prior to output mode logic and any output override logic.
**4:** This signal should be the PGx_clk domain signal prior to any synchronization into the system clock domain.
**5:** 'y' denotes a common instance (A-F).

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**REGISTER 11-10: PWMEVTy: PWM EVENT OUTPUT CONTROL REGISTER y(5) (CONTINUED)**

bit 2-0 **EVTyPGS[2:0]:** PWM Event Source Selection bits(2)
111-100 = Reserved
011 = PWM Generator 4
...
000 = PWM Generator 1

**Note 1:** The event signal is stretched using peripheral_clk because different PWM Generators may be operating from different clock sources.
**2:** No event will be produced if the selected PWM Generator is not present.
**3:** This is the PWM Generator output signal prior to output mode logic and any output override logic.
**4:** This signal should be the PGx_clk domain signal prior to any synchronization into the system clock domain.
**5:** 'y' denotes a common instance (A-F).

**REGISTER 11-11: 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]:** Linear Feedback Shift Register bits
A read of this register will provide a 15-bit pseudorandom value.


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**REGISTER 11-12: PGxCONL: PWM GENERATOR x CONTROL REGISTER LOW**

| R/W-0 | R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ON | FRZ | — | — | — | TRGCNT2 | TRGCNT1 | TRGCNT0 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | CLKSEL1 | CLKSEL0 | MODSEL2 | MODSEL1 | MODSEL0 |
| 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 **ON:** Enable bit
1 = PWM Generator is enabled
0 = PWM Generator is not enabled

bit 14 **FRZ:** Freeze bit
1 = PGx stops operation in Debug mode
0 = PGx continues operation in Debug mode

bit 13-11 **Unimplemented:** Read as '0'

bit 10-8 **TRGCNT[2:0]:** Trigger Count Select bits
111 = PWM Generator produces eight PWM cycles after triggered
110 = PWM Generator produces seven PWM cycles after triggered
101 = PWM Generator produces six PWM cycles after triggered
100 = PWM Generator produces five PWM cycles after triggered
011 = PWM Generator produces four PWM cycles after triggered
010 = PWM Generator produces three PWM cycles after triggered
001 = PWM Generator produces two PWM cycles after triggered
000 = PWM Generator produces one PWM cycle after triggered

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

bit 4-3 **CLKSEL[1:0]:** Clock Selection bits
11 = PWM Generator uses Host clock scaled by frequency scaling circuit(1)
10 = PWM Generator uses Host clock divided by clock divider circuit(1)
01 = PWM Generator uses Host clock selected by the MCLKSEL[1:0] (PCLKCON[1:0]) control bits
00 = No clock selected, PWM Generator is in lowest power state (default)

bit 2-0 **MODSEL[2:0]:** Mode Selection bits
111 = Dual Edge Center-Aligned PWM mode (interrupt/register update twice per cycle)
110 = Dual Edge Center-Aligned PWM mode (interrupt/register update once per cycle)
101 = Double-Update Center-Aligned PWM mode
100 = Center-Aligned PWM mode
011 = Reserved
010 = Independent Edge PWM mode, dual output
001 = Variable Phase PWM mode
000 = Independent Edge PWM mode

**Note 1:** The PWM Generator time base operates from the frequency scaling circuit clock, effectively scaling the duty cycle and period of the PWM Generator output.

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**REGISTER 11-13: PGxCONH: PWM GENERATOR x CONTROL REGISTER HIGH**

| R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| MDCSEL | MPERSEL | MPHSEL | — | MSTEN | UPDMOD2 | UPDMOD1 | UPDMOD0 |
| bit 15 | | | | | | | bit 8 |

| r-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | TRGMOD | — | — | SOCS3(1,2,3) | SOCS2(1,2,3) | SOCS1(1,2,3) | SOCS0(1,2,3) |
| 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 **MDCSEL:** Host Duty Cycle Register Select bit
1 = PWM Generator uses MDC register
0 = PWM Generator uses PGxDC register

bit 14 **MPERSEL:** Host Period Register Select bit
1 = PWM Generator uses MPER register
0 = PWM Generator uses PGxPER register

bit 13 **MPHSEL:** Host Phase Register Select bit
1 = PWM Generator uses MPHASE register
0 = PWM Generator uses PGxPHASE register

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

bit 11 **MSTEN:** Host Update Enable bit
1 = PWM Generator broadcasts software set/clear of the UPDREQ status bit and EOC signal to other PWM Generators
0 = PWM Generator does not broadcast the UPDREQ status bit state or EOC signal

bit 10-8 **UPDMOD[2:0]:** PWM Buffer Update Mode Selection bits
011 = Client immediate update
Updates Data registers immediately, or as soon as possible, when a Host update request is received. A Host update request will be transmitted if MSTEN = 1 and UPDREQ = 1 for the requesting PWM Generator.
010 = Client SOC update
Updates Data registers at the start of the next cycle if a Host update request is received. A Host update request will be transmitted if MSTEN = 1 and UPDREQ = 1 for the requesting PWM Generator.
001 = Immediate update
Updates Data registers immediately, or as soon as possible, if UPDREQ = 1. The UPDATE status bit will be cleared automatically after the update occurs.
000 = SOC update
Updates Data registers at start of next PWM cycle if UPDREQ = 1. The UPDATE status bit will be cleared automatically after the update occurs.(1)

bit 7 **Reserved:** Maintain as '0'

**Note 1:** The PCI selected Sync signal is always available to be OR'd with the selected SOC signal per the SOCS[3:0] bits if the PCI Sync function is enabled.

**2:** The source selected by the SOCS[3:0] bits MUST operate from the same clock source as the local PWM Generator. If not, the source must be routed through the PCI Sync logic so the trigger signal may be synchronized to the PWM Generator clock domain.

**3:** PWM Generators are grouped into groups of four: PG1-PG4 and PG5-PG8, if available. Any generator within a group of four may be used to trigger another generator within the same group.


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**REGISTER 11-13: PGxCONH: PWM GENERATOR x CONTROL REGISTER HIGH (CONTINUED)**

bit 6 **TRGMOD:** PWM Generator Trigger Mode Selection bit
1 = PWM Generator operates in Retriggerable mode
0 = PWM Generator operates in Single Trigger mode

bit 5-4 **Unimplemented:** Read as '0'

bit 3-0 **SOCS[3:0]:** Start-of-Cycle Selection bits
1111 = TRIG bit or PCI Sync function only (no hardware trigger source is selected)
1110-0101 = Reserved
0100 = Trigger output selected by PG4 PGTRGSEL[2:0] bits (PGxEVTL[2:0])
0011 = Trigger output selected by PG3 PGTRGSEL[2:0] bits (PGxEVTL[2:0])
0010 = Trigger output selected by PG2 PGTRGSEL[2:0] bits (PGxEVTL[2:0])
0001 = Trigger output selected by PG1 PGTRGSEL[2:0] bits (PGxEVTL[2:0])
0000 = Local EOC – PWM Generator is self-triggered

**Note 1:** The PCI selected Sync signal is always available to be OR'd with the selected SOC signal per the SOCS[3:0] bits if the PCI Sync function is enabled.

**2:** The source selected by the SOCS[3:0] bits MUST operate from the same clock source as the local PWM Generator. If not, the source must be routed through the PCI Sync logic so the trigger signal may be synchronized to the PWM Generator clock domain.

**3:** PWM Generators are grouped into groups of four: PG1-PG4 and PG5-PG8, if available. Any generator within a group of four may be used to trigger another generator within the same group.

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**REGISTER 11-14: PGxSTAT: PWM GENERATOR x STATUS REGISTER**

| HS/C-0 | HS/C-0 | HS/C-0 | HS/C-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| SEVT | FLTEVT | CLEVT | FFEVT | SACT | FLTACT | CLACT | FFACT |
| bit 15 | | | | | | | bit 8 |

| W-0 | W-0 | HS/R/W-0 | R-0 | W-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| TRSET | TRCLR | CAP(1) | UPDATE | UPDREQ | STEER | CAHALF | TRIG |
| bit 7 | | | | | | | bit 0 |

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

bit 15 **SEVT:** PCI Sync Event bit
1 = A PCI Sync event has occurred (rising edge on PCI Sync output or PCI Sync output is high when module is enabled)
0 = No PCI Sync event has occurred

bit 14 **FLTEVT:** PCI Fault Active Status bit
1 = A Fault event has occurred (rising edge on PCI Fault output or PCI Fault output is high when module is enabled)
0 = No Fault event has occurred

bit 13 **CLEVT:** PCI Current Limit Status bit
1 = A PCI current limit event has occurred (rising edge on PCI current limit output or PCI current limit output is high when module is enabled)
0 = No PCI current limit event has occurred

bit 12 **FFEVT:** PCI Feed-Forward Active Status bit
1 = A PCI feed-forward event has occurred (rising edge on PCI feed-forward output or PCI feed-forward output is high when module is enabled)
0 = No PCI feed-forward event has occurred

bit 11 **SACT:** PCI Sync Status bit
1 = PCI Sync output is active
0 = PCI Sync output is inactive

bit 10 **FLTACT:** PCI Fault Active Status bit
1 = PCI Fault output is active
0 = PCI Fault output is inactive

bit 9 **CLACT:** PCI Current Limit Status bit
1 = PCI current limit output is active
0 = PCI current limit output is inactive

bit 8 **FFACT:** PCI Feed-Forward Active Status bit
1 = PCI feed-forward output is active
0 = PCI feed-forward output is inactive

bit 7 **TRSET:** PWM Generator Software Trigger Set bit
User software writes a '1' to this bit location to trigger a PWM Generator cycle. The bit location always reads as '0'. The TRIG bit will indicate '1' when the PWM Generator is triggered.

bit 6 **TRCLR:** PWM Generator Software Trigger Clear bit
User software writes a '1' to this bit location to stop a PWM Generator cycle. The bit location always reads as '0'. The TRIG bit will indicate '0' when the PWM Generator is not triggered.

**Note 1:** User software may write a '1' to CAP as a request to initiate a software capture. The CAP status bit will be set when the capture event has occurred. No further captures will occur until CAP is cleared by software.


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**REGISTER 11-14: PGxSTAT: PWM GENERATOR x STATUS REGISTER (CONTINUED)**

bit 5 **CAP:** Capture Status bit
1 = PWM Generator time base value has been captured in PGxCAP
0 = No capture has occurred

bit 4 **UPDATE:** PWM Data Register Update Status bit
1 = PWM Data register update is pending – user Data registers are not writable
0 = No PWM Data register update is pending

bit 3 **UPDREQ:** PWM Data Register Update Request bit
User software writes a '1' to this bit location to request a PWM Data register update. The bit location always reads as '0'. The UPDATE status bit will indicate '1' when an update is pending.

bit 2 **STEER:** Output Steering Status bit (Push-Pull Output mode only)
1 = PWM Generator is in 2nd cycle of Push-Pull mode
0 = PWM Generator is in 1st cycle of Push-Pull mode

bit 1 **CAHALF:** Half Cycle Status bit (Center-Aligned modes only)
1 = PWM Generator is in 2nd half of time base cycle
0 = PWM Generator is in 1st half of time base cycle

bit 0 **TRIG:** PWM Trigger Status bit
1 = PWM Generator is triggered and PWM cycle is in progress
0 = No PWM cycle is in progress

**Note 1:** User software may write a '1' to CAP as a request to initiate a software capture. The CAP status bit will be set when the capture event has occurred. No further captures will occur until CAP is cleared by software.

**REGISTER 11-15: PGxIOCONL: PWM GENERATOR x I/O CONTROL 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 |
|---|---|---|---|---|---|---|---|
| CLMOD | SWAP | OVRENH | OVRENL | OVRDAT1 | OVRDAT0 | OSYNC1 | OSYNC0 |
| 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 |
|---|---|---|---|---|---|---|---|
| FLTDAT1 | FLTDAT0 | CLDAT1 | CLDAT0 | FFDAT1 | FFDAT0 | DBDAT1 | DBDAT0 |
| 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 **CLMOD:** Current Limit Mode Select bit
1 = If PCI current limit is active, then the PWMxH and PWMxL output signals are inverted (bit flipping), and the CLDAT[1:0] bits are not used
0 = If PCI current limit is active, then the CLDAT[1:0] bits define the PWM output levels

bit 14 **SWAP:** Swap PWM Signals to PWMxH and PWMxL Device Pins bit
1 = The PWMxH signal is connected to the PWMxL pin and the PWMxL signal is connected to the PWMxH pin
0 = PWMxH/L signals are mapped to their respective pins

bit 13 **OVRENH:** User Override Enable for PWMxH Pin bit
1 = OVRDAT1 provides data for output on the PWMxH pin
0 = PWM Generator provides data for the PWMxH pin

bit 12 **OVRENL:** User Override Enable for PWMxL Pin bit
1 = OVRDAT0 provides data for output on the PWMxL pin
0 = PWM Generator provides data for the PWMxL pin

bit 11-10 **OVRDAT[1:0]:** Data for PWMxH/PWMxL Pins if Override is Enabled bits
If OVERENH = 1, then OVRDAT1 provides data for PWMxH.
If OVERENL = 1, then OVRDAT0 provides data for PWMxL.

bit 9-8 **OSYNC[1:0]:** User Output Override Synchronization Control bits
11 = Reserved
10 = User output overrides via the OVRENH/L and OVRDAT[1:0] bits occur when specified by the UPDMOD[2:0] bits in the PGxCONH register
01 = User output overrides via the OVRENH/L and OVRDAT[1:0] bits occur immediately (as soon as possible)
00 = User output overrides via the OVRENH/L and OVRDAT[1:0] bits are synchronized to the local PWM time base (next Start-of-Cycle)

bit 7-6 **FLTDAT[1:0]:** Data for PWMxH/PWMxL Pins if Fault Event is Active bits
If Fault is active, then FLTDAT1 provides data for PWMxH.
If Fault is active, then FLTDAT0 provides data for PWMxL.

bit 5-4 **CLDAT[1:0]:** Data for PWMxH/PWMxL Pins if Current Limit Event is Active bits
If current limit is active, then CLDAT1 provides data for PWMxH.
If current limit is active, then CLDAT0 provides data for PWMxL.

bit 3-2 **FFDAT[1:0]:** Data for PWMxH/PWMxL Pins if Feed-Forward Event is Active bits
If feed-forward is active, then FFDAT1 provides data for PWMxH.
If feed-forward is active, then FFDAT0 provides data for PWMxL.

bit 1-0 **DBDAT[1:0]:** Data for PWMxH/PWMxL Pins if Debug Mode is Active bits
If Debug mode is active and device halted, then DBDAT1 provides data for PWMxH.
If Debug mode is active and device halted, then DBDAT0 provides data for PWMxL.


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**REGISTER 11-16: PGxIOCONH: PWM GENERATOR x I/O CONTROL REGISTER HIGH**

| U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | CAPSRC2(1) | CAPSRC1(1) | CAPSRC0(1) | — | — | — | DTCMPSEL |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | PMOD1 | PMOD0 | PENH | PENL | POLH | POLL |
| 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 **CAPSRC[2:0]:** Time Base Capture Source Selection bits
111 = Reserved
110 = Reserved
101 = Reserved
100 = Capture time base value at assertion of selected PCI Fault signal
011 = Capture time base value at assertion of selected PCI current limit signal
010 = Capture time base value at assertion of selected PCI feed-forward signal
001 = Capture time base value at assertion of selected PCI Sync signal
000 = No hardware source selected for time base capture – software only

bit 11-9 **Unimplemented:** Read as '0'

bit 8 **DTCMPSEL:** Dead-Time Compensation Select bit
1 = Dead-time compensation is controlled by PCI feed-forward limit logic
0 = Dead-time compensation is controlled by PCI Sync logic

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

bit 5-4 **PMOD[1:0]:** PWM Generator Output Mode Selection bits
11 = Reserved
10 = PWM Generator outputs operate in Push-Pull mode
01 = PWM Generator outputs operate in Independent mode
00 = PWM Generator outputs operate in Complementary mode

bit 3 **PENH:** PWMxH Output Port Enable bit
1 = PWM Generator controls the PWMxH output pin
0 = PWM Generator does not control the PWMxH output pin

bit 2 **PENL:** PWMxL Output Port Enable bit
1 = PWM Generator controls the PWMxL output pin
0 = PWM Generator does not control the PWMxL output pin

bit 1 **POLH:** PWMxH Output Polarity bit
1 = Output pin is active-low
0 = Output pin is active-high

bit 0 **POLL:** PWMxL Output Polarity bit
1 = Output pin is active-low
0 = Output pin is active-high

**Note 1:** A capture may be initiated in software at any time by writing a '1' to CAP (PGxSTAT[5]).

**REGISTER 11-17: PGxEVTL: PWM GENERATOR x EVENT 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 |
|---|---|---|---|---|---|---|---|
| ADTR1PS4 | ADTR1PS3 | ADTR1PS2 | ADTR1PS1 | ADTR1PS0 | ADTR1EN3 | ADTR1EN2 | ADTR1EN1 |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | UPDTRG1 | UPDTRG0 | PGTRGSEL2(1) | PGTRGSEL1(1) | PGTRGSEL0(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 15-11 **ADTR1PS[4:0]:** ADC Trigger 1 Postscaler Selection bits
11111 = 1:32
...
00010 = 1:3
00001 = 1:2
00000 = 1:1

bit 10 **ADTR1EN3:** ADC Trigger 1 Source is PGxTRIGC Compare Event Enable bit
1 = PGxTRIGC register compare event is enabled as trigger source for ADC Trigger 1
0 = PGxTRIGC register compare event is disabled as trigger source for ADC Trigger 1

bit 9 **ADTR1EN2:** ADC Trigger 1 Source is PGxTRIGB Compare Event Enable bit
1 = PGxTRIGB register compare event is enabled as trigger source for ADC Trigger 1
0 = PGxTRIGB register compare event is disabled as trigger source for ADC Trigger 1

bit 8 **ADTR1EN1:** ADC Trigger 1 Source is PGxTRIGA Compare Event Enable bit
1 = PGxTRIGA register compare event is enabled as trigger source for ADC Trigger 1
0 = PGxTRIGA register compare event is disabled as trigger source for ADC Trigger 1

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

bit 4-3 **UPDTRG[1:0]:** Update Trigger Select bits
11 = A write of the PGxTRIGA register automatically sets the UPDATE bit
10 = A write of the PGxPHASE register automatically sets the UPDATE bit
01 = A write of the PGxDC register automatically sets the UPDATE bit
00 = User must set the UPDREQ bit (PGxSTAT[3]) manually

bit 2-0 **PGTRGSEL[2:0]:** PWM Generator Trigger Output Selection bits
111 = Reserved
110 = Reserved
101 = Reserved
100 = Reserved
011 = PGxTRIGC compare event is the PWM Generator trigger
010 = PGxTRIGB compare event is the PWM Generator trigger
001 = PGxTRIGA compare event is the PWM Generator trigger
000 = EOC event is the PWM Generator trigger

**Note 1:** These events are derived from the internal PWM Generator time base comparison events.


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**REGISTER 11-18: PGxEVTH: PWM GENERATOR x EVENT REGISTER HIGH**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| FLTIEN(1) | CLIEN(2) | FFIEN(3) | SIEN(4) | — | — | IEVTSEL1 | IEVTSEL0 |
| 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 |
|---|---|---|---|---|---|---|---|
| ADTR2EN3 | ADTR2EN2 | ADTR2EN1 | ADTR1OFS4 | ADTR1OFS3 | ADTR1OFS2 | ADTR1OFS1 | ADTR1OFS0 |
| 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 **FLTIEN:** PCI Fault Interrupt Enable bit
1 = Fault interrupt is enabled
0 = Fault interrupt is disabled

bit 14 **CLIEN:** PCI Current Limit Interrupt Enable bit
1 = Current limit interrupt is enabled
0 = Current limit interrupt is disabled

bit 13 **FFIEN:** PCI Feed-Forward Interrupt Enable bit
1 = Feed-forward interrupt is enabled
0 = Feed-forward interrupt is disabled

bit 12 **SIEN:** PCI Sync Interrupt Enable bit
1 = Sync interrupt is enabled
0 = Sync interrupt is disabled

bit 11-10 **Unimplemented:** Read as '0'

bit 9-8 **IEVTSEL[1:0]:** Interrupt Event Selection bits
11 = Time base interrupts are disabled (Sync, Fault, current limit and feed-forward events can be independently enabled)
10 = Interrupts CPU at ADC Trigger 1 event
01 = Interrupts CPU at TRIGA compare event
00 = Interrupts CPU at EOC

bit 7 **ADTR2EN3:** ADC Trigger 2 Source is PGxTRIGC Compare Event Enable bit
1 = PGxTRIGC register compare event is enabled as trigger source for ADC Trigger 2
0 = PGxTRIGC register compare event is disabled as trigger source for ADC Trigger 2

bit 6 **ADTR2EN2:** ADC Trigger 2 Source is PGxTRIGB Compare Event Enable bit
1 = PGxTRIGB register compare event is enabled as trigger source for ADC Trigger 2
0 = PGxTRIGB register compare event is disabled as trigger source for ADC Trigger 2

bit 5 **ADTR2EN1:** ADC Trigger 2 Source is PGxTRIGA Compare Event Enable bit
1 = PGxTRIGA register compare event is enabled as trigger source for ADC Trigger 2
0 = PGxTRIGA register compare event is disabled as trigger source for ADC Trigger 2

**Note 1:** An interrupt is only generated on the rising edge of the PCI Fault active signal.
**2:** An interrupt is only generated on the rising edge of the PCI current limit active signal.
**3:** An interrupt is only generated on the rising edge of the PCI feed-forward active signal.
**4:** An interrupt is only generated on the rising edge of the PCI Sync active signal.

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**REGISTER 11-18: PGxEVTH: PWM GENERATOR x EVENT REGISTER HIGH (CONTINUED)**

bit 4-0 **ADTR1OFS[4:0]:** ADC Trigger 1 Offset Selection bits
11111 = Offset by 31 trigger events
...
00010 = Offset by 2 trigger events
00001 = Offset by 1 trigger event
00000 = No offset

**Note 1:** An interrupt is only generated on the rising edge of the PCI Fault active signal.
**2:** An interrupt is only generated on the rising edge of the PCI current limit active signal.
**3:** An interrupt is only generated on the rising edge of the PCI feed-forward active signal.
**4:** An interrupt is only generated on the rising edge of the PCI Sync active signal.


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**REGISTER 11-19: PGxyPCIL: PWM GENERATOR xy PCI REGISTER LOW (x = PWM GENERATOR #; y = F, CL, FF OR S)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TSYNCDIS | TERM2 | TERM1 | TERM0 | AQPS | AQSS2 | AQSS1 | AQSS0 |
| 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 |
|---|---|---|---|---|---|---|---|
| SWTERM | PSYNC | PPS | PSS4 | PSS3 | PSS2 | PSS1 | PSS0 |
| 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 **TSYNCDIS:** Termination Synchronization Disable bit
1 = Termination of latched PCI occurs immediately
0 = Termination of latched PCI occurs at PWM EOC

bit 14-12 **TERM[2:0]:** Termination Event Selection bits
111 = Selects PCI Source #9
110 = Selects PCI Source #8
101 = Selects PCI Source #1 (PWM Generator output selected by the PWMPCI[2:0] bits)
100 = PGxTRIGC trigger event
011 = PGxTRIGB trigger event
010 = PGxTRIGA trigger event
001 = Auto-Terminate: Terminate when PCI source transitions from active to inactive
000 = Manual Terminate: Terminate on a write of '1' to the SWTERM bit location

bit 11 **AQPS:** Acceptance Qualifier Polarity Select bit
1 = Inverted
0 = Not inverted

bit 10-8 **AQSS[2:0]:** Acceptance Qualifier Source Selection bits
111 = SWPCI control bit only (qualifier forced to '0')
110 = Selects PCI Source #9
101 = Selects PCI Source #8
100 = Selects PCI Source #1 (PWM Generator output selected by the PWMPCI[2:0] bits)
011 = PWM Generator is triggered
010 = LEB is active
001 = Duty cycle is active (base PWM Generator signal)
000 = No acceptance qualifier is used (qualifier forced to '1')

bit 7 **SWTERM:** PCI Software Termination bit
A write of '1' to this location will produce a termination event. This bit location always reads as '0'.

bit 6 **PSYNC:** PCI Synchronization Control bit
1 = PCI source is synchronized to PWM EOC
0 = PCI source is not synchronized to PWM EOC

bit 5 **PPS:** PCI Polarity Select bit
1 = Inverted
0 = Not inverted

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**REGISTER 11-19: PGxyPCIL: PWM GENERATOR xy PCI REGISTER LOW (x = PWM GENERATOR #; y = F, CL, FF OR S) (CONTINUED)**

bit 4-0 **PSS[4:0]:** PCI Source Selection bits

11111 = CLC1
11110-11100 = Reserved
11011 = Comparator 1 output
11010 = PWM Event D
11001 = PWM Event C
11000 = PWM Event B
10111 = PWM Event A
10110-10100 = Reserved
10011 = Device pin, PCI[19]
10010 = RPn input, PCI18R
10001 = RPn input, PCI17R
10000 = RPn input, PCI16R
01111 = RPn input, PCI15R
01110 = RPn input, PCI14R
01101 = RPn input, PCI13R
01100 = RPn input, PCI12R
01011 = RPn input, PCI11R
01010 = RPn input, PCI10R
01001 = RPn input, PCI9R
01000 = RPn input, PCI8R
00100-00111 = Reserved
00011 = Internally connected to Combo Trigger B
00010 = Internally connected to Combo Trigger A
00001 = Internally connected to the output of PWMPCI[2:0] MUX
00000 = Tied to '0'


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**REGISTER 11-20: PGxyPCIH: PWM GENERATOR xy PCI REGISTER HIGH (x = PWM GENERATOR #; y = F, CL, FF OR S)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| BPEN | BPSEL2(1) | BPSEL1(1) | BPSEL0(1) | — | ACP2 | ACP1 | ACP0 |
| 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 |
|---|---|---|---|---|---|---|---|
| SWPCI | SWPCIM1 | SWPCIM0 | LATMOD | TQPS | TQSS2 | TQSS1 | TQSS0 |
| 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 **BPEN:** PCI Bypass Enable bit
1 = PCI function is enabled and local PCI logic is bypassed; PWM Generator will be controlled by PCI function in the PWM Generator selected by the BPSEL[2:0] bits
0 = PCI function is not bypassed

bit 14-12 **BPSEL[2:0]:** PCI Bypass Source Selection bits
111-100 = Reserved
011 = PCI control is sourced from PWM Generator 4 PCI logic when BPEN = 1
010 = PCI control is sourced from PWM Generator 3 PCI logic when BPEN = 1
001 = PCI control is sourced from PWM Generator 2 PCI logic when BPEN = 1
000 = PCI control is sourced from PWM Generator 1 PCI logic when BPEN = 1

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

bit 10-8 **ACP[2:0]:** PCI Acceptance Criteria Selection bits
111 = Reserved
110 = Reserved
101 = Latched any edge
100 = Latched rising edge
011 = Latched
010 = Any edge
001 = Rising edge
000 = Level-sensitive

bit 7 **SWPCI:** Software PCI Control bit
1 = Drives a '1' to PCI logic assigned to by the SWPCIM[1:0] control bits
0 = Drives a '0' to PCI logic assigned to by the SWPCIM[1:0] control bits

bit 6-5 **SWPCIM[1:0]:** Software PCI Control Mode bits
11 = Reserved
10 = SWPCI bit is assigned to termination qualifier logic
01 = SWPCI bit is assigned to acceptance qualifier logic
00 = SWPCI bit is assigned to PCI acceptance logic

bit 4 **LATMOD:** PCI SR Latch Mode bit
1 = SR latch is Reset-dominant in Latched Acceptance modes
0 = SR latch is Set-dominant in Latched Acceptance modes

bit 3 **TQPS:** Termination Qualifier Polarity Select bit
1 = Inverted
0 = Not inverted

**Note 1:** Selects '0' if selected PWM Generator is not present.

**REGISTER 11-20: PGxyPCIH: PWM GENERATOR xy PCI REGISTER HIGH (x = PWM GENERATOR #; y = F, CL, FF OR S) (CONTINUED)**

bit 2-0 **TQSS[2:0]:** Termination Qualifier Source Selection bits
111 = SWPCI control bit only (qualifier forced to '0')
110 = Selects PCI Source #9
101 = Selects PCI Source #8
100 = Selects PCI Source #1 (PWM Generator output selected by the PWMPCI[2:0] bits)
011 = PWM Generator is triggered
010 = LEB is active
001 = Duty cycle is active (base PWM Generator signal)
000 = No termination qualifier used (qualifier forced to '1')

**Note 1:** Selects '0' if selected PWM Generator is not present.

**REGISTER 11-21: PGxLEBL: PWM GENERATOR x LEADING-EDGE BLANKING 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 |
|---|---|---|---|---|---|---|---|
| LEB[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| LEB[7:0](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 15-0 **LEB[15:0]:** Leading-Edge Blanking Period bits
Leading-Edge Blanking period. The three LSbs of the blanking time are not used, providing a blanking resolution of eight clock periods. The minimum blanking period is eight clock periods, which occurs when LEB[15:3] = 0.

**Note 1:** Bits[2:0] are read-only and always remain as '0'.


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**REGISTER 11-22: PGxLEBH: PWM GENERATOR x LEADING-EDGE BLANKING REGISTER HIGH**

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | PWMPCI[2:0](1) | | |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | PHR | PHF | PLR | PLF |
| 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 **PWMPCI[2:0]:** PWM Source for PCI Selection bits
111-100 = Reserved
011 = PWM Generator #4 output is made available to PCI logic
010 = PWM Generator #3 output is made available to PCI logic
001 = PWM Generator #2 output is made available to PCI logic
000 = PWM Generator #1 output is made available to PCI logic

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

bit 3 **PHR:** PWMxH Rising Edge Trigger Enable bit
1 = Rising edge of PWMxH will trigger the LEB duration counter
0 = LEB ignores the rising edge of PWMxH

bit 2 **PHF:** PWMxH Falling Edge Trigger Enable bit
1 = Falling edge of PWMxH will trigger the LEB duration counter
0 = LEB ignores the falling edge of PWMxH

bit 1 **PLR:** PWMxL Rising Edge Trigger Enable bit
1 = Rising edge of PWMxL will trigger the LEB duration counter
0 = LEB ignores the rising edge of PWMxL

bit 0 **PLF:** PWMxL Falling Edge Trigger Enable bit
1 = Falling edge of PWMxL will trigger the LEB duration counter
0 = LEB ignores the falling edge of PWMxL

**Note 1:** The selected PWM Generator source does not affect the LEB counter. This source can be optionally used as a PCI input, PCI qualifier, PCI terminator or PCI terminator qualifier (see the description in Register 11-19 and Register 11-20 for more information).

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**REGISTER 11-23: PGxPHASE: PWM GENERATOR x PHASE 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 |
|---|---|---|---|---|---|---|---|
| PGxPHASE[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 |
|---|---|---|---|---|---|---|---|
| PGxPHASE[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 **PGxPHASE[15:0]:** PWM Generator x Phase Register bits

**REGISTER 11-24: PGxDC: PWM GENERATOR x DUTY CYCLE 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 |
|---|---|---|---|---|---|---|---|
| PGxDC[15:8](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 |
|---|---|---|---|---|---|---|---|
| PGxDC[7:0](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 15-0 **PGxDC[15:0]:** PWM Generator x Duty Cycle Register bits

**Note 1:** Duty cycle values less than '0x0008' should not be used.


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**REGISTER 11-25: PGxDCA: PWM GENERATOR x DUTY CYCLE ADJUSTMENT 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PGxDCA[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 **PGxDCA[7:0]:** PWM Generator x Duty Cycle Adjustment Value bits

Depending on the state of the selected PCI source, the PGxDCA value will be added to the value in the PGxDC register to create the effective duty cycle. When the PCI source is active, PGxDCA is added.

**REGISTER 11-26: PGxPER: PWM GENERATOR x PERIOD 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 |
|---|---|---|---|---|---|---|---|
| PGxPER[15:8](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 |
|---|---|---|---|---|---|---|---|
| PGxPER[7:0](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 15-0 **PGxPER[15:0]:** PWM Generator x Period Register bits

**Note 1:** Period values less than '0x0010' should not be used.

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**REGISTER 11-27: PGxTRIGA: PWM GENERATOR x TRIGGER A 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 |
|---|---|---|---|---|---|---|---|
| PGxTRIGA[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 |
|---|---|---|---|---|---|---|---|
| PGxTRIGA[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 **PGxTRIGA[15:0]:** PWM Generator x Trigger A Register bits

**REGISTER 11-28: PGxTRIGB: PWM GENERATOR x TRIGGER B 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 |
|---|---|---|---|---|---|---|---|
| PGxTRIGB[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 |
|---|---|---|---|---|---|---|---|
| PGxTRIGB[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 **PGxTRIGB[15:0]:** PWM Generator x Trigger B Register bits

**REGISTER 11-29: PGxTRIGC: PWM GENERATOR x TRIGGER C 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 |
|---|---|---|---|---|---|---|---|
| PGxTRIGC[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 |
|---|---|---|---|---|---|---|---|
| PGxTRIGC[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 **PGxTRIGC[15:0]:** PWM Generator x Trigger C Register bits


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**REGISTER 11-30: PGxDTL: PWM GENERATOR x DEAD-TIME REGISTER LOW**

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | DTL[10:8] | | |
| 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 |
|---|---|---|---|---|---|---|---|
| DTL[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 15-11 **Unimplemented:** Read as ‘0’

bit 10-0 **DTL[10:0]:** PWMxL Dead-Time Delay bits

**REGISTER 11-31: PGxDTH: PWM GENERATOR x DEAD-TIME REGISTER HIGH**

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | DTH[10:8] | | |
| 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 |
|---|---|---|---|---|---|---|---|
| DTH[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 15-11 **Unimplemented:** Read as ‘0’

bit 10-0 **DTH[10:0]:** PWMxH Dead-Time Delay bits

**REGISTER 11-32: PGxCAP: PWM GENERATOR x CAPTURE REGISTER**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PGxCAP[15:8](1) | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PGxCAP[7:0](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 15-0 **PGxCAP[15:0]:** PGx Time Base Capture bits

**Note 1:** PGxCAP[1:0] will read as '0' in Standard Resolution mode.


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# 12.0 MOSFET GATE DRIVER MODULE

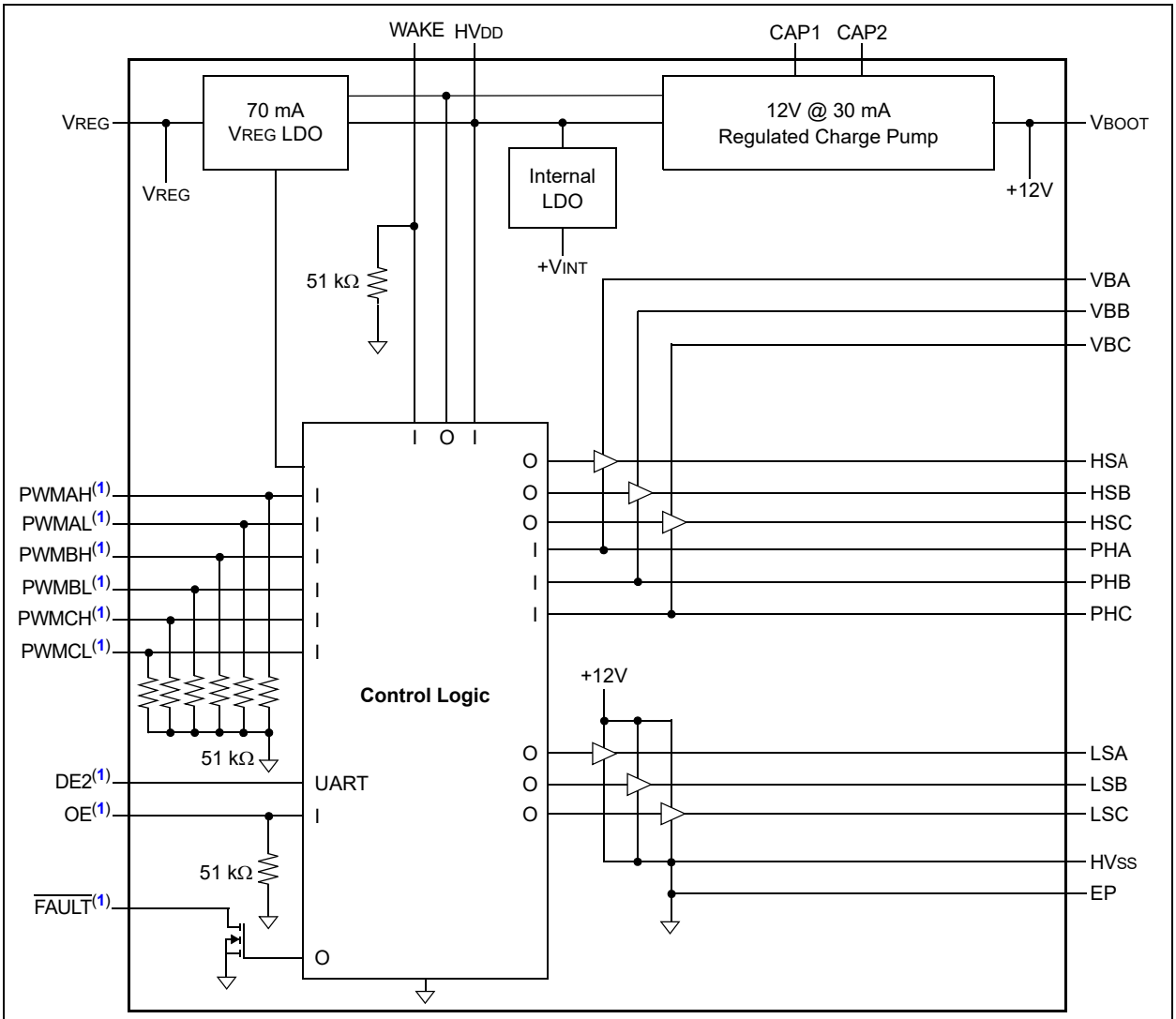
## 12.1 Functional Overview

The MOSFET Gate Driver module (MOSFET Driver module) incorporates a number of functions, that when paired with the host dsPIC® DSC, provides a single chip solution for controlling low-voltage motors. The MOSFET Driver module includes:

- Bias Generator:
  - +12V Low-Dropout (LDO) Linear Regulator
  - Charge Pump
  - +3.3V @ 70 mA LDO can be used to power the host dsPIC DSC
  - Input supply and temperature supervisor
- Motor Control Unit:
  - External drive for a three-phase bridge with NMOS/NMOS MOSFET pairs
- Communication Port:
  - Half-duplex UART with internal connection to the host dsPIC DSC

Figure 12-1 depicts the functional block diagram of the MOSFET Driver module and Figure 12-2 depicts a typical application circuit.

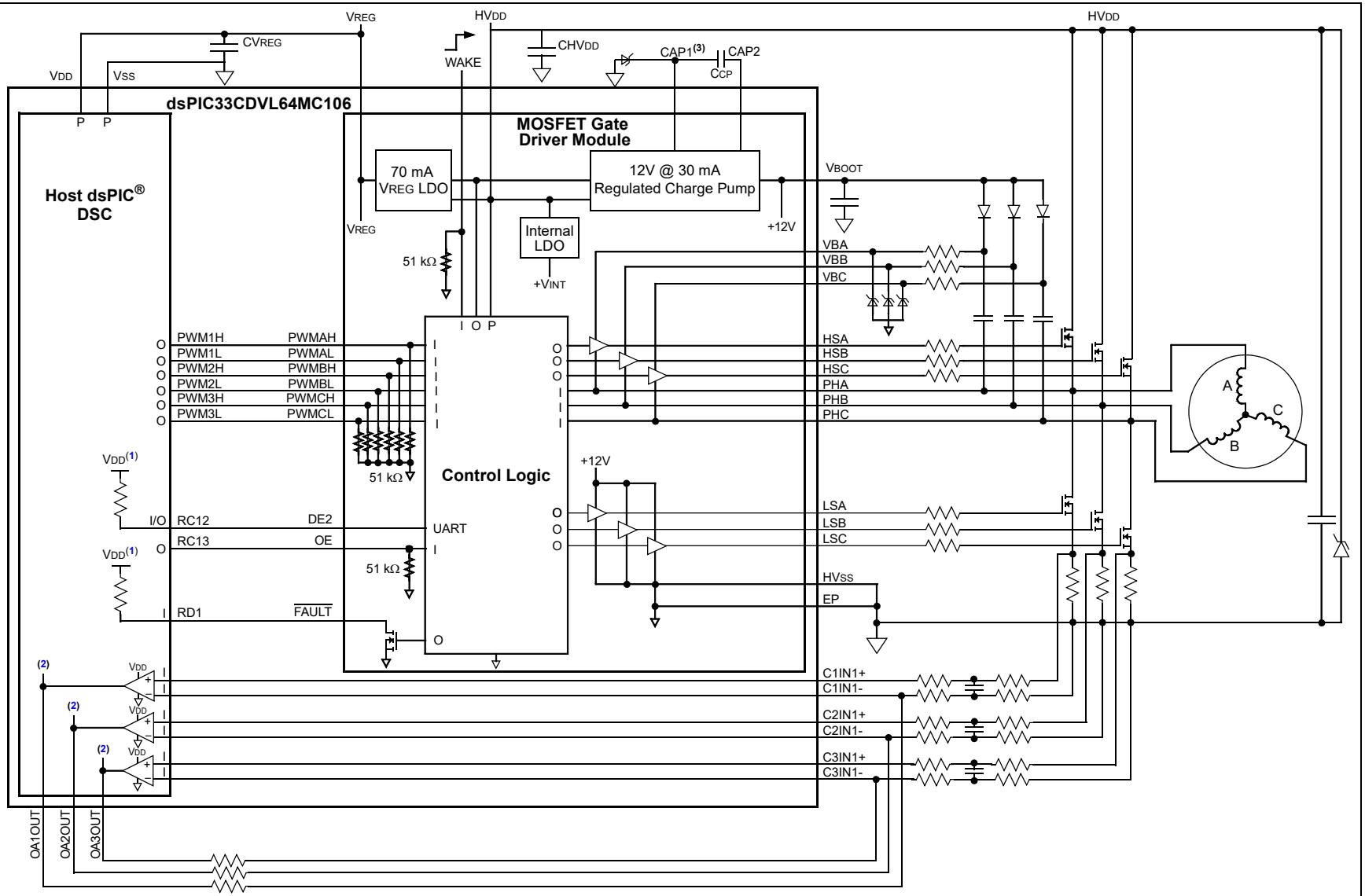
**FIGURE 12-1: FUNCTIONAL BLOCK DIAGRAM – MOSFET GATE DRIVER MODULE**




**Note 1:** Device interconnect is connected directly to the host microcontroller within the dsPIC33CDVL64MC106 device package.

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**FIGURE 12-2: MOSFET GATE DRIVER MODULE – TYPICAL MOTOR CONTROL APPLICATION CIRCUIT**




**Note 1:** Internal pull-up resistors for RC12 and RD1 must be enabled by the user by setting the corresponding bits in the CNPUC and CNPUD registers, respectively.
**2:** The ADC can be configured to internally sample op amp outputs.
**3:** A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.


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## 12.2 Communications Port (DE2 Interconnect)

Open-drain communications node. The DE2 communications is a half-duplex, 9600 baud, 8-bit, no parity communications link. The pin has a minimum drive capability of 1 mA with a $V_{DE2}$ of ≤50 mV when driving low.

The following configurations are required for successful DE2 communication between the host dsPIC and the MOSFET Gate Driver module:

- Enable the internal pull-up resistor of port pin RC12 (CNPUC[12] = 1). Enable only after MCP8021 is powered to avoid current sinking.
- TRISC12 = 1. Essential for PPS input assignments to ensure data from MCP8021 reaches UART RX buffer.
- PPS assignment of both RX and TX to port pin RC12

## 12.3 Low-Side PWM Inputs (PWMAL, PWMBL, PWMCL)

Digital PWM Inputs for low-side driver control. Each input has a 51 kΩ pull-down to ground. The PWM signals may contain dead-time timing or the system may use the CFG2 Configuration register to set the dead time.

## 12.4 High-Side PWM Inputs (PWMAH, PWMBH, PWMCH)

Digital PWM inputs for high-side driver control. Each input has a 51 kΩ pull-down to ground. The PWM signals may contain dead-time timing or the system may use the CFG2 Configuration register to set the dead time.

## 12.5 Output Enable (OE) Input

The Output Enable Input pin is used to enable/disable the output driver and the on-board functions. When OE is high, all device functions are enabled. When OE is low, the device operates in Standby or Sleep mode. When Standby mode is active, the $V_{BOOT}$ output supply and charge pump are disabled. The high-side and low-side gate drive outputs are all set to a Low state within 100 ns of OE going low. The device transitions to Standby or Sleep mode, 1 ms after OE goes low.

The OE pin may be used to clear any hardware Faults. When a Fault occurs, the OE input may be used to clear the Fault by setting the pin low and then high again. The Fault is cleared by the rising edge of the OE signal if the hardware Fault is no longer active.

The OE pin is used to enable Sleep mode when the SLEEP bit in the CFG0 Configuration register is set to a '1'. OE must be low for a minimum of ms before the transition to Standby or Sleep mode will occur. This allows time for OE to be toggled, to clear any Faults, without going into Sleep mode.

The OE pin has an internal 51 kΩ pull-down to ground.

## 12.6 Fault Output ($\overline{FAULT}$)

$\overline{FAULT}$ Output pin. The latched open-drain output will go low while a Fault is active. Table 12-5 shows the Faults that cause the $\overline{FAULT}$ pin to go low. The pin will stay low until the Fault is inactive and the OE pin is toggled, from low-to-high, to clear the internal Fault latch.

The $\overline{FAULT}$ pin is able to sink 1mA of current while maintaining less than a 50 mV drop across the output.

The $\overline{FAULT}$ pin will also be active (low) upon initial power-up until the state machine completes the $V_{REG}$ state. This may be used to signal an external host that the driver is ready.

## 12.7 Wake Input (WAKE)

The WAKE pin has an internal 51 kΩ pull-down to ground.

The device will awaken from Sleep mode on a high level of the WAKE pin, lasting for longer than $t_{WAIT\_SETUP}$. The WAKE pin is capable of operating at voltage levels up to $HV_{DD}$.

**Note:** The WAKE pin of the device has different requirements between revisions D2 and D3. See Table 12-1 for details between the two revisions.

**TABLE 12-1: WAKE PIN REVISION DETAILS**

| Revision | WAKE Pin | Requirement to Wake Device from Sleep Mode |
|---|---|---|
| **D2** | Edge Sensitive | $t_{WAIT}$ > $t_{WAIT\_SETUP}$ before sending rising-edge to WAKE pin |
| **D3** | High-Level Sensitive | Maintain a high level on the WAKE pin lasting > than $t_{WAIT\_SETUP}$ |

## 12.8 Motor Phase Inputs (PHA, PHB, PHC)

Phase signals from the motor. These signals provide a high-side N-channel MOSFET driver bias reference and Back EMF sense input. The phase signals are also used with the bootstrap capacitors to provide a high-side gate drive via the VBx inputs.

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## 12.9 High-Side N-MOSFET Gate Driver Outputs (HSA, HSB, HSC)

High-Side N-Channel MOSFET Gate Drive signals. Connect to the gate of the external MOSFETs. A resistor and gate-to-source capacitor may be used between HSA, HSB and HSC pins and the MOSFET gates to limit a phase node slew rate and MOSFET current.

## 12.10 Bootstrap Inputs (VBA, VBB, VBC)

High-side MOSFET driver bias. Connect the VBA, VBB and VBC pins between the bootstrap charge pump diode cathode and the bootstrap charge pump capacitor. The VBOOT output is used to provide the bootstrap supply voltage at the diode anodes. The phase signals are connected to the other side of the bootstrap charge pump capacitors. The bootstrap capacitors charge to VBOOT when the phase signals are pulled low by the low-side drivers. When the low-side drivers turn off and the high-side drivers turn on, the phase signal is pulled to HVDD, causing the bootstrap voltage to rise to HVDD + 12V.

## 12.11 Low-Side N-MOSFET Gate Driver Outputs (LSA, LSB, LSC)

Low-Side N-Channel MOSFET Drive signals. Connect to the gate of the external MOSFETs. A resistor and gate-to-source capacitor may be used between the LSA, LSB and LSC pins and the MOSFET gates to limit current and slew rate.

## 12.12 Bootstrap Supply (VBOOT)

Bootstrap Supply voltage regulator output. The VBOOT regulator output may be used to power external devices, such as Hall effect sensors or amplifiers. The regulator output requires an output capacitor for stability. The positive side of the output capacitor should be physically located as close to the VBOOT pin as is practical. A minimum capacitance of 4.7 µF is required to ensure stable operation of the VBOOT circuit. Larger capacitances may be used to increase transient performance. The VBOOT regulator is supplied by the internal charge pump when the charge pump is active. When the charge pump is inactive, the VBOOT regulator is supplied by HVDD.

The type of capacitor used may be ceramic, tantalum or aluminum electrolytic. The low-ESR characteristics of the ceramic will yield better noise and PSRR performance at high frequency.

## 12.13 +3.3V (VREG)

The VREG LDO may be used to power external devices, such as Hall effect sensors, amplifiers or host processors. The VREG LDO is enabled when the device is not in Sleep mode and the supply voltage is above the device shutdown voltage. The LDO requires an output capacitor for stability. The positive side of the output capacitor should be physically located as close to the VREG pin as is practical. For most applications, a minimum 4.7 µF of capacitance will ensure stable operation of the LDO circuit. Larger capacitances may be used to increase transient performance.

The type of capacitor used may be ceramic, tantalum or aluminum electrolytic. The low-ESR characteristics of the ceramic will yield better noise and PSRR performance at high frequency.


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## 12.14 Power Supply Input (HVDD)

Connect HVDD to the main supply voltage. This voltage should be the same as the motor voltage. The driver overcurrent and overvoltage shutdown features are relative to the HVDD pin. When the HVDD voltage is separate from the motor voltage, the overcurrent and overvoltage protection features may not be available.

The HVDD voltage must not exceed the maximum operating limits of the device. Connect a bulk capacitor close to this pin for good load step performance and transient protection. The actual capacitance should be equal to or larger than the sum of the capacitors attached to the driver supply outputs. The attached capacitors are the VREG, VBOOT and VBx (three bootstrap capacitors) and the charge pump capacitances.

**EQUATION 12-1: HVDD BULK CAPACITOR CALCULATION**

$$CHV_{DD} \geq CV_{REG} + CV_{BOOT} + (3 \times CV_{BX}) + C_{CAPx}$$

The type of capacitor used may be ceramic, tantalum or aluminum electrolytic. The low-ESR characteristics of the ceramic will yield lower voltage drop, better noise and PSRR performance at high frequency.

## 12.15 Charge Pump Flying Capacitor (CAP1, CAP2)

Charge Pump Flying Capacitor connections. Connect the charge pump capacitor across these two pins. The charge pump flying capacitor supplies the power for the VBOOT voltage regulator when the charge pump is active.

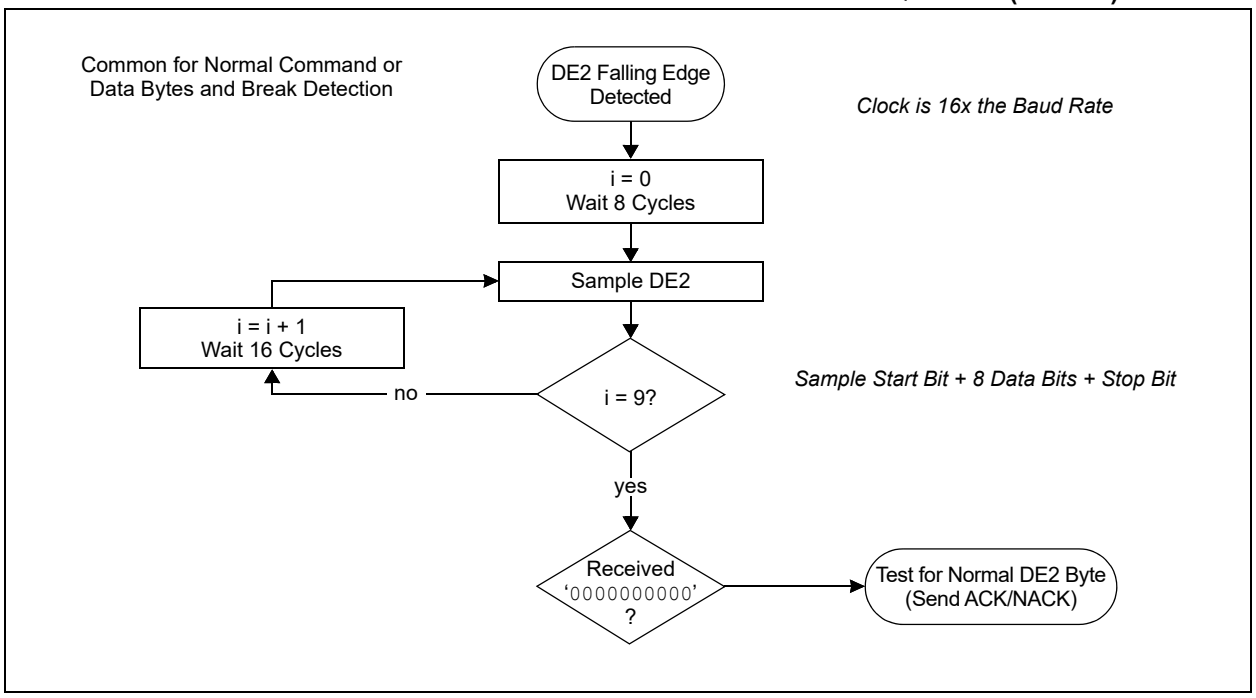
A Schottky diode between the CAP1 pin and HVSS is recommended to ensure that the CAP1 pin absolute minimum voltage specification of -0.3V is maintained.

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## 12.16 State Diagram

### 12.16.1 DE2 RECEIVE AND AUTO-BAUD SEQUENCE

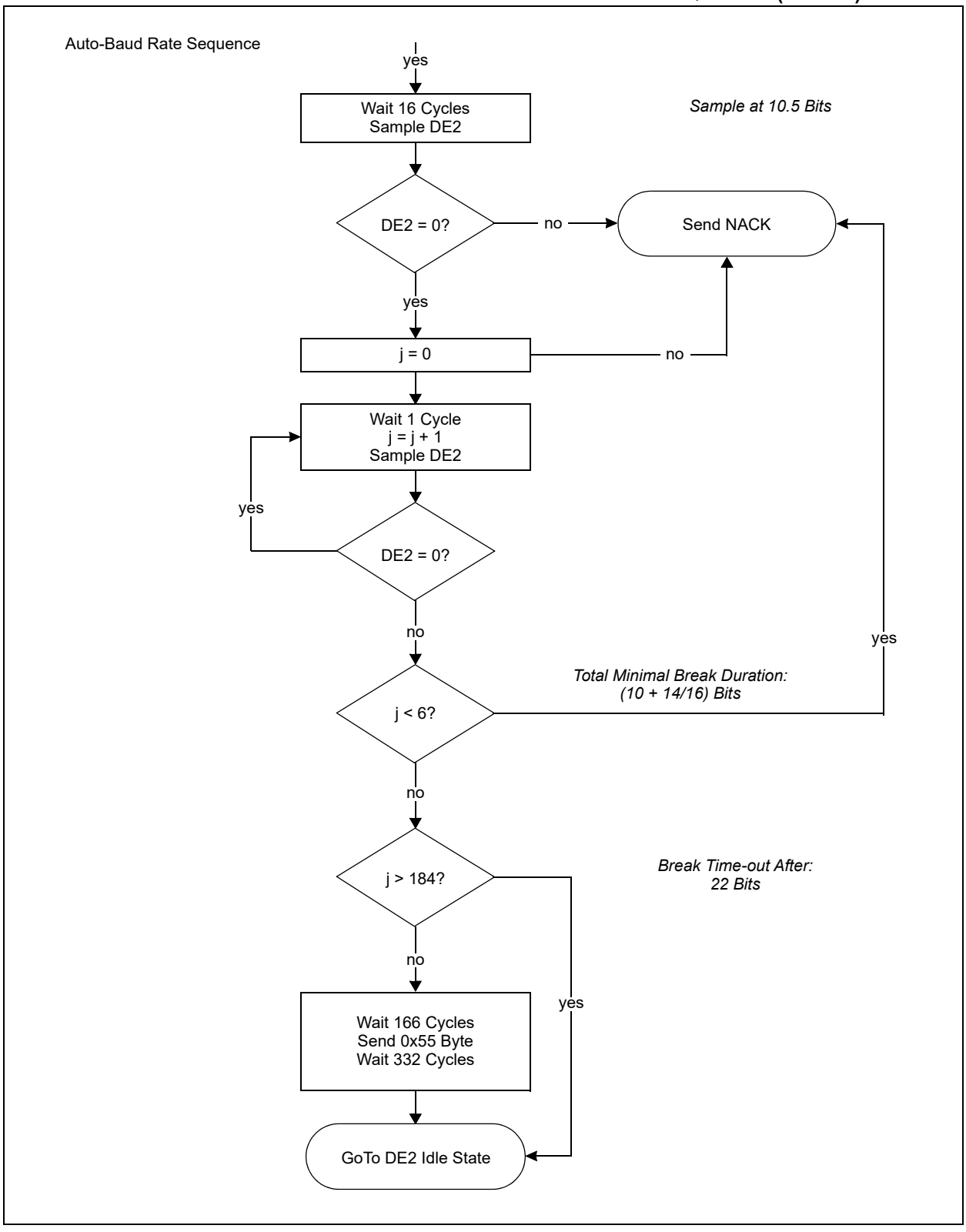
**FIGURE 12-3: DE2 DATA RECEPTION AND AUTO-BAUD RATE SEQUENCE (PART 1)**





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**FIGURE 12-4: DE2 DATA RECEPTION AND AUTO-BAUD RATE SEQUENCE (PART 2)**



## 12.17 Bias Generator

The internal bias generator controls several voltage rails. Two fixed output low-dropout linear regulators, internal bias supply LDOs and a charge pump are controlled through the bias generator. In addition, the bias generator performs supervisory functions.

### 12.17.1 CHARGE PUMP

An unregulated charge pump is utilized to boost the input to the VBOOT voltage regulator during low input supply voltage conditions. When the HVDD supply voltage drops below the CPSTART voltage, the charge pump is activated. When activated, 2 x HVDD is presented to the input of the VBOOT regulator. The charge pump is capable of maintaining a VBOOT output of +9V @ 15 mA for a HVDD supply voltage of 5.25V to 7V. The charge pump is capable of maintaining a VBOOT output of +12V @ 20 mA for a supply input voltage of 7V to 13.5V. The charge pump is disabled and bypassed at HVDD voltages above 13.5V, allowing an output voltage of +12V @ 30 mA.

The charge pump requires a capacitor between pins, CAP1 and CAP2. A typical charge pump capacitor should be a 0.1 µF to 1 µF ceramic capacitor.

### 12.17.2 VBOOT VOLTAGE REGULATOR

The VBOOT voltage regulator rail is used to supply bias voltage for the integrated 3-phase power MOSFET bridge drivers.

The regulator is capable of supplying 30 mA of external load current. The regulator has a minimum overcurrent limit of 40 mA.

The regulator gets its power from the integrated charge pump. When operating at supply voltages (HVDD) that are above +13.5V, the integrated charge pump will be disabled and the HVDD supply will power the VBOOT voltage regulator. The VBOOT regulator output may be lower than the designed voltage, while operating in the HVDD range of +12.5V to +13.0V, due to the dropout voltage of the regulator.

The VBOOT regulator requires an output capacitor, connected from VBOOT to LIN_VSS, to stabilize the internal control loop and to sustain the bootstrap capacitor energy. A minimum of 4.7 µF ceramic output capacitance is required for the VBOOT voltage regulator output; 10 µF is recommended when switching large MOSFET gate loads. The output capacitor forces a time delay between setting the OE pin high (to transition from Standby mode to Active mode) and the VBOOT regulator voltage output rising above the voltage required to set an internal VBOOT ready flag. The PWM inputs must not be activated while the VBOOT output is charging the output capacitors to the VBOOT ready voltage (typically 6.0V). The time required before allowing the PWM inputs to become active, after setting OE high to transition from Standby mode to Active mode, is dependent on output capacitance, any extra loads and supply voltage ramp-up time. The user should allow a minimum time of 0.94 ms for the VBOOT output voltage to rise above the VBOOT ready voltage. A voltage of 6V and supply current of 30 mA may be used for this delay estimation. See Equation 12-2.

**EQUATION 12-2: OE PIN HIGH TO VBOOT READY**

$$dt = (C \times dV)/(I)$$
$$dt = (4.7\ \mu F \times 6V)/(30\ mA)$$
$$dt = 0.94\ ms$$

There is a time-out function that allows the state machine to move from VBOOT to active after 15 ms, regardless of the VBOOT ready voltage. This time-out function prevents the driver from hanging up if the VBOOT voltage is overloaded.

There is also a capacitive voltage divider formed by the three bootstrap capacitors and the VBOOT capacitor. The VBOOT capacitor should be selected so that when the VBOOT supply is active and the bootstrap capacitors are charged, the voltage at the bootstrap capacitors will be greater than the driver undervoltage shutdown voltage, 4.5V. For a system with VBOOT = 12V, $V_{MIN}$ = 4.5V and N = 3 x 1 µF CBOOTSTRAP capacitors charging at the same time, the desired CVBOOT capacitor is 1.8 µF (see Equation 12-3). Since the VBOOT supply requires a 4.7 µF capacitor, a 4.7 µF capacitor should be used. The initial voltage seen by the bootstrap capacitors using a 4.7 µF VBOOT capacitor will be 7.32V. See Equation 12-4.

**EQUATION 12-3: VBOOT CAPACITOR**

$$CV_{BOOT} = \frac{(N \times C_{BOOTSTRAP})}{(V_{BOOT}) \div (V_{MIN}) - 1}$$

**EQUATION 12-4: BOOTSTRAP VOLTAGE**

$$V_{BOOTSTRAP} = \frac{(V_{BOOT} \times CV_{BOOT})}{(CV_{BOOT} + N \times C_{BOOTSTRAP})}$$

The VBOOT output is disabled when the driver transitions to Standby or Sleep mode.

Table 12-5 shows the Faults that will also disable the VBOOT voltage regulator.


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### 12.17.3 VREG LOW-DROPOUT (LDO) LINEAR REGULATOR

The 3.3V VREG LDO is used for internal gate control logic and can also be used to power the host dsPIC DSC.

The VREG LDO is capable of supplying 70 mA of external load current. The regulator has a minimum overcurrent limit of 80 mA. When the regulator current exceeds the overcurrent limit, the regulator will enter a True Current and Voltage Foldback mode based upon load impedance. As the load impedance decreases towards zero ohms, the regulator output current and voltage will also decrease until the final foldback current and voltage are attained.

When the regulator output voltage drops below the VREG undervoltage limit, the VREGUVF Undervoltage Fault bit will be set in the STAT1 register. The regulator will remain active during the Fault. Table 12-2 shows the registers and bits associated with Faults.

The VREG LDO will be disabled when the HVDD supply voltage Undervoltage Fault occurs. The VREG LDO will be re-enabled when the conditions in **Section 12.18.1 "Voltage Supervisor"** are met.

A minimum of 4.7 µF ceramic output capacitance is required for the VREG LDO; 10 µF is recommended to increase transient performance if supplying the host dsPIC DSC.

The VREG LDO is disabled while the system is in Sleep mode.

## 12.18 Supervisor

The bias generator incorporates a voltage supervisor and a temperature supervisor.

### 12.18.1 VOLTAGE SUPERVISOR

The voltage supervisor protects the MOSFET Gate Driver, external power MOSFETs and the host dsPIC DSC from damage due to overvoltage or undervoltage of the input supply, HVDD.

In the event of an undervoltage condition HVDD < UVLOACT, overvoltage condition, HVDD > UVLOACT or VREG LDO undervoltage condition VREG < VREGUVFACT, the gate drivers, charge pump and VBOOT regulator are switched off. The bias generator, communication port, operational amplifiers and the remainder of the motor control unit remain active. The Failure state is flagged on the FAULT pin, and a DE2 status message is sent.

In extreme overvoltage conditions, HVDD > OVSHDNACT, the VREG LDO will be shut down as soon as pin OE is set to a low level. The OVSHDN status flag in the STAT0 register will be set and will remain set until the register is read by a host. The DE2 communications link will be disabled together with the VREG LDO. No Fault message will be sent to the host because the device must shut down immediately to prevent high-voltage damage. The VREG LDO will be re-enabled when the HVDD supply voltage drops below the Overvoltage Lockout value, OVLOINACT.

In the event of a severe undervoltage condition, HVDD < UVSHDNACT, the entire device will shut down except for the minimal circuitry required for a Power-on Reset recovery. A UVSHDN Fault will be set. The VREG output will be turned off and pulled low to create a "clean" shutdown of an attached host processor. The Undervoltage Shutdown condition is a Latched state. The state machine will be restarted from the Power-on Reset state when either of the following two conditions are met:

1. HVDD power is cycled.
2. HVDD rises above UVLOINACT (6.0V).

### 12.18.2 TEMPERATURE SUPERVISOR

An integrated temperature sensor self-protects the device circuitry. If the temperature rises above the overtemperature shutdown threshold, all device functions are turned off except for those required to send a DE2 Fault message. A Fault will be generated and a DE2 Fault message will be sent. The functions required to send the DE2 Fault message will then be shut down if pin OE is set to a low level. Active operation resumes when the temperature has cooled down below a set hysteresis value and the Fault has been cleared by toggling the OE pin from a logic low to a logic high.

It is desirable to signal the host dsPIC DSC with a warning message before the overtemperature threshold is reached. When the Thermal Warning Temperature (TWARN) set point is exceeded, the DE2 temperature warning will be sent to the host dsPIC DSC. The warning message has no effect upon driver operation. The host dsPIC DSC may then take appropriate actions to reduce the temperature rise.

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## 12.19 Output Enable (OE)

The Output Enable (OE) pin allows the device outputs to be disabled by external control. The Output Enable pin has three modes of operation.

### 12.19.1 FAULT CLEARING STATE

The OE pin is used to clear any Faults and re-enable the driver. After toggling the OE pin low-to-high, the system requires a minimum time period to re-enable and start up all of the driver blocks. The start-up time is approximately 35 µs. The maximum pulse time for the high-low-high transition to clear the Faults should be less than 900 µs to prevent the system from transitioning through Standby mode. If the high-low-high transition is longer than 1 ms, the device will start up from the Standby state.

Any Fault status bits that are set will be cleared by the low-to-high transition of the OE pin, if and only if, the Fault condition has ceased to exist. If the Fault condition still exists, the active Fault status bit will remain active. No additional Fault messages will be sent for a Fault that remains active.

### 12.19.2 STANDBY STATE

Standby state is entered when the OE pin goes low for longer than 1 ms and the SLEEP Configuration bit is inactive. When Standby mode is entered, the following subsystems are disabled:

- High-side gate drives (HSA, HSB, HSC) forced low
- Low-side gate drives (LSA, LSB, LSC) forced low
- VBOOT LDO
- Charge pump
- Operational amplifiers if CFG0[6] = 1
- The VREG LDO and DE2 communications stay active.

### 12.19.3 SLEEP MODE

Sleep mode is entered when both a SLEEP command is sent to the device via DE2 communications and the OE pin is low. The two conditions may occur in any order. The transition to Sleep mode occurs after the last of the two conditions occurs. The SLEEP bit in the CFG0 Configuration register indicates when the device should transition to a low-power mode. The device will operate normally until the OE pin is transitioned low by an external device. At that point in time, the SLEEP bit value determines whether the device transitions to Standby mode or low-power Sleep mode. The Supply Current (ISUP) during Sleep mode will typically be 5µA. When Sleep mode is activated, most functions will be shut off, including the VREG LDO. Only the Power-on Reset monitor and minimal state machine will remain active to detect a wake-up event. This indicates that the host processor will be shut down if the host is using the VREG LDO regulator for power. The device will stay in the low-power Sleep mode until either of the following conditions is met:

- The WAKE pin receives a signal corresponding with tWAKE_SETUP. Table 12-1 specifies the signal conditions based on the device revision.
- Power is cycled.

The MOSFET Gate Driver is not required to retain configuration data while in Sleep mode. When exiting Sleep mode, the host should send a new configuration message to configure the device if the default configuration values are not desired. The same configuration sequence used during power-up may be used when exiting Sleep mode.

When activated, Sleep mode will always be entered regardless of any active Fault. This allows a transition to Sleep mode when the host is powered by the VREG LDO and the regulator is in an unreliable state. The SLEEP bit in the Configuration register will be ignored at power-up until the system has enabled the $V_{REG}$ LDO and the $V_{REG}$ LDO has entered regulation.

## 12.20 Faults

### 12.20.1 FAULT PIN OUTPUT ($\overline{FAULT}$)

The $\overline{FAULT}$ pin is used as a Fault indicator. The pin is capable of sinking a minimum of 1 mA of current while maintaining less than 50 mV of voltage across the output. An external pull-up resistor to the logic supply is required.

The open-drain $\overline{FAULT}$ pin transitions low when a Fault occurs. Table 12-2 lists the Faults that activate the $\overline{FAULT}$ signal. Warnings do not activate the $\overline{FAULT}$ signal; Table 12-3 lists the warnings.

### 12.20.2 FAULT HANDLING SEQUENCE

When a Fault occurs, the following steps will occur in sequence.

1. The gate drive outputs will be immediately turned off.
2. The $\overline{FAULT}$ pin output will go low.
3. A message will be sent via the DE2 communications link if, and only if, the Fault is not a HVDD Overvoltage Shutdown (OVSHDNACT).
4. The VREG LDO will be disabled immediately if the Fault is a HVDD Overvoltage Shutdown (OVSHDNACT) or a HVDD Undervoltage Shutdown (UVSHDNACT) Fault.
5. The VREG LDO will be disabled 5 ms after the DE2 message has been sent for an Overtemperature Shutdown (OTSHDN) Fault.


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### 12.20.3 FAULT INDICATOR

A “FAULT” indicator bit resides in the STAT0 register. The bit is the logical ‘OR’ of all of the Fault bits in the two Status registers. Warnings are not included in the FAULT indicator bit.

The FAULT bit will allow the user to read the STAT0 register in order to determine if a Fault is present in the system. If the bit is set, then the user may request the STAT1 message and interrogate the bits of both status messages to determine what Faults exist.

The Faults that are logically OR’d together to generate the FAULT bit are as follows:

- STAT0:OTPF
- STAT0:UVLOF
- STAT0:OVLOF
- STAT1:REGUVF
- STAT1:XUVLOF
- STAT1:XOCPF

**TABLE 12-2: FAULTS**

| Fault | DE2 Message |
|---|---|
| Fault Active (‘OR’ of all Faults) | 0x85 0x01 |
| Overtemperature | 0x85 0x04 |
| HVDD Input Undervoltage | 0x85 0x08 |
| HVDD Input Overvoltage | 0x85 0x10 |
| VREG Output Undervoltage | 0x86 0x01 |
| External MOSFET Undervoltage Lockout | 0x86 0x04 |
| External MOSFET Overcurrent Detection | 0x86 0x08 |

**TABLE 12-3: WARNINGS**

| Fault | DE2 Message |
|---|---|
| Temperature Warning | 0x85 0x02 |

### 12.20.4 POWER CONTROL STATUS (PCON)

The PCON[2:0] (STAT0[7:5]) bits are Power Control status bits that may be used to determine the cause of a shutdown. They are not Fault latches. The HVDD Overvoltage Shutdown Fault is an internally latched Fault that does not have a latched FAULT bit in the STAT0 or STAT1 register. That is because the device will be shut down immediately upon entering the Overvoltage Fault condition. When power is back within the device operating range, and the VREG supply is re-enabled, the host will be able to read the STAT0 register to determine the reason for a power cycle. The PCON power status bits will contain the cause of the power cycle. Table 12-4 lists the Power Status register bits in the STAT0 register.

**TABLE 12-4: POWER STATUS**

| PCON[2:0] Status Bits (STAT0[7:5]) | DE2 Message |
|---|---|
| Overtemperature Shutdown (OTSHDN) occurred | 0x85 0xA0 |
| HVDD Overvoltage Shutdown (OVSHDN) occurred | 0x85 0x80 |
| Sleep occurred | 0x85 0x60 |
| HVDD Undervoltage Shutdown (UVSHDN) occurred | 0x85 0x40 |
| Power-on Reset (POR) occurred | 0x85 0x20 |
| Normal operation | 0x85 0x00 |

#### 12.20.4.1 Internal Function Block Status

Table 12-5 shows the effects of the OE pin, Faults and the SLEEP bit upon the functional status of the internal blocks of the dsPIC33CDVL64MC106 family.

#### 12.20.4.2 Start-up/$\overline{\text{FAULT}}$ Pin State

During device start-up or Power-on Reset (POR), the $\overline{\text{FAULT}}$ pin will stay active (low) to indicate to the host that the device is initializing. The $\overline{\text{FAULT}}$ pin will stay active until the state machine powers up the VREG LDO and completes the VREG state. After the VREG LDO is powered up, the $\overline{\text{FAULT}}$ pin logic checks the state of all of the latched FAULT bits. If any FAULT bit is still active, the $\overline{\text{FAULT}}$ pin will stay active and remain low.

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**TABLE 12-5: INTERNAL FUNCTION BLOCK STATUS**

| System State | Fault | Conditions | Sleep Latch | $V_{REG}$ LDO | $V_{BOOT}$ LDO | Motor Drivers | DE2 | Op Amps | Internal UVLO, OVLO, OTP |
|---|---|---|---|---|---|---|---|---|---|
| Sleep | | OE = 0, SLEEP = 1 | W | — | — | — | — | — | — |
| Standby | | OE = 0, SLEEP = 0 | — | A | — | — | A | C | A |
| Operating | | OE = 1, $\overline{FAULT}$ = 1 | — | A | A | A | A | A | A |
| Faults<br>$\overline{FAULT}$ = 0 | Driver OTPF | $T_J$ Temperature > +160°C | — | — | — | — | D | — | A |
| | $HV_{DD}$UVLO | $HV_{DD} \leq UVLO_{INACT}$ | — | A | — | — | A | A | A |
| | $HV_{DD}$UVSHDN | $HV_{DD} \leq UVSHDN_{INACT}$ | — | — | — | — | E | — | — |
| | $HV_{DD}$OVLO | $HV_{DD} \geq OVLO_{INACT}$ | — | A | — | — | A | A | A |
| | $V_{DD}$OVSHDN | $HV_{DD} \geq OVSHDN_{INACT}$ | — | — | — | — | — | — | A |
| | $V_{REG}$ LDO UVF | $V_{REG} \leq$ 88% $V_{REG}$ | — | A | — | — | A | A | A |
| | MOSFET UVLO | $V_{HS[A:C]} < V_{DUVLO}$<br>$V_{LS[A:C]} < V_{DUVLO}$ | — | A | A | — | A | A | A |
| | MOSFET OCPF | $V_{DRAIN\ SOURCE}$ > EXTOC[1:0] setting | — | A | A | — | A | A | A |
| Warnings<br>$\overline{FAULT}$ = 1 | Driver Temperature | $T_J$ Temperature > 72% $T_{SD\_MIN}$ (+115°C for +160°C driver OTP) | — | A | A | A | A | A | A |
| Power Status | Configuration lost if Power-on Reset, wake from Sleep or recover from $HV_{DD}$ Undervoltage Shutdown occurred | Set at initial power-up when $HV_{DD} < UVSHDN_{ACT}$ or when waking from Sleep | — | A | A | A | A | A | A |

**Legend:** — = Inactive (Off); A = Active (On); C = Configurable; D = Inactive (Off) 5 ms after sent Fault message; E = Inactive (Off); R = Receiver Only; W = Wake-up (from Sleep); OCPF = Overcurrent Protection; OTPF = Overtemperature Protection; UVLO = Undervoltage Lockout; OVLO = Overvoltage Lockout; UVF = Undervoltage Fault; UVSHDN = Undervoltage Shutdown; OVSHDN = Overvoltage Shutdown


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## 12.21 Motor Control Unit

The motor control unit is comprised of the following:

- External Drive for a 3-Phase Bridge with NMOS/NMOS MOSFET Pairs
- MOSFET Driver Undervoltage Lockout
- External MOSFET Short-Circuit Current
- $\overline{\text{FAULT}}$ Pin Output
- Cross Conduction Protection
- Programmable Dead Time
- Programmable Blanking Time

### 12.21.1 EXTERNAL DRIVE FOR A 3-PHASE BRIDGE WITH NMOS/NMOS MOSFET PAIRS

Each motor phase is driven with external NMOS/NMOS MOSFET pairs. These are controlled by a low-side and a high-side gate driver. The gate drivers are controlled by the host dsPIC PWM interconnects found in Table 1-1. A logic high turns the associated gate driver on, and a logic low turns the associated gate driver off.

The low-side gate drivers are biased by the $V_{BOOT}$ regulator output, referenced to ground. The high-side gate drivers are a floating drive biased by a bootstrap capacitor circuit. The bootstrap capacitor is charged by the $V_{BOOT}$ regulator whenever the accompanying low-side MOSFET is turned on.

The high-side and low-side driver outputs all go to a Low state whenever there is a Fault, when OE = `0` for more than 1 ms or when Sleep mode is active, regardless of the PWM[A:C]H/L inputs.

### 12.21.2 MOSFET GATE DRIVER UNDERVOLTAGE LOCKOUT (UVLO)

The MOSFET Gate Driver Undervoltage Lockout Fault detection monitors the available voltage used to drive the external MOSFET gates. The Fault detection is only active while the driver is actively driving the external MOSFET gate. Any time the driver bias voltage is below the gate drive Undervoltage Lockout Threshold ($V_{DUVLO}$) for a time longer than specified by the $t_{DUVLO}$ parameter, the driver will not turn on when commanded on. A driver Fault will be indicated to the host dsPIC DSC on the $\overline{\text{FAULT}}$ open-drain output pin and also via a DE2 communications `Status_1` message. This is a latched Fault. Clearing the Fault requires either removal of device power or disabling and re-enabling the device via the device Output Enable (OE) input. The EXTUVLO bit in the CFG0 register is used to enable or disable the driver Undervoltage Lockout feature. This protection feature prevents the external MOSFETs from being controlled with a gate voltage not suitable to fully enhance the device.

### 12.21.3 EXTERNAL MOSFET SHORT-CIRCUIT CURRENT

Short-circuit protection monitors the voltage across the external MOSFETs during an On condition. The high-side driver voltage is measured from $HV_{DD}$ to PH[A:C]. The low-side driver voltage is measured from PH[A:C] to ground. If a monitored voltage rises above a user-configurable threshold after the driver HS[A:C] or LS[A:C] output voltage has been driven high, all drivers will be turned off. A driver Fault will be indicated to the host dsPIC DSC on the open-drain $\overline{\text{FAULT}}$ output pin and also via a DE2 communications `Status_1` message. This is a latched Fault. Clearing the Fault requires either removal of device power or toggling the OE input pin low-to-high. This protection feature helps detect internal motor failures, such as winding to case shorts.

> **Note:** The driver short-circuit protection is dependent on application parameters. A configuration message is provided for a set number of threshold levels. The MOSFET Gate Driver UVLO and short-circuit protection features have the option to be disabled.

The short-circuit voltage may be set via a DE2 `Set_Cfg_0` message. The EXTOC[1:0] bits of the CFG0 register are used to select the voltage level for the short-circuit comparison. If a monitored voltage differential between $HV_{DD}$ and PH[A:C], or between PH[A:C] and $P_{GND}$, exceeds the selected voltage level when the MOSFET Gate Driver is active, a Fault will be triggered. The selectable voltage levels are 250 mV, 500 mV, 750 mV and 1000 mV. The EXTSC bit of the CFG0 register is used to enable or disable the MOSFET Gate Driver short-circuit detection.

### 12.21.4 GATE CONTROL LOGIC

The gate control logic enables level shifting of the digital inputs, polarity control and cross conduction protection.

#### 12.21.4.1 Cross Conduction Protection

If both MOSFETs in the same half-bridge are commanded on by the digital PWM inputs, both will be turned off.

#### 12.21.4.2 Programmable Dead Time

The gate control logic employs a break-before-make dead-time delay that is programmable. A configuration message is provided to configure the driver dead time. The programmable dead times range from 250 ns to 2000 ns (default) in 250 ns increments. The dead time allows the PWM inputs to be direct inversions of each other and still allow proper motor operation. The dead time internally modifies the PWMH/L gate drive timing to prevent cross conduction. The DRVDT[2:0] bits of the CFG2 register are used to set the dead-time value.

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#### 12.21.4.3 Programmable Blanking Time

A configuration message is provided to configure the driver current limit blanking time. The blanking time allows the driver to ignore any current spikes that may occur when switching the driver outputs. The allowable blanking times are 500 ns, 1 µs, 2 µs and 4 µs (default). The blanking time will start after the dead-time circuitry has timed out. The DRVBL[1:0] bits of the CFG2 register are used to set the blanking time value.

The blanking time also affects the driver undervoltage lockout. The driver undervoltage lockout latches the external MOSFET undervoltage lockout Fault if the undervoltage condition lasts longer than the time specified by the tDUVLO parameter. The tDUVLO parameter takes into account the blanking time if blanking is in progress.

## 12.22 Motor Control

The commutation loop of a BLDC motor control is a Phase-Locked Loop (PLL), which locks to the rotor's position. Note that this inner loop does not attempt to modify the position of the rotor, but modifies the commutation times to match whatever position the rotor has. An outer speed loop changes the rotor velocity, and the commutation loop locks to the rotor's position to commutate the phases at the correct times.

### 12.22.1 SIX-STEP SENSORLESS MOTOR CONTROL

Many control algorithms can be implemented using the dsPIC33CDVL64MC106 devices with the internal MOSFET Gate Driver.

The following information provides a starting point for implementing a 3-phase sensorless motor control application. The motor is driven by energizing two windings at a time and sequencing the windings in a six-step per electrical revolution method. This method leaves one winding unenergized at all times. The voltage (Back EMF or BEMF) on that unenergized winding can be monitored to determine the rotor position.

#### 12.22.1.1 Start-up Sequence

When the motor being driven is at rest, the BEMF voltage is equal to zero. The motor needs to be rotating for the BEMF sensor to lock onto the rotor position and commutate the motor. The recommended start-up sequence is to bring the rotor from rest, up to a speed fast enough to allow BEMF sensing. Motor operation is comprised of five modes: Disabled mode, Bootstrap mode, Lock or Align mode, Ramp mode and Run mode. Refer to the commutation state machine in Table 12-6. The order in which the host dsPIC DSC steps through the commutation state machine determines the direction that the motor rotates.

#### 12.22.1.2 Disabled Mode (OE = 0)

When the driver output is disabled (OE = 0), all of the MOSFET driver outputs are set low.

#### 12.22.1.3 Bootstrap Mode

The high-side driver obtains the high-side biasing voltage from the VBOOT LDO, bootstrap diode and bootstrap capacitor. The bootstrap capacitors must first be charged before the high-side drives may be used. The bootstrap capacitors are all charged by activating all three low-side drivers. The active low-side drivers pull their respective phase nodes low, charging the bootstrap capacitors to the VBOOT LDO voltage. The three low-side drivers should be active for at least 1.2 ms per 1 µF of bootstrap capacitance. This assumes a 12V voltage change and 30 mA (10 mA per phase) of current coming from the VBOOT LDO.

#### 12.22.1.4 Lock Mode

Before the motor can be started, the rotor should be in a known position. In Lock mode, the host dsPIC DSC drives Phase B low and Phases A and C high. This aligns the rotor 30 electrical degrees before the center of the first Commutation state. Lock mode must last long enough to allow the motor and its load to settle into this position.

#### 12.22.1.5 Ramp Mode

At the end of Lock mode, Ramp mode is entered. In Ramp mode, the host dsPIC DSC steps through the commutation state machine, increasing the step rate linearly, until a minimum speed is reached that will result in a usable BEMF voltage. Ramp mode is an open-loop commutation. No knowledge of the rotor position is used.

#### 12.22.1.6 Run Mode

At the end of Ramp mode, Run mode is entered. In Run mode, the Back EMF sensor is enabled and commutation is now under the control of the phase-locked loop. Motor speed can be regulated by an outer speed control loop.


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**TABLE 12-6: COMMUTATION STATE MACHINE**

| State | Outputs | | | | | | BEMF Phase |
|---|---|---|---|---|---|---|---|
| | HSA | HSB | HSC | LSA | LSB | LSC | |
| OE = 0 | OFF | OFF | OFF | OFF | OFF | OFF | N/A |
| BOOTSTRAP | OFF | OFF | OFF | ON | ON | ON | N/A |
| LOCK | ON | OFF | ON | OFF | ON | OFF | N/A |
| 1 | ON | OFF | OFF | OFF | OFF | ON | Phase B |
| 2 | OFF | ON | OFF | OFF | OFF | ON | Phase A |
| 3 | OFF | ON | OFF | ON | OFF | OFF | Phase C |
| 4 | OFF | OFF | ON | ON | OFF | OFF | Phase B |
| 5 | OFF | OFF | ON | OFF | ON | OFF | Phase A |
| 6 | ON | OFF | OFF | OFF | ON | OFF | Phase C |

#### 12.22.1.7 PWM Speed Control

The inner commutation loop is a phase-locked loop, which locks to the rotor's position. This inner loop does not attempt to modify the position of the rotor but modifies the commutation times to match whatever position the rotor has. The outer speed loop changes the rotor velocity, and the inner commutation loop locks to the rotor's position to commutate the phase at the correct times.

The outer speed loop pulse width modulates the motor drive inverter to produce the desired wave shape and voltage at the motor. The inductance of the motor then integrates this PWM pattern to produce the desired average current, thus controlling the desired torque and speed of the motor. For a trapezoidal BLDC motor drive with six-step commutation, the PWM is used to generate the average voltage to produce the desired motor current and motor speed.

There are two basic methods to PWM the inverter switches. The first method returns the reactive energy in the motor inductance to the source by reversing the voltage on the motor winding during the current decay period. This method is referred to as fast decay or chop-chop. The second method circulates the reactive current in the motor with minimal voltage applied to the inductance. This method is referred to as slow decay or chop-coast.

The preferred control method employs a chop-chop PWM for any situations where the motor is being accelerated, either positively or negatively. For improved efficiency, chop-coast PWM is employed during steady-state conditions. The chop-chop speed loop is implemented by hysteretic control, fixed off time control or Average Current mode control of the motor current. This makes for a very robust controller, since the motor current is always in instantaneous control. The motor speed presented to the chop-chop loop is reduced by approximately 9%. A fixed frequency PWM that only modulates the high-side switches implements the chop-coast loop. The chop-coast loop is presented with the full motor speed, so if it is able to control the speed, the chop-chop loop will never be satisfied and will remain saturated. The chop-chop remains able to assume full control if the motor torque is exceeded, either through a load change or a change in speed that produces acceleration torque. The chop-coast loop will remain saturated, with the chop-chop loop in full control, during start-up and acceleration to full speed. The bandwidth of the chop-coast loop is set to be slower than the chop-chop loop so that any transients will be handled by the chop-chop loop and the chop-coast loop will only be active in a steady-state operation.

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## 12.23 DE2 Communication Port

A half-duplex 9600 baud UART interface is available to communicate with the host dsPIC DSC. The port is used to configure the MOSFET Gate Driver and also for status and Fault messages.

### 12.23.1 COMMUNICATIONS INTERFACE

A half-duplex, 9600 baud, 8-bit bidirectional communications interface is implemented on the DE2 interconnect. The interface consists of eight data bits, one Stop bit and one Start bit.

Dedicated UART hardware may be configured through PPS to transmit and receive messages over the DE2 communications interconnect.

The MOSFET Gate Driver side of the interface is an open-drain configuration and requires that the host dsPIC DSC uses an internal pull-up resistor to pull the DE2 interconnect high.

It is also recommended that the user enable open-drain (OCDx = 1) on the DE2 pin on the dsPIC side to allow for utilization of the pull-up, though it is not necessary if the line is properly configured for half-duplex communication.

The auto-baud frequency is temperature-dependent, as illustrated in Figure 12-4. To establish proper DE2 communication, it is recommended to synchronize the host frequency by proceeding the auto-baud function alternatively, as described in **Section 12.23.5 "Auto-Baud Function"**. The time from receiving the last bit of a command message to sending the first bit of the response message ranges from $t_{DE2\_RSP}$ to $t_{DE2\_WAIT}$, corresponding to 0 µs to 3.125 ms. The host should refrain from sending additional messages until the previously requested message has been received in order to prevent overwriting the driver response message.

All DE2 interconnect pin configuration requirements are described in **Section 12.2 "Communications Port (DE2 Interconnect)"** and provided in Example 12-1.

### 12.23.2 PACKET FORMAT

Every internal driver status change will cause the driver to send a message to the host dsPIC DSC. The interface uses a standard UART baud rate of 9600 bits per second.

In the DE2 protocol, the transmitter and the receiver do not share a clock signal. A clock signal does not emanate from one transmitter to the other receiver. Due to this reason, the protocol is asynchronous. The protocol uses only one line to communicate, so the transmit/receive packet must be done in Half-Duplex mode. A new transmit message is allowed only when a complete packet has been transmitted and responded to.

The host must listen to the DE2 line in order to check for contentions. In case of contention, the host must release the line and wait for at least three packet length times before initiating a new transfer.

Figure 12-5 illustrates a basic DE2 data packet.

### 12.23.3 PACKET TIMING

While no data are being transmitted, a logic '1' must be placed on the open-drain DE2 line by the host dsPIC DSC using an internal pull-up resistor. A data packet is composed of one Start bit, which is always a logic '0', followed by eight data bits and a Stop bit. The Stop bit must always be a logic '1'. It takes 10 bits to transmit a byte of data.

The DE2 interface detects the Start bit by detecting the transition from logic '1' to logic '0' (note that while the data line is Idle, the logic level is high). Once the Start bit is detected, the next data bit's center can be assured to be 24 ticks minus 2 (worst-case synchronizer uncertainty) later. From then on, every next data bit center is 16 clock ticks later. Figure 12-6 illustrates this point.

### 12.23.4 MESSAGE HANDLING

The driver will not transition to Sleep mode while a message is being received. If a message reception is in progress before the OE = 0 to Sleep Mode Transition ($t_{SLEEP}$) delay times out, the message will be fully received and the contents applied to the Configuration registers, if applicable. The SLEEP bit will then be checked and the system enters Sleep mode if the SLEEP bit is still active.

### 12.23.5 AUTO-BAUD FUNCTION

The MOSFET Gate Driver provides an auto-baud feature that allows the host dsPIC DSC, communicating on the DE2 communications interconnect, to determine the actual baud rate being used by the MOSFET Gate Driver. The feature allows the host to request a 0x55 byte transmission from the MOSFET Gate Driver. The host then determines the MOSFET Gate Driver baud rate and adjusts the host internal Baud Rate Generator (BRG) to match the MOSFET Gate Driver baud rate.

The DE2 pin is used to trigger the auto-baud feature. The host sets the DE2 signal to a logic low for a period of time (auto-baud Break window) that ranges between 1.29 ms and 2.0 ms. The host then releases the DE2 pin back to the host UART control. The host UART then raises the DE2 pin to a logic high value. The MOSFET Gate Driver will respond with a standard NACK ('0b00nnnnnn', where 'nnnnnn' are the six Least Significant bits (LSbs) received) if the DE2 link was held low for less than 1.29 ms and the byte was not interpreted as a valid command. The MOSFET Gate Driver will ignore the current message if the DE2 link is held low for more than 2.0 ms.


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If the driver receives a valid auto-baud request in the allotted time frame, the driver will enter an Auto-Baud state, indicating an auto-baud message has been requested. When the auto-baud function is activated, the DE2 subsystem will disable sending all unsolicited messages to the host.

If the internal Auto-Baud state is set, the driver will wait for a minimum of 0.86 ms and a maximum of 1.19 ms. After the wait time has expired, a 0x55 data byte will be immediately sent on the DE2 link by the driver.

The driver will wait 2.00 ms after sending the 0x55 baud rate data over the DE2 link before transmitting any other messages. The driver will then exit the Auto-Baud state and resume normal DE2 operations. The 2.00 ms wait is needed to allow the host to complete the auto-baud verification and update the host UART Baud Rate Generator.

The MOSFET Gate Driver will always monitor the DE2 link for a logic low before attempting to transmit.

The MOSFET Gate Driver will preempt all DE2 communications upon receiving a logic low on the DE2 link which lasts longer than ten bit times at 9600 baud (Break sequence).

The MOSFET Gate Driver will wait for a period up to 2 ms for the DE2 link to change to a Logic High state after the initial detection of a logic low on the DE2 link. If the DE2 link fails to rise to a logic high level within 2 ms of the initial logic low level, the auto-baud message will be canceled and no message will be sent. The auto-baud function will then be complete.

The driver will send any pending unsolicited messages after the auto-baud function has finished.

### 12.23.6 MESSAGING INTERFACE

A command byte will always have the Most Significant bit (MSb) 7 set to '1'. Bits 6 and 5 are reserved for future use and should be set to '0'. Bits[4:0] are used for commands; that allow for 32 possible commands.

#### 12.23.6.1 Host dsPIC DSC to MOSFET Gate Driver

Messages sent from the host dsPIC DSC to the MOSFET Gate Driver consist of either one or two 8-bit bytes. The first byte transmitted is the command byte. The second byte transmitted, if required, is the data for the command.

If a multibyte command is sent to the MOSFET Gate Driver and no second byte is received by the MOSFET Gate Driver, then a "Command Not Acknowledged" message will be sent back to the host afterwards. The host must start sending the 2nd byte of a two-byte command within 1 ms of completion of the first byte to prevent a NACK message. Once the second byte Start bit is received, the MOSFET Gate Driver internal receiver logic will handle the reception of the data byte. If the data byte Stop bit is not received within the expected reception time for the last received bit, the driver will respond with a NACK message.

#### 12.23.6.2 MOSFET Gate Driver to Host dsPIC DSC

A solicited response byte from the MOSFET Gate Driver will always echo the command byte with bit 7 set to '0' (response) and with bit 6 set to '1' for Acknowledged (ACK) or '0' for Not Acknowledged (NACK). The second byte, if required, will be the data for the host command. Any command that causes an error or is not supported will receive a NACK response.

The MOSFET Gate Driver may send unsolicited command messages to the host dsPIC DSC. All messages to the host controller do not require a response from the host controller.

### 12.23.7 MESSAGES

#### 12.23.7.1 SET_CFG_0

There is a SET_CFG_0 message that is sent by the host dsPIC DSC to the MOSFET Gate Driver to configure the driver. The SET_CFG_0 message may be sent to the driver at any time. The host is responsible for making sure the system is in a state that will not be compromised by sending the SET_CFG_0 message. The SET_CFG_0 message format is indicated in Table 12-7. The response is indicated in Table 12-8.

#### 12.23.7.2 GET_CFG_0

There is a GET_CFG_0 message that is sent by the host dsPIC DSC to the dsPIC33CDVL64MC106 device to retrieve the device Configuration register. The GET_CFG_0 message format is indicated in Table 12-7. The response is indicated in Table 12-8.

#### 12.23.7.3 STATUS_0 and STATUS_1

There are STATUS_0 and STATUS_1 messages that are sent by the host dsPIC DSC to the MOSFET Gate Driver to retrieve the device STAT0 and STAT1 registers. Unsolicited STATUS_0 and STATUS_1 messages may also be sent to the host by the MOSFET Gate Driver to inform the host of status changes. The unsolicited STATUS_0 and STATUS_1 messages will only be sent when a status bit changes to an Active state. The STATUS_0 and STATUS_1 message format is indicated in Table 12-7. The response is indicated in Table 12-8.

When a STATUS_0 or STATUS_1 message is sent to the host dsPIC DSC in response to a new Fault becoming active, the FAULT bit will be cleared, either by the host issuing a STATUS_0 or STATUS_1 request message, or by the host toggling the OE pin low then

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high. The FAULT bit will stay active and not be cleared if the Fault condition still exists at the time the host attempted to clear the Fault.

The PCONx bits of the STAT0 register will be set every time the device restarts due to various events (see Table 12-4). When the driver resumes operation, a single unsolicited STATUS_0 message will be sent to the host dsPIC DSC indicating a Reset has occurred. The message will be sent five milliseconds (5 ms) after the VREG LDO has reached its Active state. The host should check the PCONx bits to determine the cause of the power cycle. In all cases, the configuration data may have been and should be resent to the driver. The PCONx flags are reset by a host STATUS_0 request message. If the host misses the unsolicited STATUS_0 message at start-up, the host may manually request the status by sending a STATUS_0 message to the driver. The PCONx bits of the STAT0 register will contain the source of the Power-on Reset until the STAT0 register is requested by the host.

#### 12.23.7.4 SET_CFG_2

There is a SET_CFG_2 message that is sent by the host dsPIC DSC to the MOSFET Gate Driver to configure the driver current limit blanking time. The SET_CFG_2 message may be sent to the devices at any time. The host is responsible for making sure the system is in a state that will not be compromised by sending the SET_CFG_2 message. The SET_CFG_2 message format is indicated in Table 12-7. The response is indicated in Table 12-8.

#### 12.23.7.5 GET_CFG_2

There is a GET_CFG_2 message that is sent by the host dsPIC DSC to the MOSFET Gate Driver to retrieve the device Configuration Register #2. The GET_CFG_2 message format is indicated in Table 12-7. The response is indicated in Table 12-8.

**FIGURE 12-5: DE2 PACKET FORMAT**

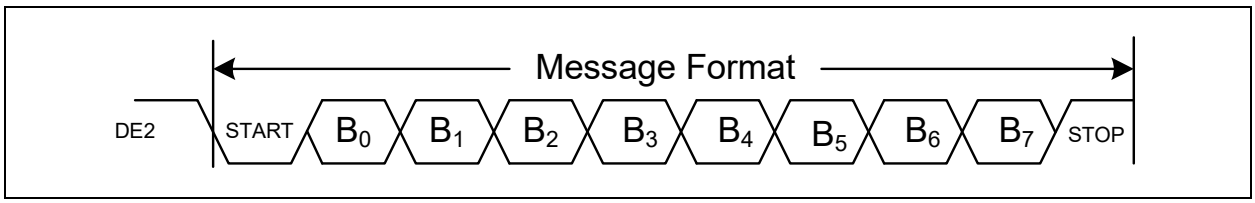
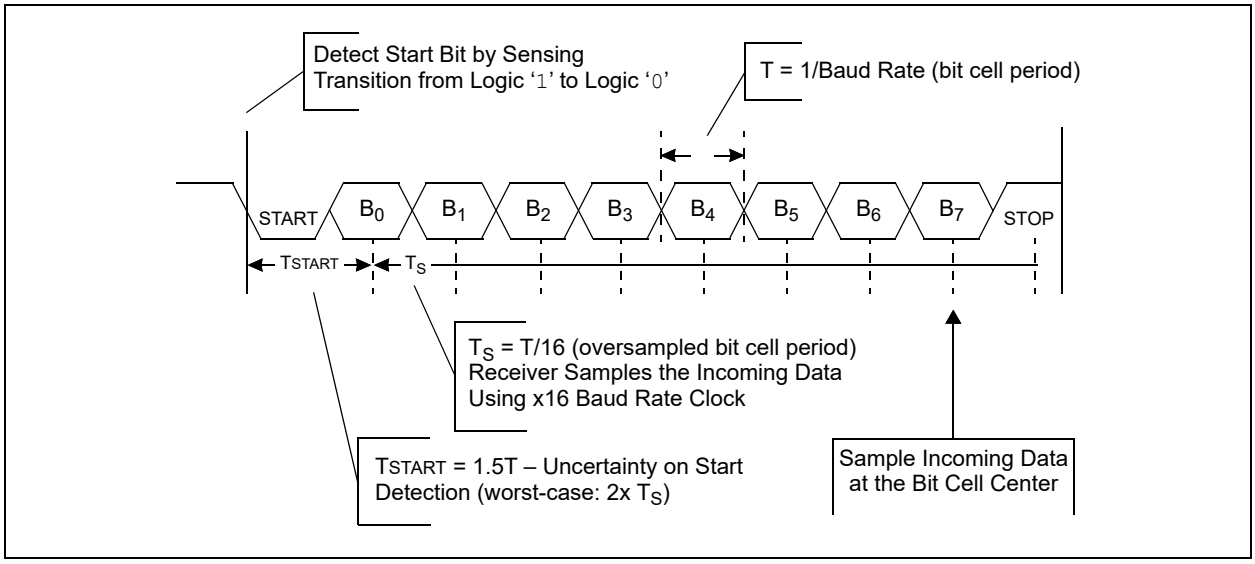



**FIGURE 12-6: DE2 PACKET TIMING**





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**TABLE 12-7: DE2 COMMUNICATION COMMANDS FROM HOST TO dsPIC33CDVL64MC106**

| Command | Byte | Bit | Value | Description |
|---|---|---|---|---|
| SET_CFG_0 | 1 | | 10000001 (81h) | Set Configuration Register 0 |
| | 2 | 7 | 0 | Reserved |
| | | 6 | 0 | Reserved |
| SET_CFG_0 | | 5 | 0 | System enters Standby mode when OE = 0, SLEEP = 0 for more than 1 ms. |
| | | | 1 | System enters Sleep mode when OE = 0, SLEEP = 1 for more than 1 ms. |
| | | 4 | 0 | Reserved |
| | | 3 | 0 | Enable external MOSFET Undervoltage Lockout (default). |
| | | | 1 | Disable external MOSFET Undervoltage Lockout. |
| | | 2 | 0 | Enable external MOSFET short-circuit detection (default). |
| | | | 1 | Disable external MOSFET short-circuit detection. |
| | | 1:0 | 00 | Set external MOSFET overcurrent limit to 0.250V (default). |
| | | | 01 | Set external MOSFET overcurrent limit to 0.500V. |
| | | | 10 | Set external MOSFET overcurrent limit to 0.750V. |
| | | | 11 | Set external MOSFET overcurrent limit to 1.000V. |
| GET_CFG_0 | 1 | | 10000010 (82h) | Get Configuration Register 0. |
| STATUS_0 | 1 | | 10000101 (85h) | Get Status Register 0. |
| STATUS_1 | 1 | | 10000110 (86h) | Get Status Register 1. |
| SET_CFG_2 | 1 | | 10000111 (87h) | Set Configuration Register 2. |
| | 2 | 7:5 | 00h | Reserved |
| | | 4:2 | — | Driver dead time (for PWMH /PWML inputs) |
| | | | 000 | 2000 ns (default) |
| | | | 001 | 1750 ns |
| | | | 010 | 1500 ns |
| | | | 011 | 1250 ns |
| | | | 100 | 1000 ns |
| | | | 101 | 750 ns |
| | | | 110 | 500 ns |
| | | | 111 | 250 ns |
| | | 1:0 | — | Driver blanking time (ignore switching current spikes) |
| | | | 00 | 4 µs (default) |
| | | | 01 | 2 µs |
| | | | 10 | 1 µs |
| | | | 11 | 500 ns |
| GET_CFG_2 | 1 | | 10001000 (88h) | Get Configuration Register 2. |
| GET_REV_ID | 1 | | 10010000 (90h) | Get device hardware revision. |

**TABLE 12-8: DE2 COMMUNICATION MESSAGES FROM dsPIC33CDVL64MC106 TO HOST**

| Message | Byte | Bit | Value | Description |
|---|---|---|---|---|
| SET_CFG_0 | 1 | 7:0 | 00000001 (01h) | Command not Acknowledged (response). |
| | | | 01000001 (41h) | Command Acknowledged (response). |
| | 2 | 7 | 0 | Reserved |
| | | 6 | 0 | Reserved |
| | | 5 | 0 | System enters Standby mode when OE = 0, SLEEP = 0 for more than 1 ms. |
| | | | 1 | System enters Sleep mode when OE = 0, SLEEP = 1 for more than 1 ms. |
| | | 4 | 0 | Reserved |
| | | 3 | 0 | External MOSFET Undervoltage Lockout enabled (default). |
| | | | 1 | External MOSFET Undervoltage Lockout disabled. |
| | | 2 | 0 | External MOSFET short-circuit detection enabled (default). |
| | | | 1 | External MOSFET short-circuit detection disabled. |
| | | 1:0 | 00 | 0.250V external MOSFET overcurrent limit (default) |
| | | | 01 | 0.500V external MOSFET overcurrent limit |
| | | | 10 | 0.750V external MOSFET overcurrent limit |
| | | | 11 | 1.000V external MOSFET overcurrent limit |
| GET_CFG_0 | 1 | 7:0 | 00000010 (02h) | Command not Acknowledged (response). |
| | | | 01000010 (42h) | Command Acknowledged (response). |
| | 2 | 7 | 0 | Reserved |
| | | 6 | 0 | Reserved |
| | | 5 | 0 | System enters Standby mode when OE = 0, SLEEP = 0 for more than 1 ms. |
| | | | 1 | System enters Sleep mode when OE = 0, SLEEP = 1 for more than 1 ms. |
| | | 4 | 0 | Reserved |
| | | 3 | 0 | External MOSFET Undervoltage Lockout enabled. |
| | | | 1 | External MOSFET Undervoltage Lockout disabled. |
| | | 2 | 0 | External MOSFET short-circuit detection enabled. |
| | | | 1 | External MOSFET short-circuit detection disabled |
| | | 1:0 | 00 | 0.250V external MOSFET overcurrent limit |
| | | | 01 | 0.500V external MOSFET overcurrent limit |
| | | | 10 | 0.750V external MOSFET overcurrent limit |
| | | | 11 | 1.000V external MOSFET overcurrent limit |


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**TABLE 12-8: DE2 COMMUNICATION MESSAGES FROM dsPIC33CDVL64MC106 TO HOST (CONTINUED)**

| Message | Byte | Bit | Value | Description |
|---|---|---|---|---|
| STATUS_0 | 1 | 7:0 | 00000101 (05h) | Command not Acknowledged (response). |
| | | | 01000101 (45h) | Command Acknowledged (response). |
| | | | 10000101 (85h) | Command sent to host (unsolicited). |
| | 2 | 7:5 | 101 | Overtemperature Shutdown (OTSHDN) occurred. |
| | | | 100 | Overvoltage Shutdown (OVSHDN) occurred. |
| | | | 011 | Sleep Shutdown (SLEEP) occurred. |
| | | | 010 | Undervoltage Shutdown (UVSHDN) occurred. |
| | | | 001 | Power-on Reset (POR) occurred. |
| | | | 000 | Normal operation |
| | | 4 | 1 | Input Overvoltage (OVLOF), $HV_{DD}$ > 32V |
| | | 3 | 1 | Input Undervoltage (UVLOF), $HV_{DD}$ < 5.5V |
| | | 2 | 1 | Overtemperature (OTPF), $T_J$ > +160°C |
| | | 1 | 1 | Overtemperature Warning (OTPW), $T_J$ > +115°C |
| | | 0 | 0 | No Fault condition exists. |
| | | | 1 | A Fault condition exists. |
| STATUS_1 | 1 | 7:0 | 00000110 (06h) | Command not Acknowledged (response). |
| | | | 01000110 (46h) | Command Acknowledged (response). |
| | | | 10000110 (86h) | Command sent to host (unsolicited). |
| | 2 | 7:4 | 0 | Reserved |
| | | 3 | 1 | External MOSFET Overcurrent (XOCPF) detected. |
| | | 2 | 1 | External MOSFET Undervoltage Lockout (XUVLOF) |
| | | 1 | 0 | Reserved |
| | | 0 | 1 | $V_{REG}$ LDO Undervoltage Fault (VREGUVF) |
| SET_CFG_2 | 1 | 7:0 | 00000111 (07h) | Command not Acknowledged (response). |
| | | | 01000111 (47h) | Command Acknowledged (response). |
| | 2 | 7:5 | 00h | Reserved |
| | | 4:2 | — | Driver dead time (for PWMH /PWML inputs) |
| | | | 000 | 2000 ns (default) |
| | | | 001 | 1750 ns |
| | | | 010 | 1500 ns |
| | | | 011 | 1250 ns |
| | | | 100 | 1000 ns |
| | | | 101 | 750 ns |
| | | | 110 | 500 ns |
| | | | 111 | 250 ns |
| | | 1:0 | — | Driver blanking time (ignore Faults) |
| | | | 00 | 4000 ns (default) |
| | | | 01 | 2000 ns |
| | | | 10 | 1000 ns |
| | | | 11 | 500 ns |

**TABLE 12-8: DE2 COMMUNICATION MESSAGES FROM dsPIC33CDVL64MC106 TO HOST (CONTINUED)**

| Message | Byte | Bit | Value | Description |
|---|---|---|---|---|
| GET_CFG_2 | 1 | 7:0 | 00001000 (08h) | Command not Acknowledged (response). |
| | | | 01001000 (48h) | Command Acknowledged (response). |
| | 2 | 7:5 | 00h | Reserved |
| | | 4:2 | — | Driver dead time (for PWMH /PWML inputs) |
| | | | 000 | 2000 ns |
| | | | 001 | 1750 ns |
| | | | 010 | 1500 ns |
| | | | 011 | 1250 ns |
| | | | 100 | 1000 ns |
| | | | 101 | 750 ns |
| | | | 110 | 500 ns |
| | | | 111 | 250 ns |
| | | 1:0 | — | Driver blanking time (ignore Faults) |
| | | | 00 | 4000 ns |
| | | | 01 | 2000 ns |
| | | | 10 | 1000 ns |
| | | | 11 | 500 ns |
| GET_REV_ID | 1 | 7:0 | 00010000 (10h) | Command not Acknowledged (response). |
| | | | 01010000 (50h) | Command Acknowledged (response). |
| | 2 | 7:3 | 00h | Reserved |
| | | 2:0 | 00h-07h | Device hardware revision |


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## 12.24 Register Definitions

**REGISTER 12-1: CFG0: CONFIGURATION REGISTER 0**

| U-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | SLEEP | — | EXTUVLO | EXTSC | EXTOC1 | EXTOC0 |
| 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 7-6 **Unimplemented:** Read as '0'

bit 5 **SLEEP:** Sleep Mode bit
Bit may only be changed while in Standby mode.
1 = System enters Sleep mode when OE = 0
0 = System enters Standby mode when OE = 0

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

bit 3 **EXTUVLO:** External MOSFET Undervoltage Lockout bit
1 = Disables
0 = Enables

bit 2 **EXTSC:** External MOSFET Short-Circuit Detection bit
1 = Disables
0 = Enables

bit 1-0 **EXTOC[1:0]:** External MOSFET Overcurrent Limit Value bits
11 = Overcurrent limit set to 1.000V
10 = Overcurrent limit set to 0.750V
01 = Overcurrent limit set to 0.500V
00 = Overcurrent limit set to 0.250V

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**REGISTER 12-2: CFG2: CONFIGURATION REGISTER 2**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | DRVDT2 | DRVDT1 | DRVDT0 | DRVBL1 | DRVBL0 |
| 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 7-5 **Unimplemented:** Read as '0'

bit 4-2 **DRVDT[2:0]:** Driver Dead-Time Selection bits
111 = 250 ns
110 = 500 ns
101 = 7500 ns
100 = 1000 ns
011 = 1250 ns
010 = 1500 ns
001 = 1750 ns
000 = 2000 ns

bit 1-0 **DRVBL[1:0]:** Driver Blanking Time Selection bits
Bits may only be changed while in Standby mode.
11 = 500 ns
10 = 1000 ns
01 = 2000 ns
00 = 4000 ns


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**REGISTER 12-3: STAT0: STATUS REGISTER 0**

| R-0 | R-0 | R-1 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PCON2 | PCON1 | PCON0 | OVLOF | UVLOF | OTPF | OTPW | FAULT |
| 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 7-5 **PCON[2:0]:** Power Control Status bits (configuration lost if non-zero value)
101 = Overtemperature Shutdown (OTSHDN) occurred
100 = Overvoltage Shutdown (OVSHDN) occurred
011 = Sleep (SLEEP) shutdown occurred
110 = Undervoltage Shutdown (UVSHDN) occurred
001 = Power-on Reset (POR) occurred
000 = Normal operation

bit 4 **OVLOF:** Input Overvoltage Lockout Fault bit
1 = $HV_{DD}$ input voltage > 32V
0 = $HV_{DD}$ input voltage < 32V

bit 3 **UVLOF:** Input Undervoltage Lockout Fault bit
1 = $HV_{DD}$ input voltage < 5.5V
0 = $HV_{DD}$ input voltage > 5.5V

bit 2 **OTPF:** Overtemperature Protection Fault bit
1 = Device junction temperature is > +165°C
0 = Device junction temperature is < +165°C

bit 1 **OTPW:** Overtemperature Protection Warning bit
1 = Device junction temperature is > +115°C
0 = Device junction temperature is < +115°C

bit 0 **FAULT:** Fault Status bit
1 = At least one Fault is active
0 = No active Faults

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**REGISTER 12-4: STAT1: STATUS REGISTER 1**

| U-0 | U-0 | U-0 | U-0 | R-0 | R-0 | U-0 | R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | XOCPF | XUVLOF | — | VREGUVF |
| 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 7-4 **Unimplemented:** Read as '0'

bit 3 **XOCPF:** External MOSFET Overcurrent Protection Fault bit
Only Valid when EXTSC (CFG0[2]) = 0.
1 = External MOSFET $V_{DS}$ > EXTOC[1:0] (CFG0[1:0]) value
0 = External MOSFET $V_{DS}$ < EXTOC[1:0] (CFG0[1:0]) value

bit 2 **XUVLOF:** External MOSFET Gate Drive Undervoltage Fault bit
Only Valid when EXTUVLO (CFG0[3]) = 0.
1 = HSx output voltage < $V_{DUVLO}$
0 = HSx output voltage > $V_{DUVLO}$

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

bit 0 **VREGUVF:** $V_{REG}$ LDO Undervoltage Fault bit
1 = $V_{REG}$ LDO output voltage < 88% of target $V_{REG}$
0 = $V_{REG}$ LDO output voltage > 92% of target $V_{REG}$

**REGISTER 12-5: REV_ID: HARDWARE REVISION ID**

| U-0 | U-0 | U-0 | U-0 | U-0 | R-0/1 | R-0/1 | R-0/1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | REVID[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 7-3 **Unimplemented:** Read as '0'

bit 2-0 **REVID[2:0]:** Device Revision bits

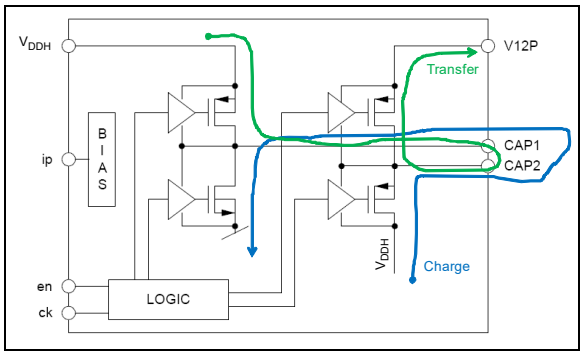

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## 12.25 Application Information

### 12.25.1 COMPONENT CALCULATIONS

#### 12.25.1.1 Charge Pump Capacitors

**FIGURE 12-7: CHARGE PUMP**




Let:

- $I_{OUT}$ = 20 mA
- $f_{CP}$ = 75 kHz (charge/discharge in one cycle)
- 50% duty cycle
- $V_{DDH}$ = 5.5V (worst case)
- $R_{DSON}$ = 7.5Ω ($R_{PMOS}$), 3.5Ω ($R_{NMOS}$)
- V12P = 2 × $V_{DDH}$ (ideal)
- $C_{ESR}$ = 20 mΩ (ceramic capacitors)
- $V_{DROP}$ = 100 mV ($V_{OUT}$ ripple)
- $T_{CHG}$ = $T_{DCHG}$ = 0.5 × 1/75 kHz = 6.67 µs

#### 12.25.1.2 Flying Capacitor

The flying capacitor should be chosen to charge to a minimum of 95% (3τ) of $V_{DDH}$ within one half of a switching cycle.

- 3 × τ = $T_{CHG}$
- τ = $T_{CHG}$/3
- RC = $T_{CHG}$/3
- C = $T_{CHG}$/(R × 3)
- C = 6.67 µs/([7.5Ω + 3.5Ω + 0.02Ω] × 3)
- C = 202 nF

Choose a 180 nF capacitor.

#### 12.25.1.3 Charge Pump Output Capacitor

Solve for the charge pump output capacitance, connected between V12P and ground, that will supply the 20 mA load for one switch cycle. The $V_{BOOT}$ LDO pin on the dsPIC33CDVL64MC106 is the "V12P" pin referenced in the calculations.

- C = $I_{OUT}$ × dt/dV
- C = $I_{OUT}$ × 13.3 µs/($V_{DROP}$ + $I_{OUT}$ × $C_{ESR}$)
- C = 20 mA × 13.3 µs/(0.1V + 20 mA × 20 mΩ)
- C ≥ 2.65 µF

For stability reasons, the $V_{BOOT}$ LDO and $V_{REG}$ LDO capacitors must be at least 4.7 µF, so choose: C ≥ 4.7 µF.

#### 12.25.1.4 Charging Path (Flying Capacitor Across CAP1 and CAP2)

- $V_{CAP}$ = $V_{DDH}$ × (1 – $e^{-T/\tau}$)
- $V_{CAP}$ = 5.5V × (1 – $e^{-[6.67\ \mu s/([7.5\Omega + 3.5\Omega + 20\ m\Omega] \times 180\ nF)]}$)

$V_{CAP}$ = 5.31V is available for transfer on the first cycle.

#### 12.25.1.5 Transfer Path (Flying and Output Capacitors)

- V12P = $V_{DDH}$ + $V_{CAP}$ – $I_{OUT}$ × dt/C
- V12P = 5.5V + 5.31V – (20 mA × 6.67 µs/180 nF)
- V12P = 10.066V

#### 12.25.1.6 Calculate the Flying Capacitor Voltage Drop in One Cycle While Supplying 20 mA

- dV = $I_{OUT}$ × dt/C
- dV = 20 mA × 6.67 µs/180 nF
- dV = 0.741V @ 20 mA

The second and subsequent transfer cycles will have a higher voltage available for transfer, since the capacitor is not completely depleted with each cycle. $V_{CAP}$ will then be $V_{CAP}$ – dV after the first transfer, plus $V_{DDH}$ – ($V_{CAP}$ – dV) times the RC constant. This repeats for each subsequent cycle, allowing a larger charge pump capacitor to be used if the system will tolerate several charge transfers before requiring full output voltage and current.

Repeating **Section 12.25.1.4 "Charging Path (Flying Capacitor Across CAP1 and CAP2)"** for the second cycle (and subsequent by recalculating for each new value of $V_{CAP}$ after each transfer):

- $V_{CAP}$ = ($V_{CAP}$ – dV) + ($V_{DDH}$ – ($V_{CAP}$ – dV)) (1 – $e^{-T/t}$)
- $V_{CAP}$ = (5.31V – 0.741V) + (5.5V – (5.31V – 0.741V)) × (1 – $e^{-[6.67\ \mu s/([7.5W + 3.5W + 20\ mW] \times 180\ nF)]}$)
- $V_{CAP}$ = 4.567V + 0.934V × 0.96535

$V_{CAP}$ = 5.468V is available for transfer on the second cycle.

#### 12.25.1.7 Charge Pump Results

The maximum charge pump flying capacitor value is 202 nF to maintain a 95% voltage transfer ratio on the first charge pump cycle. Larger capacitor values may be used, but they will require more cycles to charge to maximum voltage. The minimum required output capacitor value is 2.65 µF to supply 20 mA for 13.3 µs with a 100 mV drop. A larger output capacitor may be used to cover losses due to capacitor tolerance over temperature, capacitor dielectric and PCB losses.

These are approximate calculations. The actual voltages may vary due to incomplete charging or discharging of capacitors per cycle due to load changes. The charge pump calculations assume the charge pump is able to charge up the external boot cap within a few cycles.

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### 12.25.2 BOOTSTRAP CAPACITOR

The high-side driver bootstrap capacitor needs to power the high-side driver and gate for 1/3 of the motor electrical period for a 3-phase BLDC motor operating in Six-Step mode.

Let:

| | | |
|---|---|---|
| MOSFET Driver Current | = | 300 mA |
| PWM Period | = | 50 µs (20 kHz) |
| Minimum Duty Cycle | = | 1% (500 ns) |
| Maximum Duty Cycle | = | 99% (49.5 µs) |
| $V_{IN}$ | = | 12V |
| Minimum Gate Drive Voltage | = | 8V ($V_{GS}$) |
| Total Gate Charge | = | 130 nC (80A MOSFET) |
| Allowable $V_{GS}$ Drop ($V_{DROP}$) | = | 3V |
| Switch $R_{DSON}$ | = | 100 mW |
| Driver Internal Bias Current | = | 20 µA ($I_{BIAS}$) |

Solve for the smallest capacitance that can supply:

- 130 nC of charge to the MOSFET gate
- 1 Megohm gate source resistor current
- Driver bias current and switching losses

$Q_{MOSFET}$ = 130 nC

$Q_{RESISTOR}$ = [($V_{GS}$/R) × $T_{ON}$]

$Q_{DRIVER}$ = ($I_{BIAS}$ × $T_{ON}$)

$T_{ON}$ = 49.5 µs (99% DC) for worst case

$Q_{RESISTOR}$ = $Q_{RESISTOR}$

$Q_{DRIVER}$ = 20 µA × 49.5 µs = 0.99 nC

Sum all of the energy requirements:

- C = ($Q_{MOSFET}$ + $Q_{RESISTOR}$ + $Q_{DRIVER}$)/$V_{DROP}$
- C = (130 nC + 0.594 nC + 0.99 nC)/3V
- C = 43.86 nF

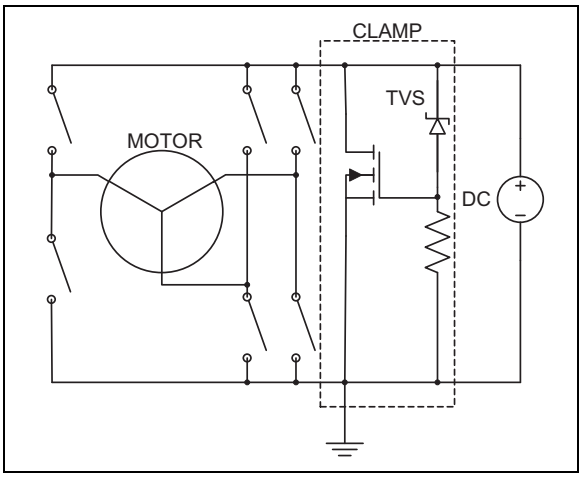
Choose a bootstrap capacitor value that is larger than 43.86 nF.

## 12.26 Device Protection

### 12.26.1 MOSFET VOLTAGE SUPPRESSION

When a motor shaft is rotating and power is removed, the magnetism of the motor components will cause the motor to act like a generator. The current that was flowing into the motor will now flow out of the motor. As the motor magnetic field decays, the generator output will also decay. The voltage across the generator terminals will be proportional to the generator current and circuit impedance of the generator circuit. If the power supply is part of the return path for the current and the power supply is disconnected, then the voltage at the generator terminals will increase until the current flows. This voltage increase must be handled externally to the driver. A voltage suppression device may be used to clamp the motor terminal voltage to a level that will not exceed the maximum system operating voltage during the high-voltage transients. A voltage suppressor circuit may be connected from power ground to the motor power supply rail to create a path for the motor current when the supply is disconnected (Figure 12-8). The PCB traces must be capable of carrying the motor current with minimum voltage and temperature rise.

**FIGURE 12-8: TRANSIENT VOLTAGE CLAMP**




An additional method is to inactivate the high-side drivers and to activate the low-side drivers. This allows current to flow through the low-side external MOSFETs and prevents the voltage from increasing at the power supply terminals.


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### 12.26.2 BOOTSTRAP VOLTAGE SUPPRESSION

The pins which handle the highest voltage during motor operation are the bootstrap pins (VBx). The bootstrap pin voltage is typically $V_{BOOT}$ (12V) higher than the associated phase voltage. When the high-side MOSFET is conducting, the phase pin voltage is typically at $HV_{DD}$ and the bootstrap pin voltage is typically at $HV_{DD}$ + 12V. When the phase MOSFETs switch, current induced voltage transients occur on the phase pins. These currents are caused by the MOSFET body diode reverse recovery and MOSFET turn-on/turn-off times. Those induced voltages cause the bootstrap pin voltages to also increase. Depending on the magnitude of the phase pin voltage, the bootstrap pin voltage may exceed the safe operating voltage of the device. The current induced transients may be reduced by slowing down the turn-on and turn-off times of the MOSFETs. The external MOSFETs may be slowed down by adding a 10 to 100 ohm resistor in series with the gate drive. A 3.3 nF to 10 nF ceramic capacitor may be added that connects each MOSFET gate and source terminal. The added capacitance slows down the switching times of the MOSFET, while allowing the gate resistance to remain small enough to keep the gate clamped off. The added capacitance also results in a lower slew rate of the phase node and limits the shoot-through current caused by the body diode reverse recovery.

The high-side MOSFETs may also be slowed down by inserting a 10Ω to 25Ω resistor between each bootstrap pin and the associated bootstrap diode capacitor junction. Another 25Ω to 50Ω resistor is then added between the gate drive and the MOSFET gate. This results in a high-side turn-on resistance of 25Ω plus the series gate resistor. The high-side turn-off resistance only consists of the series gate resistance and allows for a faster shut-off time. Care must be taken to make sure the voltage drop across the bootstrap pin resistor does not cause an external MOSFET Undervoltage Fault.

When a system motor power supply voltage clamp is not used, 33V or 36V transzorbs may be connected from each bootstrap pin (VBx) to the ground. This will ensure that the bootstrap voltage does not exceed the absolute maximum voltage allowed on the pins. The resistors connected between the bootstrap pins and the bootstrap diode/capacitor junctions, mentioned in the previous paragraph, may also be used in order to limit the transzorb current and reduce the transzorb package size.

### 12.26.3 FLOATING GATE SUPPRESSION

The gate drive pins may float when the supply voltage is lost or an overvoltage situation shuts down the driver. When an overvoltage condition exists, the driver high-side and low-side outputs are tri-state. Each external MOSFET that is connected to the gate driver should have a gate-to-source resistor to bleed off any charge that may accumulate due to the tri-state. This will help prevent inadvertent turn-on of the MOSFET.

Figure 12-9 shows the location of the overvoltage transzorbs (or equivalent circuits), gate resistors, bootstrap resistors and gate-to-source resistors.

### 12.26.4 MOSFET BODY DIODE REVERSE RECOVERY SNUBBER

When motor current is flowing through the external MOSFET body diodes and the complimentary MOSFET of the phase pair turns on, the body diode reverse recovery creates a momentary short circuit until the reverse recovery time is complete. When the body diode reverse recovery is complete, the current path is opened, causing the phase node voltage to slew rapidly towards ground or $HV_{DD}$ levels. The rapid slew rate may cause an inversion of the gate-to-source voltage on the MOSFET that is turning on and result in that MOSFET turning off.

The fast slew rate may also cause ringing on the phase node and the sense resistor if the turn-off is too fast.

The first remedy for the low-side turn-off is to slow down the MOSFET gate-to-source turn-off. That causes the $R_{DSON}$ of the low-side MOSFET to gradually increase as the gate voltage drops and the low-side MOSFET slowly turns off. The slow turn-off allows the phase voltage, generated by the motor current flowing through the low-side MOSFET $R_{DSON}$, to slowly rise towards the positive motor supply level.

The same scenario is also valid for turning on the low-side MOSFET when the high-side MOSFET has just been turned off and current was flowing from the high side into the motor.

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The MOSFET body diode reverse recovery situation occurs when the low-side MOSFETs are turned on while the motor current is flowing to the positive source through the high-side MOSFET body diode. The diode reverse recovery time allows a short circuit to exist between the positive supply and the low-side MOSFET drain until the high-side diode is reverse biased and the reverse recovery time has elapsed. The first remedies above should be used to slow the switching speeds of the MOSFETs. Then, a snubber is added to each MOSFET to fine-tune the phase node slew rate and eliminate any further transients. Adding a drain-to-source snubber slows down the slew rate of the phase node and results in a more controlled excursion of the phase node voltage. The snubber consists of a resistor and a capacitor connected in series between the drain and source of the MOSFET. The resistor is chosen to keep the initial snubber voltage below a few volts when peak motor current is flowing through the body diode. The capacitor is then chosen to provide an RC time constant longer than the MOSFET body diode reverse recovery time. A 0.1Ω resistor is typically used, along with a 0.1 µF capacitor to provide an RC of 10 ns.

The power dissipated by the capacitor is calculated by applying Equation 12-5.

**EQUATION 12-5: SNUBBER CAPACITOR POWER DISSIPATION**

$$P_{DISS} = 2 \times \pi \times f \times C \times V^2 \times Dissipation\ Factor$$

Where:

$f$ = PWM Frequency
$C$ = Capacitance
$V$ = Motor Voltage
$Dissipation\ Factor$ = 2 × p × f × C × ESR = ESR/Xc

The capacitor and resistor form factors are chosen to handle the dissipated power.

### 12.26.5 MOTOR CURRENT SENSE CIRCUITRY

A sense resistor in series with the bridge ground return provides a current signal for feedback. This resistor should be non-inductive to minimize ringing from high di/dt. Any inductance in the power circuit represents potential problems in the form of additional voltage stress and ringing, as well as increasing switching times. While impractical to eliminate, careful layout and bypassing will minimize these effects. The output stage should be as compact as heat sinking will allow, with wide, short traces carrying all pulsed currents. Each half-bridge should be separately bypassed with a low-ESR/ESL capacitor, decoupling it from the rest of the circuit. Some layouts will allow the input filter capacitor to be split into three smaller values and serve double duty as the half-bridge bypass capacitors.


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### 12.26.6 AUTO-BAUD CODE EXAMPLE

Example 12-1 is a dsPIC® DSC code example using the auto-baud function.

**EXAMPLE 12-1: dsPIC® DSC AUTO-BAUD EXAMPLE**

```
//#define FCY 70000000UL
#define TypBaudrate 9600uL
#define U1BRG_BAUDRATE (FCY/(16 * TypBaudrate)) - 1
#define U1BRG_BAUD_MIN ((((FCY/(16 * TypBaudrate)) - 1)*1.07f)) // plus 7%
#define U1BRG_BAUD_MAX ((((FCY/(16 * TypBaudrate)) - 1)*0.93f)) // minus 7%
#define U1BRG_BREAK (FCY/(16 * 7880uL)) - 1 //7880 baud-rate is midpoint of required break
//window for MCP8021

//set up Oscillator_Initialize code here


void UART1_Init(void){
  //UART configuration - set up PPS connections and UART module enable here
  _TRISC12 = 1; //required for proper UART RX receiption of DE2 messages
  _CNPUC12 = 1; //required to pull DE2 high because interconnect is open-drain
  _ODC12 = 1; //recommended so pull-up is fully utilized

  //PPS assignment of UART RX/TX to RC12

  //enable half-duplex mode if available to auto-disable transmiter when idle

  U1MODEbits.UARTEN = 1; //enable UART
  U1MODEbits.URXEN = 1; //for half-duplex communication, keep RX on always and manage TX as
                        //needed in auto-baud routine

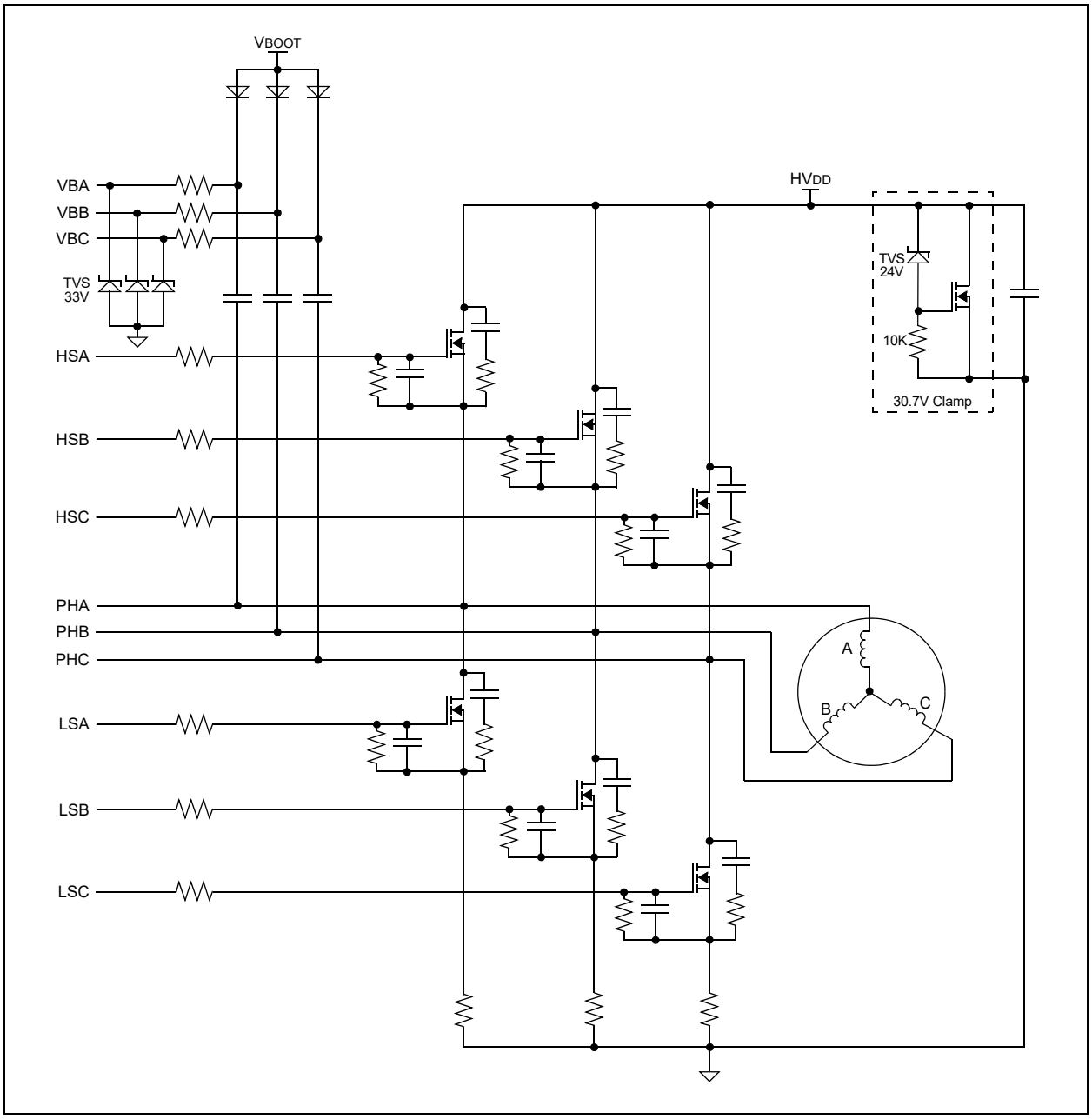
  //if half-duplex mode not available, activate TXEN for transmission and disable TXEN when idle

  __delay_ms(10); //10mS delay required after POR of MCP8021 and before requesting auto-baud

}
void UART1_AutoBaud(void){
  U1MODEbits.UTXEN = 1;   //Transmit enabled, UxTX pin controlled by UARTx.
  U1BRG = U1BRG_BREAK;   //7880baud representing 1.65ms dominant with 13bit BREAK
  U1MODEbits.UTXBRK = 1;   //Send BREAK command
  U1TXREG = 0x00;   //Dummy write to start BREAK command
  while(U1STAHbits.URXBE == 0){ //wait for transmission to end then read out RXREG to
                                //avoid collision.
     unsigned short dummy = U1RXREG;
  }

  U1MODEbits.UTXEN = 0; //disable TX while waiting on 0x55 from MCP8021
  U1MODEbits.ABAUD = 1; //start the ABAUD counter upon receipt of next byte (0x55)
  while(U1MODEbits.ABAUD); //application should handle timeout if auto-baud does not
  complete and attempt auto-baud routine again
  __delay_ms(3); //minimum delay of 2mS required after auto-baud complete
  to allow for baud rate verification by host
  //verify new baud clock is within limits of MCP8021 min and max baud-rate
  if ((U1BRG > U1BRG_BAUD_MAX) && (U1BRG < U1BRG_BAUD_MIN)){
  //success, use new baud-rate generator value
  }
  else{
  //auto-baud out of range, reload last known good BRG value and attempt auto-baud routine again
  }
}
```

**FIGURE 12-9: OVERVOLTAGE PROTECTION**





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**NOTES:**

## 13.0 HIGH-SPEED, 12-BIT ANALOG-TO-DIGITAL CONVERTER (ADC)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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)**" (www.microchip.com/DS70005213).

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

The dsPIC33CDVL64MC106 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 and DC/DC power converters. The devices implement the ADC with one shared SAR core.

### 13.1 ADC Features Overview

The High-Speed, 12-Bit Multiple SARs Analog-to-Digital Converter (ADC) includes the following features:

- One Shared (common) Core
- User-Configurable Resolution of up to 12 Bits for Each Core
- Up to 3.5 Msps Conversion Rate per Channel at 12-Bit Resolution
- Low-Latency Conversion
- Up to 16 Analog Input Channels with a Separate 16-Bit Conversion Result Register for Each Input – AN1 and AN7 Share the Same Pin
- Conversion Result can be Formatted as Unsigned or Signed Data, on a per Channel Basis, for All Channels
- Channel Scan Capability
- Multiple Conversion Trigger Options for each Core, including:
  - PWM triggers from CPU cores
  - SCCP modules triggers
  - CLC modules triggers
  - External pin trigger event (ADTRG31)
  - Software trigger
- Four Integrated Digital Comparators with Dedicated Interrupts:
  - Multiple comparison options
  - Assignable to specific analog inputs
- Four Oversampling Filters with Dedicated Interrupts:
  - Provide increased resolution
  - Assignable to a specific analog input

The module consists of one shared SAR ADC core. Simplified block diagrams of the Multiple SARs 12-Bit ADC are shown in Figure 13-1 and Figure 13-2.

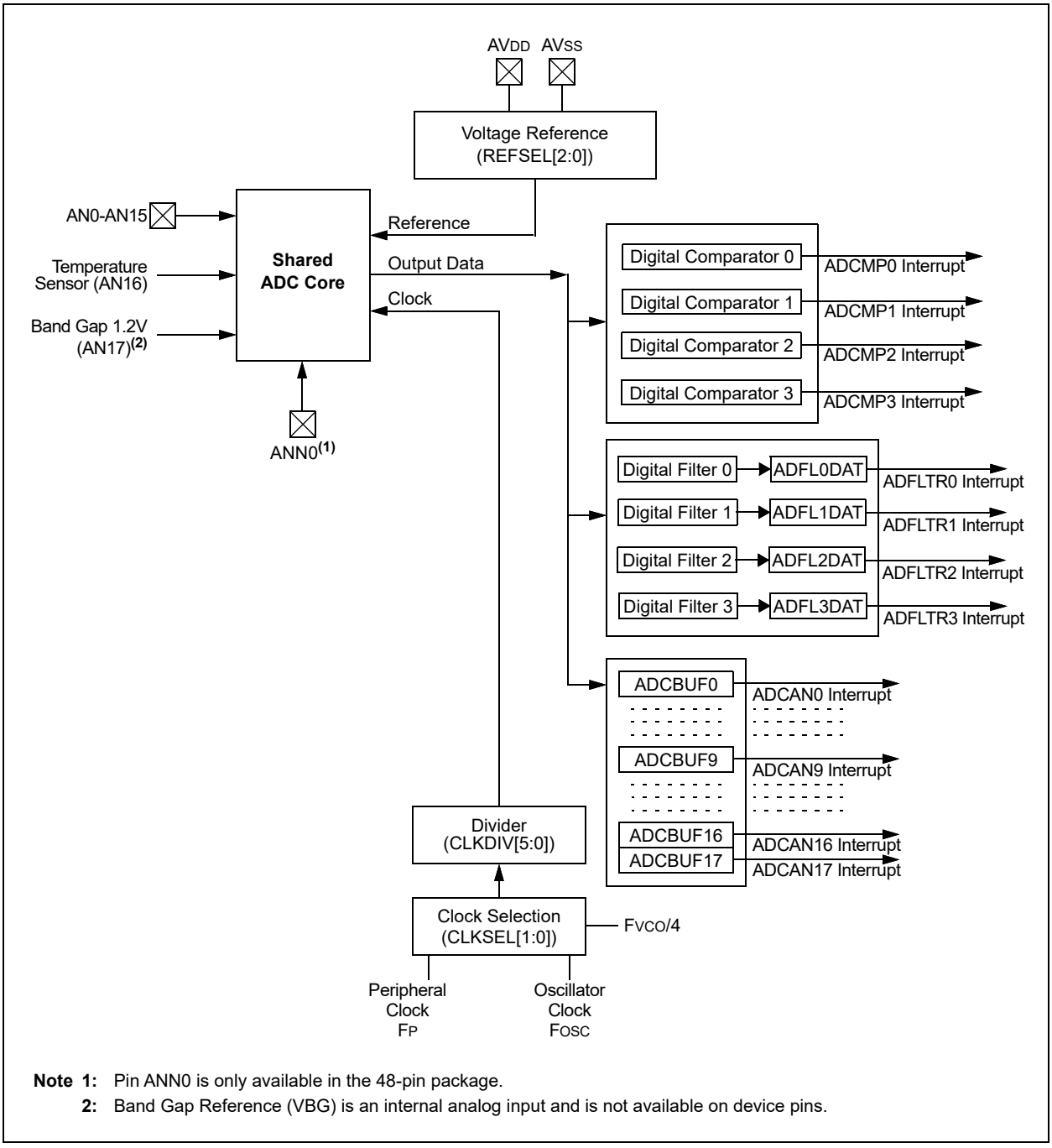
The analog inputs (channels) are connected through multiplexers and switches to the Sample-and-Hold (S&H) circuit of each ADC core. The core uses the channel information (the output format, the Measurement mode and the input number) to process the analog sample. When conversion is complete, the result 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.

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.


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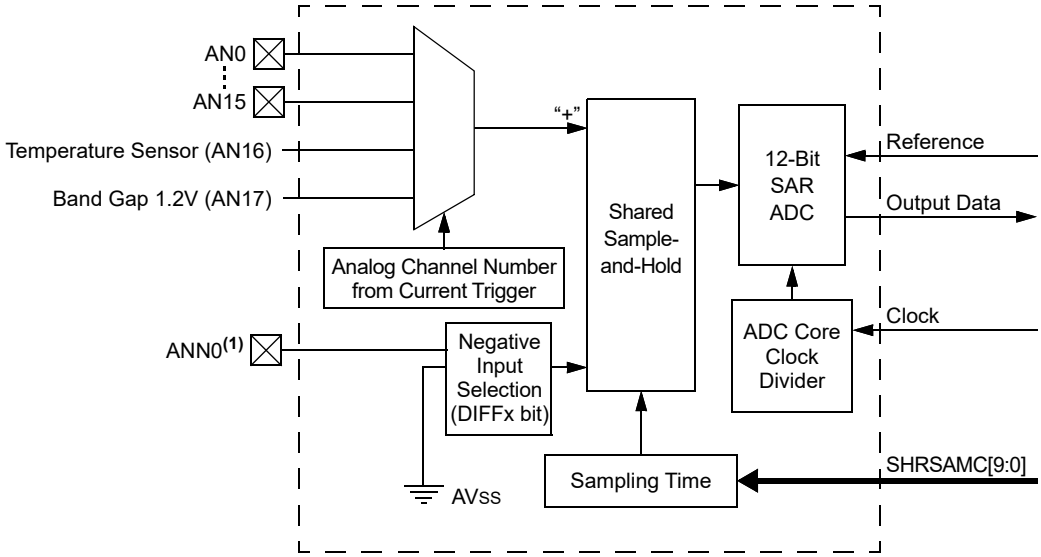
**FIGURE 13-1: ADC MODULE BLOCK DIAGRAM**




**Note 1:** Pin ANN0 is only available in the 48-pin package.

**2:** Band Gap Reference (VBG) is an internal analog input and is not available on device pins.

**FIGURE 13-2: ADC SHARED CORE BLOCK DIAGRAM**




**Note 1:** Pin ANN0 is only available in the 48-pin package.


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## 13.2 Temperature Sensor

The ADC channel, AN16, is connected to a forward-biased diode. It can be used to measure a die temperature. This diode provides a voltage output that can be monitored by the ADC.

The temperature coefficient is listed in Table 33-37 in **Section 33.0 "Electrical Characteristics"**. To get the exact gain and offset numbers, the two temperature points' calibration is recommended.

## 13.3 Analog-to-Digital Converter 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.

### 13.3.1 KEY RESOURCES

- **"12-Bit High-Speed, Multiple SARs A/D Converter (ADC)"** (www.microchip.com/DS70005213)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools

## 13.4 Differential-Mode

ANNx negative external inputs are used for Differential-mode, as shown in Figure 12-2. To enable Differential-mode, the DIFF bit (in the ADMODxL or ADMODxH register) is set for the corresponding channel.

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## 13.5 ADC Control/Status Registers

**REGISTER 13-1: ADCON1L: ADC CONTROL REGISTER 1 LOW**

| R/W-0 | U-0 | R/W-0 | U-0 | r-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| ADON(1) | — | ADSIDL | — | — | — | — | — |
| 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 = 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 = 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 **Unimplemented:** Read as '0'

bit 11 **Reserved:** Maintain as '0'

bit 10-0 **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 13-2: ADCON1H: ADC CONTROL REGISTER 1 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-1 | R/W-1 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| FORM | SHRRES1 | SHRRES0 | — | — | — | — | — |
| 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 **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 **Unimplemented:** Read as '0'

**REGISTER 13-3: ADCON2L: ADC CONTROL REGISTER 2 LOW**

| R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| REFCIE | REFERCIE | — | EIEN | PTGEN(3) | 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 |
|---|---|---|---|---|---|---|---|
| — | SHRADCS[6:0](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 **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 **Unimplemented:** Read 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 **PTGEN:** PTG Conversion Request Interface bit
1 = PTG triggers are enabled
0 = PTG triggers are disabled

bit 10-8 **SHREISEL[2:0]:** Shared Core Early Interrupt Time Selection bits
111 = Early interrupt is set and interrupt is generated eight TADCORE clocks prior to when the data are ready
110 = Early interrupt is set and interrupt is generated seven TADCORE clocks prior to when the data are ready
101 = Early interrupt is set and interrupt is generated six TADCORE clocks prior to when the data are ready
100 = Early interrupt is set and interrupt is generated five TADCORE clocks prior to when the data are ready
011 = Early interrupt is set and interrupt is generated four TADCORE clocks prior to when the data are ready
010 = Early interrupt is set and interrupt is generated three TADCORE clocks prior to when the data are ready
001 = Early interrupt is set and interrupt is generated two TADCORE clocks prior to when the data are ready
000 = Early interrupt is set and interrupt is generated one TADCORE clock prior to when the data are 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.
**2:** The ADC clock frequency, selected by the SHRADCS[6:0] bits, must not exceed 70 MHz.
**3:** Other ADC trigger sources cannot be used if PTG triggers are enabled.


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**REGISTER 13-4: ADCON2H: ADC CONTROL REGISTER 2 HIGH**

| HSC/R-0 | HSC/R-0 | U-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 **Unimplemented:** Read as '0'

bit 12-10 **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 13-5: ADCON3L: ADC CONTROL REGISTER 3 LOW**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | HSC/R-0 | R/W-0 | HSC/R/W-0 |
|---|---|---|---|---|---|---|---|
| REFSEL2 | REFSEL1 | REFSEL0 | SUSPEND | SUSPCIE | SUSPRDY | SHRSAMP | CNVRTCH |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | HSC/R/W-0 | 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 Core 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 ADTRIGnL and ADTRIGnH 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 ADTRIGnL and ADTRIGnH 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 13-6: 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(1) | CLKSEL0(1) | CLKDIV5(2) | CLKDIV4(2) | CLKDIV3(2) | CLKDIV2(2) | CLKDIV1(2) | CLKDIV0(2) |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SHREN | — | — | — | — | — | — | — |
| 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 = FVCO/4
10 = FVCO/3
01 = FOSC
00 = FP (Peripheral Clock)

bit 13-8 **CLKDIV[5:0]:** ADC Module Clock Source Divider bits
The divider forms a TCORESRC clock used by the ADC core 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 6-0 **Unimplemented:** Read as '0'

**Note 1:** The ADC input clock frequency, selected by the CLKSEL[1:0] bits, must not exceed Parameters AD9, AD10 and AD11 listed in Table 33-34.

**2:** The ADC clock frequency, after the first divider selected by the CLKDIV[5:0] bits, must not exceed Parameters AD9, AD10 and AD11 listed in Table 33-34.

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**REGISTER 13-7: ADCON5L: ADC CONTROL REGISTER 5 LOW**

| HSC/R-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SHRRDY | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SHRPWR | — | — | — | — | — | — | — |
| 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 14-8 **Unimplemented:** Read as '0'

bit 7 **SHRPWR:** Shared ADC Core Power Enable bit
1 = ADC core is powered
0 = ADC core is off

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


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**REGISTER 13-8: 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | WARMTIME[3:0] | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SHRCIE | — | — | — | — | — | — | — |
| 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 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 6-0 **Unimplemented:** Read as '0'

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**REGISTER 13-9: ADLVLTRGL: ADC LEVEL-SENSITIVE TRIGGER CONTROL 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 |
|---|---|---|---|---|---|---|---|
| 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 13-10: 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 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | LVLEN[17:16] | |
| 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 15-2 **Unimplemented:** Read as ‘0’

bit 1-0 **LVLEN[17:16]:** 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 13-11: 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 13-12: 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 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | EIEN[17:16] | |
| 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 15-2 **Unimplemented:** Read as '0'

bit 1-0 **EIEN[17:16]:** Early Interrupt Enable for Corresponding Analog Inputs bits
1 = Early interrupt is enabled for the channel
0 = Early interrupt is disabled for the channel

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**REGISTER 13-13: 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 13-14: 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 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | EISTAT[17:16] | |
| 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 15-2 **Unimplemented:** Read as '0'

bit 1-0 **EISTAT[17:16]:** 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 13-15: ADMOD0L: ADC INPUT MODE CONTROL REGISTER 0 LOW(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 |
|---|---|---|---|---|---|---|---|
| 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 through bit 1 (odd) **DIFF[7:0]:** Differential-Mode for Corresponding Analog Inputs bits
1 = Channel is differential
0 = Channel is single-ended

bit 14 through bit 0 (even) **SIGN[7:0]:** Output Data Sign for Corresponding Analog Inputs bits
1 = Channel output data are signed
0 = Channel output data are unsigned

**Note 1:** The DIFF bits are available only on devices in the 48-pin package; they are used to enable the differential input feature which is linked to the presence of the pin named ANN0. This pin is only available in 48-pin packages.

**REGISTER 13-16: ADMOD0H: ADC INPUT MODE CONTROL REGISTER 0 HIGH(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 |
|---|---|---|---|---|---|---|---|
| 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 through bit 1 (odd) **DIFF[15:8]:** Differential-Mode for Corresponding Analog Inputs bits
1 = Channel is differential
0 = Channel is single-ended

bit 14 through bit 0 (even) **SIGN[15:8]:** Output Data Sign for Corresponding Analog Inputs bits
1 = Channel output data are signed
0 = Channel output data are unsigned

**Note 1:** The DIFF bits are available only on devices in the 48-pin package; they are used to enable the differential input feature which is linked to the presence of the pin named ANN0. This pin is only available in 48-pin packages.

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**REGISTER 13-17: ADMOD1L: ADC INPUT MODE CONTROL REGISTER 1 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | 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 15-4 **Unimplemented:** Read as '0'

bit 3 through bit 1 (odd) **DIFF[17:16]:** Differential-Mode for Corresponding Analog Inputs bits
1 = Channel is differential
0 = Channel is single-ended

bit 2 through bit 0 (even) **SIGN[17:16]:** Output Data Sign for Corresponding Analog Inputs bits
1 = Channel output data are signed
0 = Channel output data are unsigned


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**REGISTER 13-18: 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]:** Channel 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 13-19: 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 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | IE[17:16] | |
| 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 15-2 **Unimplemented:** Read as '0'

bit 1-0 **IE[17:16]:** Channel 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

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**REGISTER 13-20: ADSTATL: ADC DATA READY STATUS REGISTER LOW**

| HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| AN[15:8]RDY | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| 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:** Data Ready Status for Corresponding Analog Inputs bits
1 = Channel conversion result is ready in the corresponding ADCBUFx register
0 = Channel conversion result is not ready

**REGISTER 13-21: 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 | U-0 | U-0 | U-0 | U-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | AN[17:16]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 15-2 **Unimplemented:** Read as '0'

bit 1-0 **AN[17:16]RDY:** Data Ready Status 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 13-22: ADTRIGNL/ADTRIGNH: ADC CHANNEL TRIGGER N(X) SELECTION REGISTERS LOW AND HIGH (X = 0 TO 17; N = 0 TO 4)**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | TRGSRC(x+1)4 | TRGSRC(x+1)3 | TRGSRC(x+1)2 | TRGSRC(x+1)1 | TRGSRC(x+1)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 |
|---|---|---|---|---|---|---|---|
| — | — | — | TRGSRCx4 | TRGSRCx3 | TRGSRCx2 | TRGSRCx1 | TRGSRCx0 |
| 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(x+1)[4:0]:** Trigger Source Selection for Corresponding Analog Inputs bits (TRGSRC1 to TRGSRC19 – Odd)

11111 = ADTRG31 (PPS input)
11110 = PTG12
11101 = CLC2
11100 = CLC1
11011 = Reserved
11010 = Reserved
11001 = Reserved
11000 = Reserved
10111 = SCCP4 input capture/output compare
10110 = SCCP3 input capture/output compare
10101 = SCCP2 input capture/output compare
10100 = SCCP1 input capture/output compare
10011 = Reserved
10010 = CLC4 output
10001 = CLC3 output
10000 = Reserved
01111 = SCCP4 trigger
01110 = SCCP3 trigger
01101 = SCCP2 trigger
01100 = SCCP1 trigger
01011 = PWM4 Trigger 2
01010 = PWM4 Trigger 1
01001 = PWM3 Trigger 2
01000 = PWM3 Trigger 1
00111 = PWM2 Trigger 2
00110 = PWM2 Trigger 1
00101 = PWM1 Trigger 2
00100 = PWM1 Trigger 1
00011 = Reserved
00010 = Level software trigger
00001 = Common software trigger
00000 = No trigger is enabled

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

**REGISTER 13-22: ADTRIGNL/ADTRIGNH: ADC CHANNEL TRIGGER N(X) SELECTION REGISTERS LOW AND HIGH (X = 0 TO 17; N = 0 TO 4) (CONTINUED)**

bit 4-0 **TRGSRCx[4:0]:** Common Interrupt Enable for Corresponding Analog Inputs bits (TRGSRC0 to TRGSRC20 – Even)

11111 = ADTRG31 (PPS input)
11110 = PTG12
11101 = CLC2
11100 = CLC1
11011 = Reserved
11010 = Reserved
11001 = Reserved
11000 = Reserved
10111 = SCCP4 CCP interrupt
10110 = SCCP3 CCP interrupt
10101 = SCCP2 CCP interrupt
10100 = SCCP1 CCP interrupt
10011 = Reserved
10010 = CLC4 output
10001 = CLC3 output
10000 = Reserved
01111 = SCCP4 trigger
01110 = SCCP3 trigger
01101 = SCCP2 trigger
01100 = SCCP1 trigger
01011 = PWM4 Trigger 2
01010 = PWM4 Trigger 1
01001 = PWM3 Trigger 2
01000 = PWM3 Trigger 1
00111 = PWM2 Trigger 2
00110 = PWM2 Trigger 1
00101 = PWM1 Trigger 2
00100 = PWM1 Trigger 1
00011 = Reserved
00010 = Level software trigger
00001 = Common software trigger
00000 = No trigger is enabled


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**REGISTER 13-23: ADCMPxCON: ADC DIGITAL COMPARATOR x CONTROL REGISTER (x = 0, 1, 2, 3)**

| U-0 | U-0 | U-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | CHNL[4:0] | | | | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | HC/HS/R-0 | 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
...
10010 = Reserved
10001 = Band gap, 1.2V (AN17)
10000 = Temperature sensor (AN16)
...
01110 = Reserved
...
01010 = Reserved
01001 = AN9
...
00011 = AN3
00010 = AN2
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

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**REGISTER 13-23: ADCMPxCON: ADC DIGITAL COMPARATOR x CONTROL REGISTER (x = 0, 1, 2, 3)**

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 13-24: ADCMPxENL: ADC DIGITAL COMPARATOR x CHANNEL ENABLE REGISTER LOW (x = 0 or 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 |
|---|---|---|---|---|---|---|---|
| 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 13-25: ADCMPxENH: ADC DIGITAL COMPARATOR x CHANNEL ENABLE REGISTER HIGH (x = 0 or 3)**

| 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 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | CMPEN[17:16] | |
| 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 15-2 **Unimplemented:** Read as '0'

bit 1-0 **CMPEN[17:16]:** 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

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**REGISTER 13-26: ADFLxCON: ADC DIGITAL FILTER x CONTROL REGISTER (x = 0 or 3)**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | FLCHSEL[4:0] | | | | |
| 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 Interrupts Enable bit
1 = Individual and common interrupts will be generated when the filter result is ready
0 = Individual and common interrupts 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 are ready
0 = The ADFLxDAT register has been read and new data in the ADFLxDAT register are not ready

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


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**REGISTER 13-26: ADFLxCON: ADC DIGITAL FILTER x CONTROL REGISTER (x = 0 or 3) (CONTINUED)**

bit 4-0 **FLCHSEL[4:0]:** Oversampling Filter Input Channel Selection bits

11111 = Reserved
...
10010 = Reserved
10001 = Band gap, 1.2V (AN17)
10000 = Temperature sensor (AN16)
01111 = AN15
...
00011 = AN3
00010 = AN2
00001 = AN1
00000 = AN0

## 14.0 HIGH-SPEED ANALOG COMPARATOR WITH SLOPE COMPENSATION DAC

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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 with Slope Compensation DAC"** (www.microchip.com/DS70005280).

The high-speed analog comparator module provides a method to monitor voltage, current and other critical signals in a power conversion application that may be too fast for the CPU and ADC to capture. There are a total of three comparator modules. The analog comparator module can be used to implement Peak Current mode control, Critical Conduction mode (variable frequency) and Hysteretic Control mode.

### 14.1 Overview

The high-speed analog comparator module is comprised of a high-speed comparator, Pulse Density Modulation (PDM) DAC and a slope compensation unit. The slope compensation unit provides a user-defined slope which can be used to alter the DAC output. This feature is useful in applications, such as Peak Current mode control, where slope compensation is required to maintain the stability of the power supply. The user simply specifies the direction and rate of change for the slope compensation and the output of the DAC is modified accordingly.

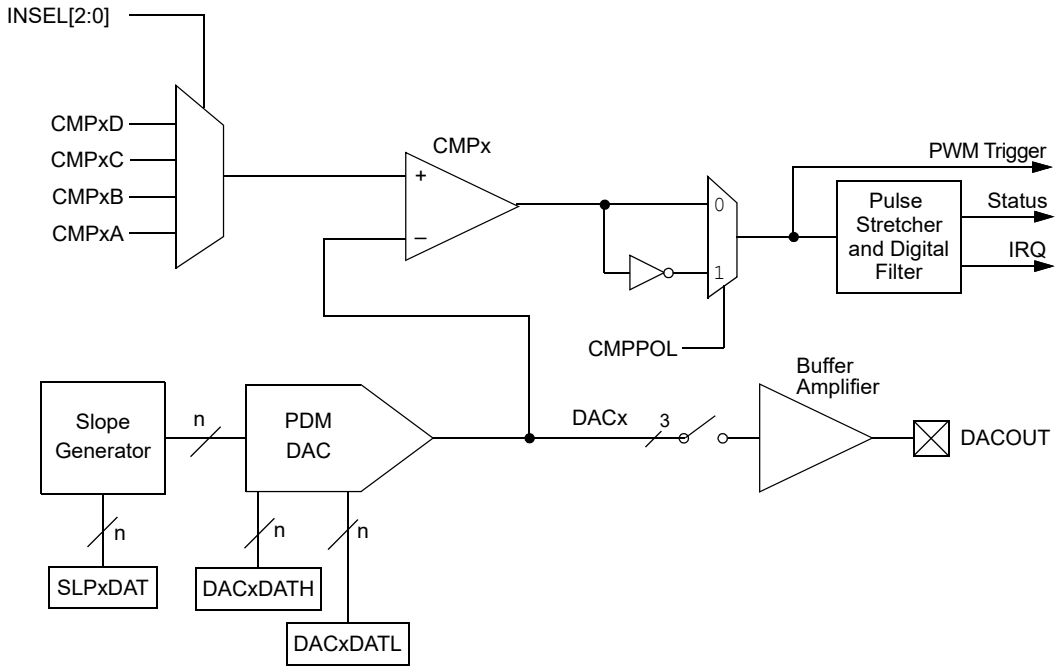
The DAC consists of a PDM unit, followed by a digitally controlled multiphase RC filter. The PDM unit uses a phase accumulator circuit to generate an output stream of pulses. The density of the pulse stream is proportional to the input data value, relative to the maximum value supported by the bit width of the accumulator. The output pulse density is representative of the desired output voltage. The pulse stream is filtered with an RC filter to yield an analog voltage. The output of the DAC is connected to the negative input of the comparator. The positive input of the comparator can be selected using a MUX from either of the input pins. The comparator provides a high-speed operation with a typical delay of 15 ns.

The output of the comparator is processed by the pulse stretcher and the digital filter blocks, which prevent a comparator response to unintended fast transients in the inputs. Figure 14-1 shows a block diagram of the high-speed analog comparator module. The DAC module can be operated in one of three modes: Slope Generation mode, Hysteretic mode and Triangle Wave mode. Each of these modes can be used in a variety of power supply applications.

**Note:** The DACOUT pin can only be associated with a single DAC output at any given time. If more than one DACOEN bit is set, the DACOUT pin will be a combination of the signals.


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**FIGURE 14-1: HIGH-SPEED ANALOG COMPARATOR MODULE BLOCK DIAGRAM**




**Note:** n = 16

## 14.2 Features Overview

- Three Rail-to-Rail Analog Comparators
- Up to Four Selectable Input Sources per Comparator
- Programmable Comparator Hysteresis
- Programmable Output Polarity
- Interrupt Generation Capability
- Dedicated Pulse Density Modulation DAC for Each Analog Comparator:
  - PDM unit followed by a digitally controlled multimode multipole RC filter
- Multimode Multipole RC Output Filter:
  - Transition mode: Provides the fastest response
  - Fast mode: For tracking DAC slopes
  - Steady-State mode: Provides 12-bit resolution
- Slope Compensation along with Each DAC:
  - Slope Generation mode
  - Hysteretic Control mode
  - Triangle Wave mode
- Functional Support for the High-Speed PWM Module which Includes:
  - PWM duty cycle control
  - PWM period control
  - PWM Fault detect

## 14.3 Control Registers

The DACCTRL1L and DACCTRL2H/L registers are common configuration registers for DAC modules.

The DACxCON, DACxDAT, SLPxCON and SLPxDAT registers specify the operation of individual modules.


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**REGISTER 14-1: DACCTRL1L: DAC CONTROL 1 LOW REGISTER**

| R/W-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| DACON | — | DACSIDL | — | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| CLKSEL1(1,3) | CLKSEL0(1,3) | CLKDIV1(1,3) | CLKDIV0(1,3) | — | FCLKDIV2(2) | FCLKDIV1(2) | FCLKDIV0(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 |

bit 15 **DACON:** Common DAC Module Enable bit
1 = Enables DAC modules
0 = Disables DAC modules and disables FSCM clocks to reduce power consumption; any pending Slope mode and/or underflow conditions are cleared

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

bit 13 **DACSIDL:** DAC Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-8 **Unimplemented:** Read as '0'

bit 7-6 **CLKSEL[1:0]:** DAC Clock Source Select bits
11 = FPLLO
10 = FVCO/3
01 = FVCO/2
00 = FVCODIV

bit 5-4 **CLKDIV[1:0]:** DAC Clock Divider bits
11 = Divide-by-4
10 = Divide-by-3 (non-uniform duty cycle)
01 = Divide-by-2
00 = 1x

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

bit 2-0 **FCLKDIV[2:0]:** Comparator Filter Clock Divider bits
111 = Divide-by-8
110 = Divide-by-7
101 = Divide-by-6
100 = Divide-by-5
011 = Divide-by-4
010 = Divide-by-3
001 = Divide-by-2
000 = 1x

**Note 1:** These bits should only be changed when DACON = 0 to avoid unpredictable behavior.
**2:** The input clock to this divider is the selected clock input, CLKSEL[1:0], and then divided by 2.
**3:** Clock source and dividers should yield an effective DAC clock input as specified in Table 33-37.

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**REGISTER 14-2: DACCTRL2H: DAC CONTROL 2 HIGH REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | SSTIME[9:8](1) | |
| bit 15 | | | | | | | bit 8 |

| R/W-1 | R/W-0 | R/W-0 | R/W-0 | R/W-1 | R/W-0 | R/W-1 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SSTIME[7:0](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 |

bit 15-10 **Unimplemented:** Read as '0'

bit 9-0 **SSTIME[9:0]:** Time from the start of Transition mode until the steady-state filter is Enabled bits

**Note 1:** The value for SSTIME[9:0] should be greater than the TMODTIME[9:0] value.

**REGISTER 14-3: DACCTRL2L: DAC CONTROL 2 LOW REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | TMODTIME[9:8](1) | |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-1 | R/W-0 | R/W-1 | R/W-0 | R/W-1 | R/W-0 | R/W-1 |
|---|---|---|---|---|---|---|---|
| TMODTIME[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 |

bit 15-10 **Unimplemented:** Read as '0'

bit 9-0 **TMODTIME[9:0]:** Transition Mode Duration bits(1)

**Note 1:** The value for TMODTIME[9:0] should be less than the SSTIME[9:0] value.


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**REGISTER 14-4: DACxCONH: DACx CONTROL HIGH REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | TMCB[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 |
|---|---|---|---|---|---|---|---|
| TMCB[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 |

bit 15-10 **Unimplemented:** Read as '0'

bit 9-0 **TMCB[9:0]:** DACx Leading-Edge Blanking bits
These register bits specify the blanking period for the comparator, following changes to the DAC output during Change-of-State (COS), for the input signal selected by the HCFSEL[3:0] bits in Register 14-9.

**REGISTER 14-5: DACxCONL: DACx CONTROL LOW REGISTER**

| R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| DACEN | IRQM1(1,2) | IRQM0(1,2) | — | — | CBE | DACOEN | FLTREN |
| bit 15 | | | | | | | bit 8 |

| R-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CMPSTAT | CMPPOL | INSEL2 | INSEL1 | INSEL0 | HYSPOL | HYSSEL1 | HYSSEL0 |
| 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 |

bit 15 **DACEN:** Individual DACx Module Enable bit
1 = Enables DACx module
0 = Disables DACx module to reduce power consumption; any pending Slope mode and/or underflow conditions are cleared

bit 14-13 **IRQM[1:0]:** Interrupt Mode select bits
11 = Generates an interrupt on either a rising or falling edge detect
10 = Generates an interrupt on a falling edge detect
01 = Generates an interrupt on a rising edge detect
00 = Interrupts are disabled

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

**Note 1:** Changing these bits during operation may generate a spurious interrupt.
**2:** The edge selection is a post-polarity selection via the CMPPOL bit.

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**REGISTER 14-5: DACxCONL: DACx CONTROL LOW REGISTER (CONTINUED)**

bit 10 **CBE:** Comparator Blank Enable bit
1 = Enables the analog comparator output to be blanked (gated off) during the recovery transition following the completion of a slope operation
0 = Disables the blanking signal to the analog comparator; therefore, the analog comparator output is always active

bit 9 **DACOEN:** DACx Output Buffer Enable bit
1 = DACx analog voltage is connected to the DACOUT pin
0 = DACx analog voltage is not connected to the DACOUT pin

bit 8 **FLTREN:** Comparator Digital Filter Enable bit
1 = Digital filter is enabled
0 = Digital filter is disabled

bit 7 **CMPSTAT:** Comparator Status bits
The current state of the comparator output including the CMPPOL selection.

bit 6 **CMPPOL:** Comparator Output Polarity Control bit
1 = Output is inverted
0 = Output is noninverted

bit 5-3 **INSEL[2:0]:** Comparator Input Source Select bits
111 = Reserved
110 = Reserved
101 = Reserved
100 = Reserved
011 = CMPxD input pin
010 = CMPxC input pin
001 = CMPxB input pin
000 = CMPxA input pin

bit 2 **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 1-0 **HYSSEL[1:0]:** Comparator Hysteresis Select bits
11 = 45 mv hysteresis
10 = 30 mv hysteresis
01 = 15 mv hysteresis
00 = No hysteresis is selected

**Note 1:** Changing these bits during operation may generate a spurious interrupt.
**2:** The edge selection is a post-polarity selection via the CMPPOL bit.


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**REGISTER 14-6: DACxDATH: DACx DATA HIGH REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | DACDATH[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 |
|---|---|---|---|---|---|---|---|
| DACDATH[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 |

bit 15-12 **Unimplemented:** Read as ‘0’

bit 11-0 **DACDATH[11:0]:** DACx Data bits
This register specifies the high DACx data value. Valid values are from 205 to 3890.

**REGISTER 14-7: DACxDATL: DACx DATA LOW REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | DACDATL[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 |
|---|---|---|---|---|---|---|---|
| DACDATL[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 |

bit 15-12 **Unimplemented:** Read as ‘0’

bit 11-0 **DACDATL[11:0]:** DACx Low Data bits
In Hysteretic mode, Slope Generator mode and Triangle mode, this register specifies the low data value for the DACx module. Valid values are from 205 to 3890.

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**REGISTER 14-8: SLPxCONH: DACx SLOPE CONTROL HIGH REGISTER**

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| SLOPEN | — | — | — | HME(1) | TWME(2) | PSE | — |
| 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 |

bit 15 **SLOPEN:** Slope Function Enable/On bit
1 = Enables slope function
0 = Disables slope function; slope accumulator is disabled to reduce power consumption

bit 14-12 **Unimplemented:** Read as '0'

bit 11 **HME:** Hysteretic Mode Enable bit(1)
1 = Enables Hysteretic mode for DACx
0 = Disables Hysteretic mode for DACx

bit 10 **TWME:** Triangle Wave Mode Enable bit(2)
1 = Enables Triangle Wave mode for DACx
0 = Disables Triangle Wave mode for DACx

bit 9 **PSE:** Positive Slope Mode Enable bit
1 = Slope mode is positive (increasing)
0 = Slope mode is negative (decreasing)

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

**Note 1:** HME mode requires the user to disable the slope function (SLOPEN = 0).
**2:** TWME mode requires the user to enable the slope function (SLOPEN = 1).


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**REGISTER 14-9: SLPxCONL: DACx SLOPE CONTROL 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 |
|---|---|---|---|---|---|---|---|
| HCFSEL3 | HCFSEL2 | HCFSEL1 | HCFSEL0 | SLPSTOPA3 | SLPSTOPA2 | SLPSTOPA1 | SLPSTOPA0 |
| 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 |
|---|---|---|---|---|---|---|---|
| SLPSTOPB3 | SLPSTOPB2 | SLPSTOPB1 | SLPSTOPB0 | SLPSTRT3 | SLPSTRT2 | SLPSTRT1 | SLPSTRT0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | |
|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' |
| -n = Value at POR | '1' = Bit is set0 | '0' = Bit is cleared |

bit 15-12 **HCFSEL[3:0]:** Hysteretic Comparator Function Input Select bits

The selected input signal controls the switching between the DACx high limit (DACxDATH) and the DACx low limit (DACxDATL) as the data source for the PDM DAC. It modifies the polarity of the comparator, and the rising and falling edges initiate the start of the LEB counter (TMCB[9:0] bits in Register 14-4).

| Input Selection | Source |
|---|---|
| 0101-1111 | 1 |
| 0100 | PWM4H |
| 0011 | PWM3H |
| 0010 | PWM2H |
| 0001 | PWM1H |
| 0000 | 0 |

bit 11-8 **SLPSTOPA[3:0]:** Slope Stop A Signal Select bits

The selected Slope Stop A signal is logically OR'd with the selected Slope Stop B signal to terminate the slope function.

| Slope Stop A Signal Selection | Source |
|---|---|
| 0101-1111 | 1 |
| 0100 | PWM4 Trigger 2 |
| 0011 | PWM3 Trigger 2 |
| 0010 | PWM2 Trigger 2 |
| 0001 | PWM1 Trigger 2 |
| 0000 | 0 |

bit 7-4 **SLPSTOPB[3:0]:** Slope Stop B Signal Select bits

The selected Slope Stop B signal is logically OR'd with the selected Slope Stop A signal to terminate the slope function.

| Slope Stop B Signal Selection | Source |
|---|---|
| 0010-1111 | 1 |
| 0001 | CMP1 Out |
| 0000 | 0 |

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**REGISTER 14-9: SLPxCONL: DACx SLOPE CONTROL LOW REGISTER (CONTINUED)**

bit 3-0 **SLPSTRT[3:0]:** Slope Start Signal Select bits

| Slope Start Signal Selection | Source |
|---|---|
| 0101-1111 | 1 |
| 0100 | PWM4 Trigger 1 |
| 0011 | PWM3 Trigger 1 |
| 0010 | PWM2 Trigger 1 |
| 0001 | PWM1 Trigger 1 |
| 0000 | 0 |

**REGISTER 14-10: SLPxDAT: DACx SLOPE DATA 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 |
|---|---|---|---|---|---|---|---|
| SLPDAT[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 |
|---|---|---|---|---|---|---|---|
| SLPDAT[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 |

bit 15-0 **SLPDAT[15:0]:** Slope Ramp Rate Value bits
The SLPDATx value is in 12.4 format.

**Note 1:** Register data are left justified.


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**NOTES:**

## 15.0 QUADRATURE ENCODER INTERFACE (QEI)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive resource. For more information, refer to **"Quadrature Encoder Interface (QEI)"** (www.microchip.com/DS70000601).

The Quadrature Encoder Interface (QEI) module provides the interface to incremental encoders for obtaining mechanical position data. The dsPIC33CDVL64MC106 family implements one instance of the QEI. Quadrature Encoders, also known as incremental encoders or optical encoders, detect position and speed of rotating motion systems. Quadrature Encoders enable closed-loop control of motor control applications, such as Switched Reluctance (SR) and AC Induction Motors (ACIM).

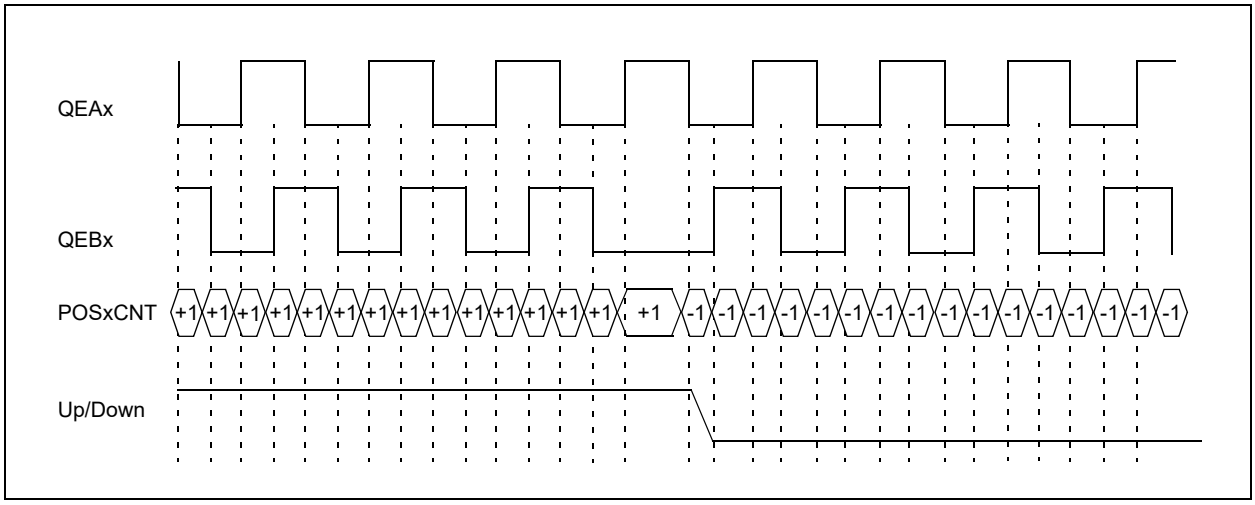
A typical Quadrature Encoder includes a slotted wheel attached to the shaft of the motor and an emitter/detector module that senses the slots in the wheel. Typically, three output channels, Phase A (QEAx), Phase B (QEBx) and Index (INDXx), provide information on the movement of the motor shaft, including distance and direction.

The two channels, Phase A (QEAx) and Phase B (QEBx), are typically 90 degrees out of phase with respect to each other. The Phase A and Phase B channels have a unique relationship. If Phase A leads Phase B, the direction of the motor is deemed positive or forward. If Phase A lags Phase B, the direction of the motor is deemed negative or reverse. The Index pulse occurs once per mechanical revolution and is used as a reference to indicate an absolute position. Figure 15-1 illustrates the Quadrature Encoder Interface signals.

The Quadrature signals from the encoder can have four unique states ('01', '00', '10' and '11') that reflect the relationship between QEAx and QEBx. Figure 15-1 illustrates these states for one count cycle. The order of the states get reversed when the direction of travel changes.

The Quadrature Decoder increments or decrements the 32-bit up/down Position x Counter (POSxCNTH/L) registers for each Change-of-State (COS). The counter increments when QEAx leads QEBx and decrements when QEBx leads QEAx.

**FIGURE 15-1: QUADRATURE ENCODER INTERFACE SIGNALS**





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Table 15-1 shows the truth table that describes how the Quadrature signals are decoded.

**TABLE 15-1: TRUTH TABLE FOR QUADRATURE ENCODER**

| Current Quadrature State | | Previous Quadrature State | | Action |
|---|---|---|---|---|
| QEA | QEB | QEA | QEB | |
| 1 | 1 | 1 | 1 | No count or direction change |
| 1 | 1 | 1 | 0 | Count up |
| 1 | 1 | 0 | 1 | Count down |
| 1 | 1 | 0 | 0 | Invalid state change; ignore |
| 1 | 0 | 1 | 1 | Count down |
| 1 | 0 | 1 | 0 | No count or direction change |
| 1 | 0 | 0 | 1 | Invalid state change; ignore |
| 1 | 0 | 0 | 0 | Count up |
| 0 | 1 | 1 | 1 | Count up |
| 0 | 1 | 1 | 0 | Invalid state change; ignore |
| 0 | 1 | 0 | 1 | No count or direction change |
| 0 | 1 | 0 | 0 | Count down |
| 0 | 0 | 1 | 1 | Invalid state change; ignore |
| 0 | 0 | 1 | 0 | Count down |
| 0 | 0 | 0 | 1 | Count up |
| 0 | 0 | 0 | 0 | No count or direction change |

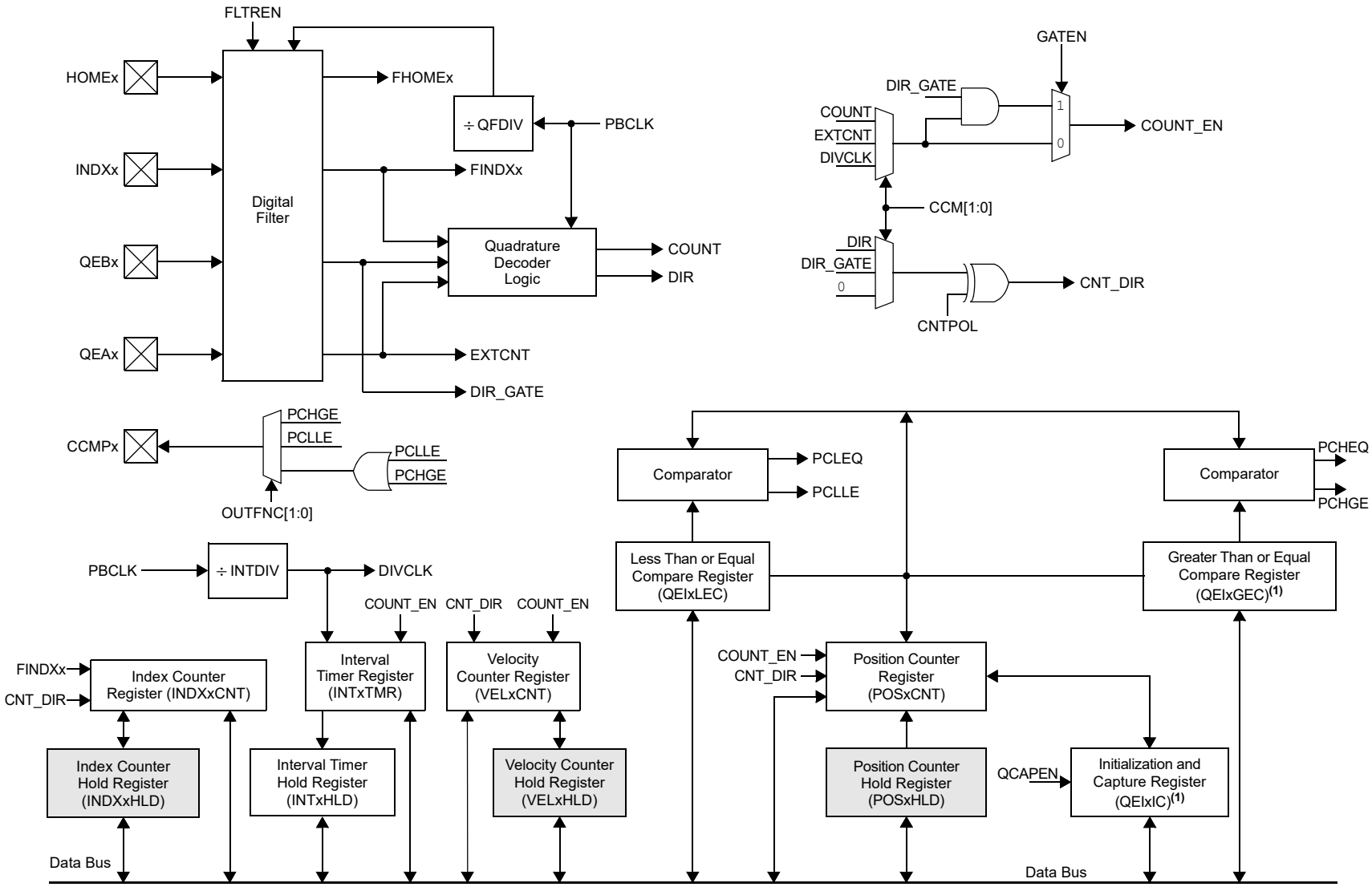
Figure 15-2 illustrates the simplified block diagram of the QEI module. The QEI module consists of decoder logic to interpret the Phase A (QEAx) and Phase B (QEBx) signals, and an up/down counter to accumulate the count. The counter pulses are generated when the Quadrature state changes. The count direction information must be maintained in a register until a direction change is detected. The module also includes digital noise filters, which condition the input signal.

The QEI module consists of the following major features:

- Four Input Pins: Two Phase Signals, an Index Pulse and a Home Pulse
- Programmable Digital Noise Filters on Inputs
- Quadrature Decoder providing Counter Pulses and Count Direction
- Count Direction Status
- 4x Count Resolution
- Index (INDXx) Pulse to Reset the Position Counter
- General Purpose 32-Bit Timer/Counter Mode
- Interrupts generated by QEI or Counter Events
- 32-Bit Velocity Counter
- 32-Bit Position Counter
- 32-Bit Index Pulse Counter
- 32-Bit Interval Timer
- 32-Bit Position Initialization/Capture Register
- 32-Bit Compare Less Than and Greater Than Registers
- External Up/Down Count Mode
- External Gated Count Mode
- External Gated Timer Mode
- Interval Timer Mode

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**FIGURE 15-2: QUADRATURE ENCODER INTERFACE (QEI) MODULE BLOCK DIAGRAM**




**Note 1:** These registers map to the same memory location.

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## 15.1 QEI Control/Status Registers

**REGISTER 15-1: QEIxCON: QEIx 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 |
|---|---|---|---|---|---|---|---|
| QEIEN | — | QEISIDL | PIMOD2(1,5) | PIMOD1(1,5) | PIMOD0(1,5) | IMV1(2) | IMV0(2) |
| 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 |
|---|---|---|---|---|---|---|---|
| — | INTDIV2(3) | INTDIV1(3) | INTDIV0(3) | CNTPOL | GATEN | CCM1 | CCM0 |
| 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 **QEIEN:** Quadrature Encoder Interface Module Enable bit
1 = Module counters are enabled
0 = Module counters are disabled, but SFRs can be read or written

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

bit 13 **QEISIDL:** QEI Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-10 **PIMOD[2:0]:** Position Counter Initialization Mode Select bits
111 = Modulo Count mode for position counter and every Index event resets the position counter(4)
110 = Modulo Count mode for position counter
101 = Resets the position counter when the position counter equals the QEIxGEC register
100 = Second Index event after Home event initializes position counter with contents of QEIxIC register
011 = First Index event after Home event initializes position counter with contents of QEIxIC register
010 = Next Index input event initializes the position counter with contents of QEIxIC register
001 = Every Index input event resets the position counter
000 = Index input event does not affect the position counter

bit 9-8 **IMV[1:0]:** Index Match Value bits
11 = Index match occurs when QEBx = 1 and QEAx = 1
10 = Index match occurs when QEBx = 1 and QEAx = 0
01 = Index match occurs when QEBx = 0 and QEAx = 1
00 = Index match occurs when QEBx = 0 and QEAx = 0

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

**Note 1:** When CCMx = 10 or CCMx = 11, all of the QEI counters operate as timers and the PIMOD[2:0] bits are ignored.

**2:** When CCMx = 00, and QEAx and QEBx values match the Index Match Value (IMV), the POSxCNTH and POSxCNTL registers are reset.

**3:** The selected clock rate should be at least twice the expected maximum quadrature count rate.

**4:** Not all devices support this mode.

**5:** The QCAPEN and HCAPEN bits must be cleared during PIMODx Modes 2 through 7 to ensure proper functionality. Not all devices support HCAPEN.

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**REGISTER 15-1: QEIxCON: QEIx CONTROL REGISTER (CONTINUED)**

bit 6-4 **INTDIV[2:0]:** Timer Input Clock Prescale Select bits
(interval timer, main timer (position counter), velocity counter and index counter internal clock divider select)
111 = 1:128 prescale value
110 = 1:64 prescale value
101 = 1:32 prescale value
100 = 1:16 prescale value
011 = 1:8 prescale value
010 = 1:4 prescale value
001 = 1:2 prescale value
000 = 1:1 prescale value

bit 3 **CNTPOL:** Position and Index Counter/Timer Direction Select bit
1 = Counter direction is negative unless modified by external up/down signal
0 = Counter direction is positive unless modified by external up/down signal

bit 2 **GATEN:** External Count Gate Enable bit
1 = External gate signal controls position counter operation
0 = External gate signal does not affect position counter operation

bit 1-0 **CCM[1:0]:** Counter Control Mode Selection bits
11 = Internal Timer mode
10 = External Clock Count with External Gate mode
01 = External Clock Count with External Up/Down mode
00 = Quadrature Encoder mode

**Note 1:** When CCMx = 10 or CCMx = 11, all of the QEI counters operate as timers and the PIMOD[2:0] bits are ignored.

**2:** When CCMx = 00, and QEAx and QEBx values match the Index Match Value (IMV), the POSxCNTH and POSxCNTL registers are reset.

**3:** The selected clock rate should be at least twice the expected maximum quadrature count rate.

**4:** Not all devices support this mode.

**5:** The QCAPEN and HCAPEN bits must be cleared during PIMODx Modes 2 through 7 to ensure proper functionality. Not all devices support HCAPEN.


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**REGISTER 15-2: QEIxIOC: QEIx I/O 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 |
|---|---|---|---|---|---|---|---|
| QCAPEN | FLTREN | QFDIV2 | QFDIV1 | QFDIV0 | OUTFNC1 | OUTFNC0 | SWPAB |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-x | R-x | R-x | R-x |
|---|---|---|---|---|---|---|---|
| HOMPOL | IDXPOL | QEBPOL | QEAPOL | HOME | INDEX | QEB | QEA |
| 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 **QCAPEN:** QEIx Position Counter Input Capture Enable bit
1 = HOMEx input event (positive edge) triggers a position capture event (HCAPEN must be cleared)
0 = HOMEx input event (positive edge) does not trigger a position capture event

bit 14 **FLTREN:** QEAx/QEBx/INDXx/HOMEx Digital Filter Enable bit
1 = Input pin digital filter is enabled
0 = Input pin digital filter is disabled (bypassed)

bit 13-11 **QFDIV[2:0]:** QEAx/QEBx/INDXx/HOMEx Digital Input Filter Clock Divide Select bits
111 = 1:256 clock divide
110 = 1:64 clock divide
101 = 1:32 clock divide
100 = 1:16 clock divide
011 = 1:8 clock divide
010 = 1:4 clock divide
001 = 1:2 clock divide
000 = 1:1 clock divide

bit 10-9 **OUTFNC[1:0]:** QEIx Module Output Function Mode Select bits
11 = The QEICMPx pin goes high when POSxCNT $\leq$ QEIxLEC or POSxCNT $\geq$ QEIxGEC
10 = The QEICMPx pin goes high when POSxCNT $\leq$ QEIxLEC
01 = The QEICMPx pin goes high when POSxCNT $\geq$ QEIxGEC
00 = Output is disabled

bit 8 **SWPAB:** Swap QEAx and QEBx Inputs bit
1 = QEAx and QEBx are swapped prior to Quadrature Decoder logic
0 = QEAx and QEBx are not swapped

bit 7 **HOMPOL:** HOMEx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 6 **IDXPOL:** INDXx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 5 **QEBPOL:** QEBx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 4 **QEAPOL:** QEAx Input Polarity Select bit
1 = Input is inverted
0 = Input is not inverted

bit 3 **HOME:** Status of HOMEx Input Pin After Polarity Control bit (read-only)
1 = Pin is at logic '1' if the HOMPOL bit is set to '0'; pin is at logic '0' if the HOMPOL bit is set to '1'
0 = Pin is at logic '0' if the HOMPOL bit is set to '0'; pin is at logic '1' if the HOMPOL bit is set to '1'

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**REGISTER 15-2: QEIxIOC: QEIx I/O CONTROL REGISTER (CONTINUED)**

bit 2 **INDEX:** Status of INDXx Input Pin After Polarity Control bit (read-only)

1 = Pin is at logic '1' if the IDXPOL bit is set to '0'; pin is at logic '0' if the IDXPOL bit is set to '1'
0 = Pin is at logic '0' if the IDXPOL bit is set to '0'; pin is at logic '1' if the IDXPOL bit is set to '1'

bit 1 **QEB:** Status of QEBx Input Pin After Polarity Control and SWPAB Pin Swapping bit (read-only)

1 = Physical pin, QEBx, is at logic '1' if the QEBPOL bit is set to '0' and the SWPAB bit is set to '0';
physical pin, QEBx, is at logic '0' if the QEBPOL bit is set to '1' and the SWPAB bit is set to '0';
physical pin, QEBx, is at logic '1' if the QEBPOL bit is set to '0' and the SWPAB bit is set to '1';
physical pin, QEBx, is at logic '0' if the QEBPOL bit is set to '1' and the SWPAB bit is set to '1'

0 = Physical pin, QEBx, is at logic '0' if the QEBPOL bit is set to '0' and the SWPAB bit is set to '0';
physical pin, QEBx, is at logic '1' if the QEBPOL bit is set to '1' and the SWPAB bit is set to '0';
physical pin, QEBx, is at logic '0' if the QEBPOL bit is set to '0' and the SWPAB bit is set to '1';
physical pin, QEBx, is at logic '1' if the QEBPOL bit is set to '1' and the SWPAB bit is set to '1'

bit 0 **QEA:** Status of QEAx Input Pin After Polarity Control and SWPAB Pin Swapping bit (read-only)

1 = Physical pin, QEAx, is at logic '1' if the QEAPOL bit is set to '0' and the SWPAB bit is set to '0';
physical pin, QEAx, is at logic '0' if the QEAPOL bit is set to '1' and the SWPAB bit is set to '0';
physical pin, QEAx, is at logic '1' if the QEAPOL bit is set to '0' and the SWPAB bit is set to '1';
physical pin, QEAx, is at logic '0' if the QEAPOL bit is set to '1' and the SWPAB bit is set to '1'

0 = Physical pin, QEAx, is at logic '0' if the QEAPOL bit is set to '0' and the SWPAB bit is set to '0';
physical pin, QEAx, is at logic '1' if the QEAPOL bit is set to '1' and the SWPAB bit is set to '0';
physical pin, QEAx, is at logic '0' if the QEAPOL bit is set to '0' and the SWPAB bit is set to '1';
physical pin, QEAx, is at logic '1' if the QEAPOL bit is set to '1' and the SWPAB bit is set to '1'

**REGISTER 15-3: QEIxIOCH: QEIx I/O CONTROL HIGH 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 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | HCAPEN |
| 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 **HCAPEN:** Position Counter Input Capture by Home Event Enable bit

1 = HOMEx input event (positive edge) triggers a position capture event
0 = HOMEx input event (positive edge) does not trigger a position capture event


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**REGISTER 15-4: QEIxSTAT: QEIx STATUS REGISTER**

| U-0 | U-0 | HS/R/C-0 | R/W-0 | HS/R/C-0 | R/W-0 | HS/R/C-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | PCHEQIRQ | PCHEQIEN | PCLEQIRQ | PCLEQIEN | POSOVIRQ | POSOVIEN |
| bit 15 | | | | | | | bit 8 |

| HS/R/C-0 | R/W-0 | HS/R/C-0 | R/W-0 | HS/R/C-0 | R/W-0 | HS/R/C-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PCIIRQ(1) | PCIIEN | VELOVIRQ | VELOVIEN | HOMIRQ | HOMIEN | IDXIRQ | IDXIEN |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = 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 **PCHEQIRQ:** Position Counter Greater Than Compare Status bit
1 = POSxCNT ≥ QEIxGEC
0 = POSxCNT < QEIxGEC

bit 12 **PCHEQIEN:** Position Counter Greater Than Compare Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 11 **PCLEQIRQ:** Position Counter Less Than Compare Status bit
1 = POSxCNT ≤ QEIxLEC
0 = POSxCNT > QEIxLEC

bit 10 **PCLEQIEN:** Position Counter Less Than Compare Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 9 **POSOVIRQ:** Position Counter Overflow Status bit
1 = Overflow has occurred
0 = No overflow has occurred

bit 8 **POSOVIEN:** Position Counter Overflow Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 7 **PCIIRQ:** Position Counter (Homing) Initialization Process Complete Status bit
1 = POSxCNT was reinitialized
0 = POSxCNT was not reinitialized

bit 6 **PCIIEN:** Position Counter (Homing) Initialization Process Complete Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 5 **VELOVIRQ:** Velocity Counter Overflow Status bit
1 = Overflow has occurred
0 = No overflow has occurred

bit 4 **VELOVIEN:** Velocity Counter Overflow Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 3 **HOMIRQ:** Status Flag for Home Event Status bit
1 = Home event has occurred
0 = No Home event has occurred

**Note 1:** This status bit is only applicable to PIMOD[2:0] modes, '011' and '100'.

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**REGISTER 15-4: QEIxSTAT: QEIx STATUS REGISTER (CONTINUED)**

bit 2 **HOMIEN:** Home Input Event Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 1 **IDXIRQ:** Status Flag for Index Event Status bit
1 = Index event has occurred
0 = No Index event has occurred

bit 0 **IDXIEN:** Index Input Event Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

**Note 1:** This status bit is only applicable to PIMOD[2:0] modes, '011' and '100'.


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**REGISTER 15-5: POSxCNTL: POSITION x COUNTER 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 |
|---|---|---|---|---|---|---|---|
| POSCNT[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 |
|---|---|---|---|---|---|---|---|
| POSCNT[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 **POSCNT[15:0]:** Low Word Used to Form 32-Bit Position Counter Register (POSxCNT) bits

**REGISTER 15-6: POSxCNTH: POSITION x COUNTER REGISTER 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 |
|---|---|---|---|---|---|---|---|
| POSCNT[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| POSCNT[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 15-0 **POSCNT[31:16]:** High Word Used to Form 32-Bit Position Counter Register (POSxCNT) bits

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**REGISTER 15-7: POSxHLD: POSITION x COUNTER HOLD 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 |
|---|---|---|---|---|---|---|---|
| POSHLD[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 |
|---|---|---|---|---|---|---|---|
| POSHLD[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 **POSHLD[15:0]:** Hold Register for Reading/Writing Position Counter x High Word Register (POSxCNTH (POSxCNT[31:16])) bits


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**REGISTER 15-8: VELxCNT: VELOCITY x COUNTER 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 |
|---|---|---|---|---|---|---|---|
| VELCNT[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 |
|---|---|---|---|---|---|---|---|
| VELCNT[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 **VELCNT[15:0]:** Velocity Counter bits

**REGISTER 15-9: VELxCNTH: VELOCITY x COUNTER REGISTER 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 |
|---|---|---|---|---|---|---|---|
| VELCNT[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| VELCNT[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 15-0 **VELCNT[31:16]:** Velocity Counter bits

**REGISTER 15-10: VELxHLD: VELOCITY x COUNTER HOLD 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 |
|---|---|---|---|---|---|---|---|
| VELHLD[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 |
| VELHLD[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 **VELHLD[15:0]:** Hold Register for Reading/Writing Velocity Counter x High Word Register (VELxCNTH (VELxCNT[31:16])) bits


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**REGISTER 15-11: INTxTMRL: INTERVAL x TIMER 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 |
|---|---|---|---|---|---|---|---|
| INTTMR[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 |
|---|---|---|---|---|---|---|---|
| INTTMR[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 **INTTMR[15:0]:** Low Word Used to Form 32-Bit Interval Timer Register (INTxTMR) bits

**REGISTER 15-12: INTxTMRH: INTERVAL x TIMER REGISTER 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 |
|---|---|---|---|---|---|---|---|
| INTTMR[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| INTTMR[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 15-0 **INTTMR[31:16]:** High Word Used to Form 32-Bit Interval Timer Register (INTxTMR) bits

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**REGISTER 15-13: INTXxHLDL: INTERVAL x TIMER HOLD 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 |
|---|---|---|---|---|---|---|---|
| INTHLD[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 |
|---|---|---|---|---|---|---|---|
| INTHLD[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 **INTHLD[15:0]:** Low Word Used to Form 32-Bit Interval Timer Hold Register (INTxHLD) bits

**REGISTER 15-14: INTXxHLDH: INTERVAL x TIMER HOLD REGISTER 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 |
|---|---|---|---|---|---|---|---|
| INTHLD[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| INTHLD[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 15-0 **INTHLD[31:16]:** High Word Used to Form 32-Bit Interval Timer Hold Register (INTxHLD) bits


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**REGISTER 15-15: INDXxCNTL: INDEX x COUNTER 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 |
|---|---|---|---|---|---|---|---|
| INDXCNT[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 |
|---|---|---|---|---|---|---|---|
| INDXCNT[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 **INDXCNT[15:0]:** Low Word Used to Form 32-Bit Index x Counter Register (INDXxCNT) bits

**REGISTER 15-16: INDXxCNTH: INDEX x COUNTER REGISTER 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 |
|---|---|---|---|---|---|---|---|
| INDXCNT[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| INDXCNT[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 15-0 **INDXCNT[31:16]:** High Word Used to Form 32-Bit Index x Counter Register (INDXxCNT) bits

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**REGISTER 15-17: INDXxHLD: INDEX x COUNTER HOLD 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 |
|---|---|---|---|---|---|---|---|
| INDXHLD[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 |
|---|---|---|---|---|---|---|---|
| INDXHLD[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 **INDXHLD[15:0]:** Hold Register for Reading/Writing Index Counter x High Word Register (INDXxCNTH (INDXxCNT[31:16])) bits


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**REGISTER 15-18: QEIxICL: QEIx INITIALIZATION/CAPTURE 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 |
|---|---|---|---|---|---|---|---|
| QEIIC[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 |
|---|---|---|---|---|---|---|---|
| QEIIC[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 **QEIIC[15:0]:** Low Word Used to Form 32-Bit Initialization/Capture Register (QEIxIC) bits

**REGISTER 15-19: QEIxICH: QEIx INITIALIZATION/CAPTURE REGISTER 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 |
|---|---|---|---|---|---|---|---|
| QEIIC[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| QEIIC[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 15-0 **QEIIC[31:16]:** High Word Used to Form 32-Bit Initialization/Capture Register (QEIxIC) bits

**REGISTER 15-20: QEIxLECL: QEIx LESS THAN OR EQUAL COMPARE 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 |
|---|---|---|---|---|---|---|---|
| QEILEC[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 |
|---|---|---|---|---|---|---|---|
| QEILEC[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 **QEILEC[15:0]:** Low Word Used to Form 32-Bit Less Than or Equal Compare Register (QEIxLEC) bits

**REGISTER 15-21: QEIxLECH: QEIx LESS THAN OR EQUAL COMPARE REGISTER 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 |
|---|---|---|---|---|---|---|---|
| QEILEC[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| QEILEC[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 15-0 **QEILEC[31:16]:** High Word Used to Form 32-Bit Less Than or Equal Compare Register (QEIxLEC) bits


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**REGISTER 15-22: QEIxGECL: QEIx GREATER THAN OR EQUAL COMPARE 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 |
|---|---|---|---|---|---|---|---|
| QEIGEC[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 |
|---|---|---|---|---|---|---|---|
| QEIGEC[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 **QEIGEC[15:0]:** Low Word Used to Form 32-Bit Greater Than or Equal Compare Register (QEIxGEC) bits

**REGISTER 15-23: QEIxGECH: QEIx GREATER THAN OR EQUAL COMPARE REGISTER 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 |
|---|---|---|---|---|---|---|---|
| QEIGEC[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| QEIGEC[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 15-0 **QEIGEC[31:16]:** High Word Used to Form 32-Bit Greater Than or Equal Compare Register (QEIxGEC) bits

## 16.0 UNIVERSAL ASYNCHRONOUS RECEIVER TRANSMITTER (UART)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Multiprotocol Universal Asynchronous Receiver Transmitter (UART) Module"** (www.microchip.com/DS70005288).

The Universal Asynchronous Receiver Transmitter (UART) is a flexible serial communication peripheral used to interface dsPIC® microcontrollers with other equipment, including computers and peripherals. The UART is a full-duplex, asynchronous communication channel that can be used to implement protocols, such as RS-232 and RS-485. The UART also supports the following hardware extensions:

- LIN/J2602
- IrDA®
- Digital Multiplex (DMX)
- Smart Card

The primary features of the UART are:

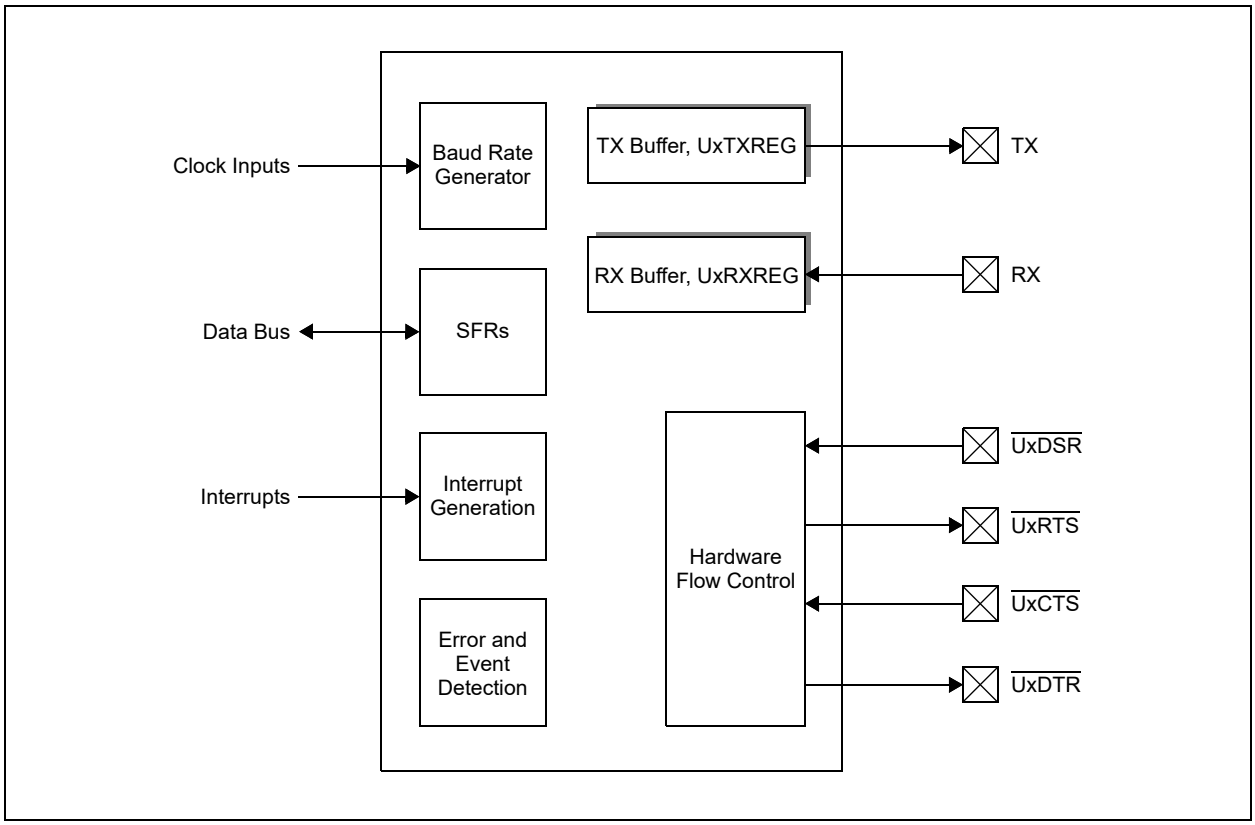
- Full or Half-Duplex Operation
- Up to 8-Deep TX and RX First In, First Out (FIFO) Buffers
- 8-Bit or 9-Bit Data Width
- Configurable Stop Bit Length
- Flow Control
- Auto-Baud Calibration
- Parity, Framing and Buffer Overrun Error Detection
- Address Detect
- Break Transmission
- Transmit and Receive Polarity Control
- Manchester Encoder/Decoder
- Operation in Sleep Mode
- Wake from Sleep on Sync Break Received Interrupt


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## 16.1 Architectural Overview

The UART transfers bytes of data, to and from device pins, using First-In First-Out (FIFO) buffers up to eight bytes deep. The status of the buffers and data is made available to user software through Special Function Registers (SFRs). The UART implements multiple interrupt channels for handling transmit, receive and error events. A simplified block diagram of the UART is shown in Figure 16-1.

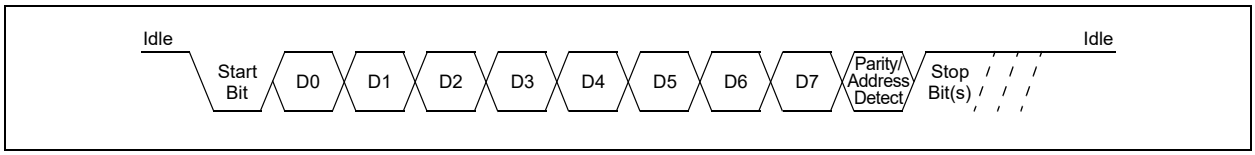
**FIGURE 16-1: SIMPLIFIED UARTx BLOCK DIAGRAM**



## 16.2 Character Frame

A typical UART character frame is shown in Figure 16-2. The Idle state is high with a 'Start' condition indicated by a falling edge. The Start bit is followed by the number of data, parity/address detect and Stop bits defined by the MOD[3:0] (UxMODE[3:0]) bits selected.

**FIGURE 16-2: UART CHARACTER FRAME**




## 16.3 Data Buffers

Both transmit and receive functions use buffers to store data shifted to/from the pins. These buffers are FIFOs and are accessed by reading the SFRs, UxTXREG and UxRXREG, respectively. Each data buffer has multiple flags associated with its operation to allow software to read the status. Interrupts can also be configured based on the space available in the buffers. The transmit and receive buffers can be cleared and their pointers reset using the associated TX/RX Buffer Empty Status bits, UTXBE (UxSTAH[5]) and URXBE (UxSTAH[1]).

## 16.4 Protocol Extensions

The UART provides hardware support for LIN/J2602, IrDA®, DMX and smart card protocol extensions to reduce software overhead. A protocol extension is enabled by writing a value to the MOD[3:0] (UxMODE[3:0]) selection bits and further configured using the UARTx Timing Parameter registers, UxP1 (Register 16-9), UxP2 (Register 16-10), UxP3 (Register 16-11) and UxP3H (Register 16-12). Details regarding operation and usage are discussed in their respective chapters.


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## 16.5 UART Control/Status Registers

**REGISTER 16-1: UxMODE: UARTx CONFIGURATION REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | HC/R/W-0(1) |
|---|---|---|---|---|---|---|---|
| UARTEN | — | USIDL | WAKE | RXBIMD | — | BRKOVR | UTXBRK |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | HC/R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| BRGH | ABAUD | UTXEN | URXEN | MOD3 | MOD2 | MOD1 | MOD0 |
| 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:** UART Enable bit
1 = UART is ready to transmit and receive
0 = UART state machine, FIFO Buffer Pointers and counters are reset; registers are readable and writable

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

bit 13 **USIDL:** UART Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **WAKE:** Wake-up Enable bit
1 = Module will continue to sample the RX pin – interrupt generated on falling edge, bit cleared in hardware on following rising edge; if ABAUD is set, Auto-Baud Detection (ABD) will begin immediately
0 = RX pin is not monitored nor rising edge detected

bit 11 **RXBIMD:** Receive Break Interrupt Mode bit
1 = RXBKIF flag when a minimum of 23 (DMX)/11 (asynchronous or LIN/J2602) low bit periods are detected
0 = RXBKIF flag when the Break makes a low-to-high transition after being low for at least 23/11 bit periods

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

bit 9 **BRKOVR:** Send Break Software Override bit
Overrides the TX Data Line:
1 = Makes the TX line active (Output 0 when UTXINV = 0, Output 1 when UTXINV = 1)
0 = TX line is driven by the shifter

bit 8 **UTXBRK:** UART Transmit Break bit(1)
1 = Sends Sync Break on next transmission; cleared by hardware upon completion
0 = Sync Break transmission is disabled or has completed

bit 7 **BRGH:** High Baud Rate Select bit
1 = High Speed: Baud rate is baudclk/4
0 = Low Speed: Baud rate is baudclk/16

bit 6 **ABAUD:** Auto-Baud Detect Enable bit (read-only when MOD[3:0] = 1xxx)
1 = Enables baud rate measurement on the next character – requires reception of a Sync field (55h); cleared in hardware upon completion
0 = Baud rate measurement is disabled or has completed

**Note 1:** R/HS/HC in DMX and LIN modes.

**REGISTER 16-1: UxMODE: UARTx CONFIGURATION REGISTER (CONTINUED)**

bit 5 **UTXEN:** UART Transmit Enable bit

1 = Transmit enabled – except during Auto-Baud Detection
0 = Transmit disabled – all transmit counters, pointers and state machines are reset; TX buffer is not flushed, status bits are not reset

bit 4 **URXEN:** UART Receive Enable bit

1 = Receive enabled – except during Auto-Baud Detection
0 = Receive disabled – all receive counters, pointers and state machines are reset; RX buffer is not flushed, status bits are not reset

bit 3-0 **MOD[3:0]:** UART Mode bits

Other = Reserved
1111 = Smart card
1110 = IrDA®
1101 = Reserved
1100 = LIN Commander/Responder
1011 = LIN Responder only
1010 = DMX
1001 = Reserved
1000 = Reserved
0111 = Reserved
0110 = Reserved
0101 = Reserved
0100 = Asynchronous 9-bit UART with address detect, ninth bit = 1 signals address
0011 = Asynchronous 8-bit UART without address detect, ninth bit is used as an even parity bit
0010 = Asynchronous 8-bit UART without address detect, ninth bit is used as an odd parity bit
0001 = Asynchronous 7-bit UART
0000 = Asynchronous 8-bit UART

**Note 1:** R/HS/HC in DMX and LIN modes.


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**REGISTER 16-2: UxMODEH: UARTx CONFIGURATION REGISTER HIGH**

| R/W-0 | R-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SLPEN | ACTIVE | — | — | BCLKMOD | BCLKSEL1 | BCLKSEL0 | HALFDPLX |
| 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 |
|---|---|---|---|---|---|---|---|
| RUNOVF | URXINV | STSEL1 | STSEL0 | C0EN | UTXINV | FLO1 | FLO0 |
| 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 **SLPEN:** Run During Sleep Enable bit
1 = UART BRG clock runs during Sleep
0 = UART BRG clock is turned off during Sleep

bit 14 **ACTIVE:** UART Running Status bit
1 = UART clock request is active (user can not update the UxMODE/UxMODEH registers)
0 = UART clock request is not active (user can update the UxMODE/UxMODEH registers)

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

bit 11 **BCLKMOD:** Baud Clock Generation Mode Select bit
1 = Uses fractional Baud Rate Generation
0 = Uses legacy divide-by-x counter for baud clock generation (x = 4 or 16 depending on the BRGH bit)

bit 10-9 **BCLKSEL[1:0]:** Baud Clock Source Selection bits
11 = FVCODIV
10 = FOSC
01 = PLL VCO/5
00 = FOSC/2 (FP)

bit 8 **HALFDPLX:** UART Half-Duplex Selection Mode bit
1 = Half-Duplex mode: UxTX is driven as an output when transmitting and tri-stated when TX is Idle
0 = Full-Duplex mode: UxTX is driven as an output at all times when both UARTEN and UTXEN are set

bit 7 **RUNOVF:** Run During Overflow Condition Mode bit
1 = When an Overflow Error (OERR) condition is detected, the RX shifter continues to run so as to remain synchronized with incoming RX data; data are not transferred to UxRXREG when it is full (i.e., no UxRXREG data are overwritten)
0 = When an Overflow Error (OERR) condition is detected, the RX shifter stops accepting new data (Legacy mode)

bit 6 **URXINV:** UART Receive Polarity bit
1 = Inverts RX polarity; Idle state is low
0 = Input is not inverted; Idle state is high

bit 5-4 **STSEL[1:0]:** Number of Stop Bits Selection bits
11 = 2 Stop bits sent, 1 checked at receive
10 = 2 Stop bits sent, 2 checked at receive
01 = 1.5 Stop bits sent, 1.5 checked at receive
00 = 1 Stop bit sent, 1 checked at receive

bit 3 **C0EN:** Enable Legacy Checksum (C0) Transmit and Receive bit
1 = Checksum Mode 1 (enhanced LIN checksum in LIN mode; add all TX/RX words in all other modes)
0 = Checksum Mode 0 (legacy LIN checksum in LIN mode; not used in all other modes)

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**REGISTER 16-2: UxMODEH: UARTx CONFIGURATION REGISTER HIGH (CONTINUED)**

bit 2 **UTXINV:** UART Transmit Polarity bit
1 = Inverts TX polarity; TX is low in Idle state
0 = Output data are not inverted; TX output is high in Idle state

bit 1-0 **FLO[1:0]:** Flow Control Enable bits (only valid when MOD[3:0] = 0xxx)
11 = Reserved
10 = $\overline{\text{RTS}}$-$\overline{\text{DSR}}$ (for TX side)/$\overline{\text{CTS}}$-DTR (for RX side) hardware flow control
01 = XON/XOFF software flow control
00 = Flow control off


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**REGISTER 16-3: UxSTA: UARTx STATUS 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 |
|---|---|---|---|---|---|---|---|
| TXMTIE | PERIE | ABDOVE | CERIE | FERIE | RXBKIE | OERIE | TXCIE |
| bit 15 | | | | | | | bit 8 |

| R-1 | R-0 | HS/R/W-0 | HS/R/W-0 | R-0 | HS/R/W-0 | HS/R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TRMT | PERR | ABDOVF | CERIF | FERR | RXBKIF | OERR | TXCIF |
| 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 **TXMTIE:** Transmit Shifter Empty Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 14 **PERIE:** Parity Error Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 13 **ABDOVE:** Auto-Baud Rate Acquisition Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 12 **CERIE:** Checksum Error Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 11 **FERIE:** Framing Error Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 10 **RXBKIE:** Receive Break Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 9 **OERIE:** Receive Buffer Overflow Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 8 **TXCIE:** Transmit Collision Interrupt Enable bit
1 = Interrupt is enabled
0 = Interrupt is disabled

bit 7 **TRMT:** Transmit Shifter Empty Interrupt Flag bit (read-only)
1 = Transmit Shift Register (TSR) is empty (end of last Stop bit when STPMD = 1 or middle of first Stop bit when STPMD = 0)
0 = Transmit Shift Register is not empty

bit 6 **PERR:** Parity Error/Address Received/Forward Frame Interrupt Flag bit
LIN and Parity Modes:
1 = Parity error detected
0 = No parity error detected
Address Mode:
1 = Address received
0 = No address detected
All Other Modes:
Not used.

**REGISTER 16-3: UxSTA: UARTx STATUS REGISTER (CONTINUED)**

bit 5 **ABDOVF:** Auto-Baud Rate Acquisition Interrupt Flag bit (must be cleared by software)
1 = BRG rolled over during the auto-baud rate acquisition sequence (must be cleared in software)
0 = BRG has not rolled over during the auto-baud rate acquisition sequence

bit 4 **CERIF:** Checksum Error Interrupt Flag bit (must be cleared by software)
1 = Checksum error
0 = No checksum error

bit 3 **FERR:** Framing Error Interrupt Flag bit
1 = Framing Error: Inverted level of the Stop bit corresponding to the topmost character in the buffer; propagates through the buffer with the received character
0 = No framing error

bit 2 **RXBKIF:** Receive Break Interrupt Flag bit (must be cleared by software)
1 = A Break was received
0 = No Break was detected

bit 1 **OERR:** Receive Buffer Overflow Interrupt Flag bit (must be cleared by software)
1 = Receive buffer has overflowed
0 = Receive buffer has not overflowed

bit 0 **TXCIF:** Transmit Collision Interrupt Flag bit (must be cleared by software)
1 = Transmitted word is not equal to the received word
0 = Transmitted word is equal to the received word


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**REGISTER 16-4: UxSTAH: UARTx STATUS REGISTER HIGH**

| U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | UTXISEL2 | UTXISEL1 | UTXISEL0 | — | URXISEL2(1) | URXISEL1(1) | URXISEL0(1) |
| bit 15 | | | | | | | bit 8 |

| HS/R/W-0 | R/W-0 | R/S-1 | R-0 | R-1 | R-1 | R/S-1 | R-0 |
|---|---|---|---|---|---|---|---|
| TXWRE | STPMD | UTXBE | UTXBF | RIDLE | XON | URXBE | URXBF |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable bit | 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 **Unimplemented:** Read as '0'

bit 14-12 **UTXISEL[2:0]:** UART Transmit Interrupt Select bits
111 = Sets transmit interrupt when there is one empty slot left in the buffer
...
010 = Sets transmit interrupt when there are six empty slots or more in the buffer
001 = Sets transmit interrupt when there are seven empty slots or more in the buffer
000 = Sets transmit interrupt when there are eight empty slots in the buffer; TX buffer is empty

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

bit 10-8 **URXISEL[2:0]:** UART Receive Interrupt Select bits
111 = Triggers receive interrupt when there are eight bytes in the buffer; RX buffer is full
...
001 = Triggers receive interrupt when there are two bytes or more in the buffer
000 = Triggers receive interrupt when there is one byte or more in the buffer

bit 7 **TXWRE:** TX Write Transmit Error Status bit
LIN and Parity modes:
1 = A new byte was written when the buffer was full or when P2[8:0] = 0 (must be cleared by software)
0 = No error
Address Detect mode:
1 = A new byte was written when the buffer was full or to P1[8:0] when P1x was full (must be cleared by software)
0 = No error
Other modes:
1 = A new byte was written when the buffer was full (must be cleared by software)
0 = No error

bit 6 **STPMD:** Stop Bit Detection Mode bit
1 = Triggers RXIF at the end of the last Stop bit
0 = Triggers RXIF in the middle of the first (or second, depending on the STSEL[1:0] setting) Stop bit

bit 5 **UTXBE:** UART TX Buffer Empty Status bit
1 = Transmit buffer is empty; writing '1' when UTXEN = 0 will reset the TX FIFO Pointers and counters
0 = Transmit buffer is not empty

bit 4 **UTXBF:** UART TX Buffer Full Status bit
1 = Transmit buffer is full
0 = Transmit buffer is not full

bit 3 **RIDLE:** Receive Idle bit
1 = UART RX line is in the Idle state
0 = UART RX line is receiving something

**Note 1:** The receive watermark interrupt is not set if PERR or FERR is set and the corresponding IE bit is set.

**REGISTER 16-4: UxSTAH: UARTx STATUS REGISTER HIGH (CONTINUED)**

bit 2 **XON:** UART in XON Mode bit
Only valid when FLO[1:0] control bits are set to XON/XOFF mode.
1 = UART has received XON
0 = UART has not received XON or XOFF was received

bit 1 **URXBE:** UART RX Buffer Empty Status bit
1 = Receive buffer is empty; writing '1' when URXEN = 0 will reset the RX FIFO Pointers and counters
0 = Receive buffer is not empty

bit 0 **URXBF:** UART RX Buffer Full Status bit
1 = Receive buffer is full
0 = Receive buffer is not full

**Note 1:** The receive watermark interrupt is not set if PERR or FERR is set and the corresponding IE bit is set.


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**REGISTER 16-5: UxBRG: UARTx BAUD RATE 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 |
|---|---|---|---|---|---|---|---|
| BRG[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 |
|---|---|---|---|---|---|---|---|
| BRG[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 **BRG[15:0]:** Baud Rate Divisor bits

**REGISTER 16-6: UxBRGH: UARTx BAUD RATE 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 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | BRG[19:16] | | | |
| 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 15-4 **Unimplemented:** Read as ‘0’

bit 3-0 **BRG[19:16]:** Baud Rate Divisor bits

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**REGISTER 16-7: UxRXREG: UARTx RECEIVE BUFFER REGISTER**

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

| R-x | R-x | R-x | R-x | R-x | R-x | R-x | R-x |
|---|---|---|---|---|---|---|---|
| RXREG[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 **RXREG[7:0]:** Received Character Data bits 7-0

**REGISTER 16-8: UxTXREG: UARTx TRANSMIT BUFFER REGISTER**

| W-x | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| LAST | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| W-x | W-x | W-x | W-x | W-x | W-x | W-x | W-x |
|---|---|---|---|---|---|---|---|
| TXREG[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 **LAST:** Last Byte Indicator for Smart Card Support bit

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

bit 7-0 **TXREG[7:0]:** Transmitted Character Data bits 7-0
If the buffer is full, further writes to the buffer are ignored.


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**REGISTER 16-9: UxP1: UARTx TIMING PARAMETER 1 REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | P1[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 |
|---|---|---|---|---|---|---|---|
| P1[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 **P1[8:0]:** Parameter 1 bits

DMX TX:
Number of Bytes to Transmit – 1 (not including Start code).

LIN Commander TX:
PID to transmit (bits[5:0]).

Asynchronous TX with Address Detect:
Address to transmit. A '1' is automatically inserted into bit 9 (bits[7:0]).

Smart Card mode:
Guard Time Counter bits. This counter is operated on the bit clock whose period is always equal to one ETU (bits[8:0]).

Other Modes:
Not used.

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**REGISTER 16-10: UxP2: UARTx TIMING PARAMETER 2 REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | P2[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 |
|---|---|---|---|---|---|---|---|
| P2[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 **P2[8:0]:** Parameter 2 bits

DMX RX:
The first byte number to receive – 1, not including Start code (bits[8:0]).

LIN Responder TX:
Number of bytes to transmit (bits[7:0]).

Asynchronous RX with Address Detect:
Address to start matching (bits[7:0]).

Smart Card mode:
Block Time Counter bits. This counter is operated on the bit clock whose period is always equal to one ETU (bits[8:0]).

Other modes:
Not used.


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**REGISTER 16-11: UxP3: UARTx TIMING PARAMETER 3 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 |
|---|---|---|---|---|---|---|---|
| P3[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 |
|---|---|---|---|---|---|---|---|
| P3[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 **P3[15:0]:** Parameter 3 bits

DMX RX:
The last byte number to receive – 1, not including Start code (bits[8:0]).

LIN Responder RX:
Number of bytes to receive (bits[7:0]).

Asynchronous RX:
Used to mask the UxP2 address bits; 1 = P2 address bit is used, 0 = P2 address bit is masked off (bits[7:0]).

Smart Card mode:
Waiting Time Counter bits (bits[15:0]).

Other modes:
Not used.

**REGISTER 16-12: UxP3H: UARTx TIMING PARAMETER 3 REGISTER 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 |
|---|---|---|---|---|---|---|---|
| P3[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 **P3[23:16]:** Parameter 3 High bits

Smart Card mode:
Waiting Time Counter bits (bits[23:16]).

Other modes:
Not used.

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**REGISTER 16-13: UxTXCHK: UARTx TRANSMIT CHECKSUM 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TXCHK[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 **TXCHK[7:0]:** Transmit Checksum bits (calculated from TX words)

LIN Modes:
C0EN = 1: Sum of all transmitted data + addition carries, including PID.
C0EN = 0: Sum of all transmitted data + addition carries, excluding PID.

LIN Responder:
Cleared when Break is detected.

LIN Commander/Responder:
Cleared when Break is detected.

Other modes:
C0EN = 1: Sum of every byte transmitted + addition carries.
C0EN = 0: Value remains unchanged.


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**REGISTER 16-14: UxRXCHK: UARTx RECEIVE CHECKSUM 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| RXCHK[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 **RXCHK[7:0]:** Receive Checksum bits (calculated from RX words)

LIN Modes:
C0EN = 1: Sum of all received data + addition carries, including PID.
C0EN = 0: Sum of all received data + addition carries, excluding PID.

LIN Responder:
Cleared when Break is detected.

LIN Commander/Responder:
Cleared when Break is detected.

Other modes:
C0EN = 1: Sum of every byte received + addition carries.
C0EN = 0: Value remains unchanged.

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**REGISTER 16-15: UxSCCON: UARTx SMART CARD CONFIGURATION 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 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | TXRPT1 | TXRPT0 | CONV | T0PD | PRTCL | — |
| 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 5-4 **TXRPT[1:0]:** Transmit Repeat Selection bits
11 = Retransmit the error byte four times
10 = Retransmit the error byte three times
01 = Retransmit the error byte twice
00 = Retransmit the error byte once

bit 3 **CONV:** Logic Convention Selection bit
1 = Inverse logic convention
0 = Direct logic convention

bit 2 **T0PD:** Pull-Down Duration for T = 0 Error Handling bit
1 = Two ETUs
0 = One ETU

bit 1 **PRTCL:** Smart Card Protocol Selection bit
1 = T = 1
0 = T = 0

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


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**REGISTER 16-16: UxSCINT: UARTx SMART CARD INTERRUPT REGISTER**

| U-0 | U-0 | HS/R/W-0 | HS/R/W-0 | U-0 | HS/R/W-0 | HS/R/W-0 | HS/R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RXRPTIF | TXRPTIF | — | BTCIF | WTCIF | GTCIF |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | RXRPTIE | TXRPTIE | — | BTCIE | WTCIE | GTCIE |
| 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 15-14 **Unimplemented:** Read as '0'

bit 13 **RXRPTIF:** Receive Repeat Interrupt Flag bit
1 = Parity error has persisted after the same character has been received five times (four retransmits)
0 = Flag is cleared

bit 12 **TXRPTIF:** Transmit Repeat Interrupt Flag bit
1 = Line error has been detected after the last retransmit per TXRPT[1:0]
0 = Flag is cleared

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

bit 10 **BTCIF:** Block Time Counter Interrupt Flag bit
1 = Block Time Counter has reached 0
0 = Block Time Counter has not reached 0

bit 9 **WTCIF:** Waiting Time Counter Interrupt Flag bit
1 = Waiting Time Counter has reached 0
0 = Waiting Time Counter has not reached 0

bit 8 **GTCIF:** Guard Time Counter Interrupt Flag bit
1 = Guard Time Counter has reached 0
0 = Guard Time Counter has not reached 0

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

bit 5 **RXRPTIE:** Receive Repeat Interrupt Enable bit
1 = An interrupt is invoked when a parity error has persisted after the same character has been received five times (four retransmits)
0 = Interrupt is disabled

bit 4 **TXRPTIE:** Transmit Repeat Interrupt Enable bit
1 = An interrupt is invoked when a line error is detected after the last retransmit per TXRPT[1:0] has been completed
0 = Interrupt is disabled

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

bit 2 **BTCIE:** Block Time Counter Interrupt Enable bit
1 = Block Time Counter interrupt is enabled
0 = Block Time Counter interrupt is disabled

bit 1 **WTCIE:** Waiting Time Counter Interrupt Enable bit
1 = Waiting Time Counter interrupt is enabled
0 = Waiting Time Counter Interrupt is disabled

bit 0 **GTCIE:** Guard Time Counter interrupt Enable bit
1 = Guard Time Counter interrupt is enabled
0 = Guard Time Counter interrupt is disabled

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**REGISTER 16-17: UxINT: UARTx INTERRUPT REGISTER**

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

| HS/R/W-0 | HS/R/W-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| WUIF | ABDIF | — | — | — | ABDIE | — | — |
| 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 15-8 **Unimplemented:** Read as '0'

bit 7 **WUIF:** Wake-up Interrupt Flag bit
- 1 = Sets when WAKE = 1 and RX makes a '1'-to-'0' transition; triggers event interrupt (must be cleared by software)
- 0 = WAKE is not enabled or WAKE is enabled, but no wake-up event has occurred

bit 6 **ABDIF:** Auto-Baud Completed Interrupt Flag bit
- 1 = Sets when ABD sequence makes the final '1'-to-'0' transition; triggers event interrupt (must be cleared by software)
- 0 = ABAUD is not enabled or ABAUD is enabled but auto-baud has not completed

bit 5-3 **Unimplemented:** Read as '0'

bit 2 **ABDIE:** Auto-Baud Completed Interrupt Enable Flag bit
- 1 = Allows ABDIF to set an event interrupt
- 0 = ABDIF does not set an event interrupt

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


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**NOTES:**

## 17.0 LIN TRANSCEIVER MODULE

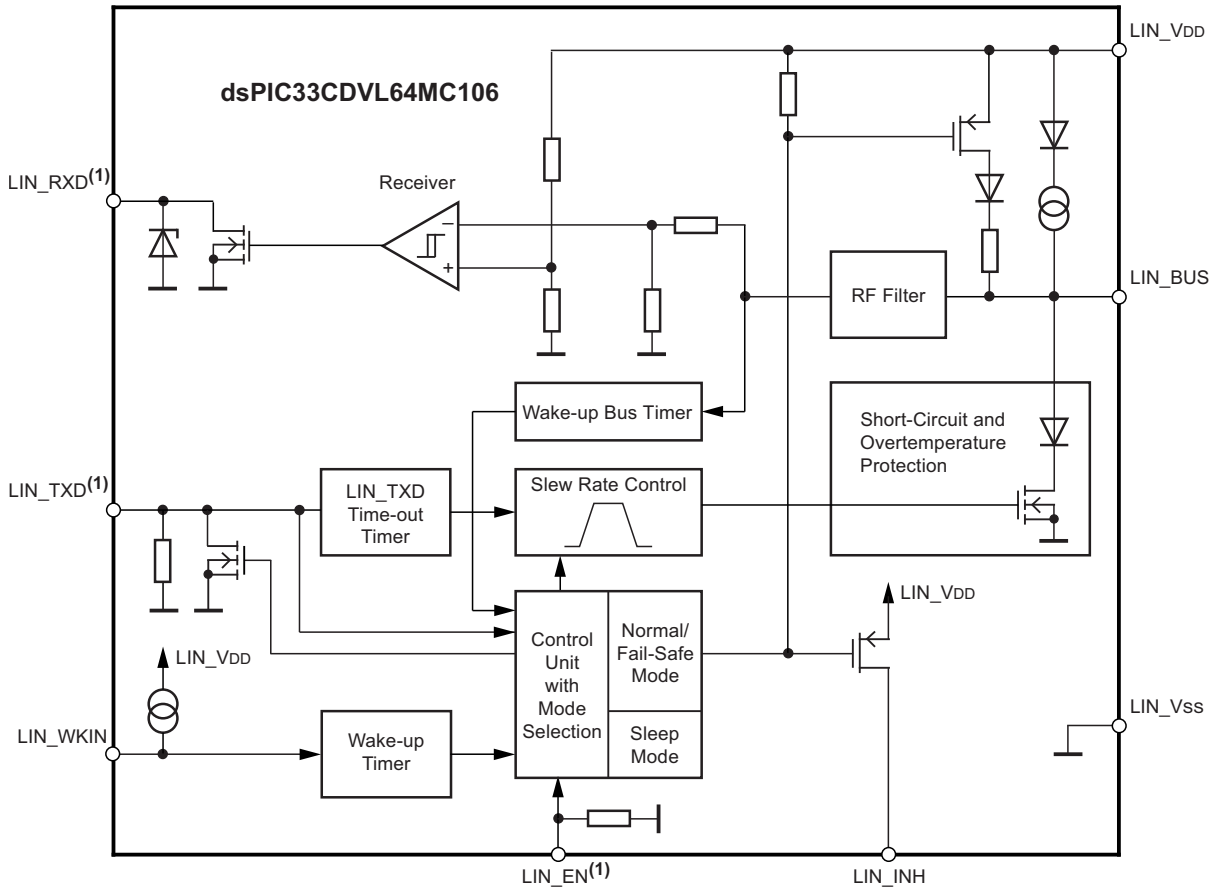
The fully integrated LIN Transceiver is designed in compliance with the LIN Specification 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2. It interfaces the LIN protocol handler and the physical layer. The device is designed to handle the low-speed data communication in vehicles, for example, in convenience electronics. Improved slope control at the LIN bus ensures data communication up to 20 kbaud. Sleep mode ensures minimal current consumption even in the case of a floating bus line or a short circuit on the LIN bus to LIN_Vss.

The primary features of the LIN Transceiver module are:

- Supply Voltage Up to 40V
- Operating Voltage Vs = 5V to 28V
- Very Low Supply Current
  - Sleep mode: Typically 9 µA
  - Fail-Safe mode: Typically 80 µA
  - Normal mode: Typically 250 µA
- Fully Compatible with 3.3V and 5V Devices
- LIN Physical Layer According to LIN 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2
- Wake-up Capability via LIN bus (100 µs dominant)
- External Wake-up via LIN_WKIN pin (100 µs low level)
- LIN_INH Output to Control an External Voltage Regulator or to Switch the Commander Pull-up
- Wake-up Source Recognition
- LIN_TXD Time-out Timer
- Bus Pin is Overtemperature and Short-Circuit Protected vs. LIN_Vss and Battery
- Advanced EMC and ESD Performance
- Fulfills the OEM *"Hardware Requirements for LIN in Automotive Applications Rev.1.3"*
- Interference and Damage Protection According to ISO7637
- Qualified According to AEC-Q100


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**FIGURE 17-1: LIN TRANSCEIVER MODULE BLOCK DIAGRAM**




**Note 1:** Pin is connected to a device interconnect; see Table 1-1 for more information.

## 17.1 Pin Description

### 17.1.1 Supply Pin (LIN_VDD)

LIN operating voltage is VS = 5V to 28V. Undervoltage detection is implemented to disable transmission if VS falls below typical, 4.5V, thereby avoiding false bus messages. After switching on VS, the IC starts in Fail-Safe mode and the LIN_INH output is switched on.

The supply current in Sleep mode is typically 9 µA.

### 17.1.2 GROUND PIN (LIN_VSS)

The IC does not affect the LIN bus in the event of LIN_VSS disconnection. It is able to handle a ground shift of up to 11.5% of VS.

### 17.1.3 BUS PIN (LIN_BUS)

A low-side driver with internal current limitation and thermal shutdown, as well as an internal pull-up resistor according to LIN Specification 2.x, is implemented. The voltage range is from -27V to +40V. This pin exhibits no reverse current from the LIN bus to VS, even in the event of a LIN_VSS shift or $V_{BAT}$ disconnection. The LIN receiver thresholds comply with the LIN protocol specification.

The fall time (from recessive to dominant) and the rise time (from dominant to recessive) are slope controlled.

During a short circuit at LIN_BUS to VBAT, the output limits the output current to $I_{BUS\_LIM}$. Due to the power dissipation, the chip temperature exceeds $T_{off}$ and the LIN_BUS output is switched off. The chip cools down and after a hysteresis of $T_{hys}$, switches the output on again. LIN_RXD stays on high because LIN_BUS is high.

During a short circuit from LIN_BUS to LIN_VSS, the IC can be switched into Sleep mode, and even in this case, the current consumption is lower than 100 µA. If the short circuit disappears, the IC starts with a remote wake-up.

The reverse current is <2 µA at pin LIN_BUS during loss of $V_{BAT}$. This is optimal behavior for bus systems where some Responder nodes are supplied from battery or ignition.

### 17.1.4 INPUT/OUTPUT (LIN_TXD)

In Normal mode, the LIN_TXD pin is the microcontroller interface for controlling the state of the LIN_BUS output. LIN_TXD must be pulled to ground in order to drive the LIN bus low. If LIN_TXD is high, the LIN_BUS output transistor is turned off and the bus is in the Recessive state. If the LIN_TXD pin stays at LIN_VSS level while switching into Normal mode, it must be pulled to a high level longer than 10 µs before the LIN Transceiver can be activated. This feature prevents the bus line from being accidentally driven to a Dominant state after Normal mode has been activated (also in case of a short circuit at LIN_TXD to LIN_VSS). During Fail-Safe mode, this pin is used as an output and signals the Fail-Safe source.

The LIN_TXD pin provides a pull-down resistor in order to have a defined level if LIN_TXD is disconnected.

An internal timer prevents the bus line from being driven permanently in the Dominant state. If LIN_TXD is forced to low longer than $t_{dom}$ > 20 ms, the LIN bus driver is switched to the Recessive state. Nevertheless, when switching to Sleep mode, the actual level at the LIN_TXD pin is relevant.

To reactivate the LIN bus driver, switch LIN_TXD to high (>10 µs).

### 17.1.5 OUTPUT PIN (LIN_RXD)

In Normal mode, this pin reports the state of the LIN bus to the microcontroller. LIN high (Recessive state) is indicated by a high level at LIN_RXD; LIN low (Dominant state) is indicated by a low level at LIN_RXD.

The output is an open-drain; therefore, it is compatible with a 3.3V or 5V power supply. The AC characteristics are defined by an external pull-up resistor of 4.7 kOhm to 5V and a load capacitor of 20 pF.

In Unpowered mode, LIN_RXD is switched off.

### 17.1.6 ENABLE INPUT PIN (LIN_EN)

The enable input pin controls the Operating mode of the device. If LIN_EN is high, the circuit is in Normal mode, with transmission paths from LIN_TXD to LIN_BUS and from LIN_BUS to LIN_RXD both active.

If LIN_EN is switched to low while LIN_TXD is still high, the device is forced to Sleep mode. No data transmission is then possible and current consumption is reduced to $I_{VSsleep}$, typically 9 µA.

The LIN_EN pin provides a pull-down resistor to force the transceiver into Recessive mode if LIN_EN is disconnected.

### 17.1.7 INHIBIT OUTPUT PIN (LIN_INH)

This pin is used to control an external voltage regulator or to switch the LIN Commander pull-up resistor on/off in case the device is used in a Commander node. The inhibit pin provides an internal switch toward the LIN_VDD pin, which is protected by temperature monitoring. If the device is in Normal or Fail-Safe mode, the inhibit high-side switch is turned on. When the device is in Sleep mode, the inhibit switch is turned off, thus disabling the voltage regulator or other connected external devices.

A wake-up event on the LIN bus or at the LIN_WKIN pin switches the LIN_INH pin to the VS level. After a system power-up (VS rises from zero), the LIN_INH pin switches to the VS level automatically.

### 17.1.8 WAKE PIN (LIN_WKIN)

This pin is a high-voltage input used for waking up the device from Sleep mode. It is usually connected to an external switch in the application to generate a local wake-up. A pull-up current source with typically 10 µA is implemented. The voltage threshold for a wake-up signal is typically 2V below the VS voltage.


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If a local wake-up is not needed in the application, the LIN_WKIN pin can be connected directly to the LIN_$V_{DD}$ pin.

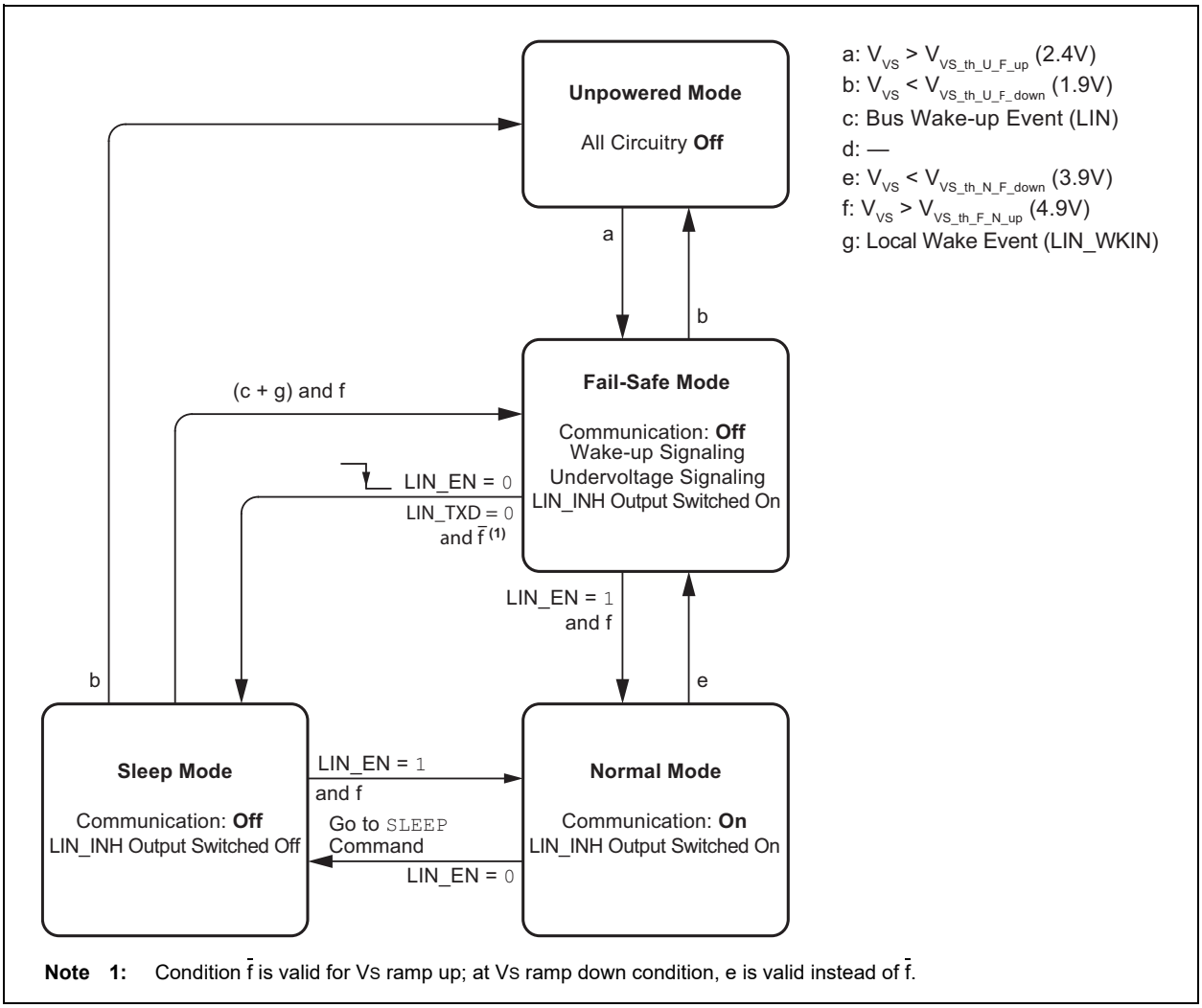
## 17.2 Functional Description

### 17.2.1 PHYSICAL LAYER COMPATIBILITY

Since the LIN physical layer is independent of higher LIN layers (for example, LIN protocol layer), all nodes with a LIN physical layer according to Revision 2.x can be mixed with LIN physical layer nodes based on earlier versions (for instance, LIN 1.0, LIN 1.1, LIN 1.2 and LIN 1.3) without any restrictions.

### 17.2.2 OPERATING MODES

**FIGURE 17-2: LIN TRANSCEIVER OPERATING MODES**




**Note 1:** Condition f̄ is valid for VS ramp up; at VS ramp down condition, e is valid instead of f̄.

**TABLE 17-1: OPERATING MODES**

| Operating Mode | Transceiver | LIN_INH | LIN_BUS | LIN_TXD | LIN_RXD |
|---|---|---|---|---|---|
| Fail-Safe | Off | On, except $V_S < V_{VS\_th\_N\_F\_down}$ | Recessive | Signaling Fail-Safe Sources (see Table 17-2) | |
| Normal | On | On | LIN_TXD Dependent | Follows Data Transmission | |
| Sleep/Unpowered | Off | Off | Recessive | Low | High Ohmic |


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### 17.2.3 NORMAL MODE

This is the normal Transmitting and Receiving mode of the LIN interface in accordance with LIN Specification 2.x.

### 17.2.4 SLEEP MODE

A falling edge at LIN_EN switches the IC into Sleep mode. While in Sleep mode, the transmission path is disabled and the device is in Low-Power mode. Supply current from $V_{BAT}$ is typically 9 µA. In Sleep mode, the LIN_INH pin is switched off. The internal termination between the LIN_BUS pin and LIN_VDD pin is disabled. Only a weak pull-up current (typically 10 µA) between the LIN_BUS pin and LIN_VDD pin is present. Sleep mode can be activated independently from the actual level on the LIN_BUS or LIN_WKIN pin.

If the LIN_TXD pin is short-circuited to LIN_VSS, it is possible to switch to Sleep mode via LIN_EN after $t > t_{dom}$.

### 17.2.5 FAIL-SAFE MODE

The device automatically switches to Fail-Safe mode at system power-up or after a wake-up event. The LIN_INH output is switched on and the LIN transceiver is switched off. The IC stays in this mode until LIN_EN is switched to high. The IC then changes to Normal mode. During Fail-Safe mode, the LIN_TXD pin is an output, and together with the LIN_RXD output pin, signals the fail-safe source.

If the device enters Fail-Safe mode coming from the Normal mode (LIN_EN = 1) due to a VS undervoltage condition ($V_{VS} < V_{VS\_th\_N\_F\_down}$), it is possible to switch into Sleep mode by a falling edge at the LIN_EN input. With this feature, the current consumption is further reduced.

A wake-up event from Sleep mode is signaled to the microcontroller using the LIN_RXD pin and the LIN_TXD pin. A VS undervoltage condition is also signaled at these two pins. The coding is shown in Table 17-2.

**TABLE 17-2: SIGNALING IN FAIL-SAFE MODE**

| Fail-Safe Sources | LIN_TXD(1) | LIN_RXD |
|---|---|---|
| LIN Wake-up (LIN_BUS pin) | Low | Low |
| Local Wake-up (LIN_WKIN pin) | Low | High |
| $VS_{th}$ (battery) Undervoltage Detection, VS < 3.9V | High | Low |

**Note 1:** Assuming an external pull-up resistor (typically 5 kΩ) has been added on pin LIN_TXD to the power supply of the microcontroller.

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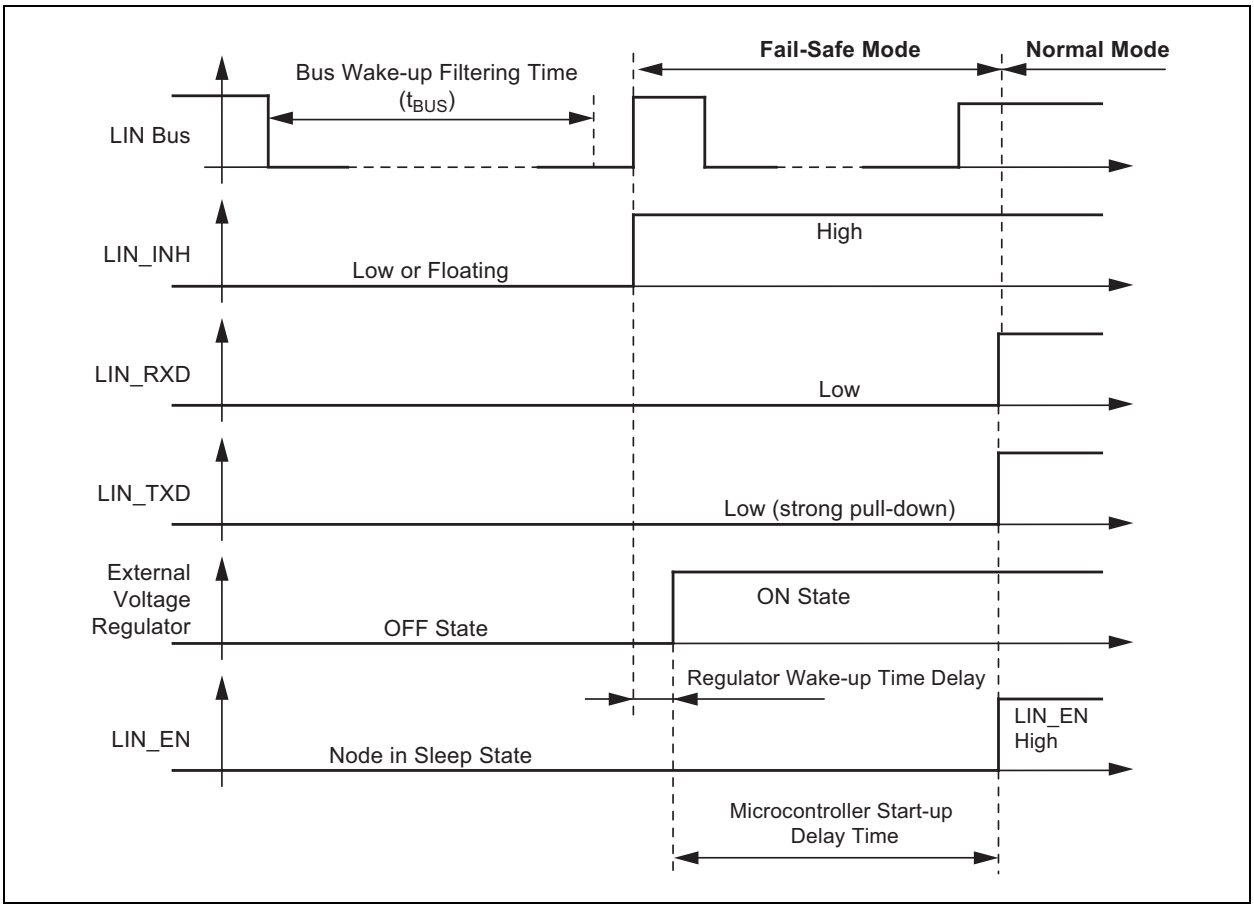
## 17.3 Wake-up Scenarios from Sleep Mode

### 17.3.1 REMOTE WAKE-UP VIA LIN_BUS

#### 17.3.1.1 Remote Wake-up from Sleep Mode

A voltage lower than the LIN pre-wake detection, VLINL at the LIN_BUS pin, activates the internal LIN receiver, and starts the wake-up detection timer. A falling edge at the LIN_BUS pin, followed by a dominant bus level maintained for a certain period of time (>$t_{bus}$), and following a rising edge at the LIN_BUS pin, results in a remote wake-up request and the device switches to Fail-Safe mode. The LIN_INH pin is activated (switches to Vs), and the internal termination resistor is switched on. The remote wake-up request is indicated by a low level at pin LIN_RXD and interrupts the microcontroller.

**FIGURE 17-3: LIN WAKE-UP FROM SLEEP MODE**



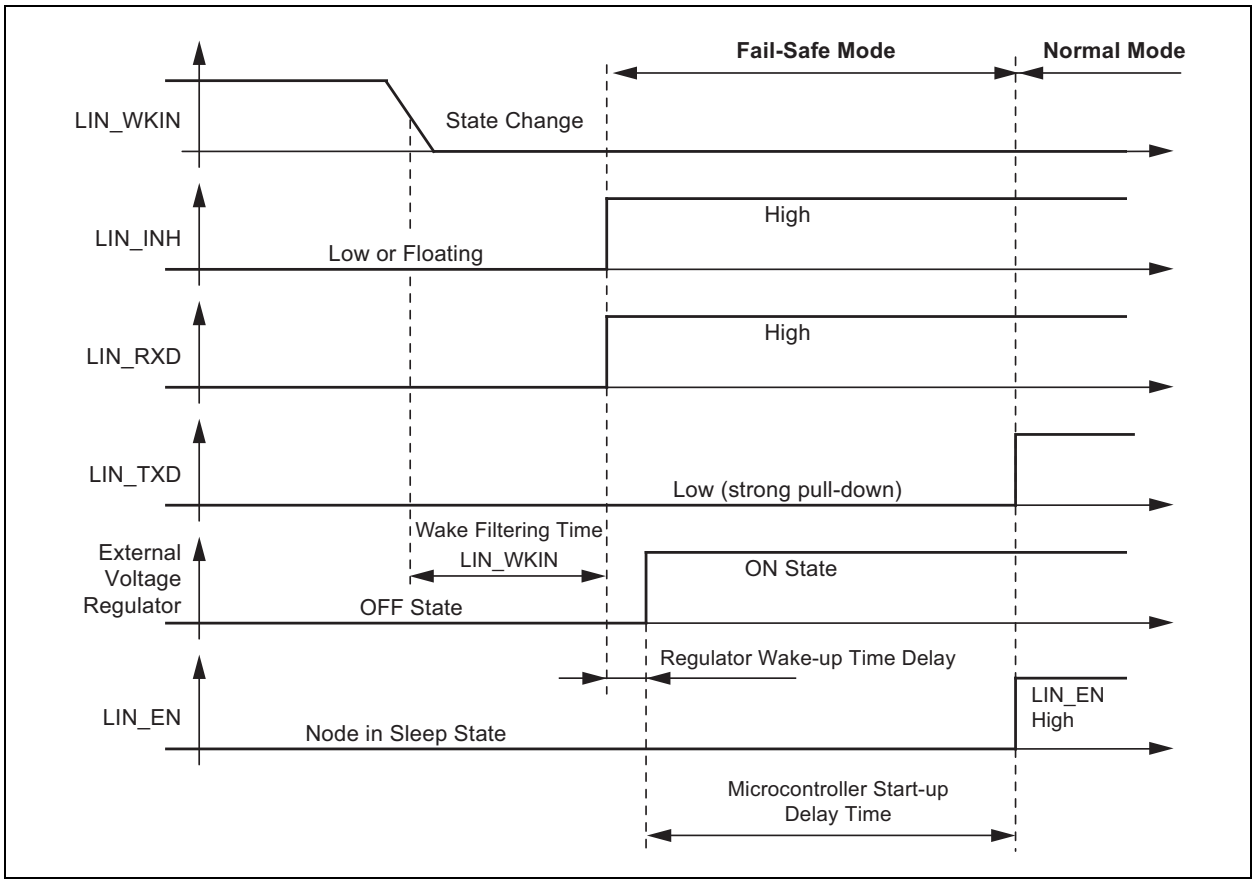


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### 17.3.2 LOCAL WAKE-UP THROUGH LIN_WKIN PIN

A falling edge at the LIN_WKIN pin followed by a low level maintained for a certain period of time (>$t_{WKin}$) results in a local wake-up request and the device switches to Fail-Safe mode. The LIN_INH pin is activated (switches to VS) and the internal Responder termination resistor is switched on. The local wake-up request is indicated by a low level at the LIN_TXD pin and a high level at the LIN_RXD pin, generating an interrupt for the microcontroller. Even when the LIN_WKIN pin is low, it is possible to switch to Sleep mode via the LIN_EN pin. In this case, the wake-up signal has to be switched to high >10 µs before the negative edge at LIN_WKIN starts a new local wake-up request.

**FIGURE 17-4: LOCAL WAKE-UP FROM WAKE-UP SWITCH**





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### 17.3.3 WAKE-UP SOURCE RECOGNITION

The device can distinguish between different wake-up sources. The wake-up source can be read on the LIN_TXD and LIN_RXD pins in Fail-Safe mode, according to Table 17-3, if an external pull-up resistor (typically 5 kΩ) has been added on pin LIN_TXD to the power supply of the microcontroller. These flags are reset immediately if the microcontroller sets pin LIN_EN to high and the IC is in Normal mode.

**TABLE 17-3: SIGNALING IN FAIL-SAFE MODE**

| Fail-Safe Sources | LIN_TXD(1) | LIN_RXD |
|---|---|---|
| LIN Wake-up (LIN_BUS pin) | Low | Low |
| Local Wake-up (LIN_WKIN pin) | Low | High |
| $V_{Sth}$ (battery) Undervoltage Detection ($V_S$ < 3.9V) | High | Low |

**Note 1:** Assuming an external pull-up resistor (typically 5 kΩ) has been added on pin LIN_TXD to the power supply of the microcontroller.

## 17.4 Behavior Under Low Supply Voltage Condition

After the battery voltage has been connected to the application circuit, the voltage at the LIN_$V_{DD}$ pin increases according to the block capacitor used in the application (see Figure 17-1). If $V_{VS}$ is higher than the minimum $V_S$ operation threshold, $V_{VS\_th\_U\_F\_up}$, the IC mode changes from Unpowered mode to Fail-Safe mode, the LIN_INH output is switched on and the LIN transceiver can be activated.

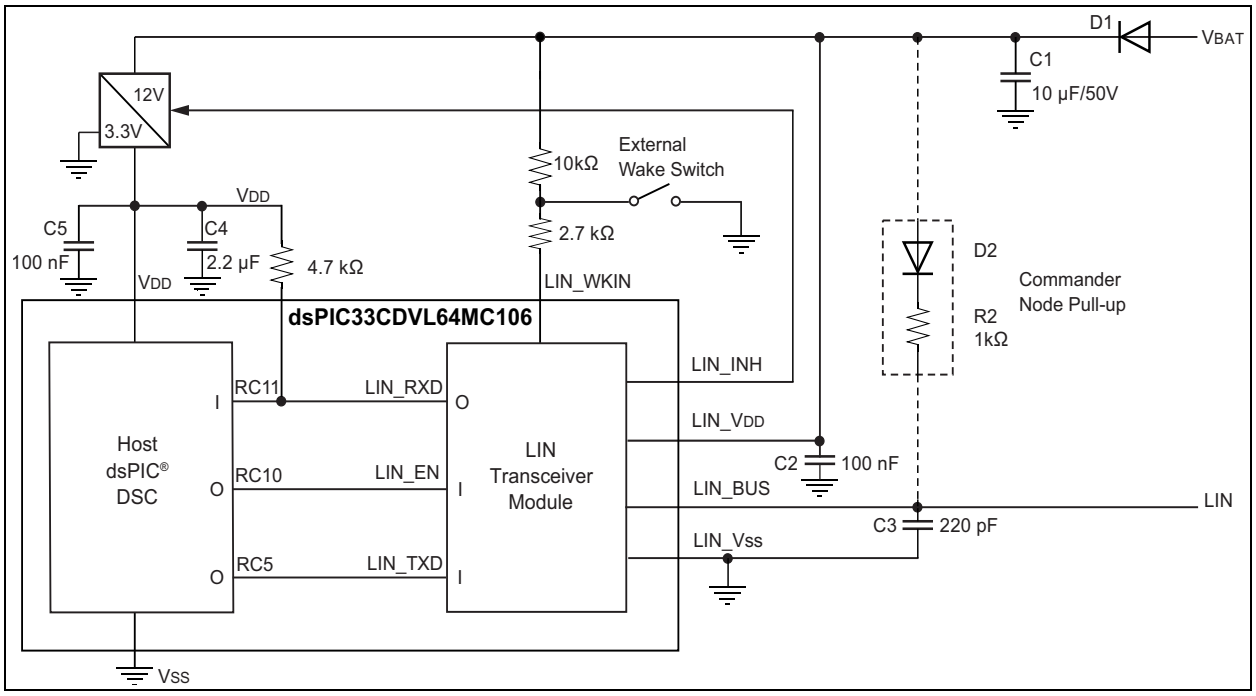
If during Sleep mode, the voltage level of $V_{VS}$ drops below the undervoltage detection threshold, $V_{VS\_th\_N\_F\_down}$ (typically 4.3V), the Operation mode is not changed and no wake-up is possible. Only if the supply voltage on the LIN_$V_{DD}$ pin drops below the $V_S$ operation threshold, $V_{VS\_th\_U\_F\_down}$ (typically 2.05V), does the IC switch to Unpowered mode.

If, during Normal mode, the voltage level on the LIN_$V_{DD}$ pin drops below the $V_S$ undervoltage detection threshold, $V_{VS\_th\_N\_F\_down}$ (typically 4.3V), the IC switches to Fail-Safe mode. This means that the LIN transceiver is disabled in order to avoid malfunctions or false bus messages. If the supply voltage, $V_{VS}$, drops further below the $V_S$ operation threshold, $V_{VS\_th\_U\_F\_down}$ (typically 2.05V), the IC switches to Unpowered mode and the LIN_INH output switches off.

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## 17.5 Application Circuit

**FIGURE 17-5: TYPICAL APPLICATION CIRCUIT**





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**NOTES:**

## 18.0 SERIAL PERIPHERAL INTERFACE (SPI)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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"** (www.microchip.com/DS70005136).

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. The dsPIC33CDVL64MC106 device includes three SPI modules. On 48-pin devices, the SPI instance of SPI2 can operate at higher speeds when selected as a non-PPS pin. The selection is done using the SPI2PIN bit (FDEVOPT[13]). If the bit for SPI2PIN is '1', the PPS pin will be used. When SPI2PIN is '0', the SPI signals are routed to dedicated pins.

The module supports operation in two Buffer modes. In Standard mode, data are shifted through a single serial buffer. In Enhanced Buffer mode, data are shifted through a FIFO buffer. The FIFO level depends on the Configured mode.

**Note:** FIFO depth for this device is four (in 8-Bit Data 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 Host or Client mode. A total of four framed SPI configurations are supported.

The module also supports Audio modes. Four different Audio modes are available.

- $I^2S$ Mode
- Left Justified Mode
- Right Justified Mode
- PCM/DSP Mode

In each of these modes, the serial clock is free-running and audio data are always transferred.

If an audio protocol data transfer takes place between two devices, then usually one device is the Host and the other is the Client. However, audio data can be transferred between two Clients. Because the audio protocols require free-running clocks, the Host can be a third-party controller. In either case, the Host 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 Client Select or Frame Synchronization I/O Pulse

The SPI module can be configured to operate using two, three or four 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.


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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 SPIxGIF. 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 Host mode of operation:

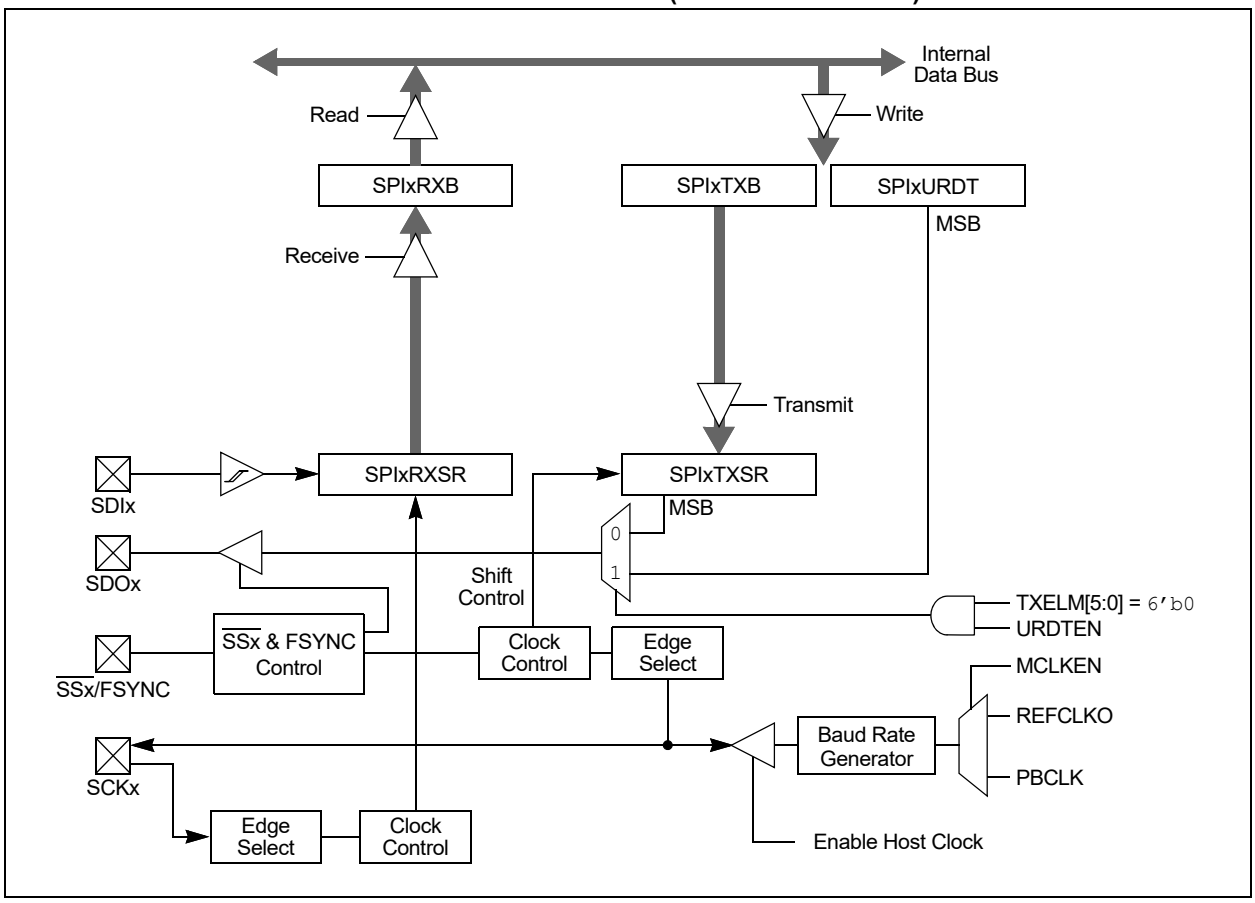
1. If using interrupts:
   a) Clear the interrupt flag bits in the respective IFSx register.
   b) Set the interrupt enable bits in the respective IECx register.
   c) Write the SPIxIP bits in the respective IPCx register to set the interrupt priority.
2. Write the desired settings to the SPIxCON1L and 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 are written to the SPIxBUFL and SPIxBUFH registers.

To set up the SPIx module for the Standard Client 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]).

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**FIGURE 18-1: SPIx MODULE BLOCK DIAGRAM (STANDARD MODE)**





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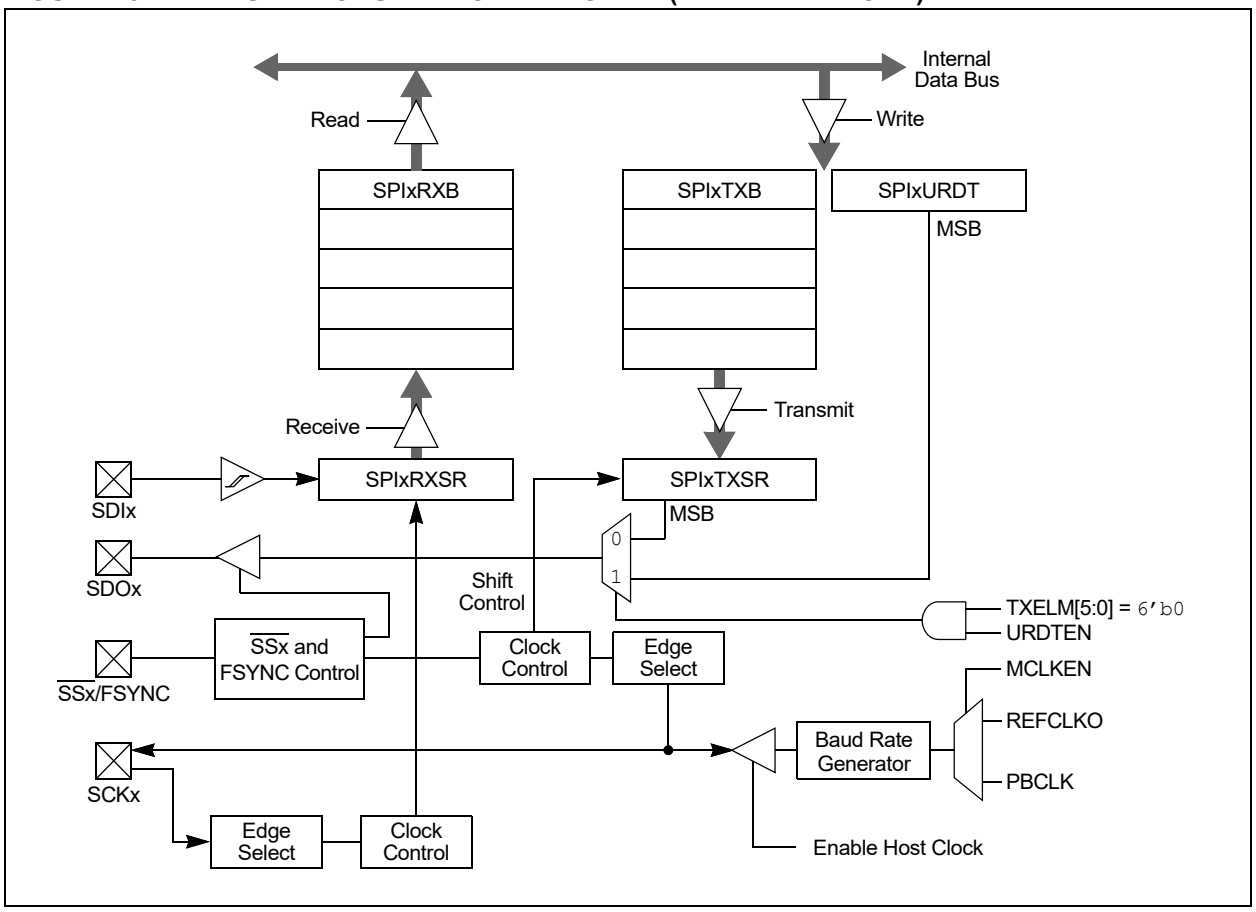
To set up the SPIx module for the Enhanced Buffer Host mode of operation:

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 are written to the SPIxBUFL and SPIxBUFH registers.

To set up the SPIx module for the Enhanced Buffer Client 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 are written to the SPIxBUFL and SPIxBUFH registers.

**Note:** After start-up, when configured for Client mode, left justified for all possible configurations of MODE[32,16] and in right justified for MODE[32,16] = {`0b00`,`0b10`}, the SPI drives ones out of SDOx if the MSb bit of the first data is a one.


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## 18.1 SPI Control/Status 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

| 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 |

bit 9 **SMP:** SPIx Data Input Sample Phase bit
Host Mode:
1 = Input data are sampled at the end of data output time
0 = Input data are sampled at the middle of data output time
Client Mode:
Input data are always sampled at the middle of data output time, regardless of the SMP setting.

bit 8 **CKE:** SPIx Clock Edge Select bit
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

**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 7 **SSEN:** Client Select Enable bit (Client mode)
1 = $\overline{SSx}$ pin is used by the macro in Client mode; $\overline{SSx}$ pin is used as the Client 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:** Host Mode Enable bit
1 = Host mode
0 = Client 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:** Host Clock Enable bit
1 = Reference Clock (REFCLKO) is used by the BRG
0 = Peripheral Clock ($F_P = F_{OSC}/2$) 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.


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**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 = 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 are sign-extended
- 0 = Data from RX FIFO are 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 are 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 are 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
- 1 = Audio data are mono (i.e., each data word is transmitted on both left and right channels)
- 0 = Audio data are stereo

bit 10 **URDTEN:** Transmit Underrun Data Enable bit
- 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
- 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:** AUDMOD[1:0] can only be written when the SPIEN bit = 0 and is 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 (Client)
0 = Frame Sync pulse output (Host)

bit 5 **FRMPOL:** Frame Sync/Client Select Polarity bit
1 = Frame Sync pulse/Client select is active-high
0 = Frame Sync pulse/Client select is active-low

bit 4 **MSSEN:** Host Mode Client Select Enable bit
1 = SPIx Client select support is enabled with polarity determined by FRMPOL ($\overline{SSx}$ pin is automatically driven during transmission in Host mode)
0 = Client 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 (SCKx) 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:** AUDMOD[1:0] can only be written when the SPIEN bit = 0 and is 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 18-3: 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

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 | HS/R/C-0 | HSC/R-0 | U-0 | U-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | FRMERR | SPIBUSY | — | — | SPITUR(1) |
| bit 15 | | | | | | | bit 8 |

| HSC/R-0 | HS/R/C-0 | HSC/R-1 | U-0 | HSC/R-1 | U-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| 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 = 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.


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**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.

**REGISTER 18-5: SPIxSTATH: SPIx STATUS REGISTER HIGH**

| U-0 | U-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| — | — | RXELM5(3) | RXELM4(2) | RXELM3(1) | RXELM2 | RXELM1 | RXELM0 |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| — | — | 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)

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

bit 5-0 **TXELM[5:0]:** Transmit Buffer Element Count bits (valid in Enhanced Buffer mode)

**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.


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**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
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

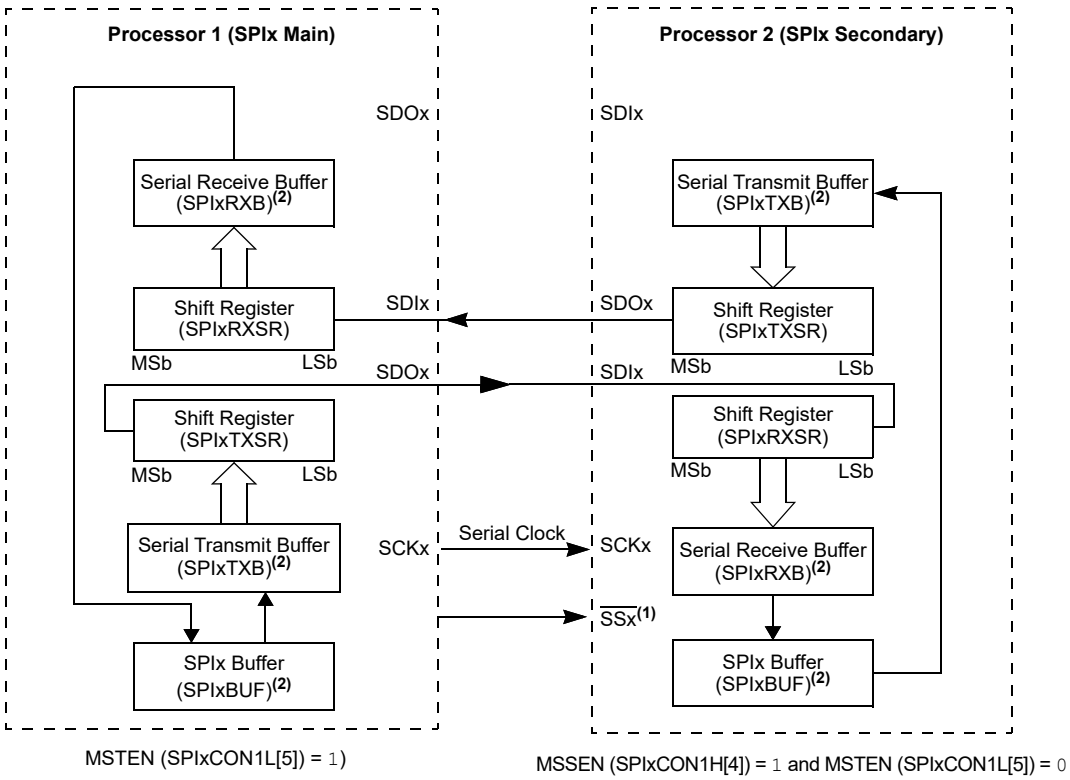
bit 6 **Unimplemented:** Read as '0'

bit 5-0 **TXMSK[5:0]:** TX Buffer Mask bits
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.


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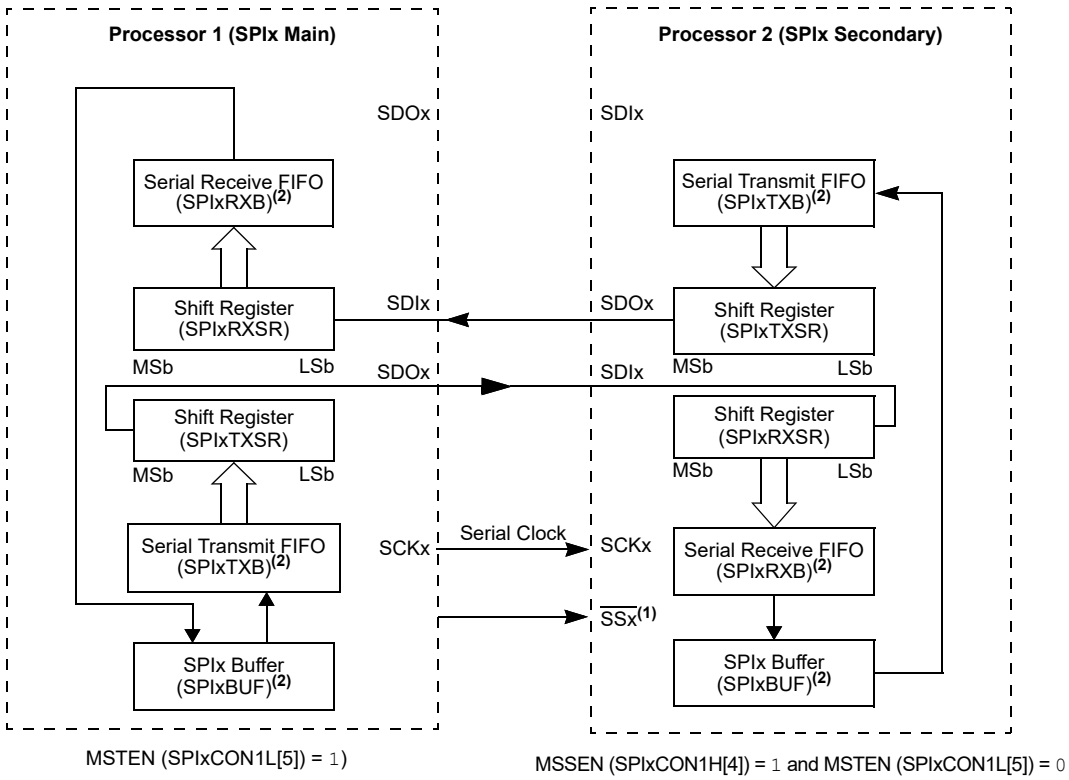
**FIGURE 18-3: SPIx MAIN/SECONDARY CONNECTION (STANDARD MODE)**




**Note 1:** Using the $\overline{SSx}$ pin in Secondary 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.

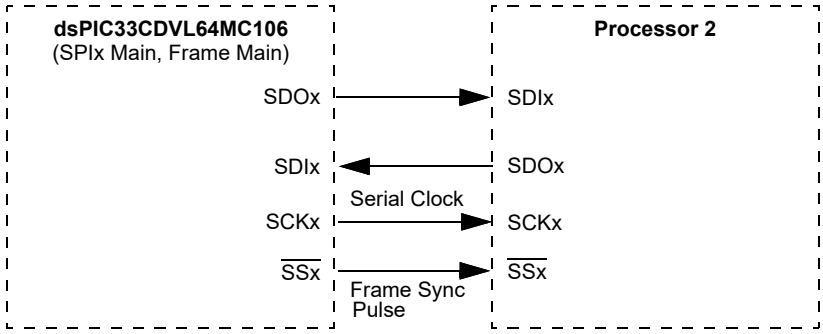
**FIGURE 18-4: SPIx MAIN/SECONDARY CONNECTION (ENHANCED BUFFER MODES)**




**Note 1:** Using the $\overline{SSx}$ pin in Secondary 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 MAIN, FRAME HOST CONNECTION DIAGRAM**





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**FIGURE 18-6: SPIx MAIN, FRAME SECONDARY CONNECTION DIAGRAM**

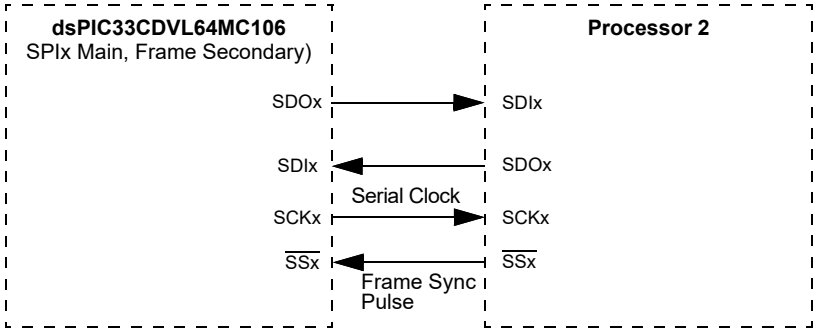



**FIGURE 18-7: SPIx SECONDARY, FRAME MAIN CONNECTION DIAGRAM**

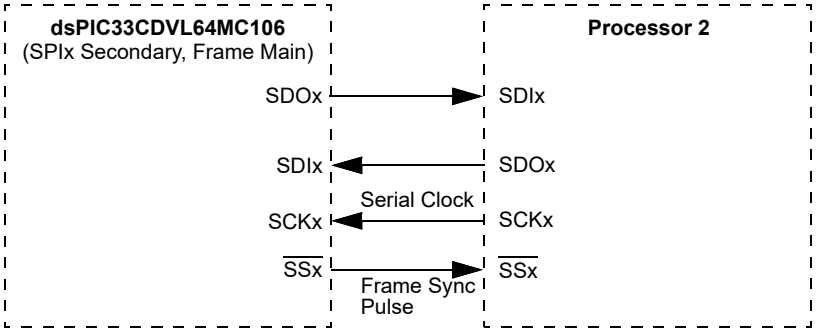
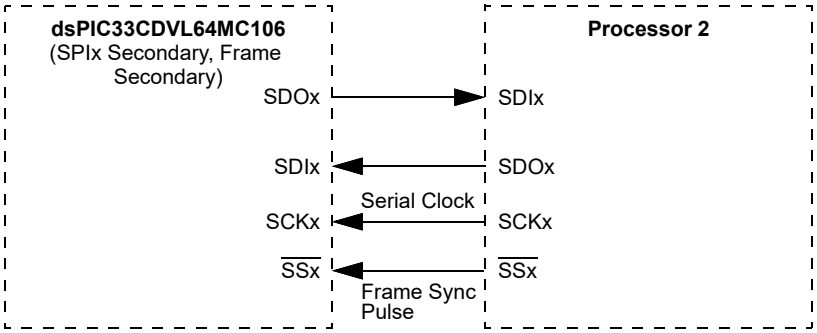



**FIGURE 18-8: SPIx SECONDARY, FRAME SECONDARY CONNECTION DIAGRAM**




**EQUATION 18-1: RELATIONSHIP BETWEEN DEVICE AND SPIx CLOCK SPEED**

$$Baud\ Rate = \frac{FP}{(2 * (SPIxBRG + 1))}$$

Where:

FP is the Peripheral Bus Clock Frequency.

## 19.0 INTER-INTEGRATED CIRCUIT ($I^2C$)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. For more information, refer to **"Inter-Integrated Circuit ($I^2C$)"** (www.microchip.com/DS70000195).

The Inter-Integrated Circuit ($I^2C$) module is a serial interface useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be serial EEPROMs, display drivers, A/D Converters, etc.

The $I^2C$ module supports these features:

- Independent Host and Client Logic
- 7-Bit and 10-Bit Device Addresses
- General Call Address as Defined in the $I^2C$ Protocol
- Clock Stretching to Provide Delays for the Processor to Respond to a Client Data Request
- Both 100 kHz and 400 kHz Bus Specifications
- Configurable Address Masking
- Multi-Host Modes to Prevent Loss of Messages in Arbitration
- Bus Repeater Mode, Allowing the Acceptance of All Messages as a Client, Regardless of the Address
- Automatic SCL

A block diagram of the module is shown in Figure 19-1.

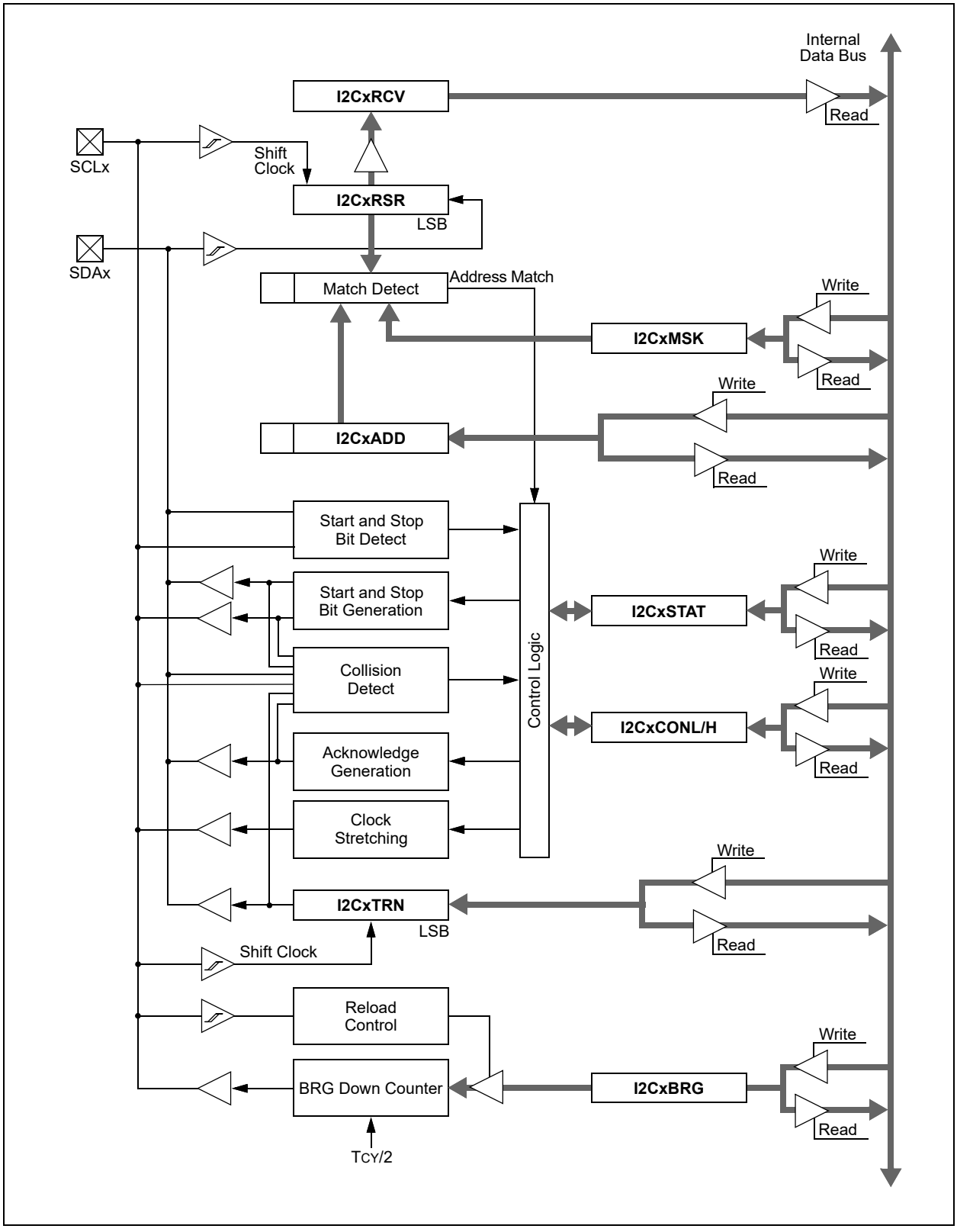
### 19.1 Communicating as a Host in a Single Host Environment

The details of sending a message in Host mode depends on the communication protocol for the device being communicated with. Typically, the sequence of events is as follows:

1. Assert a Start condition on SDAx and SCLx.
2. Send the $I^2C$ device address byte to the Client with a write indication.
3. Wait for and verify an Acknowledge from the Client.
4. Send the first data byte (sometimes known as the command) to the Client.
5. Wait for and verify an Acknowledge from the Client.
6. Send the serial memory address low byte to the Client.
7. Repeat Steps 4 and 5 until all data bytes are sent.
8. Assert a Repeated Start condition on SDAx and SCLx.
9. Send the device address byte to the Client with a read indication.
10. Wait for and verify an Acknowledge from the Client.
11. Enable Host reception to receive serial memory data.
12. Generate an ACK or NACK condition at the end of a received byte of data.
13. Generate a Stop condition on SDAx and SCLx.


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**FIGURE 19-1: I2Cx BLOCK DIAGRAM**



## 19.2 Setting Baud Rate When Operating as a Bus Host

To compute the Baud Rate Generator reload value, use Equation 19-1.

**EQUATION 19-1: COMPUTING BAUD RATE RELOAD VALUE(1,2,3,4)**

$$I2CxBRG = ((1/F_{SCL} - Delay) \bullet F_P/2) - 2$$

**Note 1:** Based on FP = FOSC/2.

**2:** These clock rate values are for guidance only. The actual clock rate can be affected by various system-level parameters. The actual clock rate should be measured in its intended application.

**3:** Typical value of delay varies from 110 ns to 150 ns.

**4:** I2CxBRG values of 0 to 3 are expressly forbidden. The user should never program the I2CxBRG with a value of 0x0, 0x1, 0x2 or 0x3 because indeterminate results may occur.

## 19.3 Client Address Masking

The I2CxMSK register (Register 19-4) designates address bit positions as “don’t care” for both 7-Bit and 10-Bit Addressing modes. Setting a particular bit location (= 1) in the I2CxMSK register causes the Client module to respond, whether the corresponding address bit value is a ‘0’ or a ‘1’. For example, when I2CxMSK is set to ‘0010000000’, the Client module will detect both addresses, ‘0000000000’ and ‘0010000000’.

To enable address masking, the Intelligent Peripheral Management Interface (IPMI) must be disabled by clearing the STRICT bit (I2CxCONL[11]).

**Note:** As a result of changes in the $I^2C$ protocol, the addresses in Table 19-2 are reserved and will not be Acknowledged in Client mode. This includes any address mask settings that include any of these addresses.

**TABLE 19-1: I2Cx CLOCK RATES(1,2)**

| FCY | FSCL | I2CxBRG Value | |
|---|---|---|---|
| | | Decimal | Hexadecimal |
| 100 MHz | 1 MHz | 41 | 29 |
| 100 MHz | 400 kHz | 116 | 74 |
| 100 MHz | 100 kHz | 491 | 1EB |
| 80 MHz | 1 MHz | 32 | 20 |
| 80 MHz | 400 kHz | 92 | 5C |
| 80 MHz | 100 kHz | 392 | 188 |
| 60 MHz | 1 MHz | 24 | 18 |
| 60 MHz | 400 kHz | 69 | 45 |
| 60 MHz | 100 kHz | 294 | 126 |
| 40 MHz | 1 MHz | 15 | 0F |
| 40 MHz | 400 kHz | 45 | 2D |
| 40 MHz | 100 kHz | 195 | C3 |
| 20 MHz | 1 MHz | 7 | 7 |
| 20 MHz | 400 kHz | 22 | 16 |
| 20 MHz | 100 kHz | 97 | 61 |

**Note 1:** Based on FP = FOSC/2.

**2:** These clock rate values are for guidance only. The actual clock rate can be affected by various system-level parameters. The actual clock rate should be measured in its intended application.


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**TABLE 19-2: I2Cx RESERVED ADDRESSES(1)**

| Client Address | R/$\overline{W}$ Bit | Description |
|---|---|---|
| 0000 000 | 0 | General Call Address(2) |
| 0000 000 | 1 | Start Byte |
| 0000 001 | x | Cbus Address |
| 0000 01x | x | Reserved |
| 0000 1xx | x | HS Mode Host Code |
| 1111 0xx | x | 10-Bit Client Upper Byte(3) |
| 1111 1xx | x | Reserved |

**Note 1:** The address bits listed here will never cause an address match independent of address mask settings.

**2:** This address will be Acknowledged only if GCEN = 1.

**3:** A match on this address can only occur on the upper byte in 10-Bit Addressing mode.

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## 19.4 I²C Control/Status Registers

**REGISTER 19-1: I2CxCONL: I2Cx CONTROL REGISTER LOW**

| R/W-0 | U-0 | HC/R/W-0 | R/W-1 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| I2CEN | — | I2CSIDL | SCLREL(1) | STRICT | A10M | DISSLW | SMEN(3) |
| bit 15 | | | | | | | bit 8 |

| 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/R/W-0 |
|---|---|---|---|---|---|---|---|
| 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 (writable from software only)
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 (I²C Client mode only)
1 = Releases the SCLx clock
0 = Holds the SCLx clock low (clock stretch)
If STREN = 1:(2)
User software may write '0' to initiate a clock stretch and write '1' to release the clock. Hardware clears at the beginning of every Client data byte transmission. Hardware clears at the end of every Client address byte reception. Hardware clears at the end of every Client data byte reception.
If STREN = 0:
User software may only write '1' to release the clock. Hardware clears at the beginning of every Client data byte transmission. Hardware clears at the end of every Client address byte reception.

bit 11 **STRICT:** I2Cx Strict Reserved Address Rule Enable bit
1 = Strict reserved addressing is enforced; for reserved addresses, refer to Table 19-2.
(In Client mode) – The device doesn't respond to reserved address space and addresses falling in that category are NACKed.
(In Host mode) – The device is allowed to generate addresses with reserved address space.
0 = Reserved addressing would be Acknowledged.
(In Client mode) – The device will respond to an address falling in the reserved address space. When there is a match with any of the reserved addresses, the device will generate an ACK.
(In Host mode) – Reserved.

bit 10 **A10M:** 10-Bit Client Address Flag bit
1 = I2CxADD is a 10-bit Client address
0 = I2CxADD is a 7-bit Client address

**Note 1:** Automatically cleared to '0' at the beginning of Client transmission; automatically cleared to '0' at the end of Client reception.
**2:** Automatically cleared to '0' at the beginning of Client transmission.
**3:** The SMB3EN Configuration bit (FDEVOPT[10]) selects between normal and SMBus 3.0 levels.


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**REGISTER 19-1: I2CxCONL: I2Cx CONTROL REGISTER LOW (CONTINUED)**

bit 9 **DISSLW:** Slew Rate Control Disable bit
1 = Slew rate control is disabled for Standard Speed mode (100 kHz, also disabled for 1 MHz mode)
0 = Slew rate control is enabled for High-Speed mode (400 kHz)

bit 8 **SMEN:** SMBus Input Levels Enable bit
1 = Enables input logic so thresholds are compliant with the SMBus specification
0 = Disables SMBus-specific inputs

bit 7 **GCEN:** General Call Enable bit ($I^2C$ Client mode only)
1 = Enables interrupt when a general call address is received in I2CxRSR; module is enabled for reception
0 = General call address is disabled.

bit 6 **STREN:** SCLx Clock Stretch Enable bit
In $I^2C$ Client mode only; used in conjunction with the SCLREL bit.
1 = Enables clock stretching
0 = Disables clock stretching

bit 5 **ACKDT:** Acknowledge Data bit
In $I^2C$ Host mode during Host Receive mode. The value that will be transmitted when the user initiates an Acknowledge sequence at the end of a receive.
In $I^2C$ Client mode when AHEN = 1 or DHEN = 1. The value that the Client will transmit when it initiates an Acknowledge sequence at the end of an address or data reception.
1 = NACK is sent
0 = ACK is sent

bit 4 **ACKEN:** Acknowledge Sequence Enable bit
In $I^2C$ Host mode only; applicable during Host Receive mode.
1 = Initiates Acknowledge sequence on SDAx and SCLx pins, and transmits ACKDT data bit
0 = Acknowledge sequence is Idle

bit 3 **RCEN:** Receive Enable bit ($I^2C$ Host mode only)
1 = Enables Receive mode for $I^2C$; automatically cleared by hardware at end of 8-bit receive data byte
0 = Receive sequence is not in progress

bit 2 **PEN:** Stop Condition Enable bit ($I^2C$ Host mode only)
1 = Initiates Stop condition on SDAx and SCLx pins
0 = Stop condition is Idle

bit 1 **RSEN:** Restart Condition Enable bit ($I^2C$ Host mode only)
1 = Initiates Restart condition on SDAx and SCLx pins
0 = Restart condition is Idle

bit 0 **SEN:** Start Condition Enable bit ($I^2C$ Host mode only)
1 = Initiates Start condition on SDAx and SCLx pins
0 = Start condition is Idle

**Note 1:** Automatically cleared to '0' at the beginning of Client transmission; automatically cleared to '0' at the end of Client reception.
**2:** Automatically cleared to '0' at the beginning of Client transmission.
**3:** The SMB3EN Configuration bit (FDEVOPT[10]) selects between normal and SMBus 3.0 levels.

**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 ($I^2C$ Client mode only).
1 = Enables interrupt on detection of Stop condition
0 = Stop detection interrupts are disabled

bit 5 **SCIE:** Start Condition Interrupt Enable bit ($I^2C$ Client 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 ($I^2C$ Client mode only)
1 = I2CxRCV is updated and an ACK is generated for a received address/data byte, ignoring the state of the I2COV bit only if 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:** Client Mode Bus Collision Detect Enable bit ($I^2C$ Client mode only)
If, on the rising edge of SCLx, SDAx is sampled low when the module is outputting 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.
1 = Enables Client bus collision interrupts
0 = Client bus collision interrupts are disabled

bit 1 **AHEN:** Address Hold Enable bit ($I^2C$ Client mode only)
1 = Following the 8th falling edge of SCLx for a matching received address byte; SCLREL bit (I2CxCONL[12]) will be cleared and the SCLx will be held low
0 = Address holding is disabled

bit 0 **DHEN:** Data Hold Enable bit ($I^2C$ Client mode only)
1 = Following the 8th falling edge of SCLx for a received data byte; Client hardware clears the SCLREL bit (I2CxCONL[12]) and SCLx is held low
0 = Data holding is disabled


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**REGISTER 19-3: I2CxSTAT: I2Cx STATUS REGISTER**

| HSC/R-0 | HSC/R-0 | HSC/R-0 | U-0 | U-0 | HSC/R/C-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| ACKSTAT | TRSTAT | ACKTIM | — | — | BCL | GCSTAT | ADD10 |
| bit 15 | | | | | | | bit 8 |

| HS/R/C-0 | HS/R/C-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| IWCOL | I2COV | D/$\overline{A}$ | P | S | R/$\overline{W}$ | RBF | TBF |
| bit 7 | | | | | | | bit 0 |

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

bit 15 **ACKSTAT:** Acknowledge Status bit (updated in all Host and Client modes)
1 = Acknowledge was not received from Client
0 = Acknowledge was received from Client

bit 14 **TRSTAT:** Transmit Status bit (when operating as $I^2C$ Host; applicable to Host transmit operation)
1 = Host transmit is in progress (eight bits + ACK)
0 = Host transmit is not in progress

bit 13 **ACKTIM:** Acknowledge Time Status bit (valid in $I^2C$ Client mode only)
1 = Indicates $I^2C$ bus is in an Acknowledge sequence, set on 8th falling edge of SCLx clock
0 = Not an Acknowledge sequence, cleared on 9th rising edge of SCLx clock

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

bit 10 **BCL:** Bus Collision Detect bit (cleared when $I^2C$ module is disabled, I2CEN = 0)
1 = A bus collision has been detected during a transmit operation
0 = No bus collision has been detected

bit 9 **GCSTAT:** General Call Status bit (cleared after Stop detection)
1 = General call address was received
0 = General call address was not received

bit 8 **ADD10:** 10-Bit Address Status bit (cleared after Stop detection)
1 = 10-bit address was matched
0 = 10-bit address was not matched

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; must be cleared in software
0 = No collision

bit 6 **I2COV:** I2Cx Receive Overflow Flag bit
1 = A byte was received while the I2CxRCV register is still holding the previous byte; I2COV is a "don't care" in Transmit mode, must be cleared in software
0 = No overflow

bit 5 **D/$\overline{A}$:** Data/$\overline{\text{Address}}$ bit (when operating as $I^2C$ Client)
1 = Indicates that the last byte received was data
0 = Indicates that the last byte received or transmitted was an address

bit 4 **P:** I2Cx Stop bit
Updated when Start, Reset or Stop is detected; cleared when the $I^2C$ module is disabled, I2CEN = 0.
1 = Indicates that a Stop bit has been detected last
0 = Stop bit was not detected last

**REGISTER 19-3: I2CxSTAT: I2Cx STATUS REGISTER (CONTINUED)**

bit 3 **S:** I2Cx Start bit
Updated when Start, Reset or Stop is detected; cleared when the $I^2C$ module is disabled, I2CEN = 0.
1 = Indicates that a Start (or Repeated Start) bit has been detected last
0 = Start bit was not detected last

bit 2 **R/$\overline{W}$:** Read/$\overline{Write}$ Information bit (when operating as $I^2C$ Client)
1 = Read: Indicates the data transfer is output from the Client
0 = Write: Indicates the data transfer is input to the Client

bit 1 **RBF:** Receive Buffer Full Status bit
1 = Receive is complete, I2CxRCV is full
0 = Receive is not complete, I2CxRCV is empty

bit 0 **TBF:** Transmit Buffer Full Status bit
1 = Transmit is in progress, I2CxTRN is full (eight bits of data)
0 = Transmit is complete, I2CxTRN is empty

**REGISTER 19-4: I2CxMSK: I2Cx CLIENT MODE ADDRESS MASK REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | MSK[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 |
|---|---|---|---|---|---|---|---|
| MSK[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 **MSK[9:0]:** I2Cx Mask for Address Bit x Select bits
1 = Enables masking for bit x of the incoming message address; bit match is not required in this position
0 = Disables masking for bit x; bit match is required in this position


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**NOTES:**

## 20.0 SINGLE-EDGE NIBBLE TRANSMISSION (SENT)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Single-Edge Nibble Transmission (SENT) Module"** (www.microchip.com/DS70005145).

The Single-Edge Nibble Transmission (SENT) module is based on the SAE J2716, *"SENT – Single-Edge Nibble Transmission for Automotive Applications"*. The SENT protocol is a one-way, single-wire, time-modulated serial communication, based on successive falling edges. It is intended for use in applications where high-resolution sensor data need to be communicated from a sensor to an Engine Control Unit (ECU).

The SENTx module has the following major features:

- Selectable Transmit or Receive Mode
- Synchronous or Asynchronous Transmit Mode
- Automatic Data Rate Synchronization
- Optional Automatic Detection of CRC Errors in Receive Mode
- Optional Hardware Calculation of CRC in Transmit Mode
- Support for Optional Pause Pulse Period
- Data Buffering for One Message Frame
- Selectable Data Length for Transmit/Receive, Up to Six Nibbles
- Automatic Detection of Framing Errors

SENT protocol timing is based on a predetermined time unit, TTICK. Both the transmitter and receiver must be preconfigured for TTICK, which can vary from 3 to 90 µs. A SENT message frame starts with a Sync pulse. The purpose of the Sync pulse is to allow the receiver to calculate the data rate of the message encoded by the transmitter. The SENT specification allows messages to be validated with up to a 20% variation in TTICK. This allows for the transmitter and receiver to run from different clocks that may be inaccurate and drift with time and temperature. The data nibbles are 4 bits in length and are encoded as the data value plus 12 ticks. This yields a zero value of 12 ticks and the maximum value, 0xF, of 27 ticks.

A SENT message consists of the following:

- A synchronization/calibration period of 56 tick times
- A status nibble of 12-27 tick times
- Up to six data nibbles of 12-27 tick times
- A CRC nibble of 12-27 tick times
- An optional pause pulse period of 12-768 tick times

Figure 20-1 shows a block diagram of the SENTx module.

Figure 20-2 shows the construction of a typical 6-nibble data frame, with the numbers representing the minimum or maximum number of tick times for each section.


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**FIGURE 20-1: SENTx MODULE BLOCK DIAGRAM**

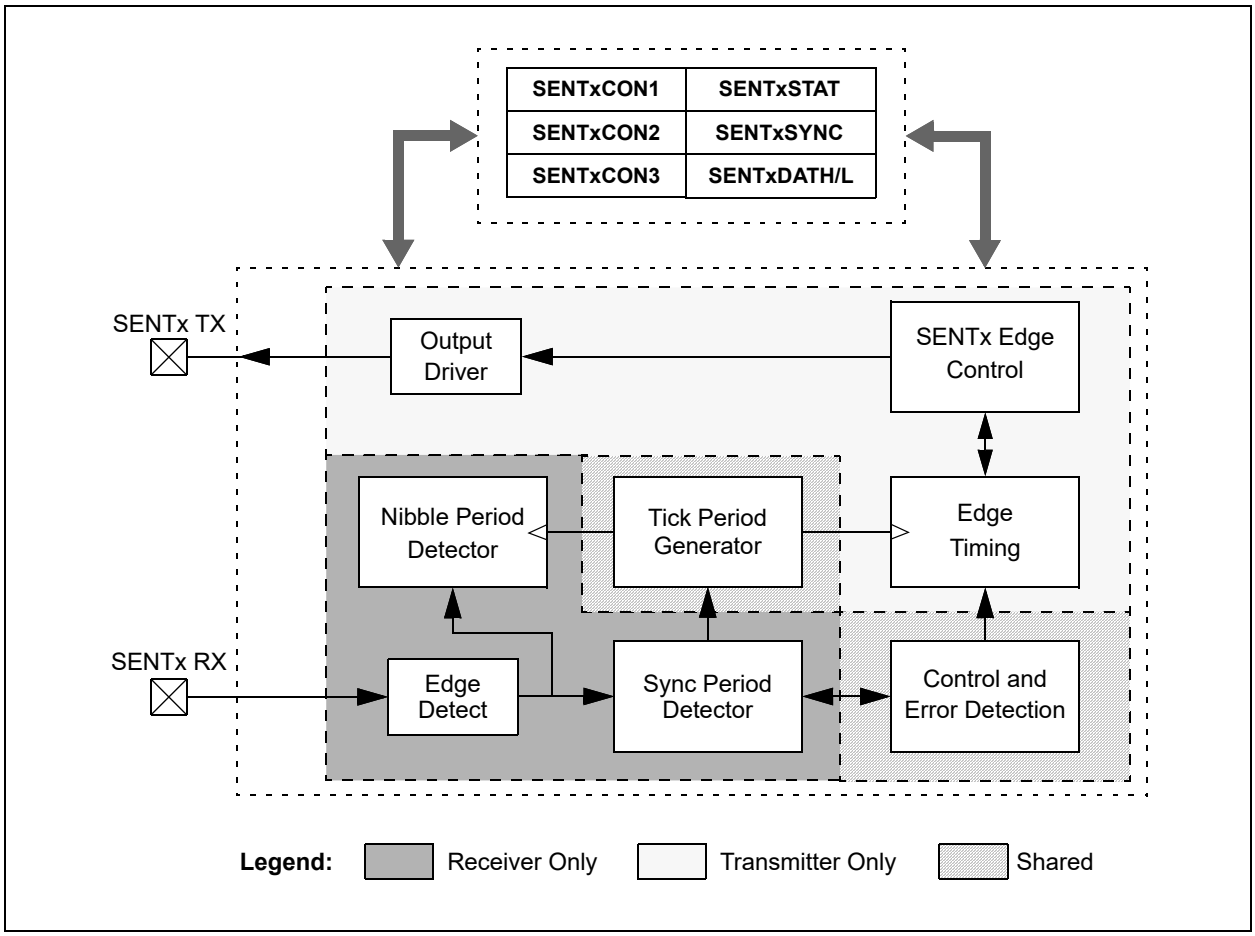
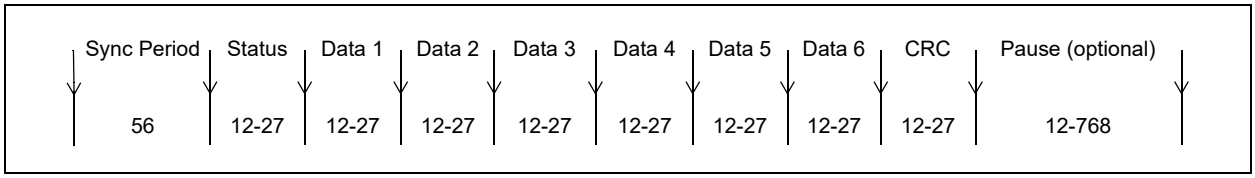



**FIGURE 20-2: SENTx PROTOCOL DATA FRAMES**



## 20.1 Transmit Mode

By default, the SENTx module is configured for a transmit operation. The module can be configured for a continuous asynchronous message frame transmission, or alternatively, for Synchronous mode triggered by software. When enabled, the transmitter will send a Sync, followed by the appropriate number of data nibbles, an optional CRC and optional pause pulse. The tick period used by the SENTx transmitter is set by writing a value to the TICKTIME[15:0] (SENTxCON2[15:0]) bits. The tick period calculations are shown in Equation 20-1.

**EQUATION 20-1: TICK PERIOD CALCULATION**

$$TICKTIME[15:0] = \frac{T_{TICK}}{T_{CLK}} - 1$$

An optional pause pulse can be used in Asynchronous mode to provide a fixed message frame time period. The frame period used by the SENTx transmitter is set by writing a value to the FRAMETIME[15:0] (SENTxCON3[15:0]) bits. The formulas used to calculate the value of frame time are shown in Equation 20-2.

**EQUATION 20-2: FRAME TIME CALCULATIONS**

$$FRAMETIME[15:0] = T_{TICK}/T_{FRAME}$$

$$FRAMETIME[15:0] \geq 122 + 27N$$

$$FRAMETIME[15:0] \geq 848 + 12N$$

Where:

$T_{FRAME}$ = Total time of the message in ms

$N$ = The number of data nibbles in message, 1-6

**Note:** The module will not produce a pause period with less than 12 ticks, regardless of the FRAMETIME[15:0] value. FRAMETIME[15:0] values beyond 2047 will have no effect on the length of a data frame.

### 20.1.1 TRANSMIT MODE CONFIGURATION

#### 20.1.1.1 Initializing the SENTx Module

Perform the following steps to initialize the module:

1. Write RCVEN (SENTxCON1[11]) = 0 for Transmit mode.
2. Write TXM (SENTxCON1[10]) = 0 for Asynchronous Transmit mode or TXM = 1 for Synchronous mode.
3. Write NIBCNT[2:0] (SENTxCON1[2:0]) for the desired data frame length.
4. Write CRCEN (SENTxCON1[8]) for hardware or software CRC calculation.
5. Write PPP (SENTxCON1[7]) for optional pause pulse.
6. If PPP = 1, write TFRAME to SENTxCON3.
7. Write SENTxCON2 with the appropriate value for the desired tick period.
8. Enable interrupts and set interrupt priority.
9. Write initial status and data values to SENTxDATH/L.
10. If CRCEN = 0, calculate CRC and write the value to CRC[3:0] (SENTxDATL[3:0]).
11. Set the SNTEN (SENTxCON1[15]) bit to enable the module.

User software updates to SENTxDATH/L must be performed after the completion of the CRC and before the next message frame's status nibble. The recommended method is to use the message frame completion interrupt to trigger data writes.


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## 20.2 Receive Mode

The module can be configured for receive operation by setting the RCVEN (SENTxCON1[11]) bit. The time between each falling edge is compared to SYNCMIN[15:0] (SENTxCON3[15:0]) and SYNCMAX[15:0] (SENTxCON2[15:0]), and if the measured time lies between the minimum and maximum limits, the module begins to receive data. The validated Sync time is captured in the SENTxSYNC register and the tick time is calculated. Subsequent falling edges are verified to be within the valid data width, and the data are stored in the SENTxDATL/H registers. An interrupt event is generated at the completion of the message, and the user software should read the SENTx Data registers before the reception of the next nibble. The equation for SYNCMIN[15:0] and SYNCMAX[15:0] is shown in Equation 20-3.

**EQUATION 20-3: SYNCMIN[15:0] AND SYNCMAX[15:0] CALCULATIONS**

$$T_{TICK} = T_{CLK} \bullet (TICKTIME[15:0] + 1)$$

$$FRAMETIME[15:0] = T_{TICK}/T_{FRAME}$$

$$SyncCount = 8 \times F_{RCV} \times T_{TICK}$$

$$SYNCMIN[15:0] = 0.8 \times SyncCount$$

$$SYNCMAX[15:0] = 1.2 \times SyncCount$$

$$FRAMETIME[15:0] \geq 122 + 27N$$

$$FRAMETIME[15:0] \geq 848 + 12N$$

Where:

$T_{FRAME}$ = Total time of the message in ms

$N$ = The number of data nibbles in message, 1-6

$F_{RCV}$ = FCY x Prescaler

$T_{CLK}$ = FCY/Prescaler

For TTICK = 3.0 µs and FCLK = 4 MHz, SYNCMIN[15:0] = 76.

**Note:** To ensure a Sync period can be identified, the value written to SYNCMIN[15:0] must be less than the value written to SYNCMAX[15:0].

### 20.2.1 RECEIVE MODE CONFIGURATION

#### 20.2.1.1 Initializing the SENTx Module

Perform the following steps to initialize the module:

1. Write RCVEN (SENTxCON1[11]) = 1 for Receive mode.
2. Write NIBCNT[2:0] (SENTxCON1[2:0]) for the desired data frame length.
3. Write CRCEN (SENTxCON1[8]) for hardware or software CRC validation.
4. Write PPP (SENTxCON1[7]) = 1 if pause pulse is present.
5. Write SENTxCON2 with the value of SYNCMAXx (Nominal Sync Period + 20%).
6. Write SENTxCON3 with the value of SYNCMINx (Nominal Sync Period – 20%).
7. Enable interrupts and set interrupt priority.
8. Set the SNTEN (SENTxCON1[15]) bit to enable the module.

The data should be read from the SENTxDATL/H registers after the completion of the CRC and before the next message frame's status nibble. The recommended method is to use the message frame completion interrupt trigger.

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## 20.3 SENT Control/Status Registers

**REGISTER 20-1: SENTxCON1: SENTx CONTROL REGISTER 1**

| R/W-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| SNTEN | — | SNTSIDL | — | RCVEN | TXM(1) | TXPOL(1) | CRCEN |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PPP | SPCEN(2) | — | PS | — | NIBCNT2 | NIBCNT1 | NIBCNT0 |
| 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 **SNTEN:** SENTx Enable bit
1 = SENTx is enabled
0 = SENTx is disabled

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

bit 13 **SNTSIDL:** SENTx Stop in Idle Mode bit
1 = Discontinues module operation when the device enters Idle mode
0 = Continues module operation in Idle mode

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

bit 11 **RCVEN:** SENTx Receive Enable bit
1 = SENTx operates as a receiver
0 = SENTx operates as a transmitter (sensor)

bit 10 **TXM:** SENTx Transmit Mode bit
1 = SENTx transmits data frame only when triggered using the SYNCTXEN status bit
0 = SENTx transmits data frames continuously while SNTEN = 1

bit 9 **TXPOL:** SENTx Transmit Polarity bit
1 = SENTx data output pin is low in the Idle state
0 = SENTx data output pin is high in the Idle state

bit 8 **CRCEN:** CRC Enable bit
Module in Receive mode (RCVEN = 1):
1 = SENTx performs CRC verification on received data using the preferred J2716 method
0 = SENTx does not perform CRC verification on received data
Module in Transmit mode (RCVEN = 0):
1 = SENTx automatically calculates CRC using the preferred J2716 method
0 = SENTx does not calculate CRC

bit 7 **PPP:** Pause Pulse Present bit
1 = SENTx is configured to transmit/receive SENT messages with pause pulse
0 = SENTx is configured to transmit/receive SENT messages without pause pulse

bit 6 **SPCEN:** Short PWM Code Enable bit
1 = SPC control from external source is enabled
0 = SPC control from external source is disabled

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

**Note 1:** This bit has no function in Receive mode (RCVEN = 1).
**2:** This bit has no function in Transmit mode (RCVEN = 0).


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**REGISTER 20-1: SENTxCON1: SENTx CONTROL REGISTER 1 (CONTINUED)**

bit 4 **PS:** SENTx Module Clock Prescaler (divider) bit
1 = Divide-by-4
0 = Divide-by-1

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

bit 2-0 **NIBCNT[2:0]:** Nibble Count Control bits
111 = Reserved; do not use
110 = Module transmits/receives six data nibbles in a SENT data packet
101 = Module transmits/receives five data nibbles in a SENT data packet
100 = Module transmits/receives four data nibbles in a SENT data packet
011 = Module transmits/receives three data nibbles in a SENT data packet
010 = Module transmits/receives two data nibbles in a SENT data packet
001 = Module transmits/receives one data nibble in a SENT data packet
000 = Reserved; do not use

**Note 1:** This bit has no function in Receive mode (RCVEN = 1).
**2:** This bit has no function in Transmit mode (RCVEN = 0).

**REGISTER 20-2: SENTxSTAT: SENTx STATUS 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/C-0 | R/C-0 | R-0 | HC/R/W-0 |
|---|---|---|---|---|---|---|---|
| PAUSE | NIB2 | NIB1 | NIB0 | CRCERR | FRMERR | RXIDLE | SYNCTXEN(1) |
| 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 15-8 **Unimplemented:** Read as '0'

bit 7 **PAUSE:** Pause Period Status bit
1 = The module is transmitting/receiving a pause period
0 = The module is not transmitting/receiving a pause period

bit 6-4 **NIB[2:0]:** Nibble Status bits
Module in Transmit Mode (RCVEN = 0):
111 = Module is transmitting a CRC nibble
110 = Module is transmitting Data Nibble 6
101 = Module is transmitting Data Nibble 5
100 = Module is transmitting Data Nibble 4
011 = Module is transmitting Data Nibble 3
010 = Module is transmitting Data Nibble 2
001 = Module is transmitting Data Nibble 1
000 = Module is transmitting a status nibble or pause period, or is not transmitting
Module in Receive Mode (RCVEN = 1):
111 = Module is receiving a CRC nibble or was receiving this nibble when an error occurred
110 = Module is receiving Data Nibble 6 or was receiving this nibble when an error occurred
101 = Module is receiving Data Nibble 5 or was receiving this nibble when an error occurred
100 = Module is receiving Data Nibble 4 or was receiving this nibble when an error occurred
011 = Module is receiving Data Nibble 3 or was receiving this nibble when an error occurred
010 = Module is receiving Data Nibble 2 or was receiving this nibble when an error occurred
001 = Module is receiving Data Nibble 1 or was receiving this nibble when an error occurred
000 = Module is receiving a status nibble or waiting for Sync

bit 3 **CRCERR:** CRC Status bit (Receive mode only)
1 = A CRC error has occurred for the 1-6 data nibbles in SENTxDATL/H
0 = A CRC error has not occurred

bit 2 **FRMERR:** Framing Error Status bit (Receive mode only)
1 = A data nibble was received with less than 12 tick periods or greater than 27 tick periods
0 = Framing error has not occurred

bit 1 **RXIDLE:** SENTx Receiver Idle Status bit (Receive mode only)
1 = The SENTx data bus has been Idle (high) for a period of SYNCMAX[15:0] or greater
0 = The SENTx data bus is not Idle

**Note 1:** In Receive mode (RCVEN = 1), the SYNCTXEN bit is read-only.


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**REGISTER 20-2: SENTxSTAT: SENTx STATUS REGISTER (CONTINUED)**

bit 0 **SYNCTXEN:** SENTx Synchronization Period Status/Transmit Enable bit

Module in Receive mode (RCVEN = 1):

1 = A valid synchronization period was detected; the module is receiving nibble data

0 = No synchronization period has been detected; the module is not receiving nibble data

Module in Asynchronous Transmit mode (RCVEN = 0, TXM = 0):

The bit always reads as '1' when the module is enabled, indicating the module transmits SENTx data frames continuously. The bit reads '0' when the module is disabled.

Module in Synchronous Transmit mode (RCVEN = 0, TXM = 1):

1 = The module is transmitting a SENTx data frame

0 = The module is not transmitting a data frame, user software may set SYNCTXEN to start another data frame transmission

**Note 1:** In Receive mode (RCVEN = 1), the SYNCTXEN bit is read-only.

**REGISTER 20-3: SENTxDATL: SENTx RECEIVE DATA REGISTER LOW(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 |
|---|---|---|---|---|---|---|---|
| DATA4[3:0] | | | | DATA5[3:0] | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| DATA6[3:0] | | | | CRC[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 15-12 **DATA4[3:0]:** Data Nibble 4 Data bits
bit 11-8 **DATA5[3:0]:** Data Nibble 5 Data bits
bit 7-4 **DATA6[3:0]:** Data Nibble 6 Data bits
bit 3-0 **CRC[3:0]:** CRC Nibble Data bits

**Note 1:** Register bits are read-only in Receive mode (RCVEN = 1). In Transmit mode, the CRC[3:0] bits are read-only when automatic CRC calculation is enabled (RCVEN = 0, CRCEN = 1).

**REGISTER 20-4: SENTxDATH: SENTx RECEIVE DATA REGISTER HIGH(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 |
|---|---|---|---|---|---|---|---|
| STAT[3:0] | | | | DATA1[3:0] | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| DATA2[3:0] | | | | DATA3[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 15-12 **STAT[3:0]:** Status Nibble Data bits
bit 11-8 **DATA1[3:0]:** Data Nibble 1 Data bits
bit 7-4 **DATA2[3:0]:** Data Nibble 2 Data bits
bit 3-0 **DATA3[3:0]:** Data Nibble 3 Data bits

**Note 1:** Register bits are read-only in Receive mode (RCVEN = 1). In Transmit mode, the CRC[3:0] bits are read-only when automatic CRC calculation is enabled (RCVEN = 0, CRCEN = 1).


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**NOTES:**

## 21.0 TIMER1

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Timer1 Module"** (www.microchip.com/DS70005279).

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
- Asynchronous Timer
- Operational during CPU Sleep Mode
- Software Selectable Prescalers 1:1, 1:8, 1:64 and 1:256
- External Clock Selection Control
- The Timer1 External Clock Input (T1CK) can Optionally be Synchronized to the Internal Device Clock, and the Clock Synchronization is Performed after the Prescaler

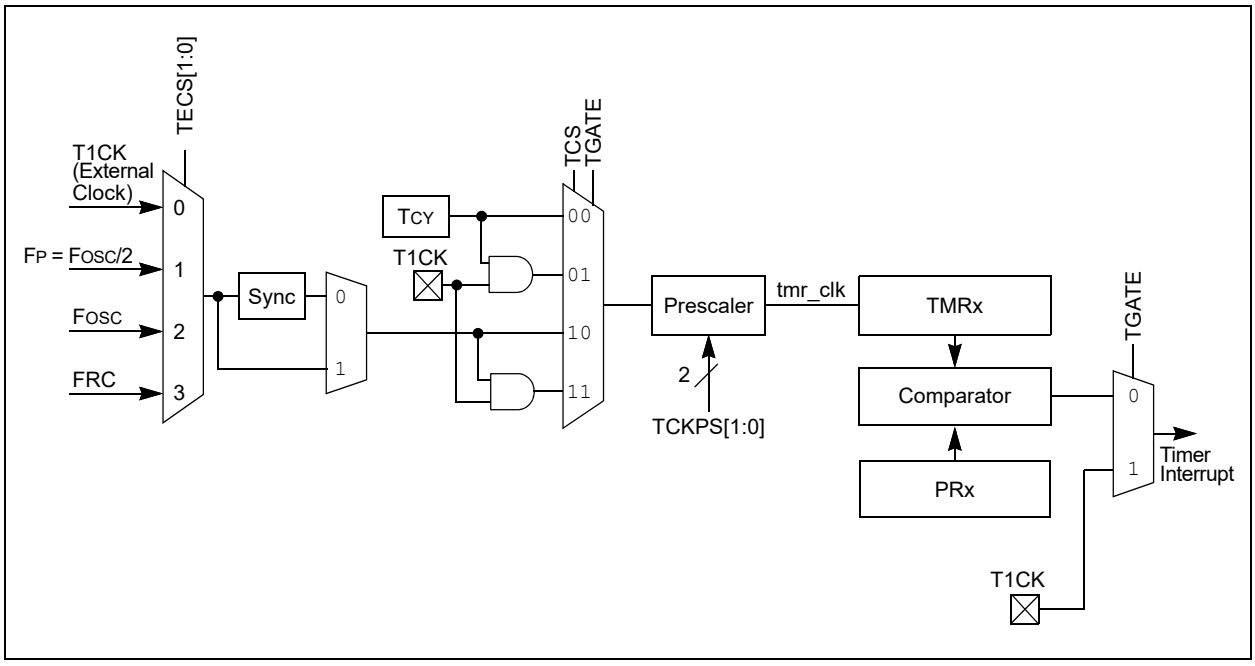
If Timer1 is used for SCCP, the timer should be running in Synchronous mode.

The Timer1 module can operate in one of the following modes:

- Timer Mode
- Gated Timer Mode
- Synchronous Counter Mode
- Asynchronous Counter Mode

A block diagram of Timer1 is shown in Figure 21-1.

**FIGURE 21-1: 16-BIT TIMER1 MODULE BLOCK DIAGRAM**





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## 21.1 Timer1 Control Register

**REGISTER 21-1: T1CON: TIMER1 CONTROL REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R-0 | R-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| TON(1) | — | SIDL | TMWDIS | TMWIP | PRWIP | TECS1 | TECS0 |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | U-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 = Starts 16-bit Timer1
0 = Stops 16-bit Timer1

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

bit 13 **SIDL:** Timer1 Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **TMWDIS:** Asynchronous Timer1 Write Disable bit
1 = Timer writes are ignored while a posted write to TMR1 or PR1 is synchronized to the asynchronous clock domain
0 = Back-to-back writes are enabled in Asynchronous mode

bit 11 **TMWIP:** Asynchronous Timer1 Write in Progress bit
1 = Write to the timer in Asynchronous mode is pending
0 = Write to the timer in Asynchronous mode is complete

bit 10 **PRWIP:** Asynchronous Period Write in Progress bit
1 = Write to the Period register in Asynchronous mode is pending
0 = Write to the Period register in Asynchronous mode is complete

bit 9-8 **TECS[1:0]:** Timer1 Extended Clock Select bits
11 = FRC Clock
10 = FOSC Oscillator Clock
01 = FP = FOSC/2 Peripheral Clock
00 = External Clock comes from the T1CK pin

bit 7 **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 6 **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.

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**REGISTER 21-1: T1CON: TIMER1 CONTROL REGISTER (CONTINUED)**

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
When TCS = 1:
1 = Synchronizes the External Clock input
0 = Does not synchronize the External Clock input
When TCS = 0:
This bit is ignored.

bit 1 **TCS:** Timer1 Clock Source Select bit
1 = External Clock source selected by TECS[1:0]
0 = Internal Peripheral 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.


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**NOTES:**

## 22.0 CAPTURE/COMPARE/PWM/ TIMER MODULES (SCCP)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. For more information on the SCCP modules, refer to **"Capture/ Compare/PWM/Timer (MCCP and SCCP)"** (www.microchip.com/DS30003035)

The dsPIC33CDVL64MC106 devices include four SCCP Capture/Compare/PWM/Timer base modules, which provide the functionality of three different peripherals from earlier PIC24F devices. The module can operate in one of three major modes:

- General Purpose Timer
- Input Capture
- Output Compare/PWM

Single Capture/Compare/PWM (SCCP) output modules provide only one PWM output.

The SCCPx modules can be operated in only one of the three major modes at any time. The other modes are not available unless the module is reconfigured for the new mode.

A conceptual block diagram for the module is shown in Figure 22-1. All three modes share a time base generator and a common Timer register pair (CCPxTMRH/L); other shared hardware components are added as a particular mode requires.

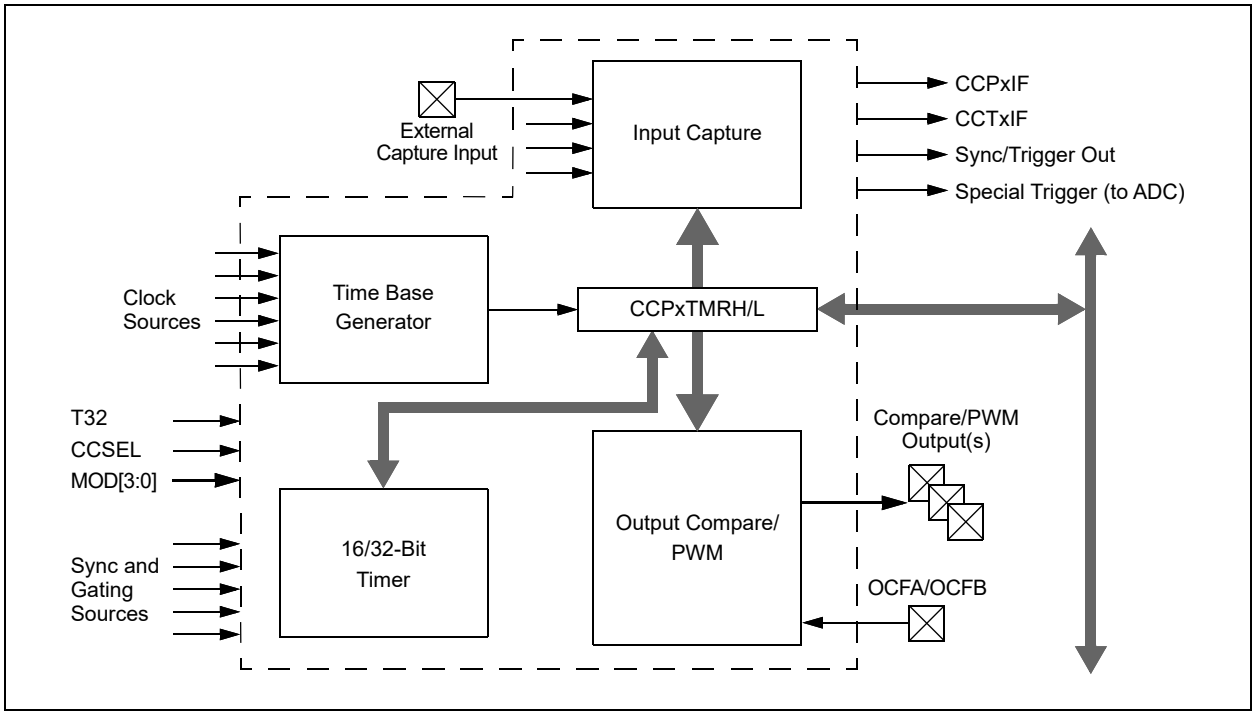
Each module has a total of six control and status registers:

- CCPxCON1L (Register 22-1)
- CCPxCON1H (Register 22-2)
- CCPxCON2L (Register 22-3)
- CCPxCON2H (Register 22-4)
- CCPxCON3H (Register 22-5)
- CCPxSTATL (Register 22-6)

Each module also includes eight buffer/counter registers that serve as Timer Value registers or data holding buffers:

- CCPxTMRH/CCPxTMRL (CCPx Timer High/Low Counters)
- CCPxPRH/CCPxPRL (CCPx Timer Period High/Low)
- CCPxRA (CCPx Primary Output Compare Data Buffer)
- CCPxRB (CCPx Secondary Output Compare Data Buffer)
- CCPxBUFH/CCPxBUFL (CCPx Input Capture High/Low Buffers)

**FIGURE 22-1: SCCPx CONCEPTUAL BLOCK DIAGRAM**





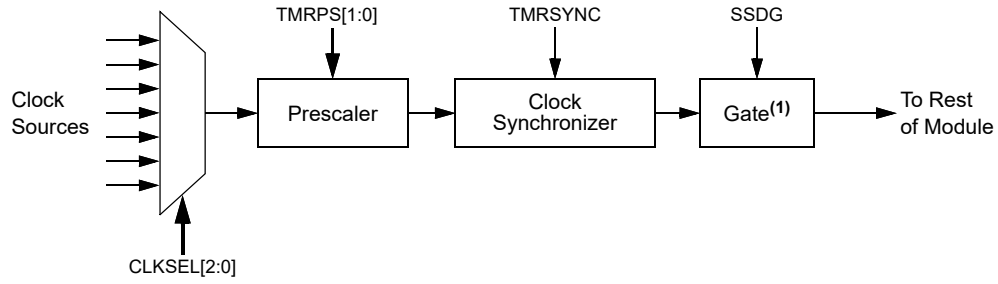
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## 22.1 Time Base Generator

The Timer Clock Generator (TCG) generates a clock for the module's internal time base, using one of the clock signals already available on the microcontroller. This is used as the time reference for the module in its three major modes. The internal time base is shown in Figure 22-2.

There are eight inputs available to the clock generator, which are selected using the CLKSEL[2:0] bits (CCPxCON1L[10:8]). Available sources include the FRC and LPRC, the Secondary Oscillator and the TCLKI External Clock inputs. The system clock is the default source (CLKSEL[2:0] = 000).

**FIGURE 22-2: TIMER CLOCK GENERATOR**




**Note 1:** Gating is available in Timer modes only.

## 22.2 General Purpose Timer

Timer mode is selected when CCSEL = 0 and MOD[3:0] = 0000. The timer can function as a 32-bit timer or a dual 16-bit timer, depending on the setting of the T32 bit (Table 22-1).

**TABLE 22-1: TIMER OPERATION MODE**

| T32 (CCPxCON1L[5]) | Operating Mode |
|---|---|
| 0 | Dual Timer mode (16-bit) |
| 1 | Timer mode (32-bit) |

Dual 16-Bit Timer mode provides a simple timer function with two independent 16-bit timer/counters. The primary timer uses CCPxTMRL and CCPxPRL. Only the primary timer can interact with other modules on the device. It generates the SCCPx sync out signals for use by other SCCP modules. It can also use the SYNC[4:0] bits signal generated by other modules.

The secondary timer uses CCPxTMRH and CCPxPRH. It is intended to be used only as a periodic interrupt source for scheduling CPU events. It does not generate an output sync/trigger signal like the primary time base. In Dual Timer mode, the CCPx Secondary Timer Period register, CCPxPRH, generates the SCCP compare event (CCPxIF) used by many other modules on the device.

The 32-Bit Timer mode uses the CCPxTMRL and CCPxTMRH registers, together, as a single 32-bit timer. When CCPxTMRL overflows, CCPxTMRH increments by one. This mode provides a simple timer function when it is important to track long time periods. Note that the T32 bit (CCPxCON1L[5]) should be set before the CCPxTMRL or CCPxPRH registers are written to initialize the 32-bit timer.

### 22.2.1 SYNC AND TRIGGER OPERATION

In both 16-bit and 32-bit modes, the timer can also function in either a synchronization (“sync”) or trigger operation. Both use the SYNC[4:0] bits (CCPxCON1H[4:0]) to determine the input signal source. The difference is how that signal affects the timer.

In the sync operation, the timer Reset or clear occurs when the input selected by SYNC[4:0] is asserted. The timer immediately begins to count again from zero unless it is held for some other reason. Sync operation is used whenever the TRIGEN bit (CCPxCON1H[7]) is cleared. SYNC[4:0] can have any value, except ‘11111’.

In the trigger operation, the timer is held in Reset until the input selected by SYNC[4:0] is asserted; when it occurs, the timer starts counting. Trigger operation is used whenever the TRIGEN bit is set. In Trigger mode, the timer will continue running after a trigger event as long as the CCPTRIG bit (CCPxSTATL[7]) is set. To clear CCPTRIG, the TRCLR bit (CCPxSTATL[5]) must be set to clear the trigger event, reset the timer and hold it at zero until another trigger event occurs. On the dsPIC33CDVL64MC106 device, the trigger operation can only be used when the system clock is the time base source (CLKSEL[2:0] = 000).


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**FIGURE 22-3: DUAL 16-BIT TIMER MODE**

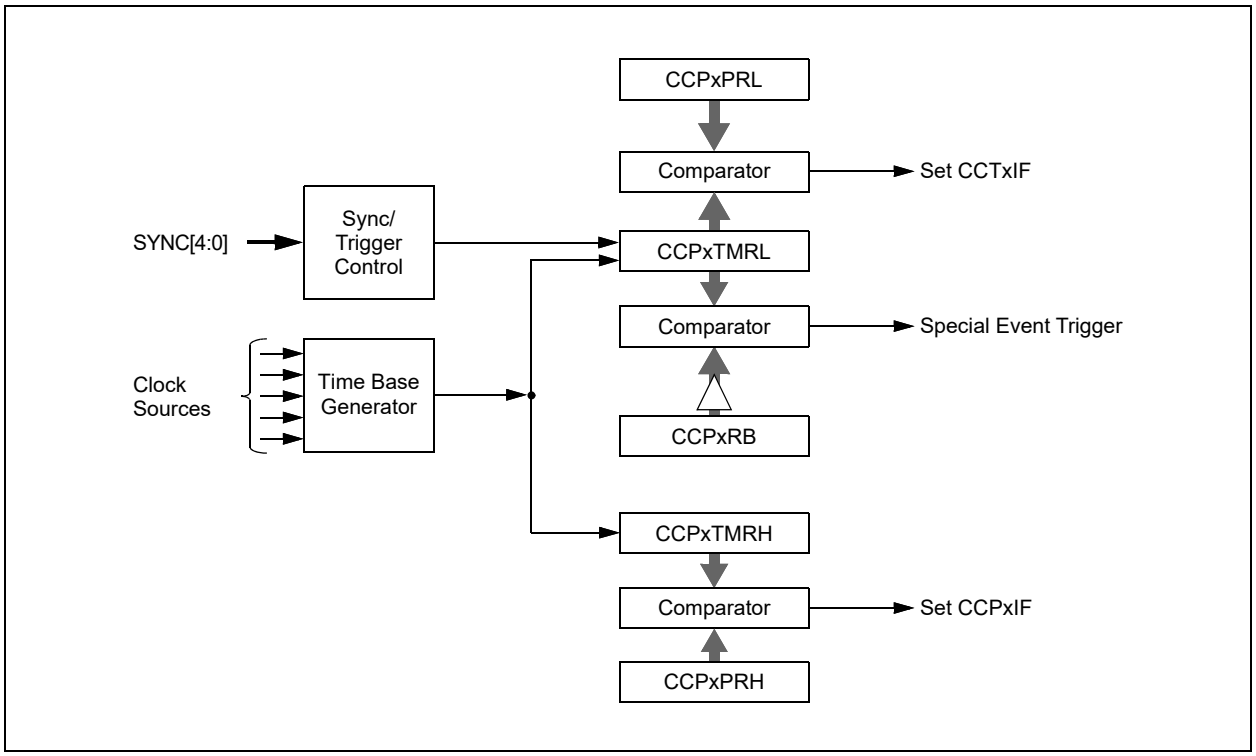
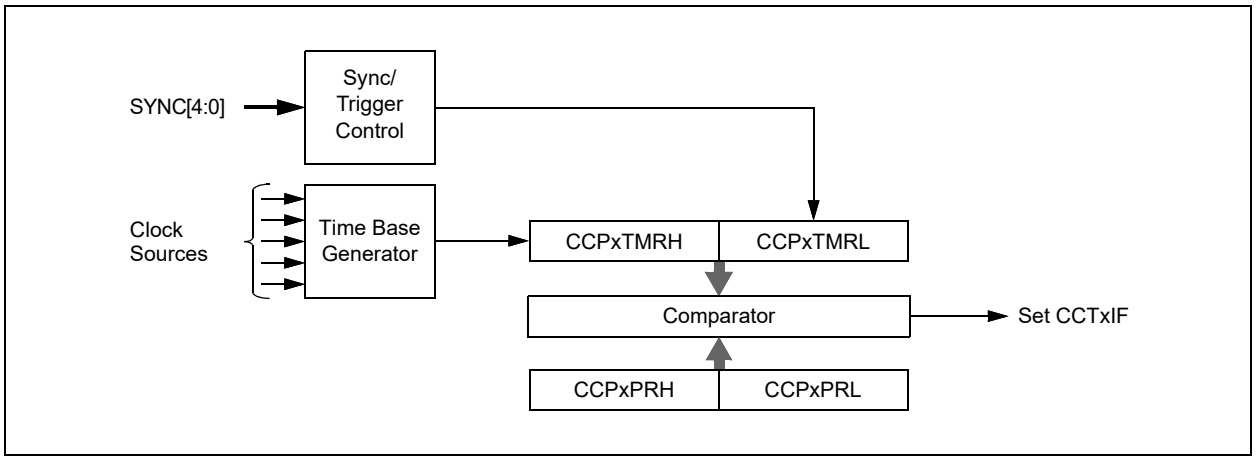



**FIGURE 22-4: 32-BIT TIMER MODE**



## 22.3 Output Compare Mode

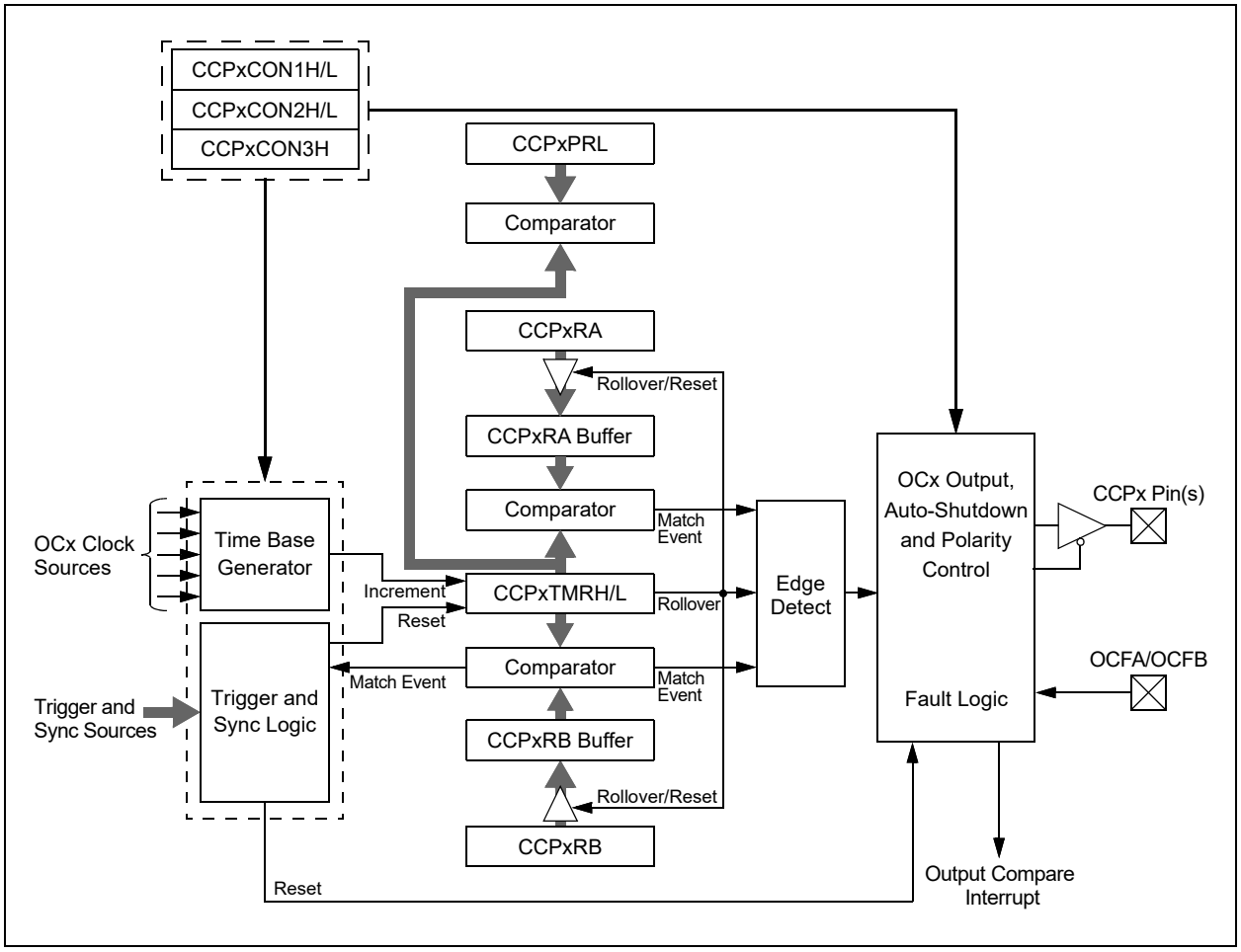
Output Compare mode compares the Timer register value with the value of one or two Compare registers, depending on its mode of operation. The Output Compare x module, on compare match events, has the ability to generate a single output transition or a train of output pulses. Like most PIC® MCU peripherals, the Output Compare x module can also generate interrupts on a compare match event.

Table 22-2 shows the various modes available in Output Compare modes.

**TABLE 22-2: OUTPUT COMPARE x/PWMx MODES**

| MOD[3:0] (CCPxCON1L[3:0]) | T32 (CCPxCON1L[5]) | Operating Mode | |
|---|---|---|---|
| 0001 | 0 | Output High on Compare (16-bit) | Single-Edge mode |
| 0001 | 1 | Output High on Compare (32-bit) | |
| 0010 | 0 | Output Low on Compare (16-bit) | |
| 0010 | 1 | Output Low on Compare (32-bit) | |
| 0011 | 0 | Output Toggle on Compare (16-bit) | |
| 0011 | 1 | Output Toggle on Compare (32-bit) | |
| 0100 | 0 | Dual Edge Compare (16-bit) | Dual Edge mode |
| 0101 | 0 | Dual Edge Compare (16-bit buffered) | PWM mode |

**FIGURE 22-5: OUTPUT COMPARE x BLOCK DIAGRAM**





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## 22.4 Input Capture Mode

Input Capture mode is used to capture a timer value from an independent timer base, upon an event, on an input pin or other internal trigger source. The input capture features are useful in applications requiring frequency (time period) and pulse measurement. Figure 22-6 depicts a simplified block diagram of Input Capture mode.

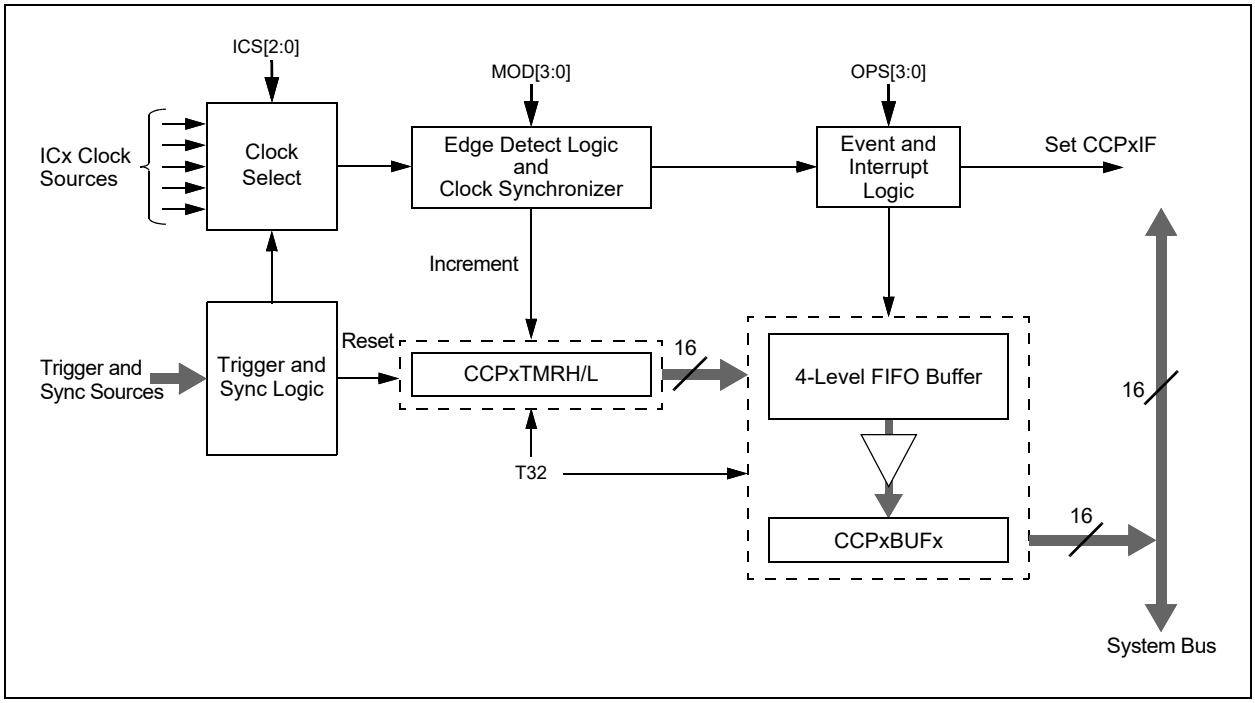
Input Capture mode uses a dedicated 16/32-bit, synchronous, up counting timer for the capture function. The timer value is written to the FIFO when a capture event occurs. The internal value may be read (with a synchronization delay) using the CCPxTMRH/L register.

To use Input Capture mode, the CCSEL bit (CCPxCON1L[4]) must be set. The T32 and the MOD[3:0] bits are used to select the proper Capture mode, as shown in Table 22-3.

**TABLE 22-3: INPUT CAPTURE x MODES**

| MOD[3:0] (CCPxCON1L[3:0]) | T32 (CCPxCON1L[5]) | Operating Mode |
|---|---|---|
| 0000 | 0 | Edge Detect (16-bit capture) |
| 0000 | 1 | Edge Detect (32-bit capture) |
| 0001 | 0 | Every Rising (16-bit capture) |
| 0001 | 1 | Every Rising (32-bit capture) |
| 0010 | 0 | Every Falling (16-bit capture) |
| 0010 | 1 | Every Falling (32-bit capture) |
| 0011 | 0 | Every Rising/Falling (16-bit capture) |
| 0011 | 1 | Every Rising/Falling (32-bit capture) |
| 0100 | 0 | Every 4th Rising (16-bit capture) |
| 0100 | 1 | Every 4th Rising (32-bit capture) |
| 0101 | 0 | Every 16th Rising (16-bit capture) |
| 0101 | 1 | Every 16th Rising (32-bit capture) |

**FIGURE 22-6: INPUT CAPTURE x BLOCK DIAGRAM**



## 22.5 Auxiliary Output

The SCCPx modules have an auxiliary (secondary) output that provides other peripherals access to internal module signals. The auxiliary output is intended to connect to other SCCP modules, or other digital peripherals, to provide these types of functions:

- Time Base Synchronization
- Peripheral Trigger and Clock Inputs
- Signal Gating

The type of output signal is selected using the AUXOUT[1:0] control bits (CCPxCON2H[4:3]). The type of output signal is also dependent on the module's operating mode.

**TABLE 22-4: AUXILIARY OUTPUT**

| AUXOUT[1:0] | CCSEL | MOD[3:0] | Comments | Signal Description |
|---|---|---|---|---|
| 00 | x | xxxx | Auxiliary Output Disabled | No Output |
| 01 | 0 | 0000 | Time Base Modes | Time Base Period Reset or Rollover |
| 10 | | | | Special Event Trigger Output |
| 11 | | | | No Output |
| 01 | 0 | 0001 through 1111 | Output Compare Modes | Time Base Period Reset or Rollover |
| 10 | | | | Output Compare Event Signal |
| 11 | | | | Output Compare Signal |
| 01 | 1 | xxxx | Input Capture Modes | Time Base Period Reset or Rollover |
| 10 | | | | Reflects the Value of the ICDIS bit |
| 11 | | | | Input Capture Event Signal |


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## 22.6 SCCP Control/Status Registers

**REGISTER 22-1: CCPxCON1L: CCPx CONTROL 1 LOW REGISTERS**

| R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| CCPON | — | CCPSIDL | CCPSLP | TMRSYNC | CLKSEL2 | CLKSEL1 | CLKSEL0 |
| 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 |
|---|---|---|---|---|---|---|---|
| TMRPS1 | TMRPS0 | T32 | CCSEL | MOD3 | MOD2 | MOD1 | MOD0 |
| 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 **CCPON:** CCPx Module Enable bit
1 = Module is enabled with an operating mode specified by the MOD[3:0] control bits
0 = Module is disabled

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

bit 13 **CCPSIDL:** CCPx Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **CCPSLP:** CCPx Sleep Mode Enable bit
1 = Module continues to operate in Sleep modes
0 = Module does not operate in Sleep modes

bit 11 **TMRSYNC:** Time Base Clock Synchronization bit
1 = Asynchronous module time base clock is selected and synchronized to the internal system clocks (CLKSEL[2:0] ≠ 000)
0 = Synchronous module time base clock is selected and does not require synchronization (CLKSEL[2:0] = 000)

bit 10-8 **CLKSEL[2:0]:** CCPx Time Base Clock Select bits
111 = PPS TxCK input
110 = CLC4
101 = CLC3
100 = CLC2
011 = CLC1
010 = Reserved
001 = Reference Clock (REFCLKO)
000 = Peripheral Clock (FP = FOSC/2)

bit 7-6 **TMRPS[1:0]:** Time Base Prescale Select bits
11 = 1:64 Prescaler
10 = 1:16 Prescaler
01 = 1:4 Prescaler
00 = 1:1 Prescaler

bit 5 **T32:** 32-Bit Time Base Select bit
1 = Uses 32-bit time base for timer, single-edge output compare or input capture function
0 = Uses 16-bit time base for timer, single-edge output compare or input capture function

bit 4 **CCSEL:** Capture/Compare Mode Select bit
1 = Input Capture peripheral
0 = Output Compare/PWM/Timer peripheral (exact function is selected by the MOD[3:0] bits)

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**REGISTER 22-1: CCPxCON1L: CCPx CONTROL 1 LOW REGISTERS (CONTINUED)**

bit 3-0 **MOD[3:0]:** CCPx Mode Select bits

For CCSEL = 1 (Input Capture modes):
1xxx = Reserved
011x = Reserved
0101 = Capture every 16th rising edge
0100 = Capture every 4th rising edge
0011 = Capture every rising and falling edge
0010 = Capture every falling edge
0001 = Capture every rising edge
0000 = Capture every rising and falling edge (Edge Detect mode)

For CCSEL = 0 (Output Compare/Timer modes):
1111 = External Input mode: Pulse generator is disabled, source is selected by ICS[2:0]
1110 = Reserved
110x = Reserved
10xx = Reserved
0111 = Reserved
0110 = Reserved
0101 = Dual Edge Compare mode, buffered
0100 = Dual Edge Compare mode
0011 = 16-Bit/32-Bit Single-Edge mode, toggles output on compare match
0010 = 16-Bit/32-Bit Single-Edge mode, drives output low on compare match
0001 = 16-Bit/32-Bit Single-Edge mode, drives output high on compare match
0000 = 16-Bit/32-Bit Timer mode, output functions are disabled


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**REGISTER 22-2: CCPxCON1H: CCPx CONTROL 1 HIGH REGISTERS**

| R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| OPSSRC(1) | RTRGEN(2) | — | — | OPS3(3) | OPS2(3) | OPS1(3) | OPS0(3) |
| 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 |
|---|---|---|---|---|---|---|---|
| TRIGEN | ONESHOT | ALTSYNC(4) | SYNC4 | SYNC3 | SYNC2 | SYNC1 | SYNC0 |
| 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 **OPSSRC:** Output Postscaler Source Select bit
1 = Output postscaler scales module trigger output events
0 = Output postscaler scales time base interrupt events

bit 14 **RTRGEN:** Retrigger Enable bit
1 = Time base can be retriggered when TRIGEN bit = 1
0 = Time base may not be retriggered when TRIGEN bit = 1

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

bit 11-8 **OPS3[3:0]:** CCPx Interrupt Output Postscale Select bits
1111 = Interrupt every 16th time base period match
1110 = Interrupt every 15th time base period match
. . .
0100 = Interrupt every 5th time base period match
0011 = Interrupt every 4th time base period match or 4th input capture event
0010 = Interrupt every 3rd time base period match or 3rd input capture event
0001 = Interrupt every 2nd time base period match or 2nd input capture event
0000 = Interrupt after each time base period match or input capture event

bit 7 **TRIGEN:** CCPx Trigger Enable bit
1 = Trigger operation of time base is enabled
0 = Trigger operation of time base is disabled

bit 6 **ONESHOT:** One-Shot Trigger Mode Enable bit
1 = One-Shot Trigger mode is enabled; trigger duration is set by OSCNT[2:0]
0 = One-Shot Trigger mode is disabled

bit 5 **ALTSYNC:** CCPx Alternate Synchronization Output Signal Select bit
1 = An alternate signal is used as the module synchronization output signal
0 = The module synchronization output signal is the Time Base Reset/rollover event

bit 4-0 **SYNC[4:0]:** CCPx Synchronization Source Select bits
See Table 22-5 for the definition of inputs.

**Note 1:** This control bit has no function in Input Capture modes.
**2:** This control bit has no function when TRIGEN = 0.
**3:** Output postscale settings, from 1:5 to 1:16 (0100-1111), will result in a FIFO buffer overflow for Input Capture modes.
**4:** Timer Base Prescaler must be 1:1 (TMRPS[1:0] = 00) if ALTSYNC = 1.

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**TABLE 22-5: SYNCHRONIZATION SOURCES**

| SYNC[4:0] | Synchronization Source |
|---|---|
| 00000 | None; Timer with Rollover on CCPxPR Match or FFFFh |
| 00001 | Sync Output SCCP1 |
| 00010 | Sync Output SCCP2 |
| 00011 | Sync Output SCCP3 |
| 00100 | Sync Output SCCP4 |
| 00101-01000 | Reserved |
| 01001 | INT0 |
| 01010 | INT1 |
| 01011 | INT2 |
| 01100 | UART1 RX Edge Detect |
| 01101 | UART1 TX Edge Detect |
| 01110 | UART2 RX Edge Detect |
| 01111 | UART2 TX Edge Detect |
| 10000 | CLC1 Output |
| 10001 | CLC2 Output |
| 10010 | CLC3 Output |
| 10011 | CLC4 Output |
| 10100 | UART3 RX Edge Detect |
| 10101 | UART3 TX Edge Detect |
| 10111 | Comparator 1 Output |
| 11000-11110 | Reserved |
| 11111 | None; Timer with Auto-Rollover (FFFFh → 0000h) |


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**REGISTER 22-3: CCPxCON2L: CCPx CONTROL 2 LOW REGISTERS**

| R/W-0 | R/W-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| PWMRSEN | ASDGM | — | SSDG | — | — | — | — |
| 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 |
|---|---|---|---|---|---|---|---|
| ASDG[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 **PWMRSEN:** CCPx PWM Restart Enable bit
1 = ASEVT bit clears automatically at the beginning of the next PWM period, after the shutdown input has ended
0 = ASEVT bit must be cleared in software to resume PWM activity on output pins

bit 14 **ASDGM:** CCPx Auto-Shutdown Gate Mode Enable bit
1 = Waits until the next Time Base Reset or rollover for shutdown to occur
0 = Shutdown event occurs immediately

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

bit 12 **SSDG:** CCPx Software Shutdown/Gate Control bit
1 = Manually forces auto-shutdown, timer clock gate or input capture signal gate event (setting of ASDGM bit still applies)
0 = Normal module operation

bit 11-8 **Unimplemented:** Read as '0'

bit 7-0 **ASDG[7:0]:** CCPx Auto-Shutdown/Gating Source Enable bits
1 = ASDGx Source n is enabled (see Table 22-6 for auto-shutdown/gating sources)
0 = ASDGx Source n is disabled

**TABLE 22-6: AUTO-SHUTDOWN AND GATING SOURCES**

| ASDG[x] Bit | Auto-Shutdown/Gating Source | | | |
|---|---|---|---|---|
| | SCCP1 | SCCP2 | SCCP3 | SCCP4 |
| 0 | Comparator 1 Output | | | |
| 2 | OCFC | | | |
| 3 | OCFD | | | |
| 4 | ICM1(1) | ICM2(1) | ICM3(1) | ICM4(1) |
| 5 | CLC1(1) | | | |
| 6 | OCFA(1) | | | |
| 7 | OCFB(1) | | | |

**Note 1:** Selected by Peripheral Pin Select (PPS).

**REGISTER 22-4: CCPxCON2H: CCPx CONTROL 2 HIGH REGISTERS**

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

| R/W-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| ICGSM1 | ICGSM0 | — | AUXOUT1 | AUXOUT0 | ICS2 | ICS1 | ICS0 |
| 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 **OENSYNC:** Output Enable Synchronization bit
1 = Update by output enable bits occurs on the next Time Base Reset or rollover
0 = Update by output enable bits occurs immediately

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

bit 7-6 **ICGSM[1:0]:** Input Capture Gating Source Mode Control bits
11 = Reserved
10 = One-Shot mode: Falling edge from gating source disables future capture events (ICDIS = 1)
01 = One-Shot mode: Rising edge from gating source enables future capture events (ICDIS = 0)
00 = Level-Sensitive mode: A high level from gating source will enable future capture events; a low level will disable future capture events

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

bit 4-3 **AUXOUT[1:0]:** Auxiliary Output Signal on Event Selection bits
11 = Input capture or output compare event; no signal in Timer mode
10 = Signal output is defined by the module Operating mode (see Table 22-4)
01 = Time base rollover event (all modes)
00 = Disabled

bit 2-0 **ICS[2:0]:** Input Capture Source Select bits
111 = CLC4 output
110 = CLC3 output
101 = CLC2 output
100 = CLC1 output
011 = Reserved
010 = Reserved
001 = Comparator 1 output
000 = Input Capture ICMx pin (PPS)


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**REGISTER 22-5: CCPxCON3H: CCPx CONTROL 3 HIGH REGISTERS**

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| OETRIG | OSCNT2 | OSCNT1 | OSCNT0 | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | R/W-0 | U-0 | R/W-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | POLACE | — | PSSACE1 | PSSACE0 | — | — |
| 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 **OETRIG:** CCPx Dead-Time Select bit
1 = For Triggered mode (TRIGEN = 1): Module does not drive enabled output pins until triggered
0 = Normal output pin operation

bit 14-12 **OSCNT[2:0]:** One-Shot Event Count bits
111 = Extends one-shot event by seven time base periods (eight time base periods total)
110 = Extends one-shot event by six time base periods (seven time base periods total)
101 = Extends one-shot event by five time base periods (six time base periods total)
100 = Extends one-shot event by four time base periods (five time base periods total)
011 = Extends one-shot event by three time base periods (four time base periods total)
010 = Extends one-shot event by two time base periods (three time base periods total)
001 = Extends one-shot event by one time base period (two time base periods total)
000 = Does not extend one-shot Trigger event

bit 11-6 **Unimplemented:** Read as '0'

bit 5 **POLACE:** CCPx Output Pins, OCMxA, OCMxC and OCMxE, Polarity Control bit
1 = Output pin polarity is active-low
0 = Output pin polarity is active-high

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

bit 3-2 **PSSACE[1:0]:** PWMx Output Pins, OCMxA, OCMxC and OCMxE, Shutdown State Control bits
11 = Pins are driven active when a shutdown event occurs
10 = Pins are driven inactive when a shutdown event occurs
0x = Pins are tri-stated when a shutdown event occurs

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

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**REGISTER 22-6: CCPxSTATL: CCPx STATUS REGISTER LOW**

| U-0 | U-0 | U-0 | U-0 | U-0 | W1-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | ICGARM | — | — |
| bit 15 | | | | | | | bit 8 |

| R-0 | W1-0 | W1-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| CCPTRIG | TRSET | TRCLR | ASEVT | SCEVT | ICDIS | ICOV | ICBNE |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | C = Clearable bit | | |
|---|---|---|---|
| R = Readable bit | W1 = Write '1' Only 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 **ICGARM:** Input Capture Gate Arm bit
A write of '1' to this location will arm the input capture gating logic for a one-shot gate event when ICGSM[1:0] = 01 or 10. Bit always reads as '0'.

bit 9-8 **Unimplemented:** Read as '0'

bit 7 **CCPTRIG:** CCPx Trigger Status bit
1 = Timer has been triggered and is running
0 = Timer has not been triggered and is held in Reset

bit 6 **TRSET:** CCPx Trigger Set Request bit
Writes '1' to this location to trigger the timer when TRIGEN = 1 (location always reads as '0').

bit 5 **TRCLR:** CCPx Trigger Clear Request bit
Writes '1' to this location to cancel the timer trigger when TRIGEN = 1 (location always reads as '0').

bit 4 **ASEVT:** CCPx Auto-Shutdown Event Status/Control bit
1 = A shutdown event is in progress; CCPx outputs are in the Shutdown state
0 = CCPx outputs operate normally

bit 3 **SCEVT:** Single-Edge Compare Event Status bit
1 = A single-edge compare event has occurred
0 = A single-edge compare event has not occurred

bit 2 **ICDIS:** Input Capture x Disable bit
1 = Event on Input Capture x pin (ICx) does not generate a capture event
0 = Event on Input Capture x pin will generate a capture event

bit 1 **ICOV:** Input Capture x Buffer Overflow Status bit
1 = The Input Capture x FIFO buffer has overflowed
0 = The Input Capture x FIFO buffer has not overflowed

bit 0 **ICBNE:** Input Capture x Buffer Status bit
1 = Input Capture x buffer has data available
0 = Input Capture x buffer is empty


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**REGISTER 22-7: CCPxSTATH: CCPx 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 | U-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 | R/C-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | PRLWIP | TMRHWIP | TMRLWIP | RBWIP | RAWIP |
| 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 15-5 **Unimplemented:** Read as '0'

bit 4 **PRLWIP:** CCPxPRL Write In Progress Status bit
1 = An update to the CCPxPRL register with the buffered contents is in progress
0 = An update to the CCPxPRL register is not in progress

bit 3 **TMRHWIP:** CCPxTMRH Write In Progress Status bit
1 = An update to the CCPxTMRH register with the buffered contents is in progress
0 = An update to the CCPxTMRH register is not in progress

bit 2 **TMRLWIP:** CCPxTMRL Write In Progress Status bit
1 = An update to the CCPxTMRL register with the buffered contents is in progress
0 = An update to the CCPxTMRL register is not in progress

bit 1 **RBWIP:** CCPxRB Write In Progress Status bit
1 = An update to the CCPxRB register with the buffered contents is in progress
0 = An update to the CCPxRB register is not in progress

bit 0 **RAWIP:** CCPxRA Write In Progress Status bit
1 = An update to the CCPxRA register with the buffered contents is in progress
0 = An update to the CCPxRA register is not in progress

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## 23.0 CONFIGURABLE LOGIC CELL (CLC)

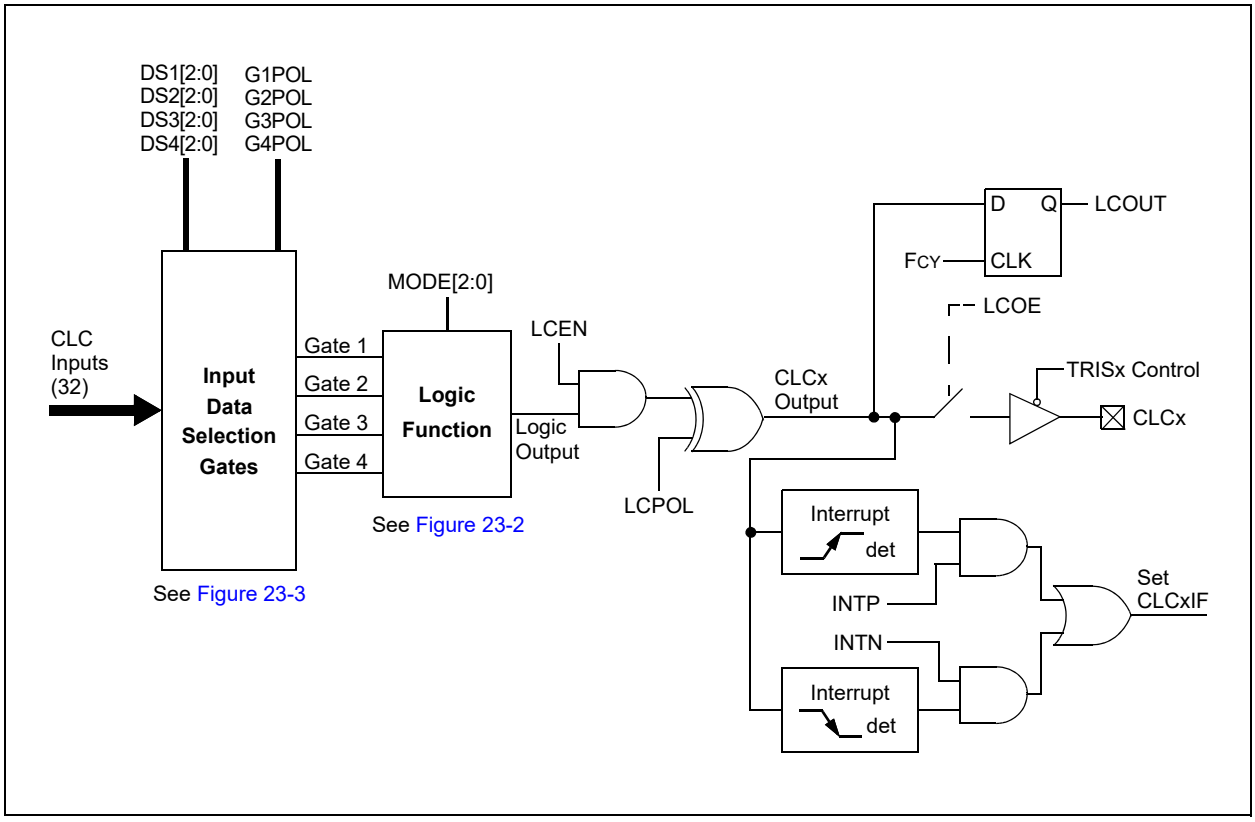
**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. For more information, refer to **"Configurable Logic Cell (CLC)"** (www.microchip.com/DS70005298). The information in this data sheet supersedes the information in the FRM.

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 23-1 shows an overview of the module.

Figure 23-3 shows the details of the data source multiplexers and Figure 23-2 shows the logic input gate connections.

**FIGURE 23-1: CLCx MODULE**

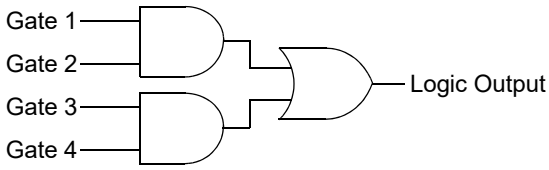




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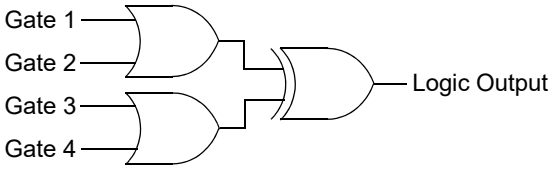
**FIGURE 23-2: CLCx LOGIC FUNCTION COMBINATORIAL OPTIONS**

**AND – OR**



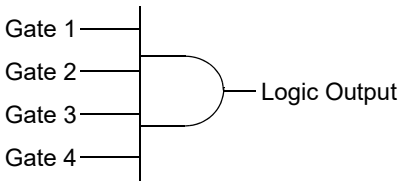

MODE[2:0] = 000

**OR – XOR**



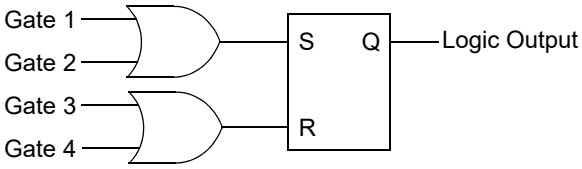

MODE[2:0] = 001

**4-Input AND**



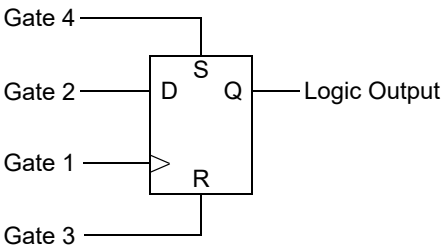

MODE[2:0] = 010

**S-R Latch**



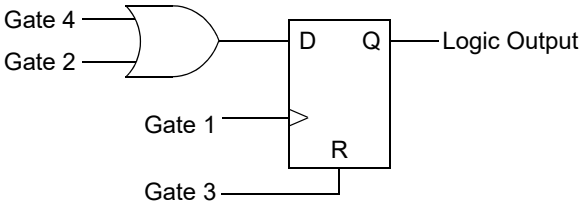

MODE[2:0] = 011

**1-Input D Flip-Flop with S and R**



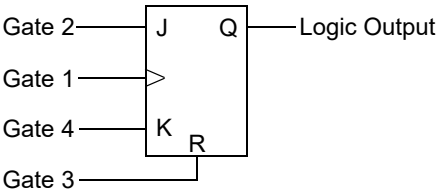

MODE[2:0] = 100

**2-Input D Flip-Flop with R**



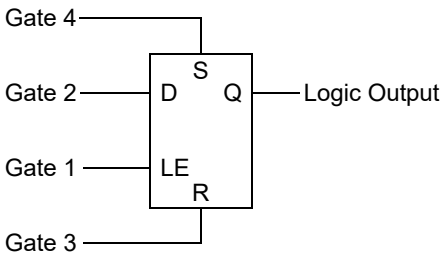

MODE[2:0] = 101

**J-K Flip-Flop with R**



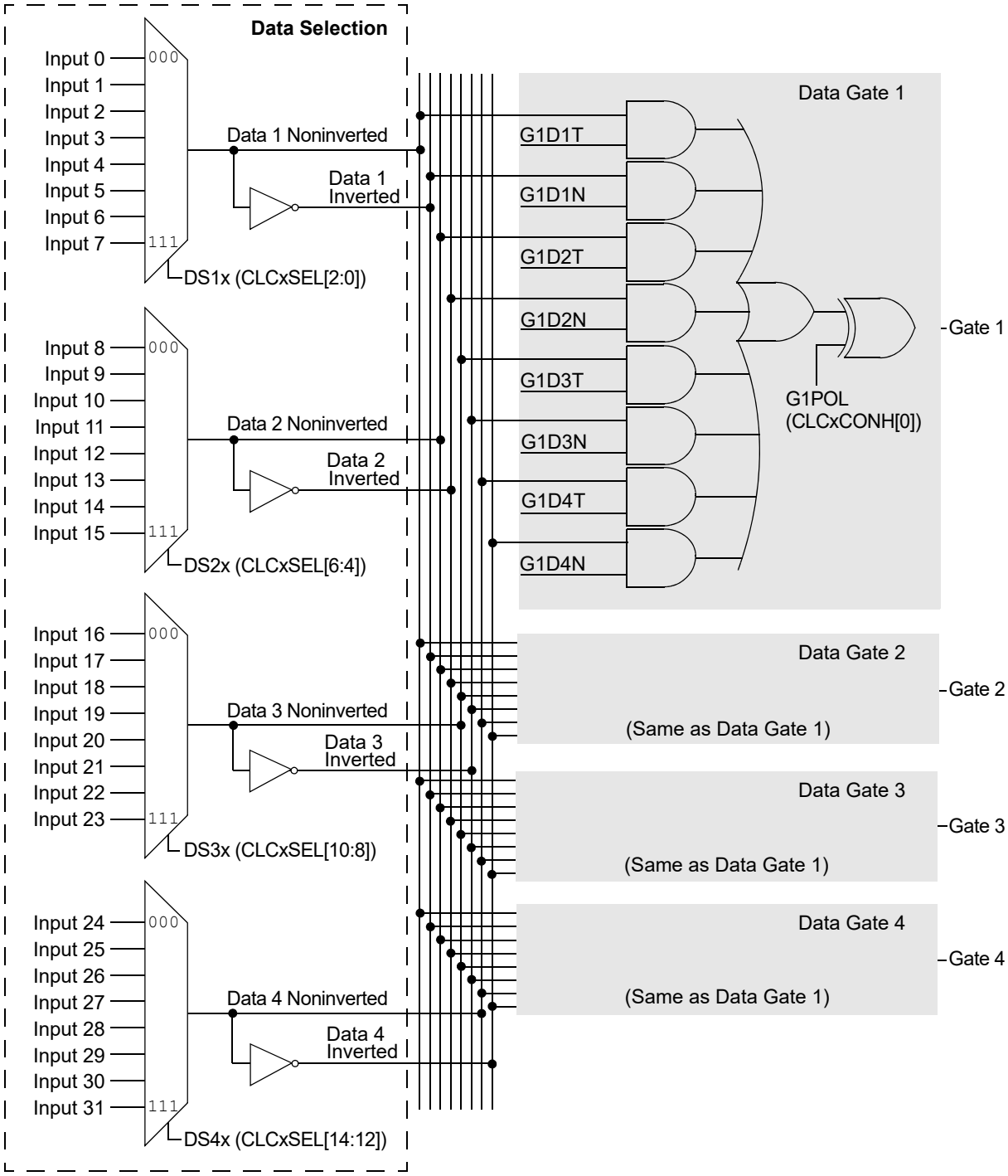

MODE[2:0] = 110

**1-Input Transparent Latch with S and R**




MODE[2:0] = 111

**FIGURE 23-3: CLCx INPUT SOURCE SELECTION DIAGRAM**




**Note:** All controls are undefined at power-up.


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## 23.1 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 four data input sources using the four data input selection multiplexers. Each multiplexer has a list of eight 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 eight signals are enabled, ORed together by the logic cell input gates. If no inputs are selected (CLCxGLS = 0x00), the output will be zero or one, depending on the GxPOL bits.

**REGISTER 23-1: 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 23-1: 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 23-2: 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


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**REGISTER 23-3: 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
- 111 = SCCP3 auxiliary out
- 110 = SCCP1 auxiliary out
- 101 = CLCIND pin
- 100 = Reserved
- 011 = SPI1 Input (SDIx)(1)
- 010 = Reserved
- 001 = CLC2 output
- 000 = PWM Event A

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

bit 10-8 **DS3[2:0]:** Data Selection MUX 3 Signal Selection bits
- 111 = SCCP4 output compare
- 110 = SCCP3 output compare
- 101 = CLC4 out
- 100 = UART1 RX
- 011 = SPI1 Output (SDOx)(1)
- 010 = Reserved
- 001 = CLC1 output
- 000 = CLCINC I/O pin

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

bit 6-4 **DS2[2:0]:** Data Selection MUX 2 Signal Selection bits
- 111 = SCCP2 output compare
- 110 = SCCP1 output compare
- 101 = Reserved
- 100 = Reserved
- 011 = UART1 TX input corresponding to CLCx module
- 010 = Comparator 1 output
- 001 = Reserved
- 000 = CLCINB I/O pin

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

**Note 1:** Valid only when SPI is used on PPS.

**REGISTER 23-3: CLCxSEL: CLCx INPUT MUX SELECT REGISTER (CONTINUED)**

bit 2-0 **DS1[2:0]:** Data Selection MUX 1 Signal Selection bits
111 = SCCP4 auxiliary out
110 = SCCP2 auxiliary out
101 = Reserved
100 = REFCLKO output
011 = INTRC/LPRC clock source
010 = CLC3 out
001 = System clock (FCY)
000 = CLCINA I/O pin

**Note 1:** Valid only when SPI is used on PPS.


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**REGISTER 23-4: 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 signal is enabled for Gate 2
0 = Data Source 4 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 signal is enabled for Gate 2
0 = Data Source 3 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 signal is enabled for Gate 2
0 = Data Source 2 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 signal is enabled for Gate 2
0 = Data Source 1 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 signal is enabled for Gate 1
0 = Data Source 4 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 signal is enabled for Gate 1
0 = Data Source 3 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

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**REGISTER 23-4: CLCxGLSL: CLCx GATE LOGIC INPUT SELECT LOW REGISTER (CONTINUED)**

bit 3 **G1D2T:** Gate 1 Data Source 2 True Enable bit
1 = Data Source 2 signal is enabled for Gate 1
0 = Data Source 2 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 signal is enabled for Gate 1
0 = Data Source 1 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 23-5: 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 signal is enabled for Gate 4
0 = Data Source 4 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 signal is enabled for Gate 4
0 = Data Source 3 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 signal is enabled for Gate 4
0 = Data Source 2 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 signal is enabled for Gate 4
0 = Data Source 1 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 signal is enabled for Gate 3
0 = Data Source 4 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 signal is enabled for Gate 3
0 = Data Source 3 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

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**REGISTER 23-5: CLCxGLSH: CLCx GATE LOGIC INPUT SELECT HIGH REGISTER (CONTINUED)**

bit 3 **G3D2T:** Gate 3 Data Source 2 True Enable bit
1 = Data Source 2 signal is enabled for Gate 3
0 = Data Source 2 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 signal is enabled for Gate 3
0 = Data Source 1 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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**NOTES:**

## 24.0 PERIPHERAL TRIGGER GENERATOR (PTG)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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)"** (www.microchip.com/DS70000669).

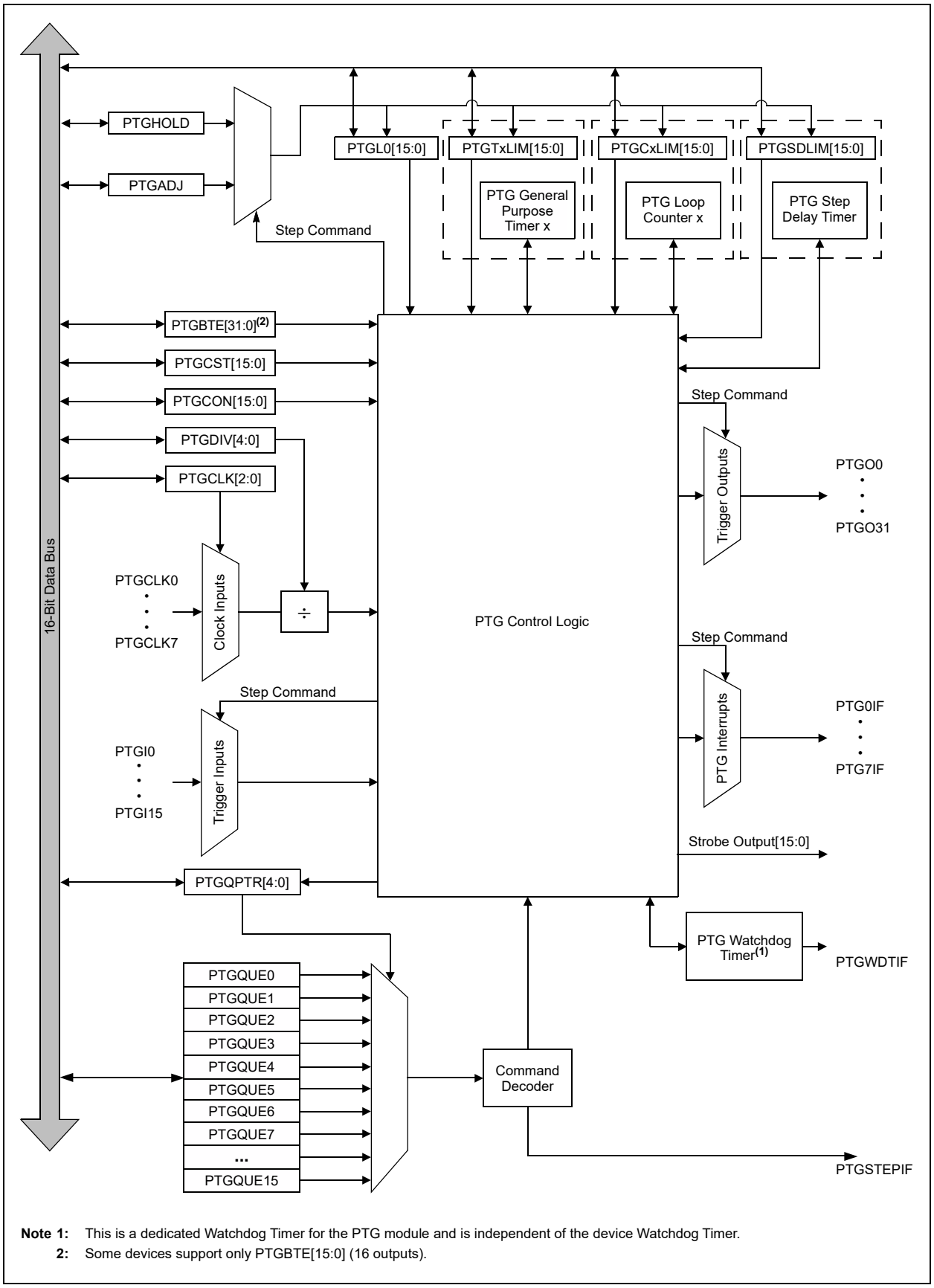
The dsPIC33CDVL64MC106 Peripheral Trigger Generator (PTG) module is a user-programmable sequencer that is capable of generating complex trigger signal sequences to coordinate the operation of other peripherals. The PTG module is designed to interface with the modules, such as an Analog-to-Digital Converter (ADC), output compare and PWM modules, timers and interrupt controllers.

### 24.1 Features

- Behavior is Step Command Driven
  - Step commands are eight bits wide.
- Commands are Stored in a Step Queue
  - Queue depth is up to 32 entries.
  - Programmable Step execution time (Step delay)
- Supports the Command Sequence Loop
  - Can be nested one-level deep.
  - Conditional or unconditional loop
  - Two 16-bit loop counters
- 15 Hardware Input Triggers
  - Sensitive to either positive or negative edges, or a high or low level
- One Software Input Trigger
- Generates up to 32 Unique Output Trigger Signals
- Generates Two Types of Trigger Outputs
  - Individual
  - Broadcast
- Generates up to Ten Unique Interrupt Signals
- Two 16-Bit General Purpose Timers
- Flexible Self-Contained Watchdog Timer (WDT) to Set an Upper Limit to Trigger Wait Time
- Single-Step Command Capability in Debug Mode
- Selectable Clock (System, Pulse-Width Modulator (PWM) or ADC)
- Programmable Clock Divider


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**FIGURE 24-1: PTG BLOCK DIAGRAM**




**Note 1:** This is a dedicated Watchdog Timer for the PTG module and is independent of the device Watchdog Timer.

**2:** Some devices support only PTGBTE[15:0] (16 outputs).

## 24.2 PTG Control/Status Registers

**REGISTER 24-1: PTGCST: PTG CONTROL/STATUS LOW REGISTER**

| R/W-0 | U-0 | R/W-0 | R/W-0 | U-0 | HC/R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGEN | — | PTGSIDL | PTGTOGL | — | PTGSWT(2) | PTGSSEN(3) | PTGIVIS |
| bit 15 | | | | | | | bit 8 |

| HC/R/W-0 | HS/R/W-0 | HS/HC/R/W-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| PTGSTRT | PTGWDTO | PTGBUSY | — | — | — | PTGITM1(1) | PTGITM0(1) |
| 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 **PTGEN:** PTG Enable bit
1 = PTG is enabled
0 = PTG is disabled

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

bit 13 **PTGSIDL:** PTG Freeze in Debug Mode bit
1 = Halts PTG operation when device is Idle
0 = PTG operation continues when device is Idle

bit 12 **PTGTOGL:** PTG Toggle Trigger Output bit
1 = Toggles state of TRIG output for each execution of PTGTRIG
0 = Generates a single TRIG pulse for each execution of PTGTRIG

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

bit 10 **PTGSWT:** PTG Software Trigger bit
1 = If the PTG state machine is executing the "Wait for software trigger" Step command (OPTION[3:0] = 1010 or 1011), the command will complete and execution will continue
0 = No action other than to clear the bit

bit 9 **PTGSSEN:** PTG Single-Step Command bit
1 = Enables single step when in Debug mode
0 = Disables single step

bit 8 **PTGIVIS:** PTG Counter/Timer Visibility bit
1 = Reading the PTGSDLIM, PTGCxLIM or PTGTxLIM registers returns the current values of their corresponding Counter/Timer registers (PTGSDLIM, PTGCxLIM and PTGTxLIM)
0 = Reading the PTGSDLIM, PTGCxLIM or PTGTxLIM registers returns the value of these Limit registers

bit 7 **PTGSTRT:** PTG Start Sequencer bit
1 = Starts to sequentially execute the commands (Continuous mode)
0 = Stops executing the 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

**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.
**3:** The PTGSSEN bit may only be written when in Debug mode.


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**REGISTER 24-1: PTGCST: PTG CONTROL/STATUS LOW REGISTER (CONTINUED)**

bit 5 **PTGBUSY:** PTG State Machine Busy bit
1 = PTG is running on the selected clock source; no SFR writes are allowed to PTGCLK[2:0] or PTGDIV[4:0]
0 = PTG state machine is not running

bit 4-2 **Unimplemented:** Read as '0'

bit 1-0 **PTGITM[1:0]:** PTG Input Trigger Operation Selection bits
11 = Single-level detect with Step delay not executed on exit of command (regardless of the PTGCTRL command) (Mode 3)
10 = Single-level detect with Step delay executed on exit of command (Mode 2)
01 = Continuous edge detect with Step delay not executed on exit of command (regardless of the PTGCTRL command) (Mode 1)
00 = Continuous edge detect with Step delay executed on exit of command (Mode 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.
**3:** The PTGSSEN bit may only be written when in Debug mode.

**REGISTER 24-2: PTGCON: PTG CONTROL/STATUS 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 |
|---|---|---|---|---|---|---|---|
| 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]:** PTG Module Clock Source Selection bits
111 = CLC1
110 = PLL VCO DIV 4 output
101 = Reserved
100 = Reserved
011 = Input from Timer1 Clock pin, T1CK
010 = PTG module clock source will be ADC clock
001 = PTG module clock source will be FOSC
000 = PTG module clock source will be FOSC/2 (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 (in PTG clock cycles) 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]:** PTG Watchdog Timer Time-out Selection 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


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**REGISTER 24-3: PTGBTE: PTG BROADCAST TRIGGER ENABLE LOW 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 |
|---|---|---|---|---|---|---|---|
| PTGBTE[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 |
|---|---|---|---|---|---|---|---|
| PTGBTE[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 **PTGBTE[15:0]:** PTG Broadcast Trigger Enable bits
1 = Generates trigger when the broadcast command is executed
0 = Does not generate trigger when the broadcast command is executed

**Note 1:** These bits are read-only when the module is executing Step commands.

**REGISTER 24-4: PTGBTEH: PTG BROADCAST TRIGGER ENABLE HIGH 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 |
|---|---|---|---|---|---|---|---|
| PTGBTE[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| PTGBTE[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 15-0 **PTGBTE[31:16]:** PTG Broadcast Trigger Enable bits
1 = Generates trigger when the broadcast command is executed
0 = Does not generate trigger when the broadcast command is executed

**Note 1:** These bits are read-only when the module is executing Step commands.

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**REGISTER 24-5: 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
This register holds the user-supplied data to be copied to the PTGTxLIM, PTGCxLIM, PTGSDLIM or PTGL0 register using the `PTGCOPY` command.

**Note 1:** These bits are read-only when the module is executing Step commands.

**REGISTER 24-6: 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.

**Note 1:** These bits are read-only when the module is executing Step commands.


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**REGISTER 24-7: 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.

**Note 1:** These bits are read-only when the module is executing Step commands.

**REGISTER 24-8: PTGSDLIM: PTG STEP DELAY 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 |
|---|---|---|---|---|---|---|---|
| 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
This register 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:** These bits are read-only when the module is executing Step commands.

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**REGISTER 24-9: 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

This register is used to specify the loop count for the `PTGJMPC0` Step command or as a Limit register for the General Purpose Counter 0.

**Note 1:** These bits are read-only when the module is executing Step commands.

**REGISTER 24-10: 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

This register is used to specify the loop count for the `PTGJMPC1` Step command or as a Limit register for the General Purpose Counter 1.

**Note 1:** These bits are read-only when the module is executing Step commands.


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**REGISTER 24-11: 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 the user-supplied data to be added to the PTGTxLIM, PTGCxLIM, PTGSDLIM or PTGL0 register using the `PTGADD` command.

**Note 1:** These bits are read-only when the module is executing Step commands.

**REGISTER 24-12: 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

**Note 1:** These bits are read-only when the module is executing Step commands.

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**REGISTER 24-13: 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:** These bits are read-only when the module is executing Step commands.

**REGISTER 24-14: PTGQUEn: PTG STEP QUEUE n POINTER REGISTER (n = 0-15)(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 |
|---|---|---|---|---|---|---|---|
| STEP2n+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 |
|---|---|---|---|---|---|---|---|
| STEP2n[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 **STEP2n+1[7:0]:** PTG Command 4n+1 bits
A queue location for storage of the STEP2n+1 command byte, where 'n' is from PTGQUEn.

bit 7-0 **STEP2n[7:0]:** PTG Command 4n+2 bits
A queue location for storage of the STEP2n command byte, where 'n' are the odd numbered Step Queue Pointers.

**Note 1:** These bits are read-only when the module is executing Step commands.
**2:** Refer to Table 24-1 for the Step command encoding.


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**TABLE 24-1: PTG STEP COMMAND FORMAT AND DESCRIPTION**

| Step Command Byte | | | | | | | |
|---|---|---|---|---|---|---|---|
| STEPx[7:0] | | | | | | | |
| CMD[3:0] | | | | OPTION[3:0] | | | |
| bit 7 | | | bit 4 | bit 3 | | | bit 0 |

| bit 7-4 | Step Command | CMD[3:0] | Command Description |
|---|---|---|---|
| | PTGCTRL | 0000 | Execute the control command as described by the OPTION[3:0] bits. |
| | PTGADD | 0001 | Add contents of the PTGADJ register to the target register as described by the OPTION[3:0] bits. |
| | PTGCOPY | | Copy contents of the PTGHOLD register to the target register as described by the OPTION[3:0] bits. |
| | PTGSTRB | 001x | This command starts an ADC conversion of the channels specified in CMD[0] and OPTION[3:0] bits. |
| | PTGWHI | 0100 | Wait for a low-to-high edge input from a selected PTG trigger input as described by the OPTION[3:0] bits. |
| | PTGWLO | 0101 | Wait for a high-to-low edge input from a selected PTG trigger input as described by the OPTION[3:0] bits. |
| | — | 0110 | Reserved; do not use.(1) |
| | PTGIRQ | 0111 | Generate individual interrupt request as described by the OPTION[3:0] bits. |
| | PTGTRIG | 100x | Generate individual trigger output as described by the bits, CMD[0]:OPTION[3:0]. |
| | PTGJMP | 101x | Copy the values contained in the bits, CMD[0]:OPTION[3:0], to the PTGQPTR register and jump to that Step queue. |
| | PTGJMPC0 | 110x | PTGC0 = PTGC0LIM: Increment the PTGQPTR register. |
| | | | PTGC0 ≠ PTGC0LIM: Increment Counter 0 (PTGC0) and copy the values contained in the bits, CMD[0]:OPTION[3:0], to the PTGQPTR register, and jump to that Step queue. |
| | PTGJMPC1 | 111x | PTGC1 = PTGC1LIM: Increment the PTGQPTR register. |
| | | | PTGC1 ≠ PTGC1LIM: Increment Counter 1 (PTGC1) and copy the values contained in the bits, CMD[0]:OPTION[3:0], to the PTGQPTR register, and jump to that Step queue. |

**Note 1:** All reserved commands or options will execute, but they do not have any affect (i.e., execute as a NOP instruction).

**TABLE 24-2: PTG COMMAND OPTIONS**

| bit 3-0 | Step Command | OPTION[3:0] | Command Description |
|---|---|---|---|
| | PTGCTRL[1] | 0000 | NOP. |
| | | 0001 | Reserved; do not use. |
| | | 0010 | Disable Step delay timer (PTGSD). |
| | | 0011 | Reserved; do not use. |
| | | 0100 | Reserved; do not use. |
| | | 0101 | Reserved; do not use. |
| | | 0110 | Enable Step delay timer (PTGSD). |
| | | 0111 | Reserved; do not use. |
| | | 1000 | Start and wait for the PTG Timer0 to match the PTGT0LIM register. |
| | | 1001 | Start and wait for the PTG Timer1 to match the PTGT1LIM register. |
| | | 1010 | Wait for the software trigger (level, PTGSWT = 1). |
| | | 1011 | Wait for the software trigger (positive edge, PTGSWT = 0 to 1). |
| | | 1100 | Copy the PTGC0LIM register contents to the strobe output. |
| | | 1101 | Copy the PTGC1LIM register contents to the strobe output. |
| | | 1110 | Reserved; do not use. |
| | | 1111 | Generate the triggers indicated in the PTGBTE register. |
| | PTGADD[1] | 0000 | Add the PTGADJ register contents to the PTGC0LIM register. |
| | | 0001 | Add the PTGADJ register contents to the PTGC1LIM register. |
| | | 0010 | Add the PTGADJ register contents to the PTGT0LIM register. |
| | | 0011 | Add the PTGADJ register contents to the PTGT1LIM register. |
| | | 0100 | Add the PTGADJ register contents to the PTGSDLIM register. |
| | | 0101 | Add the PTGADJ register contents to the PTGL0 register. |
| | | 0110 | Reserved; do not use. |
| | | 0111 | Reserved; do not use. |
| | PTGCOPY[1] | 1000 | Copy the PTGHOLD register contents to the PTGC0LIM register. |
| | | 1001 | Copy the PTGHOLD register contents to the PTGC1LIM register. |
| | | 1010 | Copy the PTGHOLD register contents to the PTGT0LIM register. |
| | | 1011 | Copy the PTGHOLD register contents to the PTGT1LIM register. |
| | | 1100 | Copy the PTGHOLD register contents to the PTGSDLIM register. |
| | | 1101 | Copy the PTGHOLD register contents to the PTGL0 register. |
| | | 1110 | Reserved; do not use. |
| | | 1111 | Reserved; do not use. |

**Note 1:** All reserved commands or options will execute, but they do not have any affect (i.e., execute as a NOP instruction).


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**TABLE 24-2: PTG COMMAND OPTIONS (CONTINUED)**

| bit 3-0 | Step Command | OPTION[3:0] | Option Description |
|---|---|---|---|
| | PTGWHI[(1)] or PTGWLO[(1)] | 0000 | PTGI0 (see Table 24-3 for input assignments). |
| | | • • • | • • • |
| | | 1111 | PTGI15 (see Table 24-3 for input assignments). |
| | PTGIRQ[(1)] | 0000 | Generate PTG Interrupt 0. |
| | | • • • | • • • |
| | | 0111 | Generate PTG Interrupt 7. |
| | | 1000 | Reserved; do not use. |
| | | • • • | • • • |
| | | 1111 | Reserved; do not use. |
| | PTGTRIG | 00000 | PTGO0 (see Table 24-4 for output assignments). |
| | | 00001 | PTGO1 (see Table 24-4 for output assignments). |
| | | • • • | • • • |
| | | 11110 | PTGO30 (see Table 24-4 for output assignments). |
| | | 11111 | PTGO31 (see Table 24-4 for output assignments). |
| | PTGWHI[(1)] or PTGWLO[(1)] | 0000 | PTGI0 (see Table 24-3 for input assignments). |
| | | • • • | • • • |
| | | 1111 | PTGI15 (see Table 24-3 for input assignments). |
| | PTGIRQ[(1)] | 0000 | Generate PTG Interrupt 0. |
| | | • • • | • • • |
| | | 0111 | Generate PTG Interrupt 7. |
| | | 1000 | Reserved; do not use. |
| | | • • • | • • • |
| | | 1111 | Reserved; do not use. |
| | PTGTRIG | 00000 | PTGO0 (see Table 24-4 for output assignments). |
| | | 00001 | PTGO1 (see Table 24-4 for output assignments). |

**Note 1:** All reserved commands or options will execute, but they do not have any affect (i.e., execute as a NOP instruction).

**TABLE 24-3: PTG INPUT DESCRIPTIONS**

| PTG Input Number | PTG Input Description |
|---|---|
| PTG Trigger Input 0 | Trigger Input from PWM1 ADC Trigger 2 |
| PTG Trigger Input 1 | Trigger Input from PWM2 ADC Trigger 2 |
| PTG Trigger Input 2 | Trigger Input from PWM3 ADC Trigger 2 |
| PTG Trigger Input 3 | Trigger Input from PWM4 ADC Trigger 2 |
| PTG Trigger Input 4 | Reserved |
| PTG Trigger Input 5 | Reserved |
| PTG Trigger Input 6 | Reserved |
| PTG Trigger Input 7 | Trigger Input from SCCP4 Input Capture/Output Compare |
| PTG Trigger Input 8 | Reserved |
| PTG Trigger Input 9 | Trigger Input from Comparator 1 |
| PTG Trigger Input 10 | Reserved |
| PTG Trigger Input 11 | Reserved |
| PTG Trigger Input 12 | Trigger Input from CLC1 |
| PTG Trigger Input 13 | Trigger Input from ADC Common Interrupt |
| PTG Trigger Input 14 | Reserved |
| PTG Trigger Input 15 | Trigger Input from INT2 PPS |

**TABLE 24-4: PTG OUTPUT DESCRIPTIONS**

| PTG Output Number | PTG Output Description |
|---|---|
| PTGO0 to PTGO11 | Reserved |
| PTGO12 | ADC TRGSRC[30] |
| PTGO13 to PTGO23 | Reserved |
| PTGO24 | PPS Output RP46 |
| PTGO25 | PPS Output RP47 |
| PTGO26 | PPS Input RP6 |
| PTGO27 | PPS Input to P7 |
| PTGO28 | PPS Input to PTGO31 |
| PTGO29 to PTGO31 | Reserved |


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**NOTES:**

## 25.0 CURRENT BIAS GENERATOR (CBG)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Current Bias Generator (CBG)"** (www.microchip.com/DS70005253).

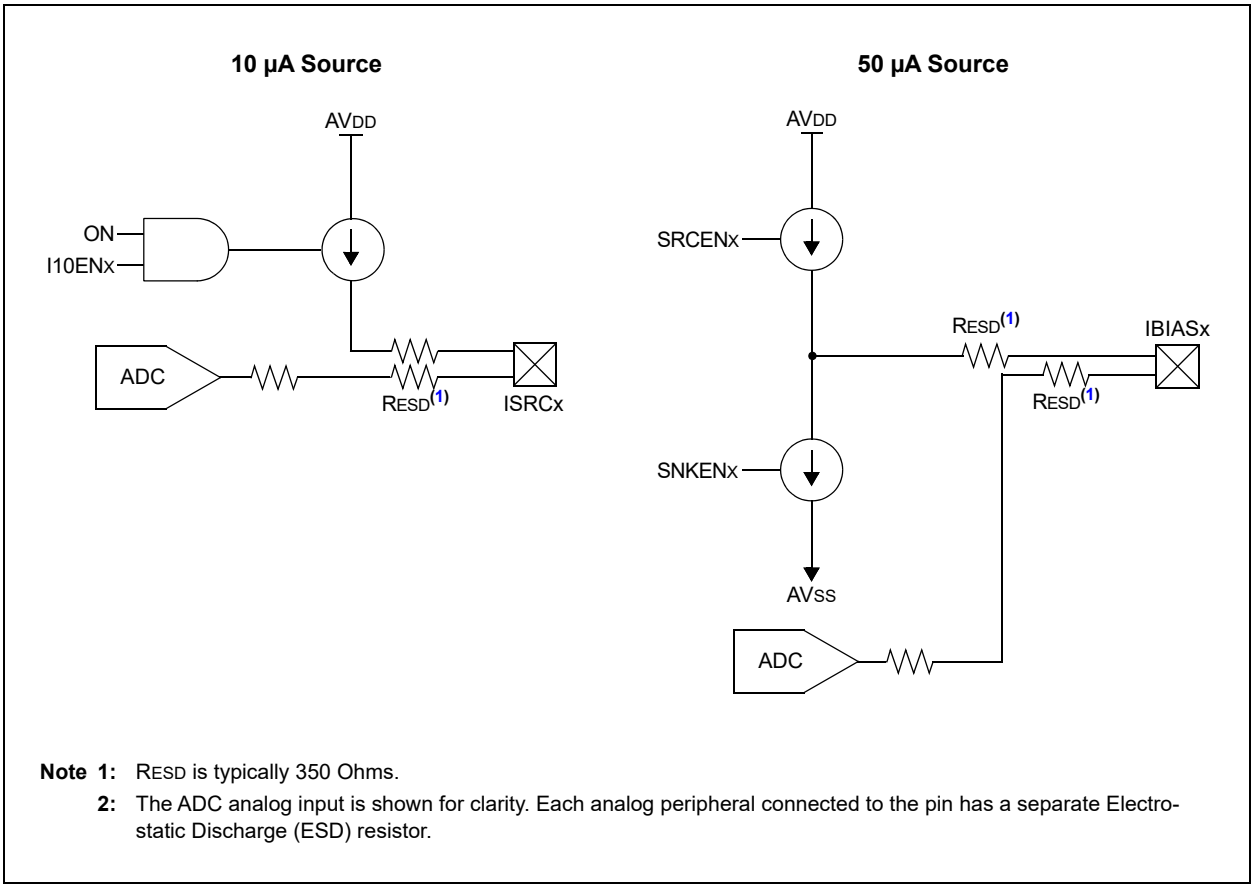
**2:** Some registers and associated bits described in this section may not be available on all devices. Refer to **Section 4.0 "Memory Organization"** for device-specific register and bit information.

The Current Bias Generator (CBG) consists of two classes of current sources: 10 µA and 50 µA. The major features of each current source are:

- 10 µA Current Sources
  - Current sourcing only
  - Up to four independent sources
- 50 µA Current Sources
  - Selectable current sourcing or sinking
  - Selectable current mirroring for sourcing and sinking

A simplified block diagram of the CBG module is shown in Figure 25-1.

**FIGURE 25-1: CONSTANT-CURRENT SOURCE MODULE BLOCK DIAGRAM(2)**




**Note 1:** RESD is typically 350 Ohms.

**2:** The ADC analog input is shown for clarity. Each analog peripheral connected to the pin has a separate Electrostatic Discharge (ESD) resistor.


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## 25.1 Current Bias Generator Control Registers

**REGISTER 25-1: BIASCON: CURRENT BIAS GENERATOR CONTROL REGISTER**

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

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | I10EN3 | I10EN2(1) | I10EN1(2) | I10EN0 |
| 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 **ON:** Current Bias Module Enable bit
1 = Module is enabled
0 = Module is disabled

bit 14-4 **Unimplemented:** Read as '0'

bit 3 **I10EN3:** 10 µA Enable for Output 3 bit
1 = 10 µA output is enabled
0 = 10 µA output is disabled

bit 2 **I10EN2:** 10 µA Enable for Output 2 bit(1)
1 = 10 µA output is enabled
0 = 10 µA output is disabled

bit 1 **I10EN1:** 10 µA Enable for Output 1 bit(2)
1 = 10 µA output is enabled
0 = 10 µA output is disabled

bit 0 **I10EN0:** 10 µA Enable for Output 0 bit
1 = 10 µA output is enabled
0 = 10 µA output is disabled

**Note 1:** This bit is only available for the 36 and 48-pin package devices.
**2:** This bit is only available for the 48-pin package devices.

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**REGISTER 25-2: IBIASCONH: CURRENT BIAS GENERATOR 50 µA CURRENT SOURCE CONTROL HIGH REGISTER**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | SHRSRCEN3(1) | SHRSNKEN3(1) | GENSRCEN3(1) | GENSNKEN3(1) | SRCEN3(1) | SNKEN3(1) |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | SHRSRCEN2(1) | SHRSNKEN2(1) | GENSRCEN2(1) | GENSNKEN2(1) | SRCEN2(1) | SNKEN2(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 15-14 **Unimplemented:** Read as '0'

bit 13 **SHRSRCEN3:** Share Source Enable for Output #3 bit
1 = Sourcing Current Mirror mode is enabled (uses reference from another source)
0 = Sourcing Current Mirror mode is disabled

bit 12 **SHRSNKEN3:** Share Sink Enable for Output #3 bit
1 = Sinking Current Mirror mode is enabled (uses reference from another source)
0 = Sinking Current Mirror mode is disabled

bit 11 **GENSRCEN3:** Generated Source Enable for Output #3 bit
1 = Source generates the current source mirror reference
0 = Source does not generate the current source mirror reference

bit 10 **GENSNKEN3:** Generated Sink Enable for Output #3 bit
1 = Source generates the current sink mirror reference
0 = Source does not generate the current sink mirror reference

bit 9 **SRCEN3:** Source Enable for Output #3 bit
1 = Current source is enabled
0 = Current source is disabled

bit 8 **SNKEN3:** Sink Enable for Output #3 bit
1 = Current sink is enabled
0 = Current sink is disabled

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

bit 5 **SHRSRCEN2:** Share Source Enable for Output #2 bit
1 = Sourcing Current Mirror mode is enabled (uses reference from another source)
0 = Sourcing Current Mirror mode is disabled

bit 4 **SHRSNKEN2:** Share Sink Enable for Output #2 bit
1 = Sinking Current Mirror mode is enabled (uses reference from another source)
0 = Sinking Current Mirror mode is disabled

bit 3 **GENSRCEN2:** Generated Source Enable for Output #2 bit
1 = Source generates the current source mirror reference
0 = Source does not generate the current source mirror reference

bit 2 **GENSNKEN2:** Generated Sink Enable for Output #2 bit
1 = Source generates the current sink mirror reference
0 = Source does not generate the current sink mirror reference

**Note 1:** This bit is only available in 48-pin package devices.


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**REGISTER 25-2: IBIASCONH: CURRENT BIAS GENERATOR 50 µA CURRENT SOURCE CONTROL HIGH REGISTER (CONTINUED)**

bit 1 **SRCEN2:** Source Enable for Output #2 bit
1 = Current source is enabled
0 = Current source is disabled

bit 0 **SNKEN2:** Sink Enable for Output #2 bit
1 = Current sink is enabled
0 = Current sink is disabled

**Note 1:** This bit is only available in 48-pin package devices.

**REGISTER 25-3: IBIASCONL: CURRENT BIAS GENERATOR 50 µA CURRENT SOURCE CONTROL LOW REGISTER**

| U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | SHRSRCEN1(1) | SHRSNKEN1(1) | GENSRCEN1(1) | GENSNKEN1(1) | SRCEN1(1) | SNKEN1(1) |
| 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 |
|---|---|---|---|---|---|---|---|
| — | — | SHRSRCEN0(1) | SHRSNKEN0(1) | GENSRCEN0(1) | GENSNKEN0(1) | SRCEN0(1) | SNKEN0(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 15-14 **Unimplemented:** Read as '0'

bit 13 **SHRSRCEN1:** Share Source Enable for Output #1 bit
1 = Sourcing Current Mirror mode is enabled (uses reference from another source)
0 = Sourcing Current Mirror mode is disabled

bit 12 **SHRSNKEN1:** Share Sink Enable for Output #1 bit
1 = Sinking Current Mirror mode is enabled (uses reference from another source)
0 = Sinking Current Mirror mode is disabled

bit 11 **GENSRCEN1:** Generated Source Enable for Output #1 bit
1 = Source generates the current source mirror reference
0 = Source does not generate the current source mirror reference

bit 10 **GENSNKEN1:** Generated Sink Enable for Output #1 bit
1 = Source generates the current sink mirror reference
0 = Source does not generate the current sink mirror reference

bit 9 **SRCEN1:** Source Enable for Output #1 bit
1 = Current source is enabled
0 = Current source is disabled

bit 8 **SNKEN1:** Sink Enable for Output #1 bit
1 = Current sink is enabled
0 = Current sink is disabled

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

bit 5 **SHRSRCEN0:** Share Source Enable for Output #0 bit
1 = Sourcing Current Mirror mode is enabled (uses reference from another source)
0 = Sourcing Current Mirror mode is disabled

bit 4 **SHRSNKEN0:** Share Sink Enable for Output #0 bit
1 = Sinking Current Mirror mode is enabled (uses reference from another source)
0 = Sinking Current Mirror mode is disabled

bit 3 **GENSRCEN0:** Generated Source Enable for Output #0 bit
1 = Source generates the current source mirror reference
0 = Source does not generate the current source mirror reference

bit 2 **GENSNKEN0:** Generated Sink Enable for Output #0 bit
1 = Source generates the current sink mirror reference
0 = Source does not generate the current sink mirror reference

**Note 1:** This bit is only available in 36 and 48-pin package devices.


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**REGISTER 25-3: IBIASCONL: CURRENT BIAS GENERATOR 50 µA CURRENT SOURCE CONTROL LOW REGISTER (CONTINUED)**

bit 1 **SRCEN0:** Source Enable for Output #0 bit
1 = Current source is enabled
0 = Current source is disabled

bit 0 **SNKEN0:** Sink Enable for Output #0 bit
1 = Current sink is enabled
0 = Current sink is disabled

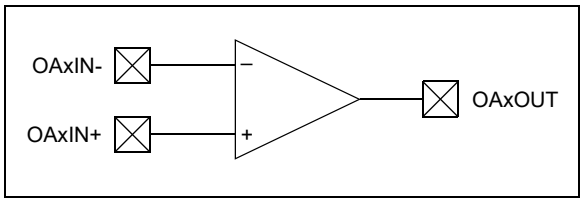
**Note 1:** This bit is only available in 36 and 48-pin package devices.

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## 26.0 OPERATIONAL AMPLIFIER

The dsPIC33CDVL64MC106 devices implement three instances of operational amplifiers (op amps). The op amps can be used for a wide variety of purposes, including signal conditioning and filtering. The three op amps are functionally identical. The block diagram for a single amplifier is shown in Figure 26-1.

**FIGURE 26-1: SINGLE OPERATIONAL AMPLIFIER BLOCK DIAGRAM**




The op amps are controlled by two SFR registers: AMPCON1L and AMPCON1H. They remain in a Low-Power state until the AMPON bit is set. Each op amp can then be enabled independently by setting the corresponding AMPENx bit (x = 1, 2, 3).

The NCHDISx bit provides some flexibility regarding input range versus Integral Nonlinearity (INL). When NCHDISx = 0 (default), the op amps have a wider input voltage range (see Table 33-41 in **Section 33.0 "Electrical Characteristics"**). When NCHDISx = 1, the wider input range is traded for improved INL performance (lower INL).


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## 26.1 Operational Amplifier Control Registers

**REGISTER 26-1: AMPCON1L: OP AMP CONTROL REGISTER LOW**

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

| U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | AMPEN3 | AMPEN2 | AMPEN1 |
| 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 **AMPON:** Op Amp Enable/On bit
1 = Enables op amp modules if their respective AMPENx bits are also asserted
0 = Disables all op amp modules

bit 14-3 **Unimplemented:** Read as ‘0’

bit 2 **AMPEN3:** Op Amp #3 Enable bit
1 = Enables Op Amp #3 if the AMPON bit is also asserted
0 = Disables Op Amp #3

bit 1 **AMPEN2:** Op Amp #2 Enable bit
1 = Enables Op Amp #2 if the AMPON bit is also asserted
0 = Disables Op Amp #2

bit 0 **AMPEN1:** Op Amp #1 Enable bit
1 = Enables Op Amp #1 if the AMPON bit is also asserted
0 = Disables Op Amp #1

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**REGISTER 26-2: AMPCON1H: OP AMP 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 | U-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | NCHDIS3(1) | NCHDIS2 | NCHDIS1 |
| 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 **NCHDIS3:** Op Amp #3 N Channel Disable bit
1 = Disables Op Amp #3 N channel input stage; reduced INL, but lowered input voltage range
0 = Wide input range for Op Amp #3

bit 1 **NCHDIS2:** Op Amp #2 N Channel Disable bit
1 = Disables Op Amp #2 N channel input stage; reduced INL, but lowered input voltage range
0 = Wide input range for Op Amp #2

bit 0 **NCHDIS1:** Op Amp #1 N Channel Disable bit
1 = Disables Op Amp #1 N channel input stage; reduced INL, but lowered input voltage range
0 = Wide input range for Op Amp #1

**Note 1:** This bit is not available on 28-pin devices.


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**NOTES:**

## 27.0 DEADMAN TIMER (DMT)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Deadman Timer (DMT)"** (www.microchip.com/DS70005155).

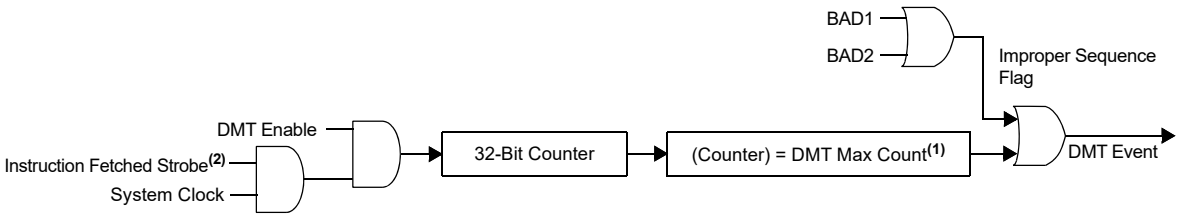
The primary function of the Deadman Timer (DMT) is to interrupt the processor in the event of a software malfunction. The DMT, which works on the system clock, is a free-running instruction fetch timer, which is clocked whenever an instruction fetch occurs, until a count match occurs. Instructions are not fetched when the processor is in Sleep mode.

DMT can be enabled in the Configuration fuse or by software in the DMTCON register by setting the ON bit. A DMT event results in a DMT interrupt on this device. The DMT consists of a 32-bit counter with a time-out count match value, as specified by the two 16-bit Configuration Fuse registers: FDMTCNTL and FDMTCNTH.

A DMT is typically used in mission-critical and safety-critical applications, where any single failure of the software functionality and sequencing must be detected.

Figure 27-1 shows a block diagram of the Deadman Timer module.

**FIGURE 27-1: DEADMAN TIMER BLOCK DIAGRAM**




**Note 1:** DMT Max Count is controlled by the initial value of the FDMTCNTL and FDMTCNTH Configuration registers.
**2:** DMT window interval is controlled by the value of the FDMTIVTL and FDMTIVTH Configuration registers.


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## 27.1 Deadman Timer Control/Status Registers

**REGISTER 27-1: DMTCON: DEADMAN TIMER CONTROL REGISTER**

| R/W-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| ON(1,2) | — | — | — | — | — | — | — |
| 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 **ON:** DMT Module Enable bit
1 = Deadman Timer module is enabled
0 = Deadman Timer module is not enabled

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

**Note 1:** This bit has control only when DMTDIS = 0 in the FDMT register.
**2:** DMT cannot be disabled in software. Writing '0' to this bit has no effect.

**REGISTER 27-2: DMTPRECLR: DEADMAN TIMER PRECLEAR 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 |
|---|---|---|---|---|---|---|---|
| STEP1[7:0](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 15-8 **STEP1[7:0]:** DMT Preclear Enable bits
01000000 = Enables the Deadman Timer preclear (Step 1)
All Other Write Patterns = Sets the BAD1 flag

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

**Note 1:** Bits[15:8] are cleared when the DMT counter is reset by writing a correct sequence of STEP1 and STEP2. STEP1 is also cleared if DMTCLR[STEP2] is loaded with the correct value in the correct sequence.

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**REGISTER 27-3: DMTCLR: DEADMAN TIMER CLEAR 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 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| STEP2[7:0](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 15-8 **Unimplemented:** Read as '0'

bit 7-0 **STEP2[7:0]:** DMT Clear Timer bits

00001000 = Clears STEP1[7:0], STEP2[7:0] and the Deadman Timer if preceded by the correct loading of the STEP1[7:0] bits in the correct sequence. The write to these bits may be verified by reading the DMTCNTL/H register and observing the counter being reset.

All Other Write Patterns = Sets the BAD2 bit; the value of STEP1[7:0] will remain unchanged, and the new value being written to STEP2[7:0] will be captured.

**Note 1:** Bits[7:0] are cleared when the DMT counter is reset by writing a correct sequence of STEP1 and STEP2.


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**REGISTER 27-4: DMTSTAT: DEADMAN TIMER STATUS REGISTER**

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

| HC/R-0 | HC/R-0 | HC/R-0 | U-0 | U-0 | U-0 | U-0 | R-0 |
|---|---|---|---|---|---|---|---|
| BAD1(1) | BAD2(1) | DMTEVENT(1) | — | — | — | — | WINOPN |
| 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 15-8 **Unimplemented:** Read as '0'

bit 7 **BAD1:** Deadman Timer Bad STEP1[7:0] Value Detect bit
1 = Incorrect STEP1[7:0] value was detected
0 = Incorrect STEP1[7:0] value was not detected

bit 6 **BAD2:** Deadman Timer Bad STEP2[7:0] Value Detect bit
1 = Incorrect STEP2[7:0] value was detected
0 = Incorrect STEP2[7:0] value was not detected

bit 5 **DMTEVENT:** Deadman Timer Event bit
1 = Deadman Timer event was detected (counter expired, or bad STEP1[7:0] or STEP2[7:0] value was entered prior to counter increment)
0 = Deadman Timer event was not detected

bit 4-1 **Unimplemented:** Read as '0'

bit 0 **WINOPN:** Deadman Timer Clear Window bit
1 = Deadman Timer clear window is open
0 = Deadman Timer clear window is not open

**Note 1:** The BAD1, BAD2 and DMTEVENT bits are cleared only on a Reset.

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**REGISTER 27-5: DMTCNTL: DEADMAN TIMER COUNT REGISTER LOW**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| COUNTER[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| COUNTER[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 **COUNTER[15:0]:** Read Current Contents of Lower DMT Counter bits

**REGISTER 27-6: DMTCNTH: DEADMAN TIMER COUNT REGISTER HIGH**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| COUNTER[31:24] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| COUNTER[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 15-0 **COUNTER[31:16]:** Read Current Contents of Higher DMT Counter bits


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**REGISTER 27-7: DMTPSCNTL: DMT POST-CONFIGURE COUNT STATUS REGISTER LOW**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSCNT[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSCNT[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 **PSCNT[15:0]:** Lower DMT Instruction Count Value Configuration Status bits
This is always the value of the FDMTCNTL Configuration register.

**REGISTER 27-8: DMTPSCNTH: DMT POST-CONFIGURE COUNT STATUS REGISTER HIGH**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSCNT[31:24] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSCNT[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 15-0 **PSCNT[31:16]:** Higher DMT Instruction Count Value Configuration Status bits
This is always the value of the FDMTCNTH Configuration register.

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**REGISTER 27-9: DMTPSINTVL: DMT POST-CONFIGURE INTERVAL STATUS REGISTER LOW**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSINTV[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSINTV[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 **PSINTV[15:0]:** Lower DMT Window Interval Configuration Status bits
This is always the value of the FDMTIVTL Configuration register.

**REGISTER 27-10: DMTPSINTVH: DMT POST-CONFIGURE INTERVAL STATUS REGISTER HIGH**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSINTV[31:24] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| PSINTV[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 15-0 **PSINTV[31:16]:** Higher DMT Window Interval Configuration Status bits
This is always the value of the FDMTIVTH Configuration register.


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**REGISTER 27-11: DMTHOLDREG: DMT HOLD REGISTER(1)**

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| UPRCNT[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 | R-0 |
|---|---|---|---|---|---|---|---|
| UPRCNT[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 **UPRCNT[15:0]:** DMTCNTH Register Value when DMTCNTL and DMTCNTH were Last Read bits

**Note 1:** The DMTHOLDREG register is initialized to '0' on Reset and is only loaded when the DMTCNTL and DMTCNTH registers are read.

## 28.0 32-BIT PROGRAMMABLE CYCLIC REDUNDANCY CHECK (CRC) GENERATOR

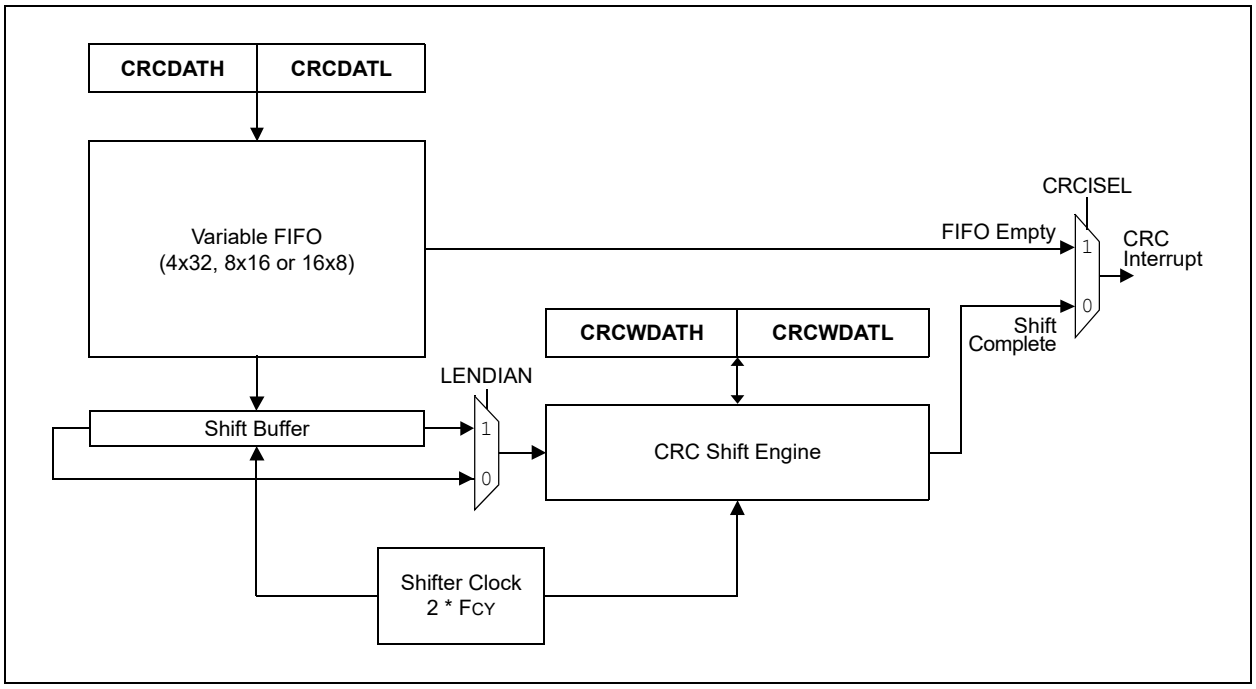
**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. For more information, refer to **"32-Bit Programmable Cyclic Redundancy Check (CRC)"** (www.microchip.com/DS30009729).

The 32-bit programmable CRC generator provides a hardware implemented method of quickly generating checksums for various networking and security applications. It offers the following features:

- User-Programmable CRC Polynomial Equation, up to 32 Bits
- Programmable Shift Direction (little or big-endian)
- Independent Data and Polynomial Lengths
- Configurable Interrupt Output
- Data FIFO

A simple version of the CRC shift engine is displayed in Figure 28-1.

**FIGURE 28-1: CRC MODULE BLOCK DIAGRAM**





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## 28.1 CRC Control Registers

**REGISTER 28-1: CRCCONL: CRC CONTROL REGISTER LOW**

| R/W-0 | U-0 | R/W-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 | HSC/R-0 |
|---|---|---|---|---|---|---|---|
| CRCEN | — | CSIDL | VWORD4 | VWORD3 | VWORD2 | VWORD1 | VWORD0 |
| bit 15 | | | | | | | bit 8 |

| HSC/R-0 | HSC/R-1 | R/W-0 | HC/R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| CRCFUL | CRCMPT | CRCISEL | CRCGO | LENDIAN | MOD | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HC = Hardware Clearable bit | 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 **CRCEN:** CRC Enable bit
1 = Enables module
0 = Disables module

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

bit 13 **CSIDL:** CRC Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12-8 **VWORD[4:0]:** Pointer Value bits
Indicates the number of valid words in the FIFO. Has a maximum value of 8 when PLEN[4:0] ≥ 7 or 16 when PLEN[4:0] ≤ 7.

bit 7 **CRCFUL:** CRC FIFO Full bit
1 = FIFO is full
0 = FIFO is not full

bit 6 **CRCMPT:** CRC FIFO Empty bit
1 = FIFO is empty
0 = FIFO is not empty

bit 5 **CRCISEL:** CRC Interrupt Selection bit
1 = Interrupt on FIFO is empty; the final word of data is still shifting through the CRC
0 = Interrupt on shift is complete and results are ready

bit 4 **CRCGO:** CRC Start bit
1 = Starts CRC serial shifter
0 = CRC serial shifter is turned off

bit 3 **LENDIAN:** Data Shift Direction Select bit
1 = Data word is shifted into the FIFO, starting with the LSb (little-endian)
0 = Data word is shifted into the FIFO, starting with the MSb (big-endian)

bit 2 **MOD:** CRC Calculation Mode bit
1 = Alternate mode
0 = Legacy mode bit

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

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**REGISTER 28-2: CRCCONH: CRC CONTROL REGISTER HIGH**

| U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | DWIDTH[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 |
|---|---|---|---|---|---|---|---|
| — | — | — | PLEN[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 **DWIDTH[4:0]:** Data Word Width Configuration bits
Configures the width of the data word (Data Word Width – 1).

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

bit 4-0 **PLEN[4:0]:** Polynomial Length Configuration bits
Configures the length of the polynomial (Polynomial Length – 1).


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**REGISTER 28-3: CRCXORL: CRC XOR POLYNOMIAL 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 |
|---|---|---|---|---|---|---|---|
| X[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 | U-0 |
|---|---|---|---|---|---|---|---|
| X[7:1] | | | | | | | — |
| 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 15-1 **X[15:1]:** XOR of Polynomial Term $x^n$ Enable bits

bit 0 **Unimplemented:** Read as ‘0’

**REGISTER 28-4: CRCXORH: CRC XOR POLYNOMIAL REGISTER, 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 |
|---|---|---|---|---|---|---|---|
| X[31:24] | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| X[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 15-0 **X[31:16]:** XOR of Polynomial Term $x^n$ Enable bits

## 29.0 POWER-SAVING FEATURES

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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"** (www.microchip.com/DS70000615).

The dsPIC33CDVL64MC106 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.

The dsPIC33CDVL64MC106 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.

### 29.1 Clock Frequency and Clock Switching

The dsPIC33CDVL64MC106 family allows 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 with High-Frequency PLL"**.

### 29.2 Instruction-Based Power-Saving Modes

The dsPIC33CDVL64MC106 family has 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 29-1.

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 29-1: `PWRSAV` INSTRUCTION SYNTAX**

```
PWRSAV  #0              ; Put the device into Sleep mode
PWRSAV  #1              ; Put the device into Idle mode
```


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### 29.2.1 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 regulators can be configured to go into standby when Sleep mode is entered by clearing the VREGS (RCON[8]) bit (default configuration).

If the application requires a faster wake-up time, and can accept higher current requirements, the VREGS (RCON[8]) bit can be set to keep the regulators active during Sleep mode. The available Low-Power Sleep modes are shown in Table 29-1. Additional regulator information is available in **Section 30.4 "On-Chip Voltage Regulator"**.

**TABLE 29-1: LOW-POWER SLEEP MODES**

| Relative Power | LPWREN | VREGS | MODE |
|---|---|---|---|
| Highest | 0 | 1 | Full power, active |
| — | 0 | 0 | Full power, standby |
| — | 1 (1) | 1 | Low power, active |
| Lowest | 1 (1) | 0 | Low power, standby |

**Note 1:** Low-Power modes; when LPWREN = 1, can only be used in the industrial temperature range.

### 29.2.2 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 29.4 "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 SIDL bit in the Timer1 Control register (T1CON[13]).

### 29.2.3 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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## 29.3 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.

## 29.4 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 1:** | 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). |

## 29.5 Power-Saving 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.

### 29.5.1 KEY RESOURCES

- **"Watchdog Timer and Power-Saving Modes"** (www.microchip.com/DS70000615)
- Code Samples
- Application Notes
- Software Libraries
- Webinars
- Development Tools


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## 29.6 PMD Control Registers

**REGISTER 29-1: PMDCON: PERIPHERAL MODULE DISABLE CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | PMDLOCK | — | — | — |
| 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 $\overline{\text{SYSRST}}$ | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 15-12 **Unimplemented:** Read as '0'

bit 11 **PMDLOCK:** PMD Lock bit
1 = PMD bits can be written
0 = PMD bits are not allowed to be written

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

**REGISTER 29-2: PMD1: PERIPHERAL MODULE DISABLE 1 CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | T1MD | QEI1MD | PWMMD | — |
| bit 15 | | | | | | | bit 8 |

| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| I2C1MD | U2MD | U1MD | SPI2MD | SPI1MD | — | — | ADC1MD |
| 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 **T1MD:** Timer1 Module Disable bit
1 = Timer1 module is disabled
0 = Timer1 module is enabled

bit 10 **QEI1MD:** QEI1 Module Disable bit
1 = QEI1 module is disabled
0 = QEI1 module is enabled

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

**REGISTER 29-2: PMD1: PERIPHERAL MODULE DISABLE 1 CONTROL REGISTER**

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

bit 0 **ADC1MD:** ADC Module Disable bit
1 = ADC module is disabled
0 = ADC module is enabled


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**REGISTER 29-3: PMD2: PERIPHERAL MODULE DISABLE 2 CONTROL 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/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | CCP4MD | CCP3MD | CCP2MD | CCP1MD |
| 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 **CCP4MD:** SCCP4 Module Disable bit
1 = SCCP4 module is disabled
0 = SCCP4 module is enabled

bit 2 **CCP3MD:** SCCP3 Module Disable bit
1 = SCCP3 module is disabled
0 = SCCP3 module is enabled

bit 1 **CCP2MD:** SCCP2 Module Disable bit
1 = SCCP2 module is disabled
0 = SCCP2 module is enabled

bit 0 **CCP1MD:** SCCP1 Module Disable bit
1 = SCCP1 module is disabled
0 = SCCP1 module is enabled

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**REGISTER 29-4: PMD3: PERIPHERAL MODULE DISABLE 3 CONTROL REGISTER**

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

| R/W-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| CRCMD | — | — | — | U3MD | — | — | — |
| 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 **CRCMD:** CRC Module Disable bit
1 = CRC module is disabled
0 = CRC module is enabled

bit 6-4 **Unimplemented:** Read as '0'

bit 3 **U3MD:** UART3 Module Disable bit
1 = UART3 module is disabled
0 = UART3 module is enabled

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


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**REGISTER 29-5: PMD4: PERIPHERAL MODULE DISABLE 4 CONTROL 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/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’

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**REGISTER 29-6: PMD6: PERIPHERAL MODULE DISABLE 6 CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | DMA3MD | DMA2MD | DMA1MD | DMA0MD |
| 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 15-12 **Unimplemented:** Read as '0'

bit 11 **DMA3MD:** DMA3 Module Disable bit
1 = DMA3 module is disabled
0 = DMA3 module is enabled

bit 10 **DMA2MD:** DMA2 Module Disable bit
1 = DMA2 module is disabled
0 = DMA2 module is enabled

bit 9 **DMA1MD:** DMA1 Module Disable bit
1 = DMA1 module is disabled
0 = DMA1 module is enabled

bit 8 **DMA0MD:** DMA0 Module Disable bit
1 = DMA0 module is disabled
0 = DMA0 module is enabled

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


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**REGISTER 29-7: PMD7: PERIPHERAL MODULE DISABLE 7 CONTROL REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | CMP1MD |
| bit 15 | | | | | | | bit 8 |

| U-0 | U-0 | U-0 | U-0 | R/W-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | PTGMD | — | — | — |
| 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 **CMP1MD:** Comparator 1 Module Disable bit
1 = Comparator 1 module is disabled
0 = Comparator 1 module is enabled

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

bit 3 **PTGMD**: PTG Module Disable bit
1 = PTG module is disabled
0 = PTG module is enabled

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

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**REGISTER 29-8: PMD8: PERIPHERAL MODULE DISABLE 8 CONTROL REGISTER**

| U-0 | U-0 | R/W-0 | U-0 | R/W-0 | U-0 | U-0 | R/W-0 |
|---|---|---|---|---|---|---|---|
| — | — | OPAMPMD | — | SENT1MD | — | — | DMTMD |
| 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 | BIASMD | — |
| 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 **OPAMPMD:** Op Amp Module Disable bit
1 = Op amp modules are disabled
0 = Op amp modules are enabled

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

bit 11 **SENT1MD:** SENT1 Module Disable bit
1 = SENT1 module is disabled
0 = SENT1 module is enabled

bit 10-9 **Unimplemented:** Read as '0'

bit 8 **DMTMD:** Deadman Timer Module Disable bit
1 = DMT module is disabled
0 = DMT module is enabled

bit 7-6 **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 **BIASMD:** 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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**TABLE 29-2: PMD REGISTERS**

| Register | Bit 15 | Bit14 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PMDCON | — | — | — | — | PMDLOCK | — | — | — | — | — | — | — | — | — | — | — |
| PMD1 | — | — | — | — | T1MD | QEIMD | PWMMD | — | I2C1MD | U2MD | U1MD | SPI2MD | SPI1MD | — | — | ADC1MD |
| PMD2 | — | — | — | — | — | — | — | — | — | — | — | — | CCP4MD | CCP3MD | CCP2MD | CCP1MD |
| PMD3 | — | — | — | — | — | — | — | — | CRCMD | — | — | — | U3MD | — | — | — |
| PMD4 | — | — | — | — | — | — | — | — | — | — | — | — | REFOMD | — | — | — |
| PMD6 | — | — | — | — | DMA3MD | DMA2MD | DMA1MD | DMA0MD | — | — | — | — | — | — | — | — |
| PMD7 | — | — | — | — | — | — | — | CMP1MD | — | — | — | — | PTGMD | — | — | — |
| PMD8 | — | — | OPAMPMD | — | SENT1MD | — | — | DMTMD | — | — | CLC4MD | CLC3MD | CLC2MD | CLC1MD | BIASMD | — |



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**NOTES:**


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## 30.0 SPECIAL FEATURES

**Note:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 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 website (www.microchip.com).

The dsPIC33CDVL64MC106 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)

### 30.1 Configuration Bits

In the dsPIC33CDVL64MC106 devices, the Configuration words are implemented as volatile memory. This means that configuration data will get loaded to volatile memory (from the Flash Configuration words) each time the device is powered up. Configuration data are stored at the end of the on-chip program memory space, known as the Flash Configuration Words. Their specific locations are shown in Table 30-1. The configuration data are automatically loaded from the Flash Configuration words to the proper Configuration Shadow registers during device Resets.

**Note:** Configuration data are 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 30-1: dsPIC33CDVL64MC106 FAMILY CONFIGURATION ADDRESSES**

| Register Name | 64 KB | 32 KB |
|---|---|---|
| FSEC | 0x00AF00 | 0x005F00 |
| FBSLIM | 0x00AF10 | 0x005F10 |
| FSIGN | 0x00AF14 | 0x005F14 |
| FOSCSEL | 0x00AF18 | 0x005F18 |
| FOSC | 0x00AF1C | 0x005F1C |
| FWDT | 0x00AF20 | 0x005F20 |
| FPOR | 0x00AF24 | 0x005F24 |
| FICD | 0x00AF28 | 0x005F28 |
| FDMTIVTL | 0x00AF2C | 0x005F2C |
| FDMTIVTH | 0x00AF30 | 0x005F30 |
| FDMTCNTL | 0x00AF34 | 0x005F34 |
| FDMTCNTH | 0x00AF38 | 0x005F38 |
| FDMT | 0x00AF3C | 0x005F3C |
| FDEVOPT | 0x00AF40 | 0x005F40 |
| FALTREG | 0x00AF44 | 0x005F44 |

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**TABLE 30-2: CONFIGURATION REGISTERS MAP**

| Register Name | 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 | — | AIVTDIS | — | — | — | CSS[2:0] | | | CWRP | GSS[1:0] | | GWRP | — | BSEN | BSS[1:0] | | BWRP |
| FBSLIM | — | — | — | — | BSLIM[12:0] | | | | | | | | | | | | |
| FSIGN | — | r(2) | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| FOSCSEL | — | — | — | — | — | — | — | — | — | IESO | — | — | — | — | FNOSC[2:0] | | |
| FOSC | — | — | — | — | XTBST | XTCFG[1:0] | | — | PLLKEN | FCKSM[1:0] | | — | — | — | OSCIOFNC | POSCMD[1:0] | |
| FWDT | — | FWDTEN | SWDTPS[4:0] | | | | | WDTWIN[1:0] | | WINDIS | RCLKSEL[1:0] | | RWDTPS[4:0] | | | | |
| FPOR | — | — | — | — | — | — | r(1) | — | — | — | BISTDIS | r(1) | r(1) | — | — | — | — |
| FICD | — | — | — | — | — | — | — | — | — | r(1) | — | JTAGEN | — | — | — | ICS[1:0] | |
| FDMTIVTL | — | DMTIVT[15:0] | | | | | | | | | | | | | | | |
| FDMTIVTH | — | DMTIVT[31:16] | | | | | | | | | | | | | | | |
| FDMTCNTL | — | DMTCNT[15:0] | | | | | | | | | | | | | | | |
| FDMTCNTH | — | DMTCNT[31:16] | | | | | | | | | | | | | | | |
| FDMT | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | DMTDIS |
| FDEVOPT | — | — | — | SPI2PIN | — | — | SMB3EN | r(2) | r(2) | r(1) | — | — | — | ALTI2C1 | r(1) | — | — |
| FALTREG | — | — | CTXT4[2:0] | | | — | CTXT3[2:0] | | | — | CTXT2[2:0] | | | — | CTXT1[2:0] | | |

**Legend:** — = unimplemented bit, read as '1'; r = reserved bit.

**Note 1:** Bit reserved, maintain as '1'.

**2:** Bit reserved, maintain as '0'.

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**REGISTER 30-1: FSEC CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R/PO-1 | U-1 | U-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| AIVTDIS | — | — | — | CSS2 | CSS1 | CSS0 | CWRP |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| GSS1 | GSS0 | GWRP | — | BSEN | BSS1 | BSS0 | BWRP |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as '1'

bit 15 **AIVTDIS:** Alternate Interrupt Vector Table Disable bit
1 = Disables AIVT
0 = Enables AIVT

bit 14-12 **Unimplemented:** Read as '1'

bit 11-9 **CSS[2:0]:** Configuration Segment Code Flash Protection Level bits
111 = No protection (other than CWRP write protection)
110 = Standard security
10x = Enhanced security
0xx = High security

bit 8 **CWRP:** Configuration Segment Write-Protect bit
1 = Configuration Segment is not write-protected
0 = Configuration Segment is write-protected

bit 7-6 **GSS[1:0]:** General Segment Code Flash Protection Level bits
11 = No protection (other than GWRP write protection)
10 = Standard security
0x = High security

bit 5 **GWRP:** General Segment Write-Protect bit
1 = User program memory is not write-protected
0 = User program memory is write-protected

bit 4 **Unimplemented:** Read as '1'

bit 3 **BSEN:** Boot Segment Control bit
1 = No Boot Segment
0 = Boot Segment size is determined by BSLIM[12:0]

bit 2-1 **BSS[1:0]:** Boot Segment Code Flash Protection Level bits
11 = No protection (other than BWRP write protection)
10 = Standard security
0x = High security

bit 0 **BWRP:** Boot Segment Write-Protect bit
1 = User program memory is not write-protected
0 = User program memory is write-protected

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**REGISTER 30-2: FBSLIM CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | BSLIM[12:8](1) | | | | |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| BSLIM[7:0](1) | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-13 **Unimplemented:** Read as '1'

bit 12-0 **BSLIM[12:0]:** Boot Segment Code Flash Page Address Limit bits

Contains the page address of the first active General 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.

**Note 1:** The BSLIMx bits are a 'write-once' element. If, after the Reset sequence, they are not erased (all '1's), then programming of the FBSLIM bits is prohibited. An attempt to do so will fail to set the WR bit (NVMCON[15]), and consequently, have no effect.

**REGISTER 30-3: FSIGN CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| r-0 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | r = Reserved bit | PO = Program Once bit | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as '1'

bit 15 **Reserved:** Maintain as '0'

bit 14-0 **Unimplemented:** Read as '1'


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**REGISTER 30-4: FOSCSEL CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | U-1 | U-1 | U-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| IESO | — | — | — | — | FNOSC2 | FNOSC1 | FNOSC0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-8 **Unimplemented:** Read as ‘1’

bit 7 **IESO:** Internal External Switchover bit
1 = Internal External Switchover mode is enabled (Two-Speed Start-up is enabled)
0 = Internal External Switchover mode is disabled (Two-Speed Start-up is disabled)

bit 6-3 **Unimplemented:** Read as ‘1’

bit 2-0 **FNOSC[2:0]:** Initial Oscillator Source Selection bits
111 = Internal Fast RC (FRC) Oscillator with Postscaler
110 = Backup Fast RC (BFRC)
101 = LPRC Oscillator
100 = Reserved
011 = Primary Oscillator with PLL (XTPLL, HSPLL, ECPLL)
010 = Primary (XT, HS, EC) Oscillator
001 = Internal Fast RC Oscillator with PLL (FRCPLL)
000 = Fast RC (FRC) Oscillator

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**REGISTER 30-5: FOSC CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 | U-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | XTBST | XTCFG1 | XTCFG0 | — | PLLKEN(1) |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | U-1 | U-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| FCKSM1 | FCKSM0 | — | — | — | OSCIOFNC | POSCMD1 | POSCMD0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-13 **Unimplemented:** Read as '1'

bit 12 **XTBST:** Oscillator Kick-Start Programmability bit
1 = Boosts the kick-start
0 = Default kick-start

bit 11-10 **XTCFG[1:0]:** Crystal Oscillator Drive Select bits
Current gain programmability for oscillator (output drive).
11 = Gain3 (use for 24-32 MHz crystals)
10 = Gain2 (use for 16-24 MHz crystals)
01 = Gain1 (use for 8-16 MHz crystals)
00 = Gain0 (use for 4-8 MHz crystals)

bit 9 **Unimplemented:** Read as '1'

bit 8 **PLLKEN:** PLL Lock Enable bit
1 = PLL clock output will be disabled if lock is lost
0 = PLL clock output will not be disabled if lock is lost

bit 7-6 **FCKSM[1:0]:** Clock Switching Mode bits
1x = Clock switching is disabled, Fail-Safe Clock Monitor is disabled
01 = Clock switching is enabled, Fail-Safe Clock Monitor is disabled
00 = Clock switching is enabled, Fail-Safe Clock Monitor is enabled

bit 5-3 **Unimplemented:** Read as '1'

bit 2 **OSCIOFNC:** OSCO Pin Function bit (except in XT and HS modes)
1 = OSCO is the clock output
0 = OSCO is the general purpose digital I/O pin

bit 1-0 **POSCMD[1:0]:** Primary Oscillator Mode Select bits
11 = Primary Oscillator is disabled
10 = HS Crystal Oscillator mode (10 MHz-32 MHz)
01 = XT Crystal Oscillator mode (3.5 MHz-10 MHz)
00 = EC (External Clock) mode

**Note 1:** A time-out period will occur when the system clock switching logic requests the PLL clock source and the PLL is not already enabled.


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**REGISTER 30-6: FWDT CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| FWDTEN | SWDTPS4 | SWDTPS3 | SWDTPS2 | SWDTPS1 | SWDTPS0 | WDTWIN1 | WDTWIN0 |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| WINDIS | RCLKSEL1 | RCLKSEL0 | RWDTPS4 | RWDTPS3 | RWDTPS2 | RWDTPS1 | RWDTPS0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as '1'

bit 15 **FWDTEN:** Watchdog Timer Enable bit
1 = WDT is enabled in hardware
0 = WDT controller via the ON bit (WDTCONL[15])

bit 14-10 **SWDTPS[4:0]:** Sleep Mode Watchdog Timer Period Select bits
11111 = Divide by 2 ^ 31 = 2,147,483,648
11110 = Divide by 2 ^ 30 = 1,073,741,824
. . .
00001 = Divide by $2^1$ = 2
00000 = Divide by $2^0$ = 1

bit 9-8 **WDTWIN[1:0]:** Watchdog Timer Window Select bits
11 = WDT window is 25% of the WDT period
10 = WDT window is 37.5% of the WDT period
01 = WDT window is 50% of the WDT period
00 = WDT Window is 75% of the WDT period

bit 7 **WINDIS:** Watchdog Timer Window Enable bit
1 = Watchdog Timer is in Non-Window mode
0 = Watchdog Timer is in Window mode

bit 6-5 **RCLKSEL[1:0]:** Watchdog Timer Clock Select bits
11 = LPRC Clock
10 = FRC Clock
01 = Peripheral Clock
00 = Reserved

bit 4-0 **RWDTPS[4:0]:** Run Mode Watchdog Timer Period Select bits
11111 = Divide by 2 ^ 31 = 2,147,483,648
11110 = Divide by 2 ^ 30 = 1,073,741,824
. . .
00001 = Divide by $2^1$ = 2
00000 = Divide by $2^0$ = 1

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**REGISTER 30-7: FPOR CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | U-1 | U-1 | U-1 | r-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-1 | R/PO-1 | r-1 | r-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | BISTDIS(1) | — | — | — | — | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | r = Reserved bit | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-11 **Unimplemented:** Read as '1'

bit 10 **Reserved:** Maintain as '1'

bit 9-7 **Unimplemented:** Read as '1'

bit 6 **BISTDIS:** Memory BIST Feature Disable bit
1 = MBIST on Reset feature is disabled
0 = MBIST on Reset feature is enabled

bit 5-4 **Reserved:** Maintain as '0b11'

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

**Note 1:** Applies to a Power-on Reset (POR) only.


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**REGISTER 30-8: FICD CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| r-1 | U-1 | R/PO-1 | U-1 | U-1 | U-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| — | — | JTAGEN | — | — | — | ICS1 | ICS0 |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | r = Reserved bit | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-8 **Unimplemented:** Read as ‘1’

bit 7 **Reserved:** Maintain as ‘1’

bit 6 **Unimplemented:** Read as ‘1’

bit 5 **JTAGEN:** JTAG Enable bit
1 = JTAG port is enabled
0 = JTAG port is disabled

bit 4-2 **Unimplemented:** Read as ‘1’

bit 1-0 **ICS[1:0]:** ICD Communication Channel Select bits
11 = Communicates on PGC1 and PGD1
10 = Communicates on PGC2 and PGD2
01 = Communicates on PGC3 and PGD3
00 = Reserved, do not use

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**REGISTER 30-9: FDMTIVTL CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTIVT[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTIVT[7:0] | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as ‘1’

bit 15-0 **DMTIVT[15:0]:** DMT Window Interval Lower 16 bits

**REGISTER 30-10: FDMTIVTH CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTIVT[31:24] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTIVT[23:16] | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as ‘1’

bit 15-0 **DMTIVT[31:16]:** DMT Window Interval Higher 16 bits


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**REGISTER 30-11: FDMTCNTL CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTCNT[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTCNT[7:0] | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as ‘1’

bit 15-0 **DMTCNT[15:0]:** DMT Instruction Count Time-out Value Lower 16 bits

**REGISTER 30-12: FDMTCNTH CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTCNT[31:24] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| DMTCNT[23:16] | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-16 **Unimplemented:** Read as ‘1’

bit 15-0 **DMTCNT[31:16]:** DMT Instruction Count Time-out Value Upper 16 bits

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**REGISTER 30-13: FDMT CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | DMTDIS |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as ‘0’ | |
| -n = Erased value | ‘1’ = Bit is set | ‘0’ = Bit is cleared | x = Bit is unknown |

bit 23-1 **Unimplemented:** Read as ‘1’

bit 0 **DMTDIS:** DMT Disable bit

1 = Deadman Timer is disabled and can be enabled by software using the ON bit (DMTCON[15])

0 = Deadman Timer is enabled and cannot be disabled by software


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**REGISTER 30-14: FDEVOPT CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | U-1 | R/PO-1 | U-1 | U-1 | R/PO-1 | r-0 | r-0 |
|---|---|---|---|---|---|---|---|
| — | — | SPI2PIN(1) | — | — | SMB3EN(2) | — | — |
| bit 15 | | | | | | | bit 8 |

| r-1 | U-1 | U-1 | U-1 | R/PO-1 | r-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | ALTI2C1 | — | — | — |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | r = Reserved bit | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-14 **Unimplemented:** Read as '1'

bit 13 **SPI2PIN:** Master SPI #2 Fast I/O Pad Disable bit
1 = Master SPI2 uses PPS (I/O remap) to make connections with device pins
0 = Master SPI2 uses direct connections with specified device pins

bit 12-11 **Unimplemented:** Read as '1'

bit 10 **SMB3EN:** SMBus 3.0 Levels Enable bit
1 = SMBus 3.0 input levels
0 = Normal SMBus input levels

bit 9-8 **Reserved:** Maintain as '0'

bit 7 **Reserved:** Maintain as '1'

bit 6-4 **Unimplemented:** Read as '1'

bit 3 **ALTI2C1:** Alternate I2C1 Pin Mapping bit
1 = Default location for SCL1/SDA1 pins
0 = Alternate location for SCL1/SDA1 pins (ASCL1/ASDA1)

bit 2 **Reserved:** Maintain as '1'

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

**Note 1:** Fixed pin option is only available for 48-pin packages.
**2:** SMBus mode is enabled by the SMEN bit (I2CxCONL[8]).

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**REGISTER 30-15: FALTREG CONFIGURATION REGISTER**

| U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 | U-1 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| U-1 | R/PO-1 | R/PO-1 | R/PO-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| — | CTXT4[2:0] | | | — | CTXT3[2:0] | | |
| bit 15 | | | | | | | bit 8 |

| U-1 | R/PO-1 | R/PO-1 | R/PO-1 | U-1 | R/PO-1 | R/PO-1 | R/PO-1 |
|---|---|---|---|---|---|---|---|
| — | CTXT2[2:0] | | | — | CTXT1[2:0] | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | PO = Program Once bit | | |
|---|---|---|---|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' | |
| -n = Erased value | '1' = Bit is set | '0' = Bit is cleared | x = Bit is unknown |

bit 23-15 **Unimplemented:** Read as '1'

bit 14-12 **CTXT4[2:0]:** Specifies the Alternate Working Register Set #4 with Interrupt Priority Levels (IPL) bits
111 = Not assigned
110 = Alternate Register Set #4 is assigned to IPL Level 7
101 = Alternate Register Set #4 is assigned to IPL Level 6
100 = Alternate Register Set #4 is assigned to IPL Level 5
011 = Alternate Register Set #4 is assigned to IPL Level 4
010 = Alternate Register Set #4 is assigned to IPL Level 3
001 = Alternate Register Set #4 is assigned to IPL Level 2
000 = Alternate Register Set #4 is assigned to IPL Level 1

bit 11 **Unimplemented:** Read as '1'

bit 10-8 **CTXT3[2:0]:** Specifies the Alternate Working Register Set #3 with Interrupt Priority Levels (IPL) bits
111 = Not assigned
110 = Alternate Register Set #3 is assigned to IPL Level 7
101 = Alternate Register Set #3 is assigned to IPL Level 6
100 = Alternate Register Set #3 is assigned to IPL Level 5
011 = Alternate Register Set #3 is assigned to IPL Level 4
010 = Alternate Register Set #3 is assigned to IPL Level 3
001 = Alternate Register Set #3 is assigned to IPL Level 2
000 = Alternate Register Set #3 is assigned to IPL Level 1

bit 7 **Unimplemented:** Read as '1'

bit 6-4 **CTXT2[2:0]:** Specifies the Alternate Working Register Set #2 with Interrupt Priority Levels (IPL) bits
111 = Not assigned
110 = Alternate Register Set #2 is assigned to IPL Level 7
101 = Alternate Register Set #2 is assigned to IPL Level 6
100 = Alternate Register Set #2 is assigned to IPL Level 5
011 = Alternate Register Set #2 is assigned to IPL Level 4
010 = Alternate Register Set #2 is assigned to IPL Level 3
001 = Alternate Register Set #2 is assigned to IPL Level 2
000 = Alternate Register Set #2 is assigned to IPL Level 1

bit 3 **Unimplemented:** Read as '1'


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**REGISTER 30-15: FALTREG CONFIGURATION REGISTER (CONTINUED)**

bit 2-0 **CTXT1[2:0]:** Specifies the Alternate Working Register Set #1 with Interrupt Priority Levels (IPL) bits

111 = Not assigned
110 = Alternate Register Set #1 is assigned to IPL Level 7
101 = Alternate Register Set #1 is assigned to IPL Level 6
100 = Alternate Register Set #1 is assigned to IPL Level 5
011 = Alternate Register Set #1 is assigned to IPL Level 4
010 = Alternate Register Set #1 is assigned to IPL Level 3
001 = Alternate Register Set #1 is assigned to IPL Level 2
000 = Alternate Register Set #1 is assigned to IPL Level 1

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## 30.2 Device Identification

The dsPIC33CDVL64MC106 family has 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 30-16 and Register 30-17.

**REGISTER 30-16: DEVREV: DEVICE REVISION REGISTER**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| 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 | R | R | R |
|---|---|---|---|---|---|---|---|
| — | — | — | — | DEVREV[3:0] | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | | |
|---|---|---|---|
| R = Read-Only 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 23-4 **Unimplemented:** Read as ‘0’

bit 3-0 **DEVREV[3:0]:** Device Revision bits


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**REGISTER 30-17: DEVID: DEVICE ID REGISTERS**

| U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 | U-0 |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — |
| bit 23 | | | | | | | bit 16 |

| R-1 | R-0 | R-0 | R-0 | R-1 | R-1 | R-1 | R-0 |
|---|---|---|---|---|---|---|---|
| FAMID[7:0] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| R | R | R | R | R | R | R | R |
|---|---|---|---|---|---|---|---|
| DEV[7:0](1) | | | | | | | |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | | | |
|---|---|---|---|
| R = Read-Only 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 23-16 **Unimplemented:** Read as '0'

bit 15-8 **FAMID[7:0]:** Device Family Identifier bits

bit 7-0 **DEV[7:0]:** Individual Device Identifier bits

**Note 1:** See Table 30-3 for the list of Device Identifier bits.

**TABLE 30-3: DEVICE IDs FOR THE dsPIC33CDVL64MC106 FAMILY**

| Device | DEVID |
|---|---|
| dsPIC33CDVL64MC106 | 0x991A |
| dsPIC33CDV64MC106 | 0x991B |

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## 30.3 User OTP Memory

The dsPIC33CDVL64MC106 family contains 64 One-Time-Programmable (OTP) double words, located at addresses, 801700h through 8017FEh. Each 48-bit OTP double word can only be written one time. The OTP words can be used for storing checksums, code revisions, manufacturing dates, manufacturing lot numbers or any other application-specific information.

The OTP area is not cleared by any erase command. This memory can be written only once.

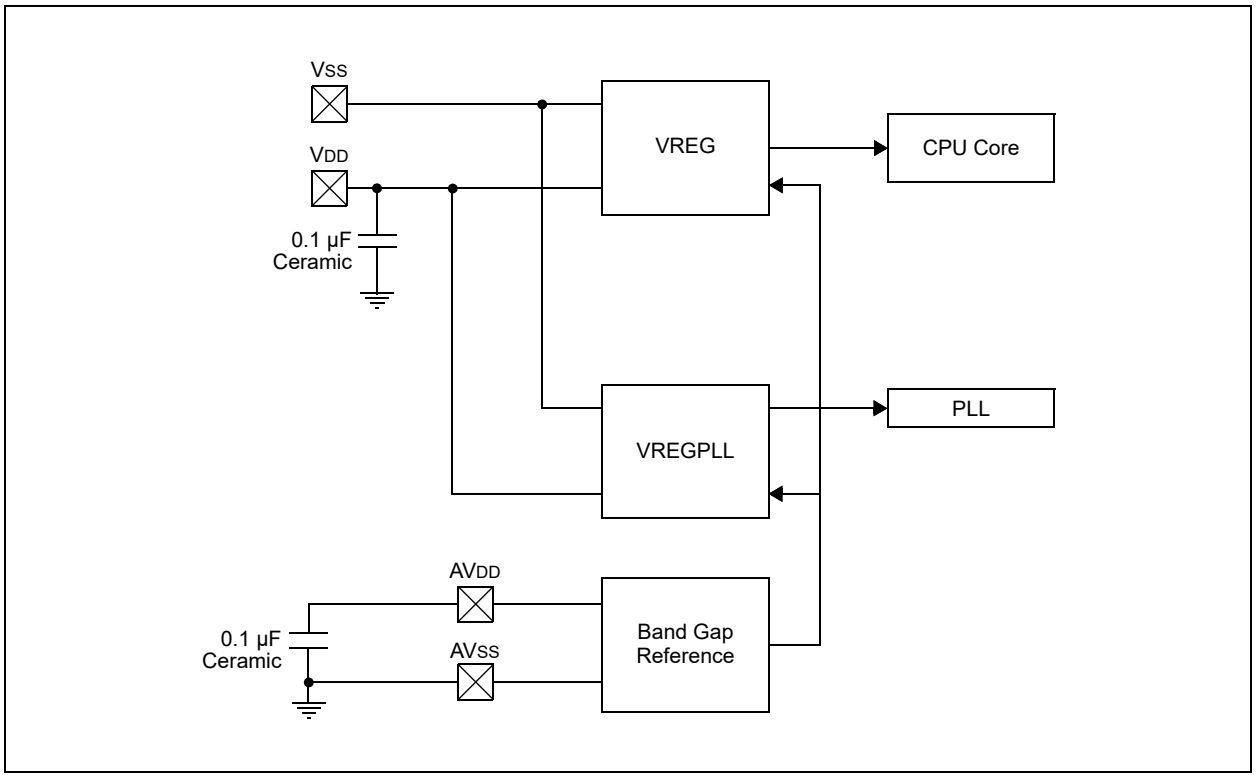
## 30.4 On-Chip Voltage Regulator

The dsPIC33CDVL64MC106 family has a capacitorless internal voltage regulator to supply power to the core at 1.2V (typical). The voltage regulator, VREG, provides power for the core. The PLL is powered using a separate regulator, VREGPLL, as shown in Figure 30-1. The regulators have Low-Power and Standby modes for use in Sleep modes. For additional information about Sleep, see **Section 29.2.1 "Sleep Mode"**.

When the regulators are in Low-Power mode (LPWREN = 1), the power available to the core is limited.

Before the LPWREN bit is set, the device should be placed into a Lower Power state by disabling peripherals and lowering CPU frequency (e.g., 8 MHz FRC without PLL).

**FIGURE 30-1: INTERNAL REGULATOR**





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**REGISTER 30-18: VREGCON: VOLTAGE REGULATOR CONTROL REGISTER(2)**

| R/W-0 | r-0 | r-0 | r-0 | r-0 | r-0 | r-0 | r-0 |
|---|---|---|---|---|---|---|---|
| LPWREN(1) | — | — | — | — | — | — | — |
| bit 15 | | | | | | | bit 8 |

| r-0 | r-0 | r-0 | r-0 | r-0 | r-0 | r-0 | r-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 **LPWREN:** Low-Power Mode Enable bit
1 = Voltage regulators are in Low-Power mode
0 = Voltage regulators are in Full Power mode

bit 14-0 **Reserved:** Maintained as '0'

**Note 1:** Low-Power mode can only be used within the industrial temperature range. The CPU should be run at slow speed (8 MHz or less) before setting this bit.

**2:** HW resets this register only on a POR Reset.

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## 30.5 Brown-out Reset (BOR)

The Brown-out Reset (BOR) module is based on an internal voltage reference circuit that monitors the regulated supply voltage. 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 selections.

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'.

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 mode and resets the device should $V_{DD}$ fall below the BOR threshold voltage.


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## 30.6 Dual Watchdog Timer (WDT)

**Note 1:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to **"Dual Watchdog Timer"** (www.microchip.com/DS70005250).

Refer to Figure 30-2 for a WDT block diagram.

The WDT, when enabled, operates from the internal Low-Power RC (BFRC/244) Oscillator clock source or a selectable clock source in Run mode. The WDT can be used to detect system software malfunctions by resetting the device if the WDT is not cleared periodically in software. The WDT can be configured in Windowed mode or Non-Windowed mode. Various WDT time-out periods can be selected using the WDT postscaler. The WDT can also be used to wake the device from Sleep or Idle mode (Power Save mode). If the WDT expires and issues a device Reset, the WTDO bit in RCON (Register 6-1) will be set.

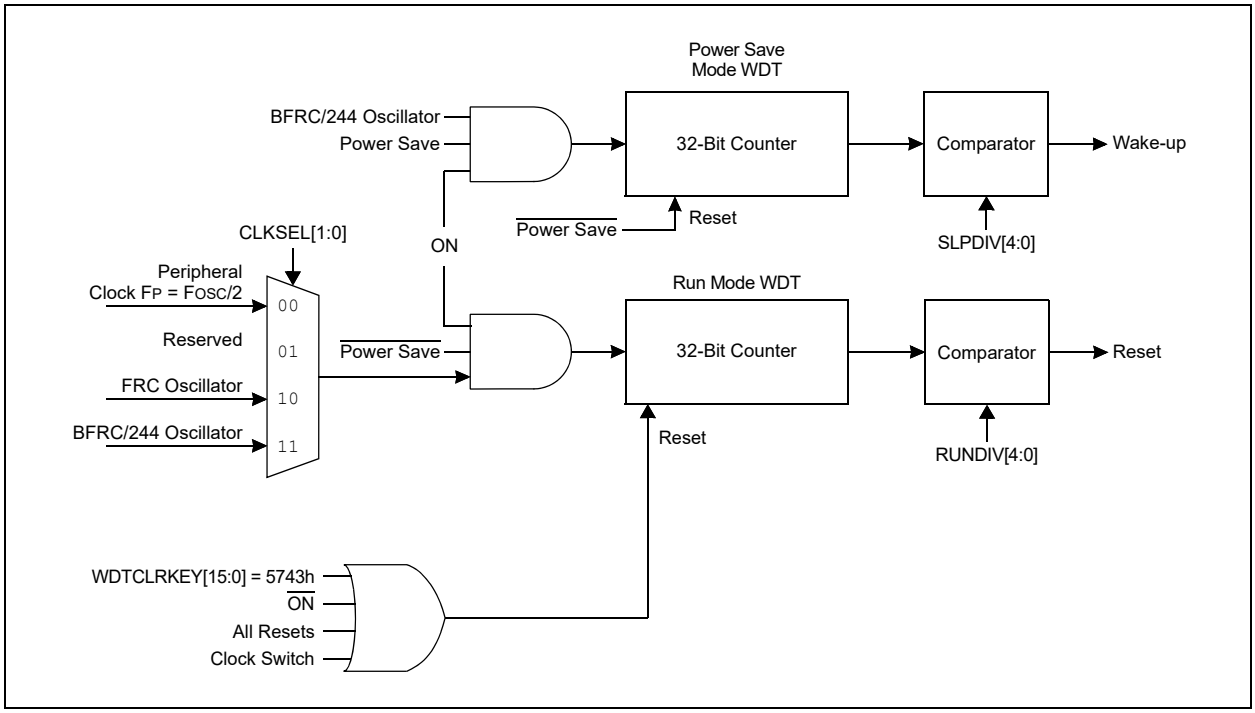
**Note:** It is recommended to have at least 1-2 WDT clock cycles of delay after a `CLRWDT` instruction, in case one needs to perform a `PWRSAV`/NVM operation soon after the `CLRWDT` instruction.

Here are some of the key features of the WDT modules:

- Configuration or Software Controlled
- Separate User-Configurable Time-out Periods for Run and Sleep/Idle
- Can Wake the Device from Sleep or Idle
- User-Selectable Clock Source in Run Mode
- Operates from BFRC/244 in Sleep/Idle Mode

**Note:** The WDT is not automatically reset when a Fail-Safe Clock Monitor event occurs. The user should issue a `CLRWDT` instruction after a clock fail event is detected.

**FIGURE 30-2: WATCHDOG TIMER BLOCK DIAGRAM**




**Note:** The Run mode WDT stalls when the device is performing any Flash operation while executing the code from the same Flash partition, and resumes its counter once the Flash operation is complete.

**REGISTER 30-19: WDTCONL: WATCHDOG TIMER CONTROL REGISTER LOW**

| R/W-0 | U-0 | U-0 | R-y | R-y | R-y | R-y | R-y |
|---|---|---|---|---|---|---|---|
| ON(1,2) | — | — | RUNDIV4(3) | RUNDIV3(3) | RUNDIV2(3) | RUNDIV1(3) | RUNDIV0(3) |
| bit 15 | | | | | | | bit 8 |

| R | R | R-y | R-y | R-y | R-y | R-y | HS/R/W-0 |
|---|---|---|---|---|---|---|---|
| CLKSEL1(3,5) | CLKSEL0(3,5) | SLPDIV4(3) | SLPDIV3(3) | SLPDIV2(3) | SLPDIV1(3) | SLPDIV0(3) | WDTWINEN(4) |
| bit 7 | | | | | | | bit 0 |

| **Legend:** | HS = Hardware Settable bit | y = Value from Configuration bit 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 **ON:** Watchdog Timer Enable bit
1 = Enables the Watchdog Timer if it is not enabled by the device configuration
0 = Disables the Watchdog Timer if it was enabled in software

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

bit 12-8 **RUNDIV[4:0]:** Sleep and Idle Mode WDT Postscaler Status bits
11111 = Divide by $2^{31}$ = 2,147,483,648
11110 = Divide by $2^{30}$ = 1,073,741,824
...
00001 = Divide by $2^{1}$ = 2
00000 = Divide by $2^{0}$ = 1

bit 7-6 **CLKSEL[1:0]:** WDT Run Mode Clock Select Status bits
11 = BFRC/244 Oscillator
10 = FRC Oscillator
01 = Reserved
00 = SYSCLK

bit 5-1 **SLPDIV[4:0]:** Sleep and Idle Mode WDT Postscaler Status bits
11111 = Divide by $2^{31}$ = 2,147,483,648
11110 = Divide by $2^{30}$ = 1,073,741,824
...
00001 = Divide by $2^{1}$ = 2
00000 = Divide by $2^{0}$ = 1

bit 0 **WDTWINEN:** Watchdog Timer Window Enable bit
1 = Enables Window mode
0 = Disables Window mode

**Note 1:** A read of this bit will result in a '1' if the WDT is enabled by the device configuration or by software.
**2:** The user's software should not read or write the peripheral's SFRs immediately following the instruction that clears the module's ON bit.
**3:** These bits reflect the value of the Configuration bits.
**4:** The WDTWINEN bit reflects the status of the Configuration bit if the bit is set. If the bit is cleared, the value is controlled by software.
**5:** The available clock sources are device-dependent.


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**REGISTER 30-20: WDTCONH: WATCHDOG TIMER CONTROL REGISTER HIGH**

| W-0 | W-0 | W-0 | W-0 | W-0 | W-0 | W-0 | W-0 |
|---|---|---|---|---|---|---|---|
| WDTCLRKEY[15:8] | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| W-0 | W-0 | W-0 | W-0 | W-0 | W-0 | W-0 | W-0 |
|---|---|---|---|---|---|---|---|
| WDTCLRKEY[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 **WDTCLRKEY[15:0]:** Watchdog Timer Clear Key bits

To clear the Watchdog Timer to prevent a time-out, software must write the value, 0x5743, to this location using a single 16-bit write.

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## 30.7 JTAG Interface

The dsPIC33CDVL64MC106 devices implement a JTAG interface, which supports boundary scan device testing. Programming is not supported through the JTAG interface; only the boundary scan is supported.

**Note:** Refer to **"Programming and Diagnostics"** (www.microchip.com/DS70000608) for further information on usage, configuration and operation of the JTAG interface.

## 30.8 In-Circuit Serial Programming™ (ICSP™)

The dsPIC33CDVL64MC106 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.

Any of the three pairs of programming clock/data pins can be used:

- PGC1 and PGD1
- PGC2 and PGD2
- PGC3 and PGD3

## 30.9 In-Circuit Debugger

When the MPLAB® tool 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 PGCx (Emulation/Debug Clock) and PGDx (Emulation/Debug Data) pin functions.

Any of the three pairs of debugging clock/data pins can be used:

- PGC1 and PGD1
- PGC2 and PGD2
- PGC3 and PGD3

To use the in-circuit debugger function of the device, the design must implement ICSP connections to MCLR, VDD, VSS and the PGCx/PGDx 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 (PGCx and PGDx).


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## 30.10 Code Protection and CodeGuard™ Security

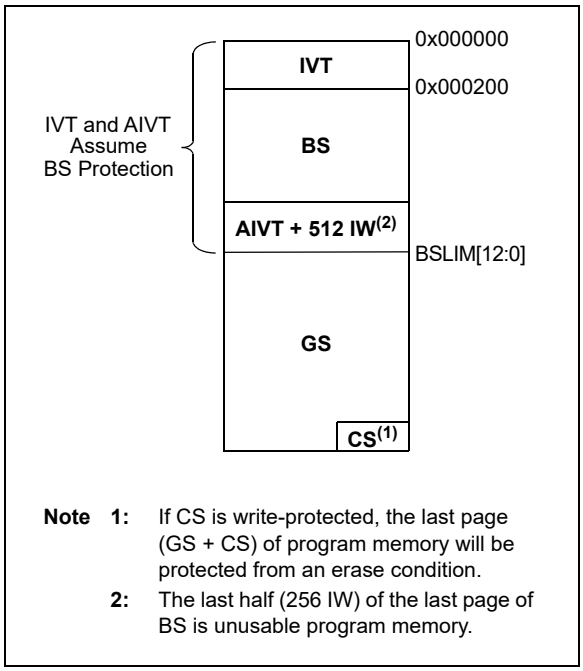
The dsPIC33CDVL64MC106 devices offer multiple levels of security for protecting individual intellectual property. The program Flash protection can be broken up into three segments: Boot Segment (BS), General Segment (GS) and Configuration Segment (CS). Boot Segment has the highest security privilege 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 1024 IW. The smallest BS size is one page, which will consist of the Interrupt Vector Table (IVT) and 512 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 (2048 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.

The different device security segments are shown in Figure 30-3. 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 30-3: SECURITY SEGMENTS EXAMPLE**




**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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## 31.0 INSTRUCTION SET SUMMARY

**Note:** This data sheet summarizes the features of the dsPIC33CDVL64MC106 devices. It is not intended to be a comprehensive reference source. To complement the information in this data sheet, refer to the **"16-Bit MCU and DSC Programmer's Reference Manual"** (www.microchip.com/DS70000157).

The dsPIC33CDVL64MC106 family 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 31-1 lists the general symbols used in describing the instructions.

The dsPIC33 instruction set summary in Table 31-2 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

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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:** In the dsPIC33CDVL64MC106 devices, read and Read-Modify-Write operations on non-CPU Special Function Registers require an additional cycle when compared to dsPIC30F, dsPIC33F, PIC24F and PIC24H devices.

**Note:** For more details on the instruction set, refer to the **"16-Bit MCU and DSC Programmer's Reference Manual"** (www.microchip.com/DS70000157).

**TABLE 31-1: 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 and 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 and 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 31-1: 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 31-2: 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 | BFEXT | BFEXT | bit4,wid5,Ws,Wb | Bit Field Extract from Ws to Wb | 2 | 2 | None |
| | | BFEXT | bit4,wid5,f,Wb | Bit Field Extract from f to Wb | 2 | 2 | None |
| 7 | BFINS | BFINS | bit4,wid5,Wb,Ws | Bit Field Insert from Wb into Ws | 2 | 2 | None |
| | | BFINS | bit4,wid5,Wb,f | Bit Field Insert from Wb into f | 2 | 2 | None |
| | | BFINS | bit4,wid5,lit8,Ws | Bit Field Insert from #lit8 to Ws | 2 | 2 | None |

**Note1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.
**2:** The divide instructions must be preceded with a "REPEAT #5" instruction, such that they are executed six consecutive times.


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**TABLE 31-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 9 | 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 |
| 10 | BREAK | BREAK | | Stop User Code Execution | 1 | 1 | None |
| 11 | BSET | BSET | f,#bit4 | Bit Set f | 1 | 1 | None |
| | | | Ws,#bit4 | Bit Set Ws | 1 | 1 | None |
| 12 | 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 |
| 13 | BTG | BTG | f,#bit4 | Bit Toggle f | 1 | 1 | None |
| | | BTG | Ws,#bit4 | Bit Toggle Ws | 1 | 1 | None |
| 14 | 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 |
| 15 | 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 |
| 16 | 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 |
| 17 | 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 |
| 18 | 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 |
| 19 | 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 |

**Note1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.
**2:** The divide instructions must be preceded with a "REPEAT #5" instruction, such that they are executed six consecutive times.

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**TABLE 31-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 20 | CLRWDT | CLRWDT | | Clear Watchdog Timer | 1 | 1 | WDTO,Sleep |
| 21 | COM | COM | f | f = $\bar{f}$ | 1 | 1 | N,Z |
| | | COM | f,WREG | WREG = $\bar{f}$ | 1 | 1 | N,Z |
| | | COM | Ws,Wd | Wd = $\overline{Ws}$ | 1 | 1 | N,Z |
| 22 | 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 |
| 23 | 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 |
| 24 | 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 |
| 25 | 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 |
| 26 | 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 |
| 27 | CPSLT | CPSLT | Wb,Wn | Compare Wb with Wn, Skip if < | 1 | 1 (2 or 3) | None |
| | | CPBLT | Wb,Wn,Expr | Compare Wb with Wn, Branch if < | 1 | 1 (5) | None |
| 28 | CPSNE | CPSNE | Wb,Wn | Compare Wb with Wn, Skip if ≠ | 1 | 1 (2 or 3) | None |
| | | CPBNE | Wb,Wn,Expr | Compare Wb with Wn, Branch if ≠ | 1 | 1 (5) | None |
| 29 | CTXTSWP | CTXTSWP | #lit3 | Switch CPU Register Context to Context Defined by lit3 | 1 | 2 | None |
| 30 | CTXTSWP | CTXTSWP | Wn | Switch CPU Register Context to Context Defined by Wn | 1 | 2 | None |
| 31 | DAW.B | DAW.B | Wn | Wn = Decimal Adjust Wn | 1 | 1 | C |
| 32 | 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 |
| 33 | 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 |
| 34 | DISI | DISI | #lit14 | Disable Interrupts for k Instruction Cycles | 1 | 1 | None |
| 35 | DIVF | DIVF | Wm,Wn | Signed 16/16-bit Fractional Divide | 1 | 18 | N,Z,C,OV |
| 36 | DIV.S(2) | DIV.S | Wm,Wn | Signed 16/16-bit Integer Divide | 1 | 6 | N,Z,C,OV |
| | | DIV.SD | Wm,Wn | Signed 32/16-bit Integer Divide | 1 | 6 | N,Z,C,OV |
| 37 | DIV.U(2) | DIV.U | Wm,Wn | Unsigned 16/16-bit Integer Divide | 1 | 6 | N,Z,C,OV |
| | | DIV.UD | Wm,Wn | Unsigned 32/16-bit Integer Divide | 1 | 6 | N,Z,C,OV |
| 38 | DIVF2(2) | DIVF2 | Wm,Wn | Signed 16/16-bit Fractional Divide (W1:W0 preserved) | 1 | 6 | N,Z,C,OV |
| 39 | DIV2.S(2) | DIV2.S | Wm,Wn | Signed 16/16-bit Integer Divide (W1:W0 preserved) | 1 | 6 | N,Z,C,OV |
| | | DIV2.SD | Wm,Wn | Signed 32/16-bit Integer Divide (W1:W0 preserved) | 1 | 6 | N,Z,C,OV |
| 40 | DIV2.U(2) | DIV2.U | Wm,Wn | Unsigned 16/16-bit Integer Divide (W1:W0 preserved) | 1 | 6 | N,Z,C,OV |
| | | DIV2.UD | Wm,Wn | Unsigned 32/16-bit Integer Divide (W1:W0 preserved) | 1 | 6 | N,Z,C,OV |
| 41 | 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 |

**Note1:** 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 31-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 42 | ED | ED | Wm*Wm,Acc,Wx,Wy,Wxd | Euclidean Distance (no accumulate) | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 43 | EDAC | EDAC | Wm*Wm,Acc,Wx,Wy,Wxd | Euclidean Distance | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 44 | EXCH | EXCH | Wns,Wnd | Swap Wns with Wnd | 1 | 1 | None |
| 46 | FBCL | FBCL | Ws,Wnd | Find Bit Change from Left (MSb) Side | 1 | 1 | C |
| 47 | FF1L | FF1L | Ws,Wnd | Find First One from Left (MSb) Side | 1 | 1 | C |
| 48 | FF1R | FF1R | Ws,Wnd | Find First One from Right (LSb) Side | 1 | 1 | C |
| 49 | FLIM | FLIM | Wb, Ws | Force Data (Upper and Lower) Range Limit without Limit Excess Result | 1 | 1 | N,Z,OV |
| | | FLIM.V | Wb, Ws, Wd | Force Data (Upper and Lower) Range Limit with Limit Excess Result | 1 | 1 | N,Z,OV |
| 50 | 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 |
| 51 | 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 |
| 52 | 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 |
| 53 | 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 |
| 54 | LAC | LAC | Wso,#Slit4,Acc | Load Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | LAC.D | Wso, #Slit4, Acc | Load Accumulator Double | 1 | 2 | OA,SA,OB,SB |
| 56 | LNK | LNK | #lit14 | Link Frame Pointer | 1 | 1 | SFA |
| 57 | 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 |
| 58 | 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 |
| 59 | MAX | MAX | Acc | Force Data Maximum Range Limit | 1 | 1 | N,OV,Z |
| | | MAX.V | Acc, Wnd | Force Data Maximum Range Limit with Result | 1 | 1 | N,OV,Z |
| 60 | MIN | MIN | Acc | If Accumulator A Less than B, Load Accumulator with B or vice versa | 1 | 1 | N,OV,Z |
| | | MIN.V | Acc, Wd | If Accumulator A Less than B Accumulator, Force Minimum Data Range Limit with Limit Excess Result | 1 | 1 | N,OV,Z |
| | | MINZ | Acc | Accumulator Force Minimum Data Range Limit | 1 | 1 | N,OV,Z |
| | | MINZ.V | Acc, Wd | Accumulator Force Minimum Data Range Limit with Limit Excess Result | 1 | 1 | N,OV,Z |

**Note1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.
**2:** The divide instructions must be preceded with a "REPEAT #5" instruction, such that they are executed six consecutive times.

**TABLE 31-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|
| 61 | 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 |
| 62 | 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 |
| | | MOVPAG Ws, DSRPAG | Move Ws[9:0] to DSRPAG | 1 | 1 | None |
| | | MOVPAG Ws, TBLPAG | Move Ws[7:0] to TBLPAG | 1 | 1 | None |
| 64 | MOVSAC | MOVSAC Acc,Wx,Wxd,Wy,Wyd,AWB | Prefetch and Store Accumulator | 1 | 1 | None |
| 65 | 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 |
| 66 | MPY.N | MPY.N Wm*Wn,Acc,Wx,Wxd,Wy,Wyd | -(Multiply Wm by Wn) to Accumulator | 1 | 1 | None |
| 67 | MSC | MSC Wm*Wm,Acc,Wx,Wxd,Wy,Wyd, AWB | Multiply and Subtract from Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| 68 | 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 |

**Note1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.
**2:** The divide instructions must be preceded with a "REPEAT #5" instruction, such that they are executed six consecutive times.


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**TABLE 31-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|
| 69 | NEG | NEG Acc | Negate Accumulator | 1 | 1 | OA,OB,OAB, SA,SB,SAB |
| | | NEG f | f = $\bar{f}$ + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | NEG f,WREG | WREG = $\bar{f}$ + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | NEG Ws,Wd | Wd = $\overline{Ws}$ + 1 | 1 | 1 | C,DC,N,OV,Z |
| 70 | NOP | NOP | No Operation | 1 | 1 | None |
| | | NOPR | No Operation | 1 | 1 | None |
| 71 | NORM | NORM Acc, Wd | Normalize Accumulator | 1 | 1 | N,OV,Z |
| 72 | 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 |
| 73 | 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 |
| 74 | PWRSAV | PWRSAV #lit1 | Go into Sleep or Idle mode | 1 | 1 | WDTO,Sleep |
| 75 | RCALL | RCALL Expr | Relative Call | 1 | 4 | SFA |
| | | RCALL Wn | Computed Call | 1 | 4 | SFA |
| 76 | REPEAT | REPEAT #lit15 | Repeat Next Instruction lit15 + 1 Times | 1 | 1 | None |
| | | REPEAT Wn | Repeat Next Instruction (Wn) + 1 Times | 1 | 1 | None |
| 77 | RESET | RESET | Software Device Reset | 1 | 1 | None |
| 78 | RETFIE | RETFIE | Return from Interrupt | 1 | 6 (5) | SFA |
| 79 | RETLW | RETLW #lit10,Wn | Return with Literal in Wn | 1 | 6 (5) | SFA |
| 80 | RETURN | RETURN | Return from Subroutine | 1 | 6 (5) | SFA |
| 81 | 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 |
| 82 | 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 |
| 83 | 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 |
| 84 | 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 |
| 85 | SAC | SAC Acc,#Slit4,Wdo | Store Accumulator | 1 | 1 | None |
| | | SAC.R Acc,#Slit4,Wdo | Store Rounded Accumulator | 1 | 1 | None |
| 86 | SE | SE Ws,Wnd | Wnd = Sign-Extended Ws | 1 | 1 | C,N,Z |
| 87 | SETM | SETM f | f = 0xFFFF | 1 | 1 | None |
| | | SETM WREG | WREG = 0xFFFF | 1 | 1 | None |
| | | SETM Ws | Ws = 0xFFFF | 1 | 1 | None |
| 88 | 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 |

**Note1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.
**2:** The divide instructions must be preceded with a "REPEAT #5" instruction, such that they are executed six consecutive times.

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**TABLE 31-2: INSTRUCTION SET OVERVIEW (CONTINUED)**

| Base Instr # | Assembly Mnemonic | Assembly Syntax | | Description | # of Words | # of Cycles(1) | Status Flags Affected |
|---|---|---|---|---|---|---|---|
| 89 | 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 |
| 91 | 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 |
| 92 | 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 |
| 93 | 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 |
| 94 | 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 |
| 95 | SWAP | SWAP.b | Wn | Wn = Nibble Swap Wn | 1 | 1 | None |
| | | SWAP | Wn | Wn = Byte Swap Wn | 1 | 1 | None |
| 96 | TBLRDH | TBLRDH | Ws,Wd | Read Prog[23:16] to Wd[7:0] | 1 | 5 | None |
| 97 | TBLRDL | TBLRDL | Ws,Wd | Read Prog[15:0] to Wd | 1 | 5 | None |
| 98 | TBLWTH | TBLWTH | Ws,Wd | Write Ws[7:0] to Prog[23:16] | 1 | 2 | None |
| 99 | TBLWTL | TBLWTL | Ws,Wd | Write Ws to Prog[15:0] | 1 | 2 | None |
| 101 | ULNK | ULNK | | Unlink Frame Pointer | 1 | 1 | SFA |
| 104 | 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 |
| 105 | ZE | ZE | Ws,Wnd | Wnd = Zero-Extend Ws | 1 | 1 | C,Z,N |

**Note1:** Read and Read-Modify-Write (e.g., bit operations and logical operations) on non-CPU SFRs incur an additional instruction cycle.
**2:** The divide instructions must be preceded with a "`REPEAT #5`" instruction, such that they are executed six consecutive times.


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## 32.0 DEVELOPMENT SUPPORT

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**NOTES:**


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## 33.0 ELECTRICAL CHARACTERISTICS

This section provides an overview of the dsPIC33CDVL64MC106 family electrical characteristics. Additional information will be provided in future revisions of this document as it becomes available.

Absolute maximum ratings for the dsPIC33CDVL64MC106 devices are listed below. 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 effect device reliability.

### Absolute Maximum Ratings

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 $V_{SS}$ (2) ..... -0.3V to ($V_{DD}$ + 0.3V)
Voltage on any 5V tolerant pin with respect to $V_{SS}$ (2) ..... -0.3V to +5.5V
Maximum current out of $V_{SS}$ pins ..... 300 mA
Maximum current into $V_{DD}$ pins (1) ..... 300 mA
Maximum current sunk/sourced by any regular I/O pin ..... 15 mA
Maximum current sunk/sourced by an I/O pin with increased current drive strength (RB1, RC8, RC9 and RD8) ..... 25 mA
Maximum current sunk by a group of I/Os between two $V_{SS}$ pins (3) ..... 75 mA
Maximum current sourced by a group of I/Os between two $V_{DD}$ pins (3) ..... 75 mA
Maximum current sunk by all I/Os (1,4) ..... 200 mA
Maximum current sourced by all I/Os (1,4) ..... 200 mA

**Note 1:** Maximum allowable current is a function of device maximum power dissipation (see Table 33-2).
**2:** See the **"Pin Diagrams"** section for the 5V tolerant pins.
**3:** Not applicable to $AV_{DD}$ and $AV_{SS}$ pins.
**4:** The maximum current sunk/sourced by all I/Os is limited by 150 mA.

## 33.1 DC Characteristics

**TABLE 33-1: dsPIC33CDVL64MC106 FAMILY OPERATING CONDITIONS**

| VDD Range | Temperature Range | Maximum CPU Clock Frequency |
|---|---|---|
| 3.0V to 3.6V | -40°C to +125°C | 100 MHz |

**TABLE 33-2: THERMAL OPERATING CONDITIONS**

| Rating | Symbol | Min. | 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 | +150 | °C |
| Operating Ambient Temperature Range | TA | -40 | +125 | °C |
| High-Temperature Devices | | | | |
| Operating Junction Temperature Range | TJ | -40 | +165 | °C |
| Operating Ambient Temperature Range | TA | -40 | +150 | °C |
| Power Dissipation:<br>Internal Chip Power Dissipation:<br>$P_{INT} = V_{DD} \times (I_{DD} - \Sigma I_{OH})$<br>I/O Pin Power Dissipation:<br>$I/O = \Sigma (\{V_{DD} - V_{OH}\} \times I_{OH}) + \Sigma (V_{OL} \times I_{OL})$ | PD | PINT + PI/O | | W |
| Maximum Allowed Power Dissipation | PDMAX | (TJ – TA)/θJA | | W |

**TABLE 33-3: PACKAGE THERMAL RESISTANCE(1)**

| Package | Symbol | Typ. | Unit |
|---|---|---|---|
| 64-Pin VGQFN 9x9 mm | θJA | 20.5 | °C/W |

**Note 1:** Junction to ambient thermal resistance, Theta-JA (θJA) numbers are achieved by package simulations.

**TABLE 33-4: OPERATING VOLTAGE SPECIFICATIONS**

**Operating Conditions (unless otherwise stated):**
-40°C ≤ TA ≤ +85°C for Industrial
-40°C ≤ TA ≤ +125°C for Extended

| Param No. | Symbol | Characteristic | Min. | Max. | Units | Conditions |
|---|---|---|---|---|---|---|
| DC10 | VDD | **Supply Voltage** | 3.0 | 3.6 | V | — |
| DC11 | AVDD | **Supply Voltage** | Greater of: VDD – 0.3 or 3.0 | Lesser of: VDD + 0.3 or 3.6 | V | The difference between the AVDD supply and VDD supply must not exceed ±300 mV at all times, including during device power-up. |
| DC16 | VPOR | **VDD Start Voltage** to Ensure Internal Power-on Reset Signal | — | VSS | V | — |
| DC17 | SVDD(2) | **VDD Rise Rate** to Ensure Internal Power-on Reset Signal | 0.03 | — | V/ms | 0V-3V in 100 ms |
| BO10 | VBOR(1) | **BOR Event** on VDD Transition High-to-Low | 2.68 | 2.99 | V | — |


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**TABLE 33-4: OPERATING VOLTAGE SPECIFICATIONS**

**Note 1:** Device is functional at $V_{BORMIN}$ < $V_{DD}$ < $V_{DDMIN}$. Analog modules (ADC and comparators) may have degraded performance. The $V_{BOR}$ parameter is for design guidance only and is not tested in manufacturing.

**2:** Failure to observe $SV_{DD}$ can result in the device remaining in Reset, even after $V_{DD}$ is raised past $V_{BORMAX}$.

**TABLE 33-5: OPERATING CURRENT (IDD)(2)**

| Parameter No. | Typ.(1) | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC20 | 5.5 | 6.6 | mA | -40°C | 3.3V | 10 MIPS (N = 1, N2 = 5, N3 = 2, M = 50, FVCO = 400 MHz, FPLLO = 40 MHz) |
| | 5.2 | 6.4 | mA | +25°C | | |
| | 5.7 | 11.9 | mA | +85°C | | |
| | 7.2 | 16 | mA | +125°C | | |
| DC21 | 7.1 | 8.4 | mA | -40°C | 3.3V | 20 MIPS (N = 1, N2 = 5, N3 = 1, M = 50, FVCO = 480 MHz, FPLLO = 80 MHz) |
| | 7.1 | 8.1 | mA | +25°C | | |
| | 7.5 | 13.4 | mA | +85°C | | |
| | 8.8 | 17.5 | mA | +125°C | | |
| DC22 | 10.6 | 12.6 | mA | -40°C | 3.3V | 40 MIPS (N = 1, N2 = 3, N3 = 1, M = 60, FVCO = 480 MHz, FPLLO = 160 MHz) |
| | 10.3 | 12.3 | mA | +25°C | | |
| | 11.6 | 17.1 | mA | +85°C | | |
| | 12.3 | 21.3 | mA | +125°C | | |
| DC23 | 15.4 | 18 | mA | -40°C | 3.3V | 70 MIPS (N = 1, N2 = 2, N3 = 1, M = 70, FVCO = 560 MHz, FPLLO = 280 MHz) |
| | 15.2 | 17.4 | mA | +25°C | | |
| | 16 | 22 | mA | +85°C | | |
| | 17.5 | 26.3 | mA | +125°C | | |
| DC24 | 19 | 22.5 | mA | -40°C | 3.3V | 90 MIPS (N = 1, N2 = 2, N3 = 1, M = 90, FVCO = 720 MHz, FPLLO = 360 MHz) |
| | 18.9 | 21.6 | mA | +25°C | | |
| | 19.7 | 26 | mA | +85°C | | |
| | 21.2 | 29.6 | mA | +125°C | | |
| DC25 | 20.7 | 22.4 | mA | -40°C | 3.3V | 100 MIPS (N = 1, N2 = 1, N3 = 1, M = 50, FVCO = 400 MHz, FPLLO = 400 MHz) |
| | 20.7 | 21.5 | mA | +25°C | | |
| | 21.4 | 25.4 | mA | +85°C | | |
| | 23 | 29.5 | mA | +125°C | | |

**Note 1:** Data in the “Typ.” column are for design guidance only and are not tested.

**2:** Base run current (IDD) is measured as follows:

- Oscillator is switched to EC+PLL mode in software.
- OSC1 pin is driven with external 8 MHz square wave with levels from 0.3V to VDD – 0.3V.
- OSC2 pin is configured as an I/O in the Configuration words (OSCIOFNC (FOSC[2]) = 0).
- FSCM is disabled (FCKSM[1:0] (FOSC[7:6]) = 01).
- Watchdog Timer is disabled (FWDTEN (FWDT[15]) = 0).
- All I/O pins (except OSC1) are configured as outputs and driving low.
- No peripheral modules are operating or being clocked (defined PMDx bits are all ‘1’s).
- JTAG is disabled (JTAGEN (FICD[5]) = 0).
- NOP instructions are executed.


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**TABLE 33-6: IDLE CURRENT (IIDLE)(2)**

| Parameter No. | Typ.(1) | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC30 | 4.5 | 5.4 | mA | -40°C | 3.3V | 10 MIPS (N = 1, N2 = 5, N3 = 2, M = 50, FVCO = 400 MHz, FPLLO = 40 MHz) |
| | 4.1 | 5.2 | mA | +25°C | | |
| | 4.7 | 9.1 | mA | +85°C | | |
| | 6.0 | 14.2 | mA | +125°C | | |
| DC31 | 4.8 | 5.9 | mA | -40°C | 3.3V | 20 MIPS (N = 1, N2 = 5, N3 = 1, M = 50, FVCO = 400 MHz, FPLLO = 80 MHz) |
| | 4.7 | 5.7 | mA | +25°C | | |
| | 5.0 | 9.6 | mA | +85°C | | |
| | 6.6 | 14.8 | mA | +125°C | | |
| DC32 | 6.2 | 7.3 | mA | -40°C | 3.3V | 40 MIPS (N = 1, N2 = 3, N3 = 1, M = 60, FVCO = 480 MHz, FPLLO = 160 MHz) |
| | 5.8 | 7.1 | mA | +25°C | | |
| | 6.5 | 11 | mA | +85°C | | |
| | 8.0 | 16.1 | mA | +125°C | | |
| DC33 | 7.8 | 9.3 | mA | -40°C | 3.3V | 70 MIPS (N = 1, N2 = 2, N3 = 1, M = 70, FVCO = 560 MHz, FPLLO = 280 MHz) |
| | 7.6 | 9.0 | mA | +25°C | | |
| | 8.1 | 12.8 | mA | +85°C | | |
| | 9.8 | 18 | mA | +125°C | | |
| DC34 | 9.3 | 11.4 | mA | -40°C | 3.3V | 90 MIPS (N = 1, N2 = 2, N3 = 1, M = 90, FVCO = 720 MHz, FPLLO = 360 MHz) |
| | 9.2 | 11.2 | mA | +25°C | | |
| | 10.0 | 14.5 | mA | +85°C | | |
| | 11.6 | 19.8 | mA | +125°C | | |
| DC35 | 10.0 | 12 | mA | -40°C | 3.3V | 100 MIPS (N = 1, N2 = 1, N3 = 1, M = 50, FVCO = 400 MHz, FPLLO = 400 MHz) |
| | 10.0 | 12 | mA | +25°C | | |
| | 10.7 | 13.4 | mA | +85°C | | |
| | 12.5 | 18.6 | mA | +125°C | | |

**Note 1:** Data in the “Typ.” column are for design guidance only and are not tested.

**2:** Base Idle current (IIDLE) is measured as follows:

- Oscillator is switched to EC+PLL mode in software.
- OSC1 pin is driven with external 8 MHz square wave with levels from 0.3V to VDD – 0.3V.
- OSC2 is configured as an I/O in the Configuration Words (OSCIOFNC (FOSC[2]) = 0).
- FSCM is disabled (FCKSM[1:0] (FOSC[7:6]) = 01).
- Watchdog Timer is disabled (FWDTEN (FWDT[15]) = 0).
- All I/O pins (except OSC1) are configured as outputs and driving low.
- No peripheral modules are operating or being clocked (defined PMDx bits are all ‘1’s).
- JTAG is disabled (JTAGEN (FICD[5]) = 0).
- NOP instructions are executed.

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**TABLE 33-7: POWER-DOWN CURRENT (IPD)(2)**

| Parameter No. | Typ.(1) | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC40(3,4) | 0.15 | 0.48 | mA | -40°C | 3.3V | VREGS bit (RCON[8]) = 0<br>LPWREN bit (VREGCON[15]) = 1 |
| | 0.23 | 1.1 | mA | +25°C | | |
| | 0.86 | 4.2 | mA | +85°C | | |
| DC41 | 0.9 | — | mA | -40°C | 3.3V | VREGS bit (RCON[8]) = 1<br>LPWREN bit (VREGCON[15]) = 1 |
| | 0.9 | — | mA | +25°C | | |
| | 1.5 | — | mA | +85°C | | |
| | 2.9 | 11 | mA | +125°C | | |

**Note 1:** Data in the "Typ." column are for design guidance only and are not tested.

**2:** Base Sleep current (IPD) is measured with:
- OSC1 pin is driven with external 8 MHz square wave with levels from 0.3V to VDD – 0.3V.
- OSC2 is configured as an I/O in the Configuration Words (OSCIOFNC (FOSC[2]) = 0).
- FSCM is disabled (FCKSM[1:0] (FOSC[7:6]) = 01).
- Watchdog Timer is disabled (FWDTEN (FWDT[15]) = 0).
- All I/O pins (except OSC1) are configured as outputs and driving low.
- No peripheral modules are operating or being clocked (defined PMDx bits are all '1's).
- JTAG is disabled (JTAGEN (FICD[5]) = 0).

**3:** The Regulator Standby mode, when the VREGS bit = 0, is operational only in industrial temperature range: -40°C ≤ TA ≤ +85°C.

**4:** The Regulator Low-Power mode, when LPWREN = 1, is operational only in industrial temperature range: -40°C ≤ TA ≤ +85°C.

**TABLE 33-8: DOZE CURRENT (IDOZE)**

| Parameter No. | Typ.(1) | Doze Ratio | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC70 | 12.1 | 1:2 | mA | -40°C | 3.3V | 70 MIPS (N = 1, N2 = 2, N3 = 1, M = 70, FVCO = 560 MHz, FPLLO = 280 MHz) |
| | 8.0 | 1:128 | mA | | | |
| | 12.0 | 1:2 | mA | +25°C | | |
| | 7.8 | 1:128 | mA | | | |
| | 12.4 | 1:2 | mA | +85°C | | |
| | 8.3 | 1:128 | mA | | | |
| | 13.8 | 1:2 | mA | +125°C | | |
| | 8.8 | 1:128 | mA | | | |
| DC71 | 15.8 | 1:2 | mA | -40°C | 3.3V | 100 MIPS (N = 1, N2 = 1, N3 = 1, M = 50, FVCO = 400 MHz, FPLLO = 400 MHz) |
| | 10.4 | 1:128 | mA | | | |
| | 15.7 | 1:2 | mA | +25°C | | |
| | 10.3 | 1:128 | mA | | | |
| | 16.6 | 1:2 | mA | +85°C | | |
| | 11.2 | 1:128 | mA | | | |
| | 18.1 | 1:2 | mA | +125°C | | |
| | 12.7 | 1:128 | mA | | | |

**Note 1:** Data in the "Typ." column are for design guidance only and are not tested.


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**TABLE 33-9: WATCHDOG TIMER DELTA CURRENT (ΔIWDT)(1)**

| Parameter No. | Typ. | Units | Conditions | |
|---|---|---|---|---|
| DC61 | 1 | µA | -40°C | 3.3V |
| | 2 | µA | +25°C | |
| | 4 | µA | +85°C | |
| | 11 | µA | +125°C | |

**Note 1:** The ΔIWDT current is the additional current consumed when the module is enabled. This current should be added to the base IPD current. All parameters are for design guidance only and are not tested.

**TABLE 33-10: PWM DELTA CURRENT(1)**

| Parameter No. | Typ. | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC100 | 5.59 | 6.8 | mA | -40°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 500 MHz), (VCO = 1000 MHz, PLLFBD = 125) |
| | 5.87 | 6.9 | mA | +25°C | | |
| | 5.99 | 7.4 | mA | +85°C | | |
| | 6.05 | 7.4 | mA | +125°C | | |
| DC101 | 4.52 | 6.2 | mA | -40°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 400 MHz), (VCO = 400 MHz, PLLFBD = 100) |
| | 4.68 | 6.5 | mA | +25°C | | |
| | 4.77 | 6.5 | mA | +85°C | | |
| | 4.81 | 6.7 | mA | +125°C | | |
| DC102 | 2.39 | 3.96 | mA | -40°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 200 MHz), (VCO = 200 MHz, PLLFBD = 50) |
| | 2.42 | 3.44 | mA | +25°C | | |
| | 2.47 | 3.4 | mA | +85°C | | |
| | 2.49 | 4.2 | mA | +125°C | | |
| DC103 | 1.24 | 2 | mA | -40°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 100 MHz), (VCO = 100 MHz, PLLFBD = 25) |
| | 1.26 | 2.1 | mA | +25°C | | |
| | 1.28 | 2.2 | mA | +85°C | | |
| | 1.31 | 2.2 | mA | +125°C | | |

**Note 1:** PLL current is not included. The PLL current will be the same if more than one PWM is running. All parameters are characterized but not tested during manufacturing.

**TABLE 33-11: ADC DELTA CURRENT(1)**

| Parameter No. | Typ. | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC120 | 5.35 | 5.9 | mA | -40°C | 3.3V | TAD = 14.3 ns (3.5 Msps conversion rate) |
| | 5.42 | 5.9 | mA | +25°C | | |
| | 5.44 | 5.7 | mA | +85°C | | |
| | 5.46 | 5.7 | mA | +125°C | | |

**Note 1:** Shared core continuous conversion. TAD = 14.3 ns (3.5 Msps conversion rate). Listed delta currents are for only one ADC core. All parameters are characterized but not tested during manufacturing.

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**TABLE 33-12: COMPARATOR + DAC DELTA CURRENT**

| Parameter No. | Typ. | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| DC130 | 1.38 | — | mA | -40°C | 3.3V | FPLLO @ 500 MHz(1) |
| | 1.28 | — | mA | +25°C | | |
| | 1.30 | — | mA | +85°C | | |
| | 1.37 | — | mA | +125°C | | |

**Note 1:** Listed delta currents are for only one comparator + DAC instance. All parameters are characterized but not tested during manufacturing.

**TABLE 33-13: OP AMP DELTA CURRENT(1)**

| Parameter No. | Typ. | Max. | Units | Conditions | |
|---|---|---|---|---|---|
| DC140 | 0.21 | 0.42 | mA | -40°C | 3.3V |
| | 0.22 | 0.44 | mA | +25°C | |
| | 0.23 | 0.52 | mA | +85°C | |
| | 0.47 | 0.89 | mA | +125°C | |

**Note 1:** Listed delta currents are for only one op amp instance. All parameters are characterized but not tested during manufacturing.


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**TABLE 33-14: I/O PIN INPUT SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | |
|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Max.** | **Units** | **Conditions** |
| DI10 | VIL | **Input Low-Level Voltage** | | | | |
| | | Any I/O Pin and $\overline{MCLR}$ | VSS | 0.2 VDD | V | |
| | | I/O Pins with SDAx, SCLx | VSS | 0.3 VDD | V | SMBus disabled |
| | | I/O Pins with SDAx, SCLx | VSS | 0.8 | V | SMBus enabled |
| | | I/O Pins with SDAx, SCLx | VSS | 0.8 | V | SMBus 3.0 enabled |
| DI20 | VIH | **Input High-Level Voltage**(1) | | | | |
| | | I/O Pins Not 5V Tolerant | 0.8 VDD | VDD | V | |
| | | I/O Pins 5V Tolerant and $\overline{MCLR}$ | 0.8 VDD | 5.5 | V | |
| | | I/O Pins 5V Tolerant with SDAx, SCLx | 0.8 VDD | 5.5 | V | SMBus disabled |
| | | I/O Pins 5V Tolerant with SDAx, SCLx | 2.1 | 5.5 | V | SMBus enabled |
| | | I/O Pins 5V Tolerant with SDAx, SCLx | 1.35 | VDD | V | SMBus 3.0 enabled |
| | | I/O Pins Not 5V Tolerant with SDAx, SCLx | 0.8 VDD | VDD | V | SMBus disabled |
| | | I/O Pins Not 5V Tolerant with SDAx, SCLx | 2.1 | VDD | V | SMBus enabled |
| | | I/O Pins Not 5V Tolerant with SDAx, SCLx | 1.35 | VDD | V | SMBus 3.0 enabled |
| DI30 | ICNPU | **Input Current with Pull-up Resistor Enabled**(2) | 175 | 545 | µA | VDD = 3.3V, VPIN = VSS |
| DI31 | ICNPD | **Input Current with Pull-Down Resistor Enabled**(2) | 65 | 360 | µA | VDD = 3.3V, VPIN = VDD |
| DI50 | IIL | **Input Leakage Current**<br>I/O Pins and $\overline{MCLR}$ Pin | -700(3) | — | nA | VPIN = VSS |
| | | | — | 700 | nA | VPIN = VDD |

**Note 1:** See the **"Pin Diagrams"** section for the 5V tolerant I/O pins.

**2:** Characterized but not tested.

**3:** Negative current is defined as current sourced by the pin.

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**TABLE 33-15: I/O PIN INPUT INJECTION CURRENT SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | |
|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Max.** | **Units** | **Conditions** |
| DI60a | IICL | **Input Low Injection Current** | 0 | -5(1,4) | mA | This parameter applies to all pins. |
| DI60b | IICH | **Input High Injection Current** | 0 | +5(2,3,4) | mA | This parameter applies to all pins, except all 5V tolerant pins. |
| DI60c | ∑IICT | **Total Input Injection Current (sum of all I/O and control pins)** | -20(5) | +20(5) | mA | Absolute instantaneous sum of all ± input injection currents from all I/O pins.<br>Σ ( \| IICL \| + \| IICH \| ) ≤ ∑IICT |

**Note 1:** VIL Source < (VSS – 0.3).

**2:** VIH Source > (VDD + 0.3) for non-5V tolerant pins only.

**3:** 5V tolerant pins do not have an internal high-side diode to VDD, and, therefore, cannot tolerate any "positive" input injection current.

**4:** Injection currents can affect the ADC results.

**5:** Any number and/or combination of I/O pins, not excluded under IICL or IICH conditions, are permitted in the sum.

**TABLE 33-16: I/O PIN OUTPUT SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **Param.** | **Symbol** | **Characteristic** | **Typ.(1)** | **Units** | **Conditions** |
| DO10 | VOL | **Sink Driver Voltage** | 0.2 | V | ISINK = 3.0 mA, VDD = 3.3V |
| | | | 0.4 | V | ISINK = 6.0 mA, VDD = 3.3V |
| | | | 0.6 | V | ISINK = 9.0 mA, VDD = 3.3V |
| | | **Sink Driver Voltage** for RB1, RC8, RC9 and RD8 Pins | 0.25 | V | ISINK = 6.0 mA, VDD = 3.3V |
| | | | 0.5 | V | ISINK = 12.0 mA, VDD = 3.3V |
| | | | 0.75 | V | ISINK = 18.0 mA, VDD = 3.3V |
| DO20 | VOH | **Source Driver Voltage** | 3.1 | V | ISOURCE = 3.0 mA, VDD = 3.3V |
| | | | 2.9 | V | ISOURCE = 6.0 mA, VDD = 3.3V |
| | | | 2.7 | V | ISOURCE = 9.0 mA, VDD = 3.3V |
| | | **Source Driver Voltage** for RB1, RC8, RC9 and RD8 Pins | 3.1 | V | ISOURCE = 6.0 mA, VDD = 3.3V |
| | | | 2.8 | V | ISOURCE = 12.0 mA, VDD = 3.3V |
| | | | 2.6 | V | ISOURCE = 18.0 mA, VDD = 3.3V |

**Note 1:** Data in the "Typ." column are at 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

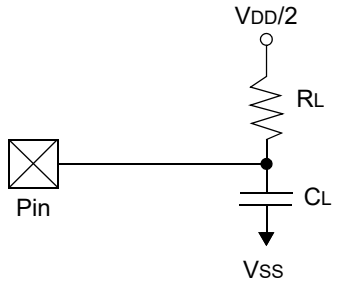

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**TABLE 33-17: PROGRAM FLASH MEMORY SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | |
|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Max.** | **Units** | **Conditions** |
| | | **Program Flash Memory** | | | | |
| D130 | EP | Cell Endurance | 10,000 | — | E/W | |
| D134 | TRETD | Characteristic Retention | 20 | — | Year | |
| D137a | TPE | Self-Timed Page Erase Time | — | 20 | ms | |
| D137b | TCE | Self-Timed Chip Erase Time | — | 20 | ms | |
| D138a | TWW | Self-Timed Double-Word Write Cycle Time | — | 52.3 | µs | 6 bytes, data are not all ‘1’s |
| D138b | TRW | Self-Timed Row Write Cycle Time | — | 2.2 | ms | 384 bytes, data are not all ‘1’s |

## 33.2 AC Characteristics and Timing Parameters

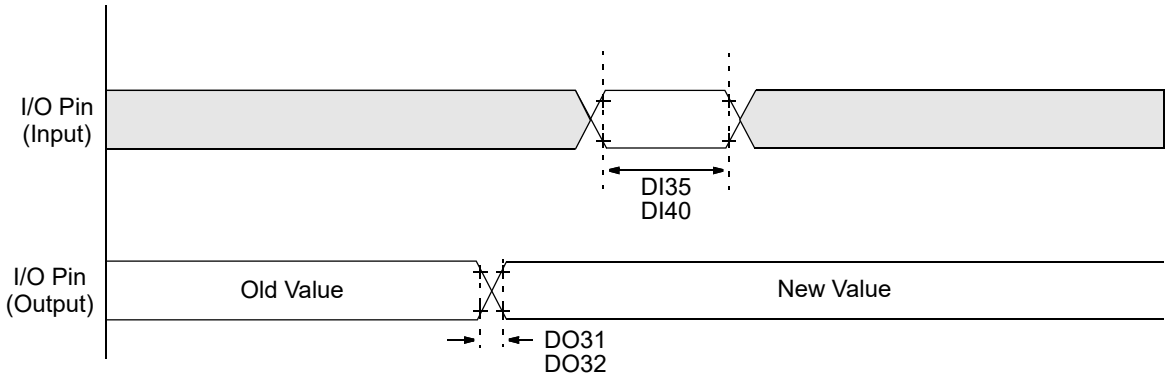
**FIGURE 33-1: LOAD CONDITIONS FOR I/O SPECIFICATIONS**




$R_L$ = 464Ω
$C_L$ = 50 pF


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**FIGURE 33-2: I/O TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.

**TABLE 33-18: I/O TIMING REQUIREMENTS**

**Operating Conditions (unless otherwise stated):**
3.0V ≤ VDD ≤ 3.6V,
-40°C ≤ TA ≤ +85°C for Industrial
-40°C ≤ TA ≤ +125°C for Extended

| Param No. | Symbol | Characteristic | Min. | Max. | Units |
|---|---|---|---|---|---|
| DO31 | TIOR | Port Output Rise Time(1) | — | 10 | ns |
| DO32 | TIOF | Port Output Fall Time(1) | — | 10 | ns |
| DI35 | TINP | INTx Input Pins High or Low Time | 20 | — | ns |
| DI40 | TRBP | I/O and CNx Inputs High or Low Time | 2 | — | TCY |

**Note 1:** This parameter is characterized but not tested in manufacturing.

**FIGURE 33-3: EXTERNAL CLOCK TIMING**

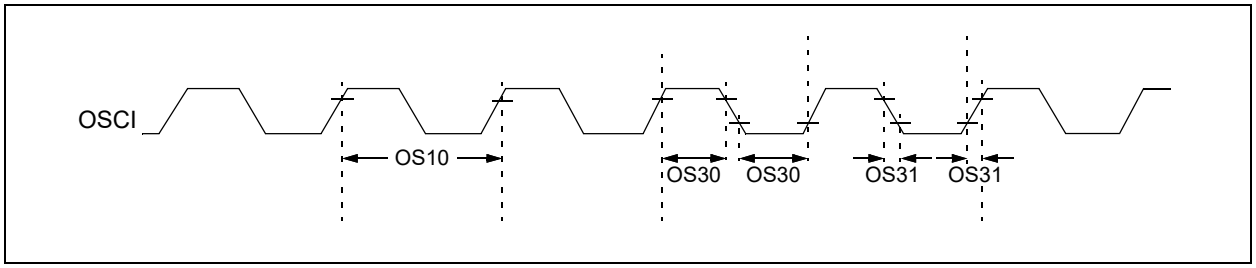



**TABLE 33-19: EXTERNAL CLOCK TIMING REQUIREMENTS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | |
|---|---|---|---|---|---|---|
| **Param No.** | **Sym** | **Characteristic** | **Min.** | **Max.** | **Units** | **Conditions** |
| OS10 | FIN | External CLKI Frequency | DC | 64 | MHz | EC |
| | | Oscillator Crystal Frequency | 3.5 | 10 | MHz | XT |
| | | | 10 | 32 | MHz | HS |
| OS30 | TosL, TosH | External Clock in (OSCI) High or Low Time | 0.45 x OS10 | 0.55 x OS10 | ns | EC |
| OS31 | TosR, TosF | External Clock in (OSCI) Rise or Fall Time(1) | — | 10 | ns | EC |

**Note 1:** This parameter is characterized but not tested in manufacturing.

**TABLE 33-20: PLL CLOCK TIMING SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Max.** | **Units** |
| OS50 | FPLLI | PLL Input Frequency Range | 8 | 64 | MHz |
| OS51 | FPFD | Phase-Frequency Detector Input Frequency (after first divider) | 8 | FVCO/16 | MHz |
| OS52 | FVCO | VCO Output Frequency | 400 | 1600 | MHz |
| OS53 | TLOCK | Lock Time for PLL(1) | — | 250 | µS |

**Note 1:** This parameter is characterized but not tested in manufacturing.


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**TABLE 33-21: FRC OSCILLATOR SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Typ(2)** | **Max** | **Units** | **Conditions** |
| F20 | AFRC | FRC Accuracy @ 8 MHz(1) | -2.0 | — | 2.0 | % | -40°C ≤ TA ≤ -5°C |
| | | | -1.5 | — | 1.5 | % | -5°C ≤ TA ≤ +85°C |
| | | | -2.0 | — | 2.0 | % | +85°C ≤ TA ≤ +125°C |
| F21 | TFRC | FRC Oscillator Start-up Time(3) | — | — | 15 | µS | — |
| F22 | STUNE | OSCTUN Step-Size | — | 0.05 | — | %/bit | — |

**Note 1:** To achieve this accuracy, physical stress applied to the microcontroller package (ex., by flexing the PCB) must be kept to a minimum.

**2:** Data in the “Typ” column are 3.3V, +25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

**3:** This parameter is characterized but not tested in manufacturing.

**TABLE 33-22: BFRC OSCILLATOR SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min** | **Max** | **Units** |
| F40 | ABFRC | BFRC Accuracy @ 8 MHz | -17 | 17 | % |

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**FIGURE 33-4: BOR AND MASTER CLEAR RESET TIMING CHARACTERISTICS**

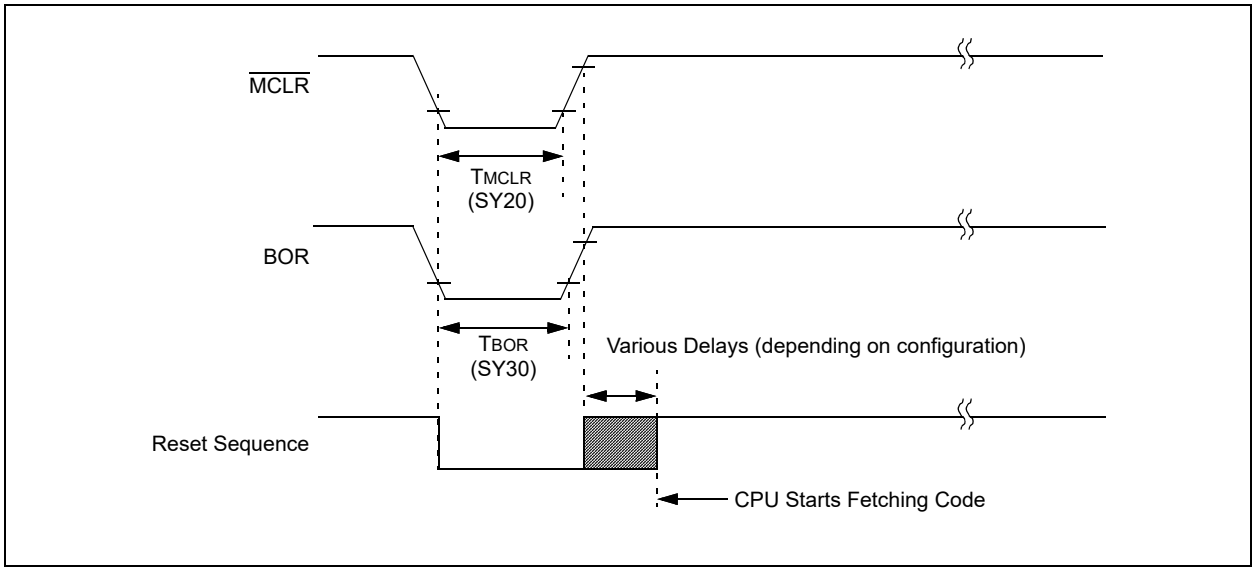



**TABLE 33-23: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER TIMING REQUIREMENTS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-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 | — | 200 | — | µs | FNOSC[2:0] are FRC |
| SY10 | TOST | Oscillator Start-up | — | 1024 TOSC | — | — | TOSC = OSCI period |
| SY13 | TIOZ | I/O High-Impedance from $\overline{\text{MCLR}}$ Low or Watchdog Timer Reset | — | 1.5 | — | 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 | — | — | 40 | µs | — |
| SY37 | TOSCDFRC | FRC Oscillator Start-up Delay | — | — | 15 | µs | From POR event |
| SY38 | TOSCDLPRC | LPRC Oscillator Start-up Delay | — | — | 50 | µs | From Reset event |

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

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


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**FIGURE 33-5: HIGH-SPEED PWMx MODULE TIMING CHARACTERISTICS**

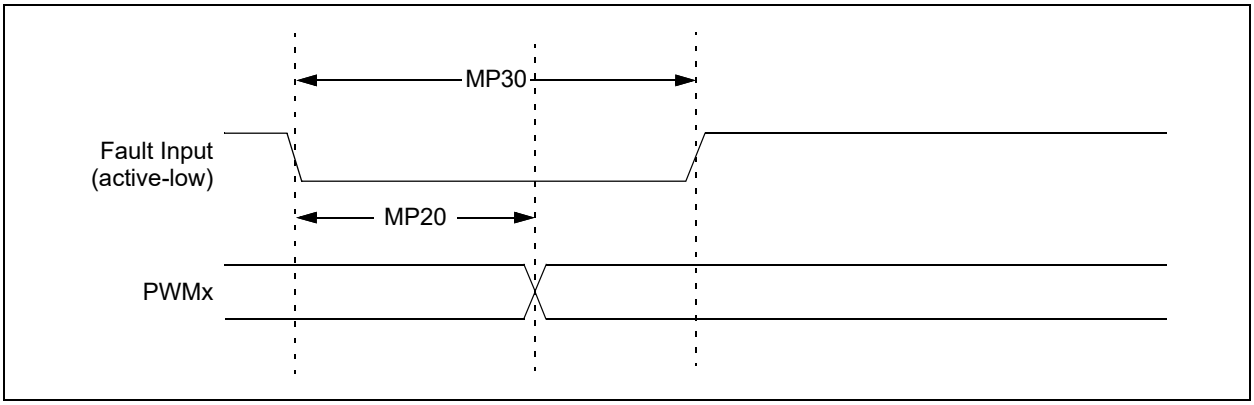



**TABLE 33-24: HIGH-SPEED PWMx MODULE TIMING REQUIREMENTS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Max.** | **Units** |
| MP10 | FIN | PWM Input Frequency(2) | — | 500 | MHz |
| MP20 | TFD | Fault Input ↓ to PWMx I/O Change | — | 26 | ns |
| MP30 | TFH | Fault Input Pulse Width | 8 | — | ns |

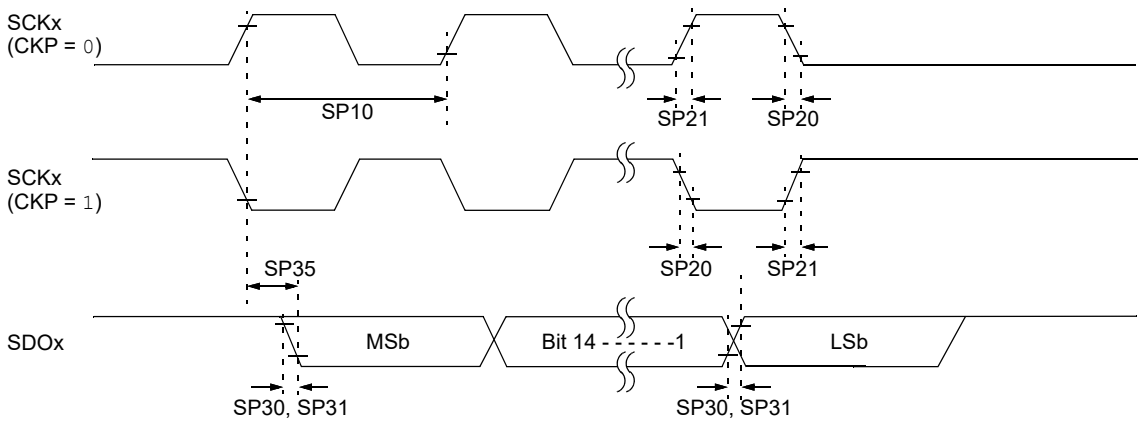
**Note 1:** These parameters are characterized but not tested in manufacturing.

**2:** Input frequency of 500 MHz must be used for High-Resolution mode.

**TABLE 33-25: SPIx MAXIMUM DATA/CLOCK RATE SUMMARY**

| SPI Host Transmit Only (Half-Duplex) | SPI Host Transmit/Receive (Full-Duplex) | SPI Client Transmit/Receive (Full-Duplex) | CKE |
|---|---|---|---|
| Figure 33-6 Table 33-26 | — | — | 0 |
| Figure 33-7 Table 33-26 | — | — | 1 |
| — | Figure 33-8 Table 33-27 | — | 0 |
| — | Figure 33-9 Table 33-28 | — | 1 |
| — | — | Figure 33-10 Table 33-30 | 0 |
| — | — | Figure 33-11 | 1 |

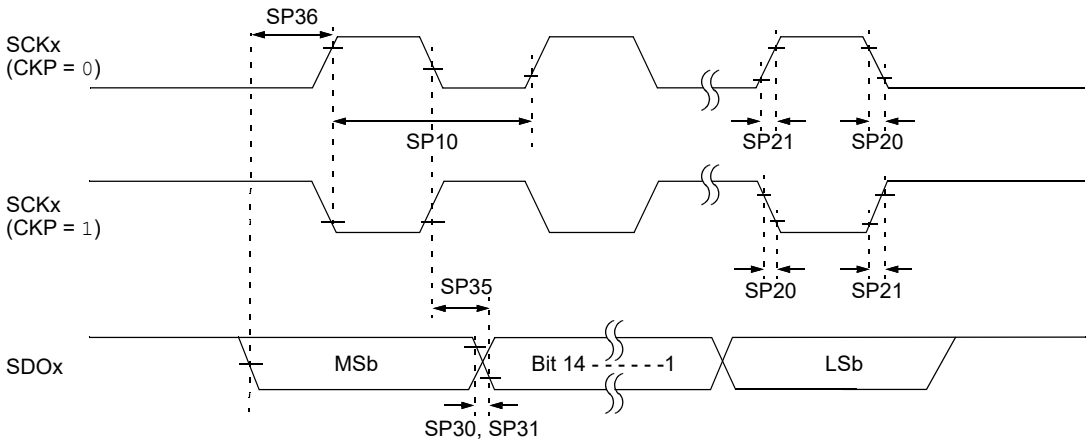
**FIGURE 33-6: SPIx HOST MODE (HALF-DUPLEX, TRANSMIT ONLY, CKE = 0) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.


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**FIGURE 33-7: SPIx HOST MODE (HALF-DUPLEX, TRANSMIT ONLY, CKE = 1) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.

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

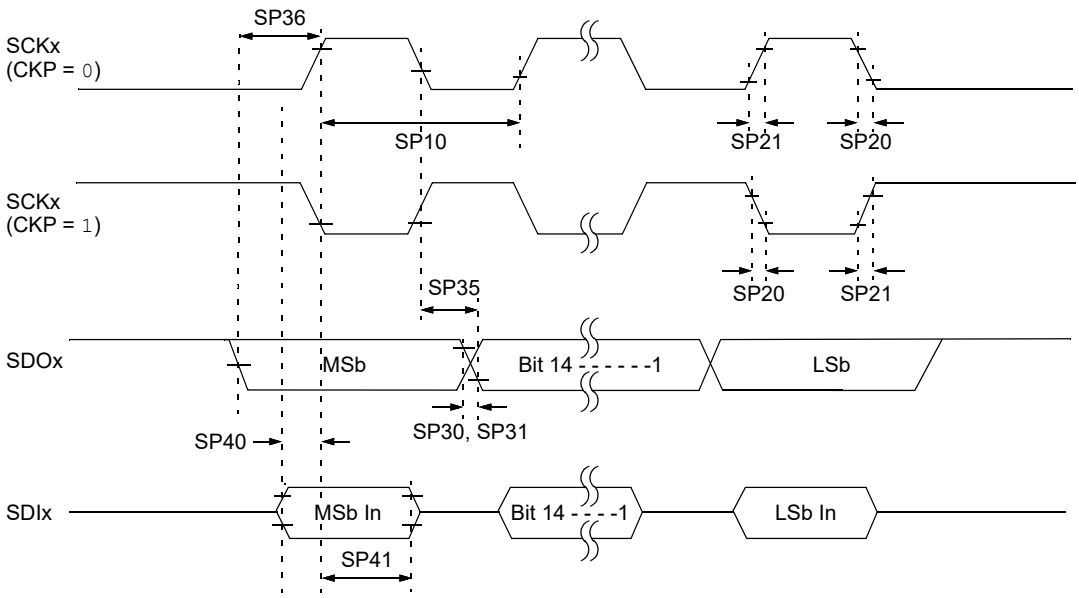
**Operating Conditions: 3.0V to 3.6V (unless otherwise stated)**
Operating temperature -40°C ≤ TA ≤ +85°C for Industrial
-40°C ≤ TA ≤ +125°C for Extended

| Param No. | Symbol | Characteristic(1) | Min. | Typ.(2) | Max. | Units | Conditions |
|---|---|---|---|---|---|---|---|
| SP10 | FscP | Maximum SCKx Frequency | — | — | 15 | MHz | Using PPS pins |
| | | | — | — | 40 | MHz | SPIx dedicated pins |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See Parameter DO31 |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 |
| 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 | Using PPS pins |
| | | | 3 | — | — | ns | SPIx dedicated pins |

**Note 1:** These parameters are characterized but not tested in manufacturing.
**2:** Data in the "Typ." column are at 3.3V, +25°C unless otherwise stated.

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**FIGURE 33-8: SPIx HOST MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 1) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.

**TABLE 33-27: SPIx HOST MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 1) TIMING REQUIREMENTS**

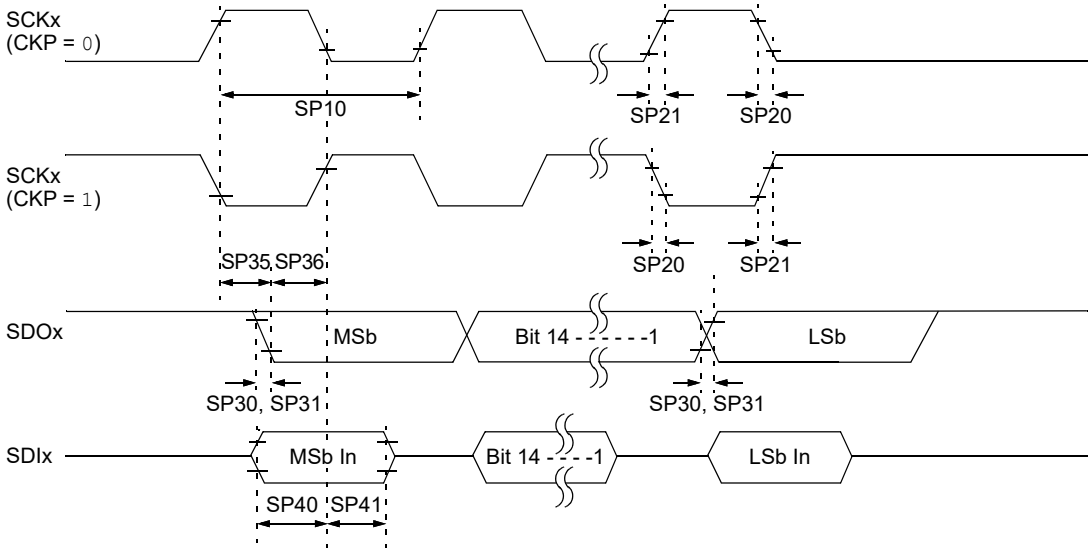
| **Operating Conditions: 3.0V to 3.6V (unless otherwise stated)**<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Frequency | — | — | 15 | MHz | Using PPS pins |
| | | | — | — | 40 | MHz | SPIx dedicated pins |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See Parameter DO31 |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 |
| 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 | Using PPS pins |
| | | | 3 | — | — | ns | SPIx dedicated pins |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 10 | — | — | ns | SPIx dedicated pins |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 15 | — | — | ns | SPIx dedicated pins |

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

**2:** Data in the "Typ." column are at 3.3V, +25°C unless otherwise stated.


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**FIGURE 33-9: SPIx HOST MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 1) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.

**TABLE 33-28: SPIx HOST MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 1) TIMING REQUIREMENTS**

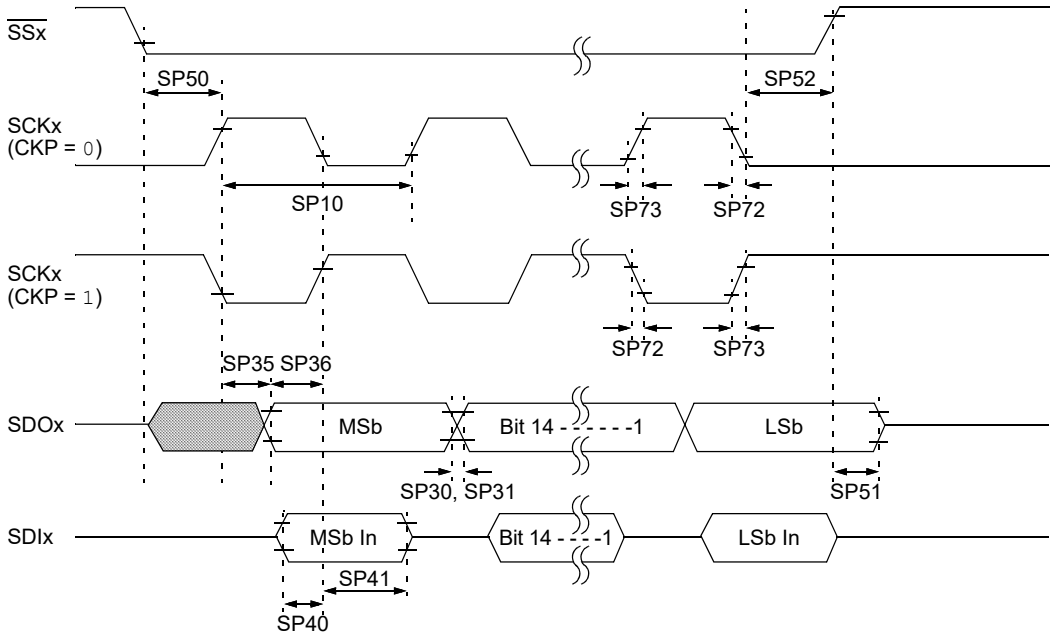
| **Operating Conditions: 3.0V to 3.6V (unless otherwise stated)**<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Frequency | — | — | 15 | MHz | Using PPS pins |
| | | | — | — | 40 | MHz | SPIx dedicated pins |
| SP20 | TscF | SCKx Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP21 | TscR | SCKx Output Rise Time | — | — | — | ns | See Parameter DO31 |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 |
| 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 | Using PPS pins |
| | | | 20 | — | — | ns | SPIx dedicated pins |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 10 | — | — | ns | SPIx dedicated pins |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 15 | — | — | ns | SPIx dedicated pins |

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

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

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**FIGURE 33-10: SPIx CLIENT MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 0) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.


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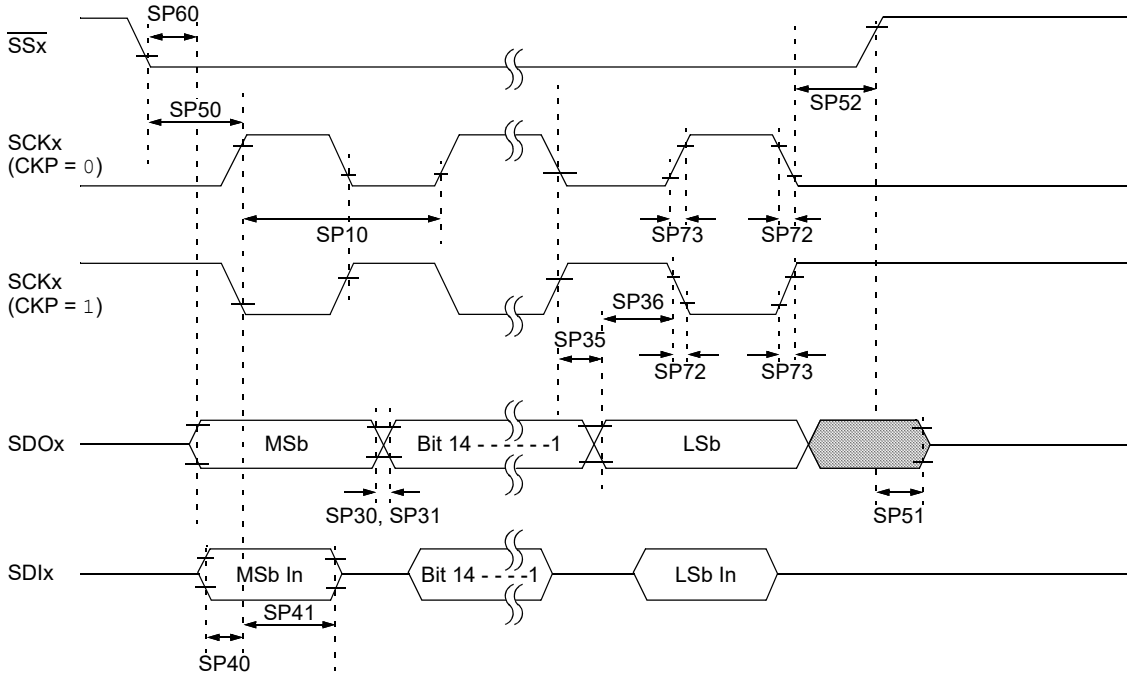
**TABLE 33-29: SPIx CLIENT MODE (FULL-DUPLEX, CKE = 0, CKP = x, SMP = 0) TIMING REQUIREMENTS**

| **Operating Conditions: 3.0V to 3.6V (unless otherwise stated)**<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic[1]** | **Min.** | **Typ.[2]** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Input Frequency | — | — | 15 | MHz | Using PPS pins |
| | | | — | — | 40 | MHz | SPIx dedicated pins |
| SP72 | TscF | SCKx Input Fall Time | — | — | — | ns | See Parameter DO32 |
| SP73 | TscR | SCKx Input Rise Time | — | — | — | ns | See Parameter DO31 |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 |
| 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 | Using PPS pins |
| | | | 20 | — | — | ns | SPIx dedicated pins |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 10 | — | — | ns | SPIx dedicated pins |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 15 | — | — | ns | SPIx dedicated pins |
| SP50 | TssL2scH, TssL2scL | $\overline{SSx}$ ↓ to SCKx ↑ or SCKx ↓ Input | 120 | — | — | ns | — |
| SP51 | TssH2doZ | $\overline{SSx}$ ↑ to SDOx Output High-Impedance | 8 | — | 50 | ns | — |
| SP52 | TscH2ssH, TscL2ssH | $\overline{SSx}$ ↑ After SCKx Edge | 1.5 TCY + 40 | — | — | ns | — |

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

**2:** Data in the "Typ." column are at 3.3V, +25°C unless otherwise stated.

**FIGURE 33-11: SPIx CLIENT MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 0) TIMING CHARACTERISTICS**




**Note:** Refer to Figure 33-1 for load conditions.


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**TABLE 33-30: SPIx CLIENT MODE (FULL-DUPLEX, CKE = 1, CKP = x, SMP = 0) TIMING REQUIREMENTS**

| **Operating Conditions: 3.0V to 3.6V (unless otherwise stated)**<br>Operating temperature -40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Typ.(2)** | **Max.** | **Units** | **Conditions** |
| SP10 | FscP | Maximum SCKx Input Frequency | — | — | 15 | MHz | Using PPS pins |
| | | | — | — | 40 | MHz | SPIx dedicated pins |
| SP72 | TscF | SCKx Input Fall Time | — | — | — | ns | See Parameter DO32 |
| SP73 | TscR | SCKx Input Rise Time | — | — | — | ns | See Parameter DO31 |
| SP30 | TdoF | SDOx Data Output Fall Time | — | — | — | ns | See Parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time | — | — | — | ns | See Parameter DO31 |
| 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 | Using PPS pins |
| | | | 20 | — | — | ns | SPIx dedicated pins |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 10 | — | — | ns | SPIx dedicated pins |
| SP41 | TscH2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 30 | — | — | ns | Using PPS pins |
| | | | 15 | — | — | ns | SPIx dedicated pins |
| SP50 | TssL2scH, TssL2scL | $\overline{SSx}$ ↓ to SCKx ↑ or SCKx ↓ Input | 120 | — | — | ns | — |
| SP51 | TssH2doZ | $\overline{SSx}$ ↑ to SDOx Output High-Impedance | 8 | — | 50 | ns | — |
| SP52 | TscH2ssH, TscL2ssH | $\overline{SSx}$ ↑ After SCKx Edge | 1.5 TCY + 40 | — | — | ns | — |
| SP60 | TssL2doV | $\overline{SDOx}$ Data Output Valid After $\overline{SSx}$ Edge | — | — | 50 | ns | — |

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

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

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**FIGURE 33-12: I2Cx BUS START/STOP BITS TIMING CHARACTERISTICS (MASTER MODE)**

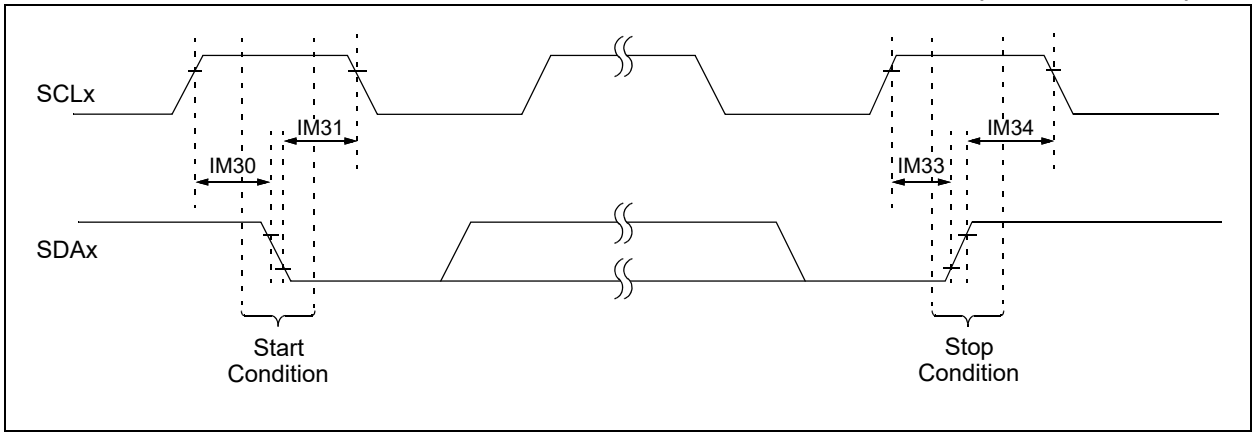
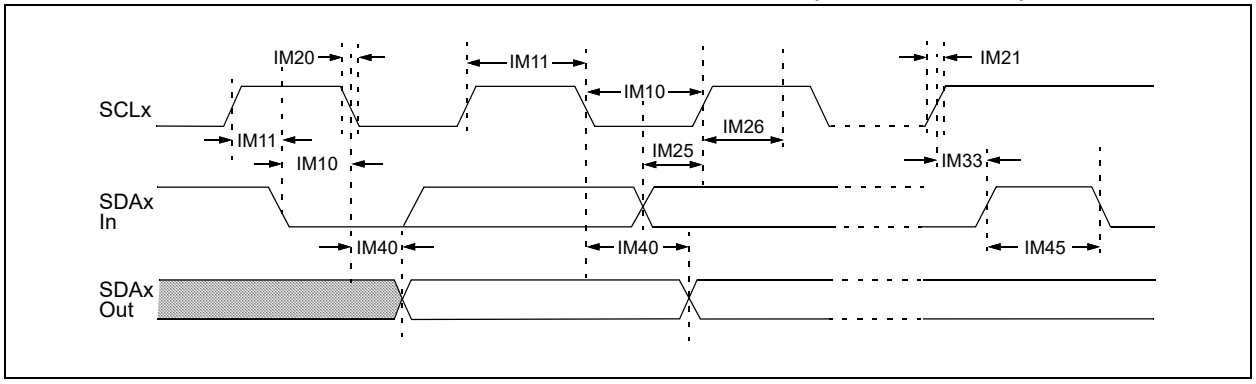



**FIGURE 33-13: I2Cx BUS DATA TIMING CHARACTERISTICS (MASTER MODE)**





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**TABLE 33-31: I2Cx BUS DATA TIMING REQUIREMENTS (MASTER MODE)**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | | **Min.(1)** | **Max.** | **Units** | **Conditions** |
| IM10 | TLO:SCL | Clock Low Time | 100 kHz mode | TCY * (BRG + 1) | — | µs | — |
| | | | 400 kHz mode | TCY * (BRG + 1) | — | µs | |
| | | | 1 MHz mode | TCY * (BRG + 1) | — | µs | |
| IM11 | THI:SCL | Clock High Time | 100 kHz mode | TCY * (BRG + 1) | — | µs | — |
| | | | 400 kHz mode | TCY * (BRG + 1) | — | µs | |
| | | | 1 MHz mode | TCY * (BRG + 1) | — | µs | |
| IM20 | TF:SCL | SDAx and SCLx Fall Time | 100 kHz mode | — | 300 | ns | — |
| | | | 400 kHz mode | 20 x (VDD/5.5V) | 300 | ns | |
| | | | 1 MHz mode | 20 x (VDD/5.5V) | 120 | ns | |
| IM21 | TR:SCL | SDAx and SCLx Rise Time | 100 kHz mode | — | 1000 | ns | — |
| | | | 400 kHz mode | 20 + 0.1 CB | 300 | ns | |
| | | | 1 MHz mode | — | 120 | ns | |
| IM25 | TSU:DAT | Data Input Setup Time | 100 kHz mode | 250 | — | ns | — |
| | | | 400 kHz mode | 100 | — | ns | |
| | | | 1 MHz mode | 50 | — | ns | |
| IM26 | THD:DAT | Data Input Hold Time | 100 kHz mode | 0 | — | µs | — |
| | | | 400 kHz mode | 0 | 0.9 | µs | |
| | | | 1 MHz mode | 0 | 0.3 | µs | |
| IM30 | TSU:STA | Start Condition Setup Time | 100 kHz mode | TCY * (BRG + 1) | — | µs | Only relevant for Repeated Start condition |
| | | | 400 kHz mode | TCY * (BRG + 1) | — | µs | |
| | | | 1 MHz mode | TCY * (BRG + 1) | — | µs | |
| IM31 | THD:STA | Start Condition Hold Time | 100 kHz mode | TCY * (BRG + 1) | — | µs | After this period, the first clock pulse is generated |
| | | | 400 kHz mode | TCY * (BRG + 1) | — | µs | |
| | | | 1 MHz mode | TCY * (BRG + 1) | — | µs | |
| IM33 | TSU:STO | Stop Condition Setup Time | 100 kHz mode | TCY * (BRG + 1) | — | µs | |
| | | | 400 kHz mode | TCY * (BRG + 1) | — | µs | |
| | | | 1 MHz mode | TCY * (BRG + 1) | — | µs | |
| IM34 | THD:STO | Stop Condition Hold Time | 100 kHz mode | TCY * (BRG + 1) | — | ns | |
| | | | 400 kHz mode | TCY * (BRG + 1) | — | ns | |
| | | | 1 MHz mode | TCY * (BRG + 1) | — | ns | |
| IM40 | TAA:SCL | Output Valid from Clock | 100 kHz mode | — | 3450 | ns | |
| | | | 400 kHz mode | — | 900 | ns | |
| | | | 1 MHz mode | — | 450 | ns | |
| IM45 | TBF:SDA | Bus Free Time | 100 kHz mode | 4.7 | — | µs | The amount of time the bus must be free before a new transmission can start |
| | | | 400 kHz mode | 1.3 | — | µs | |
| | | | 1 MHz mode | 0.5 | — | µs | |
| IM50 | CB | Bus Capacitive Loading | 100 kHz mode | — | 400 | pF | |
| | | | 400 kHz mode | — | 400 | pF | |
| | | | 1 MHz mode | — | 10 | pF | |
| IM51 | TPGD | Pulse Gobbler Delay | | 65 | 390 | ns | |

**Note 1:** BRG is the value of the $I^2C$ Baud Rate Generator.

**FIGURE 33-14: I2Cx BUS START/STOP BITS TIMING CHARACTERISTICS (SLAVE MODE)**

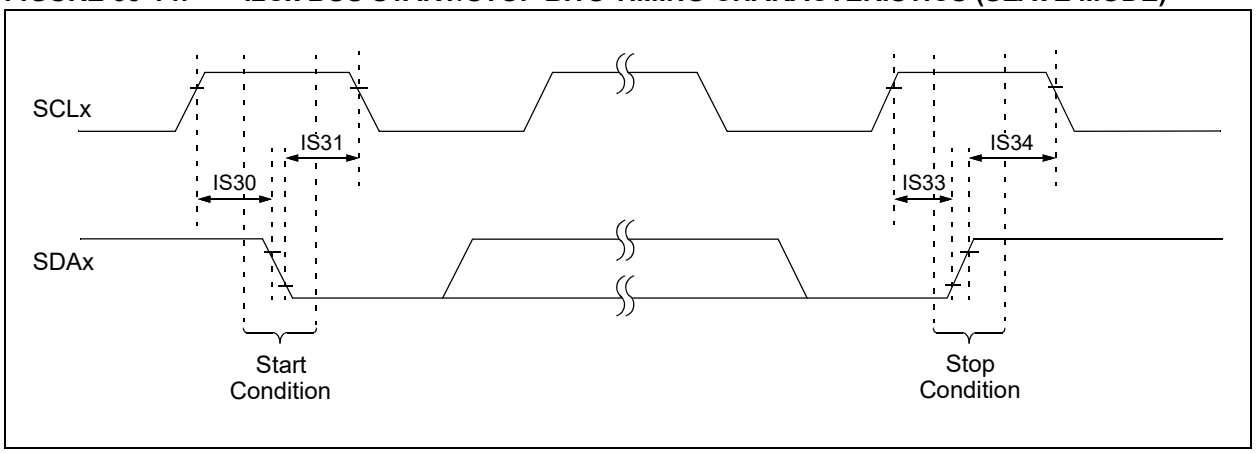
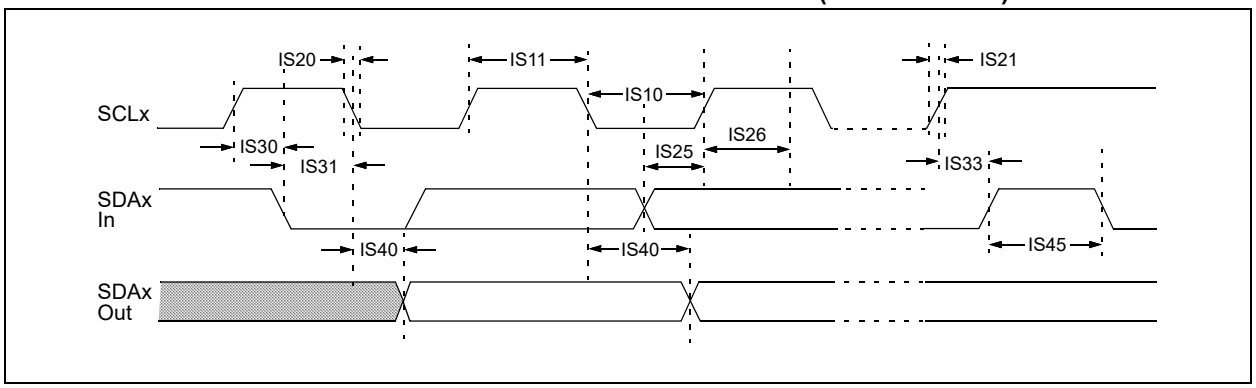



**FIGURE 33-15: I2Cx BUS DATA TIMING CHARACTERISTICS (SLAVE MODE)**





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**TABLE 33-32: I2Cx BUS DATA TIMING REQUIREMENTS (SLAVE MODE)**

**Operating Conditions (unless otherwise stated):**
3.0V ≤ $V_{DD}$ ≤ 3.6V,
-40°C ≤ $T_A$ ≤ +85°C for Industrial
-40°C ≤ $T_A$ ≤ +125°C for Extended

| Param No. | Symbol | Characteristics | | Min. | Max. | Units | Conditions |
|---|---|---|---|---|---|---|---|
| IS10 | $T_{LO:SCL}$ | Clock Low Time | 100 kHz mode | 4.7 | — | µs | CPU clock must be a minimum 800 kHz. |
| | | | 400 kHz mode | 1.3 | — | µs | CPU clock must be a minimum 3.2 MHz. |
| | | | 1 MHz mode | 0.5 | — | µs | |
| IS11 | $T_{HI:SCL}$ | Clock High Time | 100 kHz mode | 4.0 | — | µs | CPU clock must be a minimum 800 kHz. |
| | | | 400 kHz mode | 0.6 | — | µs | CPU clock must be a minimum 3.2 MHz. |
| | | | 1 MHz mode | 0.26 | — | µs | |
| IS20 | $T_{F:SCL}$ | SDAx and SCLx Fall Time | 100 kHz mode | — | 300 | ns | |
| | | | 400 kHz mode | 20 x ($V_{DD}$/5.5V) | 300 | ns | |
| | | | 1 MHz mode | 20 x ($V_{DD}$/5.5V) | 120 | ns | |
| IS21 | $T_{R:SCL}$ | SDAx and SCLx Rise Time | 100 kHz mode | — | 1000 | ns | |
| | | | 400 kHz mode | 20 + 0.1 $C_B$ | 300 | ns | |
| | | | 1 MHz mode | — | 120 | ns | |
| IS25 | $T_{SU:DAT}$ | Data Input Setup Time | 100 kHz mode | 250 | — | ns | |
| | | | 400 kHz mode | 100 | — | ns | |
| | | | 1 MHz mode | 50 | — | ns | |
| IS26 | $T_{HD:DAT}$ | Data Input Hold Time | 100 kHz mode | 0 | — | ns | |
| | | | 400 kHz mode | 0 | 0.9 | µs | |
| | | | 1 MHz mode | 0 | 0.3 | µs | |
| IS30 | $T_{SU:STA}$ | 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 | 0.26 | — | µs | |
| IS31 | $T_{HD:STA}$ | 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 | 0.26 | — | µs | |
| IS33 | $T_{SU:STO}$ | Stop Condition Setup Time | 100 kHz mode | 4.0 | — | µs | |
| | | | 400 kHz mode | 0.6 | — | µs | |
| | | | 1 MHz mode | 0.26 | — | µs | |
| IS34 | $T_{HD:STO}$ | Stop Condition Hold Time | 100 kHz mode | > 0 | — | µs | |
| | | | 400 kHz mode | > 0 | — | µs | |
| | | | 1 MHz mode | > 0 | — | µs | |
| IS40 | $T_{AA:SCL}$ | Output Valid from Clock | 100 kHz mode | 0 | 3.45 | µs | |
| | | | 400 kHz mode | 0 | 0.9 | µs | |
| | | | 1 MHz mode | 0 | 0.45 | µs | |
| IS45 | $T_{BF:SDA}$ | Bus Free Time | 100 kHz mode | 4.7 | — | µs | The amount of time the bus must be free before a new transmission can start. |
| | | | 400 kHz mode | 1.3 | — | µs | |
| | | | 1 MHz mode | 0.5 | — | µs | |
| IS50 | $C_B$ | Bus Capacitive Loading | 100 kHz mode | — | 400 | pF | |
| | | | 400 kHz mode | — | 400 | pF | |
| | | | 1 MHz mode | — | 10 | pF | |

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**FIGURE 33-16: UARTx MODULE TIMING CHARACTERISTICS**

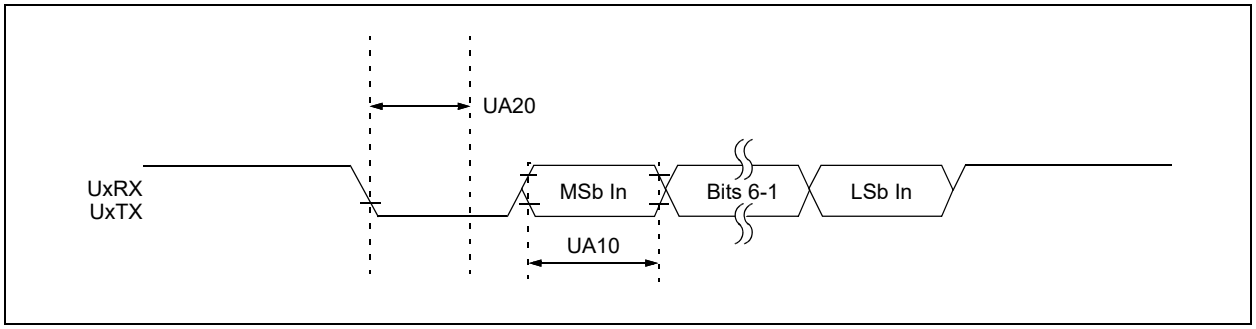



**TABLE 33-33: UARTx MODULE TIMING REQUIREMENTS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic(1)** | **Min.** | **Max.** | **Units** |
| UA10 | TUABAUD | UARTx Baud Time | 40 | — | ns |
| UA11 | FBAUD | UARTx Baud Rate | — | 40 | Mbps |
| UA20 | TCWF | Start Bit Pulse Width to Trigger UARTx Wake-up | 50 | — | ns |

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


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**TABLE 33-34: ADC MODULE SPECIFICATIONS**

| **Standard Operating Conditions: (unless otherwise stated)**<br>3.0V to 3.6V[4]<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | **Min.** | **Typical** | **Max.** | **Units** | **Conditions** |
| **Clock Requirements** | | | | | | | |
| AD9 | FSRC | ADC Module Input Frequency | — | — | 500 | MHz | Clock frequency selected by the CLKSELx bits. |
| AD10 | FCORESRC | ADC Control Clock Frequency | — | — | 250 | MHz | Clock frequency after the first divider controlled by the CLKDIVx bits. |
| AD11 | FADCORE | ADC SAR Core Clock Frequency | — | — | 70 | MHz | SAR core frequency after the second divider controlled by the ADCSx or SHRADCSx bits. |
| **Analog Input** | | | | | | | |
| AD12 | VINH-VINL | Full-Scale Input Span | AVSS | — | AVDD | V | — |
| AD14 | VIN | Absolute Input Voltage | AVSS – 0.3 | — | AVDD + 0.3 | V | — |
| AD61 | CHOLD | Capacitance | — | 14 | — | pF | Shared core[1] |
| AD62 | RIC | Input resistance | — | 500 | 1000 | Ω | **Note 1** |
| AD66 | VBG | Internal Voltage Reference Source | 1.14 | 1.2 | 1.26 | V | — |
| **ADC Accuracy** | | | | | | | |
| AD20 | Nr | Resolution | 12 data bits | | | bits | — |
| AD21b | INL _1S | Shared Core Integral Nonlinearity (1 Active Core) | -3.5 | -1.5/+1.5 | +3.5 | LSb | 2.7 Msps[5], TADC = 4 ns (250 MHz), TCORESRC = 8 ns (125 MHz), TADCORE = 16 ns (62.5 MHz), Sampling Time = 10 TADCORE, VDD = 3.3V, AVDD = 3.3V |
| AD22b | DNL_1S | Shared Core Differential Nonlinearity (1 Active Core) | -1 | 1.5 | +3.5 | LSb | |
| AD23b | GERR_1S | Shared Core Gain Error (1 Active Core) | — | +4 | — | LSb | |
| AD24b | OERR_1S | Shared Core Offset Error (1 Active Core) | — | -4 | — | LSb | |
| AD25c | — | Monotonicity | — | — | — | — | Guaranteed |
| **Dynamic Performance** | | | | | | | |
| AD31b | SINAD | Signal-to-Noise and Distortion | 56 | — | 70 | dB | **Notes 2, 3** |
| AD34b | ENOB | Effective Number of Bits | 9.8 | 10.2 | 11.4 | bits | **Notes 2, 3** |
| AD50 | TAD | ADC Clock Period | 14.3 | — | — | ns | — |
| AD51 | FTP | Throughput Rate | — | — | 2.7 | Msps | Shared core[5] |

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

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

**3:** Characterized with a 1 kHz sine wave.

**4:** The ADC module is functional at VBORMIN < VDD < VDDMIN, but with degraded performance. Unless otherwise stated, module functionality is ensured, but not characterized.

**5:** For the shared core, the throughput includes a 10 TADCORE sampling time and 13 TADCORE conversion time.

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**TABLE 33-35: ANALOG-TO-DIGITAL CONVERSION TIMING REQUIREMENTS(1)**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristics** | **Min.** | **Max.** | **Units** |
| AD50 | TAD | ADC Clock Period | 14.28 | — | ns |
| AD51 | FTP | ADC Throughput Rate (for all channels) | — | 3.5 | Msps |

**Note 1:** The equivalent model of the input stages of the ADC include the Interconnect Resistance (RIC). The RIC value is 1 kOhm (max) and the Sample/Hold Capacitance (CHOLD) value is 14 pF. For additional information, refer to **"12-Bit High-Speed, Multiple SARs A/D Converter (ADC)"** (www.microchip.com/DS70005213).

**TABLE 33-36: DIE TEMPERATURE DIODE SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.(1)** | **Max.** | **Units** | **Comments** |
| TD01 | TCOEFF | Temperature Coefficient | — | 1.5 | — | mV/C | **Note 1** |

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

**TABLE 33-37: HIGH-SPEED ANALOG COMPARATOR MODULE SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):(2)**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.(1)** | **Max.** | **Units** | **Comments** |
| CM09 | FIN | Input Frequency | 400 | — | 500 | MHz | -40°C ≤ TA ≤ +85°C |
| | | | 400 | — | 480 | | +85°C < TA ≤ +125°C |
| CM10 | VIOFF | Input Offset Voltage | -20 | — | 20 | mV | — |
| CM11 | VICM | Input Common-Mode Voltage Range | AVSS | — | AVDD | V | **Note 1** |
| CM13 | CMRR | Common-Mode Rejection Ratio | 65 | — | — | dB | **Note 1** |
| CM14 | TRESP | Large Signal Response | — | 15 | — | ns | V+ input step of 100 mV while V- input is held at AVDD/2 |
| CM15 | VHYST | Input Hysteresis | 15 | — | 45 | mV | Depends on HYSSEL[1:0](1) |

**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 33-38: DAC MODULE SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.(1)** | **Max.** | **Units** | **Comments** |
| DA02 | CVRES | Resolution | 12 | | | bits | — |
| DA03 | INL | Integral Nonlinearity Error | -38 | — | 0 | LSb | — |
| DA04 | DNL | Differential Nonlinearity Error | -5 | — | 5 | LSb | — |
| DA05 | EOFF | Offset Error | -3.5 | — | 21.5 | LSb | — |
| DA06 | EG | Gain Error | 0 | — | 41 | LSb | — |
| DA07 | TSET | Settling Time | 600 | 750 | 2000 | ns | Output with 2% of desired output voltage with a 10-90% or 90-10% step |
| DA08 | VOUT | Voltage Output Range | 0.165 | — | 3.135 | V | VDD = 3.3V(1) |
| DA09 | TTR | Transition Time | 340 | — | — | ns | Note 1 |
| DA10 | TSS | Steady-State Time | 550 | — | — | ns | Note 1 |

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

**TABLE 33-39: DAC OUTPUT (DACOUT PIN) SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-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 | — | 3 | — | mA | Sink and source |

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**TABLE 33-40: CURRENT BIAS GENERATOR SPECIFICATIONS(1)**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | |
|---|---|---|---|---|---|
| **ParamNo.** | **Symbol** | **Characteristic** | **Min.** | **Max.** | **Units** |
| CC03 | I10SRC | 10 µA Source Current | 8.8 | 11.2 | µA |
| CC04 | I50SRC | 50 µA Source Current | 44 | 56 | µA |
| CC05 | I50SNK | 50 µA Sink Current | -44 | -56 | µA |

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

**TABLE 33-41: OPERATIONAL AMPLIFIER SPECIFICATIONS(1,2,3,4)**

| **Operating Conditions (unless otherwise stated):**<br>3.0V ≤ VDD ≤ 3.6V,<br>-40°C ≤ TA ≤ +85°C for Industrial<br>-40°C ≤ TA ≤ +125°C for Extended | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Sym** | **Characteristic** | **Min** | **Typ** | **Max** | **Units** | **Comments** |
| OAMP1 | GBWP | Gain Bandwidth Product | — | 20 | — | MHz | — |
| OAMP2 | SR | Slew Rate | — | 40 | — | V/µs | — |
| OAMP3 | VIOFF | Input Offset Voltage | -3/+3 | -1/+1 | -3/+3 | mV | Unity gain configuration |
| | | | -8 | -3/+3 | +8 | | Open-loop configuration |
| OAMP4 | VICM | Common-Mode Input Voltage Range | AVSS | — | AVDD | V | NCHDISx = 0 |
| | | | AVSS | — | AVDD – 1.4V | V | NCHDISx = 1 |
| OAMP5 | CMRR | Common-Mode Rejection Ratio | — | 68 | — | db | — |
| OAMP6 | PSRR | Power Supply Rejection Ratio | — | 74 | — | dB | — |
| OAMP7 | VOR | Output Voltage Range | AVSS | — | AVDD | mV | 0.5V input overdrive, no output loading |
| OAMP8 | VIBC | Input Bias Current | — | — | — | mV | **Note 2** |
| OAMP11 | CLOAD | Output Load Capacitance | — | — | 30 | pF | Including output pin capacitance |
| OAMP12 | IOUT | Output Current Drive Strength | — | 3 | — | mA | Sink and source |
| OAMP13 | PMARGIN | Phase Margin | 44 | — | — | degree | Unity gain (1) |
| OAMP14 | GMARGIN | Gain Margin | 7 | — | — | dB | Unity gain(1) |
| OAMP15 | OLG | Open-Loop Gain | 68 | 75 | — | dB | **Note 1** |

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

**2:** The op amps use CMOS input circuitry with negligible input bias current. The maximum “effective bias current” is the I/O pin leakage specified by electrical Parameter DI50.

**3:** Parameters are characterized but not tested in manufacturing.

**4:** The module is functional at VBORMIN < VDD < VDDMIN but with degraded performance. The module functionality is tested but not characterized.


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## 34.0 HIGH-TEMPERATURE ELECTRICAL CHARACTERISTICS

This section provides an overview of the dsPIC33CDVL64MC106 family devices operating in an ambient temperature range of -40°C to +150°C.

The specifications between -40°C to +150°C are identical to those shown in **Section 33.0 "Electrical Characteristics"** for operation between -40°C to +125°C, with the exception of the parameters listed in this section.

Parameters in this section begin with an H, which denotes High temperature. For example, Parameter DC20 in **Section 33.0 "Electrical Characteristics"** is the Industrial and Extended temperature equivalent of HDC20.

Absolute maximum ratings for the dsPIC33CDVL64MC106 family high-temperature devices are listed below. 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 effect device reliability.

### Absolute Maximum Ratings

Ambient temperature under bias ..... -40°C to +150°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 $V_{SS}$ (2) ..... -0.3V to ($V_{DD}$ + 0.3V)
Voltage on any 5V tolerant pin with respect to $V_{SS}$ when $V_{DD} \geq 3.0V$ (2) ..... -0.3V to +5.5V
Voltage on any 5V tolerant pin with respect to Vss when $V_{DD} < 3.0V$ (2) ..... -0.3V to +3.6V
Maximum current out of $V_{SS}$ pin ..... 300 mA
Maximum current into $V_{DD}$ pin (1) ..... 300 mA
Maximum current sunk/sourced by any regular I/O pin ..... 15 mA
Maximum current sunk/sourced by an I/O pin with increased current drive strength (RB1, RC8, RC9 and RD8) ..... 25 mA
Maximum current sunk by a group of I/Os between two $V_{SS}$ pins (3) ..... 75 mA
Maximum current sourced by a group of I/Os between two $V_{DD}$ pins (3) ..... 75 mA
Maximum current sunk by all I/Os (1) ..... 200 mA
Maximum current sourced by all I/Os (1) ..... 200 mA

**Note 1:** Maximum allowable current is a function of device maximum power dissipation (see Table 34-2).
**2:** See the **"Pin Diagrams"** section for the 5V tolerant pins.
**3:** Not applicable to $AV_{DD}$ and $AV_{SS}$ pins.


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## 34.1 DC Characteristics

**TABLE 34-1: OPERATING MIPS vs. VOLTAGE**

| VDD Range | Temperature Range | Maximum CPU Clock Frequency |
|---|---|---|
| 3.0V to 3.6V | -40°C to +150°C | 70 |

**TABLE 34-2: THERMAL OPERATING CONDITIONS**

| Rating | Symbol | Min. | Max. | Unit |
|---|---|---|---|---|
| High-Temperature Devices | | | | |
| Operating Junction Temperature Range | TJ | -40 | +165 | °C |
| Operating Ambient Temperature Range | TA | -40 | +150 | °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 34-3: OPERATING VOLTAGE SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>-40°C ≤ TA ≤ +150°C for High | | | | | | |
|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Max.** | **Units** | **Conditions** |
| HDC10 | VDD | **Supply Voltage** | 3.0 | 3.6 | V | — |
| HDC16 | VPOR | **VDD Start Voltage**<br>to Ensure Internal Power-on Reset Signal | — | VSS | V | — |
| HDC17 | SVDD | **VDD Rise Rate**<br>to Ensure Internal Power-on Reset Signal | 0.03 | — | V/ms | 0V-3V in 100 ms |
| HBO10 | VBOR(1) | **BOR Event** on VDD Transition High-to-Low | 2.68 | 2.99 | V | — |

**Note 1:** Device is functional at VBORMIN < VDD < VDDMIN. Analog modules (ADC and comparators) may have degraded performance. The VBOR parameter is for design guidance only and is not tested in manufacturing.

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**TABLE 34-4: OPERATING CURRENT (IDD)(2)**

| Parameter No. | Typ.(1) | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| HDC20 | 10.2 | 24.1 | mA | +150°C | 3.3V | 10 MIPS (N1 = 1, N2 = 5, N3 = 2, M = 50, FVCO = 400 MHz, FPLLO = 40 MHz) |
| HDC21 | 12.2 | 25.4 | mA | +150°C | 3.3V | 20 MIPS (N1 = 1, N2 = 5, N3 = 1, M = 50, FVCO = 400 MHz, FPLLO = 80 MHz) |
| HDC22 | 15.5 | 29.0 | mA | +150°C | 3.3V | 40 MIPS (N1 = 1, N2 = 3, N3 = 1, M = 60, FVCO = 480 MHz, FPLLO = 160 MHz) |
| HDC23 | 21.2 | 34.1 | mA | +150°C | 3.3V | 70 MIPS (N1 = 1, N2 = 2, N3 = 1, M = 70, FVCO = 560 MHz, FPLLO = 280 MHz) |

**Note 1:** Data in the “Typ.” column are for design guidance only and are not tested.

**2:** Base Run current (IDD) is measured as follows:

- Oscillator is switched to EC+PLL mode in software.
- OSC1 pin is driven with external 8 MHz square wave with levels from 0.3V to VDD – 0.3V.
- OSC2 is configured as an I/O in the Configuration Words (OSCIOFCN (FOSC[2]) = `0`).
- FSCM is disabled (FCKSM[1:0] (FOSC[7:6]) = `01`).
- Watchdog Timer is disabled (FWDT[15] = `0` and WDTCONL[15] = `0`).
- All I/O pins (except OSC1) are configured as outputs and driving low.
- No peripheral modules are operating or being clocked (defined PMDx bits are all ‘`1`’s).
- JTAG is disabled (JTAGEN (FICD[5]) = `0`).
- `NOP` instructions are executed in `while(1)` loop.


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**TABLE 34-5: IDLE CURRENT ($I_{IDLE}$)(2)**

| Parameter No. | Typ.(1) | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| HDC40 | 9.0 | 17.1 | mA | +150°C | 3.3V | 10 MIPS (N1 = 1, N2 = 5, N3 = 2, M = 50, $F_{VCO}$ = 400 MHz, $F_{PLLO}$ = 40 MHz) |
| HDC41 | 9.7 | 22.6 | mA | +150°C | 3.3V | 20 MIPS (N1 = 1, N2 = 5, N3 = 1, M = 50, $F_{VCO}$ = 400 MHz, $F_{PLLO}$ = 80 MHz) |
| HDC42 | 11.2 | 24 | mA | +150°C | 3.3V | 40 MIPS (N1 = 1, N2 = 3, N3 = 1, M = 60, $F_{VCO}$ = 480 MHz, $F_{PLLO}$ = 160 MHz) |
| HDC43 | 13.4 | 25.8 | mA | +150°C | 3.3V | 70 MIPS (N1 = 1, N2 = 2, N3 = 1, M = 70, $F_{VCO}$ = 560 MHz, $F_{PLLO}$ = 280 MHz) |

**Note 1:** Data in the “Typ.” column are for design guidance only and are not tested.

**2:** Base Idle current ($I_{IDLE}$) is measured as follows:

- Oscillator is switched to EC+PLL mode in software.
- OSC1 pin is driven with external 8 MHz square wave with levels from 0.3V to $V_{DD}$ – 0.3V.
- OSC2 is configured as an I/O in the Configuration Words (OSCIOFCN (FOSC[2]) = 0).
- FSCM is disabled (FCKSM[1:0] (FOSC[7:6]) = 01).
- Watchdog Timer is disabled (FWDT[15] = 0 and WDTCONL[15] = 0).
- All I/O pins (except OSC1) are configured as outputs and driving low.
- No peripheral modules are operating or being clocked (defined PMDx bits are all ‘1’s).
- JTAG is disabled (JTAGEN (FICD[5]) = 0).
- Flash in standby with NVMSIDL (NVMCON[12]) = 1.

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**TABLE 34-6: POWER-DOWN CURRENT ($I_{PD}$)(2)**

| Parameter No. | Characteristic | Typ.(1) | Max. | Units | Conditions | |
|---|---|---|---|---|---|---|
| HDC60 | Base Power-Down Current | 6.3 | 19.8 | mA | +150°C | 3.3V |

**Note 1:** Data in the "Typ." column are for design guidance only and are not tested.

**2:** Base Sleep current ($I_{PD}$) is measured as follows:

- OSC1 pin is driven with external 8 MHz square wave with levels from 0.3V to $V_{DD}$ – 0.3V.
- OSC2 is configured as an I/O in the Configuration Words (OSCIOFCN (FOSC[2]) = 0).
- FSCM is disabled (FCKSM[1:0] (FOSC[7:6]) = 01).
- Watchdog Timer is disabled (FWDT[15] = 0 and WDTCONL[15] = 0).
- All I/O pins (except OSC1) are configured as outputs and driving low.
- No peripheral modules are operating or being clocked (defined PMDx bits are all '1's).
- JTAG is disabled (JTAGEN (FICD[5]) = 0).
- The regulators are in Active mode, VREGS bit = 1 (Standby mode only valid up to +85°C).
- The regulators are in Full-Power mode, LPWREN bit = 0 (Low-Power mode only valid up to +85°C).

**TABLE 34-7: DOZE CURRENT ($I_{DOZE}$)**

| Parameter No. | Typ.(1) | Max. | Doze Ratio | Units | Conditions | | |
|---|---|---|---|---|---|---|---|
| HDC70 | 17.9 | 30.1 | 1:2 | mA | +150°C | 3.3V | 70 MIPS (N = 1, N2 = 2, N3 = 1, M = 70, $F_{VCO}$ = 560 MHz, $F_{PLLO}$ = 280 MHz) |
| | 13.6 | 26 | 1:128 | mA | | | |

**Note 1:** Data in the "Typ." column are for design guidance only and are not tested.

**TABLE 34-8: WATCHDOG TIMER DELTA CURRENT ($\Delta I_{WDT}$)(1)**

| Parameter No. | Typ. | Max. | Units | Conditions | |
|---|---|---|---|---|---|
| HDC61 | 24 | — | µA | +150°C | 3.3V |

**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 34-9: PWM DELTA CURRENT**

| Parameter No. | Typ. | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| HDC100 | 5.48 | 7.2 | mA | +150°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 500 MHz, VCO = 1000 MHz, PLLFBD = 125) |
| HDC101 | 4.44 | 6.8 | mA | +150°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 400 MHz, VCO = 400 MHz, PLLFBD = 50) |
| HDC102 | 2.31 | 3.7 | mA | +150°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 200 MHz, VCO = 200 MHz, PLLFBD = 50) |
| HDC103 | 1.22 | 2.3 | mA | +150°C | 3.3V | PWM Output Frequency = 500 kHz, PWM Input (FPLLO = 100 MHz, VCO = 100 MHz, PLLFBD = 50) |

**TABLE 34-10: ADC DELTA CURRENT(1)**

| Parameter No. | Typ. | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|
| HDC120 | 3.76 | 6.1 | mA | +150°C | 3.3V | TAD = 14.3 ns (3.5 Msps conversion rate) |

**Note 1:** Shared core continuous conversion. TAD = 14.3 ns (3.5 Msps conversion rate). Listed delta currents are for only one ADC core. All parameters are characterized but not tested during manufacturing.

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**TABLE 34-11: COMPARATOR + DAC DELTA CURRENT**

| Parameter No. | Symbol | Characteristic | Min. | Typ. | Max. | Units | Conditions | | |
|---|---|---|---|---|---|---|---|---|---|
| HDC130 | — | — | — | 1.25 | 1.65 | mA | +150°C | 3.3V | FPLLO @ 500 MHz(1) |
| HDCM09 | FIN | Input Frequency | 400 | — | 475 | MHz | +125°C < TA ≤ +150°C | | |

**Note 1:** Listed delta currents are for only one comparator + DAC instance. All parameters are characterized but not tested during manufacturing.

**TABLE 34-12: OP AMP DELTA CURRENT(1)**

| Parameter No. | Typ. | Max. | Units | Conditions | |
|---|---|---|---|---|---|
| HDC140 | 0.58 | 2.3 | mA | +150°C | 3.3V |

**Note 1:** Listed delta currents are for only one op amp instance. All parameters are characterized but not tested during manufacturing.

**TABLE 34-13: I/O PIN INPUT SPECIFICATIONS**

**Operating Conditions (unless otherwise stated):**
3.0V < VDD < 3.6V
-40°C < TA < +150°C for High

| Param No. | Symbol | Characteristic | Min.(3) | Max.(4) | Units |
|---|---|---|---|---|---|
| HDI50 | IIL | **Input Leakage Current(1)** | | | |
| | | I/O Pins 5V Tolerant(2) | -800 | 800 | nA |
| | | I/O Pins Not 5V Tolerant(2) | -800 | 800 | nA |
| | | $\overline{\text{MCLR}}$ | -800 | 800 | nA |
| | | OSCI | -800 | 800 | nA |

**Note 1:** Negative current is defined as current sourced by the pin.
**2:** See the **Pin Diagrams** section for the 5V tolerant I/O pins.
**3:** VPIN = VSS.
**4:** VPIN = VDD.

**TABLE 34-14: INTERNAL FRC ACCURACY**

**Operating Conditions (unless otherwise stated):**
3.0V < VDD < 3.6V
-40°C < TA < +150°C for High

| Param No. | Characteristic | Min. | Max. | Units |
|---|---|---|---|---|
| HF20a | FRC @ 8 MHz(1) | -3 | +3 | % |

**Note 1:** Frequency is calibrated at +25°C and 3.3V.


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**TABLE 34-15: HIGH-SPEED ANALOG COMPARATOR MODULE SPECIFICATIONS(1)**

| **Operating Conditions (unless otherwise stated):**<br>3.0V < VDD < 3.6V<br>-40°C < TA < +150°C for High | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| CM09 | FIN | Input Frequency | 400 | — | 475 | MHz | — |

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

**TABLE 34-16: DAC MODULE SPECIFICATIONS**

| **Operating Conditions (unless otherwise stated):**<br>3.0V < VDD < 3.6V<br>-40°C < TA < +150°C for High | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Param No.** | **Symbol** | **Characteristic** | **Min.** | **Typ.** | **Max.** | **Units** | **Comments** |
| HDA03 | INL | Integral Nonlinearity Error | -45 | — | 0 | LSb | — |
| HDA04 | DNL | Differential Nonlinearity Error | -5 | — | 5 | LSb | — |
| HDA05 | EOFF | Offset Error | -21 | — | 21 | LSb | — |
| HDA06 | EG | Gain Error | -41 | — | 41 | LSb | — |

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## 35.0 MOSFET GATE DRIVER ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings†

Input Voltage, $HV_{DD}$ ..... (GND – 0.3V) to +40V
Internal Power Dissipation ..... Internally Limited
Operating Junction Temperature (2) ..... -40°C to +165°C
Transient Junction Temperature (1) ..... +170°C
Storage Temperature (2) ..... -55°C to +165°C
Digital I/O ..... -0.3V to 5.5V
Low-Voltage Analog I/O ..... -0.3V to 5.5V
VBx, WAKE ..... (GND – 0.3V) to +40V
PHx, HSx ..... (GND – 5.5V) to +40V
$V_{BOOT}$, LSx ..... (GND – 0.3V) to +13.2V
CAP1, CAP2 ..... (GND – 0.3V) to +40V

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

**Note 1:** Transient junction temperatures should not exceed one second in duration. Sustained junction temperatures above +170°C may impact the device reliability.

**2:** The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., $T_A$, $T_J$, $\theta_{JA}$). Exceeding the maximum allowable power dissipation may cause the device operating junction temperature to exceed the maximum +165°C rating. Sustained junction temperatures above +165°C can impact the device reliability.

### TABLE 35-1: AC/DC CHARACTERISTICS

**Electrical Specifications:** Unless otherwise noted: $T_J$ = -40°C to +150°C; typical values are for +25°C, $HV_{DD}$ = 13.5V, $CV_{BOOT}$ = 4.7 µF, $CV_{REG}$ = 4.7 µF, $C_{CP}$ = 220 nF.

| Parameters | Symbol | Min. | Typ. | Max. | Units | Conditions |
|---|---|---|---|---|---|---|
| **Power Supply Input** | | | | | | |
| Input Operating Voltage | $HV_{DD}$ | 4.5 | — | 40 | V | $V_{REG}$ active |
| | | 6.0 | — | 29.0 | | Driver output active |
| Input Supply Current | $I_{SUP}$ | — | 5 | 15 | µA | Sleep mode, $T_J$ = +25°C |
| | | — | 180 | 330 | | Standby, OE = 0V |
| | | — | 500 | — | | Active, $HV_{DD}$ > 13, 5V, OE > $V_{DIG\_HI\_TH}$ |
| | | — | 1200 | — | | Active, $HV_{DD}$ = 6V, $T_J$ = +25°C |
| Input Supply Current | $I_{SUP}$ | — | 5 | 15 | µA | Sleep mode, $T_J$ = +25°C |
| | | — | 200 | 350 | | Standby, OPAMP = 1, OE = 0V |
| | | — | 800 | 1300 | | Standby, OPAMP = 0, OE = 0V |
| | | — | 1000 | — | | Active, $HV_{DD}$ > 13, 5V, OE > $V_{DIG\_HI\_TH}$ |
| | | — | 1500 | — | | Active, OE > $V_{DIG\_HI\_TH}$, $HV_{DD}$ = 7V, $T_J$ = +25°C |

**Note 1:** Limits based on design, simulation or characterization. Not production tested.

**2:** On revision D2 of the device, the WAKE pin should be held low for > $t_{WAIT\_SETUP}$ time after enabling Sleep sequence. On revision D3, the WAKE pin must remain high for > $t_{WAIT\_SETUP}$ time to successfully awaken the device from Sleep.


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**TABLE 35-1: AC/DC CHARACTERISTICS (CONTINUED)**

| **Electrical Specifications:** Unless otherwise noted: $T_J$ = -40°C to +150°C; typical values are for +25°C, $HV_{DD}$ = 13.5V, $CV_{BOOT}$ = 4.7 µF, $CV_{REG}$ = 4.7 µF, $C_{CP}$ = 220 nF. | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| **Bias Generator** | | | | | | |
| **+12V Regulated Charge Pump ($V_{BOOT}$)** | | | | | | |
| Charge Pump Current | $I_{CP}$ | 20 | — | — | mA | $HV_{DD}$ = 9.0V |
| Charge Pump Start | $CP_{START}$ | 12.50 | 12.75 | — | V | Falling |
| Charge Pump Stop | $CP_{STOP}$ | — | 13.25 | 14 | V | Rising |
| Charge Pump Frequency | $CP_{FSW}$ | — | 76.80 | — | kHz | $HV_{DD}$ = 9.0V |
| | | — | 0 | — | | $HV_{DD}$ = 14V |
| Charge Pump Switch Resistance | $CP_{RDSON}$ | — | 14 | — | Ω | $R_{DSON}$ sum of high side and low side(1) |
| Output Voltage | $V_{BOOT}$ | — | 12 | — | V | $HV_{DD} \geq$ 14V, $I_{OUT}$ = 30 mA |
| | | 9 | 12 | — | | 7V ≤ $HV_{DD}$ < 14V, $C_{CP}$ = 150 nF, $I_{OUT}$ = 20 mA |
| | | 9 | — | — | | 6.25V ≤ $HV_{DD}$ < 7V, $C_{CP}$ = 270 nF, $I_{OUT}$ = 15 mA |
| Output Voltage Tolerance | $\lvert TOLV_{OUT12} \rvert$ | — | — | 4.0 | % | $I_{OUT}$ = 30 mA |
| Output Capability | $I_{BOOT}$ | 30 | — | — | mA | Average current |
| Output Current Limit | $I_{BOOTLIMIT}$ | 50 | 60 | 80 | mA | Average current |
| Output Voltage Temperature Coefficient | $TCV_{OUT12}$ | — | 160 | — | ppm/°C | Note 1 |
| Line Regulation | $\lvert \Delta V_{OUT} / (V_{OUT} \times \Delta) \rvert$ | — | 0.1 | 0.5 | %/V | 14V < $HV_{DD}$ < 19V, $I_{OUT}$ = 30 mA |
| Load Regulation | $\lvert \Delta V_{OUT}/V_{OUT} \rvert$ | — | 0.2 | 1.0 | % | $I_{OUT}$ = 0.1 mA to 30 mA, $HV_{DD}$ = 14V |
| Power Supply Rejection Ratio | PSRR | — | 60 | — | dB | f = 1 kHz, $I_{OUT}$ = 10 mA(1) |
| Output Capacitor Capacitance Range | $CV_{BOOT}$ | 4.7 | — | 10 | µF | Ceramic, Tantalum, Electrolytic(1) |
| Output Capacitor ESR Range | $CESRV_{BOOT}$ | 0.010 | — | 1.0 | Ω | Note 1 |
| Flying Capacitor Capacitance Range | $C_{CP}$ | 100 | 220 | 1000 | nF | Note 1 |
| $V_{BOOT}$ Ready Threshold | $V_{12SM\_PG}$ | — | 50 | — | %$V_{BOOT}$ | State machine $V_{BOOT}$ Power Good threshold to move to next state (1) |

**Note 1:** Limits based on design, simulation or characterization. Not production tested.

**2:** On revision D2 of the device, the WAKE pin should be held low for > $t_{WAIT\_SETUP}$ time after enabling Sleep sequence. On revision D3, the WAKE pin must remain high for > $t_{WAIT\_SETUP}$ time to successfully awaken the device from Sleep.

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**TABLE 35-1: AC/DC CHARACTERISTICS (CONTINUED)**

| **Electrical Specifications:** Unless otherwise noted: $T_J$ = -40°C to +150°C; typical values are for +25°C, $HV_{DD}$ = 13.5V, $CV_{BOOT}$ = 4.7 µF, $CV_{REG}$ = 4.7 µF, $C_{CP}$ = 220 nF. | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| **+3.3V/+5V Linear Regulator ($V_{REG}$)** | | | | | | |
| Output Voltage | $V_{REG}$ | — | — | — | V | $HV_{DD}$ = 6V, $I_{OUT}$ = 70 mA |
| | | 4.8 | 5 | 5.2 | | $V_{REG}$ = 5V |
| | | 3.168 | 3.3 | 3.432 | | $V_{REG}$ = 3.3V |
| Output Voltage Tolerance | \|TOL$V_{REG}$\| | — | — | 4.0 | % | — |
| Output Current | $I_{OUT}$ | 70 | — | — | mA | Average current |
| Output Foldback Current Corner | $I_{FOLD}$ | 80 | 95 | 120 | mA | Average current |
| Output Foldback Current Limit | $I_{FOLD\_LIM}$ | — | 10 | — | mA | $R_{LOAD}$ = 10 mΩ |
| Line Regulation | \|ΔVOUT/ (VOUT x ΔVDD)\| | — | 0.1 | 0.5 | %/V | $V_{REG}$ = 3.3V: 6V < $HV_{DD}$ < 19V, $I_{OUT}$ = 70 mA; $V_{REG}$ = 5V: 7.5V < $HV_{DD}$ < 19V, $I_{OUT}$ = 70 mA |
| Load Regulation | \|ΔVOUT/VOUT\| | — | 0.2 | 1.0 | % | $I_{OUT}$ = 0.1 mA to 70 mA |
| Power Supply Rejection Ratio | PSRR | — | 60 | — | dB | f = 1 kHz, $I_{OUT}$ = 10 mA (1) |
| Output Capacitor Capacitance Range | $CV_{REG}$ | 4.7 | — | 30 | µF | Ceramic, Tantalum, Electrolytic(1) |
| Output Capacitor ESR Range | $CESR_{VREG}$ | 0.010 | — | 1.0 | Ω | Note 1 |
| **Voltage Supervisor** | | | | | | |
| $V_{REG}$ Undervoltage Fault Inactive | $VREGUVF_{INACT}$ | — | 92 | — | %$V_{REG}$ | $V_{REG}$ rising |
| $V_{REG}$ Undervoltage Fault Active | $VREGUVF_{ACT}$ | — | 88 | — | %$V_{REG}$ | $V_{REG}$ falling |
| $V_{REG}$ Undervoltage Fault Hysteresis | $VREGUVF_{HYS}$ | — | 4 | — | %$V_{REG}$ | — |
| $HV_{DD}$ Undervoltage Lockout Inactive | $UVLO_{INACT}$ | — | 6.0 | 6.25 | V | Rising |
| $HV_{DD}$ Undervoltage Lockout Active | $UVLO_{ACT}$ | 5.1 | 5.5 | — | V | Falling |
| $HV_{DD}$ Undervoltage Lockout Hysteresis | $UVLO_{HYS}$ | — | 0.5 | — | V | — |
| $HV_{DD}$ Undervoltage Shutdown Active | $UVSHDN_{ACT}$ | 4.0 | 4.25 | 4.5 | V | $HV_{DD}$ < $UVSHDN_{ACT}$ |
| $HV_{DD}$ Undervoltage Shutdown Inactive | $UVSHDN_{INACT}$ | $UVLO_{INACT}$ | | | V | $HV_{DD}$ > $UVLO_{INACT}$ |
| $HV_{DD}$ Overvoltage Lockout Active | $OVLO_{ACT}$ | — | 32.0 | 33.0 | V | $HV_{DD}$ rising |
| $HV_{DD}$ Overvoltage Lockout Inactive | $OVLO_{INACT}$ | 29.0 | 30.0 | — | V | $HV_{DD}$ falling |
| $HV_{DD}$ Overvoltage Lockout Hysteresis | $OVLO_{HYS}$ | — | 2.0 | — | V | — |
| **Temperature Supervisor** | | | | | | |
| Thermal Warning Temperature | $T_{WARN}$ | — | 140 | — | °C | Rising temperature |
| Thermal Warning Hysteresis | ΔTWARN | — | 15 | — | °C | Falling temperature |
| Thermal Shutdown Temperature | $T_{SD}$ | 170 | 210 | — | °C | Rising temperature(1) |
| Thermal Shutdown Hysteresis | ΔTSD | — | 25 | — | °C | Falling temperature |

**Note 1:** Limits based on design, simulation or characterization. Not production tested.

**2:** On revision D2 of the device, the WAKE pin should be held low for > $t_{WAIT\_SETUP}$ time after enabling Sleep sequence. On revision D3, the WAKE pin must remain high for > $t_{WAIT\_SETUP}$ time to successfully awaken the device from Sleep.


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**TABLE 35-1: AC/DC CHARACTERISTICS (CONTINUED)**

| **Electrical Specifications:** Unless otherwise noted: $T_J$ = -40°C to +150°C; typical values are for +25°C, $HV_{DD}$ = 13.5V, $CV_{BOOT}$ = 4.7 µF, $CV_{REG}$ = 4.7 µF, $C_{CP}$ = 220 nF. | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| **Motor Control Unit** | | | | | | |
| **Gate Output Drivers** | | | | | | |
| Output Driver Source Current | $I_{SOURCE}$ | 0.25 | 0.37 | — | A | HS[A:C], LS[A:C] (1) |
| Output Driver Sink Current | $I_{SINK}$ | 0.3 | 0.49 | — | A | HS[A:C], LS[A:C] (1) |
| Output Driver Source Resistance | $R_{DSONSOURCE}$ | — | 14 | 26 | Ω | $I_{OUT}$ = -10 mA, HS[A:C], LS[A:C] |
| Output Driver Sink Resistance LS | $R_{DSONSINKLS}$ | — | 14 | 26 | Ω | $I_{OUT}$ = 10 mA, LS[A:C] |
| Output Driver Sink Resistance HS Dynamic | $R_{DSONSINKHSDYN}$ | — | 14 | 26 | Ω | $I_{OUT}$ = 10 mA, HS[A:C], t < 1 ms |
| Output Driver Sink Resistance HS | $R_{DSONSINKHS}$ | — | 19 | 31 | Ω | $I_{OUT}$ = 10 mA, HS[A:C] |
| Output Driver Fault Blanking Time (UVLO and OCP); Set in the DRVBL[1:0] bits (CFG2[1:0]) | $t_{BLANK}$ | 3900 | 4400 | 4900 | ns | 00 – Default (1) |
| | | 2000 | 2200 | 2400 | | 01 (1) |
| | | 900 | 1100 | 1300 | | 10 (1) |
| | | 400 | 550 | 700 | | 11 (1) |
| Output Driver UVLO Threshold | $V_{DUVLO}$ | 4 | — | 4.5 | V | Configuration Register 0 (bit 3 = 0) |
| Output Driver PWM Dead Time; Set in the DRVDT[2:0] bits (CFG2[4:2]) | $t_{PWM\_DEAD}$ | 1800 | 2000 | 2200 | ns | 000 – Default (1) |
| | | 1550 | 1750 | 1950 | | 001 (1) |
| | | 1350 | 1500 | 1650 | | 010 (1) |
| | | 1100 | 1250 | 1400 | | 011 (1) |
| | | 900 | 1000 | 1150 | | 100 (1) |
| | | 650 | 750 | 900 | | 101 (1) |
| | | 450 | 500 | 650 | | 110 (1) |
| | | 200 | 250 | 350 | | 111 (1) |
| Output Driver Propagation Delay Time On | $t_{GATE\_PROP\_ON}$ | — | 40 | 80 | ns | From PWMxy active to HSx/LSx > 10% (1) |
| Output Driver Propagation Delay Time Off | $t_{GATE\_PROP\_OFF}$ | — | 40 | 80 | ns | From PWMxy inactive to HSx/LSx < 90% (1) |
| Output Driver HS Drive Voltage | $V_{HS}$ | 4.5 | 12 | 12.5 | V | With respect to Phase pin (1) |
| Output Driver LS Drive Voltage | $V_{LS}$ | 4.5 | 12 | 12.5 | V | With respect to ground (1) |
| Output Driver Short-Circuit Protection Threshold (High Side: $HV_{DD}$ – VPHX), (Low Side: VPHX – $P_{GND}$); Set in the EXTOC[1:0] bits (CFG0[1:0]) | $D_{SC\_THR}$ | 0.230 | 0.250 | 0.270 | V | 00 – Default (1) |
| | | 0.470 | 0.500 | 0.530 | | 01 (1) |
| | | 0.720 | 0.750 | 0.780 | | 10 (1) |
| | | 0.960 | 1.000 | 1.040 | | 11 (1) |
| Output Driver Short-Circuit Filter Time | $T_{SC\_DLY}$ | 230 | — | 600 | ns | $C_{LOAD}$ = 1000 pF, $HV_{DD}$ = 12V, detection after filtering (1) |
| Filter Time for All Other Faults | $T_{FLT\_DLY}$ | 1400 | — | 3600 | ns | Note 1 |
| Power-up or Sleep to Standby | $t_{POWER}$ | — | 5 | — | ms | $I_{VREG}$ = 70 mA |

**Note 1:** Limits based on design, simulation or characterization. Not production tested.

**2:** On revision D2 of the device, the WAKE pin should be held low for > $t_{WAIT\_SETUP}$ time after enabling Sleep sequence. On revision D3, the WAKE pin must remain high for > $t_{WAIT\_SETUP}$ time to successfully awaken the device from Sleep.

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**TABLE 35-1: AC/DC CHARACTERISTICS (CONTINUED)**

| **Electrical Specifications:** Unless otherwise noted: $T_J$ = -40°C to +150°C; typical values are for +25°C, $HV_{DD}$ = 13.5V, $CV_{BOOT}$ = 4.7 µF, $CV_{REG}$ = 4.7 µF, $C_{CP}$ = 220 nF. | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| Standby to Motor Operational | tMOTOR | — | 35 | — | µs | OE high-low-high transition < 1 ms Fault clearing pulse(1) |
| | | — | 5 | 10 | ms | OE low-high transition, Standby state to operational(1) |
| | | — | — | 16 | ms | OE low-high transition, Standby state to operational if $V_{BOOT}$ fails to reach $V_{12SM\_PG}$(1) |
| Fault to Driver Output Turn-Off | $T_{FAULT\_OFF}$ | — | — | — | µs | $C_{LOAD}$ = 1000 pF, $HV_{DD}$ = 12V, time after Fault occurs(1) |
| | | — | 0.420 | 1.0 | | XOCP(1) |
| | | — | 2.4 | 4.0 | | OVLO(1) |
| | | — | 4.2 | 6.0 | | All other Faults(1) |
| OE Low to Driver Output Turn-Off | $T_{DEL\_OFF}$ | — | 3.2 | 4.0 | µs | $C_{LOAD}$ = 1000 pF, $HV_{DD}$ = 12V, time after OE = Low(1) |
| OE Low to Standby State | tSTANDBY | 0.9 | — | 1.35 | ms | Time after OE = Low, SLEEP bit = 0 |
| OE Low to Sleep State | tSLEEP | 0.9 | — | 1.35 | ms | Time after OE = Low, SLEEP bit = 1 |
| OE Fault Clearing Pulse | $t_{FAULT\_CLR}$ | 1 | — | 900 | µs | OE high-low-high transition time |
| **Operational Amplifiers (DSTEMP)** | | | | | | |
| Input Offset Voltage | $V_{OS}$ | -10 | — | +10 | mV | $V_{CM}$ = 0V |
| Input Offset Temperature Drift | $\Delta V_{OS}/\Delta T_A$ | — | ±2.0 | — | µV/°C | $V_{CM}$ = 0V(1) |
| Input Bias Current | $I_B$ | -1 | — | +1 | µA | — |
| Common-Mode Input Range | $V_{CMR}$ | -0.3 | — | $V_{REG}$ | V | — |
| Common-Mode Rejection Ratio | CMRR | — | 80 | — | dB | Freq = 1 kHz, $I_{OUT}$ = 10 µA(1) |
| Maximum Output Voltage Range | $V_{OL}$, $V_{OH}$ | 0.15 | — | $V_{REG}$ – 0.300 | V | $I_{OUT}$ = ±200 µA |
| Slew Rate | SR | — | ±7 | — | V/µs | Symmetrical, $C_{LOAD}$ = 20 pF(1) |
| Gain Bandwidth Product | GBWP | 4 | 10.0 | — | MHz | Note 1 |
| **I/O Ports** | | | | | | |
| **Digital Interface** | | | | | | |
| Digital Input/Output | DIGITALI/O | 0 | — | 5.5 | V | $V_{REG}$ = 5.0V version(1) |
| | | 0 | — | 3.3 | | $V_{REG}$ = 3.3V version(1) |
| Digital Open-Drain Low Voltage | DIGITALVI/O | — | — | 50 | mV | $I_{LOAD}$ = 1 mA |
| Digital Input Rising Threshold | $V_{DIG\_HI\_TH}$ | — | — | 1.26 | V | — |
| Digital Input Falling Threshold | $V_{DIG\_LO\_TH}$ | 0.54 | — | — | V | — |
| Digital Input Current | $I_{DIG}$ | — | 30 | 100 | µA | $V_{DIG}$ = 3.0V |
| | | — | 0.2 | — | | $V_{DIG}$ = 0V |
| Input Pull-Down Resistance | $R_{PULLDN}$ | — | 51 | — | kΩ | PWM[A:C]H/L, OE pins |

**Note 1:** Limits based on design, simulation or characterization. Not production tested.

**2:** On revision D2 of the device, the WAKE pin should be held low for > $t_{WAIT\_SETUP}$ time after enabling Sleep sequence. On revision D3, the WAKE pin must remain high for > $t_{WAIT\_SETUP}$ time to successfully awaken the device from Sleep.


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**TABLE 35-1: AC/DC CHARACTERISTICS (CONTINUED)**

| **Electrical Specifications:** Unless otherwise noted: $T_J$ = -40°C to +150°C; typical values are for +25°C, $HV_{DD}$ = 13.5V, $CV_{BOOT}$ = 4.7 µF, $CV_{REG}$ = 4.7 µF, $C_{CP}$ = 220 nF. | | | | | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Units** | **Conditions** |
| **Analog Interface** | | | | | | |
| Analog Low-Voltage Input | $ANALOG_{VIN}$ | 0 | — | 5.5 | V | Excludes high-voltage pins (1) |
| Analog Low-Voltage Output | $ANALOG_{VOUT}$ | 0 | — | $V_{REG}$ | V | Excludes high-voltage pins (1) |
| **WAKE Input(2)** | | | | | | |
| Input Voltage | $WAKE_{I/O}$ | 0 | — | $HV_{DD}$ | V | — |
| Input Rising Threshold | $V_{WAKE\_HI\_TH}$ | — | — | 1.26 | V | Note 1 |
| Input Falling Threshold | $V_{WAKE\_LO\_TH}$ | 0.54 | — | — | V | — |
| Input Current | $I_{WAKE}$ | — | 0.2 | — | µA | $V_{WAKE}$ = 0.0V (1) |
| | | — | 70 | — | | $V_{WAKE}$ = 3.3V (1) |
| | | — | 106 | — | | $V_{WAKE}$ = 5.0V (1) |
| | | — | 596 | — | | $V_{WAKE}$ = 28V (1) |
| Input Pull-Down Resistance | $R_{WAKE\_PULLDN}$ | — | 51 | — | kΩ | — |
| WAKE Signal Setup Time | $t_{WAIT\_SETUP}$ | 150 | — | — | µs | Minimum time WAKE pin must be logic high before triggering wake-up |
| **DE2 Communications** | | | | | | |
| Baud Rate | BAUD | 9030 | 9600 | 10170 | bps | Half-duplex |
| Power-up Delay | PU_DELAY | — | 6 | 10 | ms | Time from rising $HV_{DD} \geq$ 6V to DE2 starts sending POR message, $C_{VREG}$ = 1 µF (1) |
| DE2 Sink Current | $I_{DE2\_SINK}$ | 1 | — | — | mA | $V_{DE2} \leq$ 50 mV (1) |
| DE2 Message Response Time | $t_{DE2\_RSP}$ | 0 | — | 1 | ms | Time from last received Stop bit to response Start bit |
| DE2 Host Wait Time | $t_{DE2\_WAIT}$ | 2.8 | — | — | ms | Minimum time for host to wait for response; three packets based on 9600 Baud |
| DE2 Message Receive Time-out | $DE2_{RCVTOUT}$ | — | — | 1.45 | ms | Time after Start bit received to NACK for no Stop bit |
| Auto-Baud Detection Window (Break) | $ABAUD_{DET}$ | 1.29 | — | 2.00 | ms | Window for valid detection of continuous logic low on DE2 link |
| Auto-Baud Response Delay | $ABAUD_{DLY}$ | — | 1.00 | — | ms | Delay from $ABAUD_{DET}$ to start of sending 0x55 byte |
| Auto-Baud Complete Delay | $ABAUD_{COMP}$ | — | 2.00 | — | ms | Delay after sending 0x55 byte before exiting auto-baud function |
| Delay Between Bytes of Multibyte Message from Host | $t_{DE2\_HOST\_MULTI\_DLY}$ | — | — | 1.3 | ms | Delay between message bytes arriving from host |

**Note 1:** Limits based on design, simulation or characterization. Not production tested.

**2:** On revision D2 of the device, the WAKE pin should be held low for > $t_{WAIT\_SETUP}$ time after enabling Sleep sequence. On revision D3, the WAKE pin must remain high for > $t_{WAIT\_SETUP}$ time to successfully awaken the device from Sleep.

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## 36.0 LIN TRANSCEIVER ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings(1)

Input Voltage, LIN_$V_{DD}$ ..... (LIN_$V_{SS}$ – 0.3V) to +40.0V
Logic Pins (LIN_RXD, LIN_TXD, LIN_EN) Voltage Levels ..... -0.3V to +5.5V
Logic Output DC Currents ..... -5 mA to +5 mA
LIN_BUS DC Voltage ..... -27 to +40V
LIN_BUS DC Voltage Transient ..... -27 to +43V
LIN_BUS DC Current ..... 43V
LIN_INH DC Voltage ..... -0.3V to (LIN_VDD + 0.3V)
LIN_INH DC Current ..... -100 mA to +30 mA
LIN_WKIN DC Voltage ..... -0.3V to +40V

**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.


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**TABLE 36-1: ELECTRICAL CHARACTERISTICS**

| **Operating Conditions (unless otherwise stated):** 5V < $V_S$ < 28V, -40°C < $T_J$ < +150°C; all values refer to LIN_Vss pins | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Test Conditions** | **Pin** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Unit** | **Type** |
| LIN_VDD Pin | | | | | | | | |
| Nominal DC Voltage Range | | LIN_VDD | $V_S$ | 5 | 13.5 | 28 | V | A |
| Supply Current in Sleep Mode | Sleep mode, $V_{LIN} > V_S - 0.5V$, $V_S < 14V$, T = +27°C | LIN_VDD | $I_{VSsleep}$ | 3 | 9 | 15 | µA | B |
| | Sleep mode, $V_{LIN} > V_S - 0.5V$, $V_S < 14V$ | LIN_VDD | $I_{VSsleep}$ | 3 | 11 | 18 | µA | A |
| | Sleep mode, $V_{LIN}$ = 0V, bus shorted to LIN_Vss, $V_S < 14V$ | LIN_VDD | $I_{VSsleep\_short}$ | 20 | 50 | 100 | µA | A |
| Supply Current in Normal Mode | Bus recessive, $V_S < 14V$ | LIN_VDD | $I_{VSrec}$ | 150 | 250 | 320 | µA | A |
| Supply Current in Normal Mode | Bus dominant (internal LIN pull-up resistor active), $V_S < 14V$ | LIN_VDD | $I_{VSdom}$ | 200 | 700 | 950 | µA | A |
| Supply Current in Fail-Safe Mode | Bus recessive, $V_S < 14V$ | LIN_VDD | $I_{VSfail}$ | 40 | 80 | 110 | µA | A |
| LIN_VDD Undervoltage Threshold (switching from Normal to Fail-Safe mode) | Decreasing supply voltage | LIN_VDD | $V_{VS\_th\_N\_F\_down}$ | 3.9 | 4.3 | 4.7 | V | A |
| | Increasing supply voltage | LIN_VDD | $V_{VS\_th\_N\_F\_up}$ | 4.1 | 4.6 | 4.9 | V | A |
| LIN_VDD Undervoltage Hysteresis | | LIN_VDD | $V_{VS\_hys\_F\_N}$ | 0.1 | 0.25 | 0.4 | V | A |
| LIN_VDD Operation Threshold (switching to Unpowered mode) | Switch to Unpowered mode | LIN_VDD | $V_{VS\_th\_U\_down}$ | 1.9 | 2.05 | 2.3 | V | A |
| | Switch from Unpowered mode to Fail-Safe mode | LIN_VDD | $V_{VS\_th\_U\_F\_up}$ | 2.0 | 2.25 | 2.4 | V | A |
| LIN_VDD Undervoltage Hysteresis | | LIN_VDD | $V_{VS\_hys\_U}$ | 0.1 | 0.2 | 0.3 | V | A |
| LIN_RXD Output Pin (open-drain) | | | | | | | | |
| Low-Level Output Sink Capability | Normal mode, $V_{LIN}$ = 0V, $I_{RXD}$ = 2 mA | LIN_RXD | $V_{RXDL}$ | — | 0.2 | 0.4 | V | A |
| High-Level Leakage Current | Normal mode, $V_{LIN} = V_S$, $V_{RXD}$ = 5V | LIN_RXD | $I_{RXDH}$ | -3 | — | +3 | µA | A |
| LIN_TXD Input/Output Pin | | | | | | | | |
| Low-Level Voltage Input | | LIN_TXD | $V_{TXDL}$ | -0.3 | — | +0.8 | V | A |
| High-Level Voltage Input | | LIN_TXD | $V_{TXDH}$ | 2 | — | 5.5 | V | A |
| Pull-Down Resistor | $V_{TXD}$ = 5V | LIN_TXD | $R_{TXD}$ | 150 | 200 | 300 | kΩ | A |
| Low-Level Leakage Current | $V_{TXD}$ = 0V | LIN_TXD | $I_{TXD}$ | -3 | — | +3 | µA | A |
| Low-Level Output Sink Current at Wake-up Request | Fail-Safe mode, $V_{TXD}$ = 0.4V | LIN_RXD | $I_{TXD}$ | 2 | 2.5 | 8 | mA | A |

**Legend:** Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design Parameter

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**TABLE 36-1: ELECTRICAL CHARACTERISTICS (CONTINUED)**

| **Operating Conditions (unless otherwise stated):** 5V < $V_S$ < 28V, -40°C < $T_J$ < +150°C; all values refer to LIN_Vss pins | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Test Conditions** | **Pin** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Unit** | **Type** |
| LIN_EN Input Pin | | | | | | | | |
| Low-Level Voltage Input | | LIN_EN | $V_{ENL}$ | -0/3 | — | +0.8 | V | A |
| High-Level Voltage Input | | LIN_EN | $V_{ENH}$ | 2 | — | 5.5 | V | A |
| Pull-Down Resistor | $V_{EN}$ = 5V | LIN_EN | $R_{EN}$ | 50 | 125 | 200 | kΩ | A |
| Low-Level Input Current | $V_{EN}$ = 0V | LIN_EN | $I_{EN}$ | -3 | — | +3 | µA | A |
| LIN_WKIN Input Pin | | | | | | | | |
| High-Level Input Voltage | | LIN_WKIN | $V_{WKinH}$ | $V_S$ – 1V | — | $V_S$ + 0.3V | V | A |
| Low-Level Input Voltage | Initializes a wake-up signal | LIN_WKIN | $V_{WKinL}$ | -1 | — | $V_S$ – 3.3V | V | A |
| LIN_WKIN Pull-up Current | $V_S$ < 28V, $V_{WKin}$ = 0V | LIN_WKIN | $I_{WKin}$ | -30 | -10 | — | µA | A |
| High-Level Leakage Current | $V_S$ = 28V, $V_{WKin}$ = 28V | LIN_WKIN | $I_{WKinL}$ | -5 | — | +5 | µA | A |
| Debounce Time of Low Pulse for Wake-up via LIN_WKIN | $V_{WKin}$ = 0V | LIN_WKIN | $t_{WKin}$ | 50 | 100 | 150 | µs | A |
| LIN_INH Output Pin | | | | | | | | |
| Switch-on Resistance Between LIN_VDD and LIN_INH | Normal or Fail-Safe mode, $I_{INH}$ = -15 mA | LIN_INH | $R_{DSon,INH}$ | — | 12 | 25 | Ω | A |
| Leakage Current | Transceiver in Sleep mode, $V_{INH}$ = 0V/28V, $V_S$ = 28V | LIN_INH | $I_{leak,INH}$ | -3 | — | +3 | µA | A |
| High-Level Voltage | Normal or Fail-Safe mode, $I_{INH}$ = -15 mA | LIN_INH | $V_{INH}$ | $V_S$ – 0.375 | — | $V_S$ | V | A |
| LIN Bus Driver: Bus Load Conditions:<br>Load 1 (small): 1 nF, 1 kΩ; Load 2 (large): 10 nF, 500Ω; External Pull-up, $R_{RXD}$ = 4.7 kΩ; $C_{RXD}$ = 20 pF;<br>Load 3 (medium): 6.8 nF, 660Ω characterized on samples.<br>Duty Cycle 1 and Duty Cycle 2 specify the timing parameters for proper operation at 20 kb/s and Duty Cycle 3 and Duty Cycle 4 at 10.4 kb/s. | | | | | | | | |
| Driver Recessive Output Voltage | Load1/Load2 | LIN_BUS | $V_{BUSrec}$ | 0.9 x $V_S$ | — | $V_S$ | V | A |
| Driver Dominant Voltage | $V_{VS}$ = 7V, $R_{load}$ = 500Ω | LIN_BUS | $V_{\_LoSUP}$ | — | — | 1.2 | V | A |
| Driver Dominant Voltage | $V_{VS}$ = 18V, $R_{load}$ = 500Ω | LIN_BUS | $V_{\_HiSUP}$ | — | — | 2 | V | A |
| Driver Dominant Voltage | $V_{VS}$ = 7V, $R_{load}$ = 1000Ω | LIN_BUS | $V_{\_LoSUP\_1k}$ | 0.6 | — | — | V | A |
| Driver Dominant Voltage | $V_{VS}$ = 18V, $R_{load}$ = 1000Ω | LIN_BUS | $V_{\_HiSUP\_1k}$ | 0.8 | — | — | V | A |
| Pull-up Resistor to LIN_VDD | Serial diode is mandatory | LIN_BUS | $R_{LIN}$ | 20 | 30 | 47 | kΩ | A |
| Voltage Drop at the Serial Diodes | In pull-up path with $R_{slave}$, $I_{SerDiode}$ = 10 mA | LIN_BUS | $V_{SerDiode}$ | 0.4 | — | 1.0 | V | D |
| LIN_BUS Current Limitation | $V_{BUS}$ = $V_{Bat\_max}$ | LIN_BUS | $I_{BUS\_LIM}$ | 40 | 120 | 200 | mA | A |
| Input Leakage Current at the Receiver Including Pull-up Resistor as Specified | Input leakage current driver off, $V_{BUS}$ = 0V, $V_{BAT}$ = 12V | LIN_BUS | $I_{BUS\_PAS\_dom}$ | -1 | -0.35 | — | mA | A |
| Leakage Current LIN_BUS Recessive | Driver off, 8V < $V_{BAT}$ < 18V, 8V < $V_{BUS}$ < 18V, $V_{BUS} \geq V_{BAT}$ | LIN_BUS | IBUS_PAS_rec | — | 10 | 20 | µA | A |

**Legend:** Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design Parameter


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**TABLE 36-1: ELECTRICAL CHARACTERISTICS (CONTINUED)**

| **Operating Conditions (unless otherwise stated):** 5V < $V_S$ < 28V, -40°C < $T_J$ < +150°C; all values refer to LIN_Vss pins | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Test Conditions** | **Pin** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Unit** | **Type** |
| Leakage Current when Control Unit Disconnected from Ground; Loss of Local Ground must not Affect Communication in the Residual Network | $GND_{Device}$ = $V_S$, $V_{BAT}$ = 12V, 0V < $V_{BUS}$ < 18V | LIN_BUS | $I_{BUS\_NO\_gnd}$ | -10 | +0.5 | +10 | µA | A |
| Leakage Current at Disconnected Battery; Node has to Sustain the Current that can Flow Under this Condition; Bus Must Remain Operational Under this Condition | $V_{BAT}$ disconnected, $V_{SUP\_Device}$ = LIN_Vss, 0V < $V_{BUS}$ < 18V | LIN_BUS | $I_{BUS\_NO\_bat}$ | — | 0.1 | 2 | µA | A |
| Capacitance on Pin LIN_BUS to LIN_Vss | | LIN_BUS | $C_{LIN}$ | — | — | 20 | pF | D |
| LIN Bus Receiver | | | | | | | | |
| Center of Receiver Threshold | $V_{BUS\_CNT}$ = ($V_{th\_dom}$ + $V_{th\_rec}$)/2 | LIN_BUS | $V_{BUS\_CNT}$ | 0.475 x $V_S$ | 0.5 x $V_S$ | 0.525 x $V_S$ | V | A |
| Receiver Dominant State | $V_{EN}$ = 5V | LIN_BUS | $V_{BUSdom}$ | -27 | — | 0.4 x $V_S$ | V | A |
| Receiver Recessive State | $V_{EN}$ = 5V | LIN_BUS | $V_{BUSrec}$ | 0.6 x $V_S$ | — | 40 | V | A |
| Receiver Input Hysteresis | $V_{hys}$ = $V_{th\_rec}$ – $V_{th\_dom}$ | LIN_BUS | $V_{BUShys}$ | 0.028 x $V_S$ | 0.1 x $V_S$ | 0.175 x $V_S$ | V | A |
| Pre-Wake Detection LIN_BUS High-Level Input Voltage | | LIN_BUS | $V_{LINH}$ | $V_S$ – 2V | — | $V_S$ + 0.3V | V | A |
| Pre-Wake Detection LIN_BUS Low-Level Input Voltage | Activates the LIN receiver | LIN_BUS | $V_{LINL}$ | -27 | — | $V_S$ – 3.3V | V | A |
| Internal Timers | | | | | | | | |
| Dominant Time for Wake-up via LIN_BUS | $V_{LIN}$ = 0V | LIN_BUS | $t_{bus}$ | 50 | 100 | 150 | µs | A |
| Time Delay for Mode Change from Fail-Safe into Normal Mode via LIN_EN Pin | $V_{EN}$ = 5V | LIN_EN | $t_{norm}$ | 5 | 15 | 20 | µs | A |
| Time Delay for Mode Change from Normal Mode to Sleep Mode via LIN_EN Pin | $V_{EN}$ = 0V | LIN_EN | $t_{sleep}$ | 5 | 15 | 20 | µs | A |
| Time Delay for Mode Change from Sleep Mode to Normal Mode via LIN_EN Pin | $V_{EN}$ = 5V | LIN_EN | $t_{s\_norm}$ | — | 150 | 300 | µs | A |
| LIN_TXD Dominant Time-out Time | $V_{TXD}$ = 0V | LIN_TXD | $t_{dom}$ | 20 | 40 | 60 | ms | A |
| Duty Cycle 1 | $TH_{Rec(max)}$ = 0.744 x $V_S$, $TH_{Dom(max)}$ = 0.581 x $V_S$, $V_S$ = 7.0V to 18V, $t_{Bit}$ = 50 µs, D1 = $t_{bus\_rec(min)}$/(2 x $t_{Bit}$) | LIN_BUS | D1 | 0.396 | — | — | — | A |

**Legend:** Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design Parameter

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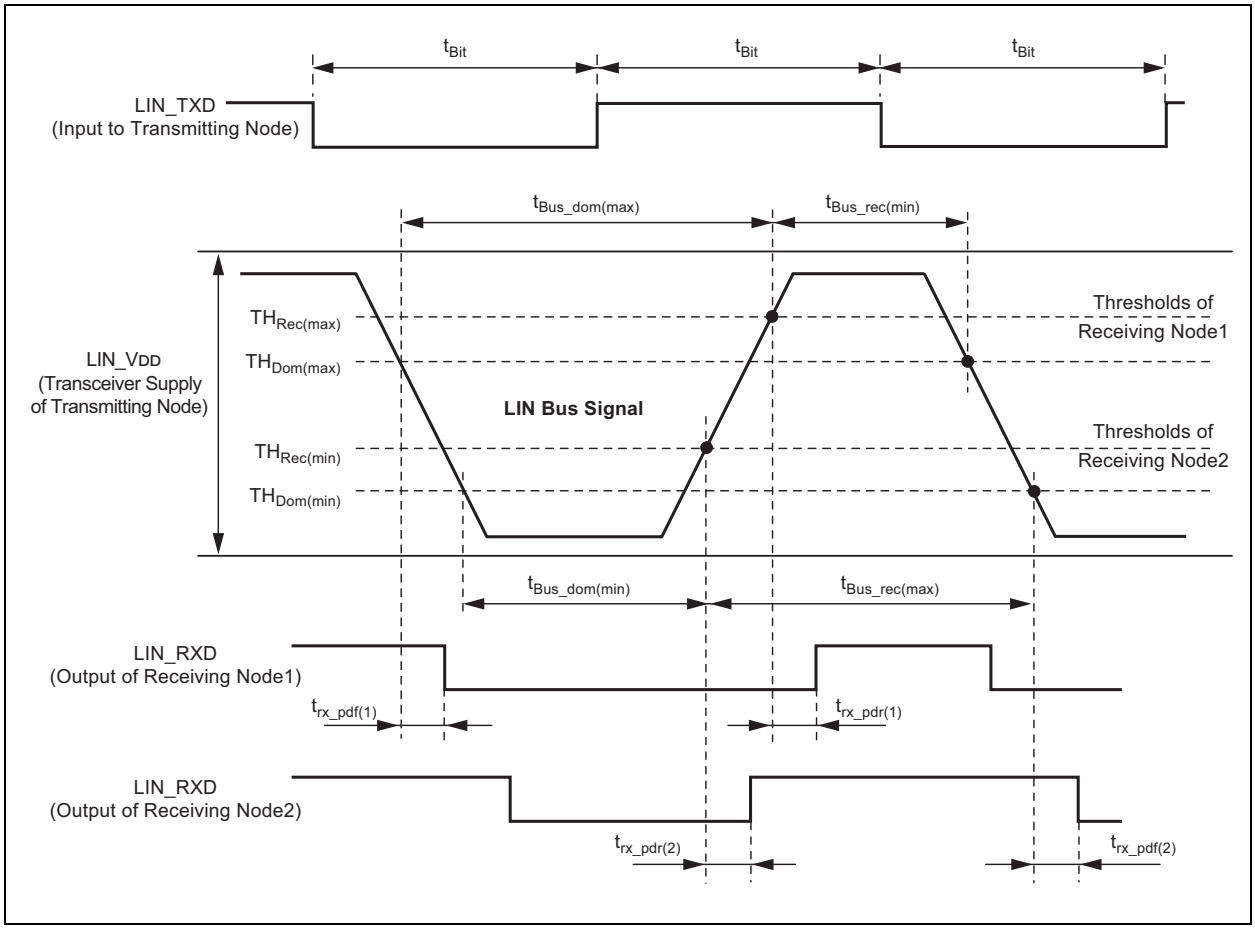
**TABLE 36-1: ELECTRICAL CHARACTERISTICS (CONTINUED)**

| **Operating Conditions (unless otherwise stated):** 5V < $V_S$ < 28V, -40°C < $T_J$ < +150°C; all values refer to LIN_Vss pins | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Test Conditions** | **Pin** | **Symbol** | **Min.** | **Typ.** | **Max.** | **Unit** | **Type** |
| Duty Cycle 2 | $TH_{Rec(min)}$ = 0.422 x $V_S$, $TH_{Dom(min)}$ = 0.284 x $V_S$, $V_S$ = 7.6V to 18V, $t_{Bit}$ = 50 µs, D2 = $t_{bus\_rec(max)}/(2 \times t_{Bit})$ | LIN_BUS | D2 | — | — | 0.581 | — | A |
| Duty Cycle 3 | $TH_{Rec(max)}$ = 0.778 x $V_S$, $TH_{Dom(max)}$ = 0.616 x $V_S$, $V_S$ = 7.0V to 18V, $t_{Bit}$ = 96 µs, D3 = $t_{bus\_rec(min)}/(2 \times t_{Bit})$ | LIN_BUS | D3 | 0.417 | — | — | — | A |
| Duty Cycle 4 | $TH_{Rec(max)}$ = 0.778 x $V_S$, $TH_{Dom(max)}$ = 0.616 x $V_S$, $V_S$ = 7.0V to 18V, $t_{Bit}$ = 96 µs, D3 = $t_{bus\_rec(min)}/(2 \times t_{Bit})$ | LIN_BUS | D4 | — | — | 0.590 | — | A |
| Slope Time Falling and Rising Edge at LIN_BUS | $V_S$ = 7.0V to 18V | LIN_BUS | $t_{SLOPE\_fall}$, $t_{SLOPE\_rise}$ | 3.5 | — | 22.5 | µs | A |
| Receiver Electrical AC Parameters of the LIN Physical Layer; LIN Receiver, LIN_RXD Load Conditions: $C_{RXD}$ = 20 pF, $R_{RXD}$ = 4.7 kΩ | | | | | | | | |
| Propagation Delay of Receiver | $V_S$ = 7.0V to 18V, $t_{rx\_pd} = \max(t_{rx\_pdr}, t_{rx\_pdf})$ | LIN_RXD | $t_{rx\_pd}$ | — | — | 6 | µs | A |
| Symmetry of Receiver Propagation Delay Rising Edge Minus Falling Edge | $V_S$ = 7.0V to 18V, $t_{rx\_sym} = t_{rx\_pdr} - t_{rx\_pdf}$ | LIN_RXD | $t_{rx\_sym}$ | -2 | — | +2 | µs | A |

**Legend:** Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design Parameter


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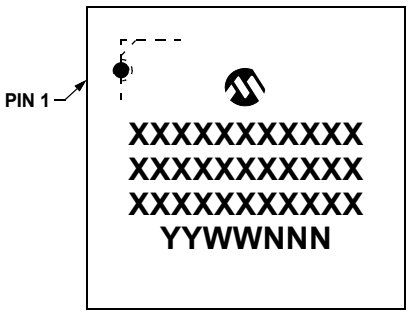
**FIGURE 36-1: DEFINITION OF LIN BUS TIMING CHARACTERISTICS**



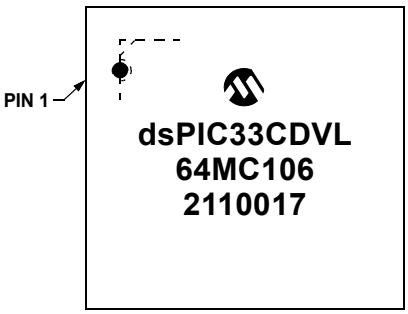
## 37.0 PACKAGING INFORMATION

### 37.1 Package Marking Information

64-Lead VGQFN (9x9 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 |

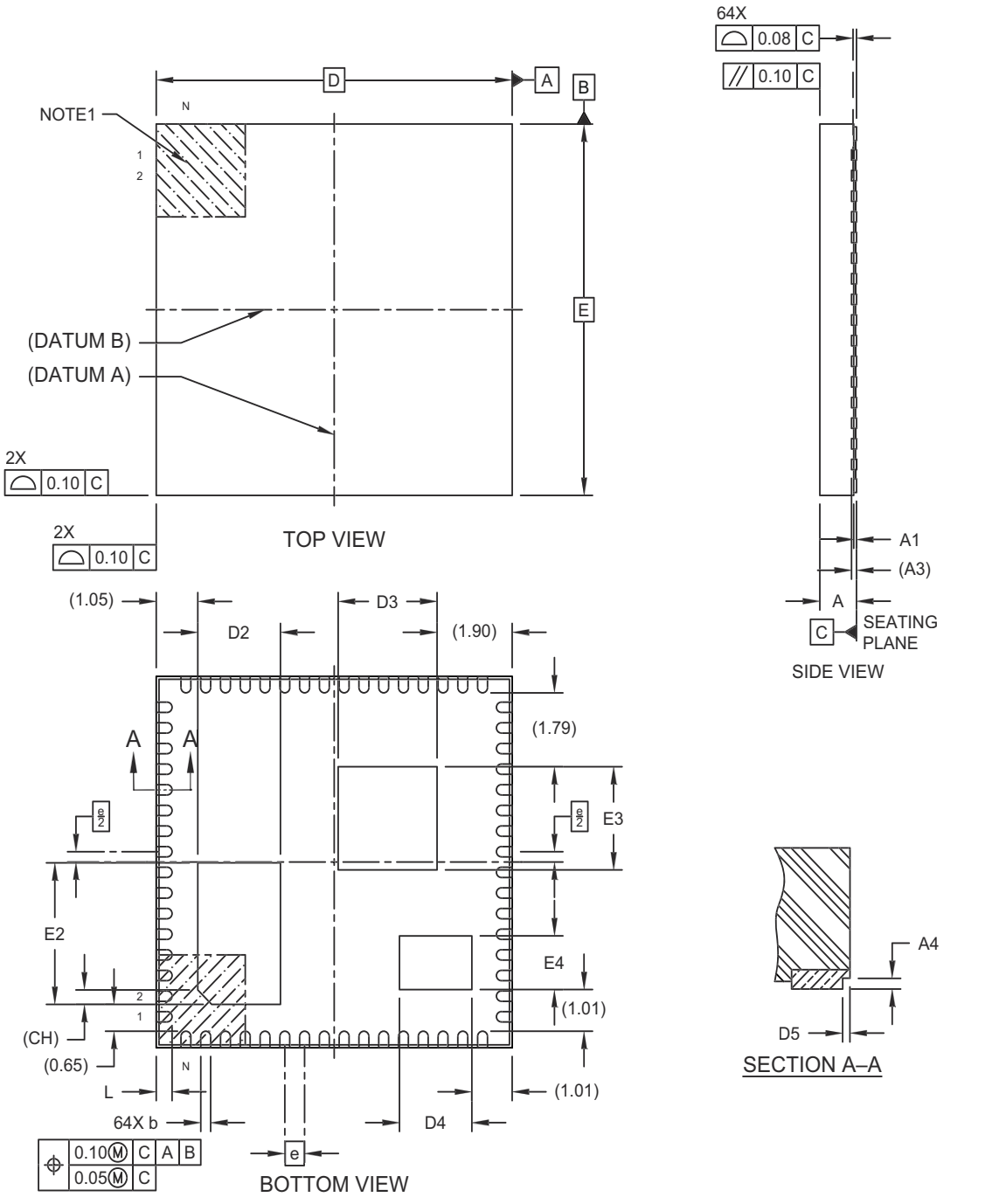
**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.


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## 37.2 Package Details

### 64-Lead Very Thin Grid Array Quad Flat Pack No-Lead (M8) - 9x9x0.927 mm Body [VGQFN] With Multiple Exposed Pads and Stepped Wettable Flanks

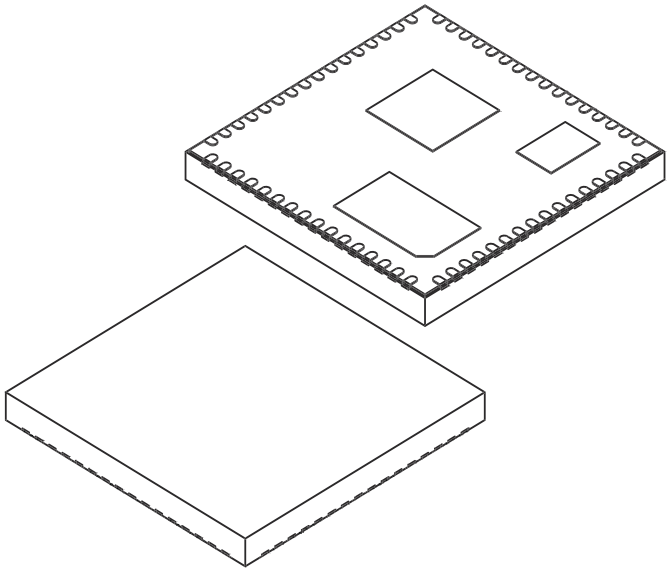
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging




Microchip Technology Drawing C04-00530-M8 Rev D Sheet 1 of 2

### 64-Lead Very Thin Grid Array Quad Flat Pack No-Lead (M8) - 9x9x0.927 mm Body [VGQFN] With Multiple Exposed Pads and Stepped Wettable Flanks

**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 | | 64 | |
| Pitch | e | | 0.50 BSC | |
| Overall Height | A | 0.827 | 0.877 | 0.927 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Terminal Thickness | A3 | | 0.127 REF | |
| Overall Length | D | | 9.00 BSC | |
| Exposed Pad Length | D2 | 1.99 | 2.09 | 2.19 |
| Exposed Pad Length | D3 | 2.40 | 2.50 | 2.60 |
| Exposed Pad Length | D4 | 1.73 | 1.83 | 1.93 |
| Overall Width | E | | 9.00 BSC | |
| Exposed Pad Width | E2 | 3.33 | 3.43 | 3.53 |
| Exposed Pad Width | E3 | 2.40 | 2.50 | 2.60 |
| Exposed Pad Width | E4 | 1.20 | 1.30 | 1.40 |
| Terminal Width | b | 0.20 | 0.25 | 0.30 |
| Terminal Length | L | 0.30 | 0.40 | 0.50 |
| Exposed Pad Corner Chamfer | CH | | 0.35 REF | |
| Wettable Flank Step Cut Length | D5 | 0.01 | 0.05 | 0.09 |
| Wettable Flank Step Cut Height | A4 | 0.03 | - | - |

Notes:

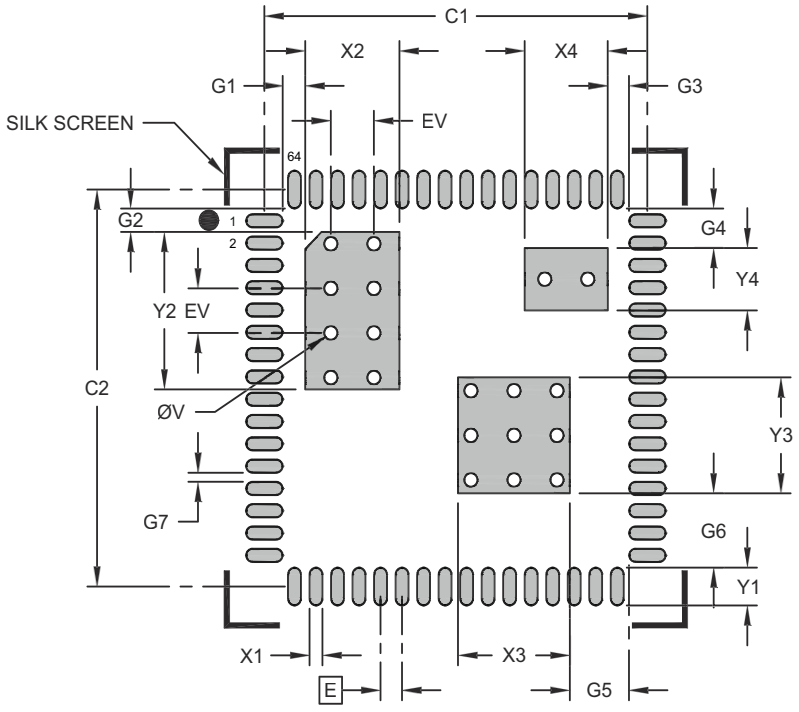
1. The Pin 1 visual index feature may vary, but it must be located within the hatched area.
2. The package is saw singulated.
3. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-00530-M8 Rev D Sheet 2 of 2


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### 64-Lead Very Thin Grid Array Quad Flat Pack No-Lead (M8) - 9x9x0.927 mm Body [VGQFN] With Multiple Exposed Pads and Stepped Wettable Flanks

**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 | |
| Center Pad Width | X2 | | | 2.19 |
| Center Pad Length | Y2 | | | 3.53 |
| Center Pad Width | X3 | | | 2.60 |
| Center Pad Length | Y3 | | | 2.60 |
| Center Pad Width | X4 | | | 1.93 |
| Center Pad Length | Y4 | | | 1.40 |
| Contact Pad Spacing | C1 | | 8.90 | |
| Contact Pad Spacing | C2 | | 8.90 | |
| Contact Pad Width (Xnn) | X1 | | | 0.30 |
| Contact Pad Length (Xnn) | Y1 | | | 0.85 |
| Contact Pad to Center Pad | G1 | 0.53 | | |
| Contact Pad to Center Pad | G2 | 0.53 | | |
| Contact Pad to Center Pad | G3 | 0.50 | | |
| Contact Pad to Center Pad | G4 | 0.86 | | |
| Contact Pad to Center Pad | G5 | 1.38 | | |
| Contact Pad to Center Pad | G6 | 1.67 | | |
| Contact Pad to Contact Pad | G7 | 0.20 | | |
| Thermal Via Diameter | V | | 0.30 | |
| Thermal Via Pitch | EV | | 1.00 | |

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 the reflow process.

Microchip Technology Drawing C04-02530-M8 Rev D

# APPENDIX A: REVISION HISTORY

## Revision A (September 2020)

This is the initial version of the document.

## Revision B (October 2021)

- Sections:
  - Updated **"Peripheral Features"**, **"Protection Features"**, **"Pin Diagrams"**, **Section 33.0 "Electrical Characteristics"** and **Section 35.0 "MOSFET Gate Driver Electrical Characteristics"**.
- Tables:
  - Updated Table 1, Table 1-1, Table 1-2, Table 34-1 and Table 34-2.
- Figures:
  - Updated Figure 1-2.
- Registers:
  - Updated Register 26-1 and Register 26-2.

## Revision C (March 2023)

- Sections:
  - Updated **Section "Operating Conditions"**, **Section "Host dsPIC DSC Features"**, **Section "High-Resolution PWM"**, **Section "High-Speed Analog-to-Digital Converter"**, **Section "Microcontroller Features"**, **Section "Peripheral Features"**, **Section "Analog Features"**, **Section "Debug Features"**, **Section "Safety Features"**, **Section "Functional Safety Readiness – ISO 26262 / IEC 61508 / IEC 60730"**, **Section "Qualification"**, **Section 4.3 "BIST Overview"**, **Section 4.3.3 "Fault Simulation"**, **Section 4.5.1.1 "Extended X Data Space"**, **Section 5.4 "Error Correcting Code (ECC)"**, **Section 9.2 "CPU Clocking"**, **Section 9.4 "Internal Fast RC (FRC) Oscillator"**, **Section 11.0 "High-Resolution PWM with Fine Edge Placement"**, **Section 13.2 "Temperature Sensor"**, **Section 16.0 "Universal Asynchronous Receiver Transmitter (UART)"**, **Section 17.0 "LIN Transceiver Module"**, **Section 29.2.1 "Sleep Mode"**, **Section 29.2.2 "Idle Mode"**, **Section 35.0 "MOSFET Gate Driver Electrical Characteristics"**, **Section 36.0 "LIN Transceiver Electrical Characteristics"**, and **Section 37.2 "Package Details".**
  - Added **"Terminology Cross Reference"**, **Section 9.5 "Low-Power RC (LPRC) Oscillator"**, **Section 13.4 "Differential-Mode"**.
- Tables:
  - Updated Table 4-11, Table 7-1, Table 7-2, Table 9-1, Table 24-3, Table 30-1, Table 33-34, Table 33-7, Table 33-38 and Table 36-1.
  - Added Table 33-36.
- Figures:
  - Updated Figure 7-2, Figure 9-1, Figure 9-2, Figure 9-5, Figure 13-1 and Figure 13-2.
- Registers:
  - Updated Register 5-1, Register 7-5, Register 9-1, Register 9-6, Register 11-21, Register 11-24, Register 11-26, Register 11-32, Register 13-6, Register 13-23, Register 14-7, Register 14-9, Register 15-2, Register 15-7, Register 15-10, Register 15-17, Register 23-3, Register 30-4, Register 30-6, Register 30-13 and Register 30-18.
  - Added Register 3-4


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- Equations:
  - Updated Equation 20-2 and Equation 20-3.
- Examples:
  - Added Example 8-1

## Revision D (January 2024)

- Sections:
  - Updated **Section 2.1 “Basic Connection Requirements”**, **Section 12.19.3 “Sleep Mode”**, **Section 27.0 “Deadman Timer (DMT)”** and **Section 36.0 “LIN Transceiver Electrical Characteristics”**.
  - Added **Section “Excessive trace length and other physical interaction can lead to poor signal quality. Poorly tuned oscillator circuits can have reduced amplitude, incorrect frequency (runt pulses), distorted waveforms and long start-up times that may result in unpredictable application behavior, such as instruction misexecution, illegal op code fetch, etc. Ensure that the crystal oscillator circuit is at full amplitude and correct frequency before the system begins to execute code. In planning the application’s routing and I/O assignments, ensure that adjacent port pins and other signals in close proximity to the oscillator do not have high frequencies, short rise and fall times and other similar noise. For further information on the Primary Oscillator, see Section 9.4 “Internal Fast RC (FRC) Oscillator”.”** and **Section 9.3.1 “Primary Oscillator Pin Functionality”**.
- Tables:
  - Updated Table 1-2, and Table 7-2
- Figures:
  - Updated Figure 2-1 and Figure 13-1.
  - Added Figure 12-5.
- Registers:
  - Updated Register 7-5, Register 15-1, and Register 27-1.

## Revision E (June 2025)

- Sections:
  - Updated **Section “Host dsPIC DSC Features”**, **Section “Functional Safety Readiness – ISO 26262 / IEC 61508 / IEC 60730”**, **Section “Referenced Sources”**, **Section 2.1 “Basic Connection Requirements”**, **Section 12.2 “Communications Port (DE2 Interconnect)”**, **Section 12.3 “Low-Side PWM Inputs (PWMAL, PWMBL, PWMCL)”**, **Section 12.4 “High-Side PWM Inputs (PWMAH, PWMBH, PWMCH)”**, **Section 12.5 “Output Enable (OE) Input”**, **Section 12.7 “Wake Input (WAKE)”**, **Section 12.19.3 “Sleep Mode”**, **Section 12.23.1 “Communications Interface”**, **Section 33.0 “Electrical Characteristics”** and **Section 35.0 “MOSFET Gate Driver Electrical Characteristics”**.
  - Removed **Section 2.6 “MOSFET Gate Driver Sleep Mode Requirements”**.
- Tables:
  - Updated Table 2, Table 3, Table 1-2, Table 8-2, Table 33-17, Table 33-5, Table 33-34 and Table 35-1.
  - Added Table 12-1.
- Figures:
  - Updated Figure (Pin Diagrams), Figure 12-1, Figure 12-2 and Figure 13-2.
  - Removed Figure 2-3 “Wake Extender” and Figure 12-5 “Wake Extender Example Software Flow”.
- Registers:
  - Updated Register 11-12, Register 13-5, Register 13-18, Register 13-19, Register 13-26, Register 14-2, Register 14-3, Register 14-5, Register 22-2 and Register 30-6.
  - Added Register 29-1.
- Examples:
  - Updated Example 12-1.

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**NOTES:**


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# INDEX


## A

Absolute Maximum Ratings ..... 487
AC Characteristics ..... 497
    Analog-to-Digital Conversion Requirements ..... 512
ADC
Alternate Interrupt Vector Table ..... 81
Analog-to-Digital Converter. *See* ADC.
Arithmetic Logic Unit (ALU) ..... 34

## B

Bit-Reversed Addressing ..... 57
    Example ..... 58
    Implementation ..... 57
    Sequence Table (16-Entry) ..... 58
Block Diagrams
    16-Bit Timer1 Module ..... 367
    32-Bit Timer Mode ..... 374
    ADC Module ..... 240
    ADC Shared Core ..... 241
    Addressing for Table Registers ..... 61
    `CALL` Stack Frame ..... 53
    Charge Pump ..... 232
    CLCx Input Source Selection ..... 389
    CLCx Logic Function Combinatorial Options ..... 388
    CLCx Module ..... 387
    Conceptual SCCPx Modules ..... 371
    Constant-Current Source ..... 415
    CPU Core ..... 26
    CRC Module ..... 433
    Data Access from Program Space Address Generation ..... 59
    Deadman Timer Module ..... 425
    dsPIC33CDVL64MC106 Device ..... 13
    dsPIC33CDVL64MC106 Family Core Clock Sources ..... 147
    dsPIC33CDVL64MC106 Family Core Oscillator Subsystem ..... 148
    dsPIC33CDVL64MC106 Family Interconnections ..... 11
    Dual 16-Bit Timer Mode ..... 374
    Functional Direct Memory Access (DMA) ..... 166
    High-Speed Analog Comparator ..... 266
    I2Cx Module ..... 348
    Input Capture x ..... 376
    Internal Regulator ..... 466
    LIN Transceiver Module ..... 320
    LIN Transceiver Operating Modes ..... 322
    Master Reset System ..... 75
    $\overline{\text{MCLR}}$ Pin Connections ..... 20
    MOSFET Gate Driver Module ..... 207
    MOSFET Gate Driver Typical Application Circuit ..... 208
    Multiplexing Remappable Outputs for RPn ..... 112
    Output Compare x ..... 375
    Overvoltage Protection ..... 237
    PLL and VCO ..... 149
    Programmer's Model ..... 28
    PSV Read Address Generation ..... 50
    PTG Module ..... 400
    PWM High-Level Module ..... 176
    QEI Module ..... 279
    Recommended Minimum Connection ..... 20
    Reference Clock Generator ..... 153
    Remappable Input for U1RX ..... 107
    Security Segments ..... 473
    SENTx Module ..... 358
    Shared Port Structure ..... 98
    Simplified UARTx ..... 298
    Single Operational Amplifier ..... 421
    SPIx Master, Frame Master Connection ..... 345
    SPIx Master, Frame Slave Connection ..... 346
    SPIx Master/Slave Connection (Enhanced Buffer Modes) ..... 345
    SPIx Master/Slave Connection (Standard Mode) ..... 344
    SPIx Module (Enhanced Mode) ..... 332
    SPIx Module (Standard Mode) ..... 331
    SPIx Slave, Frame Master Connection ..... 346
    SPIx Slave, Frame Slave Connection ..... 346
    Timer Clock Generator ..... 372
    Transient Voltage Clamp ..... 233
    Uncompressed/Compressed Format ..... 62
    Watchdog Timer (WDT) ..... 469
Brown-out Reset (BOR) ..... 449, 468
Built-In Self-Test. *See* BIST.

## C

Capture/Compare/PWM/Timer
    Auto-Shutdown and Gating Sources ..... 382
    Auxiliary Output ..... 377
    Control/Status Registers ..... 378
    General Purpose Timer ..... 373
    Input Capture Mode ..... 376
    Output Compare Mode ..... 375
    Synchronization Sources ..... 381
    Time Base Generator ..... 372
Capture/Compare/PWM/Timer (SCCP) ..... 371
CLC
    Control Registers ..... 390
Code Examples
    dsPIC DSC Auto-Baud ..... 236
    `PWRSAV` Instruction Syntax ..... 437
    Using PLL (50 MIPS) with POSC ..... 151
    Using PLL with 8 MHz Internal FRC ..... 151
Code Protection ..... 449, 473
CodeGuard Security ..... 449, 473
Comparator/DAC
    Control Registers ..... 267
    Features Overview ..... 267
Configurable Logic Cell (CLC) ..... 387
Configurable Logic Cell. *See* CLC.
Configuration Bits ..... 449
    Bit Values for Clock Selection ..... 155
CPU ..... 25
    Addressing Modes ..... 25
    Control Registers ..... 30
    Data Space Addressing ..... 25
    Instruction Set ..... 25
    Registers ..... 25
    Resources ..... 29
CRC
    Control Registers ..... 434
Current Bias Generator (CBG) ..... 415
    Control Registers ..... 416
Current Bias Generator. *See* CBG.
Customer Change Notification Service ..... 540
Customer Notification Service ..... 540
Customer Support ..... 540
Cyclic Redundancy Check. *See* CRC.

## D


Data Address Space ..... 37
  Memory Map for dsPIC33CDVL64MC106 Family ..... 39
  Near Data Space ..... 38
  Organization, Alignment ..... 37
  SFR Space ..... 38
  Width ..... 37
  X and Y Data Spaces ..... 40
Data Memory Test (BIST) ..... 40
  At Run Time ..... 40
  At Start-up ..... 40
  Flowchart ..... 40
Data Space
  Extended X ..... 53
  Paged Data Memory Space (figure) ..... 51
  Paged Memory Scheme ..... 50
DC Characteristics
  Operating Conditions ..... 488
Deadman Timer (DMT) ..... 425
  Control/Status Registers ..... 426
Deadman Timer. *See* DMT.
Development Support ..... 485
Device Identification ..... 464
Device Overview ..... 11
Direct Memory Access (DMA) Controller ..... 165
Direct Memory Access Controller. *See* DMA.
DMA
  Channel Trigger Sources ..... 173
  Control Registers ..... 169
  Peripheral Module Disable (PMD) ..... 169
  Summary of Operations ..... 167
  Types of Data Transfers ..... 168
  Typical Setup ..... 169
Doze Mode ..... 439
DSP Engine ..... 34
Dual Watchdog Timer (Dual WDT) ..... 469


## E


ECC
  Control Registers ..... 70
Electrical Characteristics ..... 487
  AC ..... 497
  ADC Delta Current ..... 492
  ADC Specifications ..... 511
  BFRC Oscillator Specifications ..... 500
  Comparator + DAC Delta Current ..... 493
  Current Bias Generator Specifications ..... 514
  DAC Output (DACOUT Pin) Specifications ..... 513
  DAC Specifications ..... 513
  Die Temperature Diode Specifications ..... 512
  Doze Current (IDOZE) ..... 491
  External Clock Timing Requirements ..... 499
  FRC Oscillator Specifications ..... 500
  High-Speed Analog Comparator Specifications ..... 512
  High-Speed PWMx Timing Requirements ..... 502
  I/O Pin Input Injection Current Specifications ..... 495
  I/O Pin Input Specifications ..... 494
  I/O Pin Output Specifications ..... 495
  I/O Timing Requirements ..... 498
  I2Cx Bus Data Requirements (Master Mode) ..... 507
  I2Cx Bus Data Timing Requirements (Slave Mode) ..... 509
  Idle Current (IIDLE) ..... 490
  Load Conditions for I/O Specifications ..... 497
  Op Amp Delta Current ..... 493
  Operating Current (IDD) ..... 489
  Operating Voltage Specifications ..... 488
  Operational Amplifier Specifications ..... 514
  Package Thermal Resistance ..... 488
  PLL Clock Timing Specifications ..... 499
  Power-Down Current (IPD) ..... 491
  Program Flash Memory Specifications ..... 496
  PWM Delta Current ..... 492
  Reset, Watchdog Timer, Oscillator Start-up Timer Requirements ..... 501
  SPIx Master Mode Requirements ..... 504
  SPIx Slave Mode Timing Requirements ..... 505
  Thermal Operating Conditions ..... 488
  UARTx Timing Requirements ..... 510
  Watchdog Timer Delta Current (ΔIWDT) ..... 492
Equations
  Bootstrap Voltage ..... 213
  Calculating Frequency Output ..... 154
  FPLLO Calculation ..... 150
  Frame Time Calculations ..... 359
  FVCO Calculation ..... 150
  HVDD Bulk Capacitor Calculation ..... 210
  $I^2C$ Baud Rate Reload Calculation ..... 349
  OE Pin High to VBOOT Ready ..... 213
  Relationship Between Device and SPIx Clock Speed ..... 346
  Snubber Capacitor Power Dissipation ..... 235
  SYNCMINx and SYNCMAXx Calculations ..... 360
  Tick Period Calculation ..... 359
  VBOOT Capacitor ..... 213
Errata ..... 9
Error Correcting Code (ECC) ..... 69
  Fault Injection ..... 69


## F


Flash OTP by ICSP Write Inhibit ..... 73
  Activation ..... 73
Flash Program Memory ..... 61
  and Table Instructions ..... 61
  Control Registers ..... 63
  RTSP Operation ..... 62
Flexible Configuration ..... 449
Flowcharts
  DE2 Data Reception, Auto-Baud Rate Sequence (Part 1) ..... 211
  DE2 Data Reception, Auto-Baud Rate Sequence (Part 2) ..... 212


## G


Getting Started Guidelines ..... 19
  Connection Requirements ..... 19
  Decoupling Capacitors ..... 19
  External Oscillator Pins ..... 21
  ICSP Pins ..... 21
  Master Clear ($\overline{MCLR}$) Pin ..... 20
  Oscillator Value Conditions on Start-up ..... 23
  Targeted Applications ..... 23
  Unused I/Os ..... 23



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**H**

High-Speed Analog Comparator with
Slope Compensation DAC ..... 265
High-Speed, 12-Bit Analog-to-Digital Converter (ADC) .... 239
Control/Status Registers ..... 243
Features Overview ..... 239
Resources ..... 242
Temperature Sensor ..... 242
HRPWM
Architecture Overview ..... 176
Control Registers ..... 177
PWM4H Output on PPS ..... 176
Write Restrictions ..... 176

**I**

I/O Ports
Configuring Analog/Digital Port Pins ..... 99
Control Registers ..... 99
Helpful Tips ..... 115
Parallel I/O (PIO) ..... 97
Resources ..... 116
Write/Read Timing ..... 99
$I^2C$
Clock Rates ..... 349
Communicating as Master in Single Master Environment ..... 347
Control/Status Registers ..... 351
Reserved Addresses ..... 350
Setting Baud Rate as Bus Master ..... 349
Slave Address Masking ..... 349
In-Circuit Debugger ..... 472
In-Circuit Emulation ..... 449
In-Circuit Serial Programming (ICSP) ..... 449, 472
Input Change Notification (ICN) ..... 106
Instruction Addressing Modes ..... 54
File Register Instructions ..... 54
Fundamental Modes Supported ..... 54
MAC Instructions ..... 55
MCU Instructions ..... 54
Move and Accumulator Instructions ..... 55
Other Instructions ..... 55
Instruction Set Summary ..... 475
Overview ..... 478
Symbols Used in Opcode Descriptions ..... 476
Instruction-Based Power-Saving Modes ..... 437
Idle ..... 438
Sleep ..... 438
Inter-Integrated Circuit. *See* $I^2C$.
Internet Address ..... 540
Interrupt Controller
Alternate Interrupt Vector Table (AIVT) ..... 79
Control and Status Registers ..... 88
INTCON1 ..... 88
INTCON2 ..... 88
INTCON3 ..... 88
INTCON4 ..... 88
INTTREG ..... 88
Interrupt Vector Details ..... 83
Interrupt Vector Table (IVT) ..... 79
Reset Sequence ..... 79
Resources ..... 88
Trap Vector Details ..... 82
Interrupt Vector Table ..... 80
Interrupts Coincident with Power Save Instructions ..... 438

**J**

JTAG Boundary Scan Interface ..... 449
JTAG Interface ..... 472

**L**

LIN Transceiver ..... 319
Absolute Maximum Ratings ..... 521
Application Circuit ..... 327
Behavior Under Low Supply Voltage Condition ..... 326
Electrical Characteristics ..... 521
Functional Description ..... 322
Fail-Safe Mode ..... 323
Normal Mode ..... 323
Operating Modes ..... 322
Physical Layer Compatibility ..... 322
Sleep Mode ..... 323
Pin Description ..... 321
Bus Pin (LIN_BUS) ..... 321
Enable Input Pin (LIN_EN) ..... 321
Ground Pin (LIN_VSS) ..... 321
Inhibit Output Pin (LIN_INH) ..... 321
Input/Output Pin (LIN_TXD) ..... 321
Output Pin (LIN_RXD) ..... 321
Supply Pin (LIN_VDD) ..... 321
Wake Pin (LIN_WKIN) ..... 321
Wake-up Scenarios from Sleep Mode ..... 324
Low-Power Sleep Modes (table) ..... 438

**M**

Memory Organization ..... 35
Resources ..... 42
Microchip Internet Website ..... 540
Modulo Addressing ..... 56
Applicability ..... 57
Operation Example ..... 56
Start and End Address ..... 56
W Address Register Selection ..... 56
MOSFET Gate Driver ..... 207
+3.3V (VREG) ..... 210
Absolute Maximum Ratings ..... 515
AC/DC Characteristics ..... 515
Application Information ..... 232
Bias Generator ..... 213
Bootstrap Inputs (VBA, VBB, VBC) ..... 209
Bootstrap Supply (VBOOT) ..... 210
Charge Pump Flying Capacitor (CAP1, CAP2) ..... 210
Communications Port (DE2) ..... 209
DE2 Communication Port ..... 221
Device Protection ..... 233
Electrical Characteristics ..... 515
Fault Output ($\overline{\text{FAULT}}$) ..... 209
Faults ..... 215
Functional Overview ..... 207
High-Side N-MOSFET Gate Driver Outputs (HSA, HSB, HSC) ..... 209
High-Side PWM Inputs (PWMAH, PWMBH, PWMCH) ..... 209
Low-Side N-MOSFET Gate Driver Outputs (LSA, LSB, LSC) ..... 210
Low-Side PWM Inputs (PWMAL, PWMBL, PWMCL) ..... 209
Motor Control ..... 219
Motor Control Unit ..... 218
Motor Phase Inputs (PHA, PHB, PHC) ..... 209


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Output Enable (OE) ..... 215
Output Enable (OE) Input ..... 209
Power Supply Input (HVDD) ..... 210
Register Definitions ..... 228
State Diagram ..... 211
Supervisor ..... 214
Wake Input (WAKE) ..... 209

**O**

Operational Amplifier ..... 421
Control Registers ..... 422
Oscillator
Backup Internal Fast RC (BFRC) ..... 153
Configuration ..... 155
Control Registers ..... 156
CPU Clocking ..... 152
Internal Fast RC (FRC) ..... 153
OSCCON Unlock Sequence ..... 155
Primary (POSC) ..... 153
Pin Functionality ..... 153
Primary PLL ..... 149
Reference Clock Output ..... 153
Oscillator with High-Frequency PLL ..... 147

**P**

Packaging ..... 527
Details ..... 528
Marking ..... 527
Peripheral Module Disable (PMD) ..... 439
Control Registers ..... 440
Peripheral Pin Select (PPS) ..... 106
Available Peripherals ..... 106
Available Pins ..... 106
Configuration Change Control ..... 107
Control Registers ..... 119
Input Mapping ..... 107
Output Mapping ..... 112
Output Selection for Remappable Pins ..... 114
Remappable Output Pin Registers ..... 113
Remappable Pin Inputs ..... 108
Selectable Input Sources ..... 110
Peripheral Trigger Generator (PTG) ..... 399
Peripheral Trigger Generator. *See* PTG.
Pin and ANSELx Availability ..... 98
Pin Diagrams ..... 4, 6
Pinout I/O Descriptions (table) ..... 14
Power-Saving Features ..... 437
Clock Frequency and Switching ..... 437
Resources ..... 439
Program Address Space
Code Memory Map ..... 35
Program Memory
Address Space ..... 35
Construction ..... 59
Data Access from Program Memory Using Table Instructions ..... 60
Table Read High Instructions (TBLRDH) ..... 60
Table Read Low Instructions (TBLRDL) ..... 60
Interfacing with Data Memory Spaces ..... 59
Organization ..... 36
Reset Vector ..... 36
Programmer's Model ..... 27
Register Descriptions ..... 27
PTG
Command Options ..... 411
Control/Status Registers ..... 401
Features ..... 399
Input Descriptions ..... 413
Output Descriptions ..... 413
Step Command Format/Description ..... 410

**Q**

QEI
Control/Status Registers ..... 280
Truth Table ..... 278
Quadrature Encoder Interface (QEI) ..... 277
Quadrature Encoder Interface. *See* QEI.

**R**

Referenced Sources ..... 10
Register Maps
Configuration ..... 450
Interrupt Enable ..... 86
Interrupt Flag ..... 86
Interrupt Priority ..... 87
PMD ..... 447
PORTA ..... 117
PORTB ..... 117
PORTC ..... 118
PORTD ..... 118
PPS Input Control ..... 144
PPS Output Control ..... 145
Registers
ADCMPxCON (ADC Digital Comparator x Control) ..... 260
ADCMPxENH (ADC Digital Comparator x Channel Enable High) ..... 262
ADCMPxENL (ADC Digital Comparator x Channel Enable Low) ..... 262
ADCON1H (ADC Control 1 High) ..... 244
ADCON1L (ADC Control 1 Low) ..... 243
ADCON2H (ADC Control 2 High) ..... 246
ADCON2L (ADC Control 2 Low) ..... 245
ADCON3H (ADC Control 3 High) ..... 248
ADCON3L (ADC Control 3 Low) ..... 247
ADCON5H (ADC Control 5 High) ..... 250
ADCON5L (ADC Control 5 Low) ..... 249
ADEIEH (ADC Early Interrupt Enable High) ..... 252
ADEIEL (ADC Early Interrupt Enable Low) ..... 252
ADEISTATH (ADC Early Interrupt Status High) ..... 253
ADEISTATL (ADC Early Interrupt Status Low) ..... 253
ADFLxCON (ADC Digital Filter x Control) ..... 263
ADIEH (ADC Interrupt Enable High) ..... 256
ADIEL (ADC Interrupt Enable Low) ..... 256
ADLVLTRGH (ADC Level-Sensitive Trigger Control High) ..... 251
ADLVLTRGL (ADC Level-Sensitive Trigger Control Low) ..... 251
ADMOD0H (ADC Input Mode Control 0 High) ..... 254
ADMOD0L (ADC Input Mode Control 0 Low) ..... 254
ADMOD1L (ADC Input Mode Control 1 Low) ..... 255
ADSTATH (ADC Data Ready Status High) ..... 257
ADSTATL (ADC Data Ready Status Low) ..... 257
ADTRIGnL/ADTRIGnH (ADC Channel Trigger n(x) Selection Low/High) ..... 258
AMPCON1H (Op Amp Control High) ..... 423



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AMPCON1L (Op Amp Control Low) ..... 422
ANSELx (Analog Select for PORTx)..... 99
BIASCON (Current Bias Generator Control)..... 416
CCPxCON1H (CCPx Control 1 High) ..... 380
CCPxCON1L (CCPx Control 1 Low)..... 378
CCPxCON2H (CCPx Control 2 High) ..... 383
CCPxCON2L (CCPx Control 2 Low)..... 382
CCPxCON3H (CCPx Control 3 High) ..... 384
CCPxSTATH (CCPx Status High) ..... 386
CCPxSTATL (CCPx Status Low)..... 385
CFG0 (Configuration 0)..... 228
CFG2 (Configuration 2)..... 229
CLCxCONH (CLCx Control High)..... 391
CLCxCONL (CLCx Control Low) ..... 390
CLCxGLSH (CLCx Gate Logic Input Select High).... 396
CLCxGLSL (CLCx Gate Logic Input Select Low) ..... 394
CLCxSEL (CLCx Input MUX Select)..... 392
CLKDIV (Clock Divider) ..... 158
CMBTRIGH (Combinational Trigger High)..... 182
CMBTRIGL (Combinational Trigger Low)..... 181
CNCONx (Change Notification Control for PORTx)..... 103
CNEN0x (Interrupt Change Notification Interrupt Enable for PORTx) ..... 103
CNEN1x (Interrupt Change Notification Interrupt Edge Select for PORTx) ..... 104
CNFx (Interrupt Change Notification Interrupt Flag for PORTx)..... 105
CNPDx (Change Notification Pull-Down Enable for PORTx)..... 102
CNPUx (Change Notification Pull-up Enable for PORTx)..... 102
CNSTATx (Interrupt Change Notification Interrupt Status for PORTx) ..... 104
CORCON (Core Control) ..... 32, 90
CRCCONH (CRC Control High) ..... 435
CRCCONL (CRC Control Low)..... 434
CRCXORH (CRC XOR Polynomial, High)..... 436
CRCXORL (CRC XOR Polynomial, Low) ..... 436
CTXTSTAT (CPU W Register Context Status)..... 33
DACCTRL1L (DAC Control 1 Low)..... 268
DACCTRL2H (DAC Control 2 High) ..... 269
DACCTRL2L (DAC Control 2 Low)..... 269
DACxCONH (DACx Control High) ..... 270
DACxCONL (DACx Control Low)..... 270
DACxDATH (DACx Data High)..... 272
DACxDATL (DACx Data Low) ..... 272
DEVID (Device ID)..... 465
DEVREV (Device Revision)..... 464
DMACHn (DMA Channel n Control) ..... 171
DMACON (DMA Engine Control)..... 170
DMAINTn (DMA Channel n Interrupt)..... 172
DMTCLR (Deadman Timer Clear) ..... 427
DMTCNTH (Deadman Timer Count High)..... 429
DMTCNTL (Deadman Timer Count Low) ..... 429
DMTCON (Deadman Timer Control) ..... 426
DMTHOLDREG (DMT Hold)..... 432
DMTPRECLR (Deadman Timer Preclear)..... 426
DMTPSCNTH (DMT Post-Configure Count Status High)..... 430
DMTPSCNTL (DMT Post-Configure Count Status Low)..... 430
DMTPSINTVH (DMT Post-Configure Interval Status High)..... 431
DMTPSINTVL (DMT Post-Configure Interval Status Low) ..... 431
DMTSTAT (Deadman Timer Status) ..... 428
ECCADDRH (ECC Fault Inject Address Compare High)..... 71
ECCADDRL (ECC Fault Inject Address Compare Low)..... 71
ECCCONH (ECC Fault Injection Configuration High)..... 70
ECCCONL (ECC Fault Injection Configuration Low) ..... 70
ECCSTATH (ECC System Status Display High)..... 72
ECCSTATL (ECC System Status Display Low) ..... 72
FALTREG Configuration..... 462
FBSLIM Configuration ..... 452
FDEVOPT Configuration ..... 461
FDMT Configuration ..... 460
FDMTCNTH Configuration ..... 459
FDMTCNTL Configuration..... 459
FDMTIVTH Configuration ..... 458
FDMTIVTL Configuration..... 458
FICD Configuration..... 457
FOSC Configuration ..... 454
FOSCSEL Configuration ..... 453
FPOR Configuration ..... 456
FSCL (Frequency Scale)..... 178
FSEC Configuration..... 451
FSIGN Configuration ..... 452
FSMINPER (Frequency Scaling Minimum Period) ..... 178
FWDT Configuration..... 455
I2CxCONH (I2Cx Control High)..... 353
I2CxCONL (I2Cx Control Low) ..... 351
I2CxMSK (I2Cx Slave Mode Address Mask)..... 355
I2CxSTAT (I2Cx Status)..... 354
IBIASCONH (Current Bias Generator Current Source Control High)..... 417
IBIASCONL (Current Bias Generator Current Source Control Low)..... 419
INDXxCNTH (Index x Counter High)..... 292
INDXxCNTL (Index x Counter Low) ..... 292
INDXxHLD (Index x Counter Hold)..... 293
INTCON1 (Interrupt Control 1) ..... 91
INTCON2 (Interrupt Control 2) ..... 93
INTCON3 (Interrupt Control 3) ..... 94
INTCON4 (Interrupt Control 4) ..... 95
INTTREG (Interrupt Control and Status) ..... 96
INTxTMRH (Interval x Timer High)..... 290
INTxTMRL (Interval x Timer Low) ..... 290
INTXxHLDH (Interval x Timer Hold High)..... 291
INTXxHLDL (Interval x Timer Hold Low) ..... 291
LATx (Output Data for PORTx) ..... 101
LFSR (Linear Feedback Shift)..... 186
LOGCONy (Combinatorial PWM Logic Control y).... 183
MBISTCON (MBIST Control)..... 41
MDC (Master Duty Cycle)..... 179
MPER (Master Period) ..... 180
MPHASE (Master Phase)..... 179
NVMADR (Nonvolatile Memory Lower Address)..... 66
NVMADRU (Nonvolatile Memory Upper Address) ..... 66
NVMCON (Nonvolatile Memory (NVM) Control) ..... 64
NVMKEY (Nonvolatile Memory Key)..... 67
NVMSRCADRH (NVM Source Data Address High)... 68
NVMSRCADRL (NVM Source Data Address Low) .... 68

ODCx (Open-Drain Enable for PORTx) ..... 101
OSCCON (Oscillator Control) ..... 156
OSCTUN (FRC Oscillator Tuning) ..... 161
PCLKCON (PWM Clock Control) ..... 177
PGxCAP (PWM Generator x Capture) ..... 206
PGxCONH (PWM Generator x Control High) ..... 188
PGxCONL (PWM Generator x Control Low) ..... 187
PGxDC (PWM Generator x Duty Cycle) ..... 202
PGxDCA (PWM Generator x Duty Cycle Adjustment) ..... 203
PGxDTH (PWM Generator x Dead-Time High) ..... 205
PGxDTL (PWM Generator x Dead-Time Low) ..... 205
PGxEVTH (PWM Generator x Event High) ..... 195
PGxEVTL (PWM Generator x Event Low) ..... 194
PGxIOCONH (PWM Generator x I/O Control High) ..... 193
PGxIOCONL (PWM Generator x I/O Control Low) ..... 192
PGxLEBH (PWM Generator x Leading-Edge Blanking High) ..... 201
PGxLEBL (PWM Generator x Leading-Edge Blanking Low) ..... 200
PGxPER (PWM Generator x Period) ..... 203
PGxPHASE (PWM Generator x Phase) ..... 202
PGxSTAT (PWM Generator x Status) ..... 190
PGxTRIGA (PWM Generator x Trigger A) ..... 204
PGxTRIGB (PWM Generator x Trigger B) ..... 204
PGxTRIGC (PWM Generator x Trigger C) ..... 204
PGxyPCIH (PWM Generator xy PCI High) ..... 199
PGxyPCIL (PWM Generator xy PCI Low) ..... 197
PLLDIV (PLL Output Divider) ..... 162
PLLFBD (PLL Feedback Divider) ..... 160
PMD1 (PMD1 Control) ..... 440
PMD2 (PMD2 Control) ..... 441
PMD3 (PMD3 Control) ..... 442
PMD4 (PMD4 Control) ..... 443
PMD6 (PMD6 Control) ..... 444
PMD7 (PMD7 Control) ..... 445
PMD8 (PMD8 Control) ..... 446
PORTx (Input Data for PORTx) ..... 100
POSxCNTH (Position x Counter High) ..... 286
POSxCNTL (Position x Counter Low) ..... 286
POSxHLD (Position x Counter Hold) ..... 287
PTGADJ (PTG Adjust) ..... 408
PTGBTE (PTG Broadcast Trigger Enable Low) ..... 404
PTGBTEH (PTG Broadcast Trigger Enable High) ..... 404
PTGC0LIM (PTG Counter 0 Limit) ..... 407
PTGC1LIM (PTG Counter 1 Limit) ..... 407
PTGCON (PTG Control/Status High) ..... 403
PTGCST (PTG Control/Status Low) ..... 401
PTGHOLD (PTG Hold) ..... 405
PTGL0 (PTG Literal 0) ..... 408
PTGQPTR (PTG Step Queue Pointer) ..... 409
PTGQUEn (PTG Step Queue n Pointer) ..... 409
PTGSDLIM (PTG Step Delay Limit) ..... 406
PTGT0LIM (PTG Timer0 Limit) ..... 405
PTGT1LIM (PTG Timer1 Limit) ..... 406
PWMEVTy (PWM Event Output Control y) ..... 185
QEIxCON (QEIx Control) ..... 280
QEIxGECH (QEIx Greater Than or Equal Compare High) ..... 296
QEIxGECL (QEIx Greater Than or Equal Compare Low) ..... 296
QEIxICH (QEIx Initialization/Capture High) ..... 294
QEIxICL (QEIx Initialization/Capture Low) ..... 294
QEIxIOC (QEIx I/O Control) ..... 282
QEIxIOCH (QEIx I/O Control High) ..... 283
QEIxLECH (QEIx Less Than or Equal Compare High) ..... 295
QEIxLECL (QEIx Less Than or Equal Compare Low) ..... 295
QEIxSTAT (QEIx Status) ..... 284
RCON (Reset Control) ..... 77
REFOCONH (Reference Clock Control High) ..... 164
REFOCONL (Reference Clock Control Low) ..... 163
REFOTRIMH (Reference Oscillator Trim) ..... 164
REV_ID (Hardware Revision ID) ..... 231
RPCON (Peripheral Remapping Configuration) ..... 119
RPINR0 (Peripheral Pin Select Input 0) ..... 119
RPINR1 (Peripheral Pin Select Input 1) ..... 120
RPINR11 (Peripheral Pin Select Input 11) ..... 123
RPINR12 (Peripheral Pin Select Input 12) ..... 123
RPINR13 (Peripheral Pin Select Input 13) ..... 124
RPINR14 (Peripheral Pin Select Input 14) ..... 124
RPINR15 (Peripheral Pin Select Input 15) ..... 125
RPINR18 (Peripheral Pin Select Input 18) ..... 125
RPINR19 (Peripheral Pin Select Input 19) ..... 126
RPINR2 (Peripheral Pin Select Input 2) ..... 120
RPINR20 (Peripheral Pin Select Input 20) ..... 126
RPINR21 (Peripheral Pin Select Input 21) ..... 127
RPINR22 (Peripheral Pin Select Input 22) ..... 127
RPINR23 (Peripheral Pin Select Input 23) ..... 128
RPINR27 (Peripheral Pin Select Input 27) ..... 128
RPINR3 (Peripheral Pin Select Input 3) ..... 121
RPINR37 (Peripheral Pin Select Input 37) ..... 129
RPINR38 (Peripheral Pin Select Input 38) ..... 129
RPINR4 (Peripheral Pin Select Input 4) ..... 121
RPINR42 (Peripheral Pin Select Input 42) ..... 130
RPINR43 (Peripheral Pin Select Input 43) ..... 130
RPINR44 (Peripheral Pin Select Input 44) ..... 131
RPINR45 (Peripheral Pin Select Input 45) ..... 131
RPINR46 (Peripheral Pin Select Input 46) ..... 132
RPINR47 (Peripheral Pin Select Input 47) ..... 132
RPINR48 (Peripheral Pin Select Input 48) ..... 133
RPINR49 (Peripheral Pin Select Input 49) ..... 133
RPINR5 (Peripheral Pin Select Input 5) ..... 122
RPINR6 (Peripheral Pin Select Input 6) ..... 122
RPOR0 (Peripheral Pin Select Output 0) ..... 134
RPOR1 (Peripheral Pin Select Output 1) ..... 134
RPOR10 (Peripheral Pin Select Output 10) ..... 139
RPOR11 (Peripheral Pin Select Output 11) ..... 139
RPOR12 (Peripheral Pin Select Output 12) ..... 140
RPOR13 (Peripheral Pin Select Output 13) ..... 140
RPOR14 (Peripheral Pin Select Output 14) ..... 141
RPOR15 (Peripheral Pin Select Output 15) ..... 141
RPOR16 (Peripheral Pin Select Output 16) ..... 142
RPOR17 (Peripheral Pin Select Output 17) ..... 142
RPOR18 (Peripheral Pin Select Output 18) ..... 143
RPOR19 (Peripheral Pin Select Output 19) ..... 143
RPOR2 (Peripheral Pin Select Output 2) ..... 135
RPOR3 (Peripheral Pin Select Output 3) ..... 135
RPOR4 (Peripheral Pin Select Output 4) ..... 136
RPOR5 (Peripheral Pin Select Output 5) ..... 136
RPOR6 (Peripheral Pin Select Output 6) ..... 137
RPOR7 (Peripheral Pin Select Output 7) ..... 137
RPOR8 (Peripheral Pin Select Output 8) ..... 138
RPOR9 (Peripheral Pin Select Output 9) ..... 138
SENTxCON1 (SENTx Control 1) ..... 361
SENTxDATH (SENTx Receive Data High) ..... 365
SENTxDATL (SENTx Receive Data Low) ..... 365


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SENTxSTAT (SENTx Status) ..... 363
SLPxCONH (DACx Slope Control High) ..... 273
SLPxCONL (DACx Slope Control Low) ..... 274
SLPxDAT (DACx Slope Data) ..... 275
SPIxCON1H (SPIx Control 1 High) ..... 336
SPIxCON1L (SPIx Control 1 Low) ..... 334
SPIxCON2L (SPIx Control 2 Low) ..... 338
SPIxIMSKH (SPIx Interrupt Mask High) ..... 343
SPIxIMSKL (SPIx Interrupt Mask Low) ..... 342
SPIxSTATH (SPIx Status High) ..... 341
SPIxSTATL (SPIx Status Low) ..... 339
SR (CPU STATUS) ..... 30, 89
STAT0 (Status 0) ..... 230
STAT1 (Status 1) ..... 231
T1CON (Timer1 Control) ..... 368
TRISx (Output Enable for PORTx) ..... 100
UxBRG (UARTx Baud Rate) ..... 308
UxBRGH (UARTx Baud Rate High) ..... 308
UxINT (UARTx Interrupt) ..... 317
UxMODE (UARTx Configuration) ..... 300
UxMODEH (UARTx Configuration High) ..... 302
UxP1 (UARTx Timing Parameter 1) ..... 310
UxP2 (UARTx Timing Parameter 2) ..... 311
UxP3 (UARTx Timing Parameter 3) ..... 312
UxP3H (UARTx Timing Parameter 3 High) ..... 312
UxRXCHK (UARTx Receive Checksum) ..... 314
UxRXREG (UARTx Receive Buffer) ..... 309
UxSCCON (UARTx Smart Card Configuration) ..... 315
UxSCINT (UARTx Smart Card Interrupt) ..... 316
UxSTA (UARTx Status) ..... 304
UxSTAH (UARTx Status High) ..... 306
UxTXCHK (UARTx Transmit Checksum) ..... 313
UxTXREG (UARTx Transmit Buffer) ..... 309
VELxCNT (Velocity x Counter) ..... 288
VELxCNTH (Velocity x Counter High) ..... 288
VELxHLD (Velocity x Counter Hold) ..... 289
VREGCON (Voltage Regulator Control) ..... 467
WDTCONH (Watchdog Timer Control High) ..... 471
WDTCONL (Watchdog Timer Control Low) ..... 470
Resets ..... 75
Brown-out Reset (BOR) ..... 75
Configuration Mismatch Reset (CM) ..... 75
Illegal Condition Reset (IOPUWR) ..... 75
Illegal Opcode ..... 75
Security ..... 75
Uninitialized W Register ..... 75
Master Clear ($\overline{MCLR}$) Pin Reset ..... 75
Power-on Reset (POR) ..... 75
RESET Instruction (SWR) ..... 75
Resources ..... 76
Trap Conflict Reset (TRAPR) ..... 75
Watchdog Timer Time-out Reset (WDTO) ..... 75
Revision History ..... 531


## S


SENTx Protocol Data Frames ..... 358
Serial Peripheral Interface (SPI) ..... 329
Serial Peripheral Interface. *See* SPI.
SFR Blocks
000h ..... 42
100h ..... 43
200h ..... 43
300h-400h ..... 44
800h ..... 45
900h ..... 46
A00h ..... 47
B00h ..... 47
C00h ..... 47
D00h ..... 48
E00h ..... 48
F00h ..... 49
Single-Edge Nibble Transmission (SENT) ..... 357
Control/Status Registers ..... 361
Receive Mode ..... 360
Configuration ..... 360
Transmit Mode ..... 359
Configuration ..... 359
Single-Edge Nibble Transmission for Automotive Applications ..... 357
Single-Edge Nibble Transmission. *See* SENT.
Special Features of the CPU ..... 449
SPI
Control/Status Registers ..... 334


## T


Timer1 ..... 367
Control Register ..... 368
Timing Diagrams
BOR and Master Clear Reset Characteristics ..... 501
Clock/Instruction Cycle ..... 152
DE2 Packet ..... 223
External Clock ..... 499
High-Speed PWMx Characteristics ..... 502
I/O Characteristics ..... 498
I2Cx Bus Data (Master Mode) ..... 506
I2Cx Bus Data (Slave Mode) ..... 508
I2Cx Bus Start/Stop Bits (Master Mode) ..... 506
I2Cx Bus Start/Stop Bits (Slave Mode) ..... 508
LIN Bus Characteristics ..... 526
LIN Wake-up from Sleep Mode ..... 324
Local Wake-up from Wake-up Switch ..... 325
QEI Interface Signals ..... 277
SPIx Master Mode (CKE = 0) Characteristics ..... 503
SPIx Master Mode (CKE = 1) Characteristics ..... 503
SPIx Slave Mode (CKE = 0) Characteristics ..... 504
SPIx Slave Mode (CKE = 1) Characteristics ..... 505
UARTx Characteristics ..... 510


## U


UART
Architectural Overview ..... 298
Character Frame ..... 299
Control/Status Registers ..... 300
Data Buffers ..... 299
Protocol Extensions ..... 299
Unique Device Identifier (UDID) ..... 37
Unique Device Identifier. *See* UDID.
Universal Asynchronous Receiver Transmitter (UART) ..... 297
Universal Asynchronous Receiver Transmitter. *See* UART.
User OTP Memory ..... 466


## V


Voltage Regulator (On-Chip) ..... 466


## W

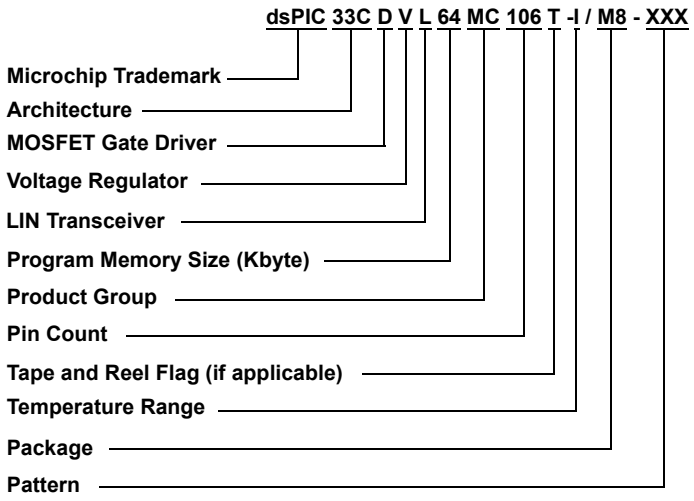

Watchdog Timer (WDT) ..... 449
WWW Address ..... 540
WWW, On-Line Support ..... 9

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## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.




| | | |
|---|---|---|
| **Architecture:** | 33 | = 16-Bit Digital Signal Controller |
| **Product Group:** | MC | = Motor Control |
| **Pin Count:** | 06 | = 64-pin |
| **Temperature Range:** | I | = -40°C to +85°C (Industrial) |
| | E | = -40°C to +125°C (Extended) |
| | H | = -40°C to +150°C (High) |
| **Package:** | M8 | = Very Thin Grid Array Quad Flat – (64-pin) 9x9 mm body (VGQFN) |

**Example:**

dsPIC33CDVL64MC106-I/M8:
dsPIC33, 64-Kbyte Program Memory,
Motor Control, 64-Pin,
Industrial Temperature,
VGQFN Package.

**NOTES:**


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