PIC18F2682/2685/4682/4685 Data Sheet

28/40/44-Pin Enhanced Flash Microcontrollers with ECAN™ Technology, 10-Bit A/D and nanoWatt Technology
Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip’s Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip’s code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.
28/40/44-Pin Enhanced Flash Microcontrollers with ECAN™ Technology, 10-Bit A/D and nanoWatt Technology

Power-Managed Modes:
- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 μA typical
- Sleep mode currents down to 0.1 μA typical
- Timer1 Oscillator: 1.1 μA, 32 kHz, 2V
- Watchdog Timer: 2.1 μA
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:
- Four Crystal modes, up to 40 MHz
- 4x Phase Lock Loop (PLL) – available for crystal and internal oscillators
- Two External RC modes, up to 4 MHz
- Two External Clock modes, up to 40 MHz
- Internal Oscillator Block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - Provides a complete range of clock speeds, from 31 kHz to 32 MHz when used with PLL
  - User-tunable to compensate for frequency drift
- Secondary Oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor
  - Allows for safe shutdown if peripheral clock stops

Special Microcontroller Features:
- C compiler Optimized Architecture with optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory typical
- 1,000,000 Erase/Write Cycle Data EEPROM Memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-Programmable under Software Control
- Priority Levels for Interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Wide operating voltage range: 2.0V to 5.5V

Peripheral Highlights:
- High-CURRENT Sink/source 25 mA/25 mA
- Three External Interrupts
- One Capture/Compare/PWM (CCP1) module
- Enhanced Capture/Compare/PWM (ECCP1) module (40/44-pin devices only):
  - One, two or four PWM outputs
  - Selectable polarity
  - Programmable dead time
  - Auto-shutdown and auto-restart
- Master Synchronous Serial Port (MSSP) module supporting 3-Wire SPI (all 4 modes) and I²C™ Master and Slave modes
- Enhanced Addressable USART module:
  - Supports RS-485, RS-232 and LIN 1.3
  - RS-232 operation using internal oscillator block (no external crystal required)
  - Auto-wake-up on Start bit
  - Auto-Baud Detect
- 10-Bit, up to 11-Channel Analog-to-Digital Converter module (A/D), up to 100 ksp:
  - Auto-acquisition capability
  - Conversion available during Sleep
- Dual Analog Comparators with Input Multiplexing

ECAN Module Features:
- Message bit rates up to 1 Mbps
- Conforms to CAN 2.0B ACTIVE Specification
- Fully Backward Compatible with PIC18XXX8 CAN modules
- Three Modes of Operation:
  - Legacy, Enhanced Legacy, FIFO
- Two Dedicated Transmit Buffers with Prioritization
- Six Programmable Receive/Transmit Buffers
- Three Full, 29-Bit Acceptance Masks
- 16 Full, 29-Bit Acceptance Filters w/Dynamic Association
- DeviceNet™ Data Byte Filter Support
- Automatic Remote Frame Handling
- Advanced Error Management Features

<table>
<thead>
<tr>
<th>Device</th>
<th>Program Memory</th>
<th>Data Memory</th>
<th>I/O</th>
<th>10-Bit A/D (ch)</th>
<th>CCP1/ECCP1 (PWM)</th>
<th>MSSP</th>
<th>USART</th>
<th>Comp.</th>
<th>Timers 8/16-bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC18F2682</td>
<td>80K</td>
<td>1024</td>
<td>28</td>
<td>1/0</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>0</td>
<td>1/3</td>
</tr>
<tr>
<td>PIC18F2685</td>
<td>96K</td>
<td>1024</td>
<td>28</td>
<td>1/0</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>0</td>
<td>1/3</td>
</tr>
<tr>
<td>PIC18F4682</td>
<td>80K</td>
<td>1024</td>
<td>40/44</td>
<td>1/1</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>2</td>
<td>1/3</td>
</tr>
<tr>
<td>PIC18F4685</td>
<td>96K</td>
<td>1024</td>
<td>40/44</td>
<td>1/1</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>2</td>
<td>1/3</td>
</tr>
</tbody>
</table>

© 2009 Microchip Technology Inc. DS39761C-page 3
### Pin Diagrams

**28-Pin PDIP, SOIC**

<table>
<thead>
<tr>
<th>Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCLR/Vpp/RE3</td>
</tr>
<tr>
<td>RA0/AN0</td>
</tr>
<tr>
<td>RA1/AN1</td>
</tr>
<tr>
<td>RA2/AN2/VREF-</td>
</tr>
<tr>
<td>RA3/AN3/VREF+</td>
</tr>
<tr>
<td>RA4/T0CKI</td>
</tr>
<tr>
<td>RA5/AN4/SS/HLVDIN</td>
</tr>
<tr>
<td>VSS</td>
</tr>
<tr>
<td>OSC1/CLKI/RA7</td>
</tr>
<tr>
<td>OSC2/CLKO/RA6</td>
</tr>
<tr>
<td>RC0/T1OSO/T13CKI</td>
</tr>
<tr>
<td>RC1/T1OSI</td>
</tr>
<tr>
<td>RC2/CCP1</td>
</tr>
<tr>
<td>RC3/SCK/SCL</td>
</tr>
<tr>
<td>RB7/KBI3/PGD</td>
</tr>
<tr>
<td>RB6/KBI2/PGC</td>
</tr>
<tr>
<td>RB5/KBI1/PGM</td>
</tr>
<tr>
<td>RB4/KBI0/AN9</td>
</tr>
<tr>
<td>RB3/CANRX</td>
</tr>
<tr>
<td>RB2/INT2/CANTX</td>
</tr>
<tr>
<td>RB1/INT1/AN8</td>
</tr>
<tr>
<td>RB0/INT0/AN10</td>
</tr>
<tr>
<td>VDD</td>
</tr>
<tr>
<td>VSS</td>
</tr>
<tr>
<td>RD7/PSP7/P1D</td>
</tr>
<tr>
<td>RD6/PSP6/P1C</td>
</tr>
<tr>
<td>RD5/PSP5/P1B</td>
</tr>
<tr>
<td>RD4/PSP4/ECCP1/P1A</td>
</tr>
<tr>
<td>RC7/RX/DT</td>
</tr>
<tr>
<td>RC6/TX/CK</td>
</tr>
<tr>
<td>RC5/SDO</td>
</tr>
<tr>
<td>RC4/SDI/SDA</td>
</tr>
<tr>
<td>RE0/RD/AN5</td>
</tr>
<tr>
<td>RE1/WR/AN6/C1OUT</td>
</tr>
<tr>
<td>RE2/CS/AN7/C2OUT</td>
</tr>
<tr>
<td>VDD</td>
</tr>
<tr>
<td>VSS</td>
</tr>
<tr>
<td>OSC1/CLKI/RA7</td>
</tr>
<tr>
<td>OSC2/CLKO/RA6</td>
</tr>
<tr>
<td>RC0/T1OSO/T13CKI</td>
</tr>
</tbody>
</table>

**40-Pin PDIP**

<table>
<thead>
<tr>
<th>Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCLR/Vpp/RE3</td>
</tr>
<tr>
<td>RA0/AN0</td>
</tr>
<tr>
<td>RA1/AN1</td>
</tr>
<tr>
<td>RA2/AN2/VREF-</td>
</tr>
<tr>
<td>RA3/AN3/VREF+</td>
</tr>
<tr>
<td>RA4/T0CKI</td>
</tr>
<tr>
<td>RA5/AN4/SS/HLVDIN</td>
</tr>
<tr>
<td>RE0/RD/AN5</td>
</tr>
<tr>
<td>RE1/WR/AN6/C1OUT</td>
</tr>
<tr>
<td>RE2/CS/AN7/C2OUT</td>
</tr>
<tr>
<td>VDD</td>
</tr>
<tr>
<td>VSS</td>
</tr>
<tr>
<td>OSC1/CLKI/RA7</td>
</tr>
<tr>
<td>OSC2/CLKO/RA6</td>
</tr>
<tr>
<td>RC0/T1OSO/T13CKI</td>
</tr>
<tr>
<td>RC1/T1OSI</td>
</tr>
<tr>
<td>RC2/CCP1</td>
</tr>
<tr>
<td>RC3/SCK/SCL</td>
</tr>
<tr>
<td>RD6/PSP0/C1IN+</td>
</tr>
<tr>
<td>RD1/PSP1/C1IN-</td>
</tr>
<tr>
<td>RB7/KBI3/PGD</td>
</tr>
<tr>
<td>RB6/KBI2/PGC</td>
</tr>
<tr>
<td>RB5/KBI1/PGM</td>
</tr>
<tr>
<td>RB4/KBI0/AN9</td>
</tr>
<tr>
<td>RB3/CANRX</td>
</tr>
<tr>
<td>RB2/INT2/CANTX</td>
</tr>
<tr>
<td>RB1/INT1/AN8</td>
</tr>
<tr>
<td>RB0/INT0/AN10</td>
</tr>
<tr>
<td>VDD</td>
</tr>
<tr>
<td>VSS</td>
</tr>
<tr>
<td>RD7/PSP7/P1D</td>
</tr>
<tr>
<td>RD6/PSP6/P1C</td>
</tr>
<tr>
<td>RD5/PSP5/P1B</td>
</tr>
<tr>
<td>RD4/PSP4/ECCP1/P1A</td>
</tr>
<tr>
<td>RC7/RX/DT</td>
</tr>
<tr>
<td>RC6/TX/CK</td>
</tr>
<tr>
<td>RC5/SDO</td>
</tr>
<tr>
<td>RC4/SDI/SDA</td>
</tr>
<tr>
<td>RD3/PSP3/C2IN-</td>
</tr>
<tr>
<td>RD2/PSP2/C2IN+</td>
</tr>
</tbody>
</table>

**Note:** Pinouts are subject to change.
Note: Pinouts are subject to change.
Table of Contents

1.0 Device Overview ........................................................................................................... 9
2.0 Oscillator Configurations ............................................................................................ 25
3.0 Power-Managed Modes ............................................................................................... 35
4.0 Reset ............................................................................................................................ 43
5.0 Memory Organization .................................................................................................. 63
6.0 Flash Program Memory ............................................................................................... 97
7.0 Data EEPROM Memory .............................................................................................. 107
8.0 8 x 8 Hardware Multiplier ......................................................................................... 113
9.0 Interrupts ..................................................................................................................... 115
10.0 I/O Ports ...................................................................................................................... 131
11.0 Timer0 Module ......................................................................................................... 149
12.0 Timer1 Module .......................................................................................................... 153
13.0 Timer2 Module .......................................................................................................... 159
14.0 Timer3 Module .......................................................................................................... 161
15.0 Capture/Compare/PWM (CCP1) Modules ................................................................... 165
16.0 Enhanced Capture/Compare/PWM (ECCP1) Module ................................................ 175
17.0 Master Synchronous Serial Port (MSSP) Module .................................................... 189
18.0 Enhanced Universal Synchronous Receiver Transmitter (EUSART) ......................... 229
19.0 10-Bit Analog-to-Digital Converter (A/D) Module .................................................... 249
20.0 Comparator Module .................................................................................................... 259
21.0 Comparator Voltage Reference Module .................................................................... 265
22.0 High/Low-Voltage Detect (HLVD) ........................................................................... 269
23.0 ECAN™ Technology ................................................................................................. 275
24.0 Special Features of the CPU ...................................................................................... 345
25.0 Instruction Set Summary ............................................................................................ 365
26.0 Development Support ............................................................................................... 415
27.0 Electrical Characteristics ......................................................................................... 419
28.0 DC and AC Characteristics Graphs and Tables ....................................................... 455
29.0 Packaging Information ............................................................................................... 457
Appendix A: Revision History .......................................................................................... 465
Appendix B: Device Differences ...................................................................................... 465
Appendix C: Conversion Considerations .......................................................................... 466
Appendix D: Migration From Baseline to Enhanced Devices .......................................... 466
Appendix E: Migration from Mid-Range to Enhanced Devices ...................................... 467
Appendix F: Migration from High-End to Enhanced Devices ......................................... 467
The Microchip Web Site .................................................................................................. 481
Customer Change Notification Service ............................................................................ 481
Customer Support ........................................................................................................... 481
Reader Response ............................................................................................................. 482
PIC18F2682/2685/4682/4685 Product Identification System ............................................. 483
TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your Microchip products. To this end, we will continue to improve our publications to better suit your needs. Our publications will be refined and enhanced as new volumes and updates are introduced.

If you have any questions or comments regarding this publication, please contact the Marketing Communications Department via E-mail at docerrors@microchip.com or fax the Reader Response Form in the back of this data sheet to (480) 792-4150. We welcome your feedback.

Most Current Data Sheet

To obtain the most up-to-date version of this data sheet, please register at our Worldwide Web site at:

http://www.microchip.com

You can determine the version of a data sheet by examining its literature number found on the bottom outside corner of any page. The last character of the literature number is the version number, (e.g., DS30000A is version A of document DS30000).

Errata

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

To determine if an errata sheet exists for a particular device, please check with one of the following:

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

When contacting a sales office, please specify which device, revision of silicon and data sheet (include literature number) you are using.

Customer Notification System

Register on our web site at www.microchip.com to receive the most current information on all of our products.
1.0 DEVICE OVERVIEW

This document contains device-specific information for the following devices:

• PIC18F2682
• PIC18F2685
• PIC18F4682
• PIC18F4685

This family of devices offers the advantages of all PIC18 microcontrollers – namely, high computational performance at an economical price – with the addition of high-endurance, Enhanced Flash program memory. In addition to these features, the PIC18F2682/2685/4682/4685 family introduces design enhancements that make these microcontrollers a logical choice for many high-performance, power sensitive applications.

1.1 New Core Features
1.1.1 nanoWatt TECHNOLOGY

All of the devices in the PIC18F2682/2685/4682/4685 family incorporate a range of features that can significantly reduce power consumption during operation. Key items include:

• Alternate Run Modes: By clocking the controller from the Timer1 source or the internal oscillator block, power consumption during code execution can be reduced by as much as 90%.
• Multiple Idle Modes: The controller can also run with its CPU core disabled but the peripherals still active. In these states, power consumption can be reduced even further, to as little as 4% of normal operation requirements.
• On-the-Fly Mode Switching: The power-managed modes are invoked by user code during operation, allowing the user to incorporate power-saving ideas into their application’s software design.
• Lower Consumption in Key Modules: The power requirements for both Timer1 and the Watchdog Timer have been reduced by up to 80%, with typical values of 1.1 and 2.1 μA, respectively.
• Extended Instruction Set: In addition to the standard 75 instructions of the PIC18 instruction set, PIC18F2682/2685/4682/4685 devices also provide an optional extension to the core CPU functionality. The added features include eight additional instructions that augment indirect and indexed addressing operations and the implementation of Indexed Literal Offset Addressing mode for many of the standard PIC18 instructions.

1.1.2 MULTIPLE OSCILLATOR OPTIONS AND FEATURES

All of the devices in the PIC18F2682/2685/4682/4685 family offer ten different oscillator options, allowing users a wide range of choices in developing application hardware. These options include:

• Four Crystal modes, using crystals or ceramic resonators
• Two External Clock modes, offering the option of using two pins (oscillator input and a divide-by-4 clock output) or one pin (oscillator input, with the second pin reassigned as general I/O)
• Two External RC Oscillator modes with the same pin options as the External Clock modes
• An internal oscillator block which provides an 8 MHz clock (±2% accuracy) and an INTRC source (approximately 31 kHz, stable over temperature and VDD), as well as a range of 6 user selectable clock frequencies, between 125 kHz to 4 MHz, for a total of 8 clock frequencies. This option frees the two oscillator pins for use as additional general purpose I/O.
• A Phase Lock Loop (PLL) frequency multiplier, available to both the High-Speed Crystal and Internal Oscillator modes, which allows clock speeds of up to 40 MHz. Used with the internal oscillator, the PLL gives users a complete selection of clock speeds, from 31 kHz to 32 MHz – all without using an external crystal or clock circuit.

Besides its availability as a clock source, the internal oscillator block provides a stable reference source that gives the family additional features for robust operation:

• Fail-Safe Clock Monitor: This option constantly monitors the main clock source against a reference signal provided by the internal oscillator. If a clock failure occurs, the controller is switched to the internal oscillator block, allowing for continued low-speed operation or a safe application shutdown.
• Two-Speed Start-up: This option allows the internal oscillator to serve as the clock source from Power-on Reset, or wake-up from Sleep mode, until the primary clock source is available.
1.2 Other Special Features

- **Memory Endurance**: The Enhanced Flash cells for both program memory and data EEPROM are rated to last for many thousands of erase/write cycles – up to 100,000 for program memory and 1,000,000 for EEPROM. Data retention without refresh is conservatively estimated to be greater than 40 years.

- **Self-Programmability**: These devices can write to their own program memory spaces under internal software control. By using a bootloader routine located in the protected Boot Block at the top of program memory, it becomes possible to create an application that can update itself in the field.

- **Extended Instruction Set**: The PIC18F2682/2685/4682/4685 family introduces an optional extension to the PIC18 instruction set, which adds 8 new instructions and an Indexed Addressing mode. This extension, enabled as a device configuration option, has been specifically designed to optimize re-entrant application code originally developed in high-level languages, such as C.

- **Enhanced CCP1 Module**: In PWM mode, this module provides 1, 2 or 4 modulated outputs for controlling half-bridge and full-bridge drivers. Other features include auto-shutdown, for disabling PWM outputs on interrupt or other select conditions, and auto-restart to reactivate outputs once the condition has cleared.

- **Enhanced Addressable USART**: This serial communication module is capable of standard RS-232 operation and provides support for the LIN bus protocol. Other enhancements include Auto-Baud Rate Detection and a 16-bit Baud Rate Generator for improved resolution. When the microcontroller is using the internal oscillator block, the EUSART provides stable operation for applications that talk to the outside world without using an external crystal (or its accompanying power requirement).

- **10-Bit A/D Converter**: This module incorporates programmable acquisition time, allowing for a channel to be selected and a conversion to be initiated without waiting for a sampling period and thus, reduce code overhead.

- **Extended Watchdog Timer (WDT)**: This enhanced version incorporates a 16-bit prescaler, allowing a time-out range from 4 ms to over 131 seconds, that is stable across operating voltage and temperature.

1.3 Details on Individual Family Members

Devices in the PIC18F2682/2685/4682/4685 family are available in 28-pin (PIC18F2682/2685) and 40/44-pin (PIC18F4682/4685) packages. Block diagrams for the two groups are shown in Figure 1-1 and Figure 1-2.

The devices are differentiated from each other in six ways:

1. Flash program memory (80 Kbytes for PIC18F2682/2685 devices, 96 Kbytes for PIC18F2685/4685 devices).
3. I/O ports (3 bidirectional ports and 1 input only port on PIC18F2682/2685 devices, 5 bidirectional ports on PIC18F4682/4685 devices).
4. CCP1 and Enhanced CCP1 implementation (PIC18F2682/2685 devices have 1 standard CCP1 module, PIC18F4682/4685 devices have one standard CCP1 module and one ECCP1 module).
5. Parallel Slave Port (present only on PIC18F4682/4685 devices).
6. PIC18F4682/4685 devices provide two comparators.

All other features for devices in this family are identical. These are summarized in Table 1-1.

The pinouts for all devices are listed in Table 1-2 and Table 1-3.

Like all Microchip PIC18 devices, members of the PIC18F2682/2685/4682/4685 family are available as both standard and low-voltage devices. Standard devices with Enhanced Flash memory, designated with an “F” in the part number (such as PIC18F2685), accommodate an operating VDD range of 4.2V to 5.5V. Low-voltage parts, designated by “LF” (such as PIC18LF2685), function over an extended VDD range of 2.0V to 5.5V.
**TABLE 1-1: DEVICE FEATURES**

<table>
<thead>
<tr>
<th>Features</th>
<th>PIC18F2682</th>
<th>PIC18F2685</th>
<th>PIC18F4682</th>
<th>PIC18F4685</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>DC – 40 MHz</td>
<td>DC – 40 MHz</td>
<td>DC – 40 MHz</td>
<td>DC – 40 MHz</td>
</tr>
<tr>
<td>Program Memory (Bytes)</td>
<td>80K</td>
<td>96K</td>
<td>80K</td>
<td>96K</td>
</tr>
<tr>
<td>Program Memory (Instructions)</td>
<td>40960</td>
<td>49152</td>
<td>40960</td>
<td>49152</td>
</tr>
<tr>
<td>Data Memory (Bytes)</td>
<td>3328</td>
<td>3328</td>
<td>3328</td>
<td>3328</td>
</tr>
<tr>
<td>Data EEPROM Memory (Bytes)</td>
<td>1024</td>
<td>1024</td>
<td>1024</td>
<td>1024</td>
</tr>
<tr>
<td>Interrupt Sources</td>
<td>19</td>
<td>19</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Timers</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Capture/Compare/PWM Modules</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Enhanced Capture/Compare/PWM Modules</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ECAN Module</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Serial Communications</td>
<td>MSSP,</td>
<td>MSSP,</td>
<td>MSSP,</td>
<td>MSSP,</td>
</tr>
<tr>
<td></td>
<td>Enhanced USART</td>
<td>Enhanced USART</td>
<td>Enhanced USART</td>
<td>Enhanced USART</td>
</tr>
<tr>
<td>Parallel Slave Port Communications (PSP)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10-bit Analog-to-Digital Module</td>
<td>8 Input Channels</td>
<td>8 Input Channels</td>
<td>11 Input Channels</td>
<td>11 Input Channels</td>
</tr>
<tr>
<td>Comparators</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Resets (and Delays)</td>
<td>POR, BOR,</td>
<td>POR, BOR,</td>
<td>POR, BOR,</td>
<td>POR, BOR,</td>
</tr>
<tr>
<td></td>
<td>RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT</td>
<td>RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT</td>
<td>RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT</td>
<td>RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT</td>
</tr>
<tr>
<td>Programmable High/Low-Voltage Detect</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Programmable Brown-out Reset</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Instruction Set</td>
<td>75 Instructions; 83 with Extended Instruction Set Enabled</td>
<td>75 Instructions; 83 with Extended Instruction Set Enabled</td>
<td>75 Instructions; 83 with Extended Instruction Set Enabled</td>
<td>75 Instructions; 83 with Extended Instruction Set Enabled</td>
</tr>
<tr>
<td>Packages</td>
<td>28-pin PDIP 28-pin PDIP</td>
<td>28-pin PDIP 28-pin PDIP</td>
<td>40-pin PDIP 44-pin QFN 44-pin TQFP</td>
<td>40-pin PDIP 44-pin QFN 44-pin TQFP</td>
</tr>
</tbody>
</table>
FIGURE 1-1: PIC18F2682/2685 (28-PIN) BLOCK DIAGRAM

Note 1: RE3 is multiplexed with MCLR and is only available when the MCLR Resets are disabled.

Note 2: OSC1/CLKI and OSC2/CLKO are only available in select oscillator modes and when these pins are not being used as digital I/O. Refer to Section 2.0 “Oscillator Configurations” for additional information.
FIGURE 1-2: PIC18F4682/4685 (40/44-PIN) BLOCK DIAGRAM

Note 1: RE3 is multiplexed with MCLR and is only available when the MCLR Resets are disabled.
Note 2: OSC1/CLKI and OSC2/CLKO are only available in select oscillator modes and when these pins are not being used as digital I/O. Refer to Section 2.0 “Oscillator Configurations” for additional information.
## TABLE 1-2: PIC18F2682/2685 PINOUT I/O DESCRIPTIONS

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCLR, VPP, RE3</td>
<td>1</td>
<td>I</td>
<td>ST</td>
<td>Master Clear (input) or programming voltage (input).</td>
</tr>
<tr>
<td>MCLR</td>
<td></td>
<td></td>
<td></td>
<td>Master Clear (Reset) input. This pin is an active-low Reset to the device.</td>
</tr>
<tr>
<td>VPP, RE3</td>
<td></td>
<td>P</td>
<td>I ST</td>
<td>Programming voltage input. Digit input.</td>
</tr>
<tr>
<td>OSC1/CLKI/RA7</td>
<td>9</td>
<td>I</td>
<td>ST</td>
<td>Oscillator crystal or external clock input.</td>
</tr>
<tr>
<td>OSC1</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Oscillator crystal input or external clock source input.</td>
</tr>
<tr>
<td>CLKI</td>
<td></td>
<td>I</td>
<td>CMOS</td>
<td>ST buffer when configured in RC mode; CMOS otherwise.</td>
</tr>
<tr>
<td>RA7</td>
<td></td>
<td>I/O</td>
<td>TTL</td>
<td>External clock source input. Always associated with pin function OSC1.</td>
</tr>
<tr>
<td>OSC2/CLKO/RA6</td>
<td>10</td>
<td>O</td>
<td>—</td>
<td>Oscillator crystal or clock output.</td>
</tr>
<tr>
<td>OSC2</td>
<td></td>
<td>O</td>
<td>—</td>
<td>Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.</td>
</tr>
<tr>
<td>CLKO</td>
<td></td>
<td>O</td>
<td>—</td>
<td>In RC mode, OSC2 pin outputs CLKO which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.</td>
</tr>
<tr>
<td>RA6</td>
<td></td>
<td>I/O</td>
<td>TTL</td>
<td>General purpose I/O pin.</td>
</tr>
</tbody>
</table>

**Legend:**
- TTL = TTL compatible input
- CMOS = CMOS compatible input or output
- ST = Schmitt Trigger input with CMOS levels
- I = Input
- O = Output
- P = Power
PORTA is a bidirectional I/O port.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA0/AN0</td>
<td>2</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA0</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 0.</td>
</tr>
<tr>
<td>AN0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA1/AN1</td>
<td>3</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA1</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 1.</td>
</tr>
<tr>
<td>AN1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA2/AN2/VREF-</td>
<td>4</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA2</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 2.</td>
</tr>
<tr>
<td>AN2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VREF-</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>A/D reference voltage (low) input.</td>
</tr>
<tr>
<td>RA3/AN3/VREF+</td>
<td>5</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA3</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 3.</td>
</tr>
<tr>
<td>AN3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VREF+</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>A/D reference voltage (high) input.</td>
</tr>
<tr>
<td>RA4/T0CKI</td>
<td>6</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA4</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Timer0 external clock input.</td>
</tr>
<tr>
<td>T0CKI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA5/AN4/SS/HLVDIN</td>
<td>7</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA5</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 4.</td>
</tr>
<tr>
<td>AN4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>SPI slave select input.</td>
</tr>
<tr>
<td>HLVDIN</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>High/Low-Voltage Detect input.</td>
</tr>
<tr>
<td>RA6</td>
<td></td>
<td></td>
<td></td>
<td>See the OSC2/CLKO/RA6 pin.</td>
</tr>
<tr>
<td>RA7</td>
<td></td>
<td></td>
<td></td>
<td>See the OSC1/CLKI/RA7 pin.</td>
</tr>
</tbody>
</table>

**Legend:**
- TTL = TTL compatible input
- CMOS = CMOS compatible input or output
- ST = Schmitt Trigger input with CMOS levels
- I = Input
- O = Output
- P = Power
PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB0/INT0/AN10</td>
<td>21</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB0</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>External interrupt 0.</td>
</tr>
<tr>
<td>INT0</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 10.</td>
</tr>
<tr>
<td>AN10</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB1/INT1/AN8</td>
<td>22</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB1</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>External interrupt 1.</td>
</tr>
<tr>
<td>INT1</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 8.</td>
</tr>
<tr>
<td>AN8</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB2/INT2/CANTX</td>
<td>23</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB2</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>External interrupt 2.</td>
</tr>
<tr>
<td>INT2</td>
<td></td>
<td>O</td>
<td>TTL</td>
<td>CAN bus TX.</td>
</tr>
<tr>
<td>CANTX</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB3/CANRX</td>
<td>24</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB3</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>CAN bus RX.</td>
</tr>
<tr>
<td>CANRX</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB4/KBI0/AN9</td>
<td>25</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB4</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI0</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 9.</td>
</tr>
<tr>
<td>AN9</td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB5/KBI1/PGM</td>
<td>26</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB5</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI1</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Low-Voltage ICSP™ Programming enable pin.</td>
</tr>
<tr>
<td>PGM</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td></td>
</tr>
<tr>
<td>RB6/KBI2/PGC</td>
<td>27</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB6</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI2</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>In-Circuit Debugger and ICSP programming clock pin.</td>
</tr>
<tr>
<td>PGC</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td></td>
</tr>
<tr>
<td>RB7/KBI3/PGD</td>
<td>28</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RB7</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI3</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>In-Circuit Debugger and ICSP programming data pin.</td>
</tr>
<tr>
<td>PGD</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td></td>
</tr>
</tbody>
</table>

Legend: TTL = TTL compatible input
         CMOS = CMOS compatible input or output
         ST = Schmitt Trigger input with CMOS levels
         I = Input
         O = Output
         P = Power
PORTC is a bidirectional I/O port.

Digital I/O.

Timer1 oscillator output.

Timer1 oscillator input.

Capture1 input/Compare1 output/PWM1 output.

Synchronous serial clock input/output for SPI mode.

Synchronous serial clock input/output for I^2C™ mode.

Digital I/O.

SPI data in.

I^2C data I/O.

Digital I/O.

Digital I/O.

EUSART asynchronous transmit.

EUSART synchronous clock (see related RX/DT).

EUSART asynchronous receive.

EUSART synchronous data (see related TX/CK).

See MCLR/VPP/RE3 pin.

Ground reference for logic and I/O pins.

Positive supply for logic and I/O pins.

Legend:  TTL = TTL compatible input  CMOS = CMOS compatible input or output  
          ST  = Schmitt Trigger input with CMOS levels  I  = Input  
          O  = Output  P  = Power
### TABLE 1-3: PIC18F4682/4685 PINOUT I/O DESCRIPTIONS

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCLR/VPP/RE3</td>
<td>18</td>
<td>I</td>
<td>ST</td>
<td>Master Clear (input) or programming voltage (input). Master Clear (Reset) input. This pin is an active-low Reset to the device. Programming voltage input. Digital input.</td>
</tr>
<tr>
<td>OSC1/CLKI/RA7</td>
<td>13</td>
<td>I</td>
<td>ST</td>
<td>Oscillator crystal or external clock input. Oscillator crystal input or external clock source input. ST buffer when configured in RC mode; CMOS otherwise. External clock source input. Always associated with pin function OSC1. (See related OSC2/CLKO pin.) General purpose I/O pin.</td>
</tr>
<tr>
<td>OSC2/CLKO/RA6</td>
<td>14</td>
<td>O</td>
<td>—</td>
<td>Oscillator crystal or clock output. Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. In RC mode, OSC2 pin outputs CLKO which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate. General purpose I/O pin.</td>
</tr>
</tbody>
</table>

**Legend:**
- TTL = TTL compatible input
- ST = Schmitt Trigger input with CMOS levels
- O = Output
- CMOS = CMOS compatible input or output
- I = Input
- P = Power
<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTA is a bidirectional I/O port.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA0/AN0/CVREF</td>
<td>2</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA0</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 0.</td>
</tr>
<tr>
<td>AN0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVREF</td>
<td></td>
<td>O</td>
<td>Analog</td>
<td>Analog comparator reference output.</td>
</tr>
<tr>
<td>RA1/AN1</td>
<td>3</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA1</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 1.</td>
</tr>
<tr>
<td>AN1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA2/AN2/VREF-</td>
<td>4</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA2</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 2.</td>
</tr>
<tr>
<td>AN2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VREF-</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>A/D reference voltage (low) input.</td>
</tr>
<tr>
<td>RA3/AN3/VREF+</td>
<td>5</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA3</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 3.</td>
</tr>
<tr>
<td>AN3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VREF+</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>A/D reference voltage (high) input.</td>
</tr>
<tr>
<td>RA4/T0CKI</td>
<td>6</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA4</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Timer0 external clock input.</td>
</tr>
<tr>
<td>T0CKI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA5/AN4/SS/HLVDIN</td>
<td>7</td>
<td>I/O</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RA5</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 4.</td>
</tr>
<tr>
<td>AN4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>SPI slave select input.</td>
</tr>
<tr>
<td>HLVDIN</td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>High/Low-Voltage Detect input.</td>
</tr>
<tr>
<td>RA6</td>
<td></td>
<td></td>
<td></td>
<td>See the OSC2/CLKO/RA6 pin.</td>
</tr>
<tr>
<td>RA7</td>
<td></td>
<td></td>
<td></td>
<td>See the OSC1/CLKI/RA7 pin.</td>
</tr>
</tbody>
</table>

Legend: TTL = TTL compatible input
ST = Schmitt Trigger input with CMOS levels
CMOS = CMOS compatible input or output
I = Input
O = Output
P = Power
TABLE 1-3: PIC18F4682/4685 PINOUT I/O DESCRIPTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTB</td>
<td></td>
<td></td>
<td></td>
<td>PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB0/INT0/FLT0/AN10</th>
<th>33</th>
<th>9</th>
<th>8</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB0</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>External interrupt 0.</td>
</tr>
<tr>
<td>INT0</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Enhanced PWM Fault input (ECCP1 module).</td>
</tr>
<tr>
<td>FLT0</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>Analog</td>
<td>Analog input 10.</td>
</tr>
<tr>
<td>AN10</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB1/INT1/AN8</th>
<th>34</th>
<th>10</th>
<th>9</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB1</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>External interrupt 1.</td>
</tr>
<tr>
<td>INT1</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Analog input 8.</td>
</tr>
<tr>
<td>AN8</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>Analog</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB2/INT2/CANTEX</th>
<th>35</th>
<th>11</th>
<th>10</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB2</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>External interrupt 2.</td>
</tr>
<tr>
<td>INT2</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>CAN bus TX.</td>
</tr>
<tr>
<td>CANTEX</td>
<td></td>
<td></td>
<td></td>
<td>O</td>
<td>TTL</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB3/CANRX</th>
<th>36</th>
<th>12</th>
<th>11</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB3</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>CAN bus RX.</td>
</tr>
<tr>
<td>CANRX</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB4/KBI0/AN9</th>
<th>37</th>
<th>14</th>
<th>14</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB4</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI0</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Analog input 9.</td>
</tr>
<tr>
<td>AN9</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>Analog</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB5/KBI1/PGM</th>
<th>38</th>
<th>15</th>
<th>15</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB5</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI1</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td></td>
</tr>
<tr>
<td>PGM</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Low-Voltage ICSP™ Programming enable pin.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB6/KBI2/PGC</th>
<th>39</th>
<th>16</th>
<th>16</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB6</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI2</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td></td>
</tr>
<tr>
<td>PGC</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td>In-Circuit Debugger and ICSP programming clock pin.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RB7/KBI3/PGD</th>
<th>40</th>
<th>17</th>
<th>17</th>
<th>I/O</th>
<th>TTL</th>
<th>Digital I/O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB7</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>Interrupt-on-change pin.</td>
</tr>
<tr>
<td>KBI3</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>TTL</td>
<td>In-Circuit Debugger and ICSP programming data pin.</td>
</tr>
<tr>
<td>PGD</td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>ST</td>
<td></td>
</tr>
</tbody>
</table>

Legend:  
TTL = TTL compatible input  
ST = Schmitt Trigger input with CMOS levels  
I = Input  
O = Output  
CMOS = CMOS compatible input or output  
P = Power
### TABLE 1-3:  PIC18F4682/4685 PINOUT I/O DESCRIPTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC0/T1OSO/T13CI</td>
<td>15 34 32</td>
<td>I/O</td>
<td>ST</td>
<td>PORTC is a bidirectional I/O port.</td>
</tr>
<tr>
<td>RC0</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>T1OSO</td>
<td></td>
<td>O</td>
<td></td>
<td>Timer1 oscillator output.</td>
</tr>
<tr>
<td>T13CI</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>Timer1/Timer3 external clock input.</td>
</tr>
<tr>
<td>RC1/T1OSI</td>
<td>16 35 35</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RC1</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>T1OSI</td>
<td></td>
<td>I</td>
<td>CMOS</td>
<td>Timer1 oscillator input.</td>
</tr>
<tr>
<td>RC2/CCP1</td>
<td>17 36 36</td>
<td>I/O</td>
<td>ST</td>
<td>Capture1 input/Compare1 output/PWM1 output.</td>
</tr>
<tr>
<td>RC2</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>CCP1</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td>Capture1 input/Compare1 output/PWM1 output.</td>
</tr>
<tr>
<td>RC3/SCK/SCL</td>
<td>18 37 37</td>
<td>I/O</td>
<td>ST</td>
<td>Synchronous serial clock input/output for SPI mode.</td>
</tr>
<tr>
<td>RC3</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>SCK</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td>Synchronous serial clock input/output for I²C™ mode.</td>
</tr>
<tr>
<td>SCL</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td>Synchronous serial clock input/output for I²C™ mode.</td>
</tr>
<tr>
<td>RC4/SDI/SDA</td>
<td>23 42 42</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RC4</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>SDI</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>SPI data in.</td>
</tr>
<tr>
<td>SDA</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td>I²C data I/O.</td>
</tr>
<tr>
<td>RC5/SDO</td>
<td>24 43 43</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RC5</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>SDO</td>
<td></td>
<td>O</td>
<td></td>
<td>SPI data out.</td>
</tr>
<tr>
<td>RC6/TX/CK</td>
<td>25 44 44</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RC6</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>TX</td>
<td></td>
<td>O</td>
<td></td>
<td>EUSART asynchronous transmit.</td>
</tr>
<tr>
<td>CK</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td>EUSART synchronous clock (see related RX/DT pin).</td>
</tr>
<tr>
<td>RC7/RX/DT</td>
<td>26 1 1</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RC7</td>
<td></td>
<td></td>
<td></td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RX</td>
<td></td>
<td>I</td>
<td>ST</td>
<td>EUSART asynchronous receive.</td>
</tr>
<tr>
<td>DT</td>
<td></td>
<td>I/O</td>
<td>ST</td>
<td>EUSART synchronous data (see related TX/CK pin).</td>
</tr>
</tbody>
</table>

**Legend:**

- TTL = TTL compatible input
- ST = Schmitt Trigger input with CMOS levels
- O = Output
- CMOS = CMOS compatible input or output
- = Input
- P = Power
PORTD is a bidirectional I/O port or a Parallel Slave Port (PSP) for interfacing to a microprocessor port. These pins have TTL input buffers when PSP module is enabled.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD0/PSP0/C1IN+</td>
<td>19 38 38</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RD1/PSP1/C1IN-</td>
<td>20 39 39</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RD2/PSP2/C2IN+</td>
<td>21 40 40</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RD3/PSP3/C2IN-</td>
<td>22 41 41</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RD4/PSP4/ECCP1/P1A</td>
<td>27 2 2</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O. ECCP1 PWM output A.</td>
</tr>
<tr>
<td>RD5/PSP5/P1B</td>
<td>28 3 3</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O. ECCP1 PWM output B.</td>
</tr>
<tr>
<td>RD6/PSP6/P1C</td>
<td>29 4 4</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O. ECCP1 PWM output C.</td>
</tr>
<tr>
<td>RD7/PSP7/P1D</td>
<td>30 5 5</td>
<td>I/O ST</td>
<td>TTL</td>
<td>Digital I/O. ECCP1 PWM output D.</td>
</tr>
</tbody>
</table>

Legend: TTL = TTL compatible input
ST = Schmitt Trigger input with CMOS levels
I = Input
O = Output
P = Power

CMOS = CMOS compatible input or output
TABLE 1-3: PIC18F4682/4685 PINOUT I/O DESCRIPTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Type</th>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE0/RD/AN5</td>
<td>8, 25, 26</td>
<td>I/O</td>
<td>ST</td>
<td>PORTE is a bidirectional I/O port.</td>
</tr>
<tr>
<td>RE0</td>
<td>I</td>
<td>TTL</td>
<td>Digital I/O.</td>
<td></td>
</tr>
<tr>
<td>RD</td>
<td>I</td>
<td>TTL</td>
<td>Read control for Parallel Slave Port (see also WR and CS pins).</td>
<td></td>
</tr>
<tr>
<td>AN5</td>
<td>I</td>
<td>Analog</td>
<td>Analog input 5.</td>
<td></td>
</tr>
<tr>
<td>RE1/WR/AN6/C1OUT</td>
<td>9, 26, 26</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RE1</td>
<td>I</td>
<td>TTL</td>
<td>Write control for Parallel Slave Port (see CS and RD pins).</td>
<td></td>
</tr>
<tr>
<td>WR</td>
<td>I</td>
<td>TTL</td>
<td>Analog input 6.</td>
<td></td>
</tr>
<tr>
<td>AN6/C1OUT</td>
<td>I</td>
<td>Analog</td>
<td>Comparator 1 output.</td>
<td></td>
</tr>
<tr>
<td>RE2/CS/AN7/C2OUT</td>
<td>10, 27, 27</td>
<td>I/O</td>
<td>ST</td>
<td>Digital I/O.</td>
</tr>
<tr>
<td>RE2</td>
<td>I</td>
<td>TTL</td>
<td>Chip select control for Parallel Slave Port (see related RD and WR pins).</td>
<td></td>
</tr>
<tr>
<td>CS</td>
<td>I</td>
<td>TTL</td>
<td>Analog input 7.</td>
<td></td>
</tr>
<tr>
<td>AN7/C2OUT</td>
<td>I</td>
<td>Analog</td>
<td>Comparator 2 output.</td>
<td></td>
</tr>
<tr>
<td>RE3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>See MCLR/VPP/RE3 pin.</td>
</tr>
<tr>
<td>Vss</td>
<td>12, 13, 28, 30, 31</td>
<td>P</td>
<td>—</td>
<td>Ground reference for logic and I/O pins.</td>
</tr>
<tr>
<td>Vdd</td>
<td>11, 12, 28, 30, 31</td>
<td>P</td>
<td>—</td>
<td>Positive supply for logic and I/O pins.</td>
</tr>
<tr>
<td>NC</td>
<td>—</td>
<td>13, 12, 13, 33, 34</td>
<td>—</td>
<td>No connect.</td>
</tr>
</tbody>
</table>

Legend: TTL = TTL compatible input  CMOS = CMOS compatible input or output
ST = Schmitt Trigger input with CMOS levels  I = Input
O = Output  P = Power

© 2009 Microchip Technology Inc.  DS39761C-page 23
2.0 OSCILLATOR CONFIGURATIONS

2.1 Oscillator Types

PIC18F2682/2685/4682/4685 devices can be operated in ten different oscillator modes. The user can program the Configuration bits, FOSC3:FOSC0, in Configuration Register 1H to select one of these ten modes:

1. LP Low-Power Crystal
2. XT Crystal/Resonator
3. HS High-Speed Crystal/Resonator
4. HSPLL High-Speed Crystal/Resonator with PLL enabled
5. RC External Resistor/Capacitor with FOSC/4 output on RA6
6. RCIO External Resistor/Capacitor with I/O on RA6
7. INTIO1 Internal Oscillator with FOSC/4 output on RA6 and I/O on RA7
8. INTIO2 Internal Oscillator with I/O on RA6 and RA7
9. EC External Clock with FOSC/4 output on RA6
10. ECIO External Clock with I/O on RA6

2.2 Crystal Oscillator/Ceramic Resonators

In XT, LP, HS or HSPLL Oscillator modes, a crystal or ceramic resonator is connected to the OSC1 and OSC2 pins to establish oscillation. Figure 2-1 shows the pin connections.

The oscillator design requires the use of a parallel cut crystal.

Note: Use of a series cut crystal may give a frequency out of the crystal manufacturer’s specifications.

2.0 OSCILLATOR CONFIGURATIONS

2.1 Oscillator Types

PIC18F2682/2685/4682/4685 devices can be operated in ten different oscillator modes. The user can program the Configuration bits, FOSC3:FOSC0, in Configuration Register 1H to select one of these ten modes:

1. LP Low-Power Crystal
2. XT Crystal/Resonator
3. HS High-Speed Crystal/Resonator
4. HSPLL High-Speed Crystal/Resonator with PLL enabled
5. RC External Resistor/Capacitor with FOSC/4 output on RA6
6. RCIO External Resistor/Capacitor with I/O on RA6
7. INTIO1 Internal Oscillator with FOSC/4 output on RA6 and I/O on RA7
8. INTIO2 Internal Oscillator with I/O on RA6 and RA7
9. EC External Clock with FOSC/4 output on RA6
10. ECIO External Clock with I/O on RA6

2.2 Crystal Oscillator/Ceramic Resonators

In XT, LP, HS or HSPLL Oscillator modes, a crystal or ceramic resonator is connected to the OSC1 and OSC2 pins to establish oscillation. Figure 2-1 shows the pin connections.

The oscillator design requires the use of a parallel cut crystal.

Note: Use of a series cut crystal may give a frequency out of the crystal manufacturer’s specifications.

FIGURE 2-1: CRYSTAL/CERAMIC RESONATOR OPERATION (XT, LP, HS OR HSPLL CONFIGURATION)

Note 1: See Table 2-1 and Table 2-2 for initial values of C1 and C2.
2: A series resistor (Rs) may be required for AT strip cut crystals.
3: RF varies with the oscillator mode chosen.

TABLE 2-1: CAPACITOR SELECTION FOR CERAMIC RESONATORS

<table>
<thead>
<tr>
<th>Mode</th>
<th>Freq</th>
<th>OSC1</th>
<th>OSC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>XT</td>
<td>455 kHz</td>
<td>56 pF</td>
<td>56 pF</td>
</tr>
<tr>
<td></td>
<td>2.0 MHz</td>
<td>47 pF</td>
<td>47 pF</td>
</tr>
<tr>
<td></td>
<td>4.0 MHz</td>
<td>33 pF</td>
<td>33 pF</td>
</tr>
<tr>
<td>HS</td>
<td>8.0 MHz</td>
<td>27 pF</td>
<td>27 pF</td>
</tr>
<tr>
<td></td>
<td>16.0 MHz</td>
<td>22 pF</td>
<td>22 pF</td>
</tr>
</tbody>
</table>

Capacitor values are for design guidance only.

These capacitors were tested with the resonators listed below for basic start-up and operation. These values are not optimized.

Different capacitor values may be required to produce acceptable oscillator operation. The user should test the performance of the oscillator over the expected VDD and temperature range for the application.

See the notes on page 26 for additional information.

Resonators Used:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>455 kHz</td>
<td>4.0 MHz</td>
</tr>
<tr>
<td>2.0 MHz</td>
<td>8.0 MHz</td>
</tr>
<tr>
<td>16.0 MHz</td>
<td></td>
</tr>
</tbody>
</table>

Note: When using resonators with frequencies above 3.5 MHz, the use of HS mode, rather than XT mode, is recommended. HS mode may be used at any VDD for which the controller is rated. If HS is selected, it is possible that the gain of the oscillator will overdrive the resonator. Therefore, a series resistor should be placed between the OSC2 pin and the resonator. As a good starting point, the recommended value of Rs is 330 Ohm.
2.3 External Clock Input

The EC and ECIO Oscillator modes require an external clock source to be connected to the OSC1 pin. There is no oscillator start-up time required after a Power-on Reset or after an exit from Sleep mode.

In the EC Oscillator mode, the oscillator frequency divided by 4 is available on the OSC2 pin. This signal may be used for test purposes or to synchronize other logic. Figure 2-3 shows the pin connections for the EC Oscillator mode.

The ECIO Oscillator mode functions like the EC mode, except that the OSC2 pin becomes an additional general purpose I/O pin. The I/O pin becomes bit 6 of PORTA (RA6). Figure 2-4 shows the pin connections for the ECIO Oscillator mode.

### TABLE 2-2: CAPACITOR SELECTION FOR CRYSTAL OSCILLATOR

<table>
<thead>
<tr>
<th>Osc Type</th>
<th>Crystal Freq</th>
<th>Typical Capacitor Values Tested:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C1</td>
</tr>
<tr>
<td>LP</td>
<td>32 kHz</td>
<td>33 pF</td>
</tr>
<tr>
<td></td>
<td>200 kHz</td>
<td>15 pF</td>
</tr>
<tr>
<td>XT</td>
<td>1 MHz</td>
<td>33 pF</td>
</tr>
<tr>
<td></td>
<td>4 MHz</td>
<td>27 pF</td>
</tr>
<tr>
<td>HS</td>
<td>4 MHz</td>
<td>27 pF</td>
</tr>
<tr>
<td></td>
<td>8 MHz</td>
<td>22 pF</td>
</tr>
<tr>
<td></td>
<td>20 MHz</td>
<td>15 pF</td>
</tr>
</tbody>
</table>

Capacitor values are for design guidance only.

These capacitors were tested with the crystals listed below for basic start-up and operation. **These values are not optimized.**

Different capacitor values may be required to produce acceptable oscillator operation. The user should test the performance of the oscillator over the expected VDD and temperature range for the application.

See the notes following this table for additional information.

**Crystals Used:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>32 kHz</td>
<td>4 MHz</td>
</tr>
<tr>
<td>200 kHz</td>
<td>8 MHz</td>
</tr>
<tr>
<td>1 MHz</td>
<td>20 MHz</td>
</tr>
</tbody>
</table>

**Note 1:** Higher capacitance increases the stability of the oscillator but also increases the start-up time.

2: When operating below 3V VDD, or when using certain ceramic resonators at any voltage, it may be necessary to use the HS mode or switch to a crystal oscillator.

3: Since each resonator/crystal has its own characteristics, the user should consult the resonator/crystal manufacturer for appropriate values of external components.

4: Rs may be required to avoid overdriving crystals with low drive level specifications.

5: Always verify oscillator performance over the VDD and temperature range that is expected for the application.
2.4 RC Oscillator

For timing insensitive applications, the "RC" and "RCIO" device options offer additional cost savings. The actual oscillator frequency is a function of several factors:

• supply voltage
• values of the external resistor (REXT) and capacitor (CEXT)
• operating temperature

Given the same device, operating voltage and temperature and component values, there will also be unit-to-unit frequency variations. These are due to factors such as:

• normal manufacturing variation
• difference in lead frame capacitance between package types (especially for low CEXT values)
• variations within the tolerance of limits of REXT and CEXT

In the RC Oscillator mode, the oscillator frequency divided by 4 is available on the OSC2 pin. This signal may be used for test purposes or to synchronize other logic. Figure 2-5 shows how the R/C combination is connected.

FIGURE 2-5: RC OSCILLATOR MODE

The RCIO Oscillator mode (Figure 2-6) functions like the RC mode, except that the OSC2 pin becomes an additional general purpose I/O pin. The I/O pin becomes bit 6 of PORTA (RA6).

FIGURE 2-6: RCIO OSCILLATOR MODE

2.5 PLL Frequency Multiplier

A Phase Locked Loop (PLL) circuit is provided as an option for users who wish to use a lower frequency oscillator circuit or to clock the device up to its highest rated frequency from a crystal oscillator. This may be useful for customers who are concerned with EMI due to high-frequency crystals or users who require higher clock speeds from an internal oscillator.

2.5.1 HSPLL OSCILLATOR MODE

The HSPLL mode makes use of the HS mode oscillator for frequencies up to 10 MHz. A PLL then multiplies the oscillator output frequency by 4 to produce an internal clock frequency up to 40 MHz.

The PLL is only available to the crystal oscillator when the FOSC3:FOSC0 Configuration bits are programmed for HSPLL mode (= 0110).

FIGURE 2-7: PLL BLOCK DIAGRAM

( HS MODE )

2.5.2 PLL AND INTOSC

The PLL is also available to the internal oscillator block in selected oscillator modes. In this configuration, the PLL is enabled in software and generates a clock output of up to 32 MHz. The operation of INTOSC with the PLL is described in Section 2.6.4 “PLL in INTOSC Modes”.

The recommended values for the external components are:

- 3 kΩ ≤ REXT ≤ 100 kΩ
- CEXT > 20 pF

These values ensure stable operation of the oscillator circuit.
2.6 Internal Oscillator Block

The PIC18F2682/2685/4682/4685 devices include an internal oscillator block which generates two different clock signals; either can be used as the microcontroller’s clock source. This may eliminate the need for external oscillator circuits on the OSC1 and/or OSC2 pins.

The main output (INTOSC) is an 8 MHz clock source, which can be used to directly drive the device clock. It also drives a postscaler, which can provide a range of clock frequencies from 31 kHz to 4 MHz. The INTOSC output is enabled when a clock frequency from 125 kHz to 8 MHz is selected.

The other clock source is the internal RC oscillator (INTRC), which provides a nominal 31 kHz output. INTRC is enabled if it is selected as the device clock source; it is also enabled automatically when any of the following are enabled:

- Power-up Timer
- Fail-Safe Clock Monitor
- Watchdog Timer
- Two-Speed Start-up

These features are discussed in greater detail in Section 24.0 “Special Features of the CPU”.

The clock source frequency (INTOSC direct, INTRC direct or INTOSC postscaler) is selected by configuring the IRCF bits of the OSCCON register (Register 2-2).

2.6.1 INTIO Modes

Using the internal oscillator as the clock source eliminates the need for up to two external oscillator pins, which can then be used for digital I/O. Two distinct configurations are available:

- In INTIO1 mode, the OSC2 pin outputs Fosc/4, while OSC1 functions as RA7 for digital input and output.
- In INTIO2 mode, OSC1 functions as RA7 and OSC2 functions as RA6, both for digital input and output.

2.6.2 INTOSC Output Frequency

The internal oscillator block is calibrated at the factory to produce an INTOSC output frequency of 8.0 MHz.

The INTRC oscillator operates independently of the INTOSC source. Any changes in INTOSC across voltage and temperature are not necessarily reflected by changes in INTRC and vice versa.

2.6.3 OSCTUNE Register

The internal oscillator’s output has been calibrated at the factory but can be adjusted in the user’s application. This is done by writing to the OSCTUNE register (Register 2-1). The tuning sensitivity is constant throughout the tuning range.

When the OSCTUNE register is modified, the INTOSC and INTRC frequencies will begin shifting to the new frequency. The INTRC clock will reach the new frequency within 8 clock cycles (approximately 8 \* 32 \( \mu s \) = 256 \( \mu s \)). The INTOSC clock will stabilize within 1 ms. Code execution continues during this shift. There is no indication that the shift has occurred.

The OSCTUNE register also implements the INTSRC and PLLEN bits, which control certain features of the internal oscillator block. The INTSRC bit allows users to select which internal oscillator provides the clock source when the 31 kHz frequency option is selected. This is covered in greater detail in Section 2.7.1 “Oscillator Control Register”.

The PLLEN bit controls the operation of the frequency multiplier, PLL, in internal oscillator modes.

2.6.4 PLL in INTOSC modes

The 4x frequency multiplier can be used with the internal oscillator block to produce faster device clock speeds than are normally possible with an internal oscillator. When enabled, the PLL produces a clock speed of up to 32 MHz.

Unlike HSPLL mode, the PLL is controlled through software. The control bit, PLLEN (OSCTUNE<6>), is used to enable or disable its operation.

The PLL is available when the device is configured to use the internal oscillator block as its primary clock source (FOSC3:FOSC0 = 1001 or 1000). Additionally, the PLL will only function when the selected output frequency is either 4 MHz or 8 MHz (OSCCON<6:4> = 111 or 110). If both of these conditions are not met, the PLL is disabled.

The PLLEN control bit is only functional in those internal oscillator modes where the PLL is available. In all other modes, it is forced to ‘0’ and is effectively unavailable.

2.6.5 INTOSC Frequency Drift

The factory calibrates the internal oscillator block output (INTOSC) for 8 MHz. However, this frequency may drift as VDD or temperature changes, which can affect the controller operation in a variety of ways. It is possible to adjust the INTOSC frequency by modifying the value in the OSCTUNE register. This has no effect on the INTRC clock source frequency.

Tuning the INTOSC source requires knowing when to make the adjustment, in which direction it should be made and in some cases, how large a change is needed. Three compensation techniques are discussed in Section 2.6.5.1 “Compensating with the EUSART”, Section 2.6.5.2 “Compensating with the Timers” and Section 2.6.5.3 “Compensating with the CCP1 Module in Capture Mode”, but other techniques may be used.
2.6.5.1 Compensating with the EUSART

An adjustment may be required when the EUSART begins to generate framing errors or receives data with errors while in Asynchronous mode. Framing errors indicate that the device clock frequency is too high. To adjust for this, decrement the value in OSCTUNE to reduce the clock frequency. On the other hand, errors in data may suggest that the clock speed is too low. To compensate, increment OSCTUNE to increase the clock frequency.

2.6.5.2 Compensating with the Timers

This technique compares device clock speed to some reference clock. Two timers may be used; one timer is clocked by the peripheral clock, while the other is clocked by a fixed reference source, such as the Timer1 oscillator.

Both timers are cleared, but the timer clocked by the reference generates interrupts. When an interrupt occurs, the internally clocked timer is read and both timers are cleared. If the internally clocked timer value is greater than expected, then the internal oscillator block is running too fast. To adjust for this, decrement the OSCTUNE register.

2.6.5.3 Compensating with the CCP1 Module in Capture Mode

The CCP1 module can use free running Timer1 (or Timer3), clocked by the internal oscillator block and an external event with a known period (i.e., AC power frequency). The time of the first event is captured in the CCPRxH:CCPRxL registers and is recorded for use later. When the second event causes a capture, the time of the first event is subtracted from the time of the second event. Since the period of the external event is known, the time difference between events can be calculated.

If the measured time is much greater than the calculated time, the internal oscillator block is running too fast. To compensate, decrement the OSCTUNE register. If the measured time is much less than the calculated time, the internal oscillator block is running too slow. To compensate, increment the OSCTUNE register.
2.7 Clock Sources and Oscillator Switching

Like previous PIC18 devices, the PIC18F2682/2685/4682/4685 family includes a feature that allows the device clock source to be switched from the main oscillator to an alternate low-frequency clock source. PIC18F2682/2685/4682/4685 devices offer two alternate clock sources. When an alternate clock source is enabled, the various power-managed operating modes are available.

Essentially, there are three clock sources for these devices:
- Primary oscillators
- Secondary oscillators
- Internal oscillator block

The primary oscillators include the External Crystal and Resonator modes, the External RC modes, the External Clock modes and the internal oscillator block. The particular mode is defined by the FOSC3:FOSC0 Configuration bits. The details of these modes are covered earlier in this chapter.

The secondary oscillators are those external sources not connected to the OSC1 or OSC2 pins. These sources may continue to operate even after the controller is placed in a power-managed mode.

PIC18F2682/2685/4682/4685 devices offer the Timer1 oscillator as a secondary oscillator. In all power-managed modes, this oscillator is often the time base for functions such as a Real-Time Clock.

Most often, a 32.768 kHz watch crystal is connected between the RC0/T1OSO/T13CKI and RC1/T1OSI pins. Like the LP mode oscillator circuit, loading capacitors are also connected from each pin to ground.

The Timer1 oscillator is discussed in greater detail in Section 12.3 “Timer1 Oscillator”.

In addition to being a primary clock source, the internal oscillator block is available as a power-managed mode clock source. The INTRC source is also used as the clock source for several special features, such as the WDT and Fail-Safe Clock Monitor.

The clock sources for the PIC18F2682/2685/4682/4685 devices are shown in Figure 2-8. See Section 24.0 “Special Features of the CPU” for Configuration register details.

FIGURE 2-8: PIC18F2682/2685/4682/4685 CLOCK DIAGRAM
2.7.1 OSCILLATOR CONTROL REGISTER

The OSCCON register (Register 2-2) controls several aspects of the device clock’s operation, both in full power operation and in power-managed modes.

The System Clock Select bits, SCS1:SCS0, select the clock source. The available clock sources are the primary clock (defined by the FOSC3:FOSC0 Configuration bits), the secondary clock (Timer1 oscillator) and the internal oscillator block. The clock source changes immediately after one or more of the bits is written to, following a brief clock transition interval. The SCS bits are cleared on all forms of Reset.

The Internal Oscillator Frequency Select bits, IRCF2:IRCF0, select the frequency output of the internal oscillator block to drive the device clock. The choices are the INTRC source, the INTOSC source (8 MHz) or one of the frequencies derived from the INTOSC postscaler (31 kHz to 4 MHz). If the internal oscillator block is supplying the device clock, changing the states of these bits will have an immediate change on the internal oscillator’s output. On device Resets, the default output frequency of the internal oscillator block is set at 1 MHz.

When an output frequency of 31 kHz is selected (IRCF2:IRCF0 = 000), users may choose which internal oscillator acts as the source. This is done with the INTSRC bit in the OSCTUNE register (OSCTUNE<7>). Setting this bit selects INTOSC as a 31.25 kHz clock source by enabling the divide-by-256 output of the INTOSC postscaler. Clearing INTSRC selects INTRC (nominally 31 kHz) as the clock source.

This option allows users to select the tunable and more precise INTOSC as a clock source, while maintaining power savings with a very low clock speed. Regardless of the setting of INTSRC, INTRC always remains the clock source for features such as the Watchdog Timer and the Fail-Safe Clock Monitor.

The OSTS, IOFS and T1RUN bits indicate which clock source is currently providing the device clock. The OSTS bit indicates that the Oscillator Start-up Timer has timed out and the primary clock is providing the device clock in primary clock modes. The IOFS bit indicates when the internal oscillator block has stabilized and is providing the device clock in RC Clock modes. The T1RUN bit (T1CON<6>) indicates when the Timer1 oscillator is providing the device clock in secondary clock modes. In power-managed modes, only one of these three bits will be set at any time. If none of these bits are set, the INTRC is providing the clock or the internal oscillator block has just started and is not yet stable.

2.7.2 OSCILLATOR TRANSITIONS

The IDLEN bit determines if the device goes into Sleep mode or one of the Idle modes when the SLEEP instruction is executed.

The use of the flag and control bits in the OSCCON register is discussed in more detail in Section 3.0 “Power-Managed Modes”.

Note 1: The Timer1 oscillator must be enabled to select the secondary clock source. The Timer1 oscillator is enabled by setting the T1OSCEN bit in the Timer1 Control register (T1CON<3>). If the Timer1 oscillator is not enabled, then any attempt to select a secondary clock source when executing a SLEEP instruction will be ignored.

2: It is recommended that the Timer1 oscillator be operating and stable before executing the SLEEP instruction, or a very long delay may occur while the Timer1 oscillator starts.

The PIC18F2682/2685/4682/4685 devices contain circuitry to prevent clock “glitches” when switching between clock sources. A short pause in the device clock occurs during the clock switch. The length of this pause is the sum of two cycles of the old clock source and three to four cycles of the new clock source. This formula assumes that the new clock source is stable.

Clock transitions are discussed in greater detail in Section 3.1.2 “Entering Power-Managed Modes”.
REGISTER 2-2: OSCCON: OSCILLATOR CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-1</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDLEN</td>
<td>IRCF2</td>
<td>IRCF1</td>
<td>IRCF0</td>
<td>OSTS</td>
<td>IOFS</td>
<td>SCS1</td>
<td>SCS0</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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  IDLEN: Idle Enable bit
   1 = Device enters Idle mode on SLEEP instruction
   0 = Device enters Sleep mode on SLEEP instruction

bit 6-4  IRCF2:IRCF0: Internal Oscillator Frequency Select bits
   111 = 8 MHz (INTOSC drives clock directly)
   110 = 4 MHz
   101 = 2 MHz
   100 = 1 MHz(3)
   011 = 500 kHz
   010 = 250 kHz
   001 = 125 kHz
   000 = 31 kHz (from either INTOSC/256 or INTRC directly)(2)

bit 3  OSTS: Oscillator Start-up Time-out Status bit(1)
   1 = Oscillator Start-up Timer time-out has expired; primary oscillator is running
   0 = Oscillator Start-up Timer time-out is running; primary oscillator is not ready

bit 2  IOFS: INTOSC Frequency Stable bit
   1 = INTOSC frequency is stable and the frequency is provided by one of the RC modes
   0 = INTOSC frequency is not stable

bit 1-0  SCS1:SCS0: System Clock Select bits
   1x = Internal oscillator block
   01 = Timer1 oscillator
   00 = Primary oscillator

Note 1: Depends on state of the IESO Configuration bit.
2: Source selected by the INTSRC bit (OSCTUNE<7>), see text.
3: Default output frequency of INTOSC on Reset.
2.8 Effects of Power-Managed Modes on the Various Clock Sources

When PRI_IDLE mode is selected, the designated primary oscillator continues to run without interruption. For all other power-managed modes, the oscillator using the OSC1 pin is disabled. The OSC1 pin (and OSC2 pin, if used by the oscillator) will stop oscillating.

In secondary clock modes (SEC_RUN and SEC_IDLE), the Timer1 oscillator is operating and providing the device clock. The Timer1 oscillator may also run in all power-managed modes if required to clock Timer1 or Timer3.

In internal oscillator modes (RC_RUN and RC_IDLE), the internal oscillator block provides the device clock source. The 31 kHz INTRC output can be used directly to provide the clock and may be enabled to support various special features, regardless of the power-managed mode (see Section 24.2 “Watchdog Timer (WDT)”, Section 24.3 “Two-Speed Start-up” and Section 24.4 “Fail-Safe Clock Monitor” for more information on WDT, Two-Speed Start-up and Fail-Safe Clock Monitor). The INTOSC output at 8 MHz may be used directly to clock the device or may be divided down by the postscaler. The INTOSC output is disabled if the clock is provided directly from the INTRC output.

If the Sleep mode is selected, all clock sources are stopped. Since all the transistor switching currents have been stopped, Sleep mode achieves the lowest current consumption of the device (only leakage currents).

Enabling any on-chip feature that will operate during Sleep will increase the current consumed during Sleep. The INTRC is required to support WDT operation. The Timer1 oscillator may be operating to support a Real-Time Clock. Other features may be operating that do not require a device clock source (i.e., MSSP slave, PSP, INTx pins and others). Peripherals that may add significant current consumption are listed in Section 27.2 “DC Characteristics: Power-Down and Supply Current”.

2.9 Power-up Delays

Power-up delays are controlled by two timers, so that no external Reset circuitry is required for most applications. The delays ensure that the device is kept in Reset until the device power supply is stable under normal circumstances and the primary clock is operating and stable. For additional information on power-up delays, see Section 4.5 “Device Reset Timers”.

The first timer is the Power-up Timer (PWRT), which provides a fixed delay on power-up (parameter 33, Table 27-10). It is enabled by clearing (= 0) the PWRTEN Configuration bit.

The second timer is the Oscillator Start-up Timer (OST), intended to keep the chip in Reset until the crystal oscillator is stable (LP, XT and HS modes). The OST does this by counting 1024 oscillator cycles before allowing the oscillator to clock the device.

When the HSPPLL Oscillator mode is selected, the device is kept in Reset for an additional 2 ms, following the HS mode OST delay, so the PLL can lock to the incoming clock frequency.

There is a delay of interval T_CSD (parameter 38, Table 27-10), following POR, while the controller becomes ready to execute instructions. This delay runs concurrently with any other delays. This may be the only delay that occurs when any of the EC, RC or INTIO modes are used as the primary clock source.

<table>
<thead>
<tr>
<th>OSC Mode</th>
<th>OSC1 Pin</th>
<th>OSC2 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC, INTIO1</td>
<td>Floating, external resistor should pull high</td>
<td>At logic low (clock/4 output)</td>
</tr>
<tr>
<td>RCIO, INTIO2</td>
<td>Floating, external resistor should pull high</td>
<td>Configured as PORTA, bit 6</td>
</tr>
<tr>
<td>ECI0</td>
<td>Floating, pulled by external clock</td>
<td>Configured as PORTA, bit 6</td>
</tr>
<tr>
<td>EC</td>
<td>Floating, pulled by external clock</td>
<td>At logic low (clock/4 output)</td>
</tr>
<tr>
<td>LP, XT and HS</td>
<td>Feedback inverter disabled at quiescent voltage level</td>
<td>Feedback inverter disabled at quiescent voltage level</td>
</tr>
</tbody>
</table>

Note: See Table 4-2 in Section 4.0 “Reset” for time-outs due to Sleep and MCLR Reset.
3.0 POWER-MANAGED MODES

PIC18F2682/2685/4682/4685 devices offer a total of seven operating modes for more efficient power management. These modes provide a variety of options for selective power conservation in applications where resources may be limited (i.e., battery-powered devices).

There are three categories of power-managed modes:
• Run modes
• Idle modes
• Sleep mode

These categories define which portions of the device are clocked and sometimes, what speed. The Run and Idle modes may use any of the three available clock sources (primary, secondary or internal oscillator block); the Sleep mode does not use a clock source.

The power-managed modes include several power saving features offered on previous PIC® devices. One is the clock switching feature, offered in other PIC18 devices, allowing the controller to use the Timer1 oscillator in place of the primary oscillator. Also included is the Sleep mode, offered by all PIC devices, where all device clocks are stopped.

3.1 Selecting Power-Managed Modes

Selecting a power-managed mode requires two decisions: if the CPU is to be clocked or not and the selection of a clock source. The IDLEN bit (OSCCON<7>) controls CPU clocking, while the SCS1:SCS0 bits (OSCCON<1:0>) select the clock source. The individual modes, bit settings, clock sources and affected modules are summarized in Table 3-1.

3.1.1 CLOCK SOURCES

The SCS1:SCS0 bits allow the selection of one of three clock sources for power-managed modes. They are:
• The primary clock as defined by the FOSC3:FOSC0 Configuration bits
• The secondary clock (the Timer1 oscillator)
• The internal oscillator block (for RC modes)

3.1.2 ENTERING POWER-MANAGED MODES

Switching from one power-managed mode to another begins by loading the OSCCON register. The SCS1:SCS0 bits select the clock source and determine which Run or Idle mode is to be used. Changing these bits causes an immediate switch to the new clock source, assuming that it is running. The switch may also be subject to clock transition delays. These are discussed in Section 3.1.3 “Clock Transitions And Status Indicators” and subsequent sections.

Entry to the power-managed Idle or Sleep modes is triggered by the execution of a SLEEP instruction. The actual mode that results depends on the status of the IDLEN bit.

Depending on the current mode and the mode being switched to, a change to a power-managed mode does not always require setting all of these bits. Many transitions may be done by changing the oscillator select bits, or changing the IDLEN bit, prior to issuing a SLEEP instruction. If the IDLEN bit is already configured correctly, it may only be necessary to perform a SLEEP instruction to switch to the desired mode.

TABLE 3-1: POWER-MANAGED MODES

<table>
<thead>
<tr>
<th>Mode</th>
<th>OSCCON Bits</th>
<th>Module Clocking</th>
<th>Available Clock and Oscillator Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IDLEN&lt;7&gt;</td>
<td>SCS1:SCS0&lt;1:0&gt;</td>
<td>CPU</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep</td>
<td>0</td>
<td>N/A</td>
<td>Off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>None – all clocks are disabled</td>
</tr>
<tr>
<td>PRI_RUN</td>
<td>N/A</td>
<td>00</td>
<td>Clocked</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Primary – LP, XT, HS, HSPLL, RC, EC, INTRC; this is the normal full power execution mode(2)</td>
</tr>
<tr>
<td>SEC_RUN</td>
<td>N/A</td>
<td>1x</td>
<td>Clocked</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Secondary – Timer1 Oscillator</td>
</tr>
<tr>
<td>RC_RUN</td>
<td>N/A</td>
<td>1x</td>
<td>Clocked</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Internal Oscillator Block(2)</td>
</tr>
<tr>
<td>PRI_IDLE</td>
<td>1</td>
<td>00</td>
<td>Off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Primary – LP, XT, HS, HSPLL, RC, EC</td>
</tr>
<tr>
<td>SEC_IDLE</td>
<td>1</td>
<td>01</td>
<td>Off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Secondary – Timer1 Oscillator</td>
</tr>
<tr>
<td>RC_IDLE</td>
<td>1</td>
<td>1x</td>
<td>Off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Internal Oscillator Block(2)</td>
</tr>
</tbody>
</table>

Note 1: IDLEN reflects its value when the SLEEP instruction is executed.

2: Includes INTOSC and INTOSC postscaler, as well as the INTRC source.
3.1.3 CLOCK TRANSITIONS AND STATUS INDICATORS

The length of the transition between clock sources is the sum of two cycles of the old clock source and three to four cycles of the new clock source. This formula assumes that the new clock source is stable.

Three bits indicate the current clock source and its status. They are:

- OSTS (OSCCON<3>)
- IOFS (OSCCON<2>)
- T1RUN (T1CON<6>)

In general, only one of these bits will be set while in a given power-managed mode. When the OSTS bit is set, the primary clock is providing the device clock. When the IOFS bit is set, the INTOSC output is providing a stable 8 MHz clock source to a divider that actually drives the device clock. When the T1RUN bit is set, the Timer1 oscillator is providing the clock. If none of these bits are set, then either the INTRC clock source is clocking the device, or the INTOSC source is not yet stable.

If the internal oscillator block is configured as the primary clock source by the FOSC3:FOSC0 Configuration bits, then both the OSTS and IOFS bits may be set when in PRI_RUN or PRI_IDLE modes. This indicates that the primary clock (INTOSC output) is generating a stable 8 MHz output. Entering another power-managed RC mode at the same frequency would clear the OSTS bit.

Note 1: Caution should be used when modifying a single IRCF bit. If VDD is less than 3V, it is possible to select a higher clock speed than is supported by the low VDD. Improper device operation may result if the VDD/FOSC specifications are violated.

2: Executing a SLEEP instruction does not necessarily place the device into Sleep mode. It acts as the trigger to place the controller into either the Sleep mode or one of the Idle modes, depending on the setting of the IDLEN bit.

3.1.4 MULTIPLE SLEEP COMMANDS

The power-managed mode that is invoked with the SLEEP instruction is determined by the setting of the IDLEN bit at the time the instruction is executed. If another SLEEP instruction is executed, the device will enter the power-managed mode specified by IDLEN at that time. If IDLEN has changed, the device will enter the new power-managed mode specified by the new setting.

3.2 Run Modes

In the Run modes, clocks to both the core and peripherals are active. The difference between these modes is the clock source.

3.2.1 PRI_RUN MODE

The PRI_RUN mode is the normal, full power execution mode of the microcontroller. This is also the default mode upon a device Reset, unless Two-Speed Start-up is enabled (see Section 24.3 “Two-Speed Start-up” for details). In this mode, the OSTS bit is set. The IOFS bit may be set if the internal oscillator block is the primary clock source (see Section 2.7.1 “Oscillator Control Register”).

3.2.2 SEC_RUN MODE

The SEC_RUN mode is the compatible mode to the “clock switching” feature offered in other PIC18 devices. In this mode, the CPU and peripherals are clocked from the Timer1 oscillator. This gives users the option of lower power consumption while still using a high accuracy clock source.

SEC_RUN mode is entered by setting the SCS1:SCS0 bits to '01'. The device clock source is switched to the Timer1 oscillator (see Figure 3-1), the primary oscillator is shut down, the T1RUN bit (T1CON<6>) is set and the OSTS bit is cleared.

Note: The Timer1 oscillator should already be running prior to entering SEC_RUN mode. If the T1OSCEN bit is not set when the SCS1:SCS0 bits are set to '01', entry to SEC_RUN mode will not occur. If the Timer1 oscillator is enabled but not yet running, device clocks will be delayed until the oscillator has started. In such situations, initial oscillator operation is far from stable and unpredictable operation may result.

On transitions from SEC_RUN to PRI_RUN mode, the peripherals and CPU continue to be clocked from the Timer1 oscillator while the primary clock is started. When the primary clock becomes ready, a clock switch back to the primary clock occurs (see Figure 3-2). When the clock switch is complete, the T1RUN bit is cleared, the OSTS bit is set and the primary clock is providing the clock. The IDLEN and SCS bits are not affected by the wake-up; the Timer1 oscillator continues to run.
3.2.3 RC_RUN MODE

In RC_RUN mode, the CPU and peripherals are clocked from the internal oscillator block using the INTOSC multiplexer; the primary clock is shut down. When using the INTRC source, this mode provides the best power conservation of all the Run modes, while still executing code. It works well for user applications which are not highly timing sensitive or do not require high-speed clocks at all times.

If the primary clock source is the internal oscillator block (either INTRC or INTOSC), there are no distinguishable differences between PRI_RUN and RC_RUN modes during execution. However, a clock switch delay will occur during entry to and exit from RC_RUN mode. Therefore, if the primary clock source is the internal oscillator block, the use of RC_RUN mode is not recommended.

This mode is entered by setting SCS1 to ‘1’. Although it is ignored, it is recommended that SCS0 also be cleared; this is to maintain software compatibility with future devices. When the clock source is switched to the INTOSC multiplexer (see Figure 3-3), the primary oscillator is shut down and the OSTS bit is cleared. The IRCF bits may be modified at any time to immediately change the clock speed.

**Note:** Caution should be used when modifying a single IRCF bit. If VDD is less than 3V, it is possible to select a higher clock speed than is supported by the low VDD. Improper device operation may result if the VDD/FOSC specifications are violated.

If the IRCF bits and the INTSRC bit are all clear, the INTOSC output is not enabled and the IOFS bit will remain clear; there will be no indication of the current clock source. The INTRC source is providing the device clocks.

If the IRCF bits are changed from all clear (thus, enabling the INTOSC output) or if INTSRC is set, the IOFS bit becomes set after the INTOSC output becomes stable. Clocks to the device continue while the INTOSC source stabilizes after an interval of TIOBST.

---

**FIGURE 3-1: TRANSITION TIMING FOR ENTRY TO SEC_RUN MODE**

<table>
<thead>
<tr>
<th>T1OSI</th>
<th>OSC1</th>
<th>CPU Clock</th>
<th>Peripheral Clock</th>
<th>Program Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PC + 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PC + 4</td>
</tr>
</tbody>
</table>

**FIGURE 3-2: TRANSITION TIMING FROM SEC_RUN MODE TO PRI_RUN MODE (HSPLL)**

<table>
<thead>
<tr>
<th>T1OSI</th>
<th>OSC1</th>
<th>PLL Clock Output</th>
<th>CPU Clock</th>
<th>Peripheral Clock</th>
<th>Program Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: TOST = 1024 TOSC; TPLL = 2 ms (approx). These intervals are not shown to scale.
If the IRCF bits were previously at a non-zero value or if INTSRC was set before setting SCS1 and the INTOSC source was already stable, the IOFS bit will remain set.

On transitions from RC_RUN mode to PRI_RUN mode, the device continues to be clocked from the INTOSC multiplexer while the primary clock is started. When the primary clock becomes ready, a clock switch to the primary clock occurs (see Figure 3-4). When the clock switch is complete, the IOFS bit is cleared, the OSTS bit is set and the primary clock is providing the device clock. The IDLEN and SCS bits are not affected by the switch. The INTRC source will continue to run if either the WDT or the Fail-Safe Clock Monitor is enabled.

**FIGURE 3-3: TRANSITION TIMING TO RC_RUN MODE**

**FIGURE 3-4: TRANSITION TIMING FROM RC_RUN MODE TO PRI_RUN MODE**

*Note 1: TOST = 1024 TOSC; TPLL = 2 ms (approx). These intervals are not shown to scale.*
3.3 Sleep Mode

The power-managed Sleep mode in the PIC18F2682/2685/4682/4685 devices is identical to the legacy Sleep mode offered in all other PIC devices. It is entered by clearing the IDLEN bit (the default state on device Reset) and executing the SLEEP instruction. This shuts down the selected oscillator (Figure 3-5). All clock source status bits are cleared.

Entering the Sleep mode from any other mode does not require a clock switch. This is because no clocks are needed once the controller has entered Sleep. If the WDT is selected, the INTRC source will continue to operate. If the Timer1 oscillator is enabled, it will also continue to run.

When a wake event occurs in Sleep mode (by interrupt, Reset or WDT time-out), the device will not be clocked until the clock source selected by the SCS1:SCS0 bits becomes ready (see Figure 3-6), or it will be clocked from the internal oscillator block if either the Two-Speed Start-up or the Fail-Safe Clock Monitor are enabled (see Section 24.0 “Special Features of the CPU”). In either case, the OSTS bit is set when the primary clock is providing the device clocks. The IDLEN and SCS bits are not affected by the wake-up.

3.4 Idle Modes

The Idle modes allow the controller’s CPU to be selectively shut down while the peripherals continue to operate. Selecting a particular Idle mode allows users to further manage power consumption.

If the IDLEN bit is set to a '1' when a SLEEP instruction is executed, the peripherals will be clocked from the clock source selected using the SCS1:SCS0 bits; however, the CPU will not be clocked. The clock source status bits are not affected. Setting IDLEN and executing a SLEEP instruction provides a quick method of switching from a given Run mode to its corresponding Idle mode.

If the WDT is selected, the INTRC source will continue to operate. If the Timer1 oscillator is enabled, it will also continue to run.

Since the CPU is not executing instructions, the only exits from any of the Idle modes are by interrupt, WDT time-out or a Reset. When a wake event occurs, CPU execution is delayed by an interval of TCSD (parameter 38, Table 27-10) while it becomes ready to execute code. When the CPU begins executing code, it resumes with the same clock source for the current Idle mode. For example, when waking from RC_IDLE mode, the internal oscillator block will clock the CPU and peripherals (in other words, RC_RUN mode). The IDLEN and SCS bits are not affected by the wake-up. While in any Idle mode or the Sleep mode, a WDT time-out will result in a WDT wake-up to the Run mode currently specified by the SCS1:SCS0 bits.

---

**FIGURE 3-5: TRANSITION TIMING FOR ENTRY TO SLEEP MODE**

<table>
<thead>
<tr>
<th>OSC1</th>
<th>Clock</th>
<th>Peripheral Clock</th>
<th>Sleep</th>
<th>Program Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td></td>
<td></td>
<td></td>
<td>PC</td>
</tr>
<tr>
<td>Q2</td>
<td></td>
<td></td>
<td></td>
<td>PC + 2</td>
</tr>
<tr>
<td>Q3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**FIGURE 3-6: TRANSITION TIMING FOR WAKE FROM SLEEP (HSPLL)**

<table>
<thead>
<tr>
<th>OSC1</th>
<th>PLL Clock Output</th>
<th>CPU Clock</th>
<th>Peripheral Clock</th>
<th>Program Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Q2; Q3; Q4; Q1; Q2; Q3; Q4; Q1; Q2; Q3; Q4</td>
<td>Q1; Q2; Q3; Q4</td>
<td>PC</td>
<td>PC + 2</td>
</tr>
</tbody>
</table>

Note 1: OSTS = 1024 TOSC; TPLL = 2 ms (approx). These intervals are not shown to scale.
3.4.1 PRI_IDLE MODE

This mode is unique among the three low-power Idle modes in that it does not disable the primary device clock. For timing sensitive applications, this allows for the fastest resumption of device operation with its more accurate primary clock source, since the clock source does not have to “warm up” or transition from another oscillator.

PRI_IDLE mode is entered from PRI_RUN mode by setting the IDLEN bit and executing a SLEEP instruction. If the device is in another Run mode, set IDLEN first, then clear the SCS bits and execute SLEEP. Although the CPU is disabled, the peripherals continue to be clocked from the primary clock source specified by the FOSC3:FOSC0 Configuration bits. The OSTS bit remains set (see Figure 3-7).

When a wake event occurs, the CPU is clocked from the primary clock source. A delay of interval TCSD is required between the wake event and when code execution starts. This is required to allow the CPU to become ready to execute instructions. After the wake-up, the OSTS bit remains set. The IDLEN and SCS bits are not affected by the wake-up (see Figure 3-8).

3.4.2 SEC_IDLE MODE

In SEC_IDLE mode, the CPU is disabled but the peripherals continue to be clocked from the Timer1 oscillator. This mode is entered from SEC_RUN by setting the IDLEN bit and executing a SLEEP instruction. If the device is in another Run mode, set the IDLEN bit first, then set the SCS1:SCS0 bits to ‘01’ and execute SLEEP. When the clock source is switched to the Timer1 oscillator, the primary oscillator is shut down, the OSTS bit is cleared and the T1RUN bit is set.

When a wake event occurs, the peripherals continue to be clocked from the Timer1 oscillator. After an interval of TCSD following the wake event, the CPU begins executing code being clocked by the Timer1 oscillator. The IDLEN and SCS bits are not affected by the wake-up; the Timer1 oscillator continues to run (see Figure 3-8).

Note: The Timer1 oscillator should already be running prior to entering SEC_IDLE mode. If the T1OSCEN bit is not set when the SLEEP instruction is executed, the SLEEP instruction will be ignored and entry to SEC_IDLE mode will not occur. If the Timer1 oscillator is enabled but not yet running, peripheral clocks will be delayed until the oscillator has started. In such situations, initial oscillator operation is far from stable and unpredictable operation may result.

FIGURE 3-7: TRANSITION TIMING FOR ENTRY TO IDLE MODE

FIGURE 3-8: TRANSITION TIMING FOR WAKE FROM IDLE TO RUN MODE
3.4.3 RC_IDLE MODE

In RC_IDLE mode, the CPU is disabled but the peripherals continue to be clocked from the internal oscillator block using the INTOSC multiplexer. This mode allows for controllable power conservation during Idle periods.

From RC_RUN, this mode is entered by setting the IDLEN bit and executing a SLEEP instruction. If the device is in another Run mode, first set IDLEN, then set the SCS1 bit and execute SLEEP. Although its value is ignored, it is recommended that SCS0 also be cleared; this is to maintain software compatibility with future devices. The INTOSC multiplexer may be used to select a higher clock frequency, by modifying the IRCF bits, before executing the SLEEP instruction. When the clock source is switched to the INTOSC multiplexer, the primary oscillator is shut down and the OSTS bit is cleared.

If the IRCF bits are set to any non-zero value or the INTSRC bit is set, the INTOSC output is enabled. The IOFS bit becomes set, after the INTOSC output becomes stable, after an interval of TIOBST (parameter 39, Table 27-10). Clocks to the peripherals continue while the INTOSC source stabilizes. If the IRCF bits were previously at a non-zero value, or INTSRC was set before the SLEEP instruction was executed and the INTOSC source was already stable, the IOFS bit will remain set. If the IRCF bits and INTSRC are all clear, the INTOSC output will not be enabled, the IOFS bit will remain clear and there will be no indication of the current clock source.

When a wake event occurs, the peripherals continue to be clocked from the INTOSC multiplexer. After a delay of Tcso following the wake event, the CPU begins executing code being clocked by the INTOSC multiplexer. The IDLEN and SCS bits are not affected by the wake-up. The INTRC source will continue to run if the internal oscillator block is the device clock source.

3.5 Exiting Idle and Sleep Modes

An exit from Sleep mode or any of the Idle modes is triggered by an interrupt, a Reset or a WDT time-out. This section discusses the triggers that cause exits from power-managed modes. The clocking subsystem actions are discussed in each of the power-managed modes (see Section 3.2 “Run Modes”, Section 3.3 “Sleep Mode” and Section 3.4 “Idle Modes”).

3.5.1 EXIT BY INTERRUPT

Any of the available interrupt sources can cause the device to exit from an Idle mode or the Sleep mode to a Run mode. To enable this functionality, an interrupt source must be enabled by setting its enable bit in one of the INTCON or PIE registers. The exit sequence is initiated when the corresponding interrupt flag bit is set. On all exits from Idle or Sleep modes by interrupt, code execution branches to the interrupt vector if the GIE/GIEH bit (INTCON<7>) is set. Otherwise, code execution continues or resumes without branching (see Section 9.0 “Interrupts”).

A fixed delay of interval Tcso following the wake event is required when leaving the Sleep and Idle modes. This delay is required for the CPU to prepare for execution. Instruction execution resumes on the first clock cycle following this delay.

3.5.2 EXIT BY WDT TIME-OUT

A WDT time-out will cause different actions depending on which power-managed mode the device is in when the time-out occurs.

If the device is not executing code (all Idle modes and Sleep mode), the time-out will result in an exit from the power-managed mode (see Section 3.2 “Run Modes” and Section 3.3 “Sleep Mode”). If the device is executing code (all Run modes), the time-out will result in a WDT Reset (see Section 24.2 “Watchdog Timer (WDT)”).

The WDT timer and postscaler are cleared by executing a SLEEP or CLRWDT instruction, the loss of a currently selected clock source (if the Fail-Safe Clock Monitor is enabled) and modifying the IRCF bits in the OSCCON register if the internal oscillator block is the device clock source.

3.5.3 EXIT BY RESET

Normally, the device is held in Reset by the Oscillator Start-up Timer (OST) until the primary clock becomes ready. At that time, the OSTS bit is set and the device begins executing code. If the internal oscillator block is the new clock source, the IOFS bit is set instead.

The exit delay time from Reset to the start of code execution depends on both the clock sources before and after the wake-up and the type of oscillator if the new clock source is the primary clock. Exit delays are summarized in Table 3-2.

Code execution can begin before the primary clock becomes ready. If either the Two-Speed Start-up (see Section 24.3 “Two-Speed Start-up”) or Fail-Safe Clock Monitor (see Section 24.4 “Fail-Safe Clock Monitor”) is enabled, the device may begin execution as soon as the Reset source has cleared. Execution is clocked by the INTOSC multiplexer driven by the internal oscillator block. Execution is clocked by the internal oscillator block until either the primary clock becomes ready or a power-managed mode is entered before the primary clock becomes ready; the primary clock is then shut down.
3.5.4 EXIT WITHOUT AN OSCILLATOR START-UP DELAY

Certain exits from power-managed modes do not invoke the OST at all. There are two cases:
- PRI_IDLE mode where the primary clock source is not stopped
- The primary clock source is not any of the LP, XT, HS or HSPLL modes

In these instances, the primary clock source either does not require an oscillator start-up delay, since it is already running (PRI_IDLE), or normally does not require an oscillator start-up delay (RC, EC and INTIO Oscillator modes). However, a fixed delay of interval TCSD following the wake event is still required when leaving the Sleep and Idle modes to allow the CPU to prepare for execution. Instruction execution resumes on the first clock cycle following this delay.

### TABLE 3-2: EXIT DELAY ON WAKE-UP BY RESET FROM SLEEP MODE OR ANY IDLE MODE (BY CLOCK SOURCES)

<table>
<thead>
<tr>
<th>Clock Source Before Wake-up</th>
<th>Clock Source After Wake-up</th>
<th>Exit Delay</th>
<th>Clock Ready Status Bit (OSCCON)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Device Clock (PRI_IDLE mode)</strong></td>
<td>LP, XT, HS</td>
<td>TOST(4)</td>
<td>OSTS</td>
</tr>
<tr>
<td></td>
<td>HSPLL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EC, RC</td>
<td>TOST + trc(4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTRC(1)</td>
<td>TCSO(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTOSC(3)</td>
<td>TIOBST(5)</td>
<td>IOFS</td>
</tr>
<tr>
<td><strong>T1OSC or INTRC(1)</strong></td>
<td>LP, XT, HS</td>
<td>TOST(4)</td>
<td>OSTS</td>
</tr>
<tr>
<td></td>
<td>HSPLL</td>
<td>TOST + trc(4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EC, RC</td>
<td>TCSO(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTRC(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTOSC(3)</td>
<td>TIOBST(5)</td>
<td>IOFS</td>
</tr>
<tr>
<td><strong>INTOSC(3)</strong></td>
<td>LP, XT, HS</td>
<td>TOST(4)</td>
<td>OSTS</td>
</tr>
<tr>
<td></td>
<td>HSPLL</td>
<td>TOST + trc(4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EC, RC</td>
<td>TCSO(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTRC(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTOSC(3)</td>
<td>None</td>
<td>IOFS</td>
</tr>
<tr>
<td><strong>None (Sleep mode)</strong></td>
<td>LP, XT, HS</td>
<td>TOST(4)</td>
<td>OSTS</td>
</tr>
<tr>
<td></td>
<td>HSPLL</td>
<td>TOST + trc(4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EC, RC</td>
<td>TCSO(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTRC(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTOSC(3)</td>
<td>TIOBST(5)</td>
<td>IOFS</td>
</tr>
</tbody>
</table>

**Note 1:** In this instance, refers specifically to the 31 kHz INTRC clock source.

**2:** TCSD (parameter 38) is a required delay when waking from Sleep and all Idle modes and runs concurrently with any other required delays (see Section 3.4 “Idle Modes”).

**3:** Includes both the INTOSC 8 MHz source and postscaler derived frequencies.

**4:** TOST is the Oscillator Start-up Timer (parameter 32). trc is the PLL Lock-out Timer (parameter F12); it is also designated as TPLL.

**5:** Execution continues during TIOBST (parameter 39), the INTOSC stabilization period.
4.0  RESET

The PIC18F2682/2685/4682/4685 devices differentiate between various kinds of Reset:

a) Power-on Reset (POR)

b) MCLR Reset during normal operation

c) MCLR Reset during power-managed modes

d) Watchdog Timer (WDT) Reset during execution

e) Programmable Brown-out Reset (BOR)

f) **RESET** Instruction

g) Stack Full Reset

h) Stack Underflow Reset

This section discusses Resets generated by MCLR, POR and BOR and covers the operation of the various start-up timers. Stack Reset events are covered in Section 5.1.2.4 “Stack Full and Underflow Resets”. WDT Resets are covered in Section 24.2 “Watchdog Timer (WDT)”.

A simplified block diagram of the on-chip Reset circuit is shown in Figure 4-1.

4.1  RCON Register

Device Reset events are tracked through the RCON register (Register 4-1). The lower five bits of the register indicate that a specific Reset event has occurred. In most cases, these bits can only be cleared by the event and must be set by the application after the event. The state of these flag bits, taken together, can be read to indicate the type of Reset that just occurred. This is described in more detail in Section 4.6 “Reset State of Registers”.

The RCON register also has control bits for setting interrupt priority (IPEN) and software control of the BOR (SBOREN). Interrupt priority is discussed in Section 9.0 “Interrupts”. BOR is covered in Section 4.4 “Brown-out Reset (BOR)”.

**FIGURE 4-1: SIMPLIFIED BLOCK DIAGRAM OF ON-CHIP RESET CIRCUIT**

---

**Note 1:** This is the INTRC source from the internal oscillator block and is separate from the RC oscillator of the CLKI pin.

**Note 2:** See Table 4-2 for time-out situations.
### REGISTER 4-1: RCON: RESET CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-1&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>U-0</th>
<th>R/W-1</th>
<th>R-1</th>
<th>R-1</th>
<th>R/W-0&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPEN</td>
<td>SBOREN</td>
<td>—</td>
<td>RI</td>
<td>TO</td>
<td>PD</td>
<td>POR</td>
<td>BOR</td>
</tr>
</tbody>
</table>

#### Legend:

- **R** = Readable bit
- **W** = Writable 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**

**IPEN**: Interrupt Priority Enable bit

- 1 = Enable priority levels on interrupts
- 0 = Disable priority levels on interrupts (PIC16CXXX Compatibility mode)

**bit 6**

**SBOREN**: BOR Software Enable bit<sup>(1)</sup>

If **BOREN1:BOREN0** = 01:

- 1 = BOR is enabled
- 0 = BOR is disabled

If **BOREN1:BOREN0** = 00, 10 or 11:

Bit is disabled and read as ‘0’.

**bit 5**

**Unimplemented**: Read as ‘0’

**bit 4**

**RI**: RESET Instruction Flag bit

- 1 = The **RESET** instruction was not executed (set by firmware only)
- 0 = The **RESET** instruction was executed causing a device Reset (must be set in software after a Brown-out Reset occurs)

**bit 3**

**TO**: Watchdog Time-out Flag bit

- 1 = Set by power-up, **CLRWDT** instruction or **SLEEP** instruction
- 0 = A WDT time-out occurred

**bit 2**

**PD**: Power-Down Detection Flag bit

- 1 = Set by power-up or by the **CLRWDT** instruction
- 0 = Set by execution of the **SLEEP** instruction

**bit 1**

**POR**: Power-on Reset Status bit

- 1 = A Power-on Reset has not occurred (set by firmware only)
- 0 = A Power-on Reset occurred (must be set in software after a Power-on Reset occurs)

**bit 0**

**BOR**: Brown-out Reset Status bit

- 1 = A Brown-out Reset has not occurred (set by firmware only)
- 0 = A Brown-out Reset occurred (must be set in software after a Brown-out Reset occurs)

**Note 1**: If SBOREN is enabled, its Reset state is ‘1’; otherwise, it is ‘0’.

**Note 2**: The actual Reset value of **POR** is determined by the type of device Reset. See the notes following this register and Section 4.6 “Reset State of Registers” for additional information.

**Note 1**: It is recommended that the **POR** bit be set after a Power-on Reset has been detected so that subsequent Power-on Resets may be detected.

**Note 2**: Brown-out Reset is said to have occurred when **BOR** is ‘0’ and **POR** is ‘1’ (assuming that **POR** was set to ‘1’ by software immediately after a Power-on Reset).
4.2 Master Clear Reset (MCLR)

The MCLR pin provides a method for triggering an external Reset of the device. A Reset is generated by holding the pin low. These devices have a noise filter in the MCLR Reset path which detects and ignores small pulses.

The MCLR pin is not driven low by any internal Resets, including the WDT.

In PIC18F2682/2685/4682/4685 devices, the MCLR input can be disabled with the MCLRE Configuration bit. When MCLR is disabled, the pin becomes a digital input. See Section 10.5 “PORTE, TRISE and LATE Registers” for more information.

4.3 Power-on Reset (POR)

A Power-on Reset pulse is generated on-chip whenever VDD rises above a certain threshold. This allows the device to start in the initialized state when VDD is adequate for operation.

To take advantage of the POR circuitry, tie the MCLR pin through a resistor (1 kΩ to 10 kΩ) to VDD. This will eliminate external RC components usually needed to create a Power-on Reset delay. A minimum rise rate for VDD is specified (parameter D004). For a slow rise time, see Figure 4-2.

When the device starts normal operation (i.e., exits the Reset condition), device operating parameters (voltage, frequency, temperature, etc.) must be met to ensure operation. If these conditions are not met, the device must be held in Reset until the operating conditions are met.

POR events are captured by the POR bit (RCON<1>). The state of the bit is set to '1' whenever a Power-on Reset occurs; it does not change for any other Reset event. POR is not reset to '0' by any hardware event. To capture multiple events, the user manually resets the bit to '1' in software following any Power-on Reset.

Note 1: External Power-on Reset circuit is required only if the VDD power-up slope is too slow. The diode D helps discharge the capacitor quickly when VDD powers down.

2: R < 40 kΩ is recommended to make sure that the voltage drop across R does not violate the device's electrical specification.

3: R1 ≥ 1 kΩ will limit any current flowing into MCLR from external capacitor C, in the event of MCLR/VPP pin breakdown, due to Electrostatic Discharge (ESD) or Electrical Overstress (EOS).
4.4 Brown-out Reset (BOR)

PIC18F2682/2685/4682/4685 devices implement a BOR circuit that provides the user with a number of configuration and power-saving options. The BOR is controlled by the BORV1:BORV0 and BOREN1:BOREN0 Configuration bits. There are a total of four BOR configurations which are summarized in Table 4-1.

The BOR threshold is set by the BORV1:BORV0 bits. If BOR is enabled (any value of BOREN1:BOREN0, except ‘00’), any drop of VDD below VBOR (parameter D005) for greater than TBOR (parameter 35) will reset the device. A Reset may or may not occur if VDD falls below VBOR for less than TBOR. The chip will remain in Brown-out Reset until VDD rises above VBOR.

If the Power-up Timer is enabled, it will be invoked after VDD rises above VBOR; it then will keep the chip in Reset for an additional time delay, TPWRT (parameter 33). If VDD drops below VBOR while the Power-up Timer is running, the chip will go back into a Brown-out Reset and the Power-up Timer will be initialized. Once VDD rises above VBOR, the Power-up Timer will execute the additional time delay.

BOR and the Power-on Timer (PWRT) are independently configured. Enabling Brown-out Reset does not automatically enable the PWRT.

4.4.1 SOFTWARE ENABLED BOR

When BOREN1:BOREN0 = 01, the BOR can be enabled or disabled by the user in software. This is done with the control bit, SBOREN (RCON<6>). Setting SBOREN enables the BOR to function as previously described. Clearing SBOREN disables the BOR entirely. The SBOREN bit operates only in this mode; otherwise it is read as ‘0’.

Placing the BOR under software control gives the user the additional flexibility of tailoring the application to its environment without having to reprogram the device to change BOR configuration. It also allows the user to tailor device power consumption in software by eliminating the incremental current that the BOR consumes. While the BOR current is typically very small, it may have some impact in low-power applications.

Note: Even when BOR is under software control, the Brown-out Reset voltage level is still set by the BORV1:BORV0 Configuration bits. It cannot be changed in software.

4.4.2 DETECTING BOR

When BOR is enabled, the BOR bit always resets to ‘0’ on any Brown-out Reset or Power-on Reset event. This makes it difficult to determine if a Brown-out Reset event has occurred just by reading the state of BOR alone. A more reliable method is to simultaneously check the state of both POR and BOR. This assumes that the POR bit is reset to ‘1’ in software immediately after any Power-on Reset event. If BOR is ‘0’ while POR is ‘1’, it can be reliably assumed that a Brown-out Reset event has occurred.

4.4.3 DISABLING BOR IN SLEEP MODE

When BOREN1:BOREN0 = 10, the BOR remains under hardware control and operates as previously described. Whenever the device enters Sleep mode, however, the BOR is automatically disabled. When the device returns to any other operating mode, BOR is automatically re-enabled.

This mode allows for applications to recover from brown-out situations, while actively executing code, when the device requires BOR protection the most. At the same time, it saves additional power in Sleep mode by eliminating the small incremental BOR current.

<table>
<thead>
<tr>
<th>BOR Configuration</th>
<th>Status of SBOREN (RCON&lt;6&gt;)</th>
<th>BOR Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOREN1 BOREN0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 0</td>
<td>Unavailable</td>
<td>BOR disabled; must be enabled by reprogramming the Configuration bits.</td>
</tr>
<tr>
<td>0 1</td>
<td>Available</td>
<td>BOR enabled in software; operation controlled by SBOREN.</td>
</tr>
<tr>
<td>1 0</td>
<td>Unavailable</td>
<td>BOR enabled in hardware in Run and Idle modes, disabled during Sleep mode.</td>
</tr>
<tr>
<td>1 1</td>
<td>Unavailable</td>
<td>BOR enabled in hardware; must be disabled by reprogramming the Configuration bits.</td>
</tr>
</tbody>
</table>
4.5 Device Reset Timers

PIC18F2682/2685/4682/4685 devices incorporate three separate on-chip timers that help regulate the Power-on Reset process. Their main function is to ensure that the device clock is stable before code is executed. These timers are:

- Power-up Timer (PWRT)
- Oscillator Start-up Timer (OST)
- PLL Lock Time-out

4.5.1 POWER-UP TIMER (PWRT)

The Power-up Timer (PWRT) of PIC18F2682/2685/4682/4685 devices is an 11-bit counter which uses the INTRC source as the clock input. This yields an approximate time interval of \(2048 \times 32 \mu s = 65.6\) ms. While the PWRT is counting, the device is held in Reset.

The power-up time delay depends on the INTRC clock and will vary from chip-to-chip due to temperature and process variation. See DC parameter 33 for details.

The PWRT is enabled by clearing the PWRTEN Configuration bit.

4.5.2 OSCILLATOR START-UP TIMER (OST)

The Oscillator Start-up Timer (OST) provides a 1024 oscillator cycle (from OSC1 input) delay after the PWRT delay is over (parameter 33). This ensures that the crystal oscillator or resonator has started and stabilized.

The OST time-out is invoked only for XT, LP, HS and HSPLL modes and only on Power-on Reset or on exit from most power-managed modes.

4.5.3 PLL LOCK TIME-OUT

With the PLL enabled in its PLL mode, the time-out sequence following a Power-on Reset is slightly different from other oscillator modes. A separate timer is used to provide a fixed time-out that is sufficient for the PLL to lock to the main oscillator frequency. This PLL lock time-out (TPLL) is typically 2 ms and follows the oscillator start-up time-out.

4.5.4 TIME-OUT SEQUENCE

On power-up, the time-out sequence is as follows:

1. After the POR pulse has cleared, PWRT time-out is invoked (if enabled).
2. Then, the OST is activated.

The total time-out will vary based on oscillator configuration and the status of the PWRT. Figure 4-3, Figure 4-4, Figure 4-5, Figure 4-6 and Figure 4-7 all depict time-out sequences on power-up, with the Power-up Timer enabled and the device operating in HS Oscillator mode. Figures 4-3 through 4-6 also apply to devices operating in XT or LP modes. For devices in RC mode and with the PWRT disabled, on the other hand, there will be no time-out at all.

Since the time-outs occur from the POR pulse, if MCLR is kept low long enough, all time-outs will expire. Bringing MCLR high will begin execution immediately (Figure 4-5). This is useful for testing purposes or to synchronize more than one PIC18FXXXX device operating in parallel.

### TABLE 4-2: TIME-OUT IN VARIOUS SITUATIONS

<table>
<thead>
<tr>
<th>Oscillator Configuration</th>
<th>Power-up(2) and Brown-out</th>
<th>Exit From Power-Managed Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PWRTEN = 0</td>
<td>PWRTEN = 1</td>
</tr>
<tr>
<td>HSPPL</td>
<td>66 ms(1) + 1024 Tosc + 2 ms(2)</td>
<td>1024 Tosc + 2 ms(2)</td>
</tr>
<tr>
<td>HS, XT, LP</td>
<td>66 ms(1) + 1024 Tosc</td>
<td>1024 Tosc</td>
</tr>
<tr>
<td>EC, EClO</td>
<td>66 ms(1)</td>
<td>—</td>
</tr>
<tr>
<td>RC, RClO</td>
<td>66 ms(1)</td>
<td>—</td>
</tr>
<tr>
<td>INTIO1, INTIO2</td>
<td>66 ms(1)</td>
<td>—</td>
</tr>
</tbody>
</table>

**Note 1:** 66 ms (65.5 ms) is the nominal Power-up Timer (PWRT) delay.

**Note 2:** 2 ms is the nominal time required for the PLL to lock.
FIGURE 4-3: TIME-OUT SEQUENCE ON POWER-UP (MCLR TIED TO VDD, VDD RISE < TPWRT)

Vdd
MCLR
INTERNAL POR
PWRT TIME-OUT
OST TIME-OUT
INTERNAL RESET

FIGURE 4-4: TIME-OUT SEQUENCE ON POWER-UP (MCLR NOT TIED TO VDD): CASE 1

Vdd
MCLR
INTERNAL POR
PWRT TIME-OUT
OST TIME-OUT
INTERNAL RESET

FIGURE 4-5: TIME-OUT SEQUENCE ON POWER-UP (MCLR NOT TIED TO VDD): CASE 2

Vdd
MCLR
INTERNAL POR
PWRT TIME-OUT
OST TIME-OUT
INTERNAL RESET
FIGURE 4-6: SLOW RISE TIME (MCLR TIED TO VDD, VDD RISE > TPWRT)

VDD 0V 1V
MCLR
INTERNAL POR
PWRT TIME-OUT
OST TIME-OUT
INTERNAL RESET

FIGURE 4-7: TIME-OUT SEQUENCE ON POR w/PLL ENABLED (MCLR TIED TO VDD)

VDD
MCLR
INTERNAL POR
PWRT TIME-OUT
OST TIME-OUT
PLL TIME-OUT
INTERNAL RESET

Note: TOST = 1024 clock cycles.
       TPLL = 2 ms max. First three stages of the Power-up Timer.
4.6 Reset State of Registers

Most registers are unaffected by a Reset. Their status is unknown on POR and unchanged by all other Resets. The other registers are forced to a “Reset state” depending on the type of Reset that occurred.

Most registers are not affected by a WDT wake-up, since this is viewed as the resumption of normal operation. Status bits from the RCON register, RI, TO, PD, POR and BOR, are set or cleared differently in different Reset situations, as indicated in Table 4-3. These bits are used in software to determine the nature of the Reset.

Table 4-4 describes the Reset states for all of the Special Function Registers. These are categorized by Power-on and Brown-out Resets, Master Clear and WDT Resets and WDT wake-ups.

### Table 4-3: Status Bits, Their Significance and the Initialization Condition for RCON Register

<table>
<thead>
<tr>
<th>Condition</th>
<th>Program Counter</th>
<th>RCON Register</th>
<th>STKPTR Register</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SBOREN</td>
<td>RI</td>
</tr>
<tr>
<td>Power-on Reset</td>
<td>0000h</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>RESET instruction</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>Brown-out Reset</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>MCLR during power-managed Run modes</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>MCLR during power-managed Idle modes and Sleep mode</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>WDT time-out during full power or power-managed Run modes</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>MCLR during full power execution</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>Stack Full Reset (STVREN = 1)</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>Stack Underflow Reset (STVREN = 1)</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>Stack Underflow Error (not an actual Reset, STVREN = 0)</td>
<td>0000h</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>WDT time-out during power-managed Idle or Sleep modes</td>
<td>PC + 2</td>
<td>u(2)</td>
<td>u</td>
</tr>
<tr>
<td>Interrupt exit from power-managed modes</td>
<td>PC + 2(1)</td>
<td>u(2)</td>
<td>u</td>
</tr>
</tbody>
</table>

**Legend:** u = unchanged

**Note 1:** When the wake-up is due to an interrupt and the GIEH or GIEL bit is set, the PC is loaded with the interrupt vector (008h or 0018h).

**Note 2:** Reset state is ‘1’ for POR and unchanged for all other Resets when software BOR is enabled (BOREN1:BOREN0 Configuration bits = 01 and SBOREN = 1); otherwise, the Reset state is ‘0’.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOSU</td>
<td>2682 2685 4682 4685</td>
<td>---- 0 0000</td>
<td>---- 0 0000</td>
<td>---- 0 ㎜㎜㎜ ³</td>
</tr>
<tr>
<td>TOSH</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜ ³</td>
</tr>
<tr>
<td>TOSL</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜ ³</td>
</tr>
<tr>
<td>STKPTR</td>
<td>2682 2685 4682 4685</td>
<td>00–0 0000</td>
<td>㎜㎜㎜ 0 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜ ³</td>
</tr>
<tr>
<td>PCLATU</td>
<td>2682 2685 4682 4685</td>
<td>---- 0 0000</td>
<td>---- 0 0000</td>
<td>---- 0 ㎜㎜㎜</td>
</tr>
<tr>
<td>PCLATH</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
</tr>
<tr>
<td>PCL</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>PC + 2²</td>
</tr>
<tr>
<td>TBLPTRU</td>
<td>2682 2685 4682 4685</td>
<td>--0 0 0000</td>
<td>--0 0 0000</td>
<td>--㎜ ㎜㎜</td>
</tr>
<tr>
<td>TBLPTRH</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
</tr>
<tr>
<td>TBLPTRL</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
</tr>
<tr>
<td>TABLAT</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
</tr>
<tr>
<td>PRODH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
</tr>
<tr>
<td>PRODL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
</tr>
<tr>
<td>INTCON</td>
<td>2682 2685 4682 4685</td>
<td>0000 00×x</td>
<td>0000 000×</td>
<td>㎜㎜㎜ ㎜㎜㎜ ¹</td>
</tr>
<tr>
<td>INTCON2</td>
<td>2682 2685 4682 4685</td>
<td>1111 –1–1</td>
<td>1111 –1–1</td>
<td>㎜mmo ㎜mmo ¹</td>
</tr>
<tr>
<td>INTCON3</td>
<td>2682 2685 4682 4685</td>
<td>11–0 0–0–0</td>
<td>11–0 0–0–0</td>
<td>㎜mmo ㎜mmo ¹</td>
</tr>
<tr>
<td>INDF0</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>POSTINC0</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>POSTDEC0</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PREINC0</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLUSW0</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>FSR0H</td>
<td>2682 2685 4682 4685</td>
<td>---- 0000</td>
<td>---- 0000</td>
<td>---- ㎜㎜㎜</td>
</tr>
<tr>
<td>FSR0L</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>㎜㎜㎜ ㎜㎜㎜</td>
<td>㎜mmo ㎜mmo</td>
</tr>
<tr>
<td>WREG</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>㎜mmo ㎜mmo</td>
<td>㎜mmo ㎜mmo</td>
</tr>
<tr>
<td>INDF1</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>POSTINC1</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>POSTDEC1</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PREINC1</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLUSW1</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>FSR1H</td>
<td>2682 2685 4682 4685</td>
<td>---- 0000</td>
<td>---- 0000</td>
<td>---- ㎜mmo</td>
</tr>
<tr>
<td>FSR1L</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>㎜mmo ㎜mmo</td>
<td>㎜mmo ㎜mmo</td>
</tr>
</tbody>
</table>

**Legend:**
- \( u \) = unchanged,
- \( x \) = unknown,
- \( \sim \) = unimplemented bit, read as '0',
- \( q \) = value depends on condition.

**Shaded cells indicate conditions do not apply for the designated device.**

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.

6: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSR</td>
<td>2682 2685 4682 4685</td>
<td>----- 0000</td>
<td>---- 0000</td>
<td>---- uuuu</td>
</tr>
<tr>
<td>INDF2</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>POSTINC2</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>POSTDEC2</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PREINC2</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PLUSW2</td>
<td>2682 2685 4682 4685</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>FSR2H</td>
<td>2682 2685 4682 4685</td>
<td>----- 0000</td>
<td>---- 0000</td>
<td>---- uuuu</td>
</tr>
<tr>
<td>FSR2L</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>STATUS</td>
<td>2682 2685 4682 4685</td>
<td>---x xxxxx</td>
<td>----u uuuu</td>
<td>---- uuuu</td>
</tr>
<tr>
<td>TMR0H</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TMR0L</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>T0CON</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>OSCCON</td>
<td>2682 2685 4682 4685</td>
<td>0100 q000</td>
<td>0100 00q0</td>
<td>uuuu uuuu uuuu</td>
</tr>
<tr>
<td>HLVDCON</td>
<td>2682 2685 4682 4685</td>
<td>0-00 0101</td>
<td>0-00 0101</td>
<td>0-uu uuuu</td>
</tr>
<tr>
<td>WDTCON</td>
<td>2682 2685 4682 4685</td>
<td>----- -----0</td>
<td>----- -----0</td>
<td>---- ----u</td>
</tr>
<tr>
<td>RCON(4)</td>
<td>2682 2685 4682 4685</td>
<td>0q-1 11q0</td>
<td>0q-1 qqqq</td>
<td>uq-u qqqq</td>
</tr>
<tr>
<td>TMR1H</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TMR1L</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>T1CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>w0ww uuuu</td>
<td>w0ww uuuu</td>
</tr>
<tr>
<td>TMR2</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>PR2</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>1111 1111</td>
</tr>
<tr>
<td>T2CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>0000 0000</td>
</tr>
<tr>
<td>SSPBUF</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SSPADD</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SSPSTAT</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SSPCON1</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SSPCON2</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>ADRESH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>ADRESL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>ADCON0</td>
<td>2682 2685 4682 4685</td>
<td>--00 0000</td>
<td>--00 0000</td>
<td>--00 0000</td>
</tr>
<tr>
<td>ADCON1</td>
<td>2682 2685 4682 4685</td>
<td>--00 0000</td>
<td>--00 0000</td>
<td>--00 0000</td>
</tr>
</tbody>
</table>

**Legend:**
- **u** = unchanged, **x** = unknown, **-** = unimplemented bit, read as '0', **q** = value depends on condition.
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

**2:** When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

**3:** When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

**4:** See Table 4-3 for Reset value for specific condition.

**5:** Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.

**6:** This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADCON2</td>
<td>2682 2685 4682 4685</td>
<td>0-00 0000</td>
<td>0-00 0000</td>
<td>uu-uu uuuuu</td>
</tr>
<tr>
<td>CCP1H</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx xxxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>CCP1L</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx xxxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>CCP1CON</td>
<td>2682 2685 4682 4685</td>
<td>--00 0000</td>
<td>--00 0000</td>
<td>--uu uuuu</td>
</tr>
<tr>
<td>ECCPR1H</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx xxxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>ECCPR1L</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx xxxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>ECCP1CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>2682 2685 4682 4685</td>
<td>01-0 0-00</td>
<td>01-0 0-00</td>
<td>--uu uuuu</td>
</tr>
<tr>
<td>ECCP1DEL</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>ECCP1AS</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>CVRCON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>CMCON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TMR3H</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx xxxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TMR3L</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx xxxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>T3CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SPBRG</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RCREG</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXREG</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXSTA</td>
<td>2682 2685 4682 4685</td>
<td>0000 000x</td>
<td>0000 000x</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RCSTA</td>
<td>2682 2685 4682 4685</td>
<td>0000 000x</td>
<td>0000 000x</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>EEADRH</td>
<td>2682 2685 4682 4685</td>
<td>---- --0x</td>
<td>---- --0x</td>
<td>---- --uu</td>
</tr>
<tr>
<td>EEADR</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>EEDATA</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>EECON2</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>EECON1</td>
<td>2682 2685 4682 4685</td>
<td>xx-0 x000</td>
<td>uu-0 u000</td>
<td>uu-0 u000</td>
</tr>
<tr>
<td>IPR3</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>PIE3</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>IPR2</td>
<td>2682 2685 4682 4685</td>
<td>1-1 1 1111</td>
<td>1-1 1 1111</td>
<td>uu-u uuuu</td>
</tr>
</tbody>
</table>

**Legend:**  
- u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition.  
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.

6: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
#### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIR2</td>
<td>2682 2685 4682 4685</td>
<td>00-0 0000</td>
<td>00-0 0000</td>
<td>uu-u uu-u (1)</td>
</tr>
<tr>
<td></td>
<td>2682 2685 4682 4685</td>
<td>0--0 000-</td>
<td>0--0 000-</td>
<td>uu-u uu- uu-</td>
</tr>
<tr>
<td>PIE2</td>
<td>2682 2685 4682 4685</td>
<td>00-0 0000</td>
<td>00-0 0000</td>
<td>uu-u uu- uu-</td>
</tr>
<tr>
<td></td>
<td>2682 2685 4682 4685</td>
<td>0--0 000-</td>
<td>0--0 000-</td>
<td>uu-u uu- uu-</td>
</tr>
<tr>
<td>IPR1</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>uu-u uu-u uu-</td>
</tr>
<tr>
<td></td>
<td>2682 2685 4682 4685</td>
<td>-111 1111</td>
<td>-111 1111</td>
<td>uu-uu uu- uu-</td>
</tr>
<tr>
<td>PIR1</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uu-u uu-u uu-</td>
</tr>
<tr>
<td></td>
<td>2682 2685 4682 4685</td>
<td>-000 0000</td>
<td>-000 0000</td>
<td>uu-uu uu- uu-</td>
</tr>
<tr>
<td>PIE1</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uu-u uu-u uu-</td>
</tr>
<tr>
<td></td>
<td>2682 2685 4682 4685</td>
<td>-000 0000</td>
<td>-000 0000</td>
<td>uu-uu uu- uu-</td>
</tr>
<tr>
<td>OSCTUNE</td>
<td>2682 2685 4682 4685</td>
<td>0q-0 0000</td>
<td>0q-0 0000</td>
<td>uu-u uu- uu- uu-</td>
</tr>
<tr>
<td>TRISE</td>
<td>2682 2685 4682 4685</td>
<td>0000 -111</td>
<td>0000 -111</td>
<td>uu-u uu- uu-</td>
</tr>
<tr>
<td>TRISD</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>uu-u uu-u uu-</td>
</tr>
<tr>
<td>TRISC</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>uu-u uu-u uu-</td>
</tr>
<tr>
<td>TRISB</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111</td>
<td>1111 1111</td>
<td>uu-u uu-u uu-</td>
</tr>
<tr>
<td>TRISA(5)</td>
<td>2682 2685 4682 4685</td>
<td>1111 1111(5)</td>
<td>1111 1111(5)</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>LATE</td>
<td>2682 2685 4682 4685</td>
<td>---- -xxx</td>
<td>---- -uuu</td>
<td>---- -uuu</td>
</tr>
<tr>
<td>LATD</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uu-u uu-u</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>LATC</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uu-u uu-u</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>LATB</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uu-u uu-u</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>LATA(5)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx(5)</td>
<td>uu-u uu-u uu-u(5)</td>
<td>uu-u uu-u uu- uu- uu-</td>
</tr>
<tr>
<td>PORTE</td>
<td>2682 2685 4682 4685</td>
<td>---- x000</td>
<td>---- x000</td>
<td>---- -uuu</td>
</tr>
<tr>
<td>PORTD</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uu-u uu-u</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>PORTC</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uu-u uu-u</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>PORTB</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uu-u uu-u</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>PORTA(5)</td>
<td>2682 2685 4682 4685</td>
<td>xx0x 0000(5)</td>
<td>uu0u 0000(5)</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>ECANCON</td>
<td>2682 2685 4682 4685</td>
<td>0001 0000</td>
<td>0001 0000</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>TXERRCNT</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>RXERRCNT</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>COMSTAT</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uu-u uu-u uu- uu-</td>
</tr>
<tr>
<td>CIOCON</td>
<td>2682 2685 4682 4685</td>
<td>--00 ----</td>
<td>--00 ----</td>
<td>---- uu- uu- uu-</td>
</tr>
</tbody>
</table>

Legend: 
- u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition.

Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.

6: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRGCON3</td>
<td>2682 2685 4682 4685</td>
<td>00-- -000</td>
<td>00-- -000</td>
<td>uu-- -uuu</td>
</tr>
<tr>
<td>BRGCON2</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>BRGCON1</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>CANCON</td>
<td>2682 2685 4682 4685</td>
<td>1000 000--</td>
<td>1000 000--</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>CANSTAT</td>
<td>2682 2685 4682 4685</td>
<td>100-- 000--</td>
<td>100-- 000--</td>
<td>uu-- uu--</td>
</tr>
<tr>
<td>RXB0D7</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D6</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D5</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D4</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D3</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D2</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D1</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0D0</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0DLC</td>
<td>2682 2685 4682 4685</td>
<td>-xxxxx</td>
<td>-xxxxx</td>
<td>-uuu uuu</td>
</tr>
<tr>
<td>RXB0EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx *-xx</td>
<td>xxxxxxx u-uu</td>
<td>uuuu u-uuu</td>
</tr>
<tr>
<td>RXB0SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB0CON</td>
<td>2682 2685 4682 4685</td>
<td>000- 0000</td>
<td>000- 0000</td>
<td>uu- uuuu</td>
</tr>
<tr>
<td>RXB1D7</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D6</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D5</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D4</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D3</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D2</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D1</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1D0</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1DLC</td>
<td>2682 2685 4682 4685</td>
<td>-xxxxx</td>
<td>-xxxxx</td>
<td>-uuu uuu</td>
</tr>
<tr>
<td>RXB1EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx</td>
<td>xxxxxxx</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxxxx *-xx</td>
<td>xxxxxxx u-uu</td>
<td>uuuu u-uuu</td>
</tr>
</tbody>
</table>

**Legend:**  
- \( u \) = unchanged,  \( x \) = unknown,  \( - \) = unimplemented bit, read as ‘0’,  \( q \) = value depends on condition.  
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read ‘0’.

6: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXB1SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXB1CON</td>
<td>2682 2685 4682 4685</td>
<td>000- 0000</td>
<td>000- 0000</td>
<td>uuuu- uuuu</td>
</tr>
<tr>
<td>TXB0D7</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D6</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D5</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D4</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D3</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D2</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D1</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0D0</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0DLC</td>
<td>2682 2685 4682 4685</td>
<td>-x-- xxxxx</td>
<td>-u-- uuuu</td>
<td>-u-- uuuu</td>
</tr>
<tr>
<td>TXB0EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxx- x-xx</td>
<td>uuuu- uu-u</td>
<td>uuuu- uu-u</td>
</tr>
<tr>
<td>TXB0SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB0CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0-00</td>
<td>0000 0-00</td>
<td>uuuu- uu-u</td>
</tr>
<tr>
<td>TXB1D7</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D6</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D5</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D4</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D3</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D2</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D1</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1D0</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1DLC</td>
<td>2682 2685 4682 4685</td>
<td>-x-- xxxxx</td>
<td>-u-- uuuu</td>
<td>-u-- uuuu</td>
</tr>
<tr>
<td>TXB1EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxx- x-xx</td>
<td>uuuu- uu-u</td>
<td>uuuu- uu-u</td>
</tr>
<tr>
<td>TXB1SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXB1CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0-00</td>
<td>0000 0-00</td>
<td>uuuu- uu-u</td>
</tr>
<tr>
<td>TXB2D7</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>00uuuu</td>
</tr>
</tbody>
</table>

**Legend:**  
- u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition.  
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read ‘0’.

6: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXB2D6</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2D5</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2D4</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2D3</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2D2</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2D1</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2D0</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>0uuuu uuuuu</td>
</tr>
<tr>
<td>TXB2DLC</td>
<td>2682 2685 4682 4685</td>
<td>-x-- xxxx</td>
<td>-u-- uuuu uuuu</td>
<td>-u-- uuuu uuuu</td>
</tr>
<tr>
<td>TXB2EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>TXB2EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>TXB2SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxx-</td>
<td>uu-uu uuuu uu-uu</td>
<td>uu-uu uuuu uu-uu</td>
</tr>
<tr>
<td>TXB2SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxx-</td>
<td>uu-uu uuuu uu-uu</td>
<td>uu-uu uuuu uu-uu</td>
</tr>
<tr>
<td>TXB2CON</td>
<td>2682 2685 4682 4685</td>
<td>0000 0-00</td>
<td>0000 0-00</td>
<td>uu-uu uuuu uu-uu</td>
</tr>
<tr>
<td>RXM1EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXM1EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXM1SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXM1SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXM0EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXM0EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXM0SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXM0SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXF5EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXF5EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXF5SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXF5SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXF4EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXF4EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXF4SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXF4SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uu-uu uu-uu uu-uu</td>
<td>uu-uu uu-uu uu-uu</td>
</tr>
<tr>
<td>RXF3EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
<tr>
<td>RXF3EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuuu uuuuu</td>
<td>uuuuu uuuuu</td>
</tr>
</tbody>
</table>

**Legend:**  
- u = unchanged, x = unknown, - = unimplemented bit, read as ‘0’, q = value depends on condition.  
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

- **Note 2:** When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).
- **Note 3:** When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.
- **Note 4:** See Table 4-3 for Reset value for specific condition.
- **Note 5:** Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read ‘0’.
- **Note 6:** Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read ‘0’.

Shaded cells indicate conditions do not apply for the designated device.
<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXF3SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuu- u-uu</td>
<td>uuu- u-uu</td>
</tr>
<tr>
<td>RXF3SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF2EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF2EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF2SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuu- u-uu</td>
<td>uuu- u-uu</td>
</tr>
<tr>
<td>RXF2SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF1EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF1EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF1SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuu- u-uu</td>
<td>uuu- u-uu</td>
</tr>
<tr>
<td>RXF1SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF0EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF0EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF0SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF0SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D7(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D6(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D5(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D4(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D3(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D2(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D1(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5D0(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5DLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>-xxx- xxxxxx</td>
<td>-uuu uuuu</td>
<td>-uuu uuuu</td>
</tr>
<tr>
<td>B5EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx- x-xx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B5CON(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B4D7(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B4D6(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B4D5(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxx</td>
<td>uuuu uuu</td>
<td>uuuu uuuu</td>
</tr>
</tbody>
</table>

Legend: u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition. Shaded cells indicate conditions do not apply for the designated device.

Note 1: One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).
2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).
3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.
4: See Table 4-3 for Reset value for specific condition.
5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.
6: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
## TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>B4D4(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4D3(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4D2(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4D1(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4D0(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4DLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B4CON(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D7(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D6(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D5(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D4(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D3(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D2(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D1(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3D0(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3DLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B3CON(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B2D7(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B2D6(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B2D5(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B2D4(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B2D3(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
<tr>
<td>B2D2(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>xxxxxxx xxxxx</td>
<td>xxxxxxx xxxxx</td>
</tr>
</tbody>
</table>

**Legend:**  
- **u** = unchanged,  
- **x** = unknown,  
- **-** = unimplemented bit, read as ’0’,  
- **q** = value depends on condition.  
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read ’0’.

6: This register reads all ’0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2D1(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B2D0(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B2DLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>¬xxx xxxxx</td>
<td>¬uuu uuuu</td>
<td>¬uuu uuuu</td>
</tr>
<tr>
<td>B2EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B2EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B2SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B2SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B2CON(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D7(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D6(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D5(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D4(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D3(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D2(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D1(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1D0(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1DLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>¬xxx xxxxx</td>
<td>¬uuu uuuu</td>
<td>¬uuu uuuu</td>
</tr>
<tr>
<td>B1EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx x-xx</td>
<td>uuuu u-uu</td>
<td>uuuu u-uu</td>
</tr>
<tr>
<td>B1SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B1CON(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D7(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D6(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D5(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D4(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D3(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D2(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D1(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0D0(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxxx xxxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0DLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>¬xxx xxxxx</td>
<td>¬uuu uuuu</td>
<td>¬uuu uuuu</td>
</tr>
</tbody>
</table>

**Legend:**
- u = unchanged, x = unknown, ¬ = unimplemented bit, read as '0', q = value depends on condition.
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:**
One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0118h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.

6: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx x-xx</td>
<td>uuuu u-uu</td>
<td>uuuu u-uu</td>
</tr>
<tr>
<td>B0SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>B0CON(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>TXBIE(6)</td>
<td>2682 2685 4682 4685</td>
<td>---0 00--</td>
<td>---u uu--</td>
<td>---u uu--</td>
</tr>
<tr>
<td>BIEO(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>BSELO(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 00--</td>
<td>0000 00--</td>
<td>uuuu uu--</td>
</tr>
<tr>
<td>MSEL3(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>MSEL2(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>MSEL1(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0101</td>
<td>0000 0101</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>MSEL0(6)</td>
<td>2682 2685 4682 4685</td>
<td>0101 0000</td>
<td>0101 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>SDFLC(6)</td>
<td>2682 2685 4682 4685</td>
<td>---0 0000</td>
<td>---0 0000</td>
<td>---u uuuu</td>
</tr>
<tr>
<td>RXFCON1(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFCON0(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON7(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON6(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON5(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON4(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON3(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON2(6)</td>
<td>2682 2685 4682 4685</td>
<td>0001 0001</td>
<td>0001 0001</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON1(6)</td>
<td>2682 2685 4682 4685</td>
<td>0001 0001</td>
<td>0001 0001</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXFBCON0(6)</td>
<td>2682 2685 4682 4685</td>
<td>0000 0000</td>
<td>0000 0000</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF15EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF15EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF15SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF15SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF14EIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF14EIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF14SIDL(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF14SIDH(6)</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
</tbody>
</table>

**Legend:**  
* u = unchanged, x = unknown, - = unimplemented bit, read as '0', q = value depends on condition.  
Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2. When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3. When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4. See Table 4-3 for Reset value for specific condition.

5. Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read '0'.

6. This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
### TABLE 4-4: INITIALIZATION CONDITIONS FOR ALL REGISTERS (CONTINUED)

<table>
<thead>
<tr>
<th>Register</th>
<th>Applicable Devices</th>
<th>Power-on Reset, Brown-out Reset</th>
<th>MCLR Resets, WDT Reset, RESET Instruction, Stack Resets</th>
<th>Wake-up via WDT or Interrupt</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXF13EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF13EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF13SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF13SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF12EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF12EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF12SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF12SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF11EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF11EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF11SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF11SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF10EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF10EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF10SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF10SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF9EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF9EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF9SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF9SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF8EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF8EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF8SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF8SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF7EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF7EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF7SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF7SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF6EIDL</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF6EIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
<tr>
<td>RXF6SIDL</td>
<td>2682 2685 4682 4685</td>
<td>xx.xx</td>
<td>uu~ uu</td>
<td>uu~ uu</td>
</tr>
<tr>
<td>RXF6SIDH</td>
<td>2682 2685 4682 4685</td>
<td>xxxx xxxx</td>
<td>uuuu uuuu</td>
<td>uuuu uuuu</td>
</tr>
</tbody>
</table>

**Legend:**
- u = unchanged, x = unknown, – = unimplemented bit, read as ‘0’, q = value depends on condition.
- Shaded cells indicate conditions do not apply for the designated device.

**Note 1:** One or more bits in the INTCONx or PIRx registers will be affected (to cause wake-up).

2: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the PC is loaded with the interrupt vector (0008h or 0018h).

3: When the wake-up is due to an interrupt and the GIEL or GIEH bit is set, the TOSU, TOSH and TOSL are updated with the current value of the PC. The STKPTR is modified to point to the next location in the hardware stack.

4: See Table 4-3 for Reset value for specific condition.

5: Bits 6 and 7 of PORTA, LATA and TRISA are enabled depending on the oscillator mode selected. When not enabled as PORTA pins, they are disabled and read ‘0’.

6: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
5.0 MEMORY ORGANIZATION

There are three types of memory in PIC18 Enhanced microcontroller devices:

- Program Memory
- Data RAM
- Data EEPROM

As Harvard architecture devices, the data and program memories use separate busses; this allows for concurrent access of the two memory spaces. The data EEPROM, for practical purposes, can be regarded as a peripheral device, since it is addressed and accessed through a set of control registers.

Additional detailed information on the operation of the Flash program memory is provided in Section 6.0 “Flash Program Memory”. Data EEPROM is discussed separately in Section 7.0 “Data EEPROM Memory”.

5.1 Program Memory Organization

PIC18 microcontrollers implement a 21-bit program counter, which is capable of addressing a 2-Mbyte program memory space. Accessing a location between the upper boundary of the physically implemented memory and the 2-Mbyte address will return all ‘0’s (a NOP instruction).

The PIC18F2682 and PIC18F4682 each have 80 Kbytes of Flash memory and can store up to 40,960 single-word instructions. The PIC18F2685 and PIC18F4685 each have 96 Kbytes of Flash memory and can store up to 49,152 single-word instructions.

PIC18 devices have two interrupt vectors. The Reset vector address is at 0000h and the interrupt vector addresses are at 0008h and 0018h.

The program memory maps for PIC18F2682/4682 and PIC18F2685/4685 devices are shown in Figure 5-1.
5.1.1 PROGRAM COUNTER

The Program Counter (PC) specifies the address of the instruction to fetch for execution. The PC is 21 bits wide and is contained in three separate 8-bit registers. The low byte, known as the PCL register, is both readable and writable. The high byte, or PCH register, contains the PC<15:8> bits; it is not directly readable or writable. Updates to the PCH register are performed through the PCLATH register. The upper byte is called PCU. This register contains the PC<20:16> bits; it is also not directly readable or writable. Updates to the PCU register are performed through the PCLATU register.

The contents of PCLATH and PCLATU are transferred to the program counter by any operation that writes to the PCL. Similarly, the upper two bytes of the program counter are transferred to PCLATH and PCLATU by an operation that reads PCL. This is useful for computed offsets to the PC (see Section 5.1.4.1 “Computed GOTO”).

The PC addresses bytes in the program memory. To prevent the PC from becoming misaligned with word instructions, the Least Significant bit of PCL is fixed to a value of '0'. The PC increments by 2 to address sequential instructions in the program memory.

The CALL, RCALL and GOTO program branch instructions write to the program counter by any operation that writes to the PCL. Similarly, the upper two bytes of the program counter are transferred to PCLATH and PCLATU by an operation that reads PCL. This is useful for computed offsets to the PC (see Section 5.1.4.1 “Computed GOTO”).

The Stack Pointer is initialized to '00000' after all Resets. There is no RAM associated with the location corresponding to a Stack Pointer value of '00000'; this is only a Reset value. Status bits indicate if the stack is full, has overflowed or has underflowed.

5.1.2 RETURN ADDRESS STACK

The return address stack allows any combination of up to 31 program calls and interrupts to occur. The PC is pushed onto the stack when a CALL, or RCALL instruction is executed, or an interrupt is Acknowledged. The PC value is pulled off the stack on a RETURN, RETLW or a RETFI instruction. PCLATH and PCLATU are not transferred to the program counter.

The CALL, RCALL and GOTO program branch instructions write to the program counter by any operation that writes to the PCL. Similarly, the upper two bytes of the program counter are transferred to PCLATH and PCLATU by an operation that reads PCL. This is useful for computed offsets to the PC (see Section 5.1.4.1 “Computed GOTO”).

The top of the return address stack (TOS) is readable and writable. A set of three registers, TOSU:TOSH:TOSL, holds the contents of the stack location pointed to by the STKPTR register (Figure 5-2). This allows users to implement a software stack if necessary. After a CALL, RCALL or interrupt, the software can read the pushed value by reading the TOSU:TOSH:TOSL registers. These values can be placed on a user defined software stack. At return time, the software can return these values to TOSU:TOSH:TOSL and do a return.

The user must disable the global interrupt enable bits while accessing the stack to prevent inadvertent stack corruption.
5.1.2.2 Return Stack Pointer (STKPTR)

The STKPTR register (Register 5-1) contains the Stack Pointer value, the STKFUL (Stack Full) status bit and the STKUNF (Stack Underflow) status bit. The value of the Stack Pointer can be 0 through 31. The Stack Pointer increments before values are pushed onto the stack and decrements after values are popped off the stack. On Reset, the Stack Pointer value will be zero. The user may read and write the Stack Pointer value. This feature can be used by a Real-Time Operating System (RTOS) for return stack maintenance.

After the PC is pushed onto the stack 31 times (without popping any values off the stack), the STKFUL bit is set. The STKFUL bit is cleared by software or by a POR.

The action that takes place when the stack becomes full depends on the state of the STVREN (Stack Overflow Reset Enable) Configuration bit. (Refer to Section 24.1 “Configuration Bits” for a description of the device Configuration bits.) If STVREN is set (default), the 31st push will push the (PC + 2) value onto the stack, set the STKFUL bit and reset the device. The STKFUL bit will remain set and the Stack Pointer will be set to zero.

If STVREN is cleared, the STKFUL bit will be set on the 31st push and the Stack Pointer will increment to 31. Any additional pushes will not overwrite the 31st push and STKPTR will remain at 31.

When the stack has been popped enough times to unload the stack, the next pop returns a value of zero to the PC and sets the STKUNF bit, while the Stack Pointer remains at zero. The STKUNF bit will remain set until cleared by software or until a POR occurs.

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>STKFUL</td>
<td>STKUNF</td>
<td>—</td>
<td>SP4 SP3 SP2 SP1 SP0</td>
</tr>
</tbody>
</table>

**Note:** Returning a value of zero to the PC on an underflow has the effect of vectoring the program to the Reset vector, where the stack conditions can be verified and appropriate actions can be taken. This is not the same as a Reset, as the contents of the SFRs are not affected.

5.1.2.3 PUSH and POP Instructions

Since the Top-of-Stack is readable and writable, the ability to push values onto the stack and pull values off the stack without disturbing normal program execution is a desirable feature. The PIC18 instruction set includes two instructions, PUSH and POP, that permit the TOS to be manipulated under software control. TOSU, TOSH and TOSL can be modified to place data or a return address on the stack.

The PUSH instruction places the current PC value onto the stack. This increments the Stack Pointer and loads the current PC value onto the stack.

The POP instruction discards the current TOS by decrementing the Stack Pointer. The previous value pushed onto the stack then becomes the TOS value.

**REGISTER 5-1: STKPTR: STACK POINTER REGISTER**

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C = Clearable bit</td>
<td>R = Readable bit</td>
<td>W = Writable bit</td>
<td>U = Unimplemented bit, read as '0'</td>
</tr>
<tr>
<td>-n = Value at POR</td>
<td>'1' = Bit is set</td>
<td>'0' = Bit is cleared</td>
<td>x = Bit is unknown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>STKFUL: Stack Full Flag bit(1)</td>
<td>STKUNF: Stack Underflow Flag bit(1)</td>
<td>Unimplemented: Read as '0'</td>
<td>SP4:SP0: Stack Pointer Location bits</td>
</tr>
</tbody>
</table>

**Note 1:** Bit 7 and bit 6 are cleared by user software or by a POR.
5.1.2.4 Stack Full and Underflow Resets
Device Resets on stack overflow and stack underflow conditions are enabled by setting the STVREN bit in Configuration Register 4L. When STVREN is set, a full or underflow condition will set the appropriate STKFUL or STKUNF bit and then cause a device Reset. When STVREN is cleared, a full or underflow condition will set the appropriate STKFUL or STKUNF bit, but not cause a device Reset. The STKFUL or STKUNF bit is cleared by user software or a Power-on Reset.

5.1.3 FAST REGISTER STACK
A Fast Register Stack is provided for the STATUS, WREG and BSR registers to provide a “fast return” option for interrupts. Each stack is only one level deep and is neither readable nor writable. It is loaded with the current value of the corresponding register when the processor vectors for an interrupt. All interrupt sources will push values into the stack registers. The values in the registers are then loaded back into their associated registers, if the RETFIE, FAST instruction is used to return from the interrupt.

If both low and high priority interrupts are enabled, the stack registers cannot be used reliably to return from low priority interrupts. If a high priority interrupt occurs while servicing a low priority interrupt, the stack register values stored by the low priority interrupt will be overwritten. In these cases, users must save the key registers in software during a low priority interrupt.

If interrupt priority is not used, all interrupts may use the Fast Register Stack for returns from interrupt. If no interrupts are used, the Fast Register Stack can be used to restore the STATUS, WREG and BSR registers at the end of a subroutine call. To use the Fast Register Stack for a subroutine call, a CALL label, FAST instruction must be executed to save the STATUS, WREG and BSR registers to the Fast Register Stack. A RETURN, FAST instruction is then executed to restore these registers from the Fast Register Stack.

Example 5-1 shows a source code example that uses the Fast Register Stack during a subroutine call and return.

```
EXAMPLE 5-1: FAST REGISTER STACK
CODE EXAMPLE

CALL SUB1, FAST ;STATUS, WREG, BSR
;SAVED IN FAST REGISTER
;STACK

SUB1

RETURN, FAST ;RESTORE VALUES SAVED
;IN FAST REGISTER STACK
```

5.1.4 LOOK-UP TABLES IN PROGRAM MEMORY
There may be programming situations that require the creation of data structures, or look-up tables, in program memory. For PIC18 devices, look-up tables can be implemented in two ways:

- **Computed GOTO**
- **Table Reads**

5.1.4.1 Computed GOTO
A computed GOTO is accomplished by adding an offset to the program counter. An example is shown in Example 5-2.

A look-up table can be formed with an ADDWF PCL instruction and a group of RETLW nn instructions. The W register is loaded with an offset into the table before executing a CALL to that table. The first instruction of the called routine is the ADDWF PCL instruction. The next instruction executed will be one of the RETLW nn instructions, that returns the value ‘nn’ to the calling function.

The offset value (in WREG) specifies the number of bytes that the program counter should advance and should be multiples of 2 (LSb = 0).

In this method, only one data byte may be stored in each instruction location and room on the return address stack is required.

```
EXAMPLE 5-2: COMPUTED GOTO USING AN OFFSET VALUE

MOVF OFFSET, W
CALL TABLE
ORG nn00h
TABLE ADDWF PCL
RETLW nnh
RETLW nnh
RETLW nnh
.
.
.
```

5.1.4.2 Table Reads and Table Writes
A better method of storing data in program memory allows two bytes of data to be stored in each instruction location.

Look-up table data may be stored two bytes per program word by using table reads and writes. The Table Pointer (TBLPTR) register specifies the byte address and the Table Latch (TABLAT) register contains the data that is read from or written to program memory. Data is transferred to or from program memory one byte at a time.

Table read and table write operations are discussed further in Section 6.1 “Table Reads and Table Writes”. 
5.2 PIC18 Instruction Cycle

5.2.1 CLOCKING SCHEME

The microcontroller clock input, whether from an internal or external source, is internally divided by four to generate four non-overlapping quadrature clocks (Q1, Q2, Q3 and Q4). Internally, the Program Counter (PC) is incremented on every Q1; the instruction is fetched from the program memory and latched into the Instruction Register (IR) during Q4. The instruction is decoded and executed during the following Q1 through Q4. The clocks and instruction execution flow are shown in Figure 5-3.

5.2.2 INSTRUCTION FLOW/PIPELINING

An “Instruction Cycle” consists of four Q cycles: Q1 through Q4. The instruction fetch and execute are pipelined in such a manner that a fetch takes one instruction cycle, while the decode and execute take another instruction cycle. However, due to the pipelining, each instruction effectively executes in one cycle. If an instruction causes the program counter to change (e.g., GOTO), then two cycles are required to complete the instruction (Example 5-3).

A fetch cycle begins with the program counter incrementing in Q1.

In the execution cycle, the fetched instruction is latched into the Instruction Register (IR) in cycle Q1. This instruction is then decoded and executed during the Q2, Q3 and Q4 cycles. Data memory is read during Q2 (operand read) and written during Q4 (destination write).

**FIGURE 5-3: CLOCK/INSTRUCTION CYCLE**

**EXAMPLE 5-3: INSTRUCTION PIPELINE FLOW**

<table>
<thead>
<tr>
<th>TCY0</th>
<th>TCY1</th>
<th>TCY2</th>
<th>TCY3</th>
<th>TCY4</th>
<th>TCY5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MOV LW 55h</td>
<td>Fetch 1</td>
<td>Execute 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. MOVWF PORTB</td>
<td>Fetch 2</td>
<td>Execute 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. BRA SUB_1</td>
<td>Fetch 3</td>
<td>Execute 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. BSF PORTA, BIT3 (Forced NOP)</td>
<td>Fetch 4</td>
<td>Flush (NOP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Instruction @ address SUB_1</td>
<td>Fetch SUB_1</td>
<td>Execute SUB_1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** All instructions are single cycle, except for any program branches. These take two cycles since the fetch instruction is “flushed” from the pipeline while the new instruction is being fetched and then executed.
5.2.3 INSTRUCTIONS IN PROGRAM MEMORY

The program memory is addressed in bytes. Instructions are stored as two bytes or four bytes in program memory. The Least Significant Byte of an instruction word is always stored in a program memory location with an even address (LSB = 0). To maintain alignment with instruction boundaries, the PC increments in steps of 2 and the LSB will always read ‘0’ (see Section 5.1.1 “Program Counter”).

Figure 5-4 shows an example of how instruction words are stored in the program memory.

The CALL and GOTO instructions have the absolute program memory address embedded into the instruction. Since instructions are always stored on word boundaries, the data contained in the instruction is a word address. The word address is written to PC<20:1>, which accesses the desired byte address in program memory. Instruction #2 in Figure 5-4 shows how the instruction GOTO 0006h is encoded in the program memory. Program branch instructions, which encode a relative address offset, operate in the same manner. The offset value stored in a branch instruction represents the number of single-word instructions that the PC will be offset by. Section 25.0 “Instruction Set Summary” provides further details of the instruction set.

FIGURE 5-4: INSTRUCTIONS IN PROGRAM MEMORY

<table>
<thead>
<tr>
<th>Program Memory Byte Locations</th>
<th>LSB = 1</th>
<th>LSB = 0</th>
<th>Word Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruction 1: MOVLMW 055h</td>
<td></td>
<td>000000h</td>
<td></td>
</tr>
<tr>
<td>Instruction 2: GOTO 0006h</td>
<td>000002h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instruction 3: MOVFF 123h, 456h</td>
<td>000004h</td>
<td>000006h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>000008h</td>
<td>00000Ah</td>
<td></td>
</tr>
<tr>
<td></td>
<td>00000Ch</td>
<td>000010h</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>000012h</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>000014h</td>
<td></td>
</tr>
</tbody>
</table>

5.2.4 TWO-WORD INSTRUCTIONS

The standard PIC18 instruction set has four two-word instructions: CALL, MOVFF, GOTO and LSFR. In all cases, the second word of the instructions always has ‘1111’ as its four Most Significant bits; the other 12 bits are literal data, usually a data memory address.

The use of ‘1111’ in the 4 MSbs of an instruction specifies a special form of NOP. If the instruction is executed in proper sequence – immediately after the first word – the data in the second word is accessed and used by the instruction sequence. If the first word is skipped for some reason and the second word is executed by itself, a NOP is executed instead. This is necessary for cases when the two-word instruction is preceded by a conditional instruction that changes the PC. Example 5-4 shows how this works.

<table>
<thead>
<tr>
<th>CASE 1:</th>
<th>TWO-WORD INSTRUCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object Code</td>
<td>Source Code</td>
</tr>
<tr>
<td>0110 0110 0000 0000</td>
<td>TSTFSZ REG1 ; is RAM location 0?</td>
</tr>
<tr>
<td>0110 0110 0010 0011</td>
<td>MOVFF REG1, REG2 ; No, skip this word</td>
</tr>
<tr>
<td>0100 0100 0101 0110</td>
<td>; Execute this word as a NOP</td>
</tr>
<tr>
<td>0010 0100 0000 0000</td>
<td>ADDWF REG3 ; continue code</td>
</tr>
</tbody>
</table>

| CASE 2: |
|---------|------------------------|
| Object Code | Source Code          |
| 0110 0110 0000 0000 | TSTFSZ REG1 ; is RAM location 0? |
| 0110 0110 0010 0011 | MOVFF REG1, REG2 ; Yes, execute this word |
| 0110 0110 0010 0110 | ; 2nd word of instruction |
| 0001 0100 0000 0000 | ADDWF REG3 ; continue code |

Note: See Section 5.5 “Program Memory and the Extended Instruction Set” for information on two-word instructions in the extended instruction set.
5.3 Data Memory Organization

The data memory in PIC18 devices is implemented as static RAM. Each register in the data memory has a 12-bit address, allowing up to 4096 bytes of data memory. The memory space is divided into as many as 16 banks that contain 256 bytes each; PIC18F2682/2685/4682/4685 devices implement all 16 banks. Figure 5-5 shows the data memory organization for the PIC18F2682/2685/4682/4685 devices.

The data memory contains Special Function Registers (SFRs) and General Purpose Registers (GPRs). The SFRs are used for control and status of the controller and peripheral functions, while GPRs are used for data storage and scratchpad operations in the user’s application. Any read of an unimplemented location will read as ’0’s.

The instruction set and architecture allow operations across all banks. The entire data memory may be accessed by Direct, Indirect or Indexed Addressing modes. Addressing modes are discussed later in this subsection.

To ensure that commonly used registers (SFRs and select GPRs) can be accessed in a single cycle, PIC18 devices implement an Access Bank. This is a 256-byte memory space that provides fast access to SFRs and the lower portion of GPR Bank 0 without using the BSR. Section 5.3.2 “Access Bank” provides a detailed description of the Access RAM.

5.3.1 BANK SELECT REGISTER (BSR)

Large areas of data memory require an efficient addressing scheme to make rapid access to any address possible. Ideally, this means that an entire address does not need to be provided for each read or write operation. For PIC18 devices, this is accomplished with a RAM banking scheme. This divides the memory space into 16 contiguous banks of 256 bytes. Depending on the instruction, each location can be addressed directly by its full 12-bit address, or an 8-bit low-order address and a 4-bit Bank Pointer.

Most instructions in the PIC18 instruction set make use of the Bank Pointer, known as the Bank Select Register (BSR). This SFR holds the 4 Most Significant bits of a location’s address; the instruction itself includes the 8 Least Significant bits. Only the four lower bits of the BSR are implemented (BSR3:BSR0). The upper four bits are unused; they will always read ’0’ and cannot be written to. The BSR can be loaded directly by using the MOVLB instruction.

The value of the BSR indicates the bank in data memory. The 8 bits in the instruction show the location in the bank and can be thought of as an offset from the bank’s lower boundary. The relationship between the BSR’s value and the bank division in data memory is shown in Figure 5-6.

Since up to 16 registers may share the same low-order address, the user must always be careful to ensure that the proper bank is selected before performing a data read or write. For example, writing what should be program data to an 8-bit address of F9h while the BSR is 0Fh, will end up resetting the program counter.

While any bank can be selected, only those banks that are actually implemented can be read or written to. Writes to unimplemented banks are ignored, while reads from unimplemented banks will return ’0’s. Even so, the STATUS register will still be affected as if the operation was successful. The data memory map in Figure 5-5 indicates which banks are implemented.

In the core PIC18 instruction set, only the MOVFF instruction fully specifies the 12-bit address of the source and target registers. This instruction ignores the BSR completely when it executes. All other instructions include only the low-order address as an operand and must use either the BSR or the Access Bank to locate their target registers.
FIGURE 5-5: DATA MEMORY MAP FOR PIC18F2682/2685/4682/4685 DEVICES

<table>
<thead>
<tr>
<th>BSR&lt;3:0&gt;</th>
<th>Data Memory Map</th>
<th>When a = 0:</th>
</tr>
</thead>
<tbody>
<tr>
<td>= 0000</td>
<td>Access RAM</td>
<td>The BSR is ignored and the Access Bank is used.</td>
</tr>
<tr>
<td></td>
<td>GPR</td>
<td>The first 128 bytes are general purpose RAM (from Bank 0).</td>
</tr>
<tr>
<td>= 0001</td>
<td>00h</td>
<td>The second 128 bytes are Special Function Registers (from Bank 15).</td>
</tr>
<tr>
<td></td>
<td>05Fh</td>
<td></td>
</tr>
<tr>
<td>= 0010</td>
<td>060h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0FFh</td>
<td></td>
</tr>
<tr>
<td>= 0011</td>
<td>100h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200h</td>
<td></td>
</tr>
<tr>
<td>= 0100</td>
<td>1FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300h</td>
<td></td>
</tr>
<tr>
<td>= 0101</td>
<td>2FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>400h</td>
<td></td>
</tr>
<tr>
<td>= 0110</td>
<td>3FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500h</td>
<td></td>
</tr>
<tr>
<td>= 0111</td>
<td>4FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>600h</td>
<td></td>
</tr>
<tr>
<td>= 1000</td>
<td>5FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700h</td>
<td></td>
</tr>
<tr>
<td>= 1001</td>
<td>6FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>800h</td>
<td></td>
</tr>
<tr>
<td>= 1010</td>
<td>7FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>900h</td>
<td></td>
</tr>
<tr>
<td>= 1011</td>
<td>8FFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A00h</td>
<td></td>
</tr>
<tr>
<td>= 1100</td>
<td>AFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B00h</td>
<td></td>
</tr>
<tr>
<td>= 1101</td>
<td>BFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C00h</td>
<td></td>
</tr>
<tr>
<td>= 1110</td>
<td>CFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D00h</td>
<td></td>
</tr>
<tr>
<td>= 1111</td>
<td>DFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E00h</td>
<td></td>
</tr>
<tr>
<td>= 1111</td>
<td>EFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F00h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F6Fh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FFh</td>
<td></td>
</tr>
</tbody>
</table>

When a = 1:
The BSR specifies the Bank used by the instruction.
5.3.2 ACCESS BANK

While the use of the BSR with an embedded 8-bit address allows users to address the entire range of data memory, it also means that the user must always ensure that the correct bank is selected. Otherwise, data may be read from or written to the wrong location. This can be disastrous if a GPR is the intended target of an operation, but an SFR is written to instead. Verifying and/or changing the BSR for each read or write to data memory can become very inefficient.

To streamline access for the most commonly used data memory locations, the data memory is configured with an Access Bank, which allows users to access a mapped block of memory without specifying a BSR. The Access Bank consists of the first 128 bytes of memory (00h-7Fh) in Bank 0 and the last 128 bytes of memory (80h-FFh) in Block 15. The lower half is known as the “Access RAM” and is composed of GPRs. The upper half is where the device’s SFRs are mapped. These two areas are mapped contiguously in the Access Bank and can be addressed in a linear fashion by an 8-bit address (Figure 5-5).

The Access Bank is used by core PIC18 instructions that include the Access RAM bit (the ‘a’ parameter in the instruction). When ‘a’ is equal to ‘1’, the instruction uses the BSR and the 8-bit address included in the opcode for the data memory address. When ‘a’ is ‘0’ however, the instruction is forced to use the Access Bank address map; the current value of the BSR is ignored entirely.

Using this “forced” addressing allows the instruction to operate on a data address in a single cycle, without updating the BSR first. For 8-bit addresses of 80h and above, this means that users can evaluate and operate on SFRs more efficiently. The Access RAM below 80h is a good place for data values that the user might need to access rapidly, such as immediate computational results or common program variables. Access RAM also allows for faster and more code efficient context saving and switching of variables.

The mapping of the Access Bank is slightly different when the extended instruction set is enabled (XINST Configuration bit = 1). This is discussed in more detail in Section 5.6.3 “Mapping the Access Bank in Indexed Literal Offset Mode”.

5.3.3 GENERAL PURPOSE REGISTER FILE

PIC18 devices may have banked memory in the GPR area. This is data RAM, which is available for use by all instructions. GPRs start at the bottom of Bank 0 (address 000h) and grow upwards towards the bottom of the SFR area. GPRs are not initialized by a Power-on Reset and are unchanged on all other Resets.
5.3.4 SPECIAL FUNCTION REGISTERS

The Special Function Registers (SFRs) are registers used by the CPU and peripheral modules for controlling the desired operation of the device. These registers are implemented as static RAM. SFRs start at the top of data memory (FFFh) and extend downward to occupy the top half of Bank 15 (F80h to FFFh). A list of these registers is given in Table 5-1 and Table 5-2.

The SFRs can be classified into two sets: those associated with the “core” device functionality (ALU, Resets and interrupts) and those related to the peripheral functions. The reset and interrupt registers are described in their respective chapters, while the ALU’s STATUS register is described later in this section. Registers related to the operation of a peripheral feature are described in the chapter for that peripheral.

The SFRs are typically distributed among the peripherals whose functions they control. Unused SFR locations are unimplemented and read as ‘0’s. 

### TABLE 5-1: SPECIAL FUNCTION REGISTER MAP FOR PIC18F2682/2685/4682/4685 DEVICES

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFFh</td>
<td>TOSU</td>
<td>0</td>
<td>INDF2</td>
<td>FBh</td>
<td>CCPR1H</td>
<td>F9h</td>
<td>IPR1</td>
</tr>
<tr>
<td>FFEh</td>
<td>TOSH</td>
<td>0</td>
<td>POSTINC2</td>
<td>FBh</td>
<td>CCP1L</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FFDh</td>
<td>TOSL</td>
<td>0</td>
<td>POSTDEC2</td>
<td>0</td>
<td>CCP1CON</td>
<td>0</td>
<td>PIE1</td>
</tr>
<tr>
<td>FFCh</td>
<td>STKPTR</td>
<td>0</td>
<td>PREINC2</td>
<td>FCb</td>
<td>ECPP1H1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FFBh</td>
<td>PCLATU</td>
<td>0</td>
<td>PLUSW2</td>
<td>FABh</td>
<td>ECPP1L1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FFAh</td>
<td>PCLATH</td>
<td>0</td>
<td>FSR2H</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99h</td>
<td>PCL</td>
<td>0</td>
<td>FSR2L</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F98h</td>
<td>TBLPTRU</td>
<td>0</td>
<td>STATUS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>BAUDCON</td>
</tr>
<tr>
<td>F97h</td>
<td>TBLPTRH</td>
<td>0</td>
<td>TMR0H</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ECPP1DEL</td>
</tr>
<tr>
<td>F96h</td>
<td>TBLPTRL</td>
<td>0</td>
<td>TMR0L</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>F97h</td>
</tr>
<tr>
<td>F95h</td>
<td>TBLAT</td>
<td>0</td>
<td>T0CON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F94h</td>
<td>PRODH</td>
<td>0</td>
<td>OSCCON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F93h</td>
<td>PRODL</td>
<td>0</td>
<td>—</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F92h</td>
<td>INTCON</td>
<td>0</td>
<td>WDTCON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F91h</td>
<td>INTCON2</td>
<td>0</td>
<td>LDCON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F90h</td>
<td>INTCON3</td>
<td>0</td>
<td>RCON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99f</td>
<td>INDF0</td>
<td>0</td>
<td>TMR1H</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99e</td>
<td>POSTINC0</td>
<td>0</td>
<td>TMR1L</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99d</td>
<td>POSTDEC0</td>
<td>0</td>
<td>T1CON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99c</td>
<td>PREINC0</td>
<td>0</td>
<td>TMR2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99b</td>
<td>PLUSW0</td>
<td>0</td>
<td>PR2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99a</td>
<td>FSR0H</td>
<td>0</td>
<td>T2CON</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F99h</td>
<td>FSR0L</td>
<td>0</td>
<td>SSPBUF</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F98h</td>
<td>WREG</td>
<td>0</td>
<td>SSPADD</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F97h</td>
<td>INDF1</td>
<td>0</td>
<td>SSPSTAT</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F96h</td>
<td>POSTINC1</td>
<td>0</td>
<td>SSPCON1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F95h</td>
<td>POSTDEC1</td>
<td>0</td>
<td>SSPCON2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F94h</td>
<td>PREINC1</td>
<td>0</td>
<td>ADRESH</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F93h</td>
<td>PLUSW1</td>
<td>0</td>
<td>ADRESL</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F92h</td>
<td>FSR1H</td>
<td>0</td>
<td>ADCON0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F91h</td>
<td>FSR1L</td>
<td>0</td>
<td>ADCON1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F90h</td>
<td>BSR</td>
<td>0</td>
<td>ADCON2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note 1:** Registers available only on PIC18F4XX8X devices; otherwise, the registers read as ‘0’.

**Note 2:** When any TX_ENn bit in RX_TX_SELn is set, then the corresponding bit in this register has transmit properties.

**Note 3:** This is not a physical register.
### TABLE 5-1: SPECIAL FUNCTION REGISTER MAP FOR PIC18F2682/2685/4682/4685 DEVICES (CONTINUED)

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>F7Fh</td>
<td>—</td>
<td>F5Fh</td>
<td>CANCON_RO0</td>
<td>F3Fh</td>
<td>CANCON_RO2</td>
<td>F1Fh</td>
<td>RXM1EIDL</td>
</tr>
<tr>
<td>F7Eh</td>
<td>—</td>
<td>F5Eh</td>
<td>CANSTAT_RO0</td>
<td>F3Eh</td>
<td>CANSTAT_RO2</td>
<td>F1Eh</td>
<td>RXM1EIDH</td>
</tr>
<tr>
<td>F7Dh</td>
<td>—</td>
<td>F5Dh</td>
<td>RXB1D7</td>
<td>F3Dh</td>
<td>TXB1D7</td>
<td>F1Dh</td>
<td>RXM1SIDL</td>
</tr>
<tr>
<td>F7Ch</td>
<td>—</td>
<td>F5Ch</td>
<td>RXB1D6</td>
<td>F3Ch</td>
<td>TXB1D6</td>
<td>F1Ch</td>
<td>RXM1SIDH</td>
</tr>
<tr>
<td>F7Bh</td>
<td>—</td>
<td>F5Bh</td>
<td>RXB1D5</td>
<td>F3Bh</td>
<td>TXB1D5</td>
<td>F1Bh</td>
<td>RXM0EIDL</td>
</tr>
<tr>
<td>F7Ah</td>
<td>—</td>
<td>F5Ah</td>
<td>RXB1D4</td>
<td>F3Ah</td>
<td>TXB1D4</td>
<td>F1Ah</td>
<td>RXM0EIDH</td>
</tr>
<tr>
<td>F79h</td>
<td>—</td>
<td>F59h</td>
<td>RXB1D3</td>
<td>F39h</td>
<td>TXB1D3</td>
<td>F19h</td>
<td>RXM0SIDL</td>
</tr>
<tr>
<td>F78h</td>
<td>—</td>
<td>F58h</td>
<td>RXB1D2</td>
<td>F38h</td>
<td>TXB1D2</td>
<td>F18h</td>
<td>RXM0SIDH</td>
</tr>
<tr>
<td>F77h</td>
<td>ECANCON</td>
<td>F57h</td>
<td>RXB1D1</td>
<td>F37h</td>
<td>TXB1D1</td>
<td>F17h</td>
<td>RXF5EIDL</td>
</tr>
<tr>
<td>F76h</td>
<td>TXERRCNT</td>
<td>F56h</td>
<td>RXB1D0</td>
<td>F36h</td>
<td>TXB1D0</td>
<td>F16h</td>
<td>RXF5EIDH</td>
</tr>
<tr>
<td>F75h</td>
<td>RXERRCNT</td>
<td>F55h</td>
<td>RXB1DLC</td>
<td>F35h</td>
<td>TXB1DLC</td>
<td>F15h</td>
<td>RXFSIDL</td>
</tr>
<tr>
<td>F74h</td>
<td>COMSTAT</td>
<td>F54h</td>
<td>RXB1EIDL</td>
<td>F34h</td>
<td>TXB1EIDL</td>
<td>F14h</td>
<td>RXFSIDH</td>
</tr>
<tr>
<td>F73h</td>
<td>CIOCON</td>
<td>F53h</td>
<td>RXB1EIDH</td>
<td>F33h</td>
<td>TXB1EIDH</td>
<td>F13h</td>
<td>RXF4EIDL</td>
</tr>
<tr>
<td>F72h</td>
<td>BRGCON3</td>
<td>F52h</td>
<td>RXB1SIDL</td>
<td>F32h</td>
<td>TXB1SIDL</td>
<td>F12h</td>
<td>RXF4EIDH</td>
</tr>
<tr>
<td>F71h</td>
<td>BRGCON2</td>
<td>F51h</td>
<td>RXB1SIDH</td>
<td>F31h</td>
<td>TXB1SIDH</td>
<td>F11h</td>
<td>RXFSIDL</td>
</tr>
<tr>
<td>F70h</td>
<td>BRGCON1</td>
<td>F50h</td>
<td>RXB1CON</td>
<td>F30h</td>
<td>TXB1CON</td>
<td>F10h</td>
<td>RXFSIDH</td>
</tr>
<tr>
<td>F6Fh</td>
<td>CANCON</td>
<td>F4Fh</td>
<td>CANCON RO1</td>
<td>F2Fh</td>
<td>CANCON RO3</td>
<td>F0Fh</td>
<td>RXF3EIDL</td>
</tr>
<tr>
<td>F6Eh</td>
<td>CANSTAT</td>
<td>F4Eh</td>
<td>CANSTAT RO1</td>
<td>F2Eh</td>
<td>CANSTAT RO3</td>
<td>F0Eh</td>
<td>RXF3EIDH</td>
</tr>
<tr>
<td>F6Dh</td>
<td>RXB0D7</td>
<td>F4Dh</td>
<td>TXB0D7</td>
<td>F2Dh</td>
<td>TXB2D7</td>
<td>F0Dh</td>
<td>RXFSIDL</td>
</tr>
<tr>
<td>F6Ch</td>
<td>RXB0D6</td>
<td>F4Ch</td>
<td>TXB0D6</td>
<td>F2Ch</td>
<td>TXB2D6</td>
<td>F0Ch</td>
<td>RXFSIDH</td>
</tr>
<tr>
<td>F6Bh</td>
<td>RXB0D5</td>
<td>F4Bh</td>
<td>TXB0D5</td>
<td>F2Bh</td>
<td>TXB2D5</td>
<td>F0Bh</td>
<td>RXF2EIDL</td>
</tr>
<tr>
<td>F6Ah</td>
<td>RXB0D4</td>
<td>F4Ah</td>
<td>TXB0D4</td>
<td>F2Ah</td>
<td>TXB2D4</td>
<td>F0Ah</td>
<td>RXF2EIDH</td>
</tr>
<tr>
<td>F69h</td>
<td>RXB0D3</td>
<td>F49h</td>
<td>TXB0D3</td>
<td>F29h</td>
<td>TXB2D3</td>
<td>F09h</td>
<td>RXF2SIDL</td>
</tr>
<tr>
<td>F68h</td>
<td>RXB0D2</td>
<td>F48h</td>
<td>TXB0D2</td>
<td>F28h</td>
<td>TXB2D2</td>
<td>F08h</td>
<td>RXF2SIDH</td>
</tr>
<tr>
<td>F67h</td>
<td>RXB0D1</td>
<td>F47h</td>
<td>TXB0D1</td>
<td>F27h</td>
<td>TXB2D1</td>
<td>F07h</td>
<td>RXF1EIDL</td>
</tr>
<tr>
<td>F66h</td>
<td>RXB0D0</td>
<td>F46h</td>
<td>TXB0D0</td>
<td>F26h</td>
<td>TXB2D0</td>
<td>F06h</td>
<td>RXF1EIDH</td>
</tr>
<tr>
<td>F65h</td>
<td>RXB0DLC</td>
<td>F45h</td>
<td>TXB0DLC</td>
<td>F25h</td>
<td>TXB2DLC</td>
<td>F05h</td>
<td>RXF1SIDL</td>
</tr>
<tr>
<td>F64h</td>
<td>RXB0EIDL</td>
<td>F44h</td>
<td>TXB0EIDL</td>
<td>F24h</td>
<td>TXB2EIDL</td>
<td>F04h</td>
<td>RXF1SIDH</td>
</tr>
<tr>
<td>F63h</td>
<td>RXB0EIDH</td>
<td>F43h</td>
<td>TXB0EIDH</td>
<td>F23h</td>
<td>TXB2EIDH</td>
<td>F03h</td>
<td>RXF0EIDL</td>
</tr>
<tr>
<td>F62h</td>
<td>RXB0SIDL</td>
<td>F42h</td>
<td>TXB0SIDL</td>
<td>F22h</td>
<td>TXB2SIDL</td>
<td>F02h</td>
<td>RXF0EIDH</td>
</tr>
<tr>
<td>F61h</td>
<td>RXB0SIDH</td>
<td>F41h</td>
<td>TXB0SIDH</td>
<td>F21h</td>
<td>TXB2SIDH</td>
<td>F01h</td>
<td>RXF0SIDL</td>
</tr>
<tr>
<td>F60h</td>
<td>RXB0CON</td>
<td>F40h</td>
<td>TXB0CON</td>
<td>F20h</td>
<td>TXB2CON</td>
<td>F00h</td>
<td>RXF0SIDH</td>
</tr>
</tbody>
</table>

**Note:**
1. Registers available only on PIC18F4X8X devices; otherwise, the registers read as ‘0’.
2. When any TX_ENn bit in RX_TX_SELn is set, then the corresponding bit in this register has transmit properties.
3. This is not a physical register.
<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFFh</td>
<td>—</td>
<td>EDFh</td>
<td>—</td>
<td>EBFh</td>
<td>—</td>
<td>E9Fh</td>
<td>—</td>
</tr>
<tr>
<td>EFEh</td>
<td>—</td>
<td>EDEh</td>
<td>—</td>
<td>EBEh</td>
<td>—</td>
<td>E9Eh</td>
<td>—</td>
</tr>
<tr>
<td>EFDh</td>
<td>—</td>
<td>EDDh</td>
<td>—</td>
<td>EBDh</td>
<td>—</td>
<td>E9Dh</td>
<td>—</td>
</tr>
<tr>
<td>EFCh</td>
<td>—</td>
<td>EDCh</td>
<td>—</td>
<td>EBCh</td>
<td>—</td>
<td>E9Ch</td>
<td>—</td>
</tr>
<tr>
<td>EFBh</td>
<td>—</td>
<td>EDBh</td>
<td>—</td>
<td>EBBh</td>
<td>—</td>
<td>E9Bh</td>
<td>—</td>
</tr>
<tr>
<td>EFAh</td>
<td>—</td>
<td>EDAh</td>
<td>—</td>
<td>EBAh</td>
<td>—</td>
<td>E9Ah</td>
<td>—</td>
</tr>
<tr>
<td>EF9h</td>
<td>—</td>
<td>ED9h</td>
<td>—</td>
<td>EB9h</td>
<td>—</td>
<td>E99h</td>
<td>—</td>
</tr>
<tr>
<td>EF8h</td>
<td>—</td>
<td>ED8h</td>
<td>—</td>
<td>EB8h</td>
<td>—</td>
<td>E98h</td>
<td>—</td>
</tr>
<tr>
<td>EF7h</td>
<td>—</td>
<td>ED7h</td>
<td>—</td>
<td>EB7h</td>
<td>—</td>
<td>E97h</td>
<td>—</td>
</tr>
<tr>
<td>EF6h</td>
<td>—</td>
<td>ED6h</td>
<td>—</td>
<td>EB6h</td>
<td>—</td>
<td>E96h</td>
<td>—</td>
</tr>
<tr>
<td>EF5h</td>
<td>—</td>
<td>ED5h</td>
<td>—</td>
<td>EB5h</td>
<td>—</td>
<td>E95h</td>
<td>—</td>
</tr>
<tr>
<td>EF4h</td>
<td>—</td>
<td>ED4h</td>
<td>—</td>
<td>EB4h</td>
<td>—</td>
<td>E94h</td>
<td>—</td>
</tr>
<tr>
<td>EF3h</td>
<td>—</td>
<td>ED3h</td>
<td>—</td>
<td>EB3h</td>
<td>—</td>
<td>E93h</td>
<td>—</td>
</tr>
<tr>
<td>EF2h</td>
<td>—</td>
<td>ED2h</td>
<td>—</td>
<td>EB2h</td>
<td>—</td>
<td>E92h</td>
<td>—</td>
</tr>
<tr>
<td>EF1h</td>
<td>—</td>
<td>ED1h</td>
<td>—</td>
<td>EB1h</td>
<td>—</td>
<td>E91h</td>
<td>—</td>
</tr>
<tr>
<td>EF0h</td>
<td>—</td>
<td>ED0h</td>
<td>—</td>
<td>EB0h</td>
<td>—</td>
<td>E90h</td>
<td>—</td>
</tr>
<tr>
<td>EEFh</td>
<td>—</td>
<td>ECFh</td>
<td>—</td>
<td>EA0h</td>
<td>—</td>
<td>E8Fh</td>
<td>—</td>
</tr>
<tr>
<td>EEEh</td>
<td>—</td>
<td>ECEh</td>
<td>—</td>
<td>EA0h</td>
<td>—</td>
<td>E8Eh</td>
<td>—</td>
</tr>
<tr>
<td>EEDh</td>
<td>—</td>
<td>ECDh</td>
<td>—</td>
<td>EADh</td>
<td>—</td>
<td>E8Dh</td>
<td>—</td>
</tr>
<tr>
<td>EECh</td>
<td>—</td>
<td>ECCh</td>
<td>—</td>
<td>EACh</td>
<td>—</td>
<td>E8Ch</td>
<td>—</td>
</tr>
<tr>
<td>EE8h</td>
<td>—</td>
<td>ECBh</td>
<td>—</td>
<td>EA8h</td>
<td>—</td>
<td>E8Bh</td>
<td>—</td>
</tr>
<tr>
<td>EEAh</td>
<td>—</td>
<td>ECAh</td>
<td>—</td>
<td>EAAh</td>
<td>—</td>
<td>E8Ah</td>
<td>—</td>
</tr>
<tr>
<td>EE9h</td>
<td>—</td>
<td>EC9h</td>
<td>—</td>
<td>EA9h</td>
<td>—</td>
<td>E89h</td>
<td>—</td>
</tr>
<tr>
<td>EE8h</td>
<td>—</td>
<td>EC8h</td>
<td>—</td>
<td>EA8h</td>
<td>—</td>
<td>E88h</td>
<td>—</td>
</tr>
<tr>
<td>EE7h</td>
<td>—</td>
<td>EC7h</td>
<td>—</td>
<td>EA7h</td>
<td>—</td>
<td>E87h</td>
<td>—</td>
</tr>
<tr>
<td>EE6h</td>
<td>—</td>
<td>EC6h</td>
<td>—</td>
<td>EA6h</td>
<td>—</td>
<td>E86h</td>
<td>—</td>
</tr>
<tr>
<td>EE5h</td>
<td>—</td>
<td>EC5h</td>
<td>—</td>
<td>EA5h</td>
<td>—</td>
<td>E85h</td>
<td>—</td>
</tr>
<tr>
<td>EE4h</td>
<td>—</td>
<td>EC4h</td>
<td>—</td>
<td>EA4h</td>
<td>—</td>
<td>E84h</td>
<td>—</td>
</tr>
<tr>
<td>EE3h</td>
<td>—</td>
<td>EC3h</td>
<td>—</td>
<td>EA3h</td>
<td>—</td>
<td>E83h</td>
<td>—</td>
</tr>
<tr>
<td>EE2h</td>
<td>—</td>
<td>EC2h</td>
<td>—</td>
<td>EA2h</td>
<td>—</td>
<td>E82h</td>
<td>—</td>
</tr>
<tr>
<td>EE1h</td>
<td>—</td>
<td>EC1h</td>
<td>—</td>
<td>EA1h</td>
<td>—</td>
<td>E81h</td>
<td>—</td>
</tr>
<tr>
<td>EE0h</td>
<td>—</td>
<td>EC0h</td>
<td>—</td>
<td>EA0h</td>
<td>—</td>
<td>E80h</td>
<td>—</td>
</tr>
</tbody>
</table>

Note 1: Registers available only on PIC18F4X8X devices; otherwise, the registers read as ‘0’.
Note 2: When any TX_ENn bit in RX_TX_SELn is set, then the corresponding bit in this register has transmit properties.
Note 3: This is not a physical register.
TABLE 5-1: SPECIAL FUNCTION REGISTER MAP FOR PIC18F2682/2685/4682/4685 DEVICES (CONTINUED)

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>E7Fh</td>
<td>CANCON_RO4</td>
<td>E6Fh</td>
<td>CANCON_RO5</td>
<td>E5Fh</td>
<td>CANCON_RO6</td>
<td>E4Fh</td>
<td>CANCON_RO7</td>
</tr>
<tr>
<td>E7Eh</td>
<td>CANSTAT_RO4</td>
<td>E6Eh</td>
<td>CANSTAT_RO5</td>
<td>E5Eh</td>
<td>CANSTAT_RO6</td>
<td>E4Eh</td>
<td>CANSTAT_RO7</td>
</tr>
<tr>
<td>E7Dh</td>
<td>B5D7(2)</td>
<td>E6Dh</td>
<td>B4D7(2)</td>
<td>E5Dh</td>
<td>B3D7(2)</td>
<td>E4Dh</td>
<td>B2D7(2)</td>
</tr>
<tr>
<td>E7Ch</td>
<td>B5D6(2)</td>
<td>E6Ch</td>
<td>B4D6(2)</td>
<td>E5Ch</td>
<td>B3D6(2)</td>
<td>E4Ch</td>
<td>B2D6(2)</td>
</tr>
<tr>
<td>E7 Bh</td>
<td>B5D5(2)</td>
<td>E6Bh</td>
<td>B4D5(2)</td>
<td>E5Bh</td>
<td>B3D5(2)</td>
<td>E4Bh</td>
<td>B2D5(2)</td>
</tr>
<tr>
<td>E7 Ah</td>
<td>B5D4(2)</td>
<td>E6Ah</td>
<td>B4D4(2)</td>
<td>E5Ah</td>
<td>B3D4(2)</td>
<td>E4Ah</td>
<td>B2D4(2)</td>
</tr>
<tr>
<td>E79h</td>
<td>B5D3(2)</td>
<td>E69h</td>
<td>B4D3(2)</td>
<td>E59h</td>
<td>B3D3(2)</td>
<td>E49h</td>
<td>B2D3(2)</td>
</tr>
<tr>
<td>E78h</td>
<td>B5D2(2)</td>
<td>E68h</td>
<td>B4D2(2)</td>
<td>E58h</td>
<td>B3D2(2)</td>
<td>E48h</td>
<td>B2D2(2)</td>
</tr>
<tr>
<td>E77h</td>
<td>B5D1(2)</td>
<td>E67h</td>
<td>B4D1(2)</td>
<td>E57h</td>
<td>B3D1(2)</td>
<td>E47h</td>
<td>B2D1(2)</td>
</tr>
<tr>
<td>E76h</td>
<td>B5D0(2)</td>
<td>E66h</td>
<td>B4D0(2)</td>
<td>E56h</td>
<td>B3D0(2)</td>
<td>E46h</td>
<td>B2D0(2)</td>
</tr>
<tr>
<td>E75h</td>
<td>B5DLC(2)</td>
<td>E65h</td>
<td>B4DLC(2)</td>
<td>E55h</td>
<td>B3DLC(2)</td>
<td>E45h</td>
<td>B2DLC(2)</td>
</tr>
<tr>
<td>E74h</td>
<td>B5EIDL(2)</td>
<td>E64h</td>
<td>B4EIDL(2)</td>
<td>E54h</td>
<td>B3EIDL(2)</td>
<td>E44h</td>
<td>B2EIDL(2)</td>
</tr>
<tr>
<td>E73h</td>
<td>B5EIDH(2)</td>
<td>E63h</td>
<td>B4EIDH(2)</td>
<td>E53h</td>
<td>B3EIDH(2)</td>
<td>E43h</td>
<td>B2EIDH(2)</td>
</tr>
<tr>
<td>E72h</td>
<td>B5SIDL(2)</td>
<td>E62h</td>
<td>B4SIDL(2)</td>
<td>E52h</td>
<td>B3SIDL(2)</td>
<td>E42h</td>
<td>B2SIDL(2)</td>
</tr>
<tr>
<td>E71h</td>
<td>B5SIDH(2)</td>
<td>E61h</td>
<td>B4SIDH(2)</td>
<td>E51h</td>
<td>B3SIDH(2)</td>
<td>E41h</td>
<td>B2SIDH(2)</td>
</tr>
<tr>
<td>E70h</td>
<td>B5CON(2)</td>
<td>E60h</td>
<td>B4CON(2)</td>
<td>E50h</td>
<td>B3CON(2)</td>
<td>E40h</td>
<td>B2CON(2)</td>
</tr>
<tr>
<td>E3Fh</td>
<td>CANCON_RO8</td>
<td>E2Fh</td>
<td>CANCON_RO9</td>
<td>E1Fh</td>
<td>—</td>
<td>E0Fh</td>
<td>—</td>
</tr>
<tr>
<td>E3Eh</td>
<td>CANSTAT_RO8</td>
<td>E2Eh</td>
<td>CANSTAT_RO9</td>
<td>E1Eh</td>
<td>—</td>
<td>E0Eh</td>
<td>—</td>
</tr>
<tr>
<td>E3Dh</td>
<td>B1D7(2)</td>
<td>E2Dh</td>
<td>B0D7(2)</td>
<td>E1Dh</td>
<td>—</td>
<td>E0Dh</td>
<td>—</td>
</tr>
<tr>
<td>E3Ch</td>
<td>B1D6(2)</td>
<td>E2Ch</td>
<td>B0D6(2)</td>
<td>E1Ch</td>
<td>—</td>
<td>E0Ch</td>
<td>—</td>
</tr>
<tr>
<td>E3 Bh</td>
<td>B1D5(2)</td>
<td>E2Bh</td>
<td>B0D5(2)</td>
<td>E1Bh</td>
<td>—</td>
<td>E0Bh</td>
<td>—</td>
</tr>
<tr>
<td>E3 Ah</td>
<td>B1D4(2)</td>
<td>E2Ah</td>
<td>B0D4(2)</td>
<td>E1Ah</td>
<td>—</td>
<td>E0Ah</td>
<td>—</td>
</tr>
<tr>
<td>E39h</td>
<td>B1D3(2)</td>
<td>E29h</td>
<td>B0D3(2)</td>
<td>E19h</td>
<td>—</td>
<td>E09h</td>
<td>—</td>
</tr>
<tr>
<td>E38h</td>
<td>B1D2(2)</td>
<td>E28h</td>
<td>B0D2(2)</td>
<td>E18h</td>
<td>—</td>
<td>E08h</td>
<td>—</td>
</tr>
<tr>
<td>E37h</td>
<td>B1D1(2)</td>
<td>E27h</td>
<td>B0D1(2)</td>
<td>E17h</td>
<td>—</td>
<td>E07h</td>
<td>—</td>
</tr>
<tr>
<td>E36h</td>
<td>B1D0(2)</td>
<td>E26h</td>
<td>B0D0(2)</td>
<td>E16h</td>
<td>—</td>
<td>E06h</td>
<td>—</td>
</tr>
<tr>
<td>E35h</td>
<td>B1DLC(2)</td>
<td>E25h</td>
<td>B0DLC(2)</td>
<td>E15h</td>
<td>—</td>
<td>E05h</td>
<td>—</td>
</tr>
<tr>
<td>E34h</td>
<td>B1EIDL(2)</td>
<td>E24h</td>
<td>B0EIDL(2)</td>
<td>E14h</td>
<td>—</td>
<td>E04h</td>
<td>—</td>
</tr>
<tr>
<td>E33h</td>
<td>B1EIDH(2)</td>
<td>E23h</td>
<td>B0EIDH(2)</td>
<td>E13h</td>
<td>—</td>
<td>E03h</td>
<td>—</td>
</tr>
<tr>
<td>E32h</td>
<td>B1SIDL(2)</td>
<td>E22h</td>
<td>B0SIDL(2)</td>
<td>E12h</td>
<td>—</td>
<td>E02h</td>
<td>—</td>
</tr>
<tr>
<td>E31h</td>
<td>B1SIDH(2)</td>
<td>E21h</td>
<td>B0SIDH(2)</td>
<td>E11h</td>
<td>—</td>
<td>E01h</td>
<td>—</td>
</tr>
<tr>
<td>E30h</td>
<td>B1CON(2)</td>
<td>E20h</td>
<td>B0CON(2)</td>
<td>E10h</td>
<td>—</td>
<td>E00h</td>
<td>—</td>
</tr>
</tbody>
</table>

Note 1: Registers available only on PIC18F4X8X devices; otherwise, the registers read as ‘0’.
2: When any TX_ENn bit in RX_TX_SELn is set, then the corresponding bit in this register has transmit properties.
3: This is not a physical register.
### TABLE 5-1: SPECIAL FUNCTION REGISTER MAP FOR PIC18F2682/2685/4682/4685 DEVICES (CONTINUED)

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFFh</td>
<td>—</td>
<td>DDFh</td>
<td>—</td>
<td>DBFh</td>
<td>—</td>
<td>D9Fh</td>
<td>—</td>
</tr>
<tr>
<td>DFEh</td>
<td>—</td>
<td>DFEh</td>
<td>—</td>
<td>DBEh</td>
<td>—</td>
<td>D9Eh</td>
<td>—</td>
</tr>
<tr>
<td>DFdh</td>
<td>—</td>
<td>DFdh</td>
<td>—</td>
<td>DBdh</td>
<td>—</td>
<td>D9dh</td>
<td>—</td>
</tr>
<tr>
<td>DFCh</td>
<td>TX8IE</td>
<td>DFCh</td>
<td>—</td>
<td>DBCh</td>
<td>—</td>
<td>D9Ch</td>
<td>—</td>
</tr>
<tr>
<td>DF8h</td>
<td>—</td>
<td>DF8h</td>
<td>—</td>
<td>DB8h</td>
<td>—</td>
<td>D98h</td>
<td>—</td>
</tr>
<tr>
<td>DFAh</td>
<td>BIE0</td>
<td>DFAh</td>
<td>—</td>
<td>DBAh</td>
<td>—</td>
<td>D9Ah</td>
<td>—</td>
</tr>
<tr>
<td>DF9h</td>
<td>—</td>
<td>DF9h</td>
<td>—</td>
<td>DB9h</td>
<td>—</td>
<td>D99h</td>
<td>—</td>
</tr>
<tr>
<td>DF8h</td>
<td>BSEL0</td>
<td>DF8h</td>
<td>—</td>
<td>SDFLC</td>
<td>—</td>
<td>D98h</td>
<td>—</td>
</tr>
<tr>
<td>DF7h</td>
<td>—</td>
<td>DF7h</td>
<td>—</td>
<td>DB7h</td>
<td>—</td>
<td>D97h</td>
<td>—</td>
</tr>
<tr>
<td>DF6h</td>
<td>—</td>
<td>DF6h</td>
<td>—</td>
<td>DB6h</td>
<td>—</td>
<td>D96h</td>
<td>—</td>
</tr>
<tr>
<td>DF5h</td>
<td>—</td>
<td>DF5h</td>
<td>—</td>
<td>RXFCON1</td>
<td>—</td>
<td>D95h</td>
<td>—</td>
</tr>
<tr>
<td>DF4h</td>
<td>—</td>
<td>DF4h</td>
<td>—</td>
<td>RXFCON0</td>
<td>—</td>
<td>D94h</td>
<td>—</td>
</tr>
<tr>
<td>DF3h</td>
<td>MSEL3</td>
<td>DF3h</td>
<td>—</td>
<td>DB3h</td>
<td>—</td>
<td>D93h</td>
<td>RXF15EIDL</td>
</tr>
<tr>
<td>DF2h</td>
<td>MSEL2</td>
<td>DF2h</td>
<td>—</td>
<td>DB2h</td>
<td>—</td>
<td>D92h</td>
<td>RXF15EIDH</td>
</tr>
<tr>
<td>DF1h</td>
<td>MSEL1</td>
<td>DF1h</td>
<td>—</td>
<td>DB1h</td>
<td>—</td>
<td>D91h</td>
<td>RXF15SIDL</td>
</tr>
<tr>
<td>DF0h</td>
<td>MSEL0</td>
<td>DF0h</td>
<td>—</td>
<td>DB0h</td>
<td>—</td>
<td>D90h</td>
<td>RXF15SIDH</td>
</tr>
<tr>
<td>DEFh</td>
<td>—</td>
<td>DEFh</td>
<td>—</td>
<td>DAFh</td>
<td>—</td>
<td>D8Fh</td>
<td>—</td>
</tr>
<tr>
<td>DEEh</td>
<td>—</td>
<td>DEEh</td>
<td>—</td>
<td>DAEh</td>
<td>—</td>
<td>D8Eh</td>
<td>—</td>
</tr>
<tr>
<td>DEdh</td>
<td>—</td>
<td>DEdh</td>
<td>—</td>
<td>DAdh</td>
<td>—</td>
<td>D8Dh</td>
<td>—</td>
</tr>
<tr>
<td>DECh</td>
<td>—</td>
<td>DECh</td>
<td>—</td>
<td>DACh</td>
<td>—</td>
<td>D8Ch</td>
<td>—</td>
</tr>
<tr>
<td>DEBh</td>
<td>—</td>
<td>DEBh</td>
<td>—</td>
<td>DAbh</td>
<td>—</td>
<td>D8Bh</td>
<td>RXF14EIDL</td>
</tr>
<tr>
<td>DEAh</td>
<td>—</td>
<td>DEAh</td>
<td>—</td>
<td>DAAh</td>
<td>—</td>
<td>D8Ah</td>
<td>RXF14EIDH</td>
</tr>
<tr>
<td>DE9h</td>
<td>—</td>
<td>DE9h</td>
<td>—</td>
<td>DA9h</td>
<td>—</td>
<td>D89h</td>
<td>RXF14SIDL</td>
</tr>
<tr>
<td>DE8h</td>
<td>—</td>
<td>DE8h</td>
<td>—</td>
<td>DA8h</td>
<td>—</td>
<td>D88h</td>
<td>RXF14SIDH</td>
</tr>
<tr>
<td>DE7h</td>
<td>RXFBCON7</td>
<td>DE7h</td>
<td>—</td>
<td>DA7h</td>
<td>—</td>
<td>D87h</td>
<td>RXF13EIDL</td>
</tr>
<tr>
<td>DE6h</td>
<td>RXFBCON6</td>
<td>DE6h</td>
<td>—</td>
<td>DA6h</td>
<td>—</td>
<td>D86h</td>
<td>RXF13EIDH</td>
</tr>
<tr>
<td>DE5h</td>
<td>RXFBCON5</td>
<td>DE5h</td>
<td>—</td>
<td>DA5h</td>
<td>—</td>
<td>D85h</td>
<td>RXF13SIDL</td>
</tr>
<tr>
<td>DE4h</td>
<td>RXFBCON4</td>
<td>DE4h</td>
<td>—</td>
<td>DA4h</td>
<td>—</td>
<td>D84h</td>
<td>RXF13SIDH</td>
</tr>
<tr>
<td>DE3h</td>
<td>RXFBCON3</td>
<td>DE3h</td>
<td>—</td>
<td>DA3h</td>
<td>—</td>
<td>D83h</td>
<td>RXF12EIDL</td>
</tr>
<tr>
<td>DE2h</td>
<td>RXFBCON2</td>
<td>DE2h</td>
<td>—</td>
<td>DA2h</td>
<td>—</td>
<td>D82h</td>
<td>RXF12EIDH</td>
</tr>
<tr>
<td>DE1h</td>
<td>RXFBCON1</td>
<td>DE1h</td>
<td>—</td>
<td>DA1h</td>
<td>—</td>
<td>D81h</td>
<td>RXF12SIDL</td>
</tr>
<tr>
<td>DE0h</td>
<td>RXFBCON0</td>
<td>DE0h</td>
<td>—</td>
<td>DA0h</td>
<td>—</td>
<td>D80h</td>
<td>RXF12SIDH</td>
</tr>
</tbody>
</table>

**Note 1:** Registers available only on PIC18F4X8X devices; otherwise, the registers read as ‘0’.

**Note 2:** When any TX_ENn bit in RX_TX_SELn is set, then the corresponding bit in this register has transmit properties.

**Note 3:** This is not a physical register.
### TABLE 5-1: SPECIAL FUNCTION REGISTER MAP FOR PIC18F2682/2685/4682/4685 DEVICES (CONTINUED)

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>D7Fh</td>
<td>—</td>
</tr>
<tr>
<td>D7Eh</td>
<td>—</td>
</tr>
<tr>
<td>D7Dh</td>
<td>—</td>
</tr>
<tr>
<td>D7Ch</td>
<td>—</td>
</tr>
<tr>
<td>D7Bh</td>
<td>RXF11EIDL</td>
</tr>
<tr>
<td>D7Ah</td>
<td>RXF11EIDH</td>
</tr>
<tr>
<td>D79h</td>
<td>RXF11SIDL</td>
</tr>
<tr>
<td>D78h</td>
<td>RXF11SIDH</td>
</tr>
<tr>
<td>D77h</td>
<td>RXF10EIDL</td>
</tr>
<tr>
<td>D76h</td>
<td>RXF10EIDH</td>
</tr>
<tr>
<td>D75h</td>
<td>RXF10SIDL</td>
</tr>
<tr>
<td>D74h</td>
<td>RXF10SIDH</td>
</tr>
<tr>
<td>D73h</td>
<td>RXF9EIDL</td>
</tr>
<tr>
<td>D72h</td>
<td>RXF9EIDH</td>
</tr>
<tr>
<td>D71h</td>
<td>RXF9SIDL</td>
</tr>
<tr>
<td>D70h</td>
<td>RXF9SIDH</td>
</tr>
<tr>
<td>D6Fh</td>
<td>—</td>
</tr>
<tr>
<td>D6 Eh</td>
<td>—</td>
</tr>
<tr>
<td>D6Dh</td>
<td>—</td>
</tr>
<tr>
<td>D6Ch</td>
<td>—</td>
</tr>
<tr>
<td>D6Bh</td>
<td>RXF8EIDL</td>
</tr>
<tr>
<td>D6Ah</td>
<td>RXF8EIDH</td>
</tr>
<tr>
<td>D69h</td>
<td>RXF8SIDL</td>
</tr>
<tr>
<td>D68h</td>
<td>RXF8SIDH</td>
</tr>
<tr>
<td>D67h</td>
<td>RXF7EIDL</td>
</tr>
<tr>
<td>D66h</td>
<td>RXF7EIDH</td>
</tr>
<tr>
<td>D65h</td>
<td>RXF7SIDL</td>
</tr>
<tr>
<td>D64h</td>
<td>RXF7SIDH</td>
</tr>
<tr>
<td>D63h</td>
<td>RXF6EIDL</td>
</tr>
<tr>
<td>D62h</td>
<td>RXF6EIDH</td>
</tr>
<tr>
<td>D61h</td>
<td>RXF6SIDL</td>
</tr>
<tr>
<td>D60h</td>
<td>RXF6SIDH</td>
</tr>
</tbody>
</table>

**Note**

1: Registers available only on PIC18F4X8X devices; otherwise, the registers read as ‘0’.
2: When any TX_ENn bit in RX_TX_SELn is set, then the corresponding bit in this register has transmit properties.
3: This is not a physical register.
TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOSU</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Top-of-Stack Register Upper Byte (TOS&lt;20:16&gt;)</td>
<td>---</td>
<td>0000</td>
<td>51, 64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOSH</td>
<td>Top-of-Stack Register High Byte (TOS&lt;15:8&gt;)</td>
<td>0000</td>
<td>0000</td>
<td>51, 64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLSL</td>
<td>Top-of-Stack Register Low Byte (TOS&lt;7:0&gt;)</td>
<td>0000</td>
<td>0000</td>
<td>51, 64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STKPTR</td>
<td>STKFUL</td>
<td>STKUNF</td>
<td>—</td>
<td>SP4</td>
<td>SP3</td>
<td>SP2</td>
<td>SP1</td>
<td>SP0</td>
<td>00-0 0000</td>
<td>51, 65</td>
</tr>
<tr>
<td>PCLATU</td>
<td>—</td>
<td>—</td>
<td>bit 21(1)</td>
<td>Holding Register for PC&lt;20:16&gt;</td>
<td>---</td>
<td>0000</td>
<td>51, 64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCLATH</td>
<td>Holding Register for PC&lt;15:8&gt;</td>
<td>0000</td>
<td>0000</td>
<td>51, 64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCL</td>
<td>PC Low Byte (PC&lt;7:0&gt;)</td>
<td>0000</td>
<td>0000</td>
<td>51, 64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBLPTRU</td>
<td>—</td>
<td>—</td>
<td>bit 21</td>
<td>Program Memory Table Pointer Upper Byte (TBLPTR&lt;20:16&gt;)</td>
<td>---</td>
<td>0000</td>
<td>51, 105</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBLPTRHR</td>
<td>Program Memory Table Pointer High Byte (TBLPTR&lt;15:8&gt;)</td>
<td>0000</td>
<td>0000</td>
<td>51, 105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBLPTRRL</td>
<td>Program Memory Table Pointer Low Byte (TBLPTR&lt;7:0&gt;)</td>
<td>0000</td>
<td>0000</td>
<td>51, 105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLAT</td>
<td>Program Memory Table Latch</td>
<td>0000</td>
<td>0000</td>
<td>51, 105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRODH</td>
<td>Product Register High Byte</td>
<td>xxxx</td>
<td>xxxx</td>
<td>51, 113</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRODL</td>
<td>Product Register Low Byte</td>
<td>xxxx</td>
<td>xxxx</td>
<td>51, 113</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMROIE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>0000 000x</td>
<td>51, 117</td>
</tr>
<tr>
<td>INTCON2</td>
<td>RBPU</td>
<td>INTEG0</td>
<td>INTEG1</td>
<td>INTEG2</td>
<td>—</td>
<td>TMR0P0</td>
<td>—</td>
<td>RBIP</td>
<td>1111 1-1-1</td>
<td>51, 118</td>
</tr>
<tr>
<td>INTCON3</td>
<td>INT2IP</td>
<td>INT1IP</td>
<td>INT2IE</td>
<td>INT1IE</td>
<td>—</td>
<td>INT2IF</td>
<td>INT1IF</td>
<td>11-0 0-00</td>
<td>51, 119</td>
<td></td>
</tr>
<tr>
<td>INDF0</td>
<td>Uses contents of FSR0 to address data memory – value of FSR0 not changed (not a physical register)</td>
<td>N/A</td>
<td>51, 91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTINC0</td>
<td>Uses contents of FSR0 to address data memory – value of FSR0 post-incremented (not a physical register)</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTDEC0</td>
<td>Uses contents of FSR0 to address data memory – value of FSR0 post-decremented (not a physical register)</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREINC0</td>
<td>Uses contents of FSR0 to address data memory – value of FSR0 pre-incremented (not a physical register)</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLUSW0</td>
<td>Uses contents of FSR0 to address data memory – value of FSR0 pre-incremented (not a physical register), value of FSR0 offset by W</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSR0H</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Indirect Data Memory Address Pointer 0 High</td>
<td>---</td>
<td>xxxx</td>
<td>51, 91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSR0L</td>
<td>Indirect Data Memory Address Pointer 0 Low Byte</td>
<td>xxxx</td>
<td>xxxx</td>
<td>51, 91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WREG</td>
<td>Working Register</td>
<td>xxxx</td>
<td>xxxx</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDF1</td>
<td>Uses contents of FSR1 to address data memory – value of FSR1 not changed (not a physical register)</td>
<td>N/A</td>
<td>51, 91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTINC1</td>
<td>Uses contents of FSR1 to address data memory – value of FSR1 post-incremented (not a physical register)</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTDEC1</td>
<td>Uses contents of FSR1 to address data memory – value of FSR1 post-decremented (not a physical register)</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREINC1</td>
<td>Uses contents of FSR1 to address data memory – value of FSR1 pre-incremented (not a physical register)</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLUSW1</td>
<td>Uses contents of FSR1 to address data memory – value of FSR1 pre-incremented (not a physical register), value of FSR1 offset by W</td>
<td>N/A</td>
<td>51, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSR1H</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Indirect Data Memory Address Pointer 1 High</td>
<td>---</td>
<td>xxxx</td>
<td>51, 91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSR1L</td>
<td>Indirect Data Memory Address Pointer 1 Low Byte</td>
<td>xxxx</td>
<td>xxxx</td>
<td>51, 91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BSR</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Bank Select Register</td>
<td>---</td>
<td>0000</td>
<td>52, 69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDF2</td>
<td>Uses contents of FSR2 to address data memory – value of FSR2 not changed (not a physical register)</td>
<td>N/A</td>
<td>52, 91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTINC2</td>
<td>Uses contents of FSR2 to address data memory – value of FSR2 post-incremented (not a physical register)</td>
<td>N/A</td>
<td>52, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTDEC2</td>
<td>Uses contents of FSR2 to address data memory – value of FSR2 post-decremented (not a physical register)</td>
<td>N/A</td>
<td>52, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREINC2</td>
<td>Uses contents of FSR2 to address data memory – value of FSR2 pre-incremented (not a physical register)</td>
<td>N/A</td>
<td>52, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLUSW2</td>
<td>Uses contents of FSR2 to address data memory – value of FSR2 pre-incremented (not a physical register), value of FSR2 offset by W</td>
<td>N/A</td>
<td>52, 92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSR2H</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Indirect Data Memory Address Pointer 2 High</td>
<td>---</td>
<td>xxxx</td>
<td>52, 91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSR2L</td>
<td>Indirect Data Memory Address Pointer 2 Low Byte</td>
<td>xxxx</td>
<td>xxxx</td>
<td>52, 91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:  
- u = unknown,  
- = unchanged,  
- = unimplemented,  
= value depends on condition. Shaded cells are unimplemented, read as '0'.

Note 1: Bit 21 of the PC is only available in Test mode and Serial Programming modes.

2: The SBOREN bit is only available when CONFIG2L<1:0> = 0; otherwise, it is disabled and reads as '0'. See Section 4.4 "Brown-out Reset (BOR)".
3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as '0'. See Section 4.4 "Brown-out Reset (BOR)".
4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as '0'. See Section 2.6.4 "PLL in INTOSC Modes".
5: The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as '0'. This bit is read-only.
6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as '0'.
7: CAN bits have multiple functions depending on the selected mode of the CAN module.
8: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
9: These registers and/or bits are available on PIC18F4682/4685 devices only.
### TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATUS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>O</td>
<td>V</td>
<td>Z</td>
<td>DC</td>
<td>C</td>
</tr>
<tr>
<td>TMR0H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0000 0000</td>
<td>52, 151</td>
</tr>
<tr>
<td>TMR0L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0000 0000</td>
<td>52, 151</td>
</tr>
<tr>
<td>T0CON</td>
<td></td>
<td></td>
<td>T0B8T</td>
<td>T0CS</td>
<td>T0SE</td>
<td>PSA</td>
<td>T0PS2</td>
<td>T0PS1</td>
<td>T0PS0</td>
<td>1111 1111</td>
</tr>
<tr>
<td>OSCCON</td>
<td>iDEN</td>
<td>IRFC2</td>
<td>IRFC1</td>
<td>IRFC0</td>
<td>OSTS</td>
<td>IOFS</td>
<td>SC0</td>
<td>SC1</td>
<td>SC3</td>
<td>0100 0000</td>
</tr>
<tr>
<td>HLVDCON</td>
<td>VDIRM</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>I VST</td>
<td>HLVEN</td>
<td>HLVLD3</td>
<td>HLVLD2</td>
<td>HLVLD1</td>
<td>0-0 0010</td>
</tr>
<tr>
<td>WDTCON</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>SWDTE</td>
<td>--- ---0</td>
</tr>
<tr>
<td>RCON</td>
<td>IPEN</td>
<td>SBOREN</td>
<td>—</td>
<td>RI</td>
<td>T0</td>
<td>PD</td>
<td>POR</td>
<td>BOR</td>
<td>0q-1 11q0</td>
<td>52, 129</td>
</tr>
<tr>
<td>TMR1H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0000 0000</td>
<td>52, 157</td>
</tr>
<tr>
<td>TMR1L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0000 0000</td>
<td>52, 157</td>
</tr>
<tr>
<td>T1CON</td>
<td>RD16</td>
<td>T1RUN</td>
<td>T1CKPS1</td>
<td>T1CKPS0</td>
<td>T1OSCEN</td>
<td>T1SYNC</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
<td>1111 1111</td>
<td>52, 153</td>
</tr>
<tr>
<td>TMR2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-000 0000</td>
<td>52, 160</td>
</tr>
<tr>
<td>PR2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-000 0000</td>
<td>52, 167</td>
</tr>
<tr>
<td>T2CON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T2OUTPS3</td>
<td>T2OUTPS2</td>
<td>T2OUTPS1</td>
<td>T2OUTPS0</td>
<td>TMR2ON</td>
<td>T2CKPS1</td>
</tr>
<tr>
<td>SSBUF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MSSP Receive/Transmit Register</td>
<td>52, 197</td>
</tr>
<tr>
<td>SSPADD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MSSP Address Register in I 2C™ Slave mode, MSSP Baud Rate Reload Register in I2C Master mode</td>
<td>52, 197</td>
</tr>
<tr>
<td>SSPSTAT</td>
<td>SMP</td>
<td>CKE</td>
<td>D/A</td>
<td>P</td>
<td>S</td>
<td>R</td>
<td>UA</td>
<td>BF</td>
<td>0000 0000</td>
<td>52, 199</td>
</tr>
<tr>
<td>SSPCON1</td>
<td>WCOL</td>
<td>SSPOV</td>
<td>SSPEN</td>
<td>CKP</td>
<td>SSPM3</td>
<td>SSPM2</td>
<td>SSPM1</td>
<td>SSPM0</td>
<td>0000 0000</td>
<td>52, 200</td>
</tr>
<tr>
<td>SSPCON2</td>
<td>GREN</td>
<td>ACKSTAT</td>
<td>ACDT</td>
<td>ACKEN</td>
<td>RCEN</td>
<td>PEN</td>
<td>RSEN</td>
<td>SEN</td>
<td>0000 0000</td>
<td>52, 201</td>
</tr>
<tr>
<td>ADRESH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A/D Result Register High Byte</td>
<td>52, 258</td>
</tr>
<tr>
<td>ADRESL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A/D Result Register Low Byte</td>
<td>52, 258</td>
</tr>
<tr>
<td>ADCON0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CHS3</td>
<td>CHS2</td>
<td>CHS1</td>
<td>CHS0</td>
<td>GS/ONE</td>
<td>ADON</td>
</tr>
<tr>
<td>ADCON1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VCFG1</td>
<td>VCFG0</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>PCFG0</td>
</tr>
<tr>
<td>ADCON2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ACFM2</td>
<td>ACFM1</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
<td>0000 0000</td>
<td>52, 251</td>
</tr>
<tr>
<td>CCP1H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Capture/Compare/PWM Register 1 High Byte</td>
<td>52, 170</td>
</tr>
<tr>
<td>CCP1L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Capture/Compare/PWM Register 1 Low Byte</td>
<td>52, 170</td>
</tr>
<tr>
<td>CCP1CON</td>
<td>—</td>
<td></td>
<td>DC1B1</td>
<td>DC1B0</td>
<td>CCP1M3</td>
<td>CCP1M2</td>
<td>CCP1M1</td>
<td>CCP1M0</td>
<td>0-000 0000</td>
<td>52, 165</td>
</tr>
<tr>
<td>ECCP1H(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 High Byte</td>
<td>52, 169</td>
</tr>
<tr>
<td>ECCP1L(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
<td>52, 169</td>
</tr>
<tr>
<td>ECCP1CON(5)</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
<td>52, 169</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDVF</td>
<td>RCDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>0-0 0-0 0-00</td>
<td>52, 232</td>
</tr>
<tr>
<td>ECCP1DEL(5)</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
<td>52, 169</td>
</tr>
<tr>
<td>ECCP1AS(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
<td>52, 169</td>
</tr>
<tr>
<td>CVCREN</td>
<td>CVREN</td>
<td>CVROE</td>
<td>CVRR</td>
<td>CVRSS</td>
<td>CVR3</td>
<td>CVR2</td>
<td>CVR1</td>
<td>CVR0</td>
<td>0000 0000</td>
<td>52, 265</td>
</tr>
<tr>
<td>CMCON(5)</td>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>C1S</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
<td>0000 0000</td>
<td>52, 259</td>
</tr>
<tr>
<td>TMR3H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Timer3 Register High Byte</td>
<td>52, 163</td>
</tr>
<tr>
<td>TMR3L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Timer3 Register Low Byte</td>
<td>52, 163</td>
</tr>
</tbody>
</table>

| T3CON     | RD16  | T3ECCP1(5)| T3CKPS1| T3CKPS0| T3CKPS(5)| T3SYNC| T3MRS1| T3MRS0| 0000 0000 | 52, 163        |
## TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page:</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>0000 0000</td>
<td>53, 233</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>0000 0000</td>
<td>53, 233</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCREG</td>
<td>EUSART Receive Register</td>
<td>0000 0000</td>
<td>53, 240</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXREG</td>
<td>EUSART Transmit Register</td>
<td>0000 0000</td>
<td>53, 238</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>0000 0010</td>
<td>53, 239</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXSTA</td>
<td>SPEN</td>
<td>0000 0000</td>
<td>53, 239</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEDRH</td>
<td>EEDR</td>
<td>0000 0000</td>
<td>53, 110</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEDATA</td>
<td>EEPROM Data Register</td>
<td>0000 0000</td>
<td>53, 107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECON2</td>
<td>EECON2</td>
<td>0000 0000</td>
<td>53, 107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECON1</td>
<td>EECON1</td>
<td>0000 0000</td>
<td>53, 107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LATD</td>
<td>LATD</td>
<td>1111 1111</td>
<td>53, 107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISD</td>
<td>TRISD</td>
<td>1111 1111</td>
<td>53, 107</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LATC</td>
<td>LATC</td>
<td>1111 1111</td>
<td>53, 137</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LATB</td>
<td>LATB</td>
<td>1111 1111</td>
<td>53, 137</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LATB</td>
<td>LATB</td>
<td>1111 1111</td>
<td>53, 137</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PORTE</td>
<td>PORTE</td>
<td>0000 0000</td>
<td>53, 140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PORTD</td>
<td>PORTD</td>
<td>0000 0000</td>
<td>53, 140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PORTC</td>
<td>PORTC</td>
<td>0000 0000</td>
<td>53, 140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:  
- x = unknown, u = unchanged, – = unimplemented, q = value depends on condition. Shaded cells are unimplemented, read as ‘0’.

**Note 1:** Bit 21 of the PC is only available in Test mode and Serial Programming modes.

2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 "Brown-out Reset (BOR)."

3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.

4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 "PLL in INTOSC Modes”.

5: The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as ‘0’. This bit is read-only.

6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.

7: CAN bits have multiple functions depending on the selected mode of the CAN module.

8: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.

9: These registers and/or bits are available on PIC18F4682/4685 devices only.

---

Legend:  
- x = unknown, u = unchanged, – = unimplemented, q = value depends on condition. Shaded cells are unimplemented, read as ‘0’.

**Note 1:** Bit 21 of the PC is only available in Test mode and Serial Programming modes.

2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 "Brown-out Reset (BOR)."

3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.

4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 "PLL in INTOSC Modes”.

5: The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as ‘0’. This bit is read-only.

6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.

7: CAN bits have multiple functions depending on the selected mode of the CAN module.

8: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.

9: These registers and/or bits are available on PIC18F4682/4685 devices only.
### TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTB</td>
<td>RB7</td>
<td>RB6</td>
<td>RB5</td>
<td>RB4</td>
<td>RB3</td>
<td>RB2</td>
<td>RB1</td>
<td>RB0</td>
<td>xxxxxxx xxxxxxx</td>
<td>54, 134</td>
</tr>
<tr>
<td>PORTA</td>
<td>RA7(6)</td>
<td>RA6(6)</td>
<td>RA5</td>
<td>RA4</td>
<td>RA3</td>
<td>RA2</td>
<td>RA1</td>
<td>RA0</td>
<td>xx00 0000</td>
<td>54, 131</td>
</tr>
<tr>
<td>ECANCON</td>
<td>MDSEL1</td>
<td>MDSEL0</td>
<td>MDSEL0</td>
<td>MDSEL0</td>
<td>MDSEL0</td>
<td>MDSEL0</td>
<td>MDSEL0</td>
<td>MDSEL0</td>
<td>EFINW</td>
<td>54, 131</td>
</tr>
<tr>
<td>TXERRCNT</td>
<td>TE5</td>
<td>TE4</td>
<td>TE3</td>
<td>TE2</td>
<td>TE1</td>
<td>TE0</td>
<td>TE0</td>
<td>TE0</td>
<td>00000 0000</td>
<td>54, 287</td>
</tr>
<tr>
<td>RXERRCNT</td>
<td>RE5</td>
<td>RE4</td>
<td>RE3</td>
<td>RE2</td>
<td>RE1</td>
<td>RE0</td>
<td>RE0</td>
<td>RE0</td>
<td>00000 0000</td>
<td>54, 296</td>
</tr>
<tr>
<td>COMSTAT Mode 0</td>
<td>RXB0OVFL</td>
<td>RXB1OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB1OVFL</td>
<td>00000 0000</td>
</tr>
<tr>
<td>COMSTAT Mode 1</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>00000 0000</td>
</tr>
<tr>
<td>COMSTAT Mode 2</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>RXB0OVFL</td>
<td>00000 0000</td>
</tr>
<tr>
<td>RXB0CON</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>RXB0D0</td>
<td>00000 0000</td>
<td>55, 295</td>
</tr>
<tr>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>RXB1D6</td>
<td>00000 0000</td>
<td>55, 295</td>
</tr>
<tr>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>RXB1D7</td>
<td>00000 0000</td>
<td>55, 295</td>
</tr>
<tr>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>RXB1D8</td>
<td>00000 0000</td>
<td>55, 295</td>
</tr>
</tbody>
</table>

**Legend:**
- x = unknown, u = unchanged, = = unimplemented, q = value depends on condition. Shaded cells are unimplemented, read as '—'.

**Note:**
1: Bit 21 of the PC is only available in Test mode and Serial Programming modes.
2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as '0'. See Section 4.4 "Brown-out Reset (BOR)".
3: These register and/or bits are not implemented on PIC18F2682/2685 devices and are read as '—'.
4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as '—'. See Section 2.6.4 "PLL in INTOSC Modes".
5: These register and/or bits are not implemented on PIC18F2682/2685 devices and are read as '—'.
6: For RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as '0'.
7: CAN bits have multiple functions depending on the selected mode of the CAN module.
8: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.
9: These registers and/or bits are available on PIC18F4682/4685 devices only.
# TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>RXB1D5</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>RXB1D4</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>RXB1D3</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>RXB1D2</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>RXB1D1</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>RXB1D0</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1DLC</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1EIDL</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1EIDH</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1SIDL</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1SIDH</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1CON</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1CON</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>TXB0D7</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>TXB0D6</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>TXB0D5</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>TXB0D4</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>TXB0D3</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>TXB0D2</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>TXB0D1</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>TXB0D0</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0DLC</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0EIDL</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0EIDH</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0SIDL</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0SIDH</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB0CON</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>TXB1F</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>TXB1D7</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>TXB1D6</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>TXB1D5</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>TXB1D4</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>TXB1D3</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>TXB1D2</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>TXB1D1</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>TXB1D0</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1DLC</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1EIDL</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>TXB1EIDH</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>RXB1SIDH</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
</tbody>
</table>

Legend: = unknown, = unchanged, = unimplemented, = value depends on condition. Shaded cells are unimplemented, read as ‘0’.

**Note 1:** Bit 21 of the PC is only available in Test mode and Serial Programming modes.

2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 “Brown-out Reset (BOR)”.

3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.

4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 “PLL in INTOSC Modes”.

5: The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 01); otherwise, RE3 reads as ‘0’. This bit is read-only.

6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.

7: CAN bits have multiple functions depending on the selected mode of the CAN module.

8: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.

9: These registers and/or bits are available on PIC18F4682/4685 devices only.
## TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXB2D0</td>
<td>TXB2D7</td>
<td>TXB2D76</td>
<td>TXB2D75</td>
<td>TXB2D74</td>
<td>TXB2D73</td>
<td>TXB2D72</td>
<td>TXB2D71</td>
<td>TXB2D70</td>
<td>xxxx xxxx</td>
<td>56, 286</td>
</tr>
<tr>
<td>TXB2D6</td>
<td>TXB2D67</td>
<td>TXB2D66</td>
<td>TXB2D65</td>
<td>TXB2D64</td>
<td>TXB2D63</td>
<td>TXB2D62</td>
<td>TXB2D61</td>
<td>TXB2D60</td>
<td>xxxx xxxx</td>
<td>57, 286</td>
</tr>
<tr>
<td>TXB2D5</td>
<td>TXB2D57</td>
<td>TXB2D56</td>
<td>TXB2D55</td>
<td>TXB2D54</td>
<td>TXB2D53</td>
<td>TXB2D52</td>
<td>TXB2D51</td>
<td>TXB2D50</td>
<td>xxxx xxxx</td>
<td>57, 286</td>
</tr>
<tr>
<td>TXB2D4</td>
<td>TXB2D47</td>
<td>TXB2D46</td>
<td>TXB2D45</td>
<td>TXB2D44</td>
<td>TXB2D43</td>
<td>TXB2D42</td>
<td>TXB2D41</td>
<td>TXB2D40</td>
<td>xxxx xxxx</td>
<td>57, 286</td>
</tr>
<tr>
<td>TXB2D3</td>
<td>TXB2D37</td>
<td>TXB2D36</td>
<td>TXB2D35</td>
<td>TXB2D34</td>
<td>TXB2D33</td>
<td>TXB2D32</td>
<td>TXB2D31</td>
<td>TXB2D30</td>
<td>xxxx xxxx</td>
<td>57, 286</td>
</tr>
<tr>
<td>TXB2D2</td>
<td>TXB2D27</td>
<td>TXB2D26</td>
<td>TXB2D25</td>
<td>TXB2D24</td>
<td>TXB2D23</td>
<td>TXB2D22</td>
<td>TXB2D21</td>
<td>TXB2D20</td>
<td>xxxx xxxx</td>
<td>57, 286</td>
</tr>
<tr>
<td>TXB2D1</td>
<td>TXB2D17</td>
<td>TXB2D16</td>
<td>TXB2D15</td>
<td>TXB2D14</td>
<td>TXB2D13</td>
<td>TXB2D12</td>
<td>TXB2D11</td>
<td>TXB2D10</td>
<td>xxxx xxxx</td>
<td>57, 296</td>
</tr>
<tr>
<td>TXB2D0</td>
<td>TXB2D07</td>
<td>TXB2D06</td>
<td>TXB2D05</td>
<td>TXB2D04</td>
<td>TXB2D03</td>
<td>TXB2D02</td>
<td>TXB2D01</td>
<td>TXB2D00</td>
<td>xxxx xxxx</td>
<td>57, 296</td>
</tr>
<tr>
<td>TXB2DLC</td>
<td>—</td>
<td>TXRTR</td>
<td>—</td>
<td>—</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
<td>xxxx xxxx</td>
<td>57, 287</td>
</tr>
<tr>
<td>TXB2EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 286</td>
</tr>
<tr>
<td>TXB2EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 285</td>
</tr>
<tr>
<td>TXB2SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDE</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 285</td>
</tr>
<tr>
<td>TXB2SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 285</td>
</tr>
<tr>
<td>TXB2CON</td>
<td>TXB1F</td>
<td>TXLARB</td>
<td>TXERR</td>
<td>TXREQ</td>
<td>—</td>
<td>TXPRI1</td>
<td>TXPRI0</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 284</td>
</tr>
<tr>
<td>RXM1EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM1EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM1SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM1SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM0EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM0EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM0SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXM0SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 307</td>
</tr>
<tr>
<td>RXF5EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF5EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF5SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF5SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF4EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF4EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF4SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 305</td>
</tr>
<tr>
<td>RXF4SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 305</td>
</tr>
<tr>
<td>RXF3EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF3EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF3SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF3SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF2EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF2EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF2SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>xxxx xxxx</td>
<td>57, 305</td>
</tr>
<tr>
<td>RXF2SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx xxxx</td>
<td>57, 305</td>
</tr>
<tr>
<td>RXF1EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
<tr>
<td>RXF1EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>xxxx xxxx</td>
<td>57, 306</td>
</tr>
</tbody>
</table>

**Legend:**

- **x** = unknown, **u** = unchanged, **-** = unimplemented, **q** = value depends on condition. Shaded cells are unimplemented, read as ‘0’.

**Note 1:** Bit 21 of the PC is only available in Test mode and Serial Programming modes.

2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 “Brown-out Reset (BOR).”

3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.

4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 “PLL in INTOSC Modes.”

5: The RE1 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as ‘0’. This bit is read-only.

6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.

7: CAN bits have multiple functions depending on the selected mode of the CAN module.

8: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.

9: These registers and/or bits are available on PIC18F4682/4685 devices only.
### TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXF0SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 305</td>
</tr>
<tr>
<td>RXF0SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 306</td>
</tr>
<tr>
<td>RXF0EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 306</td>
</tr>
<tr>
<td>RXF0EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>—</td>
<td>58, 306</td>
</tr>
<tr>
<td>RXF0SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 305</td>
</tr>
<tr>
<td>RXF0SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 306</td>
</tr>
<tr>
<td>RXF0EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 306</td>
</tr>
<tr>
<td>RXF0EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>—</td>
<td>58, 306</td>
</tr>
<tr>
<td>RXF1SIDL</td>
<td>B5D77</td>
<td>B5D76</td>
<td>B5D75</td>
<td>B5D74</td>
<td>B5D73</td>
<td>B5D72</td>
<td>B5D71</td>
<td>B5D70</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1SIDH</td>
<td>B5D67</td>
<td>B5D66</td>
<td>B5D65</td>
<td>B5D64</td>
<td>B5D63</td>
<td>B5D62</td>
<td>B5D61</td>
<td>B5D60</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1EIDL</td>
<td>B5D57</td>
<td>B5D56</td>
<td>B5D55</td>
<td>B5D54</td>
<td>B5D53</td>
<td>B5D52</td>
<td>B5D51</td>
<td>B5D50</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1EIDH</td>
<td>B5D47</td>
<td>B5D46</td>
<td>B5D45</td>
<td>B5D44</td>
<td>B5D43</td>
<td>B5D42</td>
<td>B5D41</td>
<td>B5D40</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1SIDL</td>
<td>B5D37</td>
<td>B5D36</td>
<td>B5D35</td>
<td>B5D34</td>
<td>B5D33</td>
<td>B5D32</td>
<td>B5D31</td>
<td>B5D30</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1SIDH</td>
<td>B5D27</td>
<td>B5D26</td>
<td>B5D25</td>
<td>B5D24</td>
<td>B5D23</td>
<td>B5D22</td>
<td>B5D21</td>
<td>B5D20</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1EIDL</td>
<td>B5D17</td>
<td>B5D16</td>
<td>B5D15</td>
<td>B5D14</td>
<td>B5D13</td>
<td>B5D12</td>
<td>B5D11</td>
<td>B5D10</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF1EIDH</td>
<td>B5D07</td>
<td>B5D06</td>
<td>B5D05</td>
<td>B5D04</td>
<td>B5D03</td>
<td>B5D02</td>
<td>B5D01</td>
<td>B5D00</td>
<td>—</td>
<td>58, 302</td>
</tr>
<tr>
<td>RXF0SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 303</td>
</tr>
<tr>
<td>RXF0SIDH</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 303</td>
</tr>
<tr>
<td>RXF0EIDL</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTRK</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTRK</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>—</td>
<td>58, 298</td>
</tr>
<tr>
<td>RXF0EIDH</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTRK</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTRK</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>—</td>
<td>58, 298</td>
</tr>
<tr>
<td>RXF1SIDL</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 301</td>
</tr>
<tr>
<td>RXF1SIDH</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 301</td>
</tr>
<tr>
<td>RXF1EIDL</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 301</td>
</tr>
<tr>
<td>RXF1EIDH</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>B5DXC1</td>
<td>B5DXC0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 301</td>
</tr>
<tr>
<td>RXF0SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 303</td>
</tr>
<tr>
<td>RXF0SIDH</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 303</td>
</tr>
<tr>
<td>RXF0EIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 303</td>
</tr>
<tr>
<td>RXF0EIDH</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>B5SIDH</td>
<td>B5SIDL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>58, 303</td>
</tr>
</tbody>
</table>

Legend: = unknown, unchanged, unimplemented, = value depends on condition. Shaded cells are unimplemented, read as '0'.

Note 1: Bit 21 of the PIC is only available in Test mode and Serial Programming modes.

Note 2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as '0'. See Section 4.4 "Brown-out Reset (BOR)".

Note 3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as '0'. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as '='.

Note 4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as '0'. See Section 2.6.4 "PLL in INTOSC Modes".

Note 5: The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as '0'. This bit is read-only.

Note 6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as '0'.

Note 7: CAN bits have multiple functions depending on the selected mode of the CAN module.

Note 8: This register reads all '0's until the ECAN™ technology is set up in Mode 1 or Mode 2.

Note 9: These registers and/or bits are available on PIC18F4682/4685 devices only.

---

**DS39761C-page 84 © 2009 Microchip Technology Inc.**
### TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page:</th>
</tr>
</thead>
<tbody>
<tr>
<td>B4SIDL&lt;8&gt;</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>SRR</td>
<td>EXID</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B4SIDH&lt;8&gt;</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SII7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>xxxx</td>
<td>299</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>B4CON&lt;8&gt;</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTRO</td>
<td>FILHT4</td>
<td>FILHT3</td>
<td>FILHT2</td>
<td>FILHT1</td>
<td>FILHT0</td>
<td>0000</td>
<td>298</td>
</tr>
<tr>
<td>Receive mode</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTRO</td>
<td>FILHT4</td>
<td>FILHT3</td>
<td>FILHT2</td>
<td>FILHT1</td>
<td>FILHT0</td>
<td>0000</td>
<td>298</td>
</tr>
<tr>
<td>B3D7&lt;8&gt;</td>
<td>B3D77</td>
<td>B3D76</td>
<td>B3D75</td>
<td>B3D74</td>
<td>B3D73</td>
<td>B3D72</td>
<td>B3D71</td>
<td>B3D70</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D77</td>
<td>B3D76</td>
<td>B3D75</td>
<td>B3D74</td>
<td>B3D73</td>
<td>B3D72</td>
<td>B3D71</td>
<td>B3D70</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D6&lt;8&gt;</td>
<td>B3D67</td>
<td>B3D66</td>
<td>B3D65</td>
<td>B3D64</td>
<td>B3D63</td>
<td>B3D62</td>
<td>B3D61</td>
<td>B3D60</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D67</td>
<td>B3D66</td>
<td>B3D65</td>
<td>B3D64</td>
<td>B3D63</td>
<td>B3D62</td>
<td>B3D61</td>
<td>B3D60</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D5&lt;8&gt;</td>
<td>B3D57</td>
<td>B3D56</td>
<td>B3D55</td>
<td>B3D54</td>
<td>B3D53</td>
<td>B3D52</td>
<td>B3D51</td>
<td>B3D50</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D57</td>
<td>B3D56</td>
<td>B3D55</td>
<td>B3D54</td>
<td>B3D53</td>
<td>B3D52</td>
<td>B3D51</td>
<td>B3D50</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D4&lt;8&gt;</td>
<td>B3D47</td>
<td>B3D46</td>
<td>B3D45</td>
<td>B3D44</td>
<td>B3D43</td>
<td>B3D42</td>
<td>B3D41</td>
<td>B3D40</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D47</td>
<td>B3D46</td>
<td>B3D45</td>
<td>B3D44</td>
<td>B3D43</td>
<td>B3D42</td>
<td>B3D41</td>
<td>B3D40</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D3&lt;8&gt;</td>
<td>B3D37</td>
<td>B3D36</td>
<td>B3D35</td>
<td>B3D34</td>
<td>B3D33</td>
<td>B3D32</td>
<td>B3D31</td>
<td>B3D30</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D37</td>
<td>B3D36</td>
<td>B3D35</td>
<td>B3D34</td>
<td>B3D33</td>
<td>B3D32</td>
<td>B3D31</td>
<td>B3D30</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D2&lt;8&gt;</td>
<td>B3D27</td>
<td>B3D26</td>
<td>B3D25</td>
<td>B3D24</td>
<td>B3D23</td>
<td>B3D22</td>
<td>B3D21</td>
<td>B3D20</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D27</td>
<td>B3D26</td>
<td>B3D25</td>
<td>B3D24</td>
<td>B3D23</td>
<td>B3D22</td>
<td>B3D21</td>
<td>B3D20</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D1&lt;8&gt;</td>
<td>B3D17</td>
<td>B3D16</td>
<td>B3D15</td>
<td>B3D14</td>
<td>B3D13</td>
<td>B3D12</td>
<td>B3D11</td>
<td>B3D10</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D17</td>
<td>B3D16</td>
<td>B3D15</td>
<td>B3D14</td>
<td>B3D13</td>
<td>B3D12</td>
<td>B3D11</td>
<td>B3D10</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3D0&lt;8&gt;</td>
<td>B3D07</td>
<td>B3D06</td>
<td>B3D05</td>
<td>B3D04</td>
<td>B3D03</td>
<td>B3D02</td>
<td>B3D01</td>
<td>B3D00</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>B3D07</td>
<td>B3D06</td>
<td>B3D05</td>
<td>B3D04</td>
<td>B3D03</td>
<td>B3D02</td>
<td>B3D01</td>
<td>B3D00</td>
<td>xxxx</td>
<td>300</td>
</tr>
<tr>
<td>B3DLC&lt;8&gt;</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>283</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>(8)</td>
<td>283</td>
</tr>
<tr>
<td>B3DLC&lt;8&gt;</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>RD1R</td>
<td>RB0</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>300</td>
</tr>
<tr>
<td>Receive mode</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>RD1R</td>
<td>RB0</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>300</td>
</tr>
<tr>
<td>B3DLC&lt;8&gt;</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>299</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>299</td>
</tr>
<tr>
<td>B3DLC&lt;8&gt;</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>299</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>299</td>
</tr>
<tr>
<td>B3DLC&lt;8&gt;</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>299</td>
</tr>
<tr>
<td>Transmit mode</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>299</td>
</tr>
</tbody>
</table>

**Legend:**  
- $x =$ unknown, $u =$ unchanged, $-$ = unimplemented, $q =$ value depends on condition. Shaded cells are unimplemented, read as ‘0’.  
- Transmit mode = $T$.  
- Receive mode = $R$.  
- Transmit and receive modes = $T/R$.  

**Note:**  
1. Bit 21 of the PIC is only available in Test mode and Serial Programming modes.  
2. The SBOREN bit is only available when CONFIG2L<1:0> ≠ 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 “Brown-out Reset (BOR)”.  
3. These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.  
4. The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 “PLL in INTOSC Modes”.  
5. The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as ‘0’. This bit is read-only.  
6. RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.  
7. CAN bits have multiple functions depending on the selected mode of the CAN module.  
8. This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.  
9. These registers and/or bits are available on PIC18F4682/4685 devices only.
### TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2EIDL(8)</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>.....</td>
<td>60, 301</td>
</tr>
<tr>
<td>B2EIDL(8)</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>.....</td>
<td>60, 301</td>
</tr>
<tr>
<td>B2SIDL(8)</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>SRR</td>
<td>EXID</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
<td>.....</td>
<td>58, 300</td>
</tr>
<tr>
<td>B2SIDL(8)</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>.....</td>
<td>60, 299</td>
</tr>
<tr>
<td>B2CON(8)</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTR</td>
<td>RXRTR</td>
<td>FILHIT</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
<td>.....</td>
<td>60, 298</td>
</tr>
<tr>
<td>B2CON(8)</td>
<td>TXBIF</td>
<td>TXMR</td>
<td>TLARB</td>
<td>TLARB</td>
<td>TXERR</td>
<td>—</td>
<td>RTREN</td>
<td>TXTEN</td>
<td>.....</td>
<td>60, 299</td>
</tr>
<tr>
<td>B1D7(8)</td>
<td>B1D77</td>
<td>B1D76</td>
<td>B1D75</td>
<td>B1D74</td>
<td>B1D73</td>
<td>B1D72</td>
<td>B1D71</td>
<td>B1D70</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B1D6(8)</td>
<td>B1D67</td>
<td>B1D66</td>
<td>B1D65</td>
<td>B1D64</td>
<td>B1D63</td>
<td>B1D62</td>
<td>B1D61</td>
<td>B1D60</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B1D0(8)</td>
<td>B1D07</td>
<td>B1D06</td>
<td>B1D05</td>
<td>B1D04</td>
<td>B1D03</td>
<td>B1D02</td>
<td>B1D01</td>
<td>B1D00</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B1DLC(8)</td>
<td>—</td>
<td>RXRTR</td>
<td>RB1</td>
<td>RB0</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
<td>.....</td>
<td>58, 303</td>
</tr>
<tr>
<td>B1DLC(8)</td>
<td>—</td>
<td>TXRTR</td>
<td>—</td>
<td>—</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
<td>—</td>
<td>58, 304</td>
</tr>
<tr>
<td>B1EIDL(8)</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>.....</td>
<td>60, 301</td>
</tr>
<tr>
<td>B1EIDL(8)</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>.....</td>
<td>60, 301</td>
</tr>
<tr>
<td>B1SIDL(8)</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>SRR</td>
<td>EXID</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
<td>.....</td>
<td>58, 300</td>
</tr>
<tr>
<td>B1SIDL(8)</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXID</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
<td>.....</td>
<td>58, 300</td>
</tr>
<tr>
<td>B1SIDH(8)</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>.....</td>
<td>60, 299</td>
</tr>
<tr>
<td>B1CON(8)</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTR</td>
<td>RXRTR</td>
<td>FILHT4</td>
<td>—</td>
<td>FILHT2</td>
<td>FILHT1</td>
<td>FILHT0</td>
<td>60, 298</td>
</tr>
<tr>
<td>B1CON(8)</td>
<td>TXBIF</td>
<td>TXABT</td>
<td>TLARB</td>
<td>TLARB</td>
<td>TXERR</td>
<td>—</td>
<td>RTREN</td>
<td>TXTEN</td>
<td>—</td>
<td>60, 298</td>
</tr>
<tr>
<td>B0D7(8)</td>
<td>B0D77</td>
<td>B0D76</td>
<td>B0D75</td>
<td>B0D74</td>
<td>B0D73</td>
<td>B0D72</td>
<td>B0D71</td>
<td>B0D70</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D6(8)</td>
<td>B0D67</td>
<td>B0D66</td>
<td>B0D65</td>
<td>B0D64</td>
<td>B0D63</td>
<td>B0D62</td>
<td>B0D61</td>
<td>B0D60</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D5(8)</td>
<td>B0D57</td>
<td>B0D56</td>
<td>B0D55</td>
<td>B0D54</td>
<td>B0D53</td>
<td>B0D52</td>
<td>B0D51</td>
<td>B0D50</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D4(8)</td>
<td>B0D47</td>
<td>B0D46</td>
<td>B0D45</td>
<td>B0D44</td>
<td>B0D43</td>
<td>B0D42</td>
<td>B0D41</td>
<td>B0D40</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D3(8)</td>
<td>B0D37</td>
<td>B0D36</td>
<td>B0D35</td>
<td>B0D34</td>
<td>B0D33</td>
<td>B0D32</td>
<td>B0D31</td>
<td>B0D30</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D2(8)</td>
<td>B0D27</td>
<td>B0D26</td>
<td>B0D25</td>
<td>B0D24</td>
<td>B0D23</td>
<td>B0D22</td>
<td>B0D21</td>
<td>B0D20</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D1(8)</td>
<td>B0D17</td>
<td>B0D16</td>
<td>B0D15</td>
<td>B0D14</td>
<td>B0D13</td>
<td>B0D12</td>
<td>B0D11</td>
<td>B0D10</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0D0(8)</td>
<td>B0D07</td>
<td>B0D06</td>
<td>B0D05</td>
<td>B0D04</td>
<td>B0D03</td>
<td>B0D02</td>
<td>B0D01</td>
<td>B0D00</td>
<td>.....</td>
<td>60, 302</td>
</tr>
<tr>
<td>B0DLC(8)</td>
<td>—</td>
<td>RXRTR</td>
<td>RB1</td>
<td>RB0</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
<td>—</td>
<td>58, 303</td>
</tr>
</tbody>
</table>

**Legend:**  
- U = unknown, C = unchanged, ^ = unimplemented, @ = value depends on condition. Shaded cells are unimplemented, read as ‘0’.

**Note:**  
1: Bit 21 of the PC is only available in Test mode and Serial Programming modes.
2: The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 “Brown-out Reset (BOR)”.
3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.
4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 “PLL in INTOSC Modes”.
5: The RES bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RES reads as ‘0’. This bit is read-only.
6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.
7: CAN bits have multiple functions depending on the selected mode of the CAN module.
8: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
9: These registers and/or bits are available on PIC18F4682/4685 devices only.

© 2009 Microchip Technology Inc.
<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0DLC8</td>
<td>—</td>
<td>TXRTR</td>
<td>—</td>
<td>—</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B0EIDL8</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B0EIDH8</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B0SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>SRR</td>
<td>EXID</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B0SID8</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B0SIDH</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>BOCON8</td>
<td>RXFUL</td>
<td>RXM1</td>
<td>RXRTTRO</td>
<td>FILHT4</td>
<td>FILHT3</td>
<td>FILHT2</td>
<td>FILHT1</td>
<td>FILHT0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>BOCON8</td>
<td>TXB1IF</td>
<td>TXABT</td>
<td>TXLARB</td>
<td>TXERR</td>
<td>TXREQ</td>
<td>RTREN</td>
<td>TXPRI1</td>
<td>TXPRI0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B1E8</td>
<td>B5IE</td>
<td>B4IE</td>
<td>B3IE</td>
<td>B2IE</td>
<td>B1IE</td>
<td>B0IE</td>
<td>RXB1IE</td>
<td>RXB0IE</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>BSEL8</td>
<td>B5TXEN</td>
<td>B4TXEN</td>
<td>B3TXEN</td>
<td>B2TXEN</td>
<td>B1TXEN</td>
<td>B0TXEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MSEL3</td>
<td>FIL15_1</td>
<td>FIL15_0</td>
<td>FIL14_1</td>
<td>FIL14_0</td>
<td>FIL13_1</td>
<td>FIL13_0</td>
<td>FIL12_1</td>
<td>FIL12_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MSEL2</td>
<td>FIL11_1</td>
<td>FIL11_0</td>
<td>FIL10_1</td>
<td>FIL10_0</td>
<td>FIL9_1</td>
<td>FIL9_0</td>
<td>FIL8_1</td>
<td>FIL8_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MSEL1</td>
<td>FIL7_1</td>
<td>FIL7_0</td>
<td>FIL6_1</td>
<td>FIL6_0</td>
<td>FIL5_1</td>
<td>FIL5_0</td>
<td>FIL4_1</td>
<td>FIL4_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>M0E0</td>
<td>FIL3_1</td>
<td>FIL3_0</td>
<td>FIL2_1</td>
<td>FIL2_0</td>
<td>FIL1_1</td>
<td>FIL1_0</td>
<td>FIL0_1</td>
<td>FIL0_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON7</td>
<td>F15BP_3</td>
<td>F15BP_2</td>
<td>F15BP_1</td>
<td>F15BP_0</td>
<td>F14BP_3</td>
<td>F14BP_2</td>
<td>F14BP_1</td>
<td>F14BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON6</td>
<td>F13BP_3</td>
<td>F13BP_2</td>
<td>F13BP_1</td>
<td>F13BP_0</td>
<td>F12BP_3</td>
<td>F12BP_2</td>
<td>F12BP_1</td>
<td>F12BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON5</td>
<td>F11BP_3</td>
<td>F11BP_2</td>
<td>F11BP_1</td>
<td>F11BP_0</td>
<td>F10BP_3</td>
<td>F10BP_2</td>
<td>F10BP_1</td>
<td>F10BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON4</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON3</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON2</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON1</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFBCON0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SDLC8</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFCON1</td>
<td>RXF15EN</td>
<td>RXF14EN</td>
<td>RXF13EN</td>
<td>RXF12EN</td>
<td>RXF11EN</td>
<td>RXF10EN</td>
<td>RXF9EN</td>
<td>RXF8EN</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXFCON0</td>
<td>RXF7EN</td>
<td>RXF6EN</td>
<td>RXF5EN</td>
<td>RXF4EN</td>
<td>RXF3EN</td>
<td>RXF2EN</td>
<td>RXF1EN</td>
<td>RXF0EN</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF15EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF15EDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF15SIDH</td>
<td>S02</td>
<td>S01</td>
<td>S00</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF14EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF14EDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF14SIDH</td>
<td>S02</td>
<td>S01</td>
<td>S00</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF13EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF13EDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RXF13SIDH</td>
<td>S02</td>
<td>S01</td>
<td>S00</td>
<td>—</td>
<td>EXIDEN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Legend: 
- x = unknown, u = unchanged, — = unimplemented, q = value depends on condition. Shaded cells are unimplemented, read as '0'.

Note 1: Bit 21 of the PIC is only available in Test mode and Serial Programming modes.
2: The SBOREN bit is only available when CONFIG2L<1:0> = 0; otherwise, it is disabled and reads as '0'. See Section 4.4 "Brown-out Reset (BOR)".
3: These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as '0'. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.
4: The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 "PLL in INTOSC Modes".
5: The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as ‘0’. This bit is read-only.
6: RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.
7: CAN has multiple functions depending on the selected mode of the CAN module.
8: This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
9: These registers and/or bits are available on PIC18F4682/4685 devices only.

Note: 60, 298, 58, 304, 58, 301, 60, 298, 58, 302, 58, 300, 61, 299, 60, 298, 61, 321.
## TABLE 5-2: REGISTER FILE SUMMARY (PIC18F2682/2685/4682/4685) (CONTINUED)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Value on POR, BOR</th>
<th>Details on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXF12EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF12EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF12SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF12SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>62, 305</td>
</tr>
<tr>
<td>RXF11EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF11EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF11SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF11SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>62, 305</td>
</tr>
<tr>
<td>RXF10EIDL</td>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF10EIDH</td>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF10SIDL</td>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>62, 306</td>
</tr>
<tr>
<td>RXF10SIDH</td>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
<td>62, 305</td>
</tr>
</tbody>
</table>

**Legend:**
- \(x\) = unknown,
- \(u\) = unchanged,
- \(-\) = unimplemented,
- \(q\) = value depends on condition. Shaded cells are unimplemented, read as ‘0’.

**Note 1:**
- Bit 21 of the PC is only available in Test mode and Serial Programming modes.
- The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’. See Section 4.4 “Brown-out Reset (BOR)”.
- These registers and/or bits are not implemented on PIC18F2682/2685 devices and are read as ‘0’. Reset values are shown for PIC18F4682/4685 devices; individual unimplemented bits should be interpreted as ‘—’.
- The PLLEN bit is only available in specific oscillator configurations; otherwise, it is disabled and reads as ‘0’. See Section 2.6.4 “PLL in INTOSC Modes”.
- The RE3 bit is only available when Master Clear Reset is disabled (CONFIG3H<7> = 0); otherwise, RE3 reads as ‘0’. This bit is read-only.
- RA6/RA7 and their associated latch and direction bits are individually configured as port pins based on various primary oscillator modes. When disabled, these bits read as ‘0’.
- CAN bits have multiple functions depending on the selected mode of the CAN module.
- This register reads all ‘0’s until the ECAN™ technology is set up in Mode 1 or Mode 2.
- These registers and/or bits are available on PIC18F4682/4685 devices only.
5.3.5 STATUS REGISTER

The STATUS register, shown in Register 5-2, contains the arithmetic status of the ALU. As with any other SFR, it can be the operand for any instruction.

If the STATUS register is the destination for an instruction that affects the Z, DC, C, OV or N bits, the results of the instruction are not written; instead, the status is updated according to the instruction performed. Therefore, the result of an instruction with the STATUS register as its destination may be different than intended. As an example, CLRF STATUS will set the Z bit and leave the remaining Status bits unchanged ('0000 0011').

REGISTER 5-2: STATUS REGISTER

| bit 7-5 | Unimplemented: Read as '0' |
| bit 4  | N: Negative bit |
|        | This bit is used for signed arithmetic (2’s complement). It indicates whether the result was negative (ALU MSB = 1). |
|        | 1 = Result was negative |
|        | 0 = Result was positive |
| bit 3  | OV: Overflow bit |
|        | This bit is used for signed arithmetic (2’s complement). It indicates an overflow of the 7-bit magnitude which causes the sign bit (bit 7 of the result) to change state. |
|        | 1 = Overflow occurred for signed arithmetic (in this arithmetic operation) |
|        | 0 = No overflow occurred |
| bit 2  | Z: Zero bit |
|        | 1 = The result of an arithmetic or logic operation is zero |
|        | 0 = The result of an arithmetic or logic operation is not zero |
| bit 1  | DC: Digit Carry/Borrow bit(1) |
|        | For ADDWF, ADDLW, SUBLW and SUBWF instructions: |
|        | 1 = A carry-out from the 4th low-order bit of the result occurred |
|        | 0 = No carry-out from the 4th low-order bit of the result |
| bit 0  | C: Carry/Borrow bit(2) |
|        | For ADDWF, ADDLW, SUBLW and SUBWF instructions: |
|        | 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: For Borrow, the polarity is reversed. A subtraction is executed by adding the 2’s complement of the second operand. For rotate (RFF, RLF) instructions, this bit is loaded with either bit 4 or bit 3 of the source register.

Note 2: For Borrow, the polarity is reversed. A subtraction is executed by adding the 2’s complement of the second operand. For rotate (RFF, RLF) instructions, this bit is loaded with either the high or low-order bit of the source register.
5.4 Data Addressing Modes

| Note: | The execution of some instructions in the core PIC18 instruction set are changed when the PIC18 extended instruction set is enabled. See Section 5.6 “Data Memory and the Extended Instruction Set” for more information. |

While the program memory can be addressed in only one way – through the program counter – information in the data memory space can be addressed in several ways. For most instructions, the addressing mode is fixed. Other instructions may use up to three modes, depending on which operands are used and whether or not the extended instruction set is enabled.

The addressing modes are:
- Inherent
- Literal
- Direct
- Indirect

An additional addressing mode, Indexed Literal Offset, is available when the extended instruction set is enabled (XINST Configuration bit = 1). Its operation is discussed in greater detail in Section 5.6.1 “Indexed Addressing with Literal Offset”.

5.4.1 INHERENT AND LITERAL ADDRESSING

Many PIC18 control instructions do not need any argument at all. They either perform an operation that globally affects the device or they operate implicitly on one register. This addressing mode is known as Inherent Addressing. Examples include SLEEP, RESET and DAV.

Other instructions work in a similar way but require an additional explicit argument in the opcode. This is known as Literal Addressing mode because they require some literal value as an argument. Examples include ADDLW and MOVLW which, respectively, add or move a literal value to the W register. Other examples include CALL and GOTO, which include a 20-bit program memory address.

5.4.2 DIRECT ADDRESSING

Direct Addressing mode specifies all or part of the source and/or destination address of the operation within the opcode itself. The options are specified by the arguments accompanying the instruction.

In the core PIC18 instruction set, bit-oriented and byte-oriented instructions use some version of Direct Addressing by default. All of these instructions include some 8-bit literal address as their Least Significant Byte. This address specifies either a register address in one of the banks of data RAM (Section 5.3.3 “General Purpose Register File”) or a location in the Access Bank (Section 5.3.2 “Access Bank”) as the data source for the instruction.

The Access RAM bit ‘a’ determines how the address is interpreted. When ‘a’ is ‘1’, the contents of the BSR (Section 5.3.1 “Bank Select Register (BSR)”) are used with the address to determine the complete 12-bit address of the register. When ‘a’ is ‘0’, the address is interpreted as being a register in the Access Bank. Addressing that uses the Access RAM is sometimes also known as Direct Forced Addressing mode.

A few instructions, such as MOVFF, include the entire 12-bit address (either source or destination) in their opcodes. In those cases, the BSR is ignored entirely.

The destination of the operation’s results is determined by the destination bit ‘d’. When ‘d’ is ‘1’, the results are stored back in the source register, overwriting its original contents. When ‘d’ is ‘0’, the results are stored in the W register. Instructions without the ‘d’ argument have a destination that is implicit in the instruction. Their destination is either the target register being operated on or the W register.

5.4.3 INDIRECT ADDRESSING

Indirect Addressing allows the user to access a location in data memory without giving a fixed address in the instruction. This is done by using File Select Registers (FSRs) as pointers to the locations to be read or written to. Since the FSRs are themselves located in RAM as Special Function Registers, they can also be directly manipulated under program control. This makes FSRs very useful in implementing data structures, such as tables and arrays in data memory.

The registers for Indirect Addressing are also implemented with Indirect File Operands (INDFs) that permit automatic manipulation of the pointer value with auto-incrementing, auto-decrementing or offsetting with another value. This allows for efficient code, using loops, such as the example of clearing an entire RAM bank in Example 5-5.

**EXAMPLE 5-5: HOW TO CLEAR RAM (BANK 1) USING INDIRECT ADDRESSING**

```
LFSR FSR0, 100h ;
NEXT CLRF POSTINC0 ; Clear INDF ; register then ; inc pointer
BTFSS FSR0H, 1 ; All done with ; Bank17
BRA NEXT ; NO, clear next
CONTINUE ; YES, continue
```
5.4.3.1 FSR Registers and the INDF Operand

At the core of Indirect Addressing are three sets of registers: FSR0, FSR1 and FSR2. Each represents a pair of 8-bit registers: FSRnH and FSRnL. The four upper bits of the FSRnH register are not used, so each FSR pair holds a 12-bit value. This represents a value that can address the entire range of the data memory in a linear fashion. The FSR register pairs, then, serve as pointers to data memory locations.

Indirect Addressing is accomplished with a set of Indirect File Operands: INDF0 through INDF2. These can be thought of as “virtual” registers: they are mapped in the SFR space, but are not physically implemented. Reading or writing to a particular INDF register actually accesses its corresponding FSR register pair. A read from INDF1, for example, reads the data at the address indicated by FSR1H:FSR1L. Instructions that use the INDF registers as operands actually use the contents of their corresponding FSR as a pointer to the instruction’s target. The INDF operand is just a convenient way of using the pointer.

Because Indirect Addressing uses a full 12-bit address, data RAM banking is not necessary. Thus, the current contents of the BSR and Access RAM bit have no effect on determining the target address.

FIGURE 5-7: INDIRECT ADDRESSING

Using an instruction with one of the Indirect Addressing registers as the operand....

...uses the 12-bit address stored in the FSR pair associated with that register....

...to determine the data memory location to be used in that operation.

In this case, the FSR1 pair contains ECCh. This means the contents of location ECCh will be added to that of the W register and stored back in ECCh.
5.4.3.2 FSR Registers and POSTINC, POSTDEC, PREINC and PLUSW

In addition to the INDF operand, each FSR register pair also has four additional indirect operands. Like INDF, these are “virtual” registers that cannot be indirectly read or written to. Accessing these registers actually accesses the associated FSR register pair, but also performs a specific action on its stored value. They are:

- POSTDEC: accesses the FSR value, then automatically decrements it by 1 afterwards
- POSTINC: accesses the FSR value, then automatically increments it by 1 afterwards
- PREINC: increments the FSR value by 1, then uses it in the operation
- PLUSW: adds the signed value of the W register (range of -127 to 128) to that of the FSR and uses the new value in the operation.

In this context, accessing an INDF register uses the value in the FSR registers without changing them. Similarly, accessing a PLUSW register gives the FSR value offset by that in the W register; neither value is actually changed in the operation. Accessing the other virtual registers changes the value of the FSR registers.

Operations on the FSRs with POSTDEC, POSTINC and PREINC affect the entire register pair; that is, rollovers of the FSRnL register from FFh to 00h carry over to the FSRnH register. On the other hand, results of these operations do not change the value of any flags in the STATUS register (e.g., Z, N, OV, etc.).

The PLUSW register can be used to implement a form of Indexed Addressing in the data memory space. By manipulating the value in the W register, users can reach addresses that are fixed offsets from pointer addresses. In some applications, this can be used to implement some powerful program control structure, such as software stacks, inside of data memory.

5.4.3.3 Operations by FSRs on FSRs

Indirect Addressing operations that target other FSRs or virtual registers represent special cases. For example, using an FSR to point to one of the virtual registers will not result in successful operations. As a specific case, assume that the FSR0H:FSR0L pair contains FE7h, the address of INDF1. Attempts to read the value of the INDF1 using INDF0 as an operand will return 00h. Attempts to write to INDF1 using INDF0 as the operand will result in a NOP.

On the other hand, using the virtual registers to write to an FSR pair may not occur as planned. In these cases, the value will be written to the FSR pair but without any incrementing or decrementing. Thus, writing to INDF2 or POSTDEC2 will write the same value to the FSR2H:FSR2L pair.

Since the FSRs are physical registers mapped in the SFR space, they can be manipulated through all direct operations. Users should proceed cautiously when working on these registers, particularly if their code uses Indirect Addressing.

Similarly, operations by Indirect Addressing are generally permitted on all other SFRs. Users should exercise the appropriate caution that they do not inadvertently change settings that might affect the operation of the device.
5.5 Program Memory and the Extended Instruction Set

The operation of program memory is unaffected by the use of the extended instruction set.

Enabling the extended instruction set adds eight additional two-word commands to the existing PIC18 instruction set: ADDFSR, ADDULNK, CALLW, MOVSF, MOVSS, PUSHL, SUBFSR and SUBULNK. These instructions are executed as described in Section 5.2.4 “Two-Word Instructions”.

5.6 Data Memory and the Extended Instruction Set

Enabling the PIC18 extended instruction set (XINST Configuration bit = 1) significantly changes certain aspects of data memory and its addressing. Specifically, the use of the Access Bank for many of the core PIC18 instructions is different. This is due to the introduction of a new addressing mode for the data memory space. This mode also alters the behavior of Indirect Addressing using FSR2 and its associated operands.

What does not change is just as important. The size of the data memory space is unchanged, as well as its linear addressing. The SFR map remains the same. Core PIC18 instructions can still operate in both Direct and Indirect Addressing mode; inherent and literal instructions do not change at all. Indirect Addressing with FSR0 and FSR1 also remains unchanged.

5.6.1 INDEXED ADDRESSING WITH LITERAL OFFSET

Enabling the PIC18 extended instruction set changes the behavior of Indirect Addressing using the FSR2 register pair and its associated file operands. Under the proper conditions, instructions that use the Access Bank – that is, most bit-oriented and byte-oriented – instructions – can invoke a form of Indexed Addressing using an offset specified in the instruction. This special addressing mode is known as Indexed Addressing with Literal Offset or Indexed Literal Offset mode.

When using the extended instruction set, this addressing mode requires the following:

- The use of the Access Bank is forced (‘a’ = 0); and
- The file address argument is less than or equal to 5Fh.

Under these conditions, the file address of the instruction is not interpreted as the lower byte of an address (used with the BSR in Direct Addressing), or as an 8-bit address in the Access Bank. Instead, the value is interpreted as an offset value to an Address Pointer, specified by FSR2. The offset and the contents of FSR2 are added to obtain the target address of the operation.

5.6.2 INSTRUCTIONS AFFECTED BY INDEXED LITERAL OFFSET MODE

Any of the core PIC18 instructions that can use Direct Addressing are potentially affected by the Indexed Literal Addressing mode. This includes all byte-oriented and bit-oriented instructions, or almost one-half of the standard PIC18 instruction set. Instructions that only use Inherent or Literal Addressing modes are unaffected.

Additionally, byte-oriented and bit-oriented instructions are not affected if they use the Access Bank (Access RAM bit is ‘1’), or include a file address of 60h or above. Instructions meeting these criteria will continue to execute as before. A comparison of the different possible addressing modes when the extended instruction set is enabled is shown in Figure 5-8.

Those who desire to use byte-oriented or bit-oriented instructions in the Indexed Literal Offset mode should note the changes to assembler syntax for this mode. This is described in more detail in Section 25.2.1 “Extended Instruction Syntax”.
EXAMPLE INSTRUCTION: ADDWF, f, d, a (Opcode: 0010 01da ffff ffff)

When \( a = 0 \) and \( f \geq 60h \): The instruction executes in Direct Forced mode. 'f' is interpreted as a location in the Access RAM between 060h and 0FFh. This is the same as the SFRs, or locations F60h to 0FFh (Bank 15) of data memory.

Locations below 60h are not available in this addressing mode.

When \( a = 0 \) and \( f \leq 5Fh \): The instruction executes in Indexed Literal Offset mode. 'f' is interpreted as an offset to the address value in FSR2. The two are added together to obtain the address of the target register for the instruction. The address can be anywhere in the data memory space.

Note that in this mode, the correct syntax is now: ADDWF \([k]\), d where 'k' is the same as 'f'.

When \( a = 1 \) (all values of f): The instruction executes in Direct mode (also known as Direct Long mode). 'f' is interpreted as a location in one of the 16 banks of the data memory space. The bank is designated by the Bank Select Register (BSR). The address can be in any implemented bank in the data memory space.
5.6.3 MAPPING THE ACCESS BANK IN INDEXED LITERAL OFFSET MODE

The use of Indexed Literal Offset Addressing mode effectively changes how the lower half of Access RAM (00h to 7Fh) is mapped. Rather than containing just the contents of the bottom half of Bank 0, this mode maps the contents from Bank 0 and a user defined “window” that can be located anywhere in the data memory space. The value of FSR2 establishes the lower boundary of the addresses mapped into the window, while the upper boundary is defined by FSR2 plus 95 (5Fh). Addresses in the Access RAM above 5Fh are mapped as previously described (see Section 5.3.2 “Access Bank”). An example of Access Bank remapping in this addressing mode is shown in Figure 5-9.

Remapping of the Access Bank applies only to operations using the Indexed Literal Offset mode. Operations that use the BSR (Access RAM bit is ‘1’) will continue to use Direct Addressing as before. Any indirect or indexed operation that explicitly uses any of the indirect file operands (including FSR2) will continue to operate as standard Indirect Addressing. Any instruction that uses the Access Bank, but includes a register address of greater than 05Fh, will use Direct Addressing and the normal Access Bank map.

5.6.4 BSR IN INDEXED LITERAL OFFSET MODE

Although the Access Bank is remapped when the extended instruction set is enabled, the operation of the BSR remains unchanged. Direct Addressing using the BSR to select the data memory bank operates in the same manner as previously described.

FIGURE 5-9: REMAPPING THE ACCESS BANK WITH INDEXED LITERAL OFFSET ADDRESSING

Example Situation:
ADDWF f, d, a
FSR2H:FSR2L = 120h

Locations in the region from the FSR2 Pointer (120h) to the pointer plus 05Fh (17Fh) are mapped to the bottom of the Access RAM (000h-05Fh).

Special Function Registers at F60h through FFFh are mapped to 60h through FFh, as usual.

Bank 0 addresses below 5Fh are not available in this mode. They can still be addressed by using the BSR.
6.0 FLASH PROGRAM MEMORY

The Flash program memory is readable, writable and erasable during normal operation over the entire \( V_{DD} \) range.

A read from program memory is executed on one byte at a time. A write to program memory is executed on blocks of 64 bytes at a time. Program memory is erased in blocks of 64 bytes at a time. A Bulk Erase operation may not be issued from user code.

Writing or erasing program memory will cease instruction fetches until the operation is complete. The program memory cannot be accessed during the write or erase, therefore, code cannot execute. An internal programming timer terminates program memory writes and erases.

A value written to program memory does not need to be a valid instruction. Executing a program memory location that forms an invalid instruction results in a \texttt{NOP}.

6.1 Table Reads and Table Writes

In order to read and write program memory, there are two operations that allow the processor to move bytes between the program memory space and the data RAM:

- **Table Read** (\texttt{TBLRD})
- **Table Write** (\texttt{TBLWT})

The program memory space is 16 bits wide, while the data RAM space is 8 bits wide. Table reads and table writes move data between these two memory spaces through an 8-bit register (\texttt{TABLAT}).

Table read operations retrieve data from program memory and place it into the data RAM space. Figure 6-1 shows the operation of a table read with program memory and data RAM.

Table write operations store data from the data memory space into holding registers in program memory. The procedure to write the contents of the holding registers into program memory is detailed in **Section 6.5 “Writing to Flash Program Memory”**. Figure 6-2 shows the operation of a table write with program memory and data RAM.

Table operations work with byte entities. A table block containing data, rather than program instructions, is not required to be word-aligned. Therefore, a table block can start and end at any byte address. If a table write is being used to write executable code into program memory, program instructions will need to be word-aligned.

**FIGURE 6-1: TABLE READ OPERATION**

![Table Read Operation Diagram](image)

- **Table Pointer** (TBLPTR)
- **Table Latch** (8-bit)
- **Program Memory**
- **Instruction: TBLRD**

**Note 1:** Table Pointer register points to a byte in program memory.
6.2 Control Registers

Several control registers are used in conjunction with the TBLRD and TBLWT instructions. These include the:

- EECON1 register
- EECON2 register
- TABLAT register
- TBLPTR registers

6.2.1 EECON1 AND EECON2 REGISTERS

The EECON1 register (Register 6-1) is the control register for memory accesses. The EECON2 register is not a physical register; it is used exclusively in the memory write and erase sequences. Reading EECON2 will read all '0's.

The EEPGD control bit determines if the access will be a program or data EEPROM memory access. When clear, any subsequent operations will operate on the data EEPROM memory. When set, any subsequent operations will operate on the program memory.

The CFGS control bit determines if the access will be to the Configuration/Calibration registers or to program memory/data EEPROM memory. When set, subsequent operations will operate on Configuration registers regardless of EEPGD (see Section 24.0 “Special Features of the CPU”). When clear, memory selection access is determined by EEPGD.

The FREE bit, when set, will allow a program memory erase operation. When FREE is set, the erase operation is initiated on the next WR command. When FREE is clear, only writes are enabled.

The WREN bit, when set, will allow a write operation. On power-up, the WREN bit is clear. The WRERR bit is set in hardware when the WREN bit is set, and cleared when the internal programming timer expires and the write operation is complete.

The WR control bit initiates write operations. The bit cannot be cleared, only set, in software; it is cleared in hardware at the completion of the write operation.

Note: During normal operation, the WRERR is read as '1'. This can indicate that a write operation was prematurely terminated by a Reset or a write operation was attempted improperly.

Note: The EEIF Interrupt flag bit (PIR2<4>) is set when the write is complete. It must be cleared in software.
REGISTER 6-1: EECON1: DATA EEPROM CONTROL REGISTER 1

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEPGD</td>
<td>CFGS</td>
<td>FREE</td>
<td>WRERR</td>
<td>WREN</td>
<td>WR</td>
<td>RD</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- S = Settable bit
- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as ‘0’
- -n = Value at POR ‘1’ = Bit is set ‘0’ = Bit is cleared x = Bit is unknown

- **bit 7** EEPGD: Flash Program or Data EEPROM Memory Select bit
  - 1 = Access Flash program memory
  - 0 = Access data EEPROM memory

- **bit 6** CFGS: Flash Program/Data EEPROM or Configuration Select bit
  - 1 = Access Configuration registers
  - 0 = Access Flash program or data EEPROM memory

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

- **bit 4** FREE: Flash Row Erase Enable bit
  - 1 = Erase the program memory row addressed by TBLPTR on the next WR command (cleared by completion of erase operation)
  - 0 = Perform write-only

- **bit 3** WRERR: Flash Program/Data EEPROM Error Flag bit
  - 1 = A write operation is prematurely terminated (any Reset during self-timed programming in normal operation or an improper write attempt)
  - 0 = The write operation completed

- **bit 2** WREN: Flash Program/Data EEPROM Write Enable bit
  - 1 = Allows write cycles to Flash program/data EEPROM
  - 0 = Inhibits write cycles to Flash program/data EEPROM

- **bit 1** WR: Write Control bit
  - 1 = Initiates a data EEPROM erase/write cycle or a program memory erase cycle or write cycle (The operation is self-timed and the bit is cleared by hardware once write is complete. The WR bit can only be set (not cleared) in software.)
  - 0 = Write cycle to the EEPROM is complete

- **bit 0** RD: Read Control bit
  - 1 = Initiates an EEPROM read (Read takes one cycle. RD is cleared in hardware. The RD bit can only be set (not cleared) in software. RD bit cannot be set when EEPGD = 1 or CFGS = 1.)
  - 0 = Does not initiate an EEPROM read

**Note 1:** When a WRERR occurs, the EEPGD and CFGS bits are not cleared. This allows tracing of the error condition.
6.2.2 TABLAT – TABLE LATCH REGISTER
The Table Latch (TABLAT) is an 8-bit register mapped into the SFR space. The Table Latch register is used to hold 8-bit data during data transfers between program memory and data RAM.

6.2.3 TBLPTR – TABLE POINTER REGISTER
The Table Pointer (TBLPTR) register addresses a byte within the program memory. The TBLPTR is comprised of three SFR registers: Table Pointer Upper Byte, Table Pointer High Byte and Table Pointer Low Byte (TBLPTRU:TBLPTRH:TBLPTRL). These three registers join to form a 22-bit wide pointer. The low-order 21 bits allow the device to address up to 2 Mbytes of program memory space. The 22nd bit allows access to the Device ID, the user ID and the Configuration bits.

The Table Pointer, TBLPTR, is used by the TBLRD and TBLWT instructions. These instructions can update the TBLPTR in one of four ways based on the table operation. These operations are shown in Table 6-1. These operations on the TBLPTR only affect the low-order 21 bits.

6.2.4 TABLE POINTER BOUNDARIES
TBLPTR is used in reads, writes and erases of the Flash program memory.

When a TBLRD is executed, all 22 bits of the TBLPTR determine which byte is read from program memory into TABLAT.

When a TBLWT is executed, the six LSbs of the Table Pointer register (TBLPTR<5:0>) determine which of the 64 program memory holding registers is written to. When the timed write to program memory begins (via the WR bit), the 16 MSbs of the TBLPTR (TBLPTR<21:6>) determine which program memory block of 64 bytes is written to. For more detail, see Section 6.5 “Writing to Flash Program Memory”.

When an erase of program memory is executed, the 16 MSbs of the Table Pointer register (TBLPTR<21:6>) point to the 64-byte block that will be erased. The Least Significant bits (TBLPTR<5:0>) are ignored.

Figure 6-3 describes the relevant boundaries of TBLPTR based on Flash program memory operations.

---

**TABLE 6-1: TABLE POINTER OPERATIONS WITH TBLRD AND TBLWT INSTRUCTIONS**

<table>
<thead>
<tr>
<th>Example</th>
<th>Operation on Table Pointer</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBLRD*</td>
<td></td>
</tr>
<tr>
<td>TBLRD+</td>
<td></td>
</tr>
<tr>
<td>TBLRD+*</td>
<td></td>
</tr>
<tr>
<td>TBLRD++</td>
<td></td>
</tr>
<tr>
<td>TBLRD*-</td>
<td></td>
</tr>
<tr>
<td>TBLRD*-+</td>
<td></td>
</tr>
<tr>
<td>TBLRD++*</td>
<td></td>
</tr>
<tr>
<td>TBLRD++*</td>
<td></td>
</tr>
<tr>
<td>TBLWT*</td>
<td></td>
</tr>
<tr>
<td>TBLWT+</td>
<td></td>
</tr>
<tr>
<td>TBLWT+*</td>
<td></td>
</tr>
<tr>
<td>TBLWT++</td>
<td></td>
</tr>
</tbody>
</table>

---

**FIGURE 6-3: TABLE POINTER BOUNDARIES BASED ON OPERATION**
6.3 Reading the Flash Program Memory

The TBLRD instruction is used to retrieve data from program memory and places it into data RAM. Table reads from program memory are performed one byte at a time.

TBLPTR points to a byte address in program space. Executing TBLRD places the byte pointed to into TABLAT. In addition, TBLPTR can be modified automatically for the next table read operation.

The internal program memory is typically organized by words. The Least Significant bit of the address selects between the high and low bytes of the word. Figure 6-4 shows the interface between the internal program memory and the TABLAT.

**FIGURE 6-4: READS FROM FLASH PROGRAM MEMORY**

**EXAMPLE 6-1: READING A FLASH PROGRAM MEMORY WORD**

```
MOVLW CODE_ADDR_UPPER  ; Load TBLPTR with the base address of the word
MOVWF TBLPTRU
MOVLW CODE_ADDR_HIGH
MOVWF TBLPTRH
MOVLW CODE_ADDR_LOW
MOVWF TBLPTRL
READ_WORD
TBLRD++                   ; read into TABLAT and increment
MOVF TABLAT, W           ; get data
MOVWF WORD_EVEN
TBLRD++                   ; read into TABLAT and increment
MOVF TABLAT, W           ; get data
MOVF WORD_ODD
```

```
```
6.4 Erasing Flash Program Memory

The minimum erase block is 32 words or 64 bytes. Only through the use of an external programmer, or through ICSP control, can larger blocks of program memory be Bulk Erased. Word Erase in the Flash array is not supported.

When initiating an erase sequence from the microcontroller itself, a block of 64 bytes of program memory is erased. The Most Significant 16 bits of the TBLPTR<21:6> point to the block being erased. TBLPTR<5:0> are ignored.

The EECON1 register commands the erase operation. The EEPGD bit must be set to point to the Flash program memory. The WREN bit must be set to enable write operations. The FREE bit is set to select an erase operation.

For protection, the write initiate sequence for EECON2 must be used.

A long write is necessary for erasing the internal Flash. Instruction execution is halted while in a long write cycle. The long write will be terminated by the internal programming timer.

6.4.1 FLASH PROGRAM MEMORY ERASE SEQUENCE

The sequence of events for erasing a block of internal program memory location is:

1. Load Table Pointer register with address of row being erased.
2. Set the EECON1 register for the erase operation:
   a. set EEPGD bit to point to program memory;
   b. clear the CFGS bit to access program memory;
   c. set WREN bit to enable writes;
   d. set FREE bit to enable the erase.
3. Disable interrupts.
4. Write 55h to EECON2.
5. Write 0AAh to EECON2.
6. Set the WR bit. This will begin the Row Erase cycle.
7. The CPU will stall for duration of the erase (about 2 ms using internal timer).
8. Re-enable interrupts.

**EXAMPLE 6-2: ERASING A FLASH PROGRAM MEMORY ROW**

<table>
<thead>
<tr>
<th>MOV</th>
<th>CODE_ADDR_UPPER</th>
<th>; load TBLPR with the base</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV</td>
<td>TBLPTRU</td>
<td>; address of the memory block</td>
</tr>
<tr>
<td>MOV</td>
<td>CODE_ADDR_HIGH</td>
<td></td>
</tr>
<tr>
<td>MOV</td>
<td>TBLPTRH</td>
<td></td>
</tr>
<tr>
<td>MOV</td>
<td>CODE_ADDR_LOW</td>
<td></td>
</tr>
<tr>
<td>MOV</td>
<td>TBLPTRL</td>
<td></td>
</tr>
<tr>
<td>BSF</td>
<td>EECON1, EEPGD   ; point to Flash program memory</td>
<td></td>
</tr>
<tr>
<td>BCF</td>
<td>EECON1, CFGS    ; access Flash program memory</td>
<td></td>
</tr>
<tr>
<td>BSF</td>
<td>EECON1, WREN    ; enable write to memory</td>
<td></td>
</tr>
<tr>
<td>BSF</td>
<td>EECON1, FREE    ; enable Row Erase operation</td>
<td></td>
</tr>
<tr>
<td>BCF</td>
<td>INTCON, GIE     ; disable interrupts</td>
<td></td>
</tr>
</tbody>
</table>

**Required Sequence**

| MOV | 55h |
| MOV | EECON2 ; write 55h |
| MOV | 0AAh |
| MOV | EECON2 ; write 0AAh |
| BSF | EECON1, WR ; start erase (CPU stall) |
| BSF | INTCON, GIE ; re-enable interrupts |
6.5 Writing to Flash Program Memory

The minimum programming block is 32 words or 64 bytes. Word or byte programming is not supported.

Table writes are used internally to load the holding registers needed to program the Flash memory. There are 64 holding registers used by the table writes for programming.

Since the Table Latch (TABLAT) is only a single byte, the TBLWT instruction may need to be executed 64 times for each programming operation. All of the table write operations will essentially be short writes because only the holding registers are written. At the end of updating the 64 holding registers, the EECON1 register must be written to in order to start the programming operation with a long write.

The long write is necessary for programming the internal Flash. Instruction execution is halted while in a long write cycle. The long write will be terminated by the internal programming timer.

The EEPROM on-chip timer controls the write time. The write/erase voltages are generated by an on-chip charge pump, rated to operate over the voltage range of the device.

Note: The default value of the holding registers on device Resets and after write operations is FFh. A write of FFh to a holding register does not modify that byte. This means that individual bytes of program memory may be modified, provided that the change does not attempt to change any bit from a '0' to a '1'. When modifying individual bytes, it is not necessary to load all 64 holding registers before executing a write operation.

FIGURE 6-5: TABLE WRITES TO FLASH PROGRAM MEMORY

6.5.1 FLASH PROGRAM MEMORY WRITE SEQUENCE

The sequence of events for programming an internal program memory location should be:
1. Read 64 bytes into RAM.
2. Update data values in RAM as necessary.
3. Load Table Pointer register with address being erased.
4. Execute the Row Erase procedure.
5. Load Table Pointer register with address of first byte being written.
6. Write the 64 bytes into the holding registers with auto-increment.
7. Set the EECON1 register for the write operation:
   - set EEPGD bit to point to program memory;
   - clear the CFGS bit to access program memory;
   - set WREN to enable byte writes.
8. Disable interrupts.
9. Write 55h to EECON2.
10. Write 0AAh to EECON2.
11. Set the WR bit. This will begin the write cycle.
12. The CPU will stall for duration of the write (about 2 ms using internal timer).
13. Re-enable interrupts.
14. Verify the memory (table read).

This procedure will require about 18 ms to update one row of 64 bytes of memory. An example of the required code is given in Example 6-3.

Note: Before setting the WR bit, the Table Pointer address needs to be within the intended address range of the 64 bytes in the holding register.
EXAMPLE 6-3: WRITING TO FLASH PROGRAM MEMORY

```
MOVLW D'64 ; number of bytes in erase block
MOVF COUNTER
MOVLW BUFFER_ADDR_HIGH ; point to buffer
MOVF FSR0H
MOVLW BUFFER_ADDR_LOW
MOVF FSR0L
MOVLW CODE_ADDR_UPPER ; Load TBLPTR with the base
MOVF TBLPTRU
MOVLW CODE_ADDR_HIGH
MOVF TBLPTRH
MOVLW CODE_ADDR_LOW
MOVF TBLPTRL

READ_BLOCK

TBLRD*+ ; read into TABLAT, and inc
MOVF TABLAT, W ; get data
MOVF POSTINC0 ; store data
DECF SZ COUNTER ; done?
BRA READ_BLOCK ; repeat

MODIFY_WORD

MOVLW DATA_ADDR_HIGH ; point to buffer
MOVF FSR0H
MOVLW DATA_ADDR_LOW
MOVF FSR0L
MOVLW NEW_DATA_LOW ; update buffer word
MOVF POSTINC0
MOVLW NEW_DATA_HIGH
MOVF INDF0

ERASE_BLOCK

MOVLW CODE_ADDR_UPPER ; load TBLPTR with the base
MOVF TBLPTRU ; address of the memory block
MOVLW CODE_ADDR_HIGH
MOVF TBLPTRH
MOVLW CODE_ADDR_LOW
MOVF TBLPTRL
BSF EECON1, EEPGD ; point to Flash program memory
BCF EECON1, CFGS ; access Flash program memory
BSF EECON1, WREN ; enable write to memory
BSF EECON1, FREE ; enable Row Erase operation
BCF INTCON, GIE ; disable interrupts

Required Sequence

MOVLW 55h ; write 55h
MOVF EECON2
MOVLW 0Ah ; write 0Ah
MOVF EECON2
BSF EECON1, WR ; start erase (CPU stall)
BSF INTCON, GIE ; re-enable interrupts
TBLRD*- ; dummy read decrement
MOVLW BUFFER_ADDR_HIGH
MOVF FSR0H
MOVLW BUFFER_ADDR_LOW
MOVF FSR0L

WRITE_BUFFER_BACK

MOVLW D'64 ; number of bytes in holding register
MOVF COUNTER

WRITE_BYTE_TO_HREGS

MOVF POSTINC0, W ; get low byte of buffer data
MOVF TABLAT ; present data to table latch
TBLWT*+ ; write data, perform a short write
to internal TBLWT holding register.
DECF S Z COUNTER ; loop until buffers are full
BRA WRITE_BYTE_TO_HREGS
```
EXAMPLE 6-3: WRITING TO FLASH PROGRAM MEMORY (CONTINUED)

<table>
<thead>
<tr>
<th>Required Sequence</th>
<th>Required Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVLLW 55h</td>
<td>MOVWF EEC0N2</td>
</tr>
<tr>
<td>MOVLLW 0AAh</td>
<td>MOVWF EEC0N2</td>
</tr>
<tr>
<td>BSF EEC0N1, WRE</td>
<td>BSF EEC0N1, WR</td>
</tr>
<tr>
<td>BCF EEC0N1, GIE</td>
<td>BCF EEC0N1, WRE</td>
</tr>
</tbody>
</table>

6.5.2 WRITE VERIFY

Depending on the application, good programming practice may dictate that the value written to the memory should be verified against the original value. This should be used in applications where excessive writes can stress bits near the specification limit.

6.5.3 UNEXPECTED TERMINATION OF WRITE OPERATION

If a write is terminated by an unplanned event, such as loss of power or an unexpected Reset, the memory location just programmed should be verified and reprogrammed if needed. If the write operation is interrupted by a MCLR Reset, or a WDT Time-out Reset during normal operation, the user can check the WRERR bit and rewrite the location(s) as needed.

6.5.4 PROTECTION AGAINST SPURIOUS WRITES

To protect against spurious writes to Flash program memory, the write initiate sequence must also be followed. See Section 24.0 “Special Features of the CPU” for more detail.

6.6 Flash Program Operation During Code Protection

See Section 24.5 “Program Verification and Code Protection” for details on code protection of Flash program memory.

### TABLE 6-2: REGISTERS ASSOCIATED WITH PROGRAM FLASH MEMORY

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBLPTRU</td>
<td>—</td>
<td>—</td>
<td>bit 21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>TPLTRH</td>
<td>Program Memory Table Pointer High Byte (TBLPTR&lt;15:8&gt;)</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPLTBL</td>
<td>Program Memory Table Pointer High Byte (TBLPTR&lt;7:0&gt;)</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLAT</td>
<td>Program Memory Table Latch</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE/GIEH, PEIE/GIEI</td>
<td>TMR0IE, INTOIE, RBIE, TMR0IF, INTOIF, RBIF</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECON2</td>
<td>EEPROM Control Register 2 (not a physical register)</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECON1</td>
<td>EEPGD, CFGS</td>
<td>—</td>
<td>FREE, WRERR, WREN, WR, RD</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPR2</td>
<td>OSCFIP, CMIF(1)</td>
<td>—</td>
<td>EEIP, BCLIP, HLVDIP, TMR3IP, ECCP1IF(1)</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR2</td>
<td>OSCFIF, CMIF(1)</td>
<td>—</td>
<td>EEIF, BCLIF, HLVDIF, TMR3IF, ECCP1IF(1)</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIE2</td>
<td>OSCFIE, CMIE(1)</td>
<td>—</td>
<td>EEIE, BCLIE, HLVDIE, TMR3IE, ECCP1IE(1)</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used during Flash/EEPROM access.

Note 1: These bits are available in PIC18F4682/4685 devices and reserved in PIC18F2682/2685 devices.
7.0 DATA EEPROM MEMORY

The data EEPROM is a nonvolatile memory array, separate from the data RAM and program memory, that is used for long-term storage of program data. It is not directly mapped in either the register file or program memory space but is indirectly addressed through the Special Function Registers (SFRs). The EEPROM is readable and writable during normal operation over the entire VDD range.

Five SFRs are used to read and write to the data EEPROM as well as the program memory. They are:

- EECON1
- EECON2
- EEDATA
- EEADR
- EEADRH

The data EEPROM allows byte read and write. When interfacing to the data memory block, EEDATA holds the 8-bit data for read/write and the EEADRH:EEADR register pair holds the address of the EEPROM location being accessed.

The EEPROM data memory is rated for high erase/write cycle endurance. A byte write automatically erases the location and writes the new data (erase-before-write). The write time is controlled by an on-chip timer; it will vary with voltage and temperature, as well as from chip to chip. Please refer to parameter D122 (Table 27-1 in Section 27.0 “Electrical Characteristics”) for exact limits.

7.1 EEADR and EEADRH Registers

The EEADRH:EEADR register pair is used to address the data EEPROM for read and write operations. EEADRH holds the two Most Significant bits of the address; the upper 6 bits are ignored. The 10-bit range of the pair can address a memory range of 1024 bytes (00h to 3FFh).

7.2 EECON1 and EECON2 Registers

Access to the data EEPROM is controlled by two registers: EECON1 and EECON2. These are the same registers which control access to the program memory and are used in a similar manner for the data EEPROM.

The EECON1 register (Register 7-1) is the control register for data and program memory access. Control bit EEPGD determines if the access will be to program or data EEPROM memory. When clear, operations will access the data EEPROM memory. When set, program memory is accessed.

Control bit CFGS determines if the access will be to the Configuration registers or to program memory/data EEPROM memory. When set, subsequent operations access Configuration registers. When CFGS is clear, the EEPGD bit selects either program Flash or data EEPROM memory.

The WREN bit, when set, will allow a write operation. On power-up, the WREN bit is clear. The WRERR bit is set in hardware when the WREN bit is set and cleared when the internal programming timer expires and the write operation is complete.

Note: During normal operation, the WRERR is read as ‘1’. This can indicate that a write operation was prematurely terminated by a Reset, or a write operation was attempted improperly.

The WR control bit initiates write operations. The bit cannot be cleared, only set, in software; it is cleared in hardware at the completion of the write operation.

Note: The EEIF interrupt flag bit (PIR2<4>) is set when the write is complete. It must be cleared in software.

Control bits, RD and WR, start read and erase/write operations, respectively. These bits are set by firmware and cleared by hardware at the completion of the operation.

The RD bit cannot be set when accessing program memory (EEPGD = 1). Program memory is read using table read instructions. See Section 6.1 “Table Reads and Table Writes” regarding table reads.

The EECON2 register is not a physical register. It is used exclusively in the memory write and erase sequences. Reading EECON2 will read all ‘0’s.
REGISTER 7-1: EECON1: DATA EEPROM CONTROL REGISTER 1

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEPGD</td>
<td>CFGS</td>
<td>FREE</td>
<td>WRERR</td>
<td>WREN</td>
<td>WR</td>
<td>RD</td>
<td></td>
</tr>
<tr>
<td>R/W-x</td>
<td>R/W-x</td>
<td>U-0</td>
<td>R/W-0</td>
<td>R/W-x</td>
<td>R/W-0</td>
<td>R/S-0</td>
<td>R/S-0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
</table>
| EEPGD: Flash Program or Data EEPROM Memory Select bit
  1 = Access Flash program memory
  0 = Access data EEPROM memory |
| CFGS: Flash Program/Data EEPROM or Configuration Select bit
  1 = Access Configuration registers
  0 = Access Flash program or data EEPROM memory |
| FREE: Flash Row Erase Enable bit
  1 = Erase the program memory row addressed by TBLPTR on the next WR command (cleared by completion of erase operation)
  0 = Perform write-only |
| WRERR: Flash Program/Data EEPROM Error Flag bit(1)
  1 = A write operation is prematurely terminated (any Reset during self-timed programming in normal operation, or an improper write attempt)
  0 = The write operation completed |
| WREN: Flash Program/Data EEPROM Write Enable bit
  1 = Allows write cycles to Flash program/data EEPROM
  0 = Inhibits write cycles to Flash program/data EEPROM |
| WR: Write Control bit
  1 = Initiates a data EEPROM erase/write cycle or a program memory erase cycle or write cycle. (The operation is self-timed and the bit is cleared by hardware once write is complete. The WR bit can only be set (not cleared) in software.)
  0 = Write cycle to the EEPROM is complete |
| RD: Read Control bit
  1 = Initiates an EEPROM read (Read takes one cycle. RD is cleared in hardware. The RD bit can only be set (not cleared) in software. RD bit cannot be set when EEPGD = 1 or CFGS = 1.)
  0 = Does not initiate an EEPROM read |

Note 1: When a WRERR occurs, the EEPGD and CFGS bits are not cleared. This allows tracing of the error condition.
7.3 Reading the Data EEPROM Memory

To read a data memory location, the user must write the address to the EEADRH:EEADR register pair, clear the EE PGD control bit (EECON1<7>) and then set control bit, RD (EECON1<0>). The data is available on the very next instruction cycle; therefore, the EEDATA register can be read by the next instruction. EEDATA will hold this value until another read operation, or until it is written to by the user (during a write operation).

The basic process is shown in Example 7-1.

7.4 Writing to the Data EEPROM Memory

To write an EEPROM data location, the address must first be written to the EEADRH:EEADR register pair and the data written to the EEDATA register. The sequence in Example 7-2 must be followed to initiate the write cycle.

The write will not begin if this sequence is not exactly followed (write 55h to EECON2, write 0AAh to EECON2, then set WR bit) for each byte. It is strongly recommended that interrupts be disabled during this code segment.

Additionally, the WREN bit in EECON1 must be set to enable writes. This mechanism prevents accidental writes to data EEPROM due to unexpected code execution (i.e., runaway programs). The WREN bit should be kept clear at all times, except when updating the EEPROM. The WREN bit is not cleared by hardware.

After a write sequence has been initiated, EECON1, EEADRH:EEADR and EEDATA cannot be modified. The WR bit will be inhibited from being set unless the WREN bit is set. The WREN bit must be set on a previous instruction. Both WR and WREN cannot be set with the same instruction.

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

7.5 Write Verify

Depending on the application, good programming practice may dictate that the value written to the memory should be verified against the original value. This should be used in applications where excessive writes can stress bits near the specification limit.

**EXAMPLE 7-1: DATA EEPROM READ**

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVLW DATA_EE_ADDRH</td>
<td>; Upper bits of Data Memory Address to read</td>
</tr>
<tr>
<td>MOVWF EEA DRD</td>
<td>; Upper bits of Data Memory Address to read</td>
</tr>
<tr>
<td>MOVLW DATA_EE_ADDR</td>
<td>; Lower bits of Data Memory Address to read</td>
</tr>
<tr>
<td>MOVWF EEA DRD</td>
<td>; Lower bits of Data Memory Address to read</td>
</tr>
<tr>
<td>BCF EECON1, EE PDG</td>
<td>; Point to DATA memory</td>
</tr>
<tr>
<td>BCF EECON1, CFGS</td>
<td>; Access EEPROM</td>
</tr>
<tr>
<td>BSF EECON1, RD</td>
<td>; EEPROM Read</td>
</tr>
<tr>
<td>MOVF EEDATA, W</td>
<td>; W = EEDATA</td>
</tr>
</tbody>
</table>

**EXAMPLE 7-2: DATA EEPROM WRITE**

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVLW DATA_EE_ADDRH</td>
<td>; Upper bits of Data Memory Address to write</td>
</tr>
<tr>
<td>MOVWF EEA DRH</td>
<td>; Upper bits of Data Memory Address to write</td>
</tr>
<tr>
<td>MOVLW DATA_EE_ADDR</td>
<td>; Lower bits of Data Memory Address to write</td>
</tr>
<tr>
<td>MOVWF EEA DRD</td>
<td>; Lower bits of Data Memory Address to write</td>
</tr>
<tr>
<td>MOVWF DATA_EE_DATA</td>
<td>; Data Memory Value to write</td>
</tr>
<tr>
<td>BCF EECON1, EE PDG</td>
<td>; Point to DATA memory</td>
</tr>
<tr>
<td>BCF EECON1, CFGS</td>
<td>; Access EEPROM</td>
</tr>
<tr>
<td>BSF EECON1, WREN</td>
<td>; Enable writes</td>
</tr>
<tr>
<td>BCF INTCON, GIE</td>
<td>; Disable Interrupts</td>
</tr>
</tbody>
</table>

**Required Sequence**

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVLW 55h</td>
<td>;</td>
</tr>
<tr>
<td>MOVWF EECON2</td>
<td>; Write 55h</td>
</tr>
<tr>
<td>MOVLW 0AAh</td>
<td>;</td>
</tr>
<tr>
<td>MOVWF EECON2</td>
<td>; Write 0AAh</td>
</tr>
<tr>
<td>BSF EECON1, WR</td>
<td>; Set WR bit to begin write</td>
</tr>
<tr>
<td>BSF INTCON, GIE</td>
<td>; Enable Interrupts</td>
</tr>
<tr>
<td></td>
<td>; User code execution</td>
</tr>
<tr>
<td>BCF EECON1, WREN</td>
<td>; Disable writes on write complete (EEIF set)</td>
</tr>
</tbody>
</table>
7.6  Operation During Code-Protect

Data EEPROM memory has its own code-protect bits in Configuration Words. External read and write operations are disabled if code protection is enabled.

The microcontroller itself can both read and write to the internal Data EEPROM, regardless of the state of the code-protect Configuration bit. Refer to Section 24.0 “Special Features of the CPU” for additional information.

7.7  Protection Against Spurious Write

There are conditions when the device may not want to write to the data EEPROM memory. To protect against spurious EEPROM writes, various mechanisms have been implemented. On power-up, the WREN bit is cleared. In addition, writes to the EEPROM are blocked during the Power-up Timer period (TPWRT, parameter 33).

The write initiate sequence and the WREN bit together help prevent an accidental write during brown-out, power glitch or software malfunction.

EXAMPLE 7-3:  DATA EEPROM REFRESH ROUTINE

```assembly
CLRF EEADR ; Start at address 0
CLRF EADDRH ;
BCF EECON1, CFGS ; Set for memory
BCF EECON1, EEPGD ; Set for Data EEPROM
BCF INTCON, GIE ; Disable interrupts
BSF EECON1, WREN ; Enable writes
Loop ; Loop to refresh array
BSF EECON1, RD ; Read current address
MOVLW 55h ;
MOVF EECON2 ; Write 55h
MOVLW 0AAh ;
MOVF EECON2 ; Write 0AAh
BSF EECON1, WR ; Set WR bit to begin write
BTFSC EECON1, WR ; Wait for write to complete
BRA $+2
INCFSZ EEADR, F ; Increment address
BRA LOOP ; Not zero, do it again
INCFSZ EADDRH, F ; Increment the high address
BRA LOOP ; Not zero, do it again
BCF EECON1, WREN ; Disable writes
BSF INTCON, GIE ; Enable interrupts
```

7.8  Using the Data EEPROM

The data EEPROM is a high-endurance, byte addressable array that has been optimized for the storage of frequently changing information (e.g., program variables or other data that are updated often). Frequently changing values will typically be updated more often than specification D124. If this is not the case, an array refresh must be performed. For this reason, variables that change infrequently (such as constants, IDs, calibration, etc.) should be stored in Flash program memory.

A simple data EEPROM refresh routine is shown in Example 7-3.

Note:  If data EEPROM is only used to store constants and/or data that changes rarely, an array refresh is likely not required. See specification D124.
TABLE 7-1: REGISTERS ASSOCIATED WITH DATA EEPROM MEMORY

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>EEADRH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EEPROM Address Register High Byte 53</td>
</tr>
<tr>
<td>EEADR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EEPROM Address Register Low Byte 53</td>
</tr>
<tr>
<td>EEDATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EEPROM Data Register 53</td>
</tr>
<tr>
<td>EECON2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EEPROM Control Register 2 (not a physical register) 53</td>
</tr>
<tr>
<td>EECON1</td>
<td></td>
<td>EEPGD</td>
<td>CFGS</td>
<td></td>
<td>FREE</td>
<td>WRERR</td>
<td>WREN</td>
<td>WR</td>
<td>RD 53</td>
</tr>
<tr>
<td>IPR2</td>
<td>OSCFIP</td>
<td>CMIP(1)</td>
<td></td>
<td>EEIP</td>
<td>BCLIP</td>
<td>HLVDIP</td>
<td>TMR3IP</td>
<td>ECCP1IP(1)</td>
<td>53</td>
</tr>
<tr>
<td>PIR2</td>
<td>OSCFIF</td>
<td>CMIF(1)</td>
<td></td>
<td>EEIF</td>
<td>BCLIF</td>
<td>HLVDIF</td>
<td>TMR3IF</td>
<td>ECCP1IF(1)</td>
<td>54</td>
</tr>
<tr>
<td>PIE2</td>
<td>OSCFIE</td>
<td>CMIE(1)</td>
<td></td>
<td>EEIE</td>
<td>BCLIE</td>
<td>HLVDIE</td>
<td>TMR3IE</td>
<td>ECCP1IE(1)</td>
<td>54</td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used during Flash/EEPROM access.

Note 1: These bits are available in PIC18F4682/4685 devices and reserved in PIC18F2682/2685 devices.
8.0  8 x 8 HARDWARE MULTIPLIER

8.1  Introduction

All PIC18 devices include an 8 x 8 hardware multiplier as part of the ALU. The multiplier performs an unsigned operation and yields a 16-bit result that is stored in the product register pair, PRODH:PRODL. The multiplier's operation does not affect any flags in the STATUS register.

Making multiplication a hardware operation allows it to be completed in a single instruction cycle. This has the advantages of higher computational throughput and reduced code size for multiplication algorithms and allows the PIC18 devices to be used in many applications previously reserved for digital signal processors. A comparison of various hardware and software multiply operations, along with the savings in memory and execution time, is shown in Table 8-1.

8.2  Operation

Example 8-1 shows the instruction sequence for an 8 x 8 unsigned multiplication. Only one instruction is required when one of the arguments is already loaded in the WREG register.

Example 8-2 shows the sequence to do an 8 x 8 signed multiplication. To account for the signed bits of the arguments, each argument's Most Significant bit (MSb) is tested and the appropriate subtractions are done.

**TABLE 8-1: PERFORMANCE COMPARISON FOR VARIOUS MULTIPLY OPERATIONS**

<table>
<thead>
<tr>
<th>Routine</th>
<th>Multiply Method</th>
<th>Program Memory (Words)</th>
<th>Cycles (Max)</th>
<th>Time @ 40 MHz</th>
<th>Time @ 10 MHz</th>
<th>Time @ 4 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 x 8 unsigned</td>
<td>Without hardware multiply</td>
<td>13</td>
<td>69</td>
<td>6.9 μs</td>
<td>27.6 μs</td>
<td>69 μs</td>
</tr>
<tr>
<td></td>
<td>Hardware multiply</td>
<td>1</td>
<td>1</td>
<td>100 ns</td>
<td>400 ns</td>
<td>1 μs</td>
</tr>
<tr>
<td>8 x 8 signed</td>
<td>Without hardware multiply</td>
<td>33</td>
<td>91</td>
<td>9.1 μs</td>
<td>36.4 μs</td>
<td>91 μs</td>
</tr>
<tr>
<td></td>
<td>Hardware multiply</td>
<td>6</td>
<td>6</td>
<td>600 ns</td>
<td>2.4 μs</td>
<td>6 μs</td>
</tr>
<tr>
<td>16 x 16 unsigned</td>
<td>Without hardware multiply</td>
<td>21</td>
<td>242</td>
<td>24.2 μs</td>
<td>96.8 μs</td>
<td>242 μs</td>
</tr>
<tr>
<td></td>
<td>Hardware multiply</td>
<td>28</td>
<td>28</td>
<td>2.8 μs</td>
<td>11.2 μs</td>
<td>28 μs</td>
</tr>
<tr>
<td>16 x 16 signed</td>
<td>Without hardware multiply</td>
<td>52</td>
<td>254</td>
<td>25.4 μs</td>
<td>102.6 μs</td>
<td>254 μs</td>
</tr>
<tr>
<td></td>
<td>Hardware multiply</td>
<td>35</td>
<td>40</td>
<td>4.0 μs</td>
<td>16.0 μs</td>
<td>40 μs</td>
</tr>
</tbody>
</table>

**EXAMPLE 8-1: 8 x 8 UNSIGNED MULTIPLY ROUTINE**

```
MOVW ARG1, W ;
MULWF ARG2 ; ARG1 * ARG2 -> PRODH:PRODL
```

**EXAMPLE 8-2: 8 x 8 SIGNED MULTIPLY ROUTINE**

```
MOVF ARG1, W
MULWF ARG2 ; ARG1 * ARG2 -> PRODH:PRODL
BTFSC ARG2, SB ; Test Sign Bit
SUBWF PRODH, F ; PRODH = PRODH ; - ARG1
MOVF ARG2, W
BTFSC ARG1, SB ; Test Sign Bit
SUBWF PRODH, F ; PRODH = PRODH ; - ARG2
```
Example 8-3 shows the sequence to do a 16 x 16 unsigned multiplication. Equation 8-1 shows the algorithm that is used. The 32-bit result is stored in four registers (RES3:RES0).

**EQUATION 8-1: 16 x 16 UNSIGNED MULTIPLICATION ALGORITHM**

$$
RES3:RES0 = ARG1H:ARG1L \cdot ARG2H:ARG2L = (ARG1H \cdot ARG2H \cdot 2^{16}) + (ARG1H \cdot ARG2L \cdot 2^{8}) + (ARG1L \cdot ARG2H \cdot 2^{8}) + (ARG1L \cdot ARG2L)
$$

**EXAMPLE 8-3: 16 x 16 UNSIGNED MULTIPLY ROUTINE**

```assembly
MOVF ARG1L, W
MULWF ARG2L ; ARG1L * ARG2L -> PRODH:PRODL
MOVFF PRODH, RES1 ;
MOVFF PRODL, RES0 ;
;
MOVF ARG1H, W
MULWF ARG2H ; ARG1H * ARG2H -> PRODH:PRODL
MOVFF PRODH, RES3 ;
MOVFF PRODL, RES2 ;
;
MOVF ARG1L, W
MULWF ARG2H ; ARG1L * ARG2H -> PRODH:PRODL
MOV PRODL, W ;
ADDWF RES1, F ; Add cross
MOVFF PRODH, W ; products
ADDWF RES3, F ;
;
MOVF ARG1H, W
MULWF ARG2L ; ARG1H * ARG2L -> PRODH:PRODL
MOV PRODL, W ;
ADDWF RES1, F ; Add cross
MOVFF PRODH, W ; products
ADDWF RES2, F ;
CLRF WREG ;
ADDWF RES3, F ;
;
MOVF ARG1H, W
MULWF ARG2L ; ARG1H * ARG2L -> PRODH:PRODL
MOV PRODL, W ;
ADDWF RES1, F ; Add cross
MOVFF PRODH, W ; products
ADDWF RES2, F ;
CLRF WREG ;
ADDWF RES3, F ;
;
BTFSS ARG2H, 7 ; ARG2H:ARG2L neg?
BRA SIGN_ARG1 ; no, check ARG1
MOVF ARG1H, W
SUBWF RES3 ;
MOVF ARG1H, W
SUBWFB RES2 ;
MOVF ARG1L, W
SUBWFB RES3 ;
;
SIGN_ARG1
BTFSS ARG1H, 7 ; ARG1H:ARG1L neg?
BRA CONT_CODE ; no, done
MOV ARG1L, W
SUBWF RES2 ;
MOV ARG2H, W
SUBWFB RES3 ;
;
CONT_CODE :
```

Example 8-4 shows the sequence to do a 16 x 16 signed multiply. Equation 8-2 shows the algorithm used. The 32-bit result is stored in four registers (RES3:RES0). To account for the signed bits of the arguments, the MSb for each argument pair is tested and the appropriate subtractions are done.

**EQUATION 8-2: 16 x 16 SIGNED MULTIPLICATION ALGORITHM**

$$
RES3:RES0 = ARG1H:ARG1L \cdot ARG2H:ARG2L = (ARG1H \cdot ARG2H \cdot 2^{16}) + (ARG1H \cdot ARG2L \cdot 2^{8}) + (ARG1L \cdot ARG2H \cdot 2^{8}) + (ARG1L \cdot ARG2L) + (-1 \cdot ARG2H<7> \cdot ARG1H:ARG1L \cdot 2^{16}) + (-1 \cdot ARG1H<7> \cdot ARG2H:ARG2L \cdot 2^{8})
$$

**EXAMPLE 8-4: 16 x 16 SIGNED MULTIPLY ROUTINE**

```assembly
MOVF ARG1L, W
MULWF ARG2L ; ARG1L * ARG2L -> PRODH:PRODL
MOVFF PRODH, RES1 ;
MOVFF PRODL, RES0 ;
;
MOVF ARG1H, W
MULWF ARG2H ; ARG1H * ARG2H -> PRODH:PRODL
MOVFF PRODH, RES3 ;
MOVFF PRODL, RES2 ;
;
MOVF ARG1L, W
MULWF ARG2H ; ARG1L * ARG2H -> PRODH:PRODL
MOVFF PRODL, RES1 ;
MOVFF PRODH, RES0 ;
;
MOVF ARG1H, W
MULWF ARG2L ; ARG1H * ARG2L -> PRODH:PRODL
MOV PRODL, W ;
ADDWF RES1, F ; Add cross
MOVFF PRODH, W ; products
ADDWF RES3, F ;
CLRF WREG ;
ADDWF RES3, F ;
;
MOVF ARG1H, W
MULWF ARG2L ; ARG1H * ARG2L -> PRODH:PRODL
MOV PRODL, W ;
ADDWF RES1, F ; Add cross
MOVFF PRODH, W ; products
ADDWF RES2, F ;
CLRF WREG ;
ADDWF RES3, F ;
;
BTFSS ARG2H, 7 ; ARG2H:ARG2L neg?
BRA SIGN_ARG1 ; no, check ARG1
MOVF ARG1L, W
SUBWF RES3 ;
MOVF ARG1H, W
SUBWFB RES2 ;
MOVF ARG1L, W
SUBWFB RES3 ;
;
SIGN_ARG1
BTFSS ARG1H, 7 ; ARG1H:ARG1L neg?
BRA CONT_CODE ; no, done
MOV ARG1L, W
SUBWF RES2 ;
MOV ARG2H, W
SUBWFB RES3 ;
;
CONT_CODE :
```
The PIC18F2682/2685/4682/4685 devices have multiple interrupt sources and an interrupt priority feature that allows each interrupt source to be assigned a high priority level or a low priority level. The high priority interrupt vector is at 000008h and the low priority interrupt vector is at 000018h. High priority interrupt events will interrupt any low priority interrupts that may be in progress.

There are ten registers which are used to control interrupt operation. These registers are:

- RCON
- INTCON
- INTCON2
- INTCON3
- PIR1, PIR2, PIR3
- PIE1, PIE2, PIE3
- IPR1, IPR2, IPR3

It is recommended that the Microchip header files supplied with MPLAB® IDE be used for the symbolic bit names in these registers. This allows the assembler/compiler to automatically take care of the placement of these bits within the specified register.

Each interrupt source has three bits to control its operation. The functions of these bits are:

- Flag bit to indicate that an interrupt event occurred
- Enable bit that allows program execution to branch to the interrupt vector address when the flag bit is set
- Priority bit to select high priority or low priority

The interrupt priority feature is enabled by setting the IPEN bit (RCON<7>). When interrupt priority is enabled, there are two bits which enable interrupts globally. Setting the GIEH bit (INTCON<7>) enables all interrupts that have the priority bit set (high priority). Setting the GIEL bit (INTCON<6>) enables all interrupts that have the priority bit cleared (low priority). When the interrupt flag, enable bit and appropriate global interrupt enable bit are set, the interrupt will vector immediately to address 000008h or 000018h, depending on the priority bit setting. Individual interrupts can be disabled through their corresponding enable bits.

When the IPEN bit is cleared (default state), the interrupt priority feature is disabled and interrupts are compatible with PIC® mid-range devices. In Compatibility mode, the interrupt priority bits for each source have no effect. INTCON<6> is the PEIE bit, which enables/disables all peripheral interrupt sources. INTCON<7> is the GIE bit, which enables/disables all interrupt sources. All interrupts branch to address 000008h in Compatibility mode.

When an interrupt is responded to, the global interrupt enable bit is cleared to disable further interrupts. If the IPEN bit is cleared, this is the GIE bit. If interrupt priority levels are used, this will be either the GIEH or GIEL bit. High priority interrupt sources can interrupt a low priority interrupt. Low priority interrupts are not processed while high priority interrupts are in progress.

The return address is pushed onto the stack and the PC is loaded with the interrupt vector address (000008h or 000018h). Once in the Interrupt Service Routine, the source(s) of the interrupt can be determined by polling the interrupt flag bits. The interrupt flag bits must be cleared in software before re-enabling interrupts to avoid recursive interrupts.

The "return from interrupt" instruction, RETFIE, exits the interrupt routine and sets the GIE bit (GIEH or GIEL if priority levels are used), which re-enables interrupts.

For external interrupt events, such as the INT pins or the PORTB input change interrupt, the interrupt latency will be three to four instruction cycles. The exact latency is the same for one or two-cycle instructions. Individual interrupt flag bits are set, regardless of the status of their corresponding enable bit or the GIE bit.

**Note:** Do not use the MOVFF instruction to modify any of the interrupt control registers while any interrupt is enabled. Doing so may cause erratic microcontroller behavior.
FIGURE 9-1: INTERRUPT LOGIC

- Peripheral Interrupt Flag bit
- Peripheral Interrupt Enable bit
- Peripheral Interrupt Priority bit

- TMR1F
- TMR1E
- TMR1P
- XXXXF
- XXXXE
- XXXXP

- Additional Peripheral Interrupts

- High Priority Interrupt Generation
- Low Priority Interrupt Generation

- Wake-up if in Sleep Mode
- Interrupt to CPU Vector to Location 0008h
- PEIE/GIEL
- GIE/GIEH

- TMR0IE
- TMR0IF
- TMR0IP
- INT0IF
- INT0IE
- INT0IP
- INT1IF
- INT1IE
- INT1IP
- INT2IF
- INT2IE
- INT2IP
- RBIE
- RBIP
- INT0IF
- INT0IE
- INT0IP

- IPEN
- XXXXIF
- XXXXIE
- XXXXIP
- INT0IF
- INT0IE
- INT0IP
- INT1IF
- INT1IE
- INT1IP
- INT2IF
- INT2IE
- INT2IP
- RBIE
- RBIP
- INT0IF
- INT0IE
- INT0IP
- INT1IF
- INT1IE
- INT1IP
- INT2IF
- INT2IE
- INT2IP
9.1 INTCON Registers

The INTCON registers are readable and writable registers, which contain various enable, priority and flag bits.

Note: Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global interrupt enable bit. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt. This feature allows for software polling.

REGISTER 9-1: INTCON: INTERRUPT CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF(1)</td>
</tr>
</tbody>
</table>

bit 7  
GIE/GIEH: Global Interrupt Enable bit

When IPEN = 0:
1 = Enables all unmasked interrupts
0 = Disables all interrupts

When IPEN = 1:
1 = Enables all high priority interrupts
0 = Disables all high priority interrupts

bit 6  
PEIE/GIEL: Peripheral Interrupt Enable bit

When IPEN = 0:
1 = Enables all unmasked peripheral interrupts
0 = Disables all peripheral interrupts

When IPEN = 1:
1 = Enables all low priority peripheral interrupts
0 = Disables all low priority peripheral interrupts

bit 5  
TMR0IE: TMR0 Overflow Interrupt Enable bit

1 = Enables the TMR0 overflow interrupt
0 = Disables the TMR0 overflow interrupt

bit 4  
INT0IE: INT0 External Interrupt Enable bit

1 = Enables the INT0 external interrupt
0 = Disables the INT0 external interrupt

bit 3  
RBIE: RB Port Change Interrupt Enable bit

1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2  
TMR0IF: TMR0 Overflow Interrupt Flag bit

1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow

bit 1  
INT0IF: INT0 External Interrupt Flag bit

1 = The INT0 external interrupt occurred (must be cleared in software)
0 = The INT0 external interrupt did not occur

bit 0  
RBIF: RB Port Change Interrupt Flag bit(1)

1 = At least one of the RB7:RB4 pins changed state (must be cleared in software)
0 = None of the RB7:RB4 pins have changed state

Note 1: A mismatch condition will continue to set this bit. Reading PORTB will end the mismatch condition and allow the bit to be cleared.

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

Note 1: A mismatch condition will continue to set this bit. Reading PORTB will end the mismatch condition and allow the bit to be cleared.
### REGISTER 9-2: INTCON2: INTERRUPT CONTROL REGISTER 2

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBPU</td>
<td>INTEDG0</td>
</tr>
<tr>
<td>R/W-1</td>
<td>R/W-1</td>
</tr>
</tbody>
</table>

**Legend:**
- **R** = Readable bit
- **W** = Writable 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**
- **RBPU**: PORTB Pull-up Enable bit
  - 1 = All PORTB pull-ups are disabled
  - 0 = PORTB pull-ups are enabled by individual port latch values

**bit 6**
- **INTEDG0**: External Interrupt 0 Edge Select bit
  - 1 = Interrupt on rising edge
  - 0 = Interrupt on falling edge

**bit 5**
- **INTEDG1**: External Interrupt 1 Edge Select bit
  - 1 = Interrupt on rising edge
  - 0 = Interrupt on falling edge

**bit 4**
- **INTEDG2**: External Interrupt 2 Edge Select bit
  - 1 = Interrupt on rising edge
  - 0 = Interrupt on falling edge

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

**bit 2**
- **TMR0IP**: TMR0 Overflow Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

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

**bit 0**
- **RBIP**: RB Port Change Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

**Note:** Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global interrupt enable bit. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt. This feature allows for software polling.
**REGISTER 9-3: INTCON3: INTERRUPT CONTROL REGISTER 3**

<table>
<thead>
<tr>
<th>R/W-1</th>
<th>R/W-1</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT2IP</td>
<td>INT1IP</td>
<td>—</td>
<td>INT2IE</td>
<td>INT1IE</td>
<td>—</td>
<td>INT2IF</td>
<td>INT1IF</td>
</tr>
</tbody>
</table>

*Legend:*
- **R** = Readable bit
- **W** = Writable 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**
- **INT2IP**: INT2 External Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

**bit 6**
- **INT1IP**: INT1 External Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

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

**bit 4**
- **INT2IE**: INT2 External Interrupt Enable bit
  - 1 = Enables the INT2 external interrupt
  - 0 = Disables the INT2 external interrupt

**bit 3**
- **INT1IE**: INT1 External Interrupt Enable bit
  - 1 = Enables the INT1 external interrupt
  - 0 = Disables the INT1 external interrupt

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

**bit 1**
- **INT2IF**: INT2 External Interrupt Flag bit
  - 1 = The INT2 external interrupt occurred (must be cleared in software)
  - 0 = The INT2 external interrupt did not occur

**bit 0**
- **INT1IF**: INT1 External Interrupt Flag bit
  - 1 = The INT1 external interrupt occurred (must be cleared in software)
  - 0 = The INT1 external interrupt did not occur

**Note:** Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global interrupt enable bit. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt. This feature allows for software polling.
9.2 PIR Registers

The PIR registers contain the individual flag bits for the peripheral interrupts. Due to the number of peripheral interrupt sources, there are two Peripheral Interrupt Request (Flag) registers (PIR1, PIR2).

Note 1: Interrupt flag bits are set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global interrupt enable bit, GIE (INTCON<7>).

2: User software should ensure the appropriate interrupt flag bits are cleared prior to enabling an interrupt and after servicing that interrupt.

REGISTER 9-4: PIR1: PERIPHERAL INTERRUPT REQUEST (FLAG) REGISTER 1

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit   W = Writable 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  PSPIF: Parallel Slave Port Read/Write Interrupt Flag bit(1)
1 = A read or a write operation has taken place (must be cleared in software)
0 = No read or write has occurred

bit 6  ADIF: A/D Converter Interrupt Flag bit
1 = An A/D conversion completed (must be cleared in software)
0 = The A/D conversion is not complete

bit 5  RCIF: EUSART Receive Interrupt Flag bit
1 = The EUSART receive buffer, RCREG, is full (cleared when RCREG is read)
0 = The EUSART receive buffer is empty

bit 4  TXIF: EUSART Transmit Interrupt Flag bit
1 = The EUSART transmit buffer, TXREG, is empty (cleared when TXREG is written)
0 = The EUSART transmit buffer is full

bit 3  SSPIF: Master Synchronous Serial Port Interrupt Flag bit
1 = The transmission/reception is complete (must be cleared in software)
0 = Waiting to transmit/receive

bit 2  CCP1IF: CCP1 Interrupt Flag bit

Capture mode:
1 = A TMR1 register capture occurred (must be cleared in software)
0 = No TMR1 register capture occurred

Compare mode:
1 = A TMR1 register compare match occurred (must be cleared in software)
0 = No TMR1 register compare match occurred

PWM mode:
Unused in this mode.

bit 1  TMR2IF: TMR2 to PR2 Match Interrupt Flag bit
1 = TMR2 to PR2 match occurred (must be cleared in software)
0 = No TMR2 to PR2 match occurred

bit 0  TMR1IF: TMR1 Overflow Interrupt Flag bit
1 = TMR1 register overflowed (must be cleared in software)
0 = TMR1 register did not overflow

Note 1: This bit is reserved on PIC18F2682/2685 devices; always maintain this bit clear.
## PIR2: PERIPHERAL INTERRUPT REQUEST (FLAG) REGISTER 2

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSCFIF: Oscillator Fail Interrupt Flag bit</td>
<td>CMIF: Comparator Interrupt Flag bit(1)</td>
<td>Unimplemented: Read as '0'</td>
<td>EEIF: Data EEPROM/Flash Write Operation Interrupt Flag bit</td>
<td>BCLIF: Bus Collision Interrupt Flag bit</td>
<td>HLVDIF: High/Low-Voltage Detect Interrupt Flag bit</td>
<td>TMR3IF: TMR3 Overflow Interrupt Flag bit</td>
<td>ECCP1IF: ECCP1 Interrupt Flag bit(1)</td>
</tr>
</tbody>
</table>

### Bit Legend
- **R** = Readable bit
- **W** = Writable bit
- **U** = Unimplemented bit, read as '0'
- \(-n\) = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- \(x\) = Bit is unknown

### Bit Descriptions
- **bit 7**:
  - **OSCFIF**: Oscillator Fail Interrupt Flag bit
  - 1 = Device oscillator failed, clock input has changed to INTOSC (must be cleared in software)
  - 0 = Device clock operating

- **bit 6**:
  - **CMIF**: Comparator Interrupt Flag bit(1)
  - 1 = Comparator input has changed (must be cleared in software)
  - 0 = Comparator input has not changed

- **bit 5**:
  - **EEIF**: Data EEPROM/Flash Write Operation Interrupt Flag bit
  - 1 = The write operation is complete (must be cleared in software)
  - 0 = The write operation is not complete or has not been started

- **bit 4**:
  - **BCLIF**: Bus Collision Interrupt Flag bit
  - 1 = A bus collision occurred (must be cleared in software)
  - 0 = No bus collision occurred

- **bit 3**:
  - **HLVDIF**: High/Low-Voltage Detect Interrupt Flag bit
  - 1 = A high/low-voltage condition occurred (must be cleared in software)
  - 0 = The device voltage is above the High/Low-Voltage Detect trip point

- **bit 2**:
  - **TMR3IF**: TMR3 Overflow Interrupt Flag bit
  - 1 = TMR3 register overflowed (must be cleared in software)
  - 0 = TMR3 register did not overflow

- **bit 1**:
  - **ECCP1IF**: ECCP1 Interrupt Flag bit(1)
  - Capture mode:
    - 1 = A TMR1 register capture occurred (must be cleared in software)
    - 0 = No TMR1 register capture occurred
  - Compare mode:
    - 1 = A TMR1 register compare match occurred (must be cleared in software)
    - 0 = No TMR1 register compare match occurred
  - PWM mode:
    - Unused in this mode.

### Note 1:
These bits are available in PIC18F4682/4685 and reserved in PIC18F2682/2685 devices.
**REGISTER 9-6:  PIR3: PERIPHERAL INTERRUPT REQUEST (FLAG) REGISTER 3**

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRXIF</td>
<td></td>
<td>WAKIF</td>
<td>ERRIF</td>
<td>TXB2IF</td>
<td>TXB1IF</td>
<td>TXB0IF</td>
<td>RXB1IF</td>
<td>RXB0IF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 1,2</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRXIF</td>
<td></td>
<td>WAKIF</td>
<td>ERRIF</td>
<td>TXBnIF</td>
<td>TXB1IF</td>
<td>TXB0IF</td>
<td>RXBnIF</td>
<td>FIFOWMIF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:

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

<table>
<thead>
<tr>
<th>bit 7</th>
<th>IRXIF: CAN Invalid Received Message Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>An invalid message has occurred on the CAN bus</td>
</tr>
<tr>
<td>0</td>
<td>No invalid message on CAN bus</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 6</th>
<th>WAKIF: CAN bus Activity Wake-up Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Activity on CAN bus has occurred</td>
</tr>
<tr>
<td>0</td>
<td>No activity on CAN bus</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 5</th>
<th>ERRIF: CAN bus Error Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>An error has occurred in the CAN module (multiple sources)</td>
</tr>
<tr>
<td>0</td>
<td>No CAN module errors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 4</th>
<th>TXB2IF: CAN Transmit Buffer 2 Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transmit Buffer 2 has completed transmission of a message and may be reloaded</td>
</tr>
<tr>
<td>0</td>
<td>Transmit Buffer 2 has not completed transmission of a message</td>
</tr>
</tbody>
</table>

*When CAN is in Mode 0:*

<table>
<thead>
<tr>
<th>bit 3</th>
<th>TXB1IF: CAN Transmit Buffer 1 Interrupt Flag bit(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transmit Buffer 1 has completed transmission of a message and may be reloaded</td>
</tr>
<tr>
<td>0</td>
<td>Transmit Buffer 1 has not completed transmission of a message</td>
</tr>
</tbody>
</table>

*When CAN is in Mode 1 or 2:*

<table>
<thead>
<tr>
<th>bit 2</th>
<th>TXB0IF: CAN Transmit Buffer 0 Interrupt Flag bit(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transmit Buffer 0 has completed transmission of a message and may be reloaded</td>
</tr>
<tr>
<td>0</td>
<td>Transmit Buffer 0 has not completed transmission of a message</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1</th>
<th>RXB1IF: CAN Receive Buffer 1 Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Receive Buffer 1 has received a new message</td>
</tr>
<tr>
<td>0</td>
<td>Receive Buffer 1 has not received a new message</td>
</tr>
</tbody>
</table>

*When CAN is in Mode 1 or 2:*

<table>
<thead>
<tr>
<th>bit 0</th>
<th>RXB0IF: CAN Receive Buffer 0 Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Receive Buffer 0 has received a new message</td>
</tr>
<tr>
<td>0</td>
<td>Receive Buffer 0 has not received a new message</td>
</tr>
</tbody>
</table>

*Unimplemented: Read as '0'*

*When CAN is in Mode 2:*

<table>
<thead>
<tr>
<th>bit 7</th>
<th>FIFOWMIF: FIFO Watermark Interrupt Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FIFO high watermark is reached</td>
</tr>
<tr>
<td>0</td>
<td>FIFO high watermark is not reached</td>
</tr>
</tbody>
</table>

**Note 1:** In CAN Mode 1 and 2, these bits are forced to ‘0’.
9.3 PIE Registers

The PIE registers contain the individual enable bits for the peripheral interrupts. Due to the number of peripheral interrupt sources, there are two Peripheral Interrupt Enable registers (PIE1, PIE2). When IPEN = 0, the PEIE bit must be set to enable any of these peripheral interrupts.

REGISTER 9-7: PIE1: PERIPHERAL INTERRUPT ENABLE REGISTER 1

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  
W = Writable 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  
**PSPIE**: Parallel Slave Port Read/Write Interrupt Enable bit(1)  
1 = Enables the PSP read/write interrupt  
0 = Disables the PSP read/write interrupt

bit 6  
**ADIE**: A/D Converter Interrupt Enable bit  
1 = Enables the A/D interrupt  
0 = Disables the A/D interrupt

bit 5  
**RCIE**: EUSART Receive Interrupt Enable bit  
1 = Enables the EUSART receive interrupt  
0 = Disables the EUSART receive interrupt

bit 4  
**TXIE**: EUSART Transmit Interrupt Enable bit  
1 = Enables the EUSART transmit interrupt  
0 = Disables the EUSART transmit interrupt

bit 3  
**SSPIE**: Master Synchronous Serial Port Interrupt Enable bit  
1 = Enables the MSSP interrupt  
0 = Disables the MSSP interrupt

bit 2  
**CCP1IE**: CCP1 Interrupt Enable bit  
1 = Enables the CCP1 interrupt  
0 = Disables the CCP1 interrupt

bit 1  
**TMR2IE**: TMR2 to PR2 Match Interrupt Enable bit  
1 = Enables the TMR2 to PR2 match interrupt  
0 = Disables the TMR2 to PR2 match interrupt

bit 0  
**TMR1IE**: TMR1 Overflow Interrupt Enable bit  
1 = Enables the TMR1 overflow interrupt  
0 = Disables the TMR1 overflow interrupt

**Note 1**: This bit is reserved on PIC18F2682/2685 devices; always maintain this bit clear.
REGISTER 9-8: PIE2: PERIPHERAL INTERRUPT ENABLE REGISTER 2

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Value at POR</th>
<th>Enabled</th>
<th>Disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>OSCFIE: Oscillator Fail Interrupt Enable bit</td>
<td>1</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>6</td>
<td>CMIE: Comparator Interrupt Enable bit</td>
<td></td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>5</td>
<td>Unimplemented: Read as '0'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>EEIE: Data EEPROM/Flash Write Operation</td>
<td></td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td></td>
<td>Interrupt Enable bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BCLIE: Bus Collision Interrupt Enable bit</td>
<td></td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>2</td>
<td>HLVDIE: High/Low-Voltage Detect Interrupt</td>
<td></td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td></td>
<td>Enable bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TMR3IE: TMR3 Overflow Interrupt Enable bit</td>
<td></td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>0</td>
<td>ECCP1IE: ECCP1 Interrupt Enable bit</td>
<td></td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

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

Note 1: These bits are available on PIC18F4682/4685 devices only.
REGISTER 9-9: PIE3: PERIPHERAL INTERRUPT ENABLE REGISTER 3

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IRXIE</td>
<td>WAKIE</td>
<td>ERRIE</td>
<td>TXB2IE</td>
<td>TXB1IE</td>
<td>TXBOIE</td>
<td>RXB1IE</td>
<td>RXB0IE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 1</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IRXIE</td>
<td>WAKIE</td>
<td>ERRIE</td>
<td>TXBnIE</td>
<td>TXB1IE</td>
<td>TXBOIE</td>
<td>RXBnIE</td>
<td>FIFOWMIE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 0</th>
</tr>
</thead>
</table>

Legend:
- R = Readable bit
- W = Writable 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  IRXIE: CAN Invalid Received Message Interrupt Enable bit
   1 = Enable invalid message received interrupt
   0 = Disable invalid message received interrupt

bit 6  WAKIE: CAN bus Activity Wake-up Interrupt Enable bit
   1 = Enable bus activity wake-up interrupt
   0 = Disable bus activity wake-up interrupt

bit 5  ERRIE: CAN bus Error Interrupt Enable bit
   1 = Enable CAN bus error interrupt
   0 = Disable CAN bus error interrupt

bit 4  When CAN is in Mode 0:
   TXB2IE: CAN Transmit Buffer 2 Interrupt Enable bit
   1 = Enable Transmit Buffer 2 interrupt
   0 = Disable Transmit Buffer 2 interrupt

   When CAN is in Mode 1 or 2:
   TXBnIE: CAN Transmit Buffer Interrupts Enable bit
   1 = Enable transmit buffer interrupt; individual interrupt is enabled by TXBIE and BIE0
   0 = Disable all transmit buffer interrupts

bit 3  TXB1IE: CAN Transmit Buffer 1 Interrupt Enable bit
   1 = Enable Transmit Buffer 1 interrupt
   0 = Disable Transmit Buffer 1 interrupt

bit 2  TXBOIE: CAN Transmit Buffer 0 Interrupt Enable bit
   1 = Enable Transmit Buffer 0 interrupt
   0 = Disable Transmit Buffer 0 interrupt

bit 1  When CAN is in Mode 0:
   RXB1IE: CAN Receive Buffer 1 Interrupt Enable bit
   1 = Enable Receive Buffer 1 interrupt
   0 = Disable Receive Buffer 1 interrupt

   When CAN is in Mode 1 or 2:
   RXBnIE: CAN Receive Buffer Interrupts Enable bit
   1 = Enable receive buffer interrupt; individual interrupt is enabled by BIE0
   0 = Disable all receive buffer interrupts

bit 0  When CAN is in Mode 0:
   RXBOIE: CAN Receive Buffer 0 Interrupt Enable bit
   1 = Enable Receive Buffer 0 interrupt
   0 = Disable Receive Buffer 0 interrupt

   When CAN is in Mode 1:
   Unimplemented: Read as '0'

   When CAN is in Mode 2:
   FIFOWMIE: FIFO Watermark Interrupt Enable bit
   1 = Enable FIFO watermark interrupt
   0 = Disable FIFO watermark interrupt

Note 1: In CAN Mode 1 and 2, these bits are forced to '0'.
9.4 IPR Registers

The IPR registers contain the individual priority bits for the peripheral interrupts. Due to the number of peripheral interrupt sources, there are two Peripheral Interrupt Priority registers (IPR1, IPR2). Using the priority bits requires that the Interrupt Priority Enable (IPEN) bit be set.

REGISTER 9-10: IPR1: PERIPHERAL INTERRUPT PRIORITY REGISTER 1

<table>
<thead>
<tr>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>PSPIP: Parallel Slave Port Read/Write Interrupt Priority bit(1)</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>6</td>
<td>ADIP: A/D Converter Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>5</td>
<td>RCIP: EUSART Receive Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>4</td>
<td>TXIP: EUSART Transmit Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>3</td>
<td>SSPIP: Master Synchronous Serial Port Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>2</td>
<td>CCP1IP: CCP1 Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>1</td>
<td>TMR2IP: TMR2 to PR2 Match Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
<tr>
<td>0</td>
<td>TMR1IP: TMR1 Overflow Interrupt Priority bit</td>
<td>1 = High priority, 0 = Low priority</td>
</tr>
</tbody>
</table>

Note 1: This bit is reserved on PIC18F2682/2685 devices; always maintain this bit clear.
## REGISTER 9-11:  IPR2: PERIPHERAL INTERRUPT PRIORITY REGISTER 2

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Value at POR</th>
<th>Bit</th>
<th>Description</th>
<th>Value at POR</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>OSCFIP: Oscillator Fail Interrupt Priority bit</td>
<td>1 = High priority</td>
<td>6</td>
<td>CMIP: Comparator Interrupt Priority bit(1)</td>
<td>1 = High priority</td>
</tr>
<tr>
<td></td>
<td>0 = Low priority</td>
<td></td>
<td></td>
<td>0 = Low priority</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Unimplemented: Read as ‘0’</td>
<td></td>
<td>4</td>
<td>EEIP: Data EEPROM/Flash Write Operation Interrupt Priority bit</td>
<td>1 = High priority</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 = Low priority</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BCLIP: Bus Collision Interrupt Priority bit</td>
<td>1 = High priority</td>
<td>2</td>
<td>HLVDIP: High/Low-Voltage Detect Interrupt Priority bit</td>
<td>1 = High priority</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Low priority</td>
<td></td>
<td>0 = Low priority</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TMR3IP: TMR3 Overflow Interrupt Priority bit</td>
<td>1 = High priority</td>
<td>0</td>
<td>ECCP1IP: ECCP1 Interrupt Priority bit(1)</td>
<td>1 = High priority</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Low priority</td>
<td></td>
<td>0 = Low priority</td>
<td></td>
</tr>
</tbody>
</table>

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

Note 1: These bits are available on PIC18F4682/4685 devices only.
## REGISTER 9-12: IPR3: PERIPHERAL INTERRUPT PRIORITY REGISTER 3

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRXIP</td>
<td>WAKIP</td>
<td>ERRIP</td>
<td>TXB2IP</td>
<td>TXB1IP</td>
<td>TXB0IP</td>
<td>TXB1IP</td>
<td>RXB1IP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 1,2</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRXIP</td>
<td>WAKIP</td>
<td>ERRIP</td>
<td>TXBnIP</td>
<td>TXB1IP</td>
<td>TXB0IP</td>
<td>RXBnIP</td>
<td>FIFOWMIP</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>bit 7</th>
<th><strong>IRXIP</strong>: CAN Invalid Received Message Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 6</th>
<th><strong>WAKIP</strong>: CAN bus Activity Wake-up Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 5</th>
<th><strong>ERRIP</strong>: CAN bus Error Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 4</th>
<th>When CAN is in Mode 0: <strong>TXB2IP</strong>: CAN Transmit Buffer 2 Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

When CAN is in Mode 1 or 2:
<table>
<thead>
<tr>
<th>bit 3</th>
<th><strong>TXBnIP</strong>: CAN Transmit Buffer Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 2</th>
<th><strong>TXB0IP</strong>: CAN Transmit Buffer 0 Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1</th>
<th>When CAN is in Mode 0: <strong>RXB1IP</strong>: CAN Receive Buffer 1 Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

When CAN is in Mode 1 or 2:
<table>
<thead>
<tr>
<th>bit 0</th>
<th><strong>RXBnIP</strong>: CAN Receive Buffer Interrupts Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 0</th>
<th>When CAN is in Mode 0: <strong>RXB0IP</strong>: CAN Receive Buffer 0 Interrupt Priority bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>= High priority</td>
</tr>
<tr>
<td>0</td>
<td>= Low priority</td>
</tr>
</tbody>
</table>

When CAN is in Mode 1:
| **Unimplemented**: Read as ‘0’ |

When CAN is in Mode 2:
| **FIFOWMIP**: FIFO Watermark Interrupt Priority bit |
| 1 = High priority |
| 0 = Low priority |

**Note 1**: In CAN Mode 1 and 2, these bits are forced to ‘0’. 
The RCON register contains flag bits which are used to determine the cause of the last Reset or wake-up from Idle or Sleep modes. RCON also contains the IPEN bit which enables interrupt priorities.

**REGISTER 9-13: RCON: RESET CONTROL REGISTER**

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-1(1)</th>
<th>U-0</th>
<th>R/W-1</th>
<th>R-1</th>
<th>R-1</th>
<th>R/W-0(2)</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPEN</td>
<td>SBOREN</td>
<td>—</td>
<td>RI</td>
<td>TO</td>
<td>PD</td>
<td>POR</td>
<td>BOR</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>bit 7</th>
<th>IPEN: Interrupt Priority Enable bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Enable priority levels on interrupts</td>
</tr>
<tr>
<td></td>
<td>0 = Disable priority levels on interrupts (PIC16CXXX Compatibility mode)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 6</th>
<th>SBOREN: BOR Software Enable bit(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For details of bit operation, see Register 4-1.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 5</th>
<th>Unimplemented: Read as ‘0’</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>bit 4</th>
<th>RI: RESET Instruction Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>For details of bit operation, see Register 4-1.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 3</th>
<th>TO: Watchdog Time-out Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>For details of bit operation, see Register 4-1.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 2</th>
<th>PD: Power-Down Detection Flag bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>For details of bit operation, see Register 4-1.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1</th>
<th>POR: Power-on Reset Status bit(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For details of bit operation, see Register 4-1.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 0</th>
<th>BOR: Brown-out Reset Status bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>For details of bit operation, see Register 4-1.</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** If SBOREN is enabled, its Reset state is ‘1’; otherwise, it is ‘0’.

**Note 2:** The actual Reset value of POR is determined by the type of device Reset. See Register 4-1 for additional information.
9.6 INTx Pin Interrupts

External interrupts on the RB0/INT0, RB1/INT1 and RB2/INT2 pins are edge-triggered. If the corresponding INTEDGx bit in the INTCON2 register is set (=1), the interrupt is triggered by a rising edge; if the bit is clear, the trigger is on the falling edge. When a valid edge appears on the RBx/INTx pin, the corresponding flag bit, INTxIF, is set. This interrupt can be disabled by clearing the corresponding enable bit INTxIE. Flag bit, INTxIF, must be cleared in software in the Interrupt Service Routine before re-enabling the interrupt.

All external interrupts (INT0, INT1 and INT2) can wake-up the processor from the power-managed modes if bit INTxIE was set prior to going into the power-managed modes. If the Global Interrupt Enable bit, GIE, is set, the processor will branch to the interrupt vector following wake-up.

Interrupt priority for INT1 and INT2 is determined by the value contained in the interrupt priority bits, INT1IP (INTCON3<6>) and INT2IP (INTCON3<7>). There is no priority bit associated with INT0. It is always a high priority interrupt source.

9.7 TMR0 Interrupt

In 8-bit mode (which is the default), an overflow in the TMR0 register (FFh → 00h) will set flag bit TMR0IF. In 16-bit mode, an overflow in the TMR0H:TMR0L register pair (FFFFh → 0000h) will set TMR0IF. The interrupt can be enabled/disabled by setting/clearing enable bit TMR0IE (INTCON<5>). Interrupt priority for Timer0 is determined by the value contained in the interrupt priority bit, TMR0IP (INTCON2<2>). See Section 11.0 “Timer0 Module” for further details on the Timer0 module.

9.8 PORTB Interrupt-on-Change

An input change on PORTB<7:4> sets flag bit, RBIF (INTCON<0>). The interrupt can be enabled/disabled by setting/clearing enable bit, RBIE (INTCON<3>). Interrupt priority for PORTB interrupt-on-change is determined by the value contained in the interrupt priority bit, RBIP (INTCON2<0>).

9.9 Context Saving During Interrupts

During interrupts, the return PC address is saved on the stack. Additionally, the WREG, STATUS and BSR registers are saved on the fast return stack. If a fast return from interrupt is not used (See Section 5.3 “Data Memory Organization”), the user may need to save the WREG, STATUS and BSR registers on entry to the Interrupt Service Routine. Depending on the user’s application, other registers may also need to be saved. Example 9-1 saves and restores the WREG, STATUS and BSR registers during an Interrupt Service Routine.

**EXAMPLE 9-1: SAVING STATUS, WREG AND BSR REGISTERS IN RAM**

```
MOVWF W_TEMP ; W_TEMP is in virtual bank
MOVFF STATUS, STATUS_TEMP ; STATUS_TEMP located anywhere
MOVFF BSR, BSR_TEMP ; BSR_TEMP located anywhere
;
; USER ISR CODE
;
MOVFF BSR_TEMP, BSR ; Restore BSR
MOVF W_TEMP, W ; Restore WREG
MOVFF STATUS_TEMP, STATUS ; Restore STATUS
```
10.0 I/O PORTS

Depending on the device selected and features enabled, there are up to five ports available. Some pins of the I/O ports are multiplexed with an alternate function from the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

Each port has three registers for its operation. These registers are:
- TRIS register (data direction register)
- PORT register (reads the levels on the pins of the device)
- LAT register (output latch)

The Data Latch register (LAT) is useful for read-modify-write operations on the value that the I/O pins are driving.

A simplified model of a generic I/O port, without the interfaces to other peripherals, is shown in Figure 10-1.

FIGURE 10-1: GENERIC I/O PORT OPERATION

10.1 PORTA, TRISA and LATA Registers

PORTA is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISA. Setting a TRISA bit (= 1) will make the corresponding PORTA pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISA bit (= 0) will make the corresponding PORTA pin an output (i.e., put the contents of the output latch on the selected pin).

Reading the PORTA register reads the status of the pins, whereas writing to it, will write to the port latch.

The Data Latch register (LATA) is also memory mapped. Read-modify-write operations on the LATA register read and write the latched output value for PORTA.

The RA4 pin is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. Pins RA6 and RA7 are multiplexed with the main oscillator pins. They are enabled as oscillator or I/O pins by the selection of the main oscillator in Configuration Register 1H (see Section 24.1 “Configuration Bits” for details).

When they are not used as port pins, RA6 and RA7 and their associated TRIS and LAT bits are read as '0'.

The other PORTA pins are multiplexed with analog inputs, the analog VREF+ and VREF- inputs and the comparator voltage reference output. The operation of RA5 and RA3:RA0 pins as A/D converter inputs is selected by clearing/setting the control bits in the ADCON1 register (A/D Control Register 1).

All other PORTA pins have TTL input levels and full CMOS output drivers.

The TRISA register controls the direction of the RA pins, even when they are being used as analog inputs. The user must ensure the bits in the TRISA register are maintained set when using them as analog inputs.

EXAMPLE 10-1: INITIALIZING PORTA

| CLRF PORTA ; Initialize PORTA by |
| CLRF LATA ; Alternate method |
| MOV LW 0Fh ; Configure A/D |
| MOVWF ADCON1 ; for digital inputs |
| MOVWF 07h ; Configure comparators |
| MOVWF CMCON ; for digital input |
| MOV LW 0CFh ; Value used to |
| MOVWF TRISA ; Set RA<3:0> as inputs |
| MOVWF TRISA ; RA<5:4> as outputs |

*Note 1: I/O pins have diode protection to VDD and VSS.*
### TABLE 10-1: PORTA I/O SUMMARY

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Function</th>
<th>I/O</th>
<th>TRIS</th>
<th>Buffer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA0/AN0/CVREF</td>
<td>RA0</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;0&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;0&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>AN0</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D input channel 0. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td></td>
<td>CVREF[1]</td>
<td>OUT</td>
<td>x</td>
<td>ANA</td>
<td>Comparator voltage reference analog output. Enabling this analog output overrides the digital I/O (read as clear – low level).</td>
</tr>
<tr>
<td>RA1/AN1</td>
<td>RA1</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;1&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;1&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>AN1</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D input channel 1. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td>RA2/AN2/VREF-</td>
<td>RA2</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;2&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;2&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>AN2</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D input channel 2. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td></td>
<td>VREF-</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D and comparator negative voltage analog input.</td>
</tr>
<tr>
<td>RA3/AN3/VREF+</td>
<td>RA3</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;3&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;3&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>AN3</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D input channel 3. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td></td>
<td>VREF+</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D and comparator positive voltage analog input.</td>
</tr>
<tr>
<td>RA4/T0CKI</td>
<td>RA4</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;4&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;4&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>T0CKI</td>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>Timer0 clock input.</td>
</tr>
<tr>
<td>RA5/AN4/SS/HLVDIN</td>
<td>RA5</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;5&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;5&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>AN4</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>A/D input channel 4. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>Slave select input for MSSP.</td>
</tr>
<tr>
<td></td>
<td>HLVDIN</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>High/Low-Voltage Detect external trip point input.</td>
</tr>
<tr>
<td>OSC2/CLKO/RA6</td>
<td>OSC2</td>
<td>OUT</td>
<td>x</td>
<td>ANA</td>
<td>Output connection, selected by FOSC3:FOSC0 Configuration bits. Enabling OSC2 overrides digital I/O.</td>
</tr>
<tr>
<td></td>
<td>CLKO</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Output connection, selected by FOSC3:FOSC0 Configuration bits. Enabling CLKO overrides digital I/O (Fosc/4).</td>
</tr>
<tr>
<td></td>
<td>RA6</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;6&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;6&gt; data input.</td>
</tr>
<tr>
<td>OSC1/CLKI/RA7</td>
<td>OSC1</td>
<td>IN</td>
<td>x</td>
<td>ANA</td>
<td>Main oscillator input connection, determined by FOSC3:FOSC0 Configuration bits. Enabling OSC1 overrides digital I/O.</td>
</tr>
<tr>
<td></td>
<td>CLKI</td>
<td>IN</td>
<td>x</td>
<td>ANA</td>
<td>Main clock input connection, determined by FOSC3:FOSC0 Configuration bits. Enabling CLKI overrides digital I/O.</td>
</tr>
<tr>
<td></td>
<td>RA7</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATA&lt;7&gt; data output.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTA&lt;7&gt; data input.</td>
</tr>
</tbody>
</table>

**Legend:**  
OUT = Output; IN = Input; ANA = Analog Signal; DIG = Digital Output; ST = Schmitt Buffer Input; TTL = TTL Buffer Input

**Note 1:** This bit is unimplemented on PIC18F2682/2685 devices.
### TABLE 10-2: SUMMARY OF REGISTERS ASSOCIATED WITH PORTA

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTA</td>
<td>RA7(1)</td>
<td>RA6(1)</td>
<td>RA5</td>
<td>RA4</td>
<td>RA3</td>
<td>RA2</td>
<td>RA1</td>
<td>RA0</td>
<td>54</td>
</tr>
<tr>
<td>LATA</td>
<td>LATA7(1)</td>
<td>LATA6(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>TRISA</td>
<td>TRISA7(1)</td>
<td>TRISA6(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>ADCON1</td>
<td>—</td>
<td>—</td>
<td>VCFG1</td>
<td>VCFG0</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>PCFG0</td>
<td>52</td>
</tr>
<tr>
<td>CMCON(2)</td>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>CIS</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
<td>53</td>
</tr>
<tr>
<td>CVRCON(2)</td>
<td>CVREN</td>
<td>CVROE</td>
<td>CVRR</td>
<td>CVRSS</td>
<td>CVR3</td>
<td>CVR2</td>
<td>CVR1</td>
<td>CVR0</td>
<td>53</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used by PORTA.

**Note 1:** RA7:RA6 and their associated latch and data direction bits are enabled as I/O pins based on oscillator configuration; otherwise, they are read as ‘0’.

**Note 2:** These registers are unimplemented on PIC18F2682/2685 devices.
10.2 PORTB, TRISB and LATB Registers

PORTB is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISB. Setting a TRISB bit (= 1) will make the corresponding PORTB pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISB bit (= 0) will make the corresponding PORTB pin an output (i.e., put the contents of the output latch on the selected pin).

The Data Latch register (LATB) is also memory mapped. Read-modify-write operations on the LATB register read and write the latched output value for PORTB.

Pins RB2 through RB3 are multiplexed with the ECAN peripheral. Refer to Section 23.0 “ECAN™ Technology” for proper settings of TRISB when CAN is enabled.

EXAMPLE 10-2: INITIALIZING PORTB

| CLRF PORTB ; Initialize PORTB by clearing output; data latches |
| CLRF LATB ; Alternate method to clear output; data latches |
| MOVWF ADCON1 ; Set RB<4:0> as digital I/O pins; (required if config bit PBADEN is set) |
| MOVW 0Ch ; Value used to initialize data; direction |
| MOVWF TRISB ; Set RB<3:0> as inputs; RB<5:4> as outputs; RB<7:6> as inputs |

Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-ups. This is performed by clearing bit RBPU (INTCON2<7>). The weak pull-up is automatically turned off when the port pin is configured as an output. The pull-ups are disabled on all device Resets.

Note: On a Power-on Reset, RB4:RB0 are configured as analog inputs by default and read as ‘0’; RB7:RB5 are configured as digital inputs.

By programming the Configuration bit, PBADEN (CONFIG3H<1>), RB4:RB0 will alternatively be configured as digital inputs on POR.

Four of the PORTB pins (RB7:RB4) have an interrupt-on-change feature. Only pins configured as inputs can cause this interrupt to occur (i.e., any RB7:RB4 pin configured as an output is excluded from the interrupt-on-change comparison). The input pins (of RB7:RB4) are compared with the old value latched on the last read of PORTB. The “mismatch” outputs of RB7:RB4 are ORed together to generate the RB Port Change Interrupt with Flag bit, RBIF (INTCON<0>).

This interrupt can wake the device from Sleep. The user, in the Interrupt Service Routine, can clear the interrupt in the following manner:

a) Any read or write of PORTB (except with the MOVFF (ANY), PORTB instruction). This will end the mismatch condition.

b) Clear flag bit, RBIF.

A mismatch condition will continue to set flag bit, RBIF. Reading PORTB will end the mismatch condition and allow flag bit RBIF to be cleared.

The interrupt-on-change feature is recommended for wake-up on key depression operation and operations where PORTB is only used for the interrupt-on-change feature. Polling of PORTB is not recommended while using the interrupt-on-change feature.
<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Function</th>
<th>I/O</th>
<th>TRIS</th>
<th>Buffer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB0/INT0/FLT0/AN10</td>
<td>OUT</td>
<td>DIG</td>
<td>LATB&lt;0&gt;</td>
<td>data output.</td>
<td></td>
</tr>
<tr>
<td>INT0</td>
<td>IN</td>
<td>TTL</td>
<td>PORTB&lt;0&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
<td></td>
</tr>
<tr>
<td>FLT0&lt;1&gt;</td>
<td>IN</td>
<td>ST</td>
<td>External interrupt 0 input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AN10</td>
<td>IN</td>
<td>ANA</td>
<td>Enhanced PWM Fault input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB1/INT1/AN8</td>
<td>OUT</td>
<td>DIG</td>
<td>LATB&lt;1&gt;</td>
<td>data output.</td>
<td></td>
</tr>
<tr>
<td>INT1</td>
<td>IN</td>
<td>TTL</td>
<td>PORTB&lt;1&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
<td></td>
</tr>
<tr>
<td>AN8</td>
<td>IN</td>
<td>ANA</td>
<td>A/D input channel 8. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB2/INT2/CANTX</td>
<td>OUT</td>
<td>X</td>
<td>DIG</td>
<td>LATB&lt;2&gt;</td>
<td>data output.</td>
</tr>
<tr>
<td>INT2</td>
<td>IN</td>
<td>TTL</td>
<td>PORTB&lt;2&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
<td></td>
</tr>
<tr>
<td>CANTX</td>
<td>OUT</td>
<td>1</td>
<td>DIG</td>
<td>CAN transimit signal output. The CAN interface overrides the TRIS&lt;2&gt; control when enabled.</td>
<td></td>
</tr>
<tr>
<td>RB3/CANRX</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATB&lt;3&gt;</td>
<td>data output.</td>
</tr>
<tr>
<td>CANRX</td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTB&lt;3&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
</tr>
<tr>
<td>RB4/KBI0/AN9</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATB&lt;4&gt;</td>
<td>data output.</td>
</tr>
<tr>
<td>KBI0</td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTB&lt;4&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
</tr>
<tr>
<td>AN9</td>
<td>IN</td>
<td>ANA</td>
<td>A/D input channel 9. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RB5/KBI1/PGM</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATB&lt;5&gt;</td>
<td>data output.</td>
</tr>
<tr>
<td>KBI1</td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTB&lt;5&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
</tr>
<tr>
<td>PGM</td>
<td>IN</td>
<td>X</td>
<td>ST</td>
<td>Low-Voltage Programming mode entry (ICSP™). Enabling this function overrides digital output.</td>
<td></td>
</tr>
<tr>
<td>RB6/KBI2/PGC</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATB&lt;6&gt;</td>
<td>data output.</td>
</tr>
<tr>
<td>KBI2</td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTB&lt;6&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
</tr>
<tr>
<td>PGC</td>
<td>IN</td>
<td>X</td>
<td>ST</td>
<td>Low-Voltage Programming mode entry (ICSP) clock input.</td>
<td></td>
</tr>
<tr>
<td>RB7/KBI3/PGD</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATB&lt;7&gt;</td>
<td>data output.</td>
</tr>
<tr>
<td>KBI3</td>
<td>IN</td>
<td>1</td>
<td>TTL</td>
<td>PORTB&lt;7&gt;</td>
<td>data input. Weak pull-up available only in this mode.</td>
</tr>
<tr>
<td>PGD</td>
<td>OUT</td>
<td>X</td>
<td>DIG</td>
<td>Low-Voltage Programming mode entry (ICSP) clock input.</td>
<td></td>
</tr>
</tbody>
</table>

Legend:  
OUT = Output; IN = Input; ANA = Analog Signal; DIG = Digital Output; ST = Schmitt Buffer Input; TTL – TTL Buffer Input

Note 1: This bit is unimplemented on PIC18F2682/2685 devices.
### TABLE 10-4: SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTB</td>
<td>RB7</td>
<td>RB6</td>
<td>RB5</td>
<td>RB4</td>
<td>RB3</td>
<td>RB2</td>
<td>RB1</td>
<td>RB0</td>
<td>54</td>
</tr>
<tr>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>LATB</td>
<td>54</td>
</tr>
<tr>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>TRISB</td>
<td>54</td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>INTCON2</td>
<td>RBPU</td>
<td>INTEDG0</td>
<td>INTEDG1</td>
<td>INTEDG2</td>
<td>—</td>
<td>TMR0IP</td>
<td>—</td>
<td>RBIP</td>
<td>51</td>
</tr>
<tr>
<td>INTCON3</td>
<td>INT2IP</td>
<td>INT1IP</td>
<td>—</td>
<td>INT2IE</td>
<td>INT1IE</td>
<td>—</td>
<td>INT2IF</td>
<td>INT1IF</td>
<td>51</td>
</tr>
<tr>
<td>ADCON1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>52</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used by PORTB.
10.3 PORTC, TRISC and LATC Registers

PORTC is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISC. Setting a TRISC bit (= 1) will make the corresponding PORTC pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISC bit (= 0) will make the corresponding PORTC pin an output (i.e., put the contents of the output latch on the selected pin).

The Data Latch register (LATC) is also memory mapped. Read-modify-write operations on the LATC register read and write the latched output value for PORTC.

PORTC is multiplexed with several peripheral functions (Table 10-5). The pins have Schmitt Trigger input buffers.

When enabling peripheral functions, care should be taken in defining TRIS bits for each PORTC pin. Some peripherals override the TRIS bit to make a pin an output, while other peripherals override the TRIS bit to make a pin an input. The user should refer to the corresponding peripheral section for the correct TRIS bit settings.

Note: On a Power-on Reset, these pins are configured as digital inputs.

The contents of the TRISC register are affected by peripheral overrides. Reading TRISC always returns the current contents, even though a peripheral device may be overriding one or more of the pins.

**EXAMPLE 10-3: INITIALIZING PORTC**

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLRF PORTC</td>
<td>Initialize PORTC by clearing output data latches</td>
</tr>
<tr>
<td>CLRF LATC</td>
<td>Alternate method to clear output data latches</td>
</tr>
<tr>
<td>MOVWF TRISC</td>
<td>Value used to initialize data direction</td>
</tr>
</tbody>
</table>

| MOV LW 0CFh | Set RC<3:0> as inputs RC<5:4> as outputs RC<7:6> as inputs |

CLRF PORTC ; Initialize PORTC by clearing output data latches
CLRF LATC ; Alternate method to clear output data latches
MOV LW 0CFh ; Value used to initialize data direction
MOV WF TRISC ; Set RC<3:0> as inputs RC<5:4> as outputs RC<7:6> as inputs
### TABLE 10-5: PORTC I/O SUMMARY

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Function</th>
<th>I/O</th>
<th>TRIS</th>
<th>Buffer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC0/T1OSO/</td>
<td>RC0</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;0&gt; data output.</td>
</tr>
<tr>
<td>T13CKI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;0&gt; data input.</td>
</tr>
<tr>
<td>T1OSO</td>
<td>OUT</td>
<td></td>
<td></td>
<td>ANA</td>
<td>Timer1 oscillator output – overrides the TRIS&lt;0&gt; control when enabled.</td>
</tr>
<tr>
<td>T13CKI</td>
<td>IN</td>
<td>ST</td>
<td></td>
<td></td>
<td>Timer1/Timer3 clock input.</td>
</tr>
<tr>
<td>RC1/T1OSI</td>
<td>RC1</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;1&gt; data output.</td>
</tr>
<tr>
<td>RC1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;1&gt; data input.</td>
</tr>
<tr>
<td>T1OSI</td>
<td>IN</td>
<td>ST</td>
<td></td>
<td></td>
<td>Timer1 oscillator input – overrides the TRIS&lt;1&gt; control when enabled.</td>
</tr>
<tr>
<td>RC2/CCP1</td>
<td>RC2</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;2&gt; data output.</td>
</tr>
<tr>
<td>RC2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;2&gt; data input.</td>
</tr>
<tr>
<td>CCP1</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>CCP1 compare output.</td>
</tr>
<tr>
<td>CCP1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CCP1 capture input.</td>
</tr>
<tr>
<td>RC3/SCK/SCL</td>
<td>RC3</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;3&gt; data output.</td>
</tr>
<tr>
<td>SCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;3&gt; data input.</td>
</tr>
<tr>
<td>SCK</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>SPI clock output (MSSP module) – must have TRIS set to ‘1’ to allow the MSSP module to control the bidirectional communication.</td>
</tr>
<tr>
<td>SCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SPI clock input (MSSP module).</td>
</tr>
<tr>
<td>SCL</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>I2C™/SMBus clock output (MSSP module) – must have TRIS set to ‘1’ to allow the MSSP module to control the bidirectional communication.</td>
</tr>
<tr>
<td>SCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I2C/SMBus clock input.</td>
</tr>
<tr>
<td>RC4/SDI/SDA</td>
<td>RC4</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;4&gt; data output.</td>
</tr>
<tr>
<td>SDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;4&gt; data input.</td>
</tr>
<tr>
<td>SDI</td>
<td>IN</td>
<td>ST</td>
<td></td>
<td></td>
<td>SPI data input (MSSP module).</td>
</tr>
<tr>
<td>SDA</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>I2C/SMBus data output (MSSP module) – must have TRIS set to ‘1’ to allow the MSSP module to control the bidirectional communication.</td>
</tr>
<tr>
<td>SDA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I2C/SMBus data input (MSSP module) – must have TRIS set to ‘1’ to allow the MSSP module to control the bidirectional communication.</td>
</tr>
<tr>
<td>RC5/SDO</td>
<td>RC5</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;5&gt; data output.</td>
</tr>
<tr>
<td>SDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;5&gt; data input.</td>
</tr>
<tr>
<td>RC6/TX/CK</td>
<td>RC6</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;6&gt; data output.</td>
</tr>
<tr>
<td>TX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;6&gt; data input.</td>
</tr>
<tr>
<td>TX</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>EUSART data output.</td>
</tr>
<tr>
<td>TX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EUSART synchronous clock output – must have TRIS set to ‘1’ to enable EUSART to control the bidirectional communication.</td>
</tr>
<tr>
<td>CK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EUSART synchronous clock input.</td>
</tr>
<tr>
<td>CK</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>EUSART synchronous data output – must have TRIS set to ‘1’ to enable EUSART to control the bidirectional communication.</td>
</tr>
<tr>
<td>CK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EUSART asynchronous data input.</td>
</tr>
<tr>
<td>RC7/RX/DT</td>
<td>RC7</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATC&lt;7&gt; data output.</td>
</tr>
<tr>
<td>RX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC&lt;7&gt; data input.</td>
</tr>
<tr>
<td>RX</td>
<td>IN</td>
<td>ST</td>
<td></td>
<td></td>
<td>EUSART asynchronous data input.</td>
</tr>
<tr>
<td>DT</td>
<td>OUT</td>
<td>DIG</td>
<td></td>
<td></td>
<td>EUSART synchronous data output – must have TRIS set to ‘1’ to enable EUSART to control the bidirectional communication.</td>
</tr>
<tr>
<td>DT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EUSART synchronous data input.</td>
</tr>
</tbody>
</table>

**Legend:**  
OUT = Output; IN = Input; ANA = Analog Signal; DIG = Digital Output; ST = Schmitt Buffer Input; TTL = TTL Buffer Input; I2C = Inter-Integrated Circuit; SMBus = System Management Bus
## TABLE 10-6: SUMMARY OF REGISTERS ASSOCIATED WITH PORTC

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTC</td>
<td>RC7</td>
<td>RC6</td>
<td>RC5</td>
<td>RC4</td>
<td>RC3</td>
<td>RC2</td>
<td>RC1</td>
<td>RC0</td>
<td>54</td>
</tr>
<tr>
<td>LATC</td>
<td>LATC Data Output Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>TRISC</td>
<td>PORTC Data Direction Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
</tbody>
</table>
PORTD, TRISD and LATD Registers

PORTD is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISD. Setting a TRISD bit (= 1) will make the corresponding PORTD pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISD bit (= 0) will make the corresponding PORTD pin an output (i.e., put the contents of the output latch on the selected pin).

The Data Latch register (LATD) is also memory mapped. Read-modify-write operations on the LATD register read and write the latched output value for PORTD.

All pins on PORTD are implemented with Schmitt Trigger input buffers. Each pin is individually configurable as an input or output.

Three of the PORTD pins are multiplexed with outputs P1A, P1B, P1C and P1D of the Enhanced CCP1 (ECCP1) module. The operation of these additional PWM output pins is covered in greater detail in Section 16.0 “Enhanced Capture/Compare/PWM (ECCP1) Module”.

PORTD can also be configured as an 8-bit wide microprocessor port (Parallel Slave Port) by setting control bit, PSPMODE (TRISE<4>). In this mode, the input buffers are TTL. See Section 10.6 “Parallel Slave Port” for additional information on the Parallel Slave Port (PSP).

Note: When the Enhanced PWM mode is used with either dual or quad outputs, the PSP functions of PORTD are automatically disabled.

EXAMPLE 10-4: INITIALIZING PORTD

Note: PORTD is only available on PIC18F4682/4685 devices.

Note: On a Power-on Reset, these pins are configured as digital inputs.

CLRF PORTD ; Initialize PORTD by clearing output data latches
CLRF LATD ; Alternate method to clear output data latches
MOVLW 0CFh ; Value used to initialize data direction
MOVWF TRISD ; Set RD<3:0> as inputs RD<5:4> as outputs RD<7:6> as inputs

Note: PORTD is only available on PIC18F4682/4685 devices.

Note: On a Power-on Reset, these pins are configured as digital inputs.
### TABLE 10-7: PORTD I/O SUMMARY

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Function</th>
<th>I/O</th>
<th>TRIS</th>
<th>Buffer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD0/PSP0/ C1IN+</td>
<td>RD0</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;0&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;0&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP0</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;0&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;0&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1IN+</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>Comparator 1 positive input B. Default on POR. This analog input overrides the digital input (read as clear – low level).</td>
<td></td>
</tr>
<tr>
<td>RD1/PSP1/ C1IN-</td>
<td>RD1</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;1&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;1&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP1</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;1&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;1&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1IN-</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>Comparator 1 negative input. Default on POR. This analog input overrides the digital input (read as clear – low level).</td>
<td></td>
</tr>
<tr>
<td>RD2/PSP2/ C2IN+</td>
<td>RD2</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;2&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;2&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP2</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;2&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;2&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2IN+</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>Comparator 2 positive input. Default on POR. This analog input overrides the digital input (read as clear – low level).</td>
<td></td>
</tr>
<tr>
<td>RD3/PSP3/ C2IN-</td>
<td>RD3</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;3&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;3&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP3</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;3&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;3&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2IN-</td>
<td>IN</td>
<td>1</td>
<td>ANA</td>
<td>Comparator 2 negative input. Default input on POR. This analog input overrides the digital input (read as clear – low level).</td>
<td></td>
</tr>
<tr>
<td>RD4/PSP4/ ECCP1/P1A</td>
<td>RD4</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;4&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;4&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP4</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;4&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;4&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECCP1</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>ECCP1 compare output.</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>ECCP1 capture input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1A</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>ECCP1 Enhanced PWM output, channel A.</td>
<td></td>
</tr>
<tr>
<td>RD5/PSP5/ P1B</td>
<td>RD5</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;5&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;5&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP5</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;5&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;5&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1B</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>ECCP1 Enhanced PWM output, channel B.</td>
<td></td>
</tr>
<tr>
<td>RD6/PSP6/ P1C</td>
<td>RD6</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;6&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;6&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP6</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;6&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;6&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1C</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>ECCP1 Enhanced PWM output, channel C.</td>
<td></td>
</tr>
<tr>
<td>RD7/PSP7/ P1D</td>
<td>RD7</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATD&lt;7&gt; data output.</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTD&lt;7&gt; data input.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSP7</td>
<td>OUT</td>
<td>x</td>
<td>DIG</td>
<td>Parallel Slave Port (PSP) data output (overrides the TRIS&lt;7&gt; control when enabled).</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>x</td>
<td>TTL</td>
<td>Parallel Slave Port (PSP) data input (overrides the TRIS&lt;7&gt; control when enabled).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1D</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>ECCP1 Enhanced PWM output, channel D.</td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- OUT = Output; IN = Input; ANA = Analog Signal; DIG = Digital Output; ST = Schmitt Buffer Input; TTL = TTL Buffer Input
## TABLE 10-8: SUMMARY OF REGISTERS ASSOCIATED WITH PORTD

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTD(1)</td>
<td>RD7</td>
<td>RD6</td>
<td>RD5</td>
<td>RD4</td>
<td>RD3</td>
<td>RD2</td>
<td>RD1</td>
<td>RD0</td>
<td>54</td>
</tr>
<tr>
<td>LATD(1)</td>
<td>LATD Data Output Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISD(1)</td>
<td>PORTD Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISE(1)</td>
<td>IBF</td>
<td>OBF</td>
<td>IBOV</td>
<td>PSPMODE</td>
<td>—</td>
<td>TRISE2</td>
<td>TRISE1</td>
<td>TRISE0</td>
<td>54</td>
</tr>
<tr>
<td>ECCP1CON(1)</td>
<td>EPWM1M1</td>
<td>EPWM1M0</td>
<td>EDC1B1</td>
<td>EDC1B0</td>
<td>ECCP1M3</td>
<td>ECCP1M2</td>
<td>ECCP1M1</td>
<td>ECCP1M0</td>
<td>53</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as '0'. Shaded cells are not used by PORTD.

**Note 1:** These registers are available on PIC18F4682/4685 devices only.
10.5 PORTE, TRISE and LATE Registers

Depending on the particular PIC18F2682/2685/4682/4685 device selected, PORTE is implemented in two different ways.

For PIC18F4682/4685 devices, PORTE is a 4-bit wide port. Three pins (RE0/RD/AN5, RE1/WR/AN6/C1OUT and RE2/CS/AN7/C2OUT) are individually configurable as inputs or outputs. These pins have Schmitt Trigger input buffers. When selected as an analog input, these pins will read as '0's.

The corresponding data direction register is TRISE. Setting a TRISE bit ( = 1) will make the corresponding PORTE pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISE bit ( = 0) will make the corresponding PORTE pin an output (i.e., put the contents of the output latch on the selected pin).

TRISE controls the direction of the RE pins, even when they are being used as analog inputs. The user must make sure to keep the pins configured as inputs when using them as analog inputs.

The upper four bits of the TRISE register also control the operation of the Parallel Slave Port. Their operation is explained in Register 10-1.

The Data Latch register (LATE) is also memory mapped. Read-modify-write operations on the LATE register, read and write the latched output value for PORTE.

EXAMPLE 10-5: INITIALIZING PORTE

<table>
<thead>
<tr>
<th>OUT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLRF PORTE</td>
<td>Initialize PORTE by clearing output data latches</td>
</tr>
<tr>
<td>CLRF LATE</td>
<td>Alternate method to clear output data latches</td>
</tr>
<tr>
<td>MOVWF ADCON1</td>
<td>Configure A/D for digital inputs</td>
</tr>
<tr>
<td>MOVWF CMCON</td>
<td>Value used to initialize data direction</td>
</tr>
<tr>
<td>MOVWF TRISC</td>
<td>Set RE&lt;0&gt; as inputs RE&lt;1&gt; as outputs RE&lt;2&gt; as inputs</td>
</tr>
</tbody>
</table>

Note: On a Power-on Reset, RE3 is enabled as a digital input only if Master Clear functionality is disabled.

10.5.1 PORTE IN 28-PIN DEVICES

For PIC18F2682/2685 devices, PORTE is only available when Master Clear functionality is disabled (MCLRE = 0). In these cases, PORTE is a single bit, input only port comprised of RE3 only. The pin operates as previously described.
## REGISTER 10-1: TRISE REGISTER (PIC18F4682/4685 DEVICES ONLY)

<table>
<thead>
<tr>
<th>Bit</th>
<th>IBF</th>
<th>OBF</th>
<th>IBOV</th>
<th>PSPMODE</th>
<th>TRISE2</th>
<th>TRISE1</th>
<th>TRISE0</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>R-0</td>
<td>R-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>U-0</td>
<td>R/W-1</td>
<td>R/W-1</td>
</tr>
</tbody>
</table>

**Legend:**
- **R** = Readable bit
- **W** = Writable 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**
- **IBF**: Input Buffer Full Status bit
  - 1 = A word has been received and waiting to be read by the CPU
  - 0 = No word has been received

**Bit 6**
- **OBF**: Output Buffer Full Status bit
  - 1 = The output buffer still holds a previously written word
  - 0 = The output buffer has been read

**Bit 5**
- **IBOV**: Input Buffer Overflow Detect bit (in Microprocessor mode)
  - 1 = A write occurred when a previously input word has not been read (must be cleared in software)
  - 0 = No overflow occurred

**Bit 4**
- **PSPMODE**: Parallel Slave Port Mode Select bit
  - 1 = Parallel Slave Port mode
  - 0 = General purpose I/O mode

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

**Bit 2**
- **TRISE2**: RE2 Direction Control bit
  - 1 = Input
  - 0 = Output

**Bit 1**
- **TRISE1**: RE1 Direction Control bit
  - 1 = Input
  - 0 = Output

**Bit 0**
- **TRISE0**: RE0 Direction Control bit
  - 1 = Input
  - 0 = Output
### TABLE 10-9: PORTE I/O SUMMARY

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Function</th>
<th>I/O</th>
<th>TRIS</th>
<th>Buffer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE0/RD/AN5</td>
<td>RE0</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATE&lt;0&gt; data output.</td>
</tr>
<tr>
<td></td>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td></td>
<td>PORTE&lt;0&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>RD</td>
<td>1</td>
<td>TTL</td>
<td></td>
<td>PSP read enable input.</td>
</tr>
<tr>
<td></td>
<td>AN5</td>
<td>1</td>
<td>ANA</td>
<td></td>
<td>A/D input channel 5. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td>RE1/WR/AN6/C1OUT</td>
<td>RE1</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATE&lt;1&gt; data output.</td>
</tr>
<tr>
<td></td>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td></td>
<td>PORTE&lt;1&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>WR</td>
<td>1</td>
<td>TTL</td>
<td></td>
<td>PSP write enable input.</td>
</tr>
<tr>
<td></td>
<td>AN6</td>
<td>1</td>
<td>ANA</td>
<td></td>
<td>A/D input channel 6. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td></td>
<td>C1OUT</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>Comparator 1 output.</td>
</tr>
<tr>
<td>RE2/CS/AN7/C2OUT</td>
<td>RE2</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>LATE&lt;2&gt; data output.</td>
</tr>
<tr>
<td></td>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td></td>
<td>PORTE&lt;2&gt; data input.</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>1</td>
<td>TTL</td>
<td></td>
<td>PSP chip select input.</td>
</tr>
<tr>
<td></td>
<td>AN7</td>
<td>1</td>
<td>ANA</td>
<td></td>
<td>A/D input channel 7. Enabled on POR, this analog input overrides the digital input (read as clear – low level).</td>
</tr>
<tr>
<td></td>
<td>C2OUT</td>
<td>OUT</td>
<td>0</td>
<td>DIG</td>
<td>Comparator 2 output.</td>
</tr>
<tr>
<td>MCLR/VPP/RE3</td>
<td>MCLR</td>
<td>IN</td>
<td>x</td>
<td>ST</td>
<td>External Reset input. Disabled when MCLRE Configuration bit is ‘1’.</td>
</tr>
<tr>
<td></td>
<td>VPP</td>
<td>IN</td>
<td>x</td>
<td>ANA</td>
<td>High-voltage detection; used by ICSP™ operation.</td>
</tr>
<tr>
<td></td>
<td>RE3</td>
<td>IN</td>
<td>1</td>
<td>ST</td>
<td>PORTE&lt;3&gt; data input. Disabled when MCLRE Configuration bit is ‘0’.</td>
</tr>
</tbody>
</table>

**Legend:** OUT = Output; IN = Input; ANA = Analog Signal; DIG = Digital Output; ST = Schmitt Buffer Input; TTL = TTL Buffer Input

### TABLE 10-10: SUMMARY OF REGISTERS ASSOCIATED WITH PORTE

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTE(3)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>RE3(1,2)</td>
<td>RE2</td>
<td>RE1</td>
<td>RE0</td>
</tr>
<tr>
<td>LATE(4)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>LATE Data Output Register</td>
</tr>
<tr>
<td>TRISE(3)</td>
<td>IBF</td>
<td>OBF</td>
<td>IBOV</td>
<td>PSPMODE</td>
<td>—</td>
<td>—</td>
<td>TRISE2</td>
<td>TRISE1</td>
<td>TRISE0</td>
</tr>
<tr>
<td>ADCON1</td>
<td>—</td>
<td>—</td>
<td>VCFG1</td>
<td>VCFG0</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>PCFG0</td>
<td>52</td>
</tr>
<tr>
<td>CMCON(3)</td>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>CIS</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
<td>53</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used by PORTE.

**Note 1:** Implemented only when Master Clear functionality is disabled (MCLRE Configuration bit = 0).

1. RE3 is the only PORTE bit implemented on both PIC18F2682/2685 and PIC18F4682/4685 devices. All other bits are implemented only when PORTE is implemented (i.e., PIC18F4682/4685 devices).

3. These registers are unimplemented on PIC18F2682/2685 devices.
10.6 Parallel Slave Port

In addition to its function as a general I/O port, PORTD can also operate as an 8-bit wide Parallel Slave Port (PSP) or microprocessor port. PSP operation is controlled by the 4 upper bits of the TRISE register (Register 10-1). Setting control bit, PSPMODE (TRISE<4>), enables PSP operation, as long as the Enhanced CCP1 (ECCP1) module is not operating in dual output or quad output PWM mode. In Slave mode, the port is asynchronously readable and writable by the external world.

The PSP can directly interface to an 8-bit microprocessor data bus. The external microprocessor can read or write the PORTD latch as an 8-bit latch. Setting the control bit, PSPMODE, enables the PORTE I/O pins to become control inputs for the microprocessor port. When set, port pin RE0 is the RD input, RE1 is the WR input and RE2 is the CS (Chip Select) input. For this functionality, the corresponding data direction bits of the TRISE register (TRISE<2:0>) must be configured as inputs (set). The A/D port configuration bits, PFCG3:PFCG0 (ADCON1<3:0>), must also be set to '1010'.

A write to the PSP occurs when both the CS and WR lines are first detected low and ends when either are detected high. The PSPIF and IBF flag bits are both set when the write ends.

A read from the PSP occurs when both the CS and RD lines are first detected low. The data in PORTD is read out and the OBF bit is set. If the user writes new data to PORTD to set OBF, the data is immediately read out; however, the OBF bit is not set.

When either the CS or RD line is detected high, the PORTD pins return to the input state and the PSPIF bit is set. User applications should wait for PSPIF to be set before servicing the PSP. When this happens, the IBF and OBF bits can be polled and the appropriate action taken.

The timing for the control signals in Write and Read modes is shown in Figure 10-3 and Figure 10-4, respectively.

**FIGURE 10-2: PORTD AND PORTE BLOCK DIAGRAM (PARALLEL SLAVE PORT)**

Note: I/O pins have diode protection to Vdd and Vss.
FIGURE 10-3: PARALLEL SLAVE PORT WRITE WAVEFORMS

FIGURE 10-4: PARALLEL SLAVE PORT READ WAVEFORMS

TABLE 10-11: REGISTERS ASSOCIATED WITH PARALLEL SLAVE PORT

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTD(1)</td>
<td>RD7</td>
<td>RD6</td>
<td>RD5</td>
<td>RD4</td>
<td>RD3</td>
<td>RD2</td>
<td>RD1</td>
<td>RD0</td>
<td>54</td>
</tr>
<tr>
<td>LATD(1)</td>
<td>LATD</td>
<td>LATD</td>
<td>LATD</td>
<td>LATD</td>
<td>LATD</td>
<td>LATD</td>
<td>LATD</td>
<td>LATD</td>
<td>54</td>
</tr>
<tr>
<td>TRISD(1)</td>
<td>TRISD</td>
<td>TRISD</td>
<td>TRISD</td>
<td>TRISD</td>
<td>TRISD</td>
<td>TRISD</td>
<td>TRISD</td>
<td>TRISD</td>
<td>54</td>
</tr>
<tr>
<td>PORTE(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>LATE(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>TRISE(1)</td>
<td>IBF</td>
<td>OBF</td>
<td>IBOV</td>
<td>PSPMODE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE</td>
<td>GIE</td>
<td>GIE</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>54</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIE</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1E</td>
<td>TMR2E</td>
<td>TMR1E</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIE</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1P</td>
<td>TMR2P</td>
<td>TMR1P</td>
<td>54</td>
</tr>
<tr>
<td>ADCON1</td>
<td></td>
<td></td>
<td></td>
<td>VCFG1</td>
<td>VCFG0</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>54</td>
</tr>
<tr>
<td>CMCON(1)</td>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>CIS</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
<td>54</td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used by the Parallel Slave Port.

Note 1: These registers are available on PIC18F4682/4685 devices only.

2: These bits are unimplemented on PIC18F2682/2685 devices and read as ‘0’.
11.0 TIMER0 MODULE

The Timer0 module incorporates the following features:

• Software selectable operation as a timer or counter in both 8-bit or 16-bit modes
• Readable and writable registers
• Dedicated 8-bit, software programmable prescaler
• Selectable clock source (internal or external)
• Edge select for external clock
• Interrupt-on-overflow

The T0CON register (Register 11-1) controls all aspects of the module's operation, including the prescale selection. It is both readable and writable.

A simplified block diagram of the Timer0 module in 8-bit mode is shown in Figure 11-1. Figure 11-2 shows a simplified block diagram of the Timer0 module in 16-bit mode.

REGISTER 11-1: T0CON: TIMER0 CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMR0ON</td>
<td>T08BIT</td>
<td>T0CS</td>
<td>T0SE</td>
<td>PSA</td>
<td>T0PS2</td>
<td>T0PS1</td>
<td>T0PS0</td>
</tr>
</tbody>
</table>

Legend:

- R = Readable bit
- W = Writable 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 TMR0ON: Timer0 On/Off Control bit
1 = Enables Timer0
0 = Stops Timer0

bit 6 T08BIT: Timer0 8-Bit/16-Bit Control bit
1 = Timer0 is configured as an 8-bit timer/counter
0 = Timer0 is configured as a 16-bit timer/counter

bit 5 T0CS: Timer0 Clock Source Select bit
1 = Transition on T0CKI pin
0 = Internal instruction cycle clock (CLKO)

bit 4 T0SE: Timer0 Source Edge Select bit
1 = Increment on high-to-low transition on T0CKI pin
0 = Increment on low-to-high transition on T0CKI pin

bit 3 PSA: Timer0 Prescaler Assignment bit
1 = Timer0 prescaler is NOT assigned. Timer0 clock input bypasses prescaler.
0 = Timer0 prescaler is assigned. Timer0 clock input comes from prescaler output.

bit 2-0 T0PS2:T0PS0: Timer0 Prescaler Select bits
111 = 1:256 Prescale value
110 = 1:128 Prescale value
101 = 1:64  Prescale value
100 = 1:32  Prescale value
011 = 1:16  Prescale value
010 = 1:8   Prescale value
001 = 1:4   Prescale value
000 = 1:2   Prescale value
11.1 Timer0 Operation

Timer0 can operate as either a timer or a counter; the mode is selected by clearing the T0CS bit (T0CON<5>). In Timer mode, the module increments on every clock by default unless a different prescaler value is selected (see Section 11.3 “Prescaler”). If the TMR0 register is written to, the increment is inhibited for the following two instruction cycles. The user can work around this by writing an adjusted value to the TMR0 register.

The Counter mode is selected by setting the T0CS bit (= 1). In Counter mode, Timer0 increments either on every rising or falling edge of pin RA4/T0CKI. The incrementing edge is determined by the Timer0 Source Edge Select bit, T0SE (T0CON<4>). Clearing this bit selects the rising edge. Restrictions on the external clock input are discussed below.

An external clock source can be used to drive Timer0; however, it must meet certain requirements to ensure that the external clock can be synchronized with the internal phase clock (ToSC). There is a delay between synchronization and the onset of incrementing the timer/counter.

11.2 Timer0 Reads and Writes in 16-Bit Mode

TMR0H is not the actual high byte of Timer0 in 16-bit mode; it is actually a buffered version of the real high byte of Timer0, which is not directly readable nor writable (refer to Figure 11-2). TMR0H is updated with the contents of the high byte of Timer0 during a read of TMR0L. This provides the ability to read all 16 bits of Timer0 without having to verify that the read of the high and low byte were valid, due to a rollover between successive reads of the high and low byte.

Similarly, a write to the high byte of Timer0 must also take place through the TMR0H Buffer register. The high byte is updated with the contents of TMR0H when a write occurs to TMR0L. This allows all 16 bits of Timer0 to be updated at once.

FIGURE 11-1: TIMER0 BLOCK DIAGRAM (8-BIT MODE)

Note: Upon Reset, Timer0 is enabled in 8-bit mode with clock input from T0CKI max. prescale.

FIGURE 11-2: TIMER0 BLOCK DIAGRAM (16-BIT MODE)

Note: Upon Reset, Timer0 is enabled in 8-bit mode with clock input from T0CKI max. prescale.
11.3 Prescaler

An 8-bit counter is available as a prescaler for the Timer0 module. The prescaler is not directly readable or writable; its value is set by the PSA and T0PS2:T0PS0 bits (T0CON<3:0>) which determine the prescaler assignment and prescale ratio.

Clearing the PSA bit assigns the prescaler to the Timer0 module. When it is assigned, prescale values from 1:2 through 1:256 in power-of-2 increments are selectable.

When assigned to the Timer0 module, all instructions writing to the TMR0 register (e.g., CLRF TMR0, MOVWF TMR0, BSF TMR0, etc.) clear the prescaler count.

**Note:** Writing to TMR0 when the prescaler is assigned to Timer0 will clear the prescaler count but will not change the prescaler assignment.

### 11.3.1 SWITCHING PRESCALER ASSIGNMENT

The prescaler assignment is fully under software control and can be changed “on-the-fly” during program execution.

11.4 Timer0 Interrupt

The TMR0 interrupt is generated when the TMR0 register overflows from FFh to 00h in 8-bit mode, or from FFFFh to 0000h in 16-bit mode. This overflow sets the TMR0IF flag bit. The interrupt can be masked by clearing the TMR0IE bit (INTCON<5>). Before re-enabling the interrupt, the TMR0IF bit must be cleared in software by the Interrupt Service Routine.

Since Timer0 is shut down in Sleep mode, the TMR0 interrupt cannot awaken the processor from Sleep.

### TABLE 11-1: REGISTERS ASSOCIATED WITH TIMER0

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMR0L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>TMR0H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INTOIE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INTOIF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>T0CON</td>
<td>TMR0ON</td>
<td>T08BIT</td>
<td>T0CS</td>
<td>T0SE</td>
<td>PSA</td>
<td>T0PS2</td>
<td>T0PS1</td>
<td>T0PS0</td>
<td>52</td>
</tr>
<tr>
<td>TRISA</td>
<td>TRISA7(1)</td>
<td>TRISA6(1)</td>
<td>PORTA Data Direction Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
</tbody>
</table>

**Legend:**  
- $x$ = unknown, $u$ = unchanged, — = unimplemented locations, read as ‘0’. Shaded cells are not used by Timer0.

**Note 1:** RA7:RA6 and their associated latch and data direction bits are enabled as I/O pins based on oscillator configuration; otherwise, they are read as ‘0’.
12.0 TIMER1 MODULE

The Timer1 timer/counter module incorporates these features:

- Software selectable operation as a 16-bit timer or counter
- Readable and writable 8-bit registers (TMR3H and TMR3L)
- Selectable clock source (internal or external) with device clock or Timer1 oscillator internal options
- Interrupt on overflow
- Module Reset on CCP1 Special Event Trigger
- Device clock status flag (T1RUN)

A simplified block diagram of the Timer1 module is shown in Figure 12-1. A block diagram of the module’s operation in Read/Write mode is shown in Figure 12-2. The module incorporates its own low-power oscillator to provide an additional clocking option. The Timer1 oscillator can also be used as a low-power clock source for the microcontroller in power-managed operation.

Timer1 can also be used to provide Real-Time Clock (RTC) functionality to applications with only a minimal addition of external components and code overhead. Timer1 is controlled through the T1CON Control register (Register 12-1). It also contains the Timer1 Oscillator Enable bit (T1OSCEN). Timer1 can be enabled or disabled by setting or clearing control bit, TMR1ON (T1CON<0>).

REGISTER 12-1: T1CON: TIMER1 CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD16</td>
<td>T1RUN</td>
<td>T1CKPS1</td>
<td>T1CKPS0</td>
<td>T1OSCEN</td>
<td>T1SYNC</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
</tr>
<tr>
<td>bit 7</td>
<td>bit 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:

- **R** = Readable bit
- **W** = Writable bit
- **U** = Unimplemented bit, read as '0'
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

- **RD16**: 16-Bit Read/Write Mode Enable bit
  - 1 = Enables register read/write of Timer1 in one 16-bit operation
  - 0 = Enables register read/write of Timer1 in two 8-bit operations

- **T1RUN**: Timer1 System Clock Status bit
  - 1 = Device clock is derived from Timer1 oscillator
  - 0 = Device clock is derived from another source

- **T1CKPS1:T1CKPS0**: Timer1 Input Clock Prescale Select bits
  - 11 = 1:8 Prescale value
  - 10 = 1:4 Prescale value
  - 01 = 1:2 Prescale value
  - 00 = 1:1 Prescale value

- **T1OSCEN**: Timer1 Oscillator Enable bit
  - 1 = Timer1 oscillator is enabled
  - 0 = Timer1 oscillator is shut off
  - The oscillator inverter and feedback resistor are turned off to eliminate power drain.

- **T1SYNC**: Timer1 External Clock Input Synchronization Select bit
  - When TMR1CS = 1:
    - 1 = Do not synchronize external clock input
    - 0 = Synchronize external clock input
  - When TMR1CS = 0:
    - This bit is ignored. Timer1 uses the internal clock when TMR1CS = 0.

- **TMR1CS**: Timer1 Clock Source Select bit
  - 1 = External clock from pin RC0/T1OSO/T13CKI (on the rising edge)
  - 0 = Internal clock (Fosc/4)

- **TMR1ON**: Timer1 On bit
  - 1 = Enables Timer1
  - 0 = Stops Timer1
12.1 Timer1 Operation

Timer1 can operate in one of these modes:

- Timer
- Synchronous Counter
- Asynchronous Counter

The operating mode is determined by the clock select bit, TMR3CS (T3CON<1>). When TMR3CS is cleared (= 0), Timer3 increments on every internal instruction cycle (Fosc/4). When the bit is set, Timer3 increments on every rising edge of the Timer1 external clock input or the Timer1 oscillator, if enabled.

When Timer1 is enabled, the RC1/T1OSI and RC0/T1OSO/T13CKI pins become inputs. This means the values of TRISC<1:0> are ignored and the pins are read as '0'.

**FIGURE 12-1: TIMER1 BLOCK DIAGRAM**

![Timer1 Block Diagram](image1)

**Note 1:** When enable bit, T1OSCEN, is cleared, the inverter and feedback resistor are turned off to eliminate power drain.

**FIGURE 12-2: TIMER1 BLOCK DIAGRAM (16-BIT READ/WRITE MODE)**

![Timer1 Block Diagram (16-bit)](image2)

**Note 1:** When enable bit, T1OSCEN, is cleared, the inverter and feedback resistor are turned off to eliminate power drain.
12.2 Timer1 16-Bit Read/Write Mode

Timer1 can be configured for 16-bit reads and writes (see Figure 12-2). When the RD16 control bit (T1CON<7>) is set, the address for TMR1H is mapped to a buffer register for the high byte of Timer1. A read from TMR1L will load the contents of the high byte of Timer1 into the Timer1 High Byte Buffer register. This provides the user with the ability to accurately read all 16 bits of Timer1 without having to determine whether a read of the high byte, followed by a read of the low byte, has become invalid due to a rollover between reads.

A write to the high byte of Timer1 must also take place through the TMR1H Buffer register. The Timer1 high byte is updated with the contents of TMR1H when a write occurs to TMR1L. This allows a user to write all 16 bits to both the high and low bytes of Timer1 at once. The high byte of Timer1 is not directly readable or writable in this mode. All reads and writes must take place through the Timer1 High Byte Buffer register. Writes to TMR1H do not clear the Timer1 prescaler. The prescaler is only cleared on writes to TMR1L.

12.3 Timer1 Oscillator

An on-chip crystal oscillator circuit is incorporated between pins T1OSI (input) and T1OSO (amplifier output). It is enabled by setting the Timer1 Oscillator Enable bit, T1OSCEN (T1CON<3>). The oscillator is a low-power circuit rated for 32 kHz crystals. It will continue to run during all power-managed modes. The circuit for a typical LP oscillator is shown in Figure 12-3. Table 12-1 shows the capacitor selection for the Timer1 oscillator.

The user must provide a software time delay to ensure proper start-up of the Timer1 oscillator.

**FIGURE 12-3: EXTERNAL COMPONENTS FOR THE TIMER1 LP OSCILLATOR**

<table>
<thead>
<tr>
<th>Osc Type</th>
<th>Freq</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP</td>
<td>32.768 kHz</td>
<td>27 pF</td>
<td>27 pF</td>
</tr>
</tbody>
</table>

**TABLE 12-1: CAPACITOR SELECTION FOR THE TIMER1 OSCILLATOR**

<table>
<thead>
<tr>
<th>Osc Type</th>
<th>Frequency</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP</td>
<td>32.768 kHz</td>
<td>27 pF</td>
<td>27 pF</td>
</tr>
</tbody>
</table>

- **Note 1:** Microchip suggests these values as a starting point in validating the oscillator circuit.
- **Note 2:** Higher capacitance increases the stability of the oscillator but also increases the start-up time.
- **Note 3:** Since each resonator/crystal has its own characteristics, the user should consult the resonator/crystal manufacturer for appropriate values of external components.
- **Note 4:** Capacitor values are for design guidance only.

12.3.1 USING TIMER1 AS A CLOCK SOURCE

The Timer1 oscillator is also available as a clock source in power-managed modes. By setting the Clock Select bits, SCS1:SCS0 (OSCCON<1:0>), to '01', the device switches to SEC_RUN mode; both the CPU and peripherals are clocked from the Timer1 oscillator. If the IDLEN bit (OSCCON<7>) is cleared and a SLEEP instruction is executed, the device enters SEC_IDLE mode. Additional details are available in Section 3.0 “Power-Managed Modes”.

Whenever the Timer1 oscillator is providing the clock source, the Timer1 system clock status flag, T1RUN (T1CON<6>), is set. This can be used to determine the controller’s current clocking mode. It can also indicate the clock source being currently used by the Fail-Safe Clock Monitor. If the Clock Monitor is enabled and the Timer1 oscillator fails while providing the clock, polling the T1RUN bit will indicate whether the clock is being provided by the Timer1 oscillator or another source.

12.3.2 LOW-POWER TIMER1 OPTION

The Timer1 oscillator can operate at two distinct levels of power consumption based on device configuration. When the LPT1OSC Configuration bit is set, the Timer1 oscillator operates in a low-power mode. When LPT1OSC is not set, Timer1 operates at a higher power level. Power consumption for a particular mode is relatively constant, regardless of the device’s operating mode. The default Timer1 configuration is the higher power mode.

As the low-power Timer1 mode tends to be more sensitive to interference, high noise environments may cause some oscillator instability. The low-power option is, therefore, best suited for low noise applications where power conservation is an important design consideration.
12.3.3  TIMER1 OSCILLATOR LAYOUT CONSIDERATIONS

The Timer1 oscillator circuit draws very little power during operation. Due to the low-power nature of the oscillator, it may also be sensitive to rapidly changing signals in close proximity.

The oscillator circuit, shown in Figure 12-3, should be located as close as possible to the microcontroller. There should be no circuits passing within the oscillator circuit boundaries other than VSS or VDD.

If a high-speed circuit must be located near the oscillator (such as the CCP1 pin in Output Compare or PWM mode, or the primary oscillator using the OSC2 pin), a grounded guard ring around the oscillator circuit, as shown in Figure 12-4, may be helpful when used on a single-sided PCB or in addition to a ground plane.

FIGURE 12-4: OSCILLATOR CIRCUIT WITH GROUNDED GUARD RING

12.5  Resetting Timer1 Using the CCP1 Special Event Trigger

If either of the CCP1 modules is configured in Compare mode to generate a Special Event Trigger (CCPM3:CCPM0 = 1011), this signal will reset Timer1. The trigger from ECCP1 will also start an A/D conversion if the A/D module is enabled (see Section 15.3.4 “Special Event Trigger” for more information.).

The module must be configured as either a timer or a synchronous counter to take advantage of this feature. When used this way, the CCP1H:CCPR1L register pair effectively becomes a period register for Timer1.

If Timer1 is running in Asynchronous Counter mode, this Reset operation may not work.

In the event that a write to Timer1 coincides with a Special Event Trigger, the write operation will take precedence.

12.6  Using Timer1 as a Real-Time Clock

Adding an external LP oscillator to Timer1 (such as the one described in Section 12.3 “Timer1 Oscillator”) gives users the option to include RTC functionality to their applications. This is accomplished with an inexpensive watch crystal to provide an accurate time base and several lines of application code to calculate the time. When operating in Sleep mode and using a battery or supercapacitor as a power source, it can completely eliminate the need for a separate RTC device and battery backup.

The application code routine, RTCisr, shown in Example 12-1, demonstrates a simple method to increment a counter at one-second intervals using an Interrupt Service Routine. Incrementing the TMR1 register pair to overflow triggers the interrupt and calls the routine, which increments the seconds counter by one; additional counters for minutes and hours are incremented as the previous counter overflow.

Since the register pair is 16 bits wide, counting up to overflow the register directly from a 32.768 kHz clock would take 2 seconds. To force the overflow at the required one-second intervals, it is necessary to preload it. The simplest method is to set the MSb of TMR1H with a BSF instruction. Note that the TMR1L register is never preloaded or altered; doing so may introduce cumulative error over many cycles.

For this method to be accurate, Timer1 must operate in Asynchronous mode and the Timer1 overflow interrupt must be enabled (PIE1<0> = 1) as shown in the routine, RTCinit. The Timer1 oscillator must also be enabled and running at all times.
EXAMPLE 12-1: IMPLEMENTING A REAL-TIME CLOCK USING A TIMER1 INTERRUPT SERVICE

TABLE 12-2: REGISTERS ASSOCIATED WITH TIMER1 AS A TIMER/COUNTER

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INTOI</td>
<td>RBIE</td>
<td>TMROIF</td>
<td>INTOIF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSSIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>TMR1L</td>
<td>Timer1 Register Low Byte</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR1H</td>
<td>Timer1 Register High Byte</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1CON</td>
<td>RD16</td>
<td>T1RUN</td>
<td>T1CKPS1</td>
<td>T1CKPS0</td>
<td>T1OSCN</td>
<td>T1SYNC</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
<td>52</td>
</tr>
</tbody>
</table>

Legend:  
- x = unknown,  
- u = unchanged,  
- — = unimplemented, read as ‘0’.  

Shaded cells are not used by the Timer1 module.

Note 1: These bits are unimplemented on PIC18F2682/2685 devices; always maintain these bits clear.
13.0 TIMER2 MODULE

The Timer2 module incorporates the following features:

- 8-bit timer and period registers (TMR2 and PR2, respectively)
- Readable and writable (both registers)
- Software programmable prescaler (1:1, 1:4 and 1:16)
- Software programmable postscaler (1:1 through 1:16)
- Interrupt on TMR2 to PR2 match
- Optional use as the shift clock for the MSSP module

The module is controlled through the T2CON register (Register 13-1), which enables or disables the timer and configures the prescaler and postscaler. Timer2 can be shut off by clearing control bit, TMR2ON (T2CON<2>), to minimize power consumption.

A simplified block diagram of the module is shown in Figure 13-1.

### REGISTER 13-1: T2CON: TIMER2 CONTROL REGISTER

<table>
<thead>
<tr>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>bit 7</td>
<td>T2OUTPS3</td>
<td>T2OUTPS2</td>
<td>T2OUTPS1</td>
<td>T2OUTPS0</td>
<td>TMR2ON</td>
<td>T2CKPS1</td>
<td>T2CKPS0</td>
</tr>
</tbody>
</table>

**Legend:**
- **R** = Readable bit
- **W** = Writable 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 | Unimplemented: Read as ‘0’ |
| bit 6-3 | T2OUTPS3:T2OUTPS0: Timer2 Output Postscale Select bits |
| 0000 | 1:1 Postscale |
| 0001 | 1:2 Postscale |
| 001x | 1:x Postscale |
| 1111 | 1:16 Postscale |

| bit 2 | TMR2ON: Timer2 On bit |
| 1 | Timer2 is on |
| 0 | Timer2 is off |

| bit 1-0 | T2CKPS1:T2CKPS0: Timer2 Clock Prescale Select bits |
| 00 | Prescaler is 1 |
| 01 | Prescaler is 4 |
| 1x | Prescaler is 16 |

13.1 Timer2 Operation

In normal operation, TMR2 is incremented from 00h on each clock (FOSC/4). A 2-bit counter/prescaler on the clock input gives direct input, divide-by-4 and divide-by-16 prescale options. These options are selected by the prescaler control bits, T2CKPS1:T2CKPS0 (T2CON<1:0>). The value of TMR2 is compared to that of the period register, PR2, on each clock cycle. When the two values match, the comparator generates a match signal as the timer output. This signal also resets the value of TMR2 to 00h on the next cycle and drives the output counter/postscaler (see Section 13.2 “Timer2 Interrupt”).

The TMR2 and PR2 registers are both directly readable and writable. The TMR2 register is cleared on any device Reset, while the PR2 register initializes at FFh. Both the prescaler and postscaler counters are cleared on the following events:

- a write to the TMR2 register
- a write to the T2CON register
- any device Reset (Power-on Reset, MCLR Reset, Watchdog Timer Reset or Brown-out Reset)

TMR2 is not cleared when T2CON is written.
13.2 Timer2 Interrupt

Timer2 also can generate an optional device interrupt. The Timer2 output signal (TMR2 to PR2 match) provides the input for the 4-bit output counter/postscaler. This counter generates the TMR2 match interrupt flag which is latched in TMR2IF (PIR1<1>). The interrupt is enabled by setting the TMR2 Match Interrupt Enable bit, TMR2IE (PIE1<1>).

A range of 16 postscale options (from 1:1 through 1:16 inclusive) can be selected with the postscaler control bits, T2OUTPS3:T2OUTPS0 (T2CON<6:3>).

13.3 TMR2 Output

The unscaled output of TMR2 is available primarily to the CCP1 modules, where it is used as a time base for operations in PWM mode.

Timer2 can be optionally used as the shift clock source for the MSSP module operating in SPI mode. Additional information is provided in Section 17.0 “Master Synchronous Serial Port (MSSP) Module”.

---

**TABLE 13-1: REGISTERS ASSOCIATED WITH TIMER2 AS A TIMER/COUNTER**

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>TMR2</td>
<td>Timer2 Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>T2CON</td>
<td>—</td>
<td>T2OUTPS3</td>
<td>T2OUTPS2</td>
<td>T2OUTPS1</td>
<td>T2OUTPS0</td>
<td>TMR2ON</td>
<td>T2CKPS1</td>
<td>T2CKPS0</td>
<td>52</td>
</tr>
<tr>
<td>PR2</td>
<td>Timer2 Period Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used by the Timer2 module.

**Note 1:** These bits are unimplemented on PIC18F2682/2685 devices; always maintain these bits clear.
14.0 TIMER3 MODULE

The Timer3 timer/counter module incorporates these features:

- Software selectable operation as a 16-bit timer or counter
- Readable and writable 8-bit registers (TMR3H and TMR3L)
- Selectable clock source (internal or external) with device clock or Timer1 oscillator internal options
- Interrupt on overflow
- Module Reset on CCP1 Special Event Trigger

A simplified block diagram of the Timer3 module is shown in Figure 14-1. A block diagram of the module’s operation in Read/Write mode is shown in Figure 14-2. The Timer3 module is controlled through the T3CON register (Register 14-1). It also selects the clock source options for the ECCP1/CCP1 modules (see Section 15.1.1 “CCP1 Modules and Timer Resources” for more information).

REGISTER 14-1: T3CON: TIMER3 CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD16</td>
<td>T3ECCP1</td>
<td>T3CKPS1</td>
<td>T3CKPS0</td>
<td>T3CCP1</td>
<td>T3SYNC</td>
<td>TMR3CS</td>
<td>TMR3ON</td>
</tr>
</tbody>
</table>

Legend:

R = Readable bit  
W = Writable bit  
U = Unimplemented bit, read as ‘0’  
- = Value at POR  
‘1’ = Bit is set  
‘0’ = Bit is cleared  
x = Bit is unknown

bit 7  
RD16: 16-Bit Read/Write Mode Enable bit  
1 = Enables register read/write of Timer3 in one 16-bit operation  
0 = Enables register read/write of Timer3 in two 8-bit operations

bit 6,3  
T3ECCP1:T3CCP1: Timer3 and Timer1 to ECCP1/CCP1 Enable bits  
1x = Timer3 is the capture/compare clock source for both CCP1 and ECCP1 modules  
01 = Timer3 is the capture/compare clock source for ECCP1; Timer1 is the capture/compare clock source for CCP1  
00 = Timer1 is the capture/compare clock source for both CCP1 and ECCP1 modules

bit 5-4  
T3CKPS1:T3CKPS0: Timer3 Input Clock Prescale Select bits  
11 = 1:8 Prescale value  
10 = 1:4 Prescale value  
01 = 1:2 Prescale value  
00 = 1:1 Prescale value

bit 2  
T3SYNC: Timer3 External Clock Input Synchronization Control bit  
(Not usable if the device clock comes from Timer1/Timer3.)  
When TMR3CS = 1:  
1 = Do not synchronize external clock input  
0 = Synchronize external clock input  
When TMR3CS = 0:  
This bit is ignored. Timer3 uses the internal clock when TMR3CS = 0.

bit 1  
TMR3CS: Timer3 Clock Source Select bit  
1 = External clock input from Timer1 oscillator or T13CKI (on the rising edge after the first falling edge)  
0 = Internal clock (Fosc/4)

bit 0  
TMR3ON: Timer3 On bit  
1 = Enables Timer3  
0 = Stops Timer3

Note 1: These bits and the ECCP1 module are available on PIC18F4682/4685 devices only.
14.1 Timer3 Operation

Timer3 can operate in one of three modes:
- Timer
- Synchronous Counter
- Asynchronous Counter

The operating mode is determined by the clock select bit, TMR3CS (T3CON<1>). When TMR3CS is cleared (= 0), Timer3 increments on every internal instruction cycle (Fosc/4). When the bit is set, Timer3 increments on every rising edge of the Timer1 external clock input or the Timer1 oscillator if enabled.

As with Timer1, the RC1/T1OSI and RC0/T1OSO/T13CKI pins become inputs when the Timer1 oscillator is enabled. This means the values of TRISC<1:0> are ignored and the pins are read as ‘0’.

FIGURE 14-1: TIMER3 BLOCK DIAGRAM

Note 1: When enable bit, T1OSCEN, is cleared, the inverter and feedback resistor are turned off to eliminate power drain.

FIGURE 14-2: TIMER3 BLOCK DIAGRAM (16-BIT READ/WRITE MODE)

Note 1: When enable bit, T1OSCEN, is cleared, the inverter and feedback resistor are turned off to eliminate power drain.
14.2 Timer3 16-Bit Read/Write Mode

Timer3 can be configured for 16-bit reads and writes (see Figure 14-2). When the RD16 control bit (T3CON<7>) is set, the address for TMR3H is mapped to a buffer register for the high byte of Timer3. A read from TMR3L will load the contents of the high byte of Timer3 into the Timer3 High Byte Buffer register. This provides the user with the ability to accurately read all 16 bits of Timer1 without having to determine whether a read of the high byte, followed by a read of the low byte, has become invalid due to a rollover between reads.

A write to the high byte of Timer3 must also take place through the TMR3H Buffer register. The Timer3 high byte is updated with the contents of TMR3H when a write occurs to TMR3L. This allows a user to write all 16 bits to both the high and low bytes of Timer3 at once.

The high byte of Timer3 is not directly readable or writable in this mode. All reads and writes must take place through the Timer3 High Byte Buffer register.

Writes to TMR3H do not clear the Timer3 prescaler. The prescaler is only cleared on writes to TMR3L.

14.3 Using the Timer1 Oscillator as the Timer3 Clock Source

The Timer1 internal oscillator may be used as the clock source for Timer3. The Timer1 oscillator is enabled by setting the T1OSCEN (T1CON<3>) bit. To use it as the Timer3 clock source, the TMR3CS bit must also be set. As previously noted, this also configures Timer3 to increment on every rising edge of the oscillator source.

The Timer1 oscillator is described in Section 12.0 “Timer1 Module”.

14.4 Timer3 Interrupt

The TMR3 register pair (TMR3H:TMR3L) increments from 0000h to FFFFh and overflows to 0000h. The Timer3 interrupt, if enabled, is generated on overflow and is latched in the interrupt flag bit, TMR3IF (PIR2<1>). This interrupt can be enabled or disabled by setting or clearing the Timer3 Interrupt Enable bit, TMR3IE (PIE2<1>).

14.5 Resetting Timer3 Using the ECCP1 Special Event Trigger

If the ECCP1 module is configured to generate a Special Event Trigger in Compare mode (ECCP1M3:ECCP1M0 = 1011), this signal will reset Timer3. If ECCP1M3:ECCP1M0 = 1001, this signal will also start an A/D conversion if the A/D module is enabled (see Section 15.3.4 “Special Event Trigger” for more information.).

The module must be configured as either a timer or synchronous counter to take advantage of this feature. When used this way, the ECCPR1H:ECCPR1L register pair effectively becomes a period register for Timer3.

If Timer3 is running in Asynchronous Counter mode, the Reset operation may not work.

In the event that a write to Timer3 coincides with a Special Event Trigger from a CCP1 module, the write will take precedence.

Note: The Special Event Triggers from the ECCP1 module will not set the TMR3IF interrupt flag bit (PIR2<1>).

### TABLE 14-1: REGISTERS ASSOCIATED WITH TIMER3 AS A TIMER/COUNTER

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR2</td>
<td>OSCFIF</td>
<td>CMIF(1)</td>
<td>—</td>
<td>—</td>
<td>EEIF</td>
<td>BCLIF</td>
<td>HLVDF</td>
<td>TMR3IF</td>
<td>ECCP1IF(1)</td>
</tr>
<tr>
<td>PIE2</td>
<td>OSCFIE</td>
<td>CMIE(1)</td>
<td>—</td>
<td>—</td>
<td>EEIE</td>
<td>BCLIE</td>
<td>HLVDE</td>
<td>TMR3IE</td>
<td>ECCP1IE(1)</td>
</tr>
<tr>
<td>IPR2</td>
<td>OSCFIP</td>
<td>CMIP(1)</td>
<td>—</td>
<td>—</td>
<td>EEIP</td>
<td>BCLIP</td>
<td>HLVDP</td>
<td>TMR3IP</td>
<td>ECCP1IP(1)</td>
</tr>
<tr>
<td>TMR3L</td>
<td>Timer3 Register, Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR3H</td>
<td>Timer3 Register, High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1CON</td>
<td>RD16</td>
<td>T1RUN</td>
<td>T1CKPS1</td>
<td>T1CKPS0</td>
<td>T1OSCEN</td>
<td>T1SYNC</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
<td>52</td>
</tr>
<tr>
<td>T3CON</td>
<td>RD16</td>
<td>T3ECCP1(1)</td>
<td>T3CKPS1</td>
<td>T3CKPS0</td>
<td>T3CCP1(1)</td>
<td>T3SYNC</td>
<td>TMR3CS</td>
<td>TMR3ON</td>
<td>53</td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used by the Timer3 module.

Note 1: These bits are unimplemented on PIC18F2682/2685 devices; always maintain these bits clear.
15.0 CAPTURE/COMPARE/PWM (CCP1) MODULES

PIC18F2682/2685 devices have one CCP1 module. PIC18F4682/4685 devices have two CCP1 (Capture/Compare/PWM) modules. CCP1, discussed in this chapter, implements standard Capture, Compare and Pulse-Width Modulation (PWM) modes.

ECCP1 implements an Enhanced PWM mode. The ECCP1 implementation is discussed in Section 16.0 “Enhanced Capture/Compare/PWM (ECCP1) Module”.

REGISTER 15-1: CCP1CON: CAPTURE/COMPARE/PWM CONTROL REGISTER

<table>
<thead>
<tr>
<th></th>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td>—</td>
<td>—</td>
<td>DC1B1</td>
<td>DC1B0</td>
<td>CCP1M3</td>
<td>CCP1M2</td>
<td>CCP1M1</td>
<td>CCP1M0</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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 5-4 DC1B1:DC1B0: CCP1 Module PWM Duty Cycle bit 1 and bit 0
- Capture mode: Unused.
- Compare mode: Unused.
- PWM mode: These bits are the two LSbs (bit 1 and bit 0) of the 10-bit PWM duty cycle. The eight MSbs (DC1B9:DC1B2) of the duty cycle are found in CCPR1L.

bit 3-0 CCP1M3:CCP1M0: CCP1 Module Mode Select bits
- 0000 = Capture/Compare/PWM disabled (resets CCP1 module)
- 0001 = Reserved
- 0010 = Compare mode; toggle output on match (CCP1IF bit is set)
- 0011 = Reserved
- 0100 = Capture mode; every falling edge or CAN message received (time-stamp)(1)
- 0101 = Capture mode; every rising edge or CAN message received (time-stamp)(1)
- 0110 = Capture mode; every 4th rising edge or every 4th CAN message received (time-stamp)(1)
- 0111 = Capture mode; every 16th rising edge or every 16th CAN message received (time-stamp)(1)
- 1000 = Compare mode; initialize CCP1 pin low; on compare match, force CCP1 pin high (CCP1IF bit is set)
- 1001 = Compare mode; initialize CCP pin high; on compare match, force CCP1 pin low (CCP1IF bit is set)
- 1010 = Compare mode; generate software interrupt on compare match (CCP1IF bit is set, CCP1 pin reflects I/O state)
- 1011 = Compare mode; trigger special event; reset timer (TMR1 or TMR3, CCP1IF bit is set)
- 11xx = PWM mode

Note 1: Selected by CANCAP (CIOCON<4>) bit; overrides the CCP1 input pin source.

The CCP1 module contains a 16-bit register which can operate as a 16-bit Capture register, a 16-bit Compare register or a PWM Master/Slave Duty Cycle register. For the sake of clarity, all CCP1 module operation in the following sections is described with respect to CCP1, but is equally applicable to ECCP1.

Capture/ and Compare operations described in this chapter apply to all standard and Enhanced CCP1 modules. The operations of PWM mode, described in Section 15.4 “PWM Mode”, apply to CCP1 only.
15.1 CCP1 Module Configuration

Each Capture/Compare/PWM module is associated with a control register (CCP1CON or ECCP1CON) and a data register (CCPR1 or ECCPR1). The data register, in turn, is comprised of two 8-bit registers: CCPR1L or ECCPR1L (low byte) and CCPR1H or ECCPR1H (high byte). All registers are both readable and writable.

15.1.1 CCP1 MODULES AND TIMER RESOURCES

The CCP1 modules utilize Timers 1, 2 or 3, depending on the mode selected. Timer1 and Timer3 are available to modules in Capture or Compare modes, while Timer2 is available for modules in PWM mode.

<table>
<thead>
<tr>
<th>CCP1 Mode</th>
<th>ECCP1 Mode</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture</td>
<td>Capture</td>
<td>Each module can use TMR1 or TMR3 as the time base. Time base can be different for each CCP1.</td>
</tr>
<tr>
<td>Capture</td>
<td>Compare</td>
<td>CCP1 can be configured for the Special Event Trigger to reset TMR1 or TMR3 (depending upon which time base is used). Automatic A/D conversions on trigger event can also be done. Operation of CCP1 could be affected if it is using the same timer as a time base.</td>
</tr>
<tr>
<td>Compare</td>
<td>Capture</td>
<td>CCP1 can be configured for the Special Event Trigger to reset TMR1 or TMR3 (depending upon which time base is used). Operation of CCP1 could be affected if it is using the same timer as a time base.</td>
</tr>
<tr>
<td>Compare</td>
<td>Compare</td>
<td>Either module can be configured for the Special Event Trigger to reset the time base. Automatic A/D conversions on ECCP1 trigger event can be done. Conflicts may occur if both modules are using the same time base.</td>
</tr>
<tr>
<td>Capture</td>
<td>PWM*</td>
<td>None</td>
</tr>
<tr>
<td>Compare</td>
<td>PWM*</td>
<td>None</td>
</tr>
<tr>
<td>PWM*</td>
<td>Capture</td>
<td>None</td>
</tr>
<tr>
<td>PWM*</td>
<td>Compare</td>
<td>None</td>
</tr>
<tr>
<td>PWM*</td>
<td>PWM</td>
<td>Both PWMs will have the same frequency and update rate (TMR2 interrupt).</td>
</tr>
</tbody>
</table>

* Includes standard and Enhanced PWM operation.

The assignment of a particular timer to a module is determined by the Timer to CCP1/ECCP1 enable bits in the T3CON register (Register 14-1). Both modules may be active at any given time and may share the same timer resource if they are configured to operate in the same mode (Capture/Compare or PWM) at the same time. The interactions between the two modules are summarized in Figure 15-1 and Figure 15-2.
15.2 Capture Mode

In Capture mode, the CCPR1H:CCPR1L (or ECCPR1H:ECCPR1L) register pair captures the 16-bit value of the TMR1 or TMR3 registers when an event occurs on the CCP1/ECCP1 pin (RC2 for 28/40/44-pin devices and RD4 for 40/44-pin devices). An event is defined as one of the following:

- every falling edge
- every rising edge
- every 4th rising edge
- every 16th rising edge

The event is selected by the mode select bits, CCP1M3:CCP1M0 (CCP1CON<3:0>). When a capture is made, the interrupt request flag bit, CCP1IF (PIR1<2>), is set; it must be cleared in software. If another capture occurs before the value in the CCPR1 register pair is read, the old captured value is overwritten by the new captured value.

15.2.1 CCP1 PIN CONFIGURATION

In Capture mode, the appropriate CCP1/ECCP1 pin should be configured as an input by setting the corresponding TRIS direction bit.

**Note:** If RC2/CCP1 or RD4/PSP4/ECCP1/P1A is configured as an output, a write to the port can cause a capture condition.

15.2.2 TIMER1/TIMER3 MODE SELECTION

The timers that are to be used with the capture feature (Timer1 and/or Timer3) must be running in Timer mode or Synchronized Counter mode. In Asynchronous Counter mode, the capture operation may not work. The timer to be used with each CCP1 module is selected in the T3CON register (see Section 15.1.1 “CCP1 Modules and Timer Resources”).

15.2.3 SOFTWARE INTERRUPT

When the Capture mode is changed, a false capture interrupt may be generated. The user should keep the CCP1IE or ECCP1IE interrupt enable bit clear to avoid false interrupts. The interrupt flag bit, CCP1IF or ECCP1IF, should also be cleared following any such change in operating mode.

15.2.4 CCP1 PRESCALER

There are four prescaler settings in Capture mode; they are specified as part of the operating mode selected by the mode select bits (CCP1M3:CCP1M0). Whenever the CCP1 module is turned off or the CCP1 module is not in Capture mode, the prescaler counter is cleared. This means that any Reset will clear the prescaler counter.

Switching from one capture prescaler to another may generate an interrupt. Also, the prescaler counter will not be cleared; therefore, the first capture may be from a non-zero prescaler. Example 15-1 shows the recommended method for switching between capture prescalers. This example also clears the prescaler counter and will not generate the “false” interrupt.

15.2.5 CAN MESSAGE TIME-STAMP

The CAN capture event occurs when a message is received in any of the receive buffers. When configured, the CAN module provides the trigger to the CCP1 module to cause a capture event. This feature is provided to “time-stamp” the received CAN messages.

This feature is enabled by setting the CANCAP bit of the CAN I/O Control register (CIOCON<4>). The message receive signal from the CAN module then takes the place of the events on the RC2/CCP1 pin.

If this feature is selected, then four different capture options for CCP1M<3:0> are available:

- **0100** – every time a CAN message is received
- **0101** – every time a CAN message is received
- **0110** – every 4th time a CAN message is received
- **0111** – Capture mode, every 16th time a CAN message is received

**EXAMPLE 15-1:** CHANGING BETWEEN CAPTURE PRESCALERS

| CLRF CCP1CON ; Turn CCP1 module off |
| MOVLW NEW_CAPT_PS ; Load WREG with the |
| ; new prescaler mode |
| MOVWF CCP1CON ; Load CCP1CON with |
| ; this value |

© 2009 Microchip Technology Inc. DS39761C-page 167
FIGURE 15-1: CAPTURE MODE OPERATION BLOCK DIAGRAM
15.3 Compare Mode

In Compare mode, the 16-bit CCPR1 register value is constantly compared against either the TMR1 or TMR3 register pair value. When a match occurs, the CCP1 pin can be:

- driven high
- driven low
- toggled (high-to-low or low-to-high)
- remain unchanged (that is, reflects the state of the I/O latch)

The action on the pin is based on the value of the mode select bits (CCP1M3:CCP1M0). At the same time, the interrupt flag bit, CCP1IF, is set.

15.3.1 CCP1 PIN CONFIGURATION

The user must configure the CCP1 (ECCP1) pin as an output by clearing the appropriate TRIS bit.

**Note:** Clearing the CCP1CON register will force the RC2 compare output latch to the default low level. This is not the PORTC I/O data latch.

15.3.2 TIMER1/TIMER3 MODE SELECTION

Timer1 and/or Timer3 must be running in Timer mode or Synchronized Counter mode if the CCP1 module is using the compare feature. In Asynchronous Counter mode, the compare operation may not work.

15.3.3 SOFTWARE INTERRUPT MODE

When the Generate Software Interrupt mode is chosen (CCP1M3:CCP1M0 = 1010), the CCP1 pin is not affected. Only a CCP1 interrupt is generated, if enabled and the CCP1IE bit is set.

15.3.4 SPECIAL EVENT TRIGGER

Both CCP1 modules are equipped with a Special Event Trigger. This is an internal hardware signal generated in Compare mode to trigger actions by other modules. The Special Event Trigger is enabled by selecting the Compare Special Event Trigger mode (CCP1M3:CCP1M0 = 1011).

For either the CCP1/ECCP1 module, the Special Event Trigger resets the timer register pair for whichever timer resource is currently assigned as the module’s time base. This allows the CCPR1 (ECCPR1) registers to serve as a programmable period register for either timer.

**FIGURE 15-2: COMPARE MODE OPERATION BLOCK DIAGRAM**
### TABLE 15-3: REGISTERS ASSOCIATED WITH CAPTURE, COMPARE, TIMER1 AND TIMER3

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INTOIE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INTOIF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>RCON</td>
<td>IPEN</td>
<td>SBOREN(2)</td>
<td>—</td>
<td>Rİ</td>
<td>TÖ</td>
<td>PD</td>
<td>POR</td>
<td>BOR</td>
<td>52</td>
</tr>
<tr>
<td>IPR1</td>
<td>P$\text{S}$PIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>S$\text{S}$PIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>PIR1</td>
<td>P$\text{S}$PIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>S$\text{S}$PIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>P$\text{S}$PIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>S$\text{S}$PIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR2</td>
<td>OSC$\text{F}$IP</td>
<td>CMIF(1)</td>
<td>—</td>
<td>EEIP</td>
<td>BCLIP</td>
<td>HLV$\text{D}$IP</td>
<td>TMR3IP</td>
<td>ECCP1IP(1)</td>
<td>54</td>
</tr>
<tr>
<td>PIR2</td>
<td>OSC$\text{F}$IF</td>
<td>CMIF(1)</td>
<td>—</td>
<td>EEIF</td>
<td>BCLIF</td>
<td>HLV$\text{D}$IF</td>
<td>TMR3IF</td>
<td>ECCP1IF(1)</td>
<td>54</td>
</tr>
<tr>
<td>PIE2</td>
<td>OSC$\text{F}$IE</td>
<td>CMIE(1)</td>
<td>—</td>
<td>EEIE</td>
<td>BCLIE</td>
<td>HLV$\text{D}$IE</td>
<td>TMR3IE</td>
<td>ECCP1IE(1)</td>
<td>53</td>
</tr>
<tr>
<td>TRISB</td>
<td>PORTB Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>TRISC</td>
<td>PORTC Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>TMR1L</td>
<td>Timer1 Register Low Byte</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>TMR1H</td>
<td>Timer1 Register High Byte</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>T1CON</td>
<td>RD16</td>
<td>T1RUN</td>
<td>T1CKPS1</td>
<td>T1CKPS0</td>
<td>T1OSCEN</td>
<td>T1SYNC</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
<td>52</td>
</tr>
<tr>
<td>TMR3H</td>
<td>Timer3 Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>TMR3L</td>
<td>Timer3 Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>T3CON</td>
<td>RD16</td>
<td>T3EC$\text{C}$P1(1)</td>
<td>T3CKPS1</td>
<td>T3CKPS0</td>
<td>T3CC$\text{P}$1(1)</td>
<td>T3SYNC</td>
<td>TMR3CS</td>
<td>TMR3ON</td>
<td>53</td>
</tr>
<tr>
<td>CCPR1L</td>
<td>Capture/Compare/PWM Register 1 Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>CCPR1H</td>
<td>Capture/Compare/PWM Register 1 High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>CCP1CON</td>
<td>—</td>
<td>—</td>
<td>DC1B1</td>
<td>DC1B0</td>
<td>CCP1M3</td>
<td>CCP1M2</td>
<td>CCP1M1</td>
<td>CCP1M0</td>
<td>53</td>
</tr>
<tr>
<td>ECCPR1L(1)</td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>ECCPR1H(1)</td>
<td>Enhanced Capture/Compare/PWM Register 1 High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>ECCP1CON(1)</td>
<td>EPW$\text{M}$1M1</td>
<td>EPW$\text{M}$1M0</td>
<td>EDC1B1</td>
<td>EDC1B0</td>
<td>ECCP$\text{M}$1M3</td>
<td>ECCP$\text{M}$1M2</td>
<td>ECCP$\text{M}$1M1</td>
<td>ECCP$\text{M}$1M0</td>
<td>53</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used by Capture and Compare, Timer1 or Timer3.

**Note 1:** These bits or registers are available on PIC18F4682/4685 devices only.

**Note 2:** The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’.
15.4 PWM Mode

In Pulse-Width Modulation (PWM) mode, the CCP1 pin produces up to a 10-bit resolution PWM output. Since the CCP1 pin is multiplexed with a PORTB or PORTC data latch, the appropriate TRIS bit must be cleared to make the CCP1 pin an output.

**Note:** Clearing the CCP1CON register will force the RC2 output latch to the default low level. This is not the PORTC I/O data latch.

Figure 15-3 shows a simplified block diagram of the CCP1 module in PWM mode.

For a step-by-step procedure on how to set up the CCP1 module for PWM operation, see Section 15.4.4 “Setup for PWM Operation”.

**FIGURE 15-3: SIMPLIFIED PWM BLOCK DIAGRAM**

A PWM output (Figure 15-4) has a time base (period) and a time that the output stays high (duty cycle). The frequency of the PWM is the inverse of the period (1/period).

**FIGURE 15-4: PWM OUTPUT**

15.4.1 PWM Period

The PWM period is specified by writing to the PR2 (PR4) register. The PWM period can be calculated using the following formula.

**EQUATION 15-1:**

\[
\text{PWM Frequency} = \frac{1}{\text{PWM Period}}
\]

When TMR1 (TMR3) is equal to PR2 (PR4), the following three events occur on the next increment cycle:

- TMR2 is cleared
- The CCP1 pin is set (exception: if PWM duty cycle = 0%, the CCP1 pin will not be set)
- The PWM duty cycle is latched from CCPR1L into CCPR1H

**Note:** The Timer2 postscaler (see Section 13.0 “Timer2 Module”) is not used in the determination of the PWM frequency. The postscaler could be used to have a servo update rate at a different frequency than the PWM output.

15.4.2 PWM Duty Cycle

The PWM duty cycle is specified by writing to the CCPR1L register and to the CCP1CON<5:4> bits. Up to 10-bit resolution is available. The CCPR1L contains the eight MSbs and the CCP1CON<5:4> contains the two LSbs. This 10-bit value is represented by CCPR1L:CCPR1CON<5:4>. The following equation is used to calculate the PWM duty cycle in time.

**EQUATION 15-2:**

\[
\text{PWM Duty Cycle} = \frac{\text{CCPR1L:CCP1CON<5:4> • Tosc}}{(\text{TMR2 Prescale Value})}
\]

CCPR1L and CCP1CON<5:4> can be written to at any time, but the duty cycle value is not latched into CCPR1H until after a match between PR2 and TMR2 occurs (i.e., the period is complete). In PWM mode, CCPR1H is a read-only register.
The CCPR1H register and a 2-bit internal latch are used to double-buffer the PWM duty cycle. This double-buffering is essential for glitchless PWM operation.

When the CCPR1H and 2-bit latch match TMR2, concatenated with an internal 2-bit Q clock or 2 bits of the TMR2 prescaler, the CCP1 pin is cleared.

The maximum PWM resolution (bits) for a given PWM frequency is given by the equation.

\[
\text{EQUATION 15-3:}
\]

\[
\text{PWM Resolution (max)} = \frac{\log\left(\frac{\text{Fosc}}{\text{FPWM}}\right)}{\log(2)} \text{ bits}
\]

Note: If the PWM duty cycle value is longer than the PWM period, the CCP1 pin will not be cleared.

<table>
<thead>
<tr>
<th>TABLE 15-4: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS AT 40 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWM Frequency</td>
</tr>
<tr>
<td>Timer Prescaler (1, 4, 16)</td>
</tr>
<tr>
<td>PR2 Value</td>
</tr>
<tr>
<td>Maximum Resolution (bits)</td>
</tr>
</tbody>
</table>

15.4.3 PWM AUTO-SHUTDOWN
(ECCP1 ONLY)

The PWM auto-shutdown features of the Enhanced CCP1 module are available to ECCP1 in PIC18F4682/4685 (40/44-pin) devices. The operation of this feature is discussed in detail in Section 16.4.7 “Enhanced PWM Auto-Shutdown”.

Auto-shutdown features are not available for CCP1.

15.4.4 SETUP FOR PWM OPERATION

The following steps should be taken when configuring the CCP1 module for PWM operation:
1. Set the PWM period by writing to the PR2 register.
2. Set the PWM duty cycle by writing to the CCP1L register and CCP1CON<5:4> bits.
3. Make the CCP1 pin an output by clearing the appropriate TRIS bit.
4. Set the TMR2 prescale value, then enable Timer2 by writing to T2CON.
5. Configure the CCP1 module for PWM operation.
<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td></td>
<td></td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INTOIE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
</tr>
<tr>
<td>RCON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IPEN</td>
<td></td>
<td></td>
<td></td>
<td>SBOREN(2)</td>
</tr>
<tr>
<td>PIR1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSPIF(1)</td>
<td></td>
<td></td>
<td></td>
<td>PSPIE</td>
</tr>
<tr>
<td>PIE1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
</tr>
<tr>
<td>IPR1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSPIE(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
</tr>
<tr>
<td>TRISB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTB Data Direction Register</td>
</tr>
<tr>
<td>TRISC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PORTC Data Direction Register</td>
</tr>
<tr>
<td>TMR2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Timer2 Register</td>
</tr>
<tr>
<td>PIE1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PR2</td>
</tr>
<tr>
<td>T2CON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T2OUTPS3</td>
<td>T2OUTPS2</td>
<td>T2OUTPS1</td>
<td>T2OUTPS0</td>
</tr>
<tr>
<td>CCPR1L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Capture/Compare/PWM Register 1 Low Byte</td>
</tr>
<tr>
<td>CCPR1H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Capture/Compare/PWM Register 1 High Byte</td>
</tr>
<tr>
<td>CCP1CON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>ECCPR1L(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
</tr>
<tr>
<td>ECCPR1H(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enhanced Capture/Compare/PWM Register 1 High Byte</td>
</tr>
<tr>
<td>ECCP1CON(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EPWM1M1</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as '0'. Shaded cells are not used by PWM or Timer2.

**Note 1:** These bits or registers are available on PIC18F4682/4685 devices only.

**Note 2:** The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’.
In PIC18F4682/4685 devices, ECCP1 is implemented as a standard CCP1 module with Enhanced PWM capabilities. These include the provision for 2 or 4 output channels, user-selectable polarity, dead-band control and automatic shutdown and restart. The enhanced features are discussed in detail in Section 16.4 “Enhanced PWM Mode”. Capture, Compare and single output PWM functions of the ECCP1 module are the same as described for the standard CCP1 module.

The control register for the Enhanced CCP1 module is shown in Register 16-1. It differs from the CCP1CON register in the PIC18F2682/2685 devices in that the two Most Significant bits are implemented to control PWM functionality.

REGISTER 16-1: ECCP1CON: ENHANCED CAPTURE/COMPARE/PWM CONTROL REGISTER

<table>
<thead>
<tr>
<th>Bit 7-6</th>
<th>Bit 5-4</th>
<th>Bit 3-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPWM1M1:EPWM1M0: Enhanced PWM Output Configuration bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDC1B1:EDC1B0: ECCP1 Module PWM Duty Cycle bit 1 and bit 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECCP1M3:ECCP1M0: Enhanced CCP1 Mode Select bits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- **R** = Readable bit
- **W** = Writable 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 EPWM1M1:EPWM1M0: Enhanced PWM Output Configuration bits**

<table>
<thead>
<tr>
<th>EPWM1M1</th>
<th>EPWM1M0</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx</td>
<td>xx</td>
</tr>
</tbody>
</table>

- **xx** = P1A assigned as Capture/Compare input/output; P1B, P1C, P1D assigned as port pins

- **00** = Single output: P1A modulated; P1B, P1C, P1D assigned as port pins
- **01** = Full-bridge output forward: P1D modulated; P1A active; P1B, P1C inactive
- **10** = Half-bridge output: P1A, P1B modulated with dead-band control; P1C, P1D assigned as port pins
- **11** = Full-bridge output reverse: P1B modulated; P1C active; P1A, P1D inactive

**bit 5-4 EDC1B1:EDC1B0: ECCP1 Module PWM Duty Cycle bit 1 and bit 0**

- **Capture mode:**
  - Unused.
- **Compare mode:**
  - Unused.
- **PWM mode:**
  - These bits are the two LSbs of the 10-bit PWM duty cycle. The eight MSbs of the duty cycle are found in ECCPR1L.

**bit 3-0 ECCP1M3:ECCP1M0: Enhanced CCP1 Mode Select bits**

<table>
<thead>
<tr>
<th>ECCP1M3</th>
<th>ECCP1M2</th>
<th>ECCP1M1</th>
<th>ECCP1M0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>001</td>
<td>0100</td>
<td>0110</td>
</tr>
</tbody>
</table>

- **0000** = Capture/Compare/PWM off (resets ECCP1 module)
- **0001** = Reserved
- **0010** = Compare mode; toggle output on match
- **0011** = Reserved
- **0100** = Capture mode; every falling edge
- **0101** = Capture mode; every rising edge
- **0110** = Capture mode; every 4th rising edge
- **0111** = Capture mode; every 16th rising edge
- **1000** = Compare mode; initialize ECCP1 pin low; set output on compare match (set ECCP1IF)
- **1001** = Compare mode; initialize ECCP1 pin high; clear output on compare match (set ECCP1IF)
- **1010** = Compare mode; generate software interrupt only; ECCP1 pin reverts to I/O state
- **1011** = Compare mode; trigger special event (ECCP1 resets TMR1 or TMR3, sets ECCP1IF bit and starts the A/D conversion on ECCP1 match)
- **1100** = PWM mode; P1A, P1C active-high; P1B, P1D active-high
- **1101** = PWM mode; P1A, P1C active-high; P1B, P1D active-low
- **1110** = PWM mode; P1A, P1C active-low; P1B, P1D active-high
- **1111** = PWM mode; P1A, P1C active-low; P1B, P1D active-low
In addition to the expanded range of modes available through the ECCP1CON register, the ECCP1 module has two additional registers associated with Enhanced PWM operation and auto-shutdown features. They are:
- ECCP1DEL (Dead-Band Delay)
- ECCP1AS (Auto-Shutdown Configuration)

### 16.1 ECCP1 Outputs and Configuration

The Enhanced CCP1 module may have up to four PWM outputs, depending on the selected operating mode. These outputs, designated P1A through P1D, are multiplexed with I/O pins on PORTD. The outputs that are active depend on the ECCP1 operating mode selected. The pin assignments are summarized in Table 16-1.

To configure the I/O pins as PWM outputs, the proper PWM mode must be selected by setting the EPWM1M1:EPWM1M0 and ECCP1M3:ECCP1M0 bits. The appropriate TRISD direction bits for the port pins must also be set as outputs.

#### 16.1.1 ECCP1 MODULES AND TIMER RESOURCES

Like the standard CCP1 modules, the ECCP1 module can utilize Timers 1, 2 or 3, depending on the mode selected. Timer1 and Timer3 are available for modules in Capture or Compare modes, while Timer2 is available for modules in PWM mode. Interactions between the standard and Enhanced CCP1 modules are identical to those described for standard CCP1 modules. Additional details on timer resources are provided in Section 15.1.1 “CCP1 Modules and Timer Resources”.

### 16.2 Capture and Compare Modes

Except for the operation of the Special Event Trigger discussed below, the Capture and Compare modes of the ECCP1 module are identical in operation to that of CCP1. These are discussed in detail in Section 15.2 “Capture Mode” and Section 15.3 “Compare Mode”.

#### 16.2.1 SPECIAL EVENT TRIGGER

The Special Event Trigger output of ECCP1 resets the TMR1 or TMR3 register pair, depending on which timer resource is currently selected. This allows the ECCP1 register to effectively be a 16-bit programmable period register for Timer1 or Timer3. The Special Event Trigger for ECCP1 can also start an A/D conversion. In order to start the conversion, the A/D converter must be previously enabled.

### 16.3 Standard PWM Mode

When configured in Single Output mode, the ECCP1 module functions identically to the standard CCP1 module in PWM mode, as described in Section 15.4 “PWM Mode”. This is also sometimes referred to as “Compatible CCP1” mode, as in Table 16-1.

#### TABLE 16-1: PIN ASSIGNMENTS FOR VARIOUS ECCP1 MODES

<table>
<thead>
<tr>
<th>ECCP1 Mode</th>
<th>CCP1CON Configuration</th>
<th>RD4</th>
<th>RD5</th>
<th>RD6</th>
<th>RD7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatible CCP1</td>
<td>00xx 11xx</td>
<td>ECCP1</td>
<td>RD5/PSP5</td>
<td>RD6/PSP6</td>
<td>RD7/PSP7</td>
</tr>
<tr>
<td>Dual PWM</td>
<td>10xx 11xx</td>
<td>P1A</td>
<td>P1B</td>
<td>RD6/PSP6</td>
<td>RD7/PSP7</td>
</tr>
<tr>
<td>Quad PWM</td>
<td>x1xx 11xx</td>
<td>P1A</td>
<td>P1B</td>
<td>P1C</td>
<td>P1D</td>
</tr>
</tbody>
</table>

Legend: x = Don’t care. Shaded cells indicate pin assignments not used by ECCP1 in a given mode.
16.4 Enhanced PWM Mode

The Enhanced PWM mode provides additional PWM output options for a broader range of control applications. The module is a backward compatible version of the standard CCP1 module and offers up to four outputs, designated P1A through P1D. Users are also able to select the polarity of the signal (either active-high or active-low). The module's output mode and polarity are configured by setting the EPWM1M1:EPWM1M0 and ECCP1M3:ECCP1M0 bits of the ECCP1CON register.

Figure 16-1 shows a simplified block diagram of PWM operation. All control registers are double-buffered and are loaded at the beginning of a new PWM cycle (the period boundary when Timer2 resets) in order to prevent glitches on any of the outputs. The exception is the PWM Dead-Band Delay register, ECCP1DEL, which is loaded at either the duty cycle boundary or the boundary period (whichever comes first). Because of the buffering, the module waits until the assigned timer resets instead of starting immediately. This means that Enhanced PWM waveforms do not exactly match the standard PWM waveforms, but are instead offset by one full instruction cycle (4 TOSC).

As before, the user must manually configure the appropriate TRIS bits for output.

16.4.1 PWM PERIOD

The PWM period is specified by writing to the PR2 register. The PWM period can be calculated using the following equation.

\[
\text{PWM Period} = \left(\frac{(\text{PR2}) + 1}{\text{TMR2 Prescale Value}} \right) \times 4 \times \text{Tosc}
\]

PWM frequency is defined as 1/[PWM period]. When TMR2 is equal to PR2, the following three events occur on the next increment cycle:

- TMR2 is cleared
- The ECCP1 pin is set (if PWM duty cycle = 0%, the ECCP1 pin will not be set)
- The PWM duty cycle is copied from ECCPR1L into ECCPR1H

Note: The Timer2 postscaler (see Section 13.0 “Timer2 Module”) is not used in the determination of the PWM frequency. The postscaler could be used to have a servo update rate at a different frequency than the PWM output.
16.4.2 PWM DUTY CYCLE

The PWM duty cycle is specified by writing to the ECCPR1L register and to the ECCP1CON<5:4> bits. Up to 10-bit resolution is available. The ECCPR1L contains the eight MSbs and the ECCP1CON<5:4> contains the two LSbs. This 10-bit value is represented by ECCPR1L:ECCP1CON<5:4>. The PWM duty cycle is calculated by the following equation.

**EQUATION 16-2:**

\[
\text{PWM Duty Cycle} = \frac{(\text{ECCPR1L:ECCP1CON<5:4>}) \times \text{ToSc} \times \text{(TMR2 Prescale Value)}}{\text{TOSC}}
\]

ECCPR1L and ECCP1CON<5:4> can be written to at any time, but the duty cycle value is not copied into ECCPR1H until a match between PR2 and TMR2 occurs (i.e., the period is complete). In PWM mode, ECCPR1H is a read-only register.

The ECCPR1H register and a 2-bit internal latch are used to double-buffer the PWM duty cycle. This double-buffering is essential for glitchless PWM operation. When the ECCPR1H and 2-bit latch match TMR2, concatenated with an internal 2-bit Q clock or two bits of the TMR2 prescaler, the ECCP1 pin is cleared. The maximum PWM resolution (bits) for a given PWM frequency is given by the following equation.

**EQUATION 16-3:**

\[
\text{PWM Resolution (max)} = \frac{\log\left(\frac{\text{Fosc}}{\text{FPWM}}\right)}{\log(2)} \text{ bits}
\]

**Note:** If the PWM duty cycle value is longer than the PWM period, the ECCP1 pin will not be cleared.

16.4.3 PWM OUTPUT CONFIGURATIONS

The EPWM1M1:EPWM1M0 bits in the ECCP1CON register allow one of four configurations:

- Single Output
- Half-Bridge Output
- Full-Bridge Output, Forward mode
- Full-Bridge Output, Reverse mode

The Single Output mode is the standard PWM mode discussed in Section 16.4 “Enhanced PWM Mode”. The Half-Bridge and Full-Bridge Output modes are covered in detail in the sections that follow.

The general relationship of the outputs in all configurations is summarized in Figure 16-2.

**TABLE 16-2: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS AT 40 MHz**

<table>
<thead>
<tr>
<th>PWM Frequency</th>
<th>2.44 kHz</th>
<th>9.77 kHz</th>
<th>39.06 kHz</th>
<th>156.25 kHz</th>
<th>312.50 kHz</th>
<th>416.67 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer Prescaler (1, 4, 16)</td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PR2 Value</td>
<td>FFh</td>
<td>FFh</td>
<td>FFh</td>
<td>3Fh</td>
<td>1Fh</td>
<td>17h</td>
</tr>
<tr>
<td>Maximum Resolution (bits)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>6.58</td>
</tr>
</tbody>
</table>
### Figure 16-2: PWM Output Relationships (Active-High State)

<table>
<thead>
<tr>
<th>ECCP1CON &lt;7:6&gt;</th>
<th>SIGNAL</th>
<th>0</th>
<th>Duty Cycle</th>
<th>Period</th>
<th>PR2 + 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 (Single Output)</td>
<td>P1A Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1A Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 (Half-Bridge)</td>
<td>P1B Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1A Active</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01 (Full-Bridge, Forward)</td>
<td>P1B Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1C Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1D Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 (Full-Bridge, Reverse)</td>
<td>P1A Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1B Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1C Active</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1D Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Relationships:**
- Period = $4 \times T_{osc} \times (PR2 + 1) \times (TMR2 Prescale Value)$
- Duty Cycle = $T_{osc} \times (ECCPR1L<7:0>:ECCP1CON<5:4>) \times (TMR2 Prescale Value)$
- Delay = $4 \times T_{osc} \times (ECCP1DEL<6:0>)$

**Note 1:** Dead-band delay is programmed using the ECCP1DEL register (Section 16.4.6 “Programmable Dead-Band Delay”).

### Figure 16-3: PWM Output Relationships (Active-Low State)

<table>
<thead>
<tr>
<th>ECCP1CON &lt;7:6&gt;</th>
<th>SIGNAL</th>
<th>0</th>
<th>Duty Cycle</th>
<th>Period</th>
<th>PR2 + 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 (Single Output)</td>
<td>P1A Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1A Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 (Half-Bridge)</td>
<td>P1B Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1A Active</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01 (Full-Bridge, Forward)</td>
<td>P1B Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1C Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1D Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 (Full-Bridge, Reverse)</td>
<td>P1A Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1B Modulated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1C Active</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1D Inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Relationships:**
- Period = $4 \times T_{osc} \times (PR2 + 1) \times (TMR2 Prescale Value)$
- Duty Cycle = $T_{osc} \times (ECCPR1L<7:0>:ECCP1CON<5:4>) \times (TMR2 Prescale Value)$
- Delay = $4 \times T_{osc} \times (ECCP1DEL<6:0>)$
16.4.4  HALF-BRIDGE MODE

In the Half-Bridge Output mode, two pins are used as outputs to drive push-pull loads. The PWM output signal is output on the P1A pin, while the complementary PWM output signal is output on the P1B pin (Figure 16-4). This mode can be used for half-bridge applications, as shown in Figure 16-5, or for full-bridge applications where four power switches are being modulated with two PWM signals.

In Half-Bridge Output mode, the programmable dead-band delay can be used to prevent shoot-through current in half-bridge power devices. The value of bits PDC6:PDC0, sets the number of instruction cycles before the output is driven active. If the value is greater than the duty cycle, the corresponding output remains inactive during the entire cycle. See Section 16.4.6 “Programmable Dead-Band Delay” for more details of the dead-band delay operations.

Since the P1A and P1B outputs are multiplexed with the PORTD<4> and PORTD<5> data latches, the TRISD<4> and TRISD<5> bits must be cleared to configure P1A and P1B as outputs.

FIGURE 16-5:  EXAMPLES OF HALF-BRIDGE OUTPUT MODE APPLICATIONS

<table>
<thead>
<tr>
<th>Standard Half-Bridge Circuit (“Push-Pull”)</th>
<th>Half-Bridge Output Driving a Full-Bridge Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Standard Half-Bridge Circuit" /></td>
<td><img src="image2" alt="Half-Bridge Output Driving a Full-Bridge Circuit" /></td>
</tr>
</tbody>
</table>

**FIGURE 16-4:  HALF-BRIDGE PWM OUTPUT**

<table>
<thead>
<tr>
<th>Period</th>
<th>Duty Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1A(2)</td>
<td>td</td>
</tr>
<tr>
<td>P1B(2)</td>
<td>td</td>
</tr>
</tbody>
</table>

Note 1: At this time, the TMR2 register is equal to the PR2 register.
2: Output signals are shown as active-high.

Note 2: td = Dead-Band Delay
16.4.5 FULL-BRIDGE MODE

In Full-Bridge Output mode, four pins are used as outputs; however, only two outputs are active at a time. In the Forward mode, pin P1A is continuously active and pin P1D is modulated. In the Reverse mode, pin P1C is continuously active and pin P1B is modulated. These are illustrated in Figure 16-6.

Note 1: At this time, the TMR2 register is equal to the PR2 register.
2: Output signal is shown as active-high.

P1A, P1B, P1C and P1D outputs are multiplexed with the PORTD<4>, PORTD<5>, PORTD<6> and PORTD<7> data latches. The TRISD<4>, TRISD<5>, TRISD<6> and TRISD<7> bits must be cleared to make the P1A, P1B, P1C and P1D pins outputs.
16.4.5.1 Direction Change in Full-Bridge Mode

In the Full-Bridge Output mode, the EPWM1M1 bit in the ECCP1CON register allows the user to control the forward/reverse direction. When the application firmware changes this direction control bit, the module will assume the new direction on the next PWM cycle.

Just before the end of the current PWM period, the modulated outputs (P1B and P1D) are placed in their inactive state, while the unmodulated outputs (P1A and P1C) are switched to drive in the opposite direction. This occurs in a time interval of (4 TOSC * (Timer2 Prescale Value)) before the next PWM period begins. The Timer2 prescaler will either be 1, 4 or 16, depending on the value of the T2CKPS bits (T2CON<1:0>).

During the interval from the switch of the unmodulated outputs to the beginning of the next period, the modulated outputs (P1B and P1D) remain inactive. This relationship is shown in Figure 16-8.

Note that in the Full-Bridge Output mode, the ECCP1 module does not provide any dead-band delay. In general, since only one output is modulated at all times, dead-band delay is not required. However, there is a situation where a dead-band delay might be required. This situation occurs when both of the following conditions are true:

1. The direction of the PWM output changes when the duty cycle of the output is at or near 100%.
2. The turn-off time of the power switch, including the power device and driver circuit, is greater than the turn-on time.

Figure 16-9 shows an example where the PWM direction changes from forward to reverse at a near 100% duty cycle. At time t1, the outputs P1A and P1D become inactive, while output P1C becomes active. In this example, since the turn-off time of the power devices is longer than the turn-on time, a shoot-through current may flow through power devices, QC and QD (see Figure 16-7), for the duration of ‘t’. The same phenomenon will occur to power devices, QA and QB, for PWM direction change from reverse to forward.

If changing PWM direction at high duty cycle is required for an application, one of the following requirements must be met:

1. Reduce PWM for a PWM period before changing directions.
2. Use switch drivers that can drive the switches off faster than they can drive them on.

Other options to prevent shoot-through current may exist.
FIGURE 16-8: PWM DIRECTION CHANGE

Note 1: The direction bit in the ECCP1 Control register (ECCP1CON<7>) is written any time during the PWM cycle.
2: When changing directions, the P1A and P1C signals switch before the end of the current PWM cycle at intervals of 4 Tosc, 16 Tosc or 64 Tosc, depending on the Timer2 prescaler value. The modulated P1B and P1D signals are inactive at this time.

FIGURE 16-9: PWM DIRECTION CHANGE AT NEAR 100% DUTY CYCLE

Note 1: All signals are shown as active-high.
2: tON is the turn-on delay of power switch QC and its driver.
3: tOFF is the turn-off delay of power switch QD and its driver.
16.4.6 PROGRAMMABLE DEAD-BAND DELAY

In half-bridge applications where all power switches are modulated at the PWM frequency at all times, the power switches normally require more time to turn off than to turn on. If both the upper and lower power switches are switched at the same time (one turned on and the other turned off), both switches may be on for a short period of time until one switch completely turns off. During this brief interval, a very high current (shoot-through current) may flow through both power switches, shorting the bridge supply. To avoid this potentially destructive shoot-through current from flowing during switching, turning on either of the power switches is normally delayed to allow the other switch to completely turn off.

In the Half-Bridge Output mode, a digitally programmable dead-band delay is available to avoid shoot-through current from destroying the bridge power switches. The delay occurs at the signal transition from the non-active state to the active state. See Figure 16-4 for illustration. Bits PDC6:PDC0 of the ECCP1DEL register (Register 16-2) set the delay period in terms of microcontroller instruction cycles (TCY or 4 TOSC). These bits are not available on PIC18F2682/2685 devices, as the standard CCP1 module does not support half-bridge operation.

16.4.7 ENHANCED PWM AUTO-SHUTDOWN

When the ECCP1 is programmed for any of the Enhanced PWM modes, the active output pins may be configured for auto-shutdown. Auto-shutdown immediately places the Enhanced PWM output pins into a defined shutdown state when a shutdown event occurs.

A shutdown event can be caused by either of the comparator modules, a low level on the RB0/INT0/FLT0/AN10 pin, or any combination of these three sources. The comparators may be used to monitor a voltage input proportional to a current being monitored in the bridge circuit. If the voltage exceeds a threshold, the comparator switches state and triggers a shutdown. Alternatively, a digital signal on the INT0 pin can also trigger a shutdown. The auto-shutdown feature can be disabled by not selecting any auto-shutdown sources. The auto-shutdown sources to be used are selected using the ECCPAS2:ECCPAS0 bits (bits<6:4> of the ECCP1AS register).

When a shutdown occurs, the output pins are asynchronously placed in their shutdown states, specified by the PSSAC1:PSSAC0 and PSSBD1:PSSBD0 bits (ECCP1AS3:ECCP1AS0). Each pin pair (P1A/P1C and P1B/P1D) may be set to drive high, drive low or be tri-stated (not driving). The ECCPASE bit (ECCP1AS<7>) is also set to hold the Enhanced PWM outputs in their shutdown states.

The ECCPASE bit is set by hardware when a shutdown event occurs. If automatic restarts are not enabled, the ECCPASE bit is cleared by firmware when the cause of the shutdown clears. If automatic restarts are enabled, the ECCPASE bit is automatically cleared when the cause of the auto-shutdown has cleared.

If the ECCPASE bit is set when a PWM period begins, the PWM outputs remain in their shutdown state for that entire PWM period. When the ECCPASE bit is cleared, the PWM outputs will return to normal operation at the beginning of the next PWM period.

**Note:** Writing to the ECCPASE bit is disabled while a shutdown condition is active.

### REGISTER 16-2: ECCP1DEL: PWM DEAD-BAND DELAY REGISTER(1)

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRSEN</td>
<td>PDC6</td>
<td>PDC5</td>
<td>PDC4</td>
<td>PDC3</td>
<td>PDC2</td>
<td>PDC1</td>
<td>PDC0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRSEN: PWM Restart Enable bit</td>
<td></td>
</tr>
</tbody>
</table>

- **1** = Upon auto-shutdown, the ECCPASE bit clears automatically once the shutdown event goes away; the PWM restarts automatically
- **0** = Upon auto-shutdown, ECCPASE must be cleared in software to restart the PWM

| bit 6-0 | PDC6:PDC0: PWM Delay Count bits |

Delay time, in number of Fosc/4 (4 * Tosc) cycles, between the scheduled and actual time for a PWM signal to transition to active.

**Note 1:** This register is available on PIC18F4682/4685 devices only.
**REGISTER 16-3: ECCP1AS: ENHANCED CAPTURE/COMPARE/PWM AUTO-SHUTDOWN CONFIGURATION REGISTER**(1)

<table>
<thead>
<tr>
<th></th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECCPASE</td>
<td>ECCPAS2</td>
<td>ECCPAS1</td>
<td>ECCPAS0</td>
<td>PSSAC1</td>
<td>PSSAC0</td>
<td>PSSBD1</td>
<td>PSSBD0</td>
<td>bit 0</td>
</tr>
</tbody>
</table>
| bit 7 | ECCPASE: ECCP1 Auto-Shutdown Event Status bit  
1 = A shutdown event has occurred; ECCP1 outputs are in shutdown state  
0 = ECCP1 outputs are operating  
bit 6-4 | ECCPAS2:ECCPAS0: ECCP1 Auto-Shutdown Source Select bits  
111 = RB00 or Comparator 1 or Comparator 2  
110 = RB0 or Comparator 2  
101 = RB0 or Comparator 1  
100 = RB0  
011 = Either Comparator 1 or 2  
010 = Comparator 2 output  
001 = Comparator 1 output  
000 = Auto-shutdown is disabled  
bit 3-2 | PSSAC1:PSSAC0: Pins A and C Shutdown State Control bits  
1x = Pins A and C tri-state (PIC18F4682/4685 devices)  
01 = Drive Pins A and C to ‘1’  
00 = Drive Pins A and C to ‘0’  
bit 1-0 | PSSBD1:PSSBD0: Pins B and D Shutdown State Control bits  
1x = Pins B and D tri-state  
01 = Drive Pins B and D to ‘1’  
00 = Drive Pins B and D to ‘0’  

**Note 1:** This register is available on PIC18F4682/4685 devices only.
16.4.7.1 Auto-Shutdown and Auto-Restart

The auto-shutdown feature can be configured to allow automatic restarts of the module following a shutdown event. This is enabled by setting the PRSEN bit of the ECCP1DEL register (ECCP1DEL<7>).

In Shutdown mode with PRSEN = 1 (Figure 16-10), the ECCPASE bit will remain set for as long as the cause of the shutdown continues. When the shutdown condition clears, the ECCPASE bit is cleared. If PRSEN = 0 (Figure 16-11), once a shutdown condition occurs, the ECCPASE bit will remain set until it is cleared by firmware. Once ECCPASE is cleared, the Enhanced PWM will resume at the beginning of the next PWM period.

**Note:** Writing to the ECCPASE bit is disabled while a shutdown condition is active.

Independent of the PRSEN bit setting, if the auto-shutdown source is one of the comparators, the shutdown condition is a level. The ECCPASE bit cannot be cleared as long as the cause of the shutdown persists.

The Auto-Shutdown mode can be forced by writing a ‘1’ to the ECCPASE bit.

16.4.8 START-UP CONSIDERATIONS

When the ECCP1 module is used in the PWM mode, the application hardware must use the proper external pull-up and/or pull-down resistors on the PWM output pins. When the microcontroller is released from Reset, all of the I/O pins are in the high-impedance state. The external circuits must keep the power switch devices in the OFF state until the microcontroller drives the I/O pins with the proper signal levels, or activates the PWM output(s).

The ECCP1M1:ECCP1M0 bits (ECCP1CON<1:0>) allow the user to choose whether the PWM output signals are active-high or active-low for each pair of PWM output pins (P1A/P1C and P1B/P1D). The PWM output polarities must be selected before the PWM pins are configured as outputs. Changing the polarity configuration while the PWM pins are configured as outputs is not recommended, since it may result in damage to the application circuits.

The P1A, P1B, P1C and P1D output latches may not be in the proper states when the PWM module is initialized. Enabling the PWM pins for output at the same time as the ECCP1 module may cause damage to the application circuit. The ECCP1 module must be enabled in the proper output mode and complete a full PWM cycle before configuring the PWM pins as outputs. The completion of a full PWM cycle is indicated by the TMR2IF bit being set as the second PWM period begins.
16.4.9 SETUP FOR PWM OPERATION

The following steps should be taken when configuring the ECCP1 module for PWM operation:

1. Configure the PWM pins, P1A and P1B (and P1C and P1D, if used), as inputs by setting the corresponding TRIS bits.
2. Set the PWM period by loading the PR2 register.
3. Configure the ECCP1 module for the desired PWM mode and configuration by loading the ECCP1CON register with the appropriate values:
   • Select one of the available output configurations and direction with the EPWM1M1:EPWM1M0 bits.
   • Select the polarities of the PWM output signals with the ECCP1M3:ECCP1M0 bits.
4. Set the PWM duty cycle by loading the ECCPR1L register and ECCP1CON<5:4> bits.
5. For Half-Bridge Output mode, set the dead-band delay by loading ECCP1DEL<6:0> with the appropriate value.
6. If auto-shutdown operation is required, load the ECCP1AS register:
   • Select the auto-shutdown sources using the ECCPAS2:ECCPAS0 bits.
   • Select the shutdown states of the PWM output pins using PSSAC1:PSSAC0 and PSSBD1:PSSBD0 bits.
   • Set the ECCPASE bit (ECCP1AS<7>).
   • Configure the comparators using the CMCON register.
   • Configure the comparator inputs as analog inputs.
7. If auto-restart operation is required, set the PRSEN bit (ECCP1DEL<7>).
8. Configure and start TMR2:
   • Clear the TMR2 interrupt flag bit by clearing the TMR2IF bit (PIR1<1>).
   • Set the TMR2 prescale value by loading the T2CKPS bits (T2CON<1:0>).
   • Enable Timer2 by setting the TMR2ON bit (T2CON<2>).
9. Enable PWM outputs after a new PWM cycle has started:
   • Wait until TMRx overflows (TMRxF bit is set).
   • Enable the ECCP1/P1A, P1B, P1C and/or P1D pin outputs by clearing the respective TRIS bits.
   • Clear the ECCPASE bit (ECCP1AS<7>).

16.4.10 EFFECTS OF A RESET

Both Power-on Reset and subsequent Resets will force all ports to Input mode and the ECCP1 registers to their Reset states.

This forces the Enhanced CCP1 module to reset to a state compatible with the standard CCP1 module.
### TABLE 16-3: REGISTERS ASSOCIATED WITH ECCP1 MODULE AND TIMER1 TO TIMER3

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/PEI</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>RCON</td>
<td>IPEN</td>
<td>SBOREN(3)</td>
<td>—</td>
<td>RI</td>
<td>TO</td>
<td>PD</td>
<td>POR</td>
<td>BOR</td>
<td>52</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIP(2)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(2)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>IPR2</td>
<td>OSCFIP</td>
<td>CMIP(2)</td>
<td>—</td>
<td>EEIF</td>
<td>BCLI</td>
<td>HLVDIF</td>
<td>TMR3IF</td>
<td>ECCP1IP(2)</td>
<td>53</td>
</tr>
<tr>
<td>PIE2</td>
<td>OSCFIE</td>
<td>CMIE(2)</td>
<td>—</td>
<td>EEIF</td>
<td>BCLI</td>
<td>HLVDIE</td>
<td>TMR3IE</td>
<td>ECCP1IE(2)</td>
<td>54</td>
</tr>
<tr>
<td>TRISB</td>
<td>PORTB Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISC</td>
<td>PORTC Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISD(1)</td>
<td>PORTD Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR1L</td>
<td>Timer1 Register Low Byte</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR1H</td>
<td>Timer1 Register High Byte</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1CON</td>
<td>RD16</td>
<td>T1RUN</td>
<td>T1CKPS1</td>
<td>T1CKPS0</td>
<td>T1OSCEN</td>
<td>T1SYNC</td>
<td>TMR1CS</td>
<td>TMR1ON</td>
<td>52</td>
</tr>
<tr>
<td>T2CON</td>
<td>—</td>
<td>T2OUTPS3</td>
<td>T2OUTPS2</td>
<td>T2OUTPS1</td>
<td>T2OUTPS0</td>
<td>TMR2ON</td>
<td>T2CKPS1</td>
<td>T2CKPS0</td>
<td>52</td>
</tr>
<tr>
<td>PR2</td>
<td>Timer2 Period Register</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR3L</td>
<td>Timer3 Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR3H</td>
<td>Timer3 Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3CON</td>
<td>RD16</td>
<td>T3ECCP1(2)</td>
<td>T3CKPS1</td>
<td>T3CKPS0</td>
<td>T3CCP1(2)</td>
<td>T3SYNC</td>
<td>TMR3CS</td>
<td>TMR3ON</td>
<td>53</td>
</tr>
<tr>
<td>ECCPR1L(1)</td>
<td>Enhanced Capture/Compare/PWM Register 1 Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECCPR1H(1)</td>
<td>Enhanced Capture/Compare/PWM Register 1 High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECCP1CON(1)</td>
<td>EPWM1M1</td>
<td>EPWM1M0</td>
<td>EDC1B1</td>
<td>EDC1B0</td>
<td>ECCP1M3</td>
<td>ECCP1M2</td>
<td>ECCP1M1</td>
<td>ECCP1M0</td>
<td>53</td>
</tr>
<tr>
<td>ECCP1AS(1)</td>
<td>ECCPASE</td>
<td>ECCPAS2</td>
<td>ECCPAS1</td>
<td>ECCPAS0</td>
<td>PSSAC1</td>
<td>PSSAC0</td>
<td>PSSBD1</td>
<td>PSSBD0</td>
<td>53</td>
</tr>
<tr>
<td>ECCP1DEL(1)</td>
<td>PRSEN</td>
<td>PDC6</td>
<td>PDC5</td>
<td>PDC4</td>
<td>PDC3</td>
<td>PDC2</td>
<td>PDC1</td>
<td>PDC0</td>
<td>53</td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used during ECCP1 operation.

**Note 1:** These registers are available on PIC18F4682/4685 devices only.
**Note 2:** These bits are available on PIC18F4682/4685 and reserved on PIC18F2682/2685 devices.
**Note 3:** The SBOREN bit is only available when CONFIG2L<1:0> = 01; otherwise, it is disabled and reads as ‘0’.
17.0 MASTER SYNCHRONOUS SERIAL PORT (MSSP) MODULE

17.1 Master SSP (MSSP) Module Overview

The Master Synchronous Serial Port (MSSP) module is a 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 MSSP module can operate in one of two modes:

- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit (I²C)

The I²C interface supports the following modes in hardware:

- Master mode
- Multi-Master mode
- Slave mode

17.2 Control Registers

The MSSP module has three associated registers. These include a status register (SSPSTAT) and two control registers (SSPCON1 and SSPCON2). The use of these registers and their individual Configuration bits differ significantly depending on whether the MSSP module is operating in SPI or I²C mode.

Additional details are provided under the individual sections.

17.3 SPI Mode

The SPI mode allows 8 bits of data to be synchronously transmitted and received simultaneously. All four modes of SPI are supported. To accomplish communication, typically three pins are used:

- Serial Data Out (SDO) – RC5/SDO
- Serial Data In (SDI) – RC4/SDI/SDA
- Serial Clock (SCK) – RC3/SCK/SCL

Additionally, a fourth pin may be used when in a Slave mode of operation:

- Slave Select (SS) – RA5/AN4/SS/HLV DIN

Figure 17-1 shows the block diagram of the MSSP module when operating in SPI mode.

**FIGURE 17-1: MSSP BLOCK DIAGRAM (SPI MODE)**
17.3.1 REGISTERS

The MSSP module has four registers for SPI mode operation. These are:

- MSSP Control Register 1 (SSPCON1)
- MSSP Status Register (SSPSTAT)
- Serial Receive/Transmit Buffer Register (SSPBUF)
- MSSP Shift Register (SSPSR) – Not directly accessible

SSPCON1 and SSPSTAT are the control and status registers in SPI mode operation. The SSPCON1 register is readable and writable. The lower 6 bits of the SSPSTAT are read-only. The upper two bits of the SSPSTAT are read/write.

SSPSR is the shift register used for shifting data in or out. SSPBUF is the buffer register to which data bytes are written to or read from.

In receive operations, SSPSR and SSPBUF together create a double-buffered receiver. When SSPSR receives a complete byte, it is transferred to SSPBUF and the SSPIF interrupt is set.

During transmission, the SSPBUF is not double-buffered. A write to SSPBUF will write to both SSPBUF and SSPSR.

REGISTER 17-1: SSPSTAT: MSSP STATUS REGISTER (SPI MODE)

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMP</td>
<td>CKE</td>
<td>D/A</td>
<td>P</td>
<td>S</td>
<td>R/W</td>
<td>UA</td>
<td>BF</td>
</tr>
</tbody>
</table>

Legend:

- R = Readable bit
- W = Writable 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  SMP: Sample bit

  - SPI Master mode:
    - 1 = Input data sampled at end of data output time
    - 0 = Input data sampled at middle of data output time
  - SPI Slave mode:
    - SMP must be cleared when SPI is used in Slave mode.

bit 6  CKE: SPI Clock Select bit

  - 1 = Transmit occurs on transition from active to Idle clock state
  - 0 = Transmit occurs on transition from Idle to active clock state

  Polarity of clock state is set by the CKP bit (SSPCON1<4>).

bit 5  D/A: Data/Address bit

  Used in I²C mode only.

bit 4  P: Stop bit

  Used in I²C mode only. This bit is cleared when the MSSP module is disabled, SSPEN is cleared.

bit 3  S: Start bit

  Used in I²C mode only.

bit 2  R/W: Read/Write Information bit

  Used in I²C mode only.

bit 1  UA: Update Address bit

  Used in I²C mode only.

bit 0  BF: Buffer Full Status bit (Receive mode only)

  - 1 = Receive complete, SSPBUF is full
  - 0 = Receive not complete, SSPBUF is empty
**REGISTER 17-2:  SSPCON1: MSSP CONTROL REGISTER 1 (SPI MODE)**

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3-0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WCOL</strong>: Write Collision Detect bit (Transmit mode only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = The SSPBUF register is written while it is still transmitting the previous word (must be cleared in software)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 = No collision</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SSPOV</strong>: Receive Overflow Indicator bit(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = A new byte is received while the SSPBUF register is still holding the previous data. In case of overflow, the data in SSPSR is lost. Overflow can only occur in Slave mode. The user must read the SSPBUF, even if only transmitting data, to avoid setting overflow (must be cleared in software).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 = No overflow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SSPEN</strong>: Master Synchronous Serial Port Enable bit(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = Enables serial port and configures SCK, SDO, SDI and SS as serial port pins(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 = Disables serial port and configures these pins as I/O port pins(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CKP</strong>: Clock Polarity Select bit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = Idle state for clock is a high level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 = Idle state for clock is a low level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SSPM3:SSPM0</strong>: Master Synchronous Serial Port Mode Select bits(3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0101 = SPI Slave mode, clock = SCK pin, SS pin control disabled, SS can be used as I/O pin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0100 = SPI Slave mode, clock = SCK pin, SS pin control enabled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0011 = SPI Master mode, clock = TMR2 output/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0010 = SPI Master mode, clock = Fosc/64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0001 = SPI Master mode, clock = Fosc/16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0000 = SPI Master mode, clock = Fosc/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

**Note 1:** In Master mode, the overflow bit is not set since each new reception (and transmission) is initiated by writing to the SSPBUF register.

**Note 2:** When enabled, these pins must be properly configured as input or output.

**Note 3:** Bit combinations not specifically listed here are either reserved or implemented in I²C™ mode only.
17.3.2 OPERATION

When initializing the SPI, several options need to be specified. This is done by programming the appropriate control bits (SSPCON1<5:0> and SSPSTAT<7:6>). These control bits allow the following to be specified:

- Master mode (SCK is the clock output)
- Slave mode (SCK is the clock input)
- Clock Polarity (Idle state of SCK)
- Data Input Sample Phase (middle or end of data output time)
- Clock Edge (output data on rising/falling edge of SCK)
- Clock Rate (Master mode only)
- Slave Select mode (Slave mode only)

The MSSP module consists of a transmit/receive shift register (SSPSR) and a buffer register (SSPBUF). The SSPSR shifts the data in and out of the device, MSb first. The SSPBUF holds the data that was written to the SSPSR until the received data is ready. Once the 8 bits of data have been received, that byte is moved to the SSPBUF register. Then, the Buffer Full detect bit, BF (SSPSTAT<0>) and the interrupt flag bit, SSPIF, are set. This double-buffering of the received data (SSPBUF) allows the next byte to start reception before reading the data that was just received. Any write to the SSPBUF register during transmission/reception of data will be ignored and the write collision detect bit, WCOL (SSPCON1<7>), will be set. User software must clear the WCOL bit so that it can be determined if the following write(s) to the SSPBUF register completed successfully.

When the application software is expecting to receive valid data, the SSPBUF should be read before the next byte of data to transfer is written to the SSPBUF. The Buffer Full bit, BF (SSPSTAT<0>), indicates when SSPBUF has been loaded with the received data (transmission is complete). When the SSPBUF is read, the BF bit is cleared. This data may be irrelevant if the SPI is only a transmitter. Generally, the MSSP interrupt is used to determine when the transmission/reception has completed. The SSPBUF must be read and/or written. If the interrupt method is not going to be used, then software polling can be done to ensure that a write collision does not occur. Example 17-1 shows the loading of the SSPBUF (SSPSR) for data transmission.

The SSPSR is not directly readable or writable and can only be accessed by addressing the SSPBUF register. Additionally, the MSSP Status register (SSPSTAT) indicates the various status conditions.

EXAMPLE 17-1: LOADING THE SSPBUF (SSPSR) REGISTER

```
| LOOP | BTFO       | SSPSTAT, BF | ; Has data been received (transmit complete)? |
| BRA  | LOOP       | ; No        |
| MOVF | SSPBUF, W | ; WREG reg = contents of SSPBUF |
| MOVWF | RXDATA | ; Save in user RAM, if data is meaningful |
| MOVF | TXDATA, W | ; W reg = contents of TXDATA |
| MOVWF | SSPBUF | ; New data to xmit |
```
17.3.3 ENABLING SPI I/O

To enable the serial port, MSSP Enable bit, SSPEN (SSPCON1<5>), must be set. To reset or reconfigure SPI mode, clear the SSPEN bit, reinitialize the SSPCON registers and then set the SSPEN bit. This configures the SDI, SDO, SCK and SS pins as serial port pins. For the pins to behave as the serial port function, some must have their data direction bits (in the TRIS register) appropriately programmed as follows:

- SDI is automatically controlled by the SPI module
- SDO must have TRISC<5> bit cleared
- SCK (Master mode) must have TRISC<3> bit cleared
- SCK (Slave mode) must have TRISC<3> bit set
- SS must have TRISF<7> bit set

Any serial port function that is not desired may be overridden by programming the corresponding data direction (TRIS) register to the opposite value.

17.3.4 TYPICAL CONNECTION

Figure 17-2 shows a typical connection between two microcontrollers. The master controller (Processor 1) initiates the data transfer by sending the SCK signal. Data is shifted out of both shift registers on their programmed clock edge and latched on the opposite edge of the clock. Both processors should be programmed to the same Clock Polarity (CKP), then both controllers would send and receive data at the same time. Whether the data is meaningful (or dummy data) depends on the application software. This leads to three scenarios for data transmission:

- Master sends data – Slave sends dummy data
- Master sends data – Slave sends data
- Master sends dummy data – Slave sends data
17.3.5 MASTER MODE
The master can initiate the data transfer at any time because it controls the SCK. The master determines when the slave (Processor 2, Figure 17-2) is to broadcast data by the software protocol.

In Master mode, the data is transmitted/received as soon as the SSPBUF register is written to. If the SPI is only going to receive, the SDO output could be disabled (programmed as an input). The SSPSR register will continue to shift in the signal present on the SDI pin at the programmed clock rate. As each byte is received, it will be loaded into the SSPBUF register as if a normal received byte (interrupts and status bits appropriately set). This could be useful in receiver applications as a “Line Activity Monitor” mode.

The clock polarity is selected by appropriately programming the CKP bit (SSPCON1<4>). This then, would give waveforms for SPI communication as shown in Figure 17-3, Figure 17-5 and Figure 17-6, where the MSB is transmitted first. In Master mode, the SPI clock rate (bit rate) is user-programmable to be one of the following:

- \( \text{Fosc}/4 \) (or TCY)
- \( \text{Fosc}/16 \) (or 4 • TCY)
- \( \text{Fosc}/64 \) (or 16 • TCY)
- Timer2 output/2

This allows a maximum data rate (at 40 MHz) of 10.00 Mbps.

Figure 17-3 shows the waveforms for Master mode. When the CKE bit is set, the SDO data is valid before there is a clock edge on SCK. The change of the input sample is shown based on the state of the SMP bit. The time when the SSPBUF is loaded with the received data is shown.

FIGURE 17-3: SPI MODE WAVEFORM (MASTER MODE)
17.3.6 SLAVE MODE

In Slave mode, the data is transmitted and received as the external clock pulses appear on SCK. When the last bit is latched, the SSPIF interrupt flag bit is set.

Before enabling the module in SPI Slave mode, the clock line must match the proper Idle state. The clock line can be observed by reading the SCK pin. The Idle state is determined by the CKP bit (SSPCON1<4>).

While in Slave mode, the external clock is supplied by the external clock source on the SCK pin. This external clock must meet the minimum high and low times as specified in the electrical specifications.

While in Sleep mode, the slave can transmit/receive data. When a byte is received, the device will wake-up from Sleep.

17.3.7 SLAVE SELECT

SYNCHRONIZATION

The SS pin allows a Synchronous Slave mode. The SPI must be in Slave mode with SS pin control enabled (SSPCON1<3:0> = 04h). The pin must not be driven low for the SS pin to function as an input. The data latch must be high. When the SS pin is low, transmission and reception are enabled and the SDO pin is driven. When the SS pin goes high, the SDO pin is no longer driven, even if in the middle of a transmitted byte, and becomes a floating output. External pull-up/pull-down resistors may be desirable depending on the application.

**Note 1:** When the SPI is in Slave mode with SS pin control enabled (SSPCON<3:0> = 0100), the SPI module will reset if the S$ pin is set to VDD.

**Note 2:** If the SPI is used in Slave mode with CKE set, then the SS pin control must be enabled.

When the SPI module resets, the bit counter is forced to '0'. This can be done by either forcing the SS pin to a high level or clearing the SSPEN bit.

To emulate two-wire communication, the SDO pin can be connected to the SDI pin. When the SPI needs to operate as a receiver, the SDO pin can be configured as an input. This disables transmissions from the SDO. The SDI can always be left as an input (SDI function) since it cannot create a bus conflict.

**FIGURE 17-4: SLAVE SYNCHRONIZATION WAVEFORM**
FIGURE 17-5: SPI MODE WAVEFORM (SLAVE MODE WITH CKE = 0)

FIGURE 17-6: SPI MODE WAVEFORM (SLAVE MODE WITH CKE = 1)
17.3.8 OPERATION IN POWER-MANAGED MODES

In SPI Master mode, module clocks may be operating at a different speed than when in full power mode. In the case of Sleep mode, all clocks are halted.

In most power-managed modes, a clock is provided to the peripherals. That clock should be from the primary clock source, the secondary clock (Timer1 oscillator at 32.768 kHz) or the INTOSC source. See Section 2.7 “Clock Sources and Oscillator Switching” for additional information.

In most cases, the speed that the master clocks SPI data is not important; however, this should be evaluated for each system.

If MSSP interrupts are enabled, they can wake the controller from Sleep mode, or one of the Idle modes, when the master completes sending data. If an exit from Sleep or Idle mode is not desired, MSSP interrupts should be disabled.

If the Sleep mode is selected, all module clocks are halted and the transmission/reception will remain in that state until the device wakes. After the device returns to Run mode, the module will resume transmitting and receiving data.

In SPI Slave mode, the SPI Transmit/Receive Shift register operates asynchronously to the device. This allows the device to be placed in any power-managed mode and data to be shifted into the SPI Transmit/Receive Shift register. When all 8 bits have been received, the MSSP interrupt flag bit will be set and if enabled, will wake the device.

17.3.9 EFFECTS OF A RESET

A Reset disables the MSSP module and terminates the current transfer.

17.3.10 BUS MODE COMPATIBILITY

Table 17-1 shows the compatibility between the standard SPI modes and the states of the CKP and CKE control bits.

<table>
<thead>
<tr>
<th>Standard SPI Mode Terminology</th>
<th>CKP</th>
<th>CKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, 0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0, 1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1, 0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1, 1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

There is also an SMP bit which controls when the data is sampled.

### TABLE 17-2: REGISTERS ASSOCIATED WITH SPI OPERATION

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPiF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPiE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1E</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPiP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>TRISA</td>
<td>PORTA Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISC</td>
<td>PORTC Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSPBUF</td>
<td>MSSP Receive Buffer/Transmit Register</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSPCON1</td>
<td>WCOL</td>
<td>SSPOV</td>
<td>SSPEN</td>
<td>CKP</td>
<td>SSPM3</td>
<td>SSPM2</td>
<td>SSPM1</td>
<td>SSPM0</td>
<td>52</td>
</tr>
<tr>
<td>SSPSTAT</td>
<td>SMP</td>
<td>CKE</td>
<td>D/A</td>
<td>P</td>
<td>S</td>
<td>R/W</td>
<td>UA</td>
<td>BF</td>
<td>52</td>
</tr>
</tbody>
</table>

**Legend:** "—" = unimplemented, read as ‘0’. Shaded cells are not used by the MSSP in SPI mode.

**Note 1:** These bits are unimplemented in PIC18F2682/2685 devices; always maintain these bits clear.
17.4 I²C Mode

The MSSP module in I²C mode fully implements all master and slave functions (including general call support) and provides interrupts on Start and Stop bits in hardware to determine a free bus (multi-master function). The MSSP module implements the standard mode specifications, as well as 7-bit and 10-bit addressing.

Two pins are used for data transfer:
- Serial clock (SCL) – RC3/SCK/SCL
- Serial data (SDA) – RC4/SDI/SDA

The user must configure these pins as inputs or outputs through the TRISC<4:3> bits.

**FIGURE 17-7: MSSP BLOCK DIAGRAM (I²C™ MODE)**

17.4.1 REGISTERS

The MSSP module has six registers for I²C operation. These are:
- MSSP Control Register 1 (SSPCON1)
- MSSP Control Register 2 (SSPCON2)
- MSSP Status Register (SSPSTAT)
- Serial Receive/Transmit Buffer Register (SSPBUF)
- MSSP Shift Register (SSPSR) – Not directly accessible
- MSSP Address Register (SSPADD)

SSPCON1, SSPCON2 and SSPSTAT are the control and status registers in I²C mode operation. The SSPCON1 and SSPCON2 registers are readable and writable. The lower 6 bits of the SSPSTAT are read-only. The upper two bits of the SSPSTAT are read/write.

SSPSR is the shift register used for shifting data in or out. SSPBUF is the buffer register to which data bytes are written to or read from.

SSPADD register holds the slave device address when the MSSP is configured in I²C Slave mode. When the MSSP is configured in Master mode, the lower seven bits of SSPADD act as the Baud Rate Generator reload value.

In receive operations, SSPSR and SSPBUF together create a double-buffered receiver. When SSPSR receives a complete byte, it is transferred to SSPBUF and the SSPIF interrupt is set.

During transmission, the SSPBUF is not double-buffered. A write to SSPBUF will write to both SSPBUF and SSPSR.
REGISTER 17-3:  SSPSTAT: MSSP STATUS REGISTER (I²C™ MODE)

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMP</td>
<td>CKE</td>
<td>D/A</td>
<td>p(1)</td>
<td>s(1)</td>
<td>R/W(2,3)</td>
<td>UA</td>
<td>BF</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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  SMP: Slew Rate Control bit
In Master or Slave mode:
1 = Slew rate control disabled for Standard Speed mode (100 kHz and 1 MHz)
0 = Slew rate control enabled for High-Speed mode (400 kHz)

bit 6  CKE: SMBus Select bit
In Master or Slave mode:
1 = Enable SMBus specific inputs
0 = Disable SMBus specific inputs

bit 5  D/A: Data/Address bit
In Master mode:
Reserved.
In Slave mode:
1 = Indicates that the last byte received or transmitted was data
0 = Indicates that the last byte received or transmitted was address

bit 4  P: Stop bit(1)
1 = Indicates that a Stop bit has been detected last
0 = Stop bit was not detected last

bit 3  S: Start bit(1)
1 = Indicates that a Start bit has been detected last
0 = Start bit was not detected last

bit 2  R/W: Read/Write Information bit (I²C mode only)(2,3)
In Slave mode:
1 = Read
0 = Write
In Master mode:
1 = Transmit is in progress
0 = Transmit is not in progress

bit 1  UA: Update Address bit (10-Bit Slave mode only)
1 = Indicates that the user needs to update the address in the SSPADD register
0 = Address does not need to be updated

bit 0  BF: Buffer Full Status bit
In Receive mode:
1 = Receive complete, SSPBUF is full
0 = Receive is not complete, SSPBUF is empty
In Transmit mode:
1 = Data transmit in progress (does not include the ACK and Stop bits), SSPBUF is full
0 = Data transmit complete (does not include the ACK and Stop bits), SSPBUF is empty

Note 1:  This bit is cleared on Reset and when SSPEN is cleared.
2:  This bit holds the R/W bit information following the last address match. This bit is only valid from the address match to the next Start bit, Stop bit or not ACK bit.
3:  ORing this bit with SEN, RSEN, PEN, RCEN or ACKEN will indicate if the MSSP is in Idle mode.
REGISTER 17-4: SSPCON1: MSSP CONTROL REGISTER 1 (I^{2}C™ MODE)

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCOL</td>
<td>SSPOV</td>
<td>SSPEN</td>
<td>CKP</td>
<td>SSPM3</td>
<td>SSPM2</td>
<td>SSPM1</td>
<td>SSPM0</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- W = Writable 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  **WCOL**: Write Collision Detect bit
- In Master Transmit mode:
  1 = A write to the SSPBUF register was attempted while the I^{2}C conditions were not valid for a transmission to be started (must be cleared in software)
  0 = No collision
- In Slave Transmit mode:
  1 = The SSPBUF register is written while it is still transmitting the previous word (must be cleared in software)
  0 = No collision
- In Receive mode (Master or Slave modes):
  This is a “don’t care” bit.

bit 6  **SSPOV**: Receive Overflow Indicator bit
- In Receive mode:
  1 = A byte is received while the SSPBUF register is still holding the previous byte (must be cleared in software)
  0 = No overflow
- In Transmit mode:
  This is a “don’t care” bit in Transmit mode.

bit 5  **SSPEN**: Master Synchronous Serial Port Enable bit(1)
- 1 = Enables the serial port and configures the SDA and SCL pins as the serial port pins
- 0 = Disables serial port and configures these pins as I/O port pins

bit 4  **CKP**: SCK Release Control bit
- In Slave mode:
  1 = Release clock
  0 = Holds clock low (clock stretch), used to ensure data setup time
- In Master mode:
  Unused in this mode.

bit 3-0  **SSPM3:SSPM0**: Master Synchronous Serial Port Mode Select bits(2)
- 1111 = I^{2}C Slave mode, 10-bit address with Start and Stop bit interrupts enabled
- 1110 = I^{2}C Slave mode, 7-bit address with Start and Stop bit interrupts enabled
- 1011 = I^{2}C Firmware Controlled Master mode (slave Idle)
- 1000 = I^{2}C Master mode, clock = Fosc/(4 * (SSPADD + 1))
- 0111 = I^{2}C Slave mode, 10-bit address
- 0110 = I^{2}C Slave mode, 7-bit address

Note 1: When enabled, the SDA and SCL pins must be properly configured as input or output.
Note 2: Bit combinations not specifically listed here are either reserved or implemented in SPI mode only.
## REGISTER 17-5: SSPCON2: MSSP CONTROL REGISTER 2 (I²C™ MODE)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>GCEN</td>
<td>General Call Enable bit (Slave mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Enable interrupt when a general call address (0000h) is received in the SSPSR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = General call address disabled</td>
</tr>
<tr>
<td>6</td>
<td>ACKSTAT</td>
<td>Acknowledge Status bit (Master Transmit mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Acknowledge was not received from slave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Acknowledge was received from slave</td>
</tr>
<tr>
<td>5</td>
<td>ACKDT(1)</td>
<td>Acknowledge Data bit (Master Receive mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Not Acknowledge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Acknowledge</td>
</tr>
<tr>
<td>4</td>
<td>ACKEN(2)</td>
<td>Acknowledge Sequence Enable bit (Master Receive mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Initiate Acknowledge sequence on SDA and SCL pins and transmit ACKDT data bit. Automatically cleared by hardware.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Acknowledge sequence Idle</td>
</tr>
<tr>
<td>3</td>
<td>RCEN(2)</td>
<td>Receive Enable bit (Master mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Enables Receive mode for I²C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Receive Idle</td>
</tr>
<tr>
<td>2</td>
<td>PEN(2)</td>
<td>Stop Condition Enable bit (Master mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Initiate Stop condition on SDA and SCL pins. Automatically cleared by hardware.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Stop condition Idle</td>
</tr>
<tr>
<td>1</td>
<td>RSEN(2)</td>
<td>Repeated Start Condition Enable bit (Master mode only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Initiate Repeated Start condition on SDA and SCL pins. Automatically cleared by hardware.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Repeated Start condition Idle</td>
</tr>
<tr>
<td>0</td>
<td>SEN(2)</td>
<td>Start Condition Enable/Stretch Enable bit</td>
</tr>
<tr>
<td></td>
<td>In Master mode:</td>
<td>1 = Initiate Start condition on SDA and SCL pins. Automatically cleared by hardware.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Start condition Idle</td>
</tr>
<tr>
<td></td>
<td>In Slave mode:</td>
<td>1 = Clock stretching is enabled for both slave transmit and slave receive (stretch enabled)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Clock stretching is disabled</td>
</tr>
</tbody>
</table>

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

### Notes:
1: Value that will be transmitted when the user initiates an Acknowledge sequence at the end of a receive.
2: For bits ACKEN, RCEN, PEN, RSEN, SEN: If the I²C module is not in the Idle mode, these bits may not be set (no spooling) and the SSPBUF may not be written (or writes to the SSPBUF are disabled).
17.4.2 OPERATION

The MSSP module functions are enabled by setting MSSP Enable bit, SSPEN (SSPCON<5>).

The SSPCON1 register allows control of the I\(^2\)C operation. Four mode selection bits (SSPCON<3:0>) allow one of the following I\(^2\)C modes to be selected:

- I\(^2\)C Master mode, clock = (FOSC/4) x (SSPADD + 1)
- I\(^2\)C Slave mode (7-bit address)
- I\(^2\)C Slave mode (10-bit address)
- I\(^2\)C Slave mode (7-bit address) with Start and Stop bit interrupts enabled
- I\(^2\)C Slave mode (10-bit address) with Start and Stop bit interrupts enabled
- I\(^2\)C Firmware Controlled Master mode, slave is Idle

Selection of any I\(^2\)C mode with the SSPEN bit set, forces the SCL and SDA pins to be open-drain, provided these pins are programmed to inputs by setting the appropriate TRISC bits. To ensure proper operation of the module, pull-up resistors must be provided externally to the SCL and SDA pins.

17.4.3 SLAVE MODE

In Slave mode, the SCL and SDA pins must be configured as inputs (TRISC<4:3> set). The MSSP module will override the input state with the output data when required (slave-transmitter).

The I\(^2\)C Slave mode hardware will always generate an interrupt on an address match. Through the mode select bits, the user can also choose to interrupt on Start and Stop bits

When an address is matched, or the data transfer after an address match is received, the hardware automatically will generate the Acknowledge (ACK) pulse and load the SSPBUF register with the received value currently in the SSPSR register.

Any combination of the following conditions will cause the MSSP module not to give this ACK pulse:

- The Buffer Full bit, BF (SSPSTAT<0>), was set before the transfer was received.
- The overflow bit, SSPOV (SSPCON<6>), was set before the transfer was received.

In this case, the SSPSR register value is not loaded into the SSPBUF, but bit SSPIF (PIR1<3>) is set. The BF bit is cleared by reading the SSPBUF register, while bit SSPOV is cleared through software.

The SCL clock input must have a minimum high and low for proper operation. The high and low times of the I\(^2\)C specification, as well as the requirement of the MSSP module, are shown in timing parameter 100 and parameter 101.

17.4.3.1 Addressing

Once the MSSP module has been enabled, it waits for a Start condition to occur. Following the Start condition, the 8-bits are shifted into the SSPSR register. All incoming bits are sampled with the rising edge of the clock (SCL) line. The value of register SSPSR<7:1> is compared to the value of the SSPADD register. The address is compared on the falling edge of the eighth clock (SCL) pulse. If the addresses match and the BF and SSPOV bits are clear, the following events occur:

1. The SSPSR register value is loaded into the SSPBUF register.
2. The Buffer Full bit, BF, is set.
3. An ACK pulse is generated.
4. MSSP Interrupt Flag bit, SSPIF (PIR1<3>), is set (interrupt is generated, if enabled) on the falling edge of the ninth SCL pulse.

In 10-Bit Address mode, two address bytes need to be received by the slave. The five Most Significant bits (MSbs) of the first address byte specify if this is a 10-bit address. Bit R/W (SSPSTAT<2>) must specify a write so the slave device will receive the second address byte. For a 10-bit address, the first byte would equal '11110 A9 A8 0', where 'A9' and 'A8' are the two MSbs of the address. The sequence of events for 10-bit address is as follows, with steps 7 through 9 for the slave-transmitter:

1. Receive first (high) byte of address (bits SSPIF, BF and UA (SSPSTAT<1>) are set).
2. Update the SSPADD register with second (low) byte of address (clears bit UA and releases the SCL line).
3. Read the SSPBUF register (clears bit BF) and clear flag bit, SSPIF.
4. Receive second (low) byte of address (bits SSPIF, BF and UA are set).
5. Update the SSPADD register with the first (high) byte of address. If match releases SCL line, this will clear bit UA.
6. Read the SSPBUF register (clears bit BF) and clear flag bit, SSPIF.
8. Receive first (high) byte of address (bits SSPIF and BF are set).
9. Read the SSPBUF register (clears bit BF) and clear flag bit, SSPIF.
17.4.3.2 Reception

When the R/W bit of the address byte is clear and an address match occurs, the R/W bit of the SSPSTAT register is cleared. The received address is loaded into the SSPBUF register and the SDA line is held low (ACK).

When the address byte overflow condition exists, then the no Acknowledge (ACK) pulse is given. An overflow condition is defined as either bit BF (SSPSTAT<0>) is set, or bit SSPOV (SSPCON1<6>) is set.

An MSSP interrupt is generated for each data transfer byte. Flag bit, SSPIF (PIR1<3>), must be cleared in software. The SSPSTAT register is used to determine the status of the byte.

If SEN is enabled (SSPCON2<0> = 1), RC3/SCK/SCL will be held low (clock stretch) following each data transfer. The clock must be released by setting bit CKP (SSPCON1<4>). See Section 17.4.4 “Clock Stretching” for more detail.

17.4.3.3 Transmission

When the R/W bit of the incoming address byte is set and an address match occurs, the R/W bit of the SSPSTAT register is set. The received address is loaded into the SSPBUF register. The ACK pulse will be sent on the ninth bit and pin RC3/SCK/SCL is held low regardless of SEN (see Section 17.4.4 “Clock Stretching” for more detail). By stretching the clock, the master will be unable to assert another clock pulse until the slave is done preparing the transmit data. The transmit data must be loaded into the SSPBUF register which also loads the SSPSR register. Then pin RC3/SCK/SCL should be enabled by setting bit, CKP (SSPCON1<4>). The eight data bits are shifted out on the falling edge of the SCL input. This ensures that the SDA signal is valid during the SCL high time (Figure 17-9).

The ACK pulse from the master-receiver is latched on the rising edge of the ninth SCL input pulse. If the SDA line is high (not ACK), then the data transfer is complete. In this case, when the ACK is latched by the slave, the slave logic is reset (resets SSPSTAT register) and the slave monitors for another occurrence of the Start bit. If the SDA line was low (ACK), the next transmit data must be loaded into the SSPBUF register. Again, pin RC3/SCK/SCL must be enabled by setting bit CKP.

An MSSP interrupt is generated for each data transfer byte. The SSPIF bit must be cleared in software and the SSPSTAT register is used to determine the status of the byte. The SSPIF bit is set on the falling edge of the ninth clock pulse.
FIGURE 17-8: \( \text{I}^2\text{C} \text{™ SLAVE MODE TIMING WITH SEN = 0 (RECEPTION, 7-BIT ADDRESS)} \)
FIGURE 17-9: \( \text{I}^2\text{C}\text{™ SLAVE MODE TIMING (TRANSMISSION, 7-BIT ADDRESS)} \)
FIGURE 17-10:  \(^2\text{C}^\text{TM} \) SLAVE MODE TIMING WITH SEN = 0 (RECEPTION, 10-BIT ADDRESS)
FIGURE 17-11: I 2C™ SLAVE MODE TIMING (TRANSMISSION, 10-BIT ADDRESS)

- **SDA**: Data Bus
- **SCL**: Clock Bus
- **SSPIF**: Software Status Flag
- **BF (SSPSTAT<0>)**: Buffer Flag
- **R/W**: Read/Write
- **ACK**: Acknowledge
- **S123456789**: Address Bits
- **P**: Data Bits
- **UA (SSPSTAT<1>)**: Update Address
- **SSPBUF**: Shift Register Buffer
- **CKP (SSPCON1<4>)**: Clock Stop

### Clock Timing:
- **Clock is held low until update of SSPADD has taken place**
- **Clock is held low until SSPADD has taken place**
- **Clock is held low until OPK is set to “1”**

### Addressing:
- **Receive First Byte of Address**: R/W = 0
- **Receive Second Byte of Address**: UA = 0
- **Transmitting Data Byte**: UA = 1

### Control Flags:
- **SSPBUF**: Write of SSPBUF initiates transmit
- **BF**: Dummy read of SSPBUF to clear BF flag
- **CKP**: CKP is set in software, CKP is automatically cleared in hardware, holding SCL low

### Acknowledge:
- **ACK**: Acknowledge
- **Dummy read of SSPBUF to clear BF flag**

### Address Update:
- **SSPADD**: Update address needs to be updated
- **UA**: UA is set indicating that SSPADD needs to be updated

### Data Transmission:
- **D0, D1, D2, D3, D4, D5, D6, D7**: Data bits
- **Completion of data transmission clears BF flag**
17.4.4 CLOCK STRETCHING

Both 7 and 10-Bit Slave modes implement automatic clock stretching during a transmit sequence.

The SEN bit (SSPCON2<0>) allows clock stretching to be enabled during receives. Setting SEN will cause the SCL pin to be held low at the end of each data receive sequence.

17.4.4.1 Clock Stretching for 7-Bit Slave Receive Mode (SEN = 1)

In 7-Bit Slave Receive mode, on the falling edge of the ninth clock at the end of the ACK sequence if the BF bit is set, the CKP bit in the SSPCON1 register is automatically cleared, forcing the SCL output to be held low. The CKP being cleared to '0' will assert the SCL line low. The CKP bit must be set in the user’s ISR before reception is allowed to continue. By holding the SCL line low, the user has time to service the ISR and read the contents of the SSPBUF before the master device can initiate another receive sequence. This will prevent buffer overruns from occurring (see Figure 17-13).

Note 1: If the user reads the contents of the SSPBUF before the falling edge of the ninth clock, the CKP bit will not be cleared and clock stretching will not occur.

2: The CKP bit can be set in software regardless of the state of the BF bit. The user should be careful to clear the BF bit in the ISR before the next receive sequence in order to prevent an overflow condition.

17.4.4.2 Clock Stretching for 10-Bit Slave Receive Mode (SEN = 1)

In 10-Bit Slave Receive mode during the address sequence, clock stretching automatically takes place but CKP is not cleared. During this time, if the UA bit is set after the ninth clock, clock stretching is initiated. The UA bit is set after receiving the upper byte of the 10-bit address and following the receive of the second byte of the 10-bit address with the R/W bit cleared to '0'. The release of the clock line occurs upon updating SSPADD. Clock stretching will occur on each data receive sequence as described in 7-bit mode.

Note: If the user polls the UA bit and clears it by updating the SSPADD register before the falling edge of the ninth clock occurs and if the user hasn’t cleared the BF bit by reading the SSPBUF register before that time, then the CKP bit will still NOT be asserted low. Clock stretching on the basis of the state of the BF bit only occurs during a data sequence, not an address sequence.

17.4.4.3 Clock Stretching for 7-Bit Slave Transmit Mode

7-Bit Slave Transmit mode implements clock stretching by clearing the CKP bit after the falling edge of the ninth clock if the BF bit is clear. This occurs regardless of the state of the SEN bit.

The user’s ISR must set the CKP bit before transmission is allowed to continue. By holding the SCL line low, the user has time to service the ISR and load the contents of the SSPBUF before the master device can initiate another transmit sequence (see Figure 17-9).

Note 1: If the user loads the contents of SSPBUF, setting the BF bit before the falling edge of the ninth clock, the CKP bit will not be cleared and clock stretching will not occur.

2: The CKP bit can be set in software regardless of the state of the BF bit.

17.4.4.4 Clock Stretching for 10-Bit Slave Transmit Mode

In 10-Bit Slave Transmit mode, clock stretching is controlled during the first two address sequences by the state of the UA bit, just as it is in 10-Bit Slave Receive mode. The first two addresses are followed by a third address sequence which contains the high-order bits of the 10-bit address and the R/W bit set to '1'. After the third address sequence is performed, the UA bit is not set, the module is now configured in Transmit mode and clock stretching is controlled by the BF flag as in 7-Bit Slave Transmit mode (see Figure 17-11).
17.4.4.5 Clock Synchronization and the CKP bit

When the CKP bit is cleared, the SCL output is forced to ‘0’. However, setting the CKP bit will not assert the SCL output low until the SCL output is already sampled low. Therefore, the CKP bit will not assert the SCL line until an external I²C master device has already asserted the SCL line. The SCL output will remain low until the CKP bit is set and all other devices on the I²C bus have deasserted SCL. This ensures that a write to the CKP bit will not violate the minimum high time requirement for SCL (see Figure 17-12).

FIGURE 17-12: CLOCK SYNCHRONIZATION TIMING
FIGURE 17-13: I²C™ SLAVE MODE TIMING WITH SEN = 1 (RECEPTION, 7-BIT ADDRESS)

- Clock is not held low because ACK = 1
  - SSPBUF is read
  - SSPOV is set because SSPBUF is still full. ACK is not sent.
- Clock is held low until CKP is set to '1'
  - Clock is not held low because buffer full bit is clear prior to falling edge of 9th clock
  - BF is set after falling edge of 9th clock, CKP is reset to '0' and clock stretching occurs.
FIGURE 17-14: \( \text{I}^2\text{C} \) SLAVE MODE TIMING SEN = 1 (RECEPTION, 10-BIT ADDRESS)
17.4.5 GENERAL CALL ADDRESS SUPPORT

The addressing procedure for the I^2C bus is such that the first byte after the Start condition usually determines which device will be the slave addressed by the master. The exception is the general call address which can address all devices. When this address is used, all devices should, in theory, respond with an Acknowledge.

The general call address is one of eight addresses reserved for specific purposes by the I^2C protocol. It consists of all '0's with R/W = 0.

The general call address is recognized when the General Call Enable bit, GCEN, is enabled (SSPCON2<7> set). Following a Start bit detect, 8 bits are shifted into the SSPSR and the address is compared against the SSPADD. It is also compared to the general call address and fixed in hardware.

If the general call address matches, the SSPSR is transferred to the SSPBUF, the BF flag bit is set (eighth bit) and on the falling edge of the ninth bit (ACK bit), the SSPIF interrupt flag bit is set.

When the interrupt is serviced, the source for the interrupt can be checked by reading the contents of the SSPBUF. The value can be used to determine if the address was device specific or a general call address.

In 10-Bit Address mode, the SSPADD is required to be updated for the second half of the address to match and the UA bit is set (SSPSTAT<1>). If the general call address is sampled when the GCEN bit is set, while the slave is configured in 10-Bit Address mode, then the second half of the address is not necessary, the UA bit will not be set and the slave will begin receiving data after the Acknowledge (Figure 17-15).
17.4.6 MASTER MODE

Master mode is enabled by setting and clearing the appropriate SSPM bits in SSPCON1 and by setting the SSPEN bit. In Master mode, the SCL and SDA lines are manipulated by the MSSP hardware.

Master mode of operation is supported by interrupt generation on the detection of the Start and Stop conditions. The Stop (P) and Start (S) bits are cleared from a Reset or when the MSSP module is disabled. Control of the I2C bus may be taken when the P bit is set or the bus is Idle, with both the S and P bits clear.

In Firmware Controlled Master mode, user code conducts all I2C bus operations based on Start and Stop bit conditions.

Once Master mode is enabled, the user has six options.

1. Assert a Start condition on SDA and SCL.
2. Assert a Repeated Start condition on SDA and SCL.
3. Write to the SSPBUF register initiating transmission of data/address.
4. Configure the I2C port to receive data.
5. Generate an Acknowledge condition at the end of a received byte of data.
6. Generate a Stop condition on SDA and SCL.

The following events will cause the MSSP Interrupt Flag bit, SSPIF, to be set (MSSP interrupt, if enabled):

- Start Condition
- Stop Condition
- Data Transfer Byte Transmitted/Received
- Acknowledge Transmit
- Repeated Start

**FIGURE 17-16: MSSP BLOCK DIAGRAM (I2C™ MASTER MODE)**

Note: The MSSP module, when configured in I2C Master mode, does not allow queueing of events. For instance, the user is not allowed to initiate a Start condition and immediately write the SSPBUF register to initiate transmission before the Start condition is complete. In this case, the SSPBUF will not be written to and the WCOL bit will be set, indicating that a write to the SSPBUF did not occur.
17.4.6.1 I²C Master Mode Operation

The master device generates all of the serial clock pulses and the Start and Stop conditions. A transfer is ended with a Stop condition or with a Repeated Start condition. Since the Repeated Start condition is also the beginning of the next serial transfer, the I²C bus will not be released.

In Master Transmitter mode, serial data is output through SDA, while SCL outputs the serial clock. The first byte transmitted contains the slave address of the receiving device (7 bits) and the Read/Write (R/W) bit. In this case, the R/W bit will be logic ‘0’. Serial data is transmitted 8 bits at a time. After each byte is transmitted, an Acknowledge bit is received. Start and Stop conditions are output to indicate the beginning and the end of a serial transfer.

In Master Receive mode, the first byte transmitted contains the slave address of the transmitting device (7 bits) and the R/W bit. In this case, the R/W bit will be logic ‘1’. Thus, the first byte transmitted is a 7-bit slave address followed by a ‘1’ to indicate the receive bit. Serial data is received via SDA, while SCL outputs the serial clock. Serial data is received 8 bits at a time. After each byte is received, an Acknowledge bit is transmitted. Start and Stop conditions indicate the beginning and end of transmission.

The Baud Rate Generator used for the SPI mode operation is used to set the SCL clock frequency for either 100 kHz, 400 kHz or 1 MHz I²C operation. See Section 17.4.7 “Baud Rate” for more detail.

A typical transmit sequence would go as follows:

1. The user generates a Start condition by setting the Start Enable bit, SEN (SSPCON2<0>).
2. SSPIF is set. The MSSP module will wait the required start time before any other operation takes place.
3. The user loads the SSPBUF with the slave address to transmit.
4. Address is shifted out on the SDA pin until all 8 bits are transmitted.
5. The MSSP Module shifts in the ACK bit from the slave device and writes its value into the SSPCON2 register (SSPCON2<6>).
6. The MSSP module generates an interrupt at the end of the ninth clock cycle by setting the SSPIF bit.
7. The user loads the SSPBUF with eight bits of data.
8. Data is shifted out on the SDA pin until all 8 bits are transmitted.
9. The MSSP module shifts in the ACK bit from the slave device and writes its value into the SSPCON2 register (SSPCON2<6>).
10. The MSSP module generates an interrupt at the end of the ninth clock cycle by setting the SSPIF bit.
11. The user generates a Stop condition by setting the Stop Enable bit, PEN (SSPCON2<2>).
12. Interrupt is generated once the Stop condition is complete.
17.4.7 BAUD RATE

In I²C Master mode, the Baud Rate Generator (BRG) reload value is placed in the lower 7 bits of the SSPADD register (Figure 17-17). When a write occurs to SSPBUF, the Baud Rate Generator will automatically begin counting. The BRG counts down to 0 and stops until another reload has taken place. The BRG count is decremented twice per instruction cycle (T CY) on the Q2 and Q4 clocks. In I²C Master mode, the BRG is reloaded automatically.

Once the given operation is complete (i.e., transmission of the last data bit is followed by ACK), the internal clock will automatically stop counting and the SCL pin will remain in its last state.

Table 17-3 demonstrates clock rates based on instruction cycles and the BRG value loaded into SSPADD.

![Figure 17-17: BAUD RATE GENERATOR BLOCK DIAGRAM](image)

### TABLE 17-3: I²C™ CLOCK RATE w/BRG

<table>
<thead>
<tr>
<th>FCY</th>
<th>FcY*2</th>
<th>BRG Value</th>
<th>FSCL (2 Rollovers of BRG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 MHz</td>
<td>20 MHz</td>
<td>19h</td>
<td>400 kHz(^{(1)})</td>
</tr>
<tr>
<td>10 MHz</td>
<td>20 MHz</td>
<td>20h</td>
<td>312.5 kHz</td>
</tr>
<tr>
<td>10 MHz</td>
<td>20 MHz</td>
<td>64h</td>
<td>100 kHz</td>
</tr>
<tr>
<td>4 MHz</td>
<td>8 MHz</td>
<td>0Ah</td>
<td>400 kHz(^{(1)})</td>
</tr>
<tr>
<td>4 MHz</td>
<td>8 MHz</td>
<td>0Dh</td>
<td>308 kHz</td>
</tr>
<tr>
<td>4 MHz</td>
<td>8 MHz</td>
<td>28h</td>
<td>100 kHz</td>
</tr>
<tr>
<td>1 MHz</td>
<td>2 MHz</td>
<td>03h</td>
<td>333 kHz(^{(1)})</td>
</tr>
<tr>
<td>1 MHz</td>
<td>2 MHz</td>
<td>0Ah</td>
<td>100 kHz</td>
</tr>
<tr>
<td>1 MHz</td>
<td>2 MHz</td>
<td>00h</td>
<td>1 MHz(^{(1)})</td>
</tr>
</tbody>
</table>

Note 1: The I²C™ interface does not conform to the 400 kHz I²C specification (which applies to rates greater than 100 kHz) in all details, but may be used with care where higher rates are required by the application.
17.4.7.1 Clock Arbitration

Clock arbitration occurs when the master, during any receive, transmit or Repeated Start/Stop condition, deasserts the SCL pin (SCL allowed to float high). When the SCL pin is allowed to float high, the Baud Rate Generator (BRG) is suspended from counting until the SCL pin is actually sampled high. When the SCL pin is sampled high, the Baud Rate Generator is reloaded with the contents of SSPADD<6:0> and begins counting. This ensures that the SCL high time will always be at least one BRG rollover count in the event that the clock is held low by an external device (Figure 17-18).

**FIGURE 17-18: BAUD RATE GENERATOR TIMING WITH CLOCK ARBITRATION**

![Diagram of Baud Rate Generator Timing with Clock Arbitration](image-url)
17.4.8  **I^2C** MASTER MODE START CONDITION TIMING

To initiate a Start condition, the user sets the Start Enable bit, SEN (SSPCON2<0>). If the SDA and SCL pins are sampled high, the Baud Rate Generator is reloaded with the contents of SSPADD<6:0> and starts its count. If SCL and SDA are both sampled high when the Baud Rate Generator times out (TBRG), the SDA pin is driven low. The action of the SDA being driven low while SCL is high is the Start condition and causes the S bit (SSPSTAT<3>) to be set. Following this, the Baud Rate Generator is reloaded with the contents of SSPADD<6:0> and resumes its count. When the Baud Rate Generator times out (TBRG), the SEN bit (SSPCON2<0>) will be automatically cleared by hardware, the Baud Rate Generator is suspended, leaving the SDA line held low and the Start condition is complete.

### Note:
If at the beginning of the Start condition, the SDA and SCL pins are already sampled low, or if during the Start condition, the SCL line is sampled low before the SDA line is driven low, a bus collision occurs, the Bus Collision Interrupt Flag, BCLIF, is set, the Start condition is aborted and the I^2C module is reset into its Idle state.

#### 17.4.8.1 WCOL Status Flag

If the user writes the SSPBUF when a Start sequence is in progress, the WCOL is set and the contents of the buffer are unchanged (the write doesn’t occur).

### FIGURE 17-19: FIRST START BIT TIMING

- **SDA** = 1, **SCL** = 1
- **TBRG**
- **S**
- **At completion of Start bit, hardware clears SEN bit and sets SSPIF bit**
- **Write to SSPBUF occurs here**
- **Write to SEN bit occurs here**
- **Set S bit (SSPSTAT<3>)**
- **1st bit**
- **2nd bit**

### Note:
Because queueing of events is not allowed, writing to the lower 5 bits of SSPCON2 is disabled until the Start condition is complete.
17.4.9 I²C MASTER MODE REPEATED START CONDITION TIMING

A Repeated Start condition occurs when the RSEN bit (SSPCON2<1>) is programmed high and the I²C logic module is in the idle state. When the RSEN bit is set, the SCL pin is asserted low. When the SCL pin is sampled low, the Baud Rate Generator is loaded with the contents of SSPADD<5:0> and begins counting. The SDA pin is released (brought high) for one Baud Rate Generator count (TBRG). When the Baud Rate Generator times out, if SDA is sampled high, the SCL pin will be deasserted (brought high). When SCL is sampled high, the Baud Rate Generator is reloaded with the contents of SSPADD<6:0> and begins counting. SDA and SCL must be sampled high for one TBRG. This action is then followed by assertion of the SDA pin (SDA = 0) for one TBRG while SCL is high. Following this, the RSEN bit (SSPCON2<1>) will be automatically cleared and the Baud Rate Generator will not be reloaded, leaving the SDA pin held low. As soon as a Start condition is detected on the SDA and SCL pins, the S bit (SSPSTAT<3>) will be set. The SSPIF bit will not be set until the Baud Rate Generator has timed out.

**Note 1:** If RSEN is programmed while any other event is in progress, it will not take effect.

**Note 2:** A bus collision during the Repeated Start condition occurs if:
- SDA is sampled low when SCL goes from low-to-high.
- SCL goes low before SDA is asserted low. This may indicate that another master is attempting to transmit a data ‘1’.

Immediately following the SSPIF bit getting set, the user may write the SSPBUF with the 7-bit address in 7-bit mode, or the default first address in 10-bit mode. After the first eight bits are transmitted and an ACK is received, the user may then transmit an additional eight bits of address (10-bit mode) or eight bits of data (7-bit mode).

### 17.4.9.1 WCOL Status Flag

If the user writes the SSPBUF when a Repeated Start sequence is in progress, the WCOL is set and the contents of the buffer are unchanged (the write doesn’t occur).

**Note:** Because queueing of events is not allowed, writing of the lower 5 bits of SSPCON2 is disabled until the Repeated Start condition is complete.

---

**FIGURE 17-20: REPEATED START CONDITION WAVEFORM**
17.4.10  I²C MASTER MODE TRANSMISSION

Transmission of a data byte, a 7-bit address or the other half of a 10-bit address is accomplished by simply writing a value to the SSPBUF register. This action will set the Buffer Full flag bit, BF and allow the Baud Rate Generator to begin counting and start the next transmission. Each bit of address/data will be shifted out onto the SDA pin after the falling edge of SCL is asserted (see data hold time specification parameter 106). SCL is held low for one Baud Rate Generator rollover count (TBRG). Data should be valid before SCL is released high (see data setup time specification parameter 107). When the SCL pin is released high, it is held that way for TBRG. The data on the SDA pin must remain stable for that duration and some hold time after the next falling edge of SCL. After the eighth bit is shifted out (the falling edge of the eighth clock), the BF flag is cleared and the master releases SDA. This allows the slave device being addressed to respond with an ACK bit during the ninth bit time if an address match occurred or if data was received properly. The status of ACK is written into the ACKDT bit on the falling edge of the ninth clock. If the master receives an Acknowledge, the Acknowledge status bit, ACKSTAT, is cleared. If not, the bit is set. After the ninth clock, the SSPIF bit is set and the master clock (Baud Rate Generator) is suspended until the next data byte is loaded into the SSPBUF, leaving SCL low and SDA unchanged (Figure 17-21).

After the write to the SSPBUF, each bit of address will be shifted out on the falling edge of SCL until all seven address bits and the R/W bit are completed. On the falling edge of the eighth clock, the master will deassert the SDA pin, allowing the slave to respond with an Acknowledge. On the falling edge of the ninth clock, the master will sample the SDA pin to see if the address was recognized by a slave. The status of the ACK bit is loaded into the ACKSTAT status bit (SSPCON2<6>). Following the falling edge of the ninth clock transmission of the address, the SSPIF is set, the BF flag is cleared and the Baud Rate Generator is turned off until another write to the SSPBUF takes place, holding SCL low and allowing SDA to float.

17.4.10.1  BF Status Flag

In Transmit mode, the BF bit (SSPSTAT<0>) is set when the CPU writes to SSPBUF and is cleared when all 8 bits are shifted out.

17.4.10.2  WCOL Status Flag

If the user writes the SSPBUF when a transmit is already in progress (i.e., SSPSR is still shifting out a data byte), the WCOL is set and the contents of the buffer are unchanged (the write doesn’t occur). WCOL must be cleared in software.

17.4.10.3  ACKSTAT Status Flag

In Transmit mode, the ACKSTAT bit (SSPCON2<6>) is cleared when the slave has sent an Acknowledge (ACK = 0) and is set when the slave does not Acknowledge (ACK = 1). A slave sends an Acknowledge when it has recognized its address (including a general call), or when the slave has properly received its data.

17.4.11  I²C MASTER MODE RECEPTION

Master mode reception is enabled by programming the Receive Enable bit, RCEN (SSPCON2<3>).

The Baud Rate Generator begins counting and on each rollover, the state of the SCL pin changes (high-to-low/low-to-high) and data is shifted into the SSPSR. After the falling edge of the eighth clock, the receive enable flag is automatically cleared, the contents of the SSPSR are loaded into the SSPBUF, the BF flag bit is set, the SSPIF flag bit is set and the Baud Rate Generator is suspended from counting, holding SCL low. The MSSP is now in Idle state awaiting the next command. When the buffer is read by the CPU, the BF flag bit is automatically cleared. The user can then send an Acknowledge bit at the end of reception by setting the Acknowledge sequence enable bit, ACKEN (SSPCON2<4>).

17.4.11.1  BF Status Flag

In receive operation, the BF bit is set when an address or data byte is loaded into SSPBUF from SSPSR. It is cleared when the SSPBUF register is read.

17.4.11.2  SSPOV Status Flag

In receive operation, the SSPOV bit is set when 8 bits are received into the SSPSR and the BF flag bit is already set from a previous reception.

17.4.11.3  WCOL Status Flag

If the user writes the SSPBUF when a receive is already in progress (i.e., SSPSR is still shifting in a data byte), the WCOL bit is set and the contents of the buffer are unchanged (the write doesn’t occur).
**FIGURE 17-21: \( \text{i}^2\text{C™ MASTER MODE WAVEFORM (TRANSMISSION, 7 OR 10-BIT ADDRESS)} \)**

- **SDA**: Serial Data Line
- **SCL**: Serial Clock Line
- **SSPIF**: Serial Port Interrupt Flag
- **BF**: SSP Status Register bit<0>
- **SEN**: Start Condition
- **ACK**: Acknowledge
- **R/W**: Read/Write
- **SSPBUF**: SSP Buffer
- **SSPCON2<0>**: SEN bit
- **ACKSTAT**: SSP Control Register bit<6>

From slave, clear ACKSTAT bit SSPCON2<6>.

Cleared in software from MSSP interrupt.

- **Write SSPCON2<0>**: SEN = 1
  - Start condition begins
  - SSPBUF written with 7-bit address and R/W.
  - Transmitter Address to Slave
  - SEN = 1
  - R/W = 1
  - A7 A6 A5 A4 A3 A2 A1
  - ACK = 0
  - SSPBUF written in software
  - SSPBUF is written in software

- **Start condition**: SEN cleared by hardware.

- **SSPF**: SSP Status Register
- ** PEN**: SSP Buffer Empty
- **R/W**: Read/Write

Cleared in software.
**FIGURE 17-22: I²C™ MASTER MODE WAVEFORM (RECEPTION, 7-BIT ADDRESS)**

Bus master terminates transfer

ACK is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
ACK from Slave

Read Address to Slave

SDA = ACKDT (SSPCON2<5>) = 0

RCEN cleared automatically

SSPIF is set because SSPBUF is still full

SDA = ACKDT = 0, SCL = 1 while CPU (SSPSTAT<0>) responds to SSPIF

BF (SSPSTAT<2>)

SSPOV

A2 A6 A5 A4 A3 A2 A1 SDA
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4

SCL 12 3 4 5 6 7 8 9 12 3 4 5 6 7 8 9

Write to SSPCON2<4> to start Acknowledge sequence

SDA = ACKDT (SSPCON2<5>) = 0

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

Cleared in software

SSPOV is set because SSPBUF is still full

Last bit is shifted into SSPSR and contents are unloaded into SSPBUF

Cleared in software

Set SSPIF interrupt at end of receive

Set SSPIF interrupt at end of receive

Cleared in software

Set SSPIF interrupt at end of receive

Cleared in software

Send Data to Slave

Transmit Address to Slave

ACK

R/W

= 1

Transmit Address to Slave

ACK

Set PEN bit = 1 written here

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

ACK

is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
ACK from Slave

Read Address to Slave

SDA = ACKDT (SSPCON2<5>) = 0

RCEN cleared automatically

SSPIF is set because SSPBUF is still full

SDA = ACKDT = 0, SCL = 1 while CPU (SSPSTAT<0>) responds to SSPIF

BF (SSPSTAT<2>)

SSPOV

A2 A6 A5 A4 A3 A2 A1 SDA
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4

SCL 12 3 4 5 6 7 8 9 12 3 4 5 6 7 8 9

Write to SSPCON2<4> to start Acknowledge sequence

SDA = ACKDT (SSPCON2<5>) = 0

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

Cleared in software

SSPOV is set because SSPBUF is still full

Last bit is shifted into SSPSR and contents are unloaded into SSPBUF

Cleared in software

Set SSPIF interrupt at end of receive

Cleared in software

Set SSPIF interrupt at end of Acknowledge sequence

SSPIF is set at end of receive

Cleared in software

Set SSPIF interrupt at end of Acknowledge sequence

ACK

is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
ACK from Slave

Read Address to Slave

ACK

Set PEN bit = 1 written here

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

ACK

is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
ACK from Slave

Read Address to Slave

ACK

Set PEN bit = 1 written here

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

ACK

is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
ACK from Slave

Read Address to Slave

ACK

Set PEN bit = 1 written here

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

ACK

is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
ACK from Slave

Read Address to Slave

ACK

Set PEN bit = 1 written here

Set ACKEN, start Acknowledge sequence

SDA = ACKDT = 1

RCEN cleared automatically

SSPIF is set at end of Acknowledge sequence

Set SSPIF interrupt at end of Acknowledge sequence

ACK

is not sent

Write to SSPCON2<0> (SEN = 1),
Write to SSPBUF occurs here,
17.4.12 ACKNOWLEDGE SEQUENCE TIMING

An Acknowledge sequence is enabled by setting the Acknowledge sequence enable bit, ACKEN (SSPCON2<4>). When this bit is set, the SCL pin is pulled low and the contents of the Acknowledge data bit are presented on the SDA pin. If the user wishes to generate an Acknowledge, then the ACKDT bit should be cleared. If not, the user should set the ACKDT bit before starting an Acknowledge sequence. The Baud Rate Generator then counts for one rollover period (TBRG) and the SCL pin is deasserted (pulled high). When the SCL pin is sampled high (clock arbitration), the Baud Rate Generator counts for TBRG. The SCL pin is then pulled low. Following this, the ACKEN bit is automatically cleared, the Baud Rate Generator is turned off and the MSSP module then goes into Idle mode (Figure 17-23).

17.4.12.1 WCOL Status Flag

If the user writes the SSPBUF when an Acknowledge sequence is in progress, then WCOL is set and the contents of the buffer are unchanged (the write doesn’t occur).

17.4.13 STOP CONDITION TIMING

A Stop bit is asserted on the SDA pin at the end of a receive/transmit by setting the Stop Sequence Enable bit, PEN (SSPCON2<2>). At the end of a receive/transmit, the SCL line is held low after the falling edge of the ninth clock. When the PEN bit is set, the master will assert the SDA line low. When the SDA line is sampled low, the Baud Rate Generator is reloaded and counts down to 0. When the Baud Rate Generator times out, the SCL pin will be brought high and one TBRG (Baud Rate Generator rollover count) later, the SDA pin will be deasserted. When the SDA pin is sampled high while SCL is high, the P bit (SSPSTAT<4>) is set. A TBRG later, the PEN bit is cleared and the SSPIF bit is set (Figure 17-24).

17.4.13.1 WCOL Status Flag

If the user writes the SSPBUF when a Stop sequence is in progress, then the WCOL bit is set and the contents of the buffer are unchanged (the write doesn’t occur).

**FIGURE 17-23: ACKNOWLEDGE SEQUENCE WAVEFORM**

![Acknowledge Sequence Waveform Diagram](image)

**FIGURE 17-24: STOP CONDITION RECEIVE OR TRANSMIT MODE**

![Stop Condition Receive or Transmit Mode Diagram](image)

**Note:** TBRG = one Baud Rate Generator period.
17.4.14 SLEEP OPERATION
While in Sleep mode, the I\(^2\)C module can receive addresses or data and when an address match or complete byte transfer occurs, wake the processor from Sleep (if the MSSP interrupt is enabled).

17.4.15 EFFECT OF A RESET
A Reset disables the MSSP module and terminates the current transfer.

17.4.16 MULTI-MASTER MODE
In Multi-Master mode, the interrupt generation on the detection of the Start and Stop conditions allows the determination of when the bus is free. The Stop (P) and Start (S) bits are cleared from a Reset or when the MSSP module is disabled. Control of the I\(^2\)C bus may be taken when the P bit (SSPSTAT<4>) is set, or the bus is Idle, with both the S and P bits clear. When the bus is busy, enabling the MSSP interrupt will generate the interrupt when the Stop condition occurs.

In multi-master operation, the SDA line must be monitored for arbitration to see if the signal level is the expected output level. This check is performed in hardware with the result placed in the BCLIF bit.

The states where arbitration can be lost are:
- Address Transfer
- Data Transfer
- A Start Condition
- A Repeated Start Condition
- An Acknowledge Condition

17.4.17 MULTI-MASTER COMMUNICATION, BUS COLLISION AND BUS ARBITRATION
Multi-Master mode support is achieved by bus arbitration. When the master outputs address/data bits onto the SDA pin, arbitration takes place when the master outputs a ‘\(^1\)’ on SDA, by letting SDA float high and another master asserts a ‘\(^0\)’. When the SCL pin floats high, data should be stable. If the expected data on SDA is a ‘\(^1\)’ and the data sampled on the SDA pin = \(^0\), then a bus collision has taken place. The master will set the Bus Collision Interrupt Flag, BCLIF and reset the I\(^2\)C port to its Idle state (Figure 17-25).

If a transmit was in progress when the bus collision occurred, the transmission is halted, the BF flag is cleared, the SDA and SCL lines are deasserted and the SSPBUF can be written to. When the user services the bus collision Interrupt Service Routine and if the I\(^2\)C bus is free, the user can resume communication by asserting a Start condition.

If a Start, Repeated Start, Stop or Acknowledge condition was in progress when the bus collision occurred, the condition is aborted, the SDA and SCL lines are deasserted and the respective control bits in the SSPCON2 register are cleared. When the user services the bus collision Interrupt Service Routine and if the I\(^2\)C bus is free, the user can resume communication by asserting a Start condition.

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

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

In Multi-Master mode, the interrupt generation on the detection of Start and Stop conditions allows the determination of when the bus is free. Control of the I\(^2\)C bus can be taken when the P bit is set in the SSPSTAT register, or the bus is Idle and the S and P bits are cleared.

**FIGURE 17-25: BUS COLLISION TIMING FOR TRANSMIT AND ACKNOWLEDGE**
17.4.17.1 Bus Collision During a Start Condition

During a Start condition, a bus collision occurs if:

a) SDA or SCL are sampled low at the beginning of the Start condition (Figure 17-26).

b) SCL is sampled low before SDA is asserted low (Figure 17-27).

During a Start condition, both the SDA and the SCL pins are monitored.

If the SDA pin is already low, or the SCL pin is already low, then all of the following occur:

- the Start condition is aborted,
- the BCLIF flag is set; and
- the MSSP module is reset to its Idle state (Figure 17-26).

The Start condition begins with the SDA and SCL pins deasserted. When the SDA pin is sampled high, the Baud Rate Generator is loaded from SSPADD<6:0> and counts down to 0. If the SCL pin is sampled low while SDA is high, a bus collision occurs because it is assumed that another master is attempting to drive a data '1' during the Start condition.

If the SDA pin is sampled low during this count, the BRG is reset and the SDA line is asserted early (Figure 17-28). If, however, a '1' is sampled on the SDA pin, the SDA pin is asserted low at the end of the BRG count. The Baud Rate Generator is then reloaded and counts down to 0 and during this time, if the SCL pins are sampled as '0', a bus collision does not occur. At the end of the BRG count, the SCL pin is asserted low.

**Note:** The reason that bus collision is not a factor during a Start condition is that no two bus masters can assert a Start condition at the exact same time. Therefore, one master will always assert SDA before the other. This condition does not cause a bus collision because the two masters must be allowed to arbitrate the first address following the Start condition. If the address is the same, arbitration must be allowed to continue into the data portion, Repeated Start or Stop conditions.

**FIGURE 17-26: BUS COLLISION DURING START CONDITION (SDA ONLY)**

- **SDA**
  - SDA goes low before the SEN bit is set. Set BCLIF, S bit and SSPIF set because SDA = 0, SCL = 1.

- **SCL**
  - SCL sampled low before Start condition. Set BCLIF, S bit and SSPIF set because SDA = 0, SCL = 1.

- **SEn**
  - SDA = 0, SCL = 1. SEN cleared automatically because of bus collision. MSSP module reset into Idle state.

- **BCLIF**
  - BCLIF set and enabled Start condition if SDA = 1, SCL = 1.

- **S**
  - S bit and SSPIF set because SDA = 0, SCL = 1.

- **SSPIF**
  - SSPIF and BCLIF are cleared in software.
FIGURE 17-27: BUS COLLISION DURING START CONDITION (SCL = 0)

SDA = 0, SCL = 1

Set SEN, enable Start sequence if SDA = 1, SCL = 1

SCL = 0 before SDA = 0, SCL = 1
bus collision occurs. Set BCLIF.

Set SEN, enable START sequence if SDA = 1, SCL = 1

SCL pulled low by other master.
Reset BRG and assert SDA.

FIGURE 17-28: BRG RESET DUE TO SDA ARBITRATION DURING START CONDITION

SDA = 0, SCL = 1

SCL = 0 before BRG time-out, bus collision occurs. Set BCLIF.

Interrupt cleared in software

Set S
Set SSPIF

SSPIF

SDA pulled low after BRG time-out

SCL pulled low after BRG time-out

Set SEN, enable START sequence if SDA = 1, SCL = 1

Set SSPIF

Interrupts cleared in software

SDA pulled low by other master.
Reset BRG and assert SDA.
17.4.17.2 Bus Collision During a Repeated Start Condition

During a Repeated Start condition, a bus collision occurs if:

a) A low level is sampled on SDA when SCL goes from low level to high level.

b) SCL goes low before SDA is asserted low, indicating that another master is attempting to transmit a data ‘1’.

When the user deasserts SDA and the pin is allowed to float high, the BRG is loaded with SSPADD<6:0> and counts down to 0. The SCL pin is then deasserted and when sampled high, the SDA pin is sampled.

If SDA is low, a bus collision has occurred (i.e., another master is attempting to transmit a data ‘0’, Figure 17-29). If SDA is sampled high, the BRG is reloaded and begins counting. If SDA goes from high to low before the BRG times out, no bus collision occurs because no two masters can assert SDA at exactly the same time.

If SCL goes from high to low before the BRG times out and SDA has not already been asserted, a bus collision occurs. In this case, another master is attempting to transmit a data ‘1’ during the Repeated Start condition, see Figure 17-30.

If, at the end of the BRG time-out, both SCL and SDA are still high, the SDA pin is driven low and the BRG is reloaded and begins counting. At the end of the count, regardless of the status of the SCL pin, the SCL pin is driven low and the Repeated Start condition is complete.

**FIGURE 17-29: BUS COLLISION DURING A REPEATED START CONDITION (CASE 1)**

- SDA
- SCL
- RSEN
- BCLIF
- SSPIF

Sample SDA when SCL goes high.
If SDA = 0, set BCLIF and release SDA and SCL.

Cleared in software

**FIGURE 17-30: BUS COLLISION DURING A REPEATED START CONDITION (CASE 2)**

- SDA
- SCL
- BCLIF
- RSEN
- SSPIF

SCL goes low before SDA, set BCLIF. Release SDA and SCL.

Interrupt cleared in software

‘0’
17.4.17.3 Bus Collision During a Stop Condition

Bus collision occurs during a Stop condition if:

a) After the SDA pin has been deasserted and allowed to float high, SDA is sampled low after the BRG has timed out.

b) After the SCL pin is deasserted, SCL is sampled low before SDA goes high.

The Stop condition begins with SDA asserted low. When SDA is sampled low, the SCL pin is allowed to float. When the pin is sampled high (clock arbitration), the Baud Rate Generator is loaded with SSPADD<6:0> and counts down to 0. After the BRG times out, SDA is sampled. If SDA is sampled low, a bus collision has occurred. This is due to another master attempting to drive a data ‘0’ (Figure 17-31). If the SCL pin is sampled low before SDA is allowed to float high, a bus collision occurs. This is another case of another master attempting to drive a data ‘0’ (Figure 17-32).

**FIGURE 17-31: BUS COLLISION DURING A STOP CONDITION (CASE 1)**

![Diagram of bus collision during a stop condition case 1](image)

**FIGURE 17-32: BUS COLLISION DURING A STOP CONDITION (CASE 2)**

![Diagram of bus collision during a stop condition case 2](image)
18.0 **ENHANCED UNIVERSAL SYNCHRONOUS RECEIVER TRANSMITTER (EUSART)**

The Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) module is one of the two serial I/O modules. (USART is also known as a Serial Communications Interface or SCI.) The EUSART can be configured as a full-duplex asynchronous system that can communicate with peripheral devices, such as CRT terminals and personal computers. It can also be configured as a half-duplex synchronous system that can communicate with peripheral devices, such as A/D or D/A integrated circuits, serial EEPROMs and so on.

The EUSART module implements additional features, including Auto-Baud Rate Detection and calibration, automatic wake-up on Sync Break reception and 12-bit Break character transmit. These features make it ideally suited for use in Local Interconnect Network bus (LIN bus) systems.

The EUSART can be configured in the following modes:

- Asynchronous (full duplex) with:
  - Auto-Wake-up on Character Reception
  - Auto-Baud Calibration
  - 12-Bit Break Character Transmission
- Synchronous – Master (half duplex) with Selectable Clock Polarity
- Synchronous – Slave (half duplex) with Selectable Clock Polarity

The pins of the Enhanced USART are multiplexed with PORTC. In order to configure RC6/TX/CK and RC7/RX/DT as an EUSART:

- bit SPEN (RCSTA<7>) must be set (= 1)
- bit TRISC<7> must be set (= 1)
- bit TRISC<6> must be cleared (= 0) for Asynchronous and Synchronous Master modes, or set (= 1) for Synchronous Slave mode

**Note:** The EUSART control will automatically reconfigure the pin from input to output as needed.

The operation of the Enhanced USART module is controlled through three registers:

- Transmit Status and Control (TXSTA)
- Receive Status and Control (RCSTA)
- Baud Rate Control (BAUDCON)

These are detailed on the following pages in Register 18-1, Register 18-2 and Register 18-3, respectively.
REGISTER 18-1: TXSTA: TRANSMIT STATUS AND CONTROL REGISTER

<table>
<thead>
<tr>
<th></th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R-1</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN(1)</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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  CSRC: Clock Source Select bit
Asynchronous mode:
Don’t care.
Synchronous mode:
1 = Master mode (clock generated internally from BRG)
0 = Slave mode (clock from external source)

bit 6  TX9: 9-Bit Transmit Enable bit
1 = Selects 9-bit transmission
0 = Selects 8-bit transmission

bit 5  TXEN: Transmit Enable bit(1)
1 = Transmit enabled
0 = Transmit disabled

bit 4  SYNC: EUSART Mode Select bit
1 = Synchronous mode
0 = Asynchronous mode

bit 3  SENDB: Send Break Character bit
Asynchronous mode:
1 = Send Sync Break on next transmission (cleared by hardware upon completion)
0 = Sync Break transmission completed
Synchronous mode:
Don’t care.

bit 2  BRGH: High Baud Rate Select bit
Asynchronous mode:
1 = High speed
0 = Low speed
Synchronous mode:
Unused in this mode.

bit 1  TRMT: Transmit Shift Register Status bit
1 = TSR empty
0 = TSR full

bit 0  TX9D: 9th bit of Transmit Data
Can be address/data bit or a parity bit.

Note 1: SREN/CREN overrides TXEN in Sync mode.
REGISTER 18-2: RCSTA: RECEIVE STATUS AND CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- W = Writable 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  SPEN: Serial Port Enable bit
1 = Serial port enabled (configures RX/DT and TX/CK pins as serial port pins)
0 = Serial port disabled (held in Reset)

bit 6  RX9: 9-Bit Receive Enable bit
1 = Selects 9-bit reception
0 = Selects 8-bit reception

bit 5  SREN: Single Receive Enable bit
Asynchronous mode:
Don’t care.
Synchronous mode – Master:
1 = Enables single receive
0 = Disables single receive
This bit is cleared after reception is complete.
Synchronous mode – Slave:
Don’t care.

bit 4  CREN: Continuous Receive Enable bit
Asynchronous mode:
1 = Enables receiver
0 = Disables receiver
Synchronous mode:
1 = Enables continuous receive until enable bit CREN is cleared (CREN overrides SREN)
0 = Disables continuous receive

bit 3  ADDEN: Address Detect Enable bit
Asynchronous mode 9-bit (RX9 = 1):
1 = Enables address detection, enables interrupt and loads the receive buffer when RSR<8> is set
0 = Disables address detection, all bytes are received and ninth bit can be used as parity bit
Asynchronous mode 9-bit (RX9 = 0):
Don’t care.

bit 2  FERR: Framing Error bit
1 = Framing error (can be updated by reading RCREG register and receiving next valid byte)
0 = No framing error

bit 1  OERR: Overrun Error bit
1 = Overrun error (can be cleared by clearing bit CREN)
0 = No overrun error

bit 0  RX9D: 9th bit of Received Data
This can be an address/data bit or a parity bit and must be calculated by user firmware.
### REGISTER 18-3: BAUDCON: BAUD RATE CONTROL REGISTER

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABDOVF</strong></td>
<td><strong>RCIDL</strong></td>
<td>—</td>
<td><strong>SCKP</strong></td>
<td><strong>BRG16</strong></td>
<td>—</td>
<td><strong>WUE</strong></td>
<td><strong>ABDEN</strong></td>
</tr>
</tbody>
</table>

#### Legend:
- **R** = Readable bit
- **W** = Writable 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: **ABDOVF** - Auto-Baud Acquisition Rollover Status bit
- **1** = A BRG rollover has occurred during Auto-Baud Rate Detect mode (must be cleared in software)
- **0** = No BRG rollover has occurred

#### Bit 6: **RCIDL** - Receive Operation Idle Status bit
- **1** = Receive operation is Idle
- **0** = Receive operation is active

#### Bit 5: **Unimplemented** - Read as '0'

#### Bit 4: **SCKP** - Synchronous Clock Polarity Select bit
- **Asynchronous mode:**
  - Unused in this mode.
- **Synchronous mode:**
  - **1** = Idle state for clock (CK) is a high level
  - **0** = Idle state for clock (CK) is a low level

#### Bit 3: **BRG16** - 16-Bit Baud Rate Register Enable bit
- **1** = 16-bit Baud Rate Generator – SPBRGH and SPBRG
- **0** = 8-bit Baud Rate Generator – SPBRG only (Compatible mode), SPBRGH value ignored

#### Bit 2: **Unimplemented** - Read as '0'

#### Bit 1: **WUE** - Wake-up Enable bit
- **Asynchronous mode:**
  - **1** = EUSART will continue to sample the RX pin – interrupt generated on falling edge; bit cleared in hardware on following rising edge
  - **0** = RX pin not monitored or rising edge detected
- **Synchronous mode:**
  - Unused in this mode.

#### Bit 0: **ABDEN** - Auto-Baud Detect Enable bit
- **Asynchronous mode:**
  - **1** = Enable baud rate measurement on the next character. Requires reception of a Sync field (55h); cleared in hardware upon completion.
  - **0** = Baud rate measurement disabled or completed
- **Synchronous mode:**
  - Unused in this mode.
18.1 Baud Rate Generator (BRG)

The BRG is a dedicated 8-bit or 16-bit generator that supports both the Asynchronous and Synchronous modes of the EUSART. By default, the BRG operates in 8-bit mode; setting the BRG16 bit (BAUDCON<3>) selects 16-bit mode.

The SPBRGH:SPBRG register pair controls the period of a free-running timer. In Asynchronous mode, bits BRGH (TXSTA<2>) and BRG16 (BAUDCON<3>) also control the baud rate. In Synchronous mode, BRGH is ignored. Table 18-1 shows the formula for computation of the baud rate for different EUSART modes which only apply in Master mode (internally generated clock).

Given the desired baud rate and Fosc, the nearest integer value for the SPBRGH:SPBRG registers can be calculated using the formulas in Table 18-1. From this, the error in baud rate can be determined. An example calculation is shown in Example 18-1. Typical baud rates and error values for the various Asynchronous modes are shown in Table 18-2. It may be advantageous to use the high baud rate (BRGH = 1) or the 16-bit BRG to reduce the baud rate error, or achieve a slow baud rate for a fast oscillator frequency.

Writing a new value to the SPBRGH:SPBRG registers causes the BRG timer to be reset (or cleared). This ensures that the BRG does not wait for a timer overflow before outputting the new baud rate.

18.1.1 OPERATION IN POWER-MANAGED MODES

The device clock is used to generate the desired baud rate. When one of the power-managed modes is entered, the new clock source may be operating at a different frequency. This may require an adjustment to the value in the SPBRG register pair.

18.1.2 SAMPLING

The data on the RX pin is sampled three times by a majority detect circuit to determine if a high or a low level is present at the RX pin.

<table>
<thead>
<tr>
<th>TABLE 18-1: BAUD RATE FORMULAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration Bits</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>SYNC BRG16 BRGH</td>
</tr>
<tr>
<td>0 0 0</td>
</tr>
<tr>
<td>0 1 0</td>
</tr>
<tr>
<td>0 1 1</td>
</tr>
<tr>
<td>1 0 x</td>
</tr>
<tr>
<td>1 1 x</td>
</tr>
</tbody>
</table>

Legend:  \(x\) = Don't care, \(n\) = value of SPBRGH:SPBRG register pair

**EXAMPLE 18-1: CALCULATING BAUD RATE ERROR**

For a device with Fosc of 16 MHz, desired baud rate of 9600, Asynchronous mode, 8-bit BRG:

Desired Baud Rate = $F_{osc}/(64 ([SPBRGH:SPBRG] + 1))$

Solving for SPBRGH:SPBRG:

\[
X = \left(\frac{F_{osc}}{\text{Desired Baud Rate}}\right) / 64 - 1 = \left(\frac{16000000}{9600}\right) / 64 - 1 = \left[25.042\right] - 1 = 25
\]

Calculated Baud Rate = $16000000/(64 (25 + 1)) = 9615$

Error = $(\text{Calculated Baud Rate} - \text{Desired Baud Rate}) / \text{Desired Baud Rate} = (9615 - 9600) / 9600 = 0.16\%$

**TABLE 18-2: REGISTERS ASSOCIATED WITH BAUD RATE GENERATOR**

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABD0VF</td>
<td>RCIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used by the BRG.
# TABLE 18-3: BAUD RATES FOR ASYNCHRONOUS MODES

<table>
<thead>
<tr>
<th>BAUD RATE (K)</th>
<th>Fosc = 40.000 MHz</th>
<th>Fosc = 20.000 MHz</th>
<th>Fosc = 10.000 MHz</th>
<th>Fosc = 8.000 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual Rate (K)</td>
<td>% Error</td>
<td>SPBRG value (decimal)</td>
<td>Actual Rate (K)</td>
</tr>
<tr>
<td>0.3</td>
<td>0.300</td>
<td>0.16</td>
<td>207</td>
<td>0.300</td>
</tr>
<tr>
<td>1.2</td>
<td>1.202</td>
<td>0.16</td>
<td>51</td>
<td>1.201</td>
</tr>
<tr>
<td>2.4</td>
<td>2.404</td>
<td>0.16</td>
<td>12</td>
<td>2.403</td>
</tr>
<tr>
<td>9.6</td>
<td>9.766</td>
<td>1.73</td>
<td>31</td>
<td>9.766</td>
</tr>
<tr>
<td>19.2</td>
<td>19.531</td>
<td>1.73</td>
<td>31</td>
<td>19.531</td>
</tr>
<tr>
<td>57.6</td>
<td>62.500</td>
<td>8.51</td>
<td>42</td>
<td>52.083</td>
</tr>
<tr>
<td>115.2</td>
<td>125.000</td>
<td>8.51</td>
<td>4</td>
<td>78.125</td>
</tr>
</tbody>
</table>
### TABLE 18-3: BAUD RATES FOR ASYNCHRONOUS MODES (CONTINUED)

<table>
<thead>
<tr>
<th>BAUD RATE (K)</th>
<th>( F_{OSC} = 40.000 \text{ MHz} )</th>
<th>( F_{OSC} = 20.000 \text{ MHz} )</th>
<th>( F_{OSC} = 10.000 \text{ MHz} )</th>
<th>( F_{OSC} = 8.000 \text{ MHz} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\text{Actual Rate (K)}] % Error</td>
<td>[\text{SPBRG value (decimal)}]</td>
<td>[\text{Actual Rate (K)}] % Error</td>
<td>[\text{SPBRG value (decimal)}]</td>
</tr>
<tr>
<td>0.3</td>
<td>0.300 0.00 8332</td>
<td>0.300 0.02 4165</td>
<td>0.300 0.02 2082</td>
<td>0.300 -0.04 1665</td>
</tr>
<tr>
<td>1.2</td>
<td>1.200 0.02 2082</td>
<td>1.200 -0.03 1041</td>
<td>1.200 -0.03 520</td>
<td>1.201 -0.16 415</td>
</tr>
<tr>
<td>2.4</td>
<td>2.402 0.06 1040</td>
<td>2.399 -0.03 520</td>
<td>2.404 0.16 259</td>
<td>2.403 -0.16 207</td>
</tr>
<tr>
<td>9.6</td>
<td>9.615 0.16 259</td>
<td>9.615 0.16 129</td>
<td>9.615 0.16 64</td>
<td>9.615 -0.16 51</td>
</tr>
<tr>
<td>19.2</td>
<td>19.231 0.16 129</td>
<td>19.231 0.16 64</td>
<td>19.531 1.73 31</td>
<td>19.230 -0.16 25</td>
</tr>
<tr>
<td>57.6</td>
<td>58.140 0.94 42</td>
<td>56.818 -1.36 21</td>
<td>56.818 -1.36 10</td>
<td>55.555 3.55 8</td>
</tr>
<tr>
<td>115.2</td>
<td>113.636 -1.36 21</td>
<td>113.636 -1.36 10</td>
<td>125.000 8.51 4</td>
<td>— — — — — — — — — — — — — — — — — —</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BAUD RATE (K)</th>
<th>( F_{OSC} = 4.000 \text{ MHz} )</th>
<th>( F_{OSC} = 2.000 \text{ MHz} )</th>
<th>( F_{OSC} = 1.000 \text{ MHz} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\text{Actual Rate (K)}] % Error</td>
<td>[\text{SPBRG value (decimal)}]</td>
<td>[\text{Actual Rate (K)}] % Error</td>
</tr>
<tr>
<td>0.3</td>
<td>0.300 0.04 832</td>
<td>0.300 -0.16 415</td>
<td>0.300 -0.16 207</td>
</tr>
<tr>
<td>1.2</td>
<td>1.202 0.16 207</td>
<td>1.201 -0.16 103</td>
<td>1.201 -0.16 51</td>
</tr>
<tr>
<td>2.4</td>
<td>2.403 0.16 103</td>
<td>2.403 -0.16 51</td>
<td>2.403 -0.16 25</td>
</tr>
<tr>
<td>9.6</td>
<td>9.615 0.16 25</td>
<td>9.615 -0.16 12</td>
<td>9.615 -0.16 25</td>
</tr>
<tr>
<td>19.2</td>
<td>19.231 0.16 12</td>
<td>— — — — — — — — — — — — — — — — — —</td>
<td></td>
</tr>
<tr>
<td>57.6</td>
<td>62.500 8.51 3</td>
<td>— — — — — — — — — — — — — — — — — —</td>
<td></td>
</tr>
<tr>
<td>115.2</td>
<td>125.000 8.51 1</td>
<td>— — — — — — — — — — — — — — — — — —</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BAUD RATE (K)</th>
<th>( F_{OSC} = 4.000 \text{ MHz} )</th>
<th>( F_{OSC} = 2.000 \text{ MHz} )</th>
<th>( F_{OSC} = 1.000 \text{ MHz} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\text{Actual Rate (K)}] % Error</td>
<td>[\text{SPBRG value (decimal)}]</td>
<td>[\text{Actual Rate (K)}] % Error</td>
</tr>
<tr>
<td>0.3</td>
<td>0.300 0.00 33332</td>
<td>0.300 0.00 16665</td>
<td>0.300 0.00 8332</td>
</tr>
<tr>
<td>1.2</td>
<td>1.200 0.00 8332</td>
<td>1.200 0.02 2082</td>
<td>1.200 0.02 1041</td>
</tr>
<tr>
<td>2.4</td>
<td>2.400 0.02 4165</td>
<td>2.400 0.02 2082</td>
<td>2.402 0.06 1040</td>
</tr>
<tr>
<td>9.6</td>
<td>9.606 0.06 1040</td>
<td>9.596 -0.03 520</td>
<td>9.615 0.16 259</td>
</tr>
<tr>
<td>19.2</td>
<td>19.193 -0.03 520</td>
<td>19.231 0.16 259</td>
<td>19.231 0.16 129</td>
</tr>
<tr>
<td>57.6</td>
<td>57.803 0.35 172</td>
<td>57.471 -0.22 86</td>
<td>58.140 0.94 42</td>
</tr>
<tr>
<td>115.2</td>
<td>114.943 -0.22 86</td>
<td>116.279 0.94 42</td>
<td>113.636 -1.36 21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BAUD RATE (K)</th>
<th>( F_{OSC} = 4.000 \text{ MHz} )</th>
<th>( F_{OSC} = 2.000 \text{ MHz} )</th>
<th>( F_{OSC} = 1.000 \text{ MHz} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\text{Actual Rate (K)}] % Error</td>
<td>[\text{SPBRG value (decimal)}]</td>
<td>[\text{Actual Rate (K)}] % Error</td>
</tr>
<tr>
<td>0.3</td>
<td>0.300 0.01 33332</td>
<td>0.300 -0.04 1665</td>
<td>0.300 -0.04 832</td>
</tr>
<tr>
<td>1.2</td>
<td>1.200 0.04 832</td>
<td>1.201 -0.16 415</td>
<td>1.201 -0.16 207</td>
</tr>
<tr>
<td>2.4</td>
<td>2.404 0.16 415</td>
<td>2.403 -0.16 207</td>
<td>2.403 -0.16 103</td>
</tr>
<tr>
<td>9.6</td>
<td>9.615 0.16 103</td>
<td>9.615 -0.16 51</td>
<td>9.615 -0.16 25</td>
</tr>
<tr>
<td>19.2</td>
<td>19.231 0.16 51</td>
<td>19.230 -0.16 25</td>
<td>19.230 -0.16 12</td>
</tr>
<tr>
<td>57.6</td>
<td>58.824 2.12 16</td>
<td>55.555 3.55 8</td>
<td>— — — — — — — — — — — — — — — — — —</td>
</tr>
<tr>
<td>115.2</td>
<td>111.111 -3.55 8</td>
<td>— — — — — — — — — — — — — — — — — —</td>
<td></td>
</tr>
</tbody>
</table>
18.1.3 AUTO-BAUD RATE DETECT

The Enhanced USART module supports the automatic detection and calibration of baud rate. This feature is active only in Asynchronous mode and while the WUE bit is clear.

The automatic baud rate measurement sequence (Figure 18-1) begins whenever a Start bit is received and the ABDEN bit is set. The calculation is self-averaging.

In the Auto-Baud Rate Detect (ABD) mode, the clock to the BRG is reversed. Rather than the BRG clocking the incoming RX signal, the RX signal is timing the BRG. In ABD mode, the internal Baud Rate Generator is used as a counter to time the bit period of the incoming serial byte stream.

Once the ABDEN bit is set, the state machine will clear the BRG and look for a Start bit. The Auto-Baud Rate Detection must receive a byte with the value 55h (ASCII "U", which is also the LIN bus Sync character) in order to calculate the proper bit rate. The measurement is taken over both a low and high bit time in order to minimize any effects caused by asymmetry of the incoming signal. After a Start bit, the SPBRG begins counting up, using the preselected clock source on the first rising edge of RX. After eight bits on the RX pin or the fifth rising edge, an accumulated value totalling the proper BRG period is left in the SPBRGH:SPBRG register pair. Once the 5th edge is seen (this should correspond to the Stop bit), the ABDEN bit is automatically cleared.

If a rollover of the BRG occurs (an overflow from FFFFh to 0000h), the event is trapped by the ABDOVF status bit (BAUDCON<7>). It is set in hardware by BRG rollovers and can be set or cleared by the user in software. ABD mode remains active after rollover events and the ABDEN bit remains set (Figure 18-2).

While the ABD sequence takes place, the EUSART state machine is held in Idle. The RCIF interrupt is set once the fifth rising edge on RX is detected. The value in the RCREG needs to be read to clear the RCIF interrupt. The contents of RCREG should be discarded.

While calibrating the baud rate period, the BRG registers are clocked at 1/8th the preconfigured clock rate. Note that the BRG clock will be configured by the BRG16 and BRGH bits. Independent of the BRG16 bit setting, both the SPBRG and SPBRGH will be used as a 16-bit counter. This allows the user to verify that no carry occurred for 8-bit modes by checking for 00h in the SPBRGH register. Refer to Table 18-4 for counter clock rates to the BRG.

### TABLE 18-4: BRG COUNTER CLOCK RATES

<table>
<thead>
<tr>
<th>BRG16</th>
<th>BRGH</th>
<th>BRG Counter Clock</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Fosc/512</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Fosc/128</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Fosc/128</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Fosc/32</td>
</tr>
</tbody>
</table>

Note: During the ABD sequence, SPBRG and SPBRGH are both used as a 16-bit counter, independent of the BRG16 setting.

18.1.3.1 ABD and EUSART Transmission

Since the BRG clock is reversed during ABD acquisition, the EUSART transmitter cannot be used during ABD. This means that whenever the ABDEN bit is set, TXREG cannot be written to. Users should also ensure that ABDEN does not become set during a transmit sequence. Failing to do this may result in unpredictable EUSART operation.
**FIGURE 18-1: AUTOMATIC BAUD RATE CALCULATION**

<table>
<thead>
<tr>
<th>BRG Value</th>
<th>XXXXh</th>
<th>0000h</th>
<th>001Ch</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX pin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRG Clock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABDEN bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCIF bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read RCREG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRG</td>
<td></td>
<td>XXXXh</td>
<td>1Ch</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>XXXXh</td>
<td>00h</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The ABD sequence requires the EUSART module to be configured in Asynchronous mode and WUE = 0.

**FIGURE 18-2: BRG OVERFLOW SEQUENCE**

<table>
<thead>
<tr>
<th>BRG Clock</th>
<th></th>
<th></th>
<th>FFFFh</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABDEN bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RX pin</td>
<td>Start</td>
<td>bit 0</td>
<td></td>
</tr>
<tr>
<td>ABDOVF bit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRG Value</td>
<td>XXXXh</td>
<td>0000h</td>
<td>0000h</td>
</tr>
</tbody>
</table>

The table and figure illustrate the automatic baud rate calculation and the BRG overflow sequence for the PIC18F2682/2685/4682/4685 devices.
18.2 EUSART Asynchronous Mode

The Asynchronous mode of operation is selected by clearing the SYNC bit (TXSTA<4>). In this mode, the EUSART uses standard Non-Return-to-Zero (NRZ) format (one Start bit, eight or nine data bits and one Stop bit). The most common data format is 8 bits. An on-chip, dedicated 8-bit/16-bit Baud Rate Generator can be used to derive standard baud rate frequencies from the oscillator.

The EUSART transmits and receives the LSb first. The EUSART’s transmitter and receiver are functionally independent but use the same data format and baud rate. The Baud Rate Generator produces a clock, either x16 or x64 of the bit shift rate depending on the BRGH and BRG16 bits (TXSTA<2> and BAUDCON<3>). Parity is not supported by the hardware, but can be implemented in software and stored as the 9th data bit.

When operating in Asynchronous mode, the EUSART module consists of the following important elements:

- Baud Rate Generator
- Sampling Circuit
- Asynchronous Transmitter
- Asynchronous Receiver
- Auto-Wake-up on Sync Break Character
- 12-Bit Break Character Transmit
- Auto-Baud Rate Detection

18.2.1 EUSART ASYNCHRONOUS TRANSMITTER

The EUSART transmitter block diagram is shown in Figure 18-3. The heart of the transmitter is the Transmit (Serial) Shift Register (TSR). The Shift register obtains its data from the Read/Write Transmit Buffer register, TXREG. The TXREG register is loaded with data in software. The TSR register is not loaded until the Stop bit has been transmitted from the previous load. As soon as the Stop bit is transmitted, the TSR is loaded with new data from the TXREG register (if available). Once the TXREG register transfers the data to the TSR register (occurs in one TCY), the TXREG register is empty and the TXIF flag bit (PIR1<4>) is set. This interrupt can be enabled or disabled by setting or clearing the interrupt enable bit, TXIE (PIE1<4>). TXIF will be set regardless of the state of TXIE; it cannot be cleared in software. TXIF is also not cleared immediately upon loading TXREG, but becomes valid in the second instruction cycle following the load instruction. Polling TXIF immediately following a load of TXREG will return invalid results.

While TXIF indicates the status of the TXREG register, another bit, TRMT (TXSTA<1>), shows the status of the TSR register. TRMT is a read-only bit which is set when the TSR register is empty. No interrupt logic is tied to this bit so the user has to poll this bit in order to determine if the TSR register is empty.

Note 1: The TSR register is not mapped in data memory so it is not available to the user.
2: Flag bit, TXIF, is set when enable bit, TXEN, is set.

To set up an Asynchronous Transmission:

1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Enable the asynchronous serial port by clearing bit SYNC and setting bit SPEN.
3. If interrupts are desired, set enable bit TXIE.
4. If 9-bit transmission is desired, set transmit bit TX9. Can be used as address/data bit.
5. Enable the transmission by setting bit TXEN which will also set bit TXIF.
6. If 9-bit transmission is selected, the ninth bit should be loaded in bit TX9D.
7. Load data to the TXREG register (starts transmission).
8. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

FIGURE 18-3: EUSART TRANSMIT BLOCK DIAGRAM
**TABLE 18-5: REGISTERS ASSOCIATED WITH ASYNCHRONOUS TRANSMISSION**

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INTOIE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INTOIF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF$^{(1)}$</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE$^{(1)}$</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPRI</td>
<td>PSPIp$^{(1)}$</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1P</td>
<td>TMR2P</td>
<td>TMR1P</td>
<td>54</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>TXREG</td>
<td>EUSART Transmit Register</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDOVF</td>
<td>RCIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBREG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented locations read as '0'. Shaded cells are not used for asynchronous transmission.

**Note 1:** Reserved in PIC18F2682/2685 devices; always maintain these bits clear.
18.2.2 EUSART ASYNCHRONOUS RECEIVER

The receiver block diagram is shown in Figure 18-6. The data is received on the RX pin and drives the data recovery block. The data recovery block is actually a high-speed shifter operating at x16 times the baud rate, whereas the main receive serial shifter operates at the bit rate or at Fosc. This mode would typically be used in RS-232 systems.

To set up an Asynchronous Reception:
1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Enable the asynchronous serial port by clearing bit SYNC and setting bit SPEN.
3. If interrupts are desired, set enable bit, RCIE.
4. If 9-bit reception is desired, set bit RX9.
5. Enable the reception by setting bit CREN.
6. Flag bit RCIF will be set when reception is complete and an interrupt will be generated if enable bit RCIE was set.
7. Read the RCSTA register to get the 9th bit (if enabled) and determine if any error occurred during reception.
8. Read the 8-bit received data by reading the RCREG register.
9. If any error occurred, clear the error by clearing enable bit CREN.
10. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

18.2.3 SETTING UP 9-BIT MODE WITH ADDRESS DETECT

This mode would typically be used in RS-485 systems. To set up an Asynchronous Reception with Address Detect Enable:
1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Enable the asynchronous serial port by clearing the SYNC bit and setting the SPEN bit.
3. If interrupts are required, set the RCEN bit and select the desired priority level with the RCIP bit.
4. Set the RX9 bit to enable 9-bit reception.
5. Set the ADDEN bit to enable address detect.
6. Enable reception by setting the CREN bit.
7. The RCIF bit will be set when reception is complete. The interrupt will be Acknowledged if the RCIE and GIE bits are set.
8. Read the RCSTA register to determine if any error occurred during reception, as well as read bit 9 of data (if applicable).
9. Read RCREG to determine if the device is being addressed.
10. If any error occurred, clear the ADDEN bit.
11. If the device has been addressed, clear the ADDEN bit to allow all received data into the receive buffer and interrupt the CPU.

FIGURE 18-6: EUSART RECEIVE BLOCK DIAGRAM
FIGURE 18-7: ASYNCHRONOUS RECEPTION

Table 18-6: Registers Associated with Asynchronous Reception

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1E</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>RCREG</td>
<td>EUSART Receive Register</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDOVF</td>
<td>RCIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: — = unimplemented locations read as ‘0’. Shaded cells are not used for asynchronous reception.

Note 1: Reserved in PIC18F2682/2685 devices; always maintain these bits clear.
18.2.4 AUTO-WAKE-UP ON SYNC BREAK CHARACTER

During Sleep mode, all clocks to the EUSART are suspended. Because of this, the Baud Rate Generator is inactive and a proper byte reception cannot be performed. The auto-wake-up feature allows the controller to wake-up due to activity on the RX/DT line while the EUSART is operating in Asynchronous mode.

The auto-wake-up feature is enabled by setting the WUE bit (BAUDCON<1>). Once set, the typical receive sequence on RX/DT is disabled and the EUSART remains in an Idle state, monitoring for a wake-up event independent of the CPU mode. A wake-up event consists of a high-to-low transition on the RX/DT line. (This coincides with the start of a Sync Break or a Wake-up Signal character for the LIN protocol.)

Following a wake-up event, the module generates an RCIF interrupt. The interrupt is generated synchronously to the Q clocks in normal operating modes (Figure 18-8) and asynchronously, if the device is in Sleep mode (Figure 18-9). The interrupt condition is cleared by reading the RCREG register.

The WUE bit is automatically cleared once a low-to-high transition is observed on the RX line following the wake-up event. At this point, the EUSART module is in Idle mode and returns to normal operation. This signals to the user that the Sync Break event is over.

18.2.4.1 Special Considerations Using Auto-Wake-up

Since auto-wake-up functions by sensing rising edge transitions on RX/DT, information with any state changes before the Stop bit may signal a false End-of-Character and cause data or framing errors. To work properly, therefore, the initial character in the transmission must be all ‘0’s. This can be 00h (8 bytes) for standard RS-232 devices or 000h (12 bits) for LIN bus.

Oscillator start-up time must also be considered, especially in applications using oscillators with longer start-up intervals (i.e., XT or HS mode). The Sync Break (or Wake-up Signal) character must be of sufficient length and be followed by a sufficient interval to allow enough time for the selected oscillator to start and provide proper initialization of the EUSART.

18.2.4.2 Special Considerations Using the WUE Bit

The timing of WUE and RCIF events may cause some confusion when it comes to determining the validity of received data. As noted, setting the WUE bit places the EUSART in an Idle mode. The wake-up event causes a receive interrupt by setting the RCIF bit. The WUE bit is cleared after this when a rising edge is seen on RX/DT. The interrupt condition is then cleared by reading the RCREG register. Ordinarily, the data in RCREG will be dummy data and should be discarded.

The fact that the WUE bit has been cleared (or is still set), and the RCIF flag is set, should not be used as an indicator of the integrity of the data in RCREG. Users should consider implementing a parallel method in firmware to verify received data integrity.

To assure that no actual data is lost, check the RCIDL bit to verify that a receive operation is not in process. If a receive operation is not occurring, the WUE bit may then be set just prior to entering the Sleep mode.

**FIGURE 18-8: AUTO-WAKE-UP BIT (WUE) TIMINGS DURING NORMAL OPERATION**

<table>
<thead>
<tr>
<th>OSC1</th>
<th>WUE bit(f)</th>
<th>RX/DT Line</th>
<th>RCIF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bit set by user</td>
<td>Auto-Cleared</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: The EUSART remains in Idle while the WUE bit is set.

**FIGURE 18-9: AUTO-WAKE-UP BIT (WUE) TIMINGS DURING SLEEP**

<table>
<thead>
<tr>
<th>OSC1</th>
<th>WUE bit(f)</th>
<th>RX/DT Line</th>
<th>RCIF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bit set by user</td>
<td>Auto-Cleared</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: If the wake-up event requires long oscillator warm-up time, the auto-clear of the WUE bit can occur while the stposc signal is still active. This sequence should not depend on the presence of Q clocks.

2: The EUSART remains in Idle while the WUE bit is set.
18.2.5 BREAK CHARACTER SEQUENCE

The Enhanced EUSART module has the capability of sending the special Break character sequences that are required by the LIN bus standard. The Break character transmit consists of a Start bit, followed by twelve '0' bits and a Stop bit. The frame Break character is sent whenever the SENDB and TXEN bits (TXSTA<3> and TXSTA<5>) are set while the Transmit Shift register is loaded with data. Note that the value of data written to TXREG will be ignored and all '0's will be transmitted.

The SENDB bit is automatically reset by hardware after the corresponding Stop bit is sent. This allows the user to preload the transmit FIFO with the next transmit byte following the Break character (typically, the Sync character in the LIN specification).

Note that the data value written to the TXREG for the Break character is ignored. The write simply serves the purpose of initiating the proper sequence.

The TRMT bit indicates when the transmit operation is active or Idle, just as it does during normal transmission. See Figure 18-10 for the timing of the Break character sequence.

18.2.5.1 Break and Sync Transmit Sequence

The following sequence will send a message frame header made up of a Break, followed by an Auto-Baud Sync byte. This sequence is typical of a LIN bus master.

1. Configure the EUSART for the desired mode.
2. Set the TXEN and SENDB bits to set up the Break character.
3. Load the TXREG with a dummy character to initiate transmission (the value is ignored).
4. Write '55h' to TXREG to load the Sync character into the transmit FIFO buffer.
5. After the Break has been sent, the SENDB bit is reset by hardware. The Sync character now transmits in the preconfigured mode.

When the TXREG becomes empty, as indicated by the TXIF, the next data byte can be written to TXREG.

18.2.6 RECEIVING A BREAK CHARACTER

The Enhanced USART module can receive a Break character in two ways.

The first method forces configuration of the baud rate at a frequency of 9/13 the typical speed. This allows for the Stop bit transition to be at the correct sampling location (13 bits for Break versus Start bit and 8 data bits for typical data).

The second method uses the auto-wake-up feature described in Section 18.2.4 "Auto-Wake-up on Sync Break Character". By enabling this feature, the EUSART will sample the next two transitions on RX/DT, cause an RCIF interrupt and receive the next data byte followed by another interrupt.

Note that following a Break character, the user will typically want to enable the Auto-Baud Rate Detect feature. For both methods, the user can set the ABD bit once the TXIF interrupt is observed.

---

**FIGURE 18-10: SEND BREAK CHARACTER SEQUENCE**
18.3 EUSART Synchronous Master Mode

The Synchronous Master mode is entered by setting the CSRC bit (TXSTA<7>). In this mode, the data is transmitted in a half-duplex manner (i.e., transmission and reception do not occur at the same time). When transmitting data, the reception is inhibited and vice versa. Synchronous mode is entered by setting bit SYNC (TXSTA<4>). In addition, enable bit, SPEN (RCSTA<7>), is set in order to configure the TX and RX pins to CK (clock) and DT (data) lines, respectively.

The Master mode indicates that the processor transmits the master clock on the CK line. Clock polarity is selected with the SCKP bit (BAUDCON<4>); setting SCKP sets the Idle state on CK as high, while clearing the bit sets the Idle state as low. This option is provided to support Microwire devices with this module.

18.3.1 EUSART SYNCHRONOUS MASTER TRANSMISSION

The EUSART transmitter block diagram is shown in Figure 18-3. The heart of the transmitter is the Transmit (Serial) Shift Register (TSR). The Shift register obtains its data from the Read/Write Transmit Buffer register, TXREG. The TXREG register is loaded with data in software. The TSR register is not loaded until the last bit has been transmitted from the previous load. As soon as the last bit is transmitted, the TSR is loaded with new data from the TXREG (if available).

Once the TXREG register transfers the data to the TSR register (occurs in one TCYCLE), the TXREG is empty and the TXIF flag bit (PIR1<4>) is set. The interrupt can be enabled or disabled by setting or clearing the interrupt enable bit, TXIE (PIE1<4>). TXIF is set regardless of the state of enable bit TXIE; it cannot be cleared in software. It will reset only when new data is loaded into the TXREG register.

While flag bit TXIF indicates the status of the TXREG register, another bit, TRMT (TXSTA<1>), shows the status of the TSR register. TRMT is a read-only bit which is set when the TSR is empty. No interrupt logic is tied to this bit so the user has to poll this bit in order to determine if the TSR register is empty. The TSR is not mapped in data memory so it is not available to the user.

To set up a Synchronous Master Transmission:

1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRG16 bit, as required, to achieve the desired baud rate.
2. Enable the synchronous master serial port by setting bits SYNC SPEN and CSRC.
3. If interrupts are desired, set enable bit TXIE.
4. If 9-bit transmission is desired, set bit TX9.
5. Enable the transmission by setting bit TXEN.
6. If 9-bit transmission is selected, the ninth bit should be loaded in bit TX9D.
7. Start transmission by loading data to the TXREG register.
8. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

Note: Sync Master mode, SPBRG = 0, continuous transmission of two 8-bit words.
TABLE 18-7: REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER TRANSMISSION

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE</td>
<td>GIEH</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>TXREG</td>
<td>EUSART Transmit Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDOVF</td>
<td>RCIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used for synchronous master transmission.

Note 1: Reserved in PIC18F2682/2685 devices; always maintain these bits clear.
18.3.2 EUSART SYNCHRONOUS MASTER RECEPTION

Once Synchronous mode is selected, reception is enabled by setting either the Single Receive Enable bit, SREN (RCSTA<5>), or the Continuous Receive Enable bit, CREN (RCSTA<4>). Data is sampled on the RX pin on the falling edge of the clock.

If enable bit SREN is set, only a single word is received. If enable bit CREN is set, the reception is continuous until CREN is cleared. If both bits are set, then CREN takes precedence.

To set up a Synchronous Master Reception:

1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRG16 bit, as required, to achieve the desired baud rate.
2. Enable the synchronous master serial port by setting bits SYNC, SPEN and CSRC.
3. Ensure bits CREN and SREN are clear.
4. If interrupts are desired, set enable bit RCIE.
5. If 9-bit reception is desired, set bit RX9.
6. If a single reception is required, set bit SREN. For continuous reception, set bit CREN.
7. Interrupt flag bit RCIF will be set when reception is complete and an interrupt will be generated if the enable bit RCIE was set.
8. Read the RCSTA register to get the 9th bit (if enabled) and determine if any error occurred during reception.
9. Read the 8-bit received data by reading the RCREG register.
10. If any error occurred, clear the error by clearing bit CREN.
11. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

FIGURE 18-13: SYNCHRONOUS RECEPTION (MASTER MODE, SREN)

TABLE 18-8: REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER RECEPTION

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMROIE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMROIF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF&lt;1&gt;</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIF&lt;1&gt;</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIF&lt;1&gt;</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>RCREG</td>
<td>EUSART Receive Register</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDOVF</td>
<td>RCIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as '0'. Shaded cells are not used for synchronous master reception.

Note 1: Reserved in PIC18F2682/2685 devices; always maintain these bits clear.
18.4 EUSART Synchronous Slave Mode

Synchronous Slave mode is entered by clearing bit, CSRC (TXSTA<7>). This mode differs from the Synchronous Master mode in that the shift clock is supplied externally at the CK pin (instead of being supplied internally in Master mode). This allows the device to transfer or receive data while in any low-power mode.

18.4.1 EUSART SYNCHRONOUS SLAVE TRANSMIT

The operation of the Synchronous Master and Slave modes are identical, except in the case of the Sleep mode.

If two words are written to the TXREG and then the SLEEP instruction is executed, the following will occur:

a) The first word will immediately transfer to the TSR register and transmit.
b) The second word will remain in the TXREG register.
c) Flag bit TXIF will not be set.
d) When the first word has been shifted out of TSR, the TXREG register will transfer the second word to the TSR and flag bit TXIF will now be set.
e) If enable bit TXIE is set, the interrupt will wake the chip from Sleep. If the global interrupt is enabled, the program will branch to the interrupt vector.

To set up a Synchronous Slave Transmission:
1. Enable the synchronous slave serial port by setting bits SYNC and SPEN and clearing bit CSRC.
2. Clear bits CREN and SREN.
3. If interrupts are desired, set enable bit TXIE.
4. If 9-bit transmission is desired, set bit TX9.
5. Enable the transmission by setting enable bit TXEN.
6. If 9-bit transmission is selected, the ninth bit should be loaded in bit TX9D.
7. Start transmission by loading data to the TXREG register.
8. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

TABLE 18-9: REGISTERS ASSOCIATED WITH SYNCHRONOUS SLAVE TRANSMISSION

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>TXREG</td>
<td>EUSART Transmit Register</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SENDB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDVF</td>
<td>RCIIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as '0'. Shaded cells are not used for synchronous slave transmission.

Note 1: Reserved in PIC18F2682/2685 devices; always maintain these bits clear.
18.4.2 EUSART SYNCHRONOUS SLAVE RECEPTION

The operation of the Synchronous Master and Slave modes is identical, except in the case of Sleep or any Idle mode, and bit SREN, which is a “don’t care” in Slave mode.

If receive is enabled by setting the CREN bit prior to entering Sleep or any Idle mode, then a word may be received while in this low-power mode. Once the word is received, the RSR register will transfer the data to the RCREG register; if the RCIE enable bit is set, the interrupt generated will wake the chip from the low-power mode. If the global interrupt is enabled, the program will branch to the interrupt vector.

To set up a Synchronous Slave Reception:
1. Enable the synchronous master serial port by setting bits SYNC and SPEN and clearing bit CSRC.
2. If interrupts are desired, set enable bit RCIE.
3. If 9-bit reception is desired, set bit RX9.
4. To enable reception, set enable bit CREN.
5. Flag bit RCIF will be set when reception is complete. An interrupt will be generated if enable bit RCIE was set.
6. Read the RCSTA register to get the 9th bit (if enabled) and determine if any error occurred during reception.
7. Read the 8-bit received data by reading the RCREG register.
8. If any error occurred, clear the error by clearing bit CREN.
9. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMROIE</td>
<td>INTOIE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPIE(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPIF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPIE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPIE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPIE(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPIP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>RCSTA</td>
<td>SPEN</td>
<td>RX9</td>
<td>SREN</td>
<td>CREN</td>
<td>ADDEN</td>
<td>FERR</td>
<td>OERR</td>
<td>RX9D</td>
<td>53</td>
</tr>
<tr>
<td>RCREG</td>
<td>EUSART Receive Register</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXSTA</td>
<td>CSRC</td>
<td>TX9</td>
<td>TXEN</td>
<td>SYNC</td>
<td>SendB</td>
<td>BRGH</td>
<td>TRMT</td>
<td>TX9D</td>
<td>53</td>
</tr>
<tr>
<td>BAUDCON</td>
<td>ABDOVF</td>
<td>RCIDL</td>
<td>—</td>
<td>SCKP</td>
<td>BRG16</td>
<td>—</td>
<td>WUE</td>
<td>ABDEN</td>
<td>53</td>
</tr>
<tr>
<td>SPBRG</td>
<td>EUSART Baud Rate Generator Register Low Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPBRGH</td>
<td>EUSART Baud Rate Generator Register High Byte</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are not used for synchronous slave reception.

**Note 1:** Reserved in PIC18F2682/2685 devices; always maintain these bits clear.
19.0 10-BIT ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The Analog-to-Digital (A/D) converter module has 8 inputs for the PIC18F2682/2685 devices and 11 for the PIC18F4682/4685 devices. This module allows conversion of an analog input signal to a corresponding 10-bit digital number.

The module has five registers:
- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1 (ADCON1)
- A/D Control Register 2 (ADCON2)

The ADCON0 register, shown in Register 19-1, controls the operation of the A/D module. The ADCON1 register, shown in Register 19-2, configures the functions of the port pins. The ADCON2 register, shown in Register 19-3, configures the A/D clock source, programmed acquisition time and justification.

REGISTER 19-1: ADCON0: A/D CONTROL REGISTER 0

<table>
<thead>
<tr>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>CHS3</td>
<td>CHS2</td>
<td>CHS1</td>
<td>CHS0</td>
<td>GO/DONE</td>
<td>ADON</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- W = Writable 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 5-2 CHS3:CHS0: Analog Channel Select bits
- 0000 = Channel 0 (AN0)
- 0001 = Channel 1 (AN1)
- 0010 = Channel 2 (AN2)
- 0011 = Channel 3 (AN3)
- 0100 = Channel 4 (AN4)
- 0101 = Channel 5 (AN5)\(^{(1,2)}\)
- 0110 = Channel 6 (AN6)\(^{(1,2)}\)
- 0111 = Channel 7 (AN7)\(^{(1,2)}\)
- 1000 = Channel 8 (AN8)
- 1001 = Channel 9 (AN9)
- 1010 = Channel 10 (AN10)
- 1011 = Unused
- 1100 = Unused
- 1101 = Unused
- 1110 = Unused
- 1111 = Unused

bit 1 GO/DONE: A/D Conversion Status bit

When ADON = 1:
- 1 = A/D conversion in progress
- 0 = A/D Idle

bit 0 ADON: A/D On bit
- 1 = A/D converter module is enabled
- 0 = A/D converter module is disabled

Note 1: These channels are not implemented on PIC18F2682/2685 devices.

2: Performing a conversion on unimplemented channels will return full-scale measurements.
REGISTER 19-2: A/D CONTROL REGISTER 1

<table>
<thead>
<tr>
<th>bit 7-6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unimplemented: Read as '0'</td>
<td>VCFG1: Voltage Reference Configuration bit (VREF- source)</td>
<td>VCFG0: Voltage Reference Configuration bit (VREF+ source)</td>
<td>PCFG3:PCFG0: A/D Port Configuration Control bits:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PCFG3: PCFG0</th>
<th>AN10</th>
<th>AN9</th>
<th>AN8</th>
<th>AN7(1)</th>
<th>AN6(2)</th>
<th>AN5(2)</th>
<th>AN4</th>
<th>AN3</th>
<th>AN2</th>
<th>AN1</th>
<th>AN0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000(1)</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0001</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0010</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0011</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0100</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0101</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0110</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>0111(1)</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1000</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1001</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1010</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1011</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1100</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1101</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>1110</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>1111</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

A = Analog input  D = Digital I/O

**Note 1:** The POR value of the PCFG bits depends on the value of the PBADEN bit in Configuration Register 3H. When PBADEN = 1, PCFG<3:0> = 0000; when PBADEN = 0, PCFG<3:0> = 0111.

**Note 2:** AN5 through AN7 are available only on PIC18F4682/4685 devices.
## REGISTER 19-3: ADCON2: A/D CONTROL REGISTER 2

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADFM</td>
<td>—</td>
<td>ACQT2</td>
<td>ACQT1</td>
<td>ACQT0</td>
<td>ADCS2</td>
<td>ADCS1</td>
<td>ADCS0</td>
</tr>
</tbody>
</table>

### Legend:
- **R** = Readable bit
- **W** = Writable 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  
**ADFM**: A/D Result Format Select bit  
1 = Right justified  
0 = Left justified

#### bit 6  
**Unimplemented**: Read as ‘0’

#### bit 5-3  
**ACQT2:ACQT0**: A/D Acquisition Time Select bits  
- 111 = 20 TAD  
- 110 = 16 TAD  
- 101 = 12 TAD  
- 100 = 8 TAD  
- 011 = 6 TAD  
- 010 = 4 TAD  
- 001 = 2 TAD  
- 000 = 0 TAD(1)

#### bit 2-0  
**ADCS2:ADCS0**: A/D Conversion Clock Select bits  
- 111 = FRC (clock derived from A/D RC oscillator)(1)  
- 110 = Fosc/64  
- 101 = Fosc/16  
- 100 = Fosc/4  
- 011 = FRC (clock derived from A/D RC oscillator)(1)  
- 010 = Fosc/32  
- 001 = Fosc/8  
- 000 = Fosc/2

### Note 1:  
If the A/D FRC clock source is selected, a delay of one TCY (instruction cycle) is added before the A/D clock starts. This allows the SLEEP instruction to be executed before starting a conversion.

---

© 2009 Microchip Technology Inc.  
DS39761C-page 251
The analog reference voltage is software selectable to either the device’s positive and negative supply voltage (AVDD and AVSS), or the voltage level on the RA3/AN3/ VREF+ and RA2/AN2/VREF-/CVREF pins.

The A/D converter has a unique feature of being able to operate while the device is in Sleep mode. To operate in Sleep, the A/D conversion clock must be derived from the A/D converter’s internal RC oscillator.

The output of the sample and hold is the input into the converter, which generates the result via successive approximation.

A device Reset forces all registers to their Reset state. This forces the A/D module to be turned off and any conversion in progress is aborted.

Each port pin associated with the A/D converter can be configured as an analog input, or as a digital I/O. The ADRESH and ADRESL registers contain the result of the A/D conversion. When the A/D conversion is complete, the result is loaded into the ADRESH/ADRESL registers, the GO/DONE bit (ADCON0 register) is cleared and A/D Interrupt Flag bit, ADIF, is set. The block diagram of the A/D module is shown in Figure 19-1.

**FIGURE 19-1: A/D BLOCK DIAGRAM**

---

**Note 1:** Channels AN5 through AN7 are not available on PIC18F2682/2685 devices.

**2:** I/O pins have diode protection to VDD and VSS.
The value in the ADRESH/ADRESL registers is not modified for a Power-on Reset. The ADRESH/ADRESL registers will contain unknown data after a Power-on Reset.

After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channels must have their corresponding TRIS bits selected as inputs. To determine acquisition time, see Section 19.1 “A/D Acquisition Requirements”. After this acquisition time has elapsed, the A/D conversion can be started. An acquisition time can be programmed to occur between setting the GO/DONE bit and the actual start of the conversion.

The following steps should be followed to perform an A/D conversion:

1. Configure the A/D module:
   - Configure analog pins, voltage reference and digital I/O (ADCON1)
   - Select A/D input channel (ADCON0)
   - Select A/D acquisition time (ADCON2)
   - Select A/D conversion clock (ADCON2)
   - Turn on A/D module (ADCON0)

2. Configure A/D interrupt (if desired):
   - Clear ADIF bit
   - Set ADIE bit
   - Set GIE bit

3. Wait the required acquisition time (if required).

4. Start conversion:
   - Set GO/DONE bit (ADCON0 register)

5. Wait for A/D conversion to complete, by either:
   - Polling for the GO/DONE bit to be cleared
   - Waiting for the A/D interrupt

6. Read A/D Result registers (ADRESH:ADRESL); clear bit, ADIF, if required.

7. For next conversion, go to step 1 or step 2, as required. The A/D conversion time per bit is defined as TAD. A minimum wait of 2 TAD is required before next acquisition starts.

---

**FIGURE 19-2: ANALOG INPUT MODEL**

[Diagram of analog input model with labels for various components and parameters.]

**Legend:**
- CPIN = Input Capacitance
- VT = Threshold Voltage
- ILEAKAGE = Leakage Current at the pin due to various junctions
- RIC = Interconnect Resistance
- SS = Sampling Switch
- CHOLD = Sample/Hold Capacitance (from DAC)
- RSS = Sampling Switch Resistance
19.1 A/D Acquisition Requirements

For the A/D converter to meet its specified accuracy, the charge holding capacitor (\(C_{\text{HOLD}}\)) must be allowed to fully charge to the input channel voltage level. The analog input model is shown in Figure 19-2. The source impedance (\(R_s\)) and the internal sampling switch (\(R_{\text{SS}}\)) impedance directly affect the time required to charge the capacitor \(C_{\text{HOLD}}\). The sampling switch (\(R_{\text{SS}}\)) impedance varies over the device voltage (\(V_{\text{DD}}\)). The source impedance affects the offset voltage at the analog input (due to pin leakage current). The maximum recommended impedance for analog sources is 2.5 k\(\Omega\). After the analog input channel is selected (changed), the channel must be sampled for at least the minimum acquisition time before starting a conversion.

Note: When the conversion is started, the holding capacitor is disconnected from the input pin.

To calculate the minimum acquisition time, Equation 19-1 may be used. This equation assumes that 1/2 LSb error is used (1024 steps for the A/D). The 1/2 LSb error is the maximum error allowed for the A/D to meet its specified resolution.

Example 19-3 shows the calculation of the minimum required acquisition time \(T_{\text{ACQ}}\). This calculation is based on the following application system assumptions:

- \(C_{\text{HOLD}} = 120 \text{ pF}\)
- \(R_s = 2.5 \text{ k}\Omega\)
- Conversion Error \(\leq 1/2 \text{ LSb}\)
- \(V_{\text{DD}} = 5 \text{ V} \rightarrow R_{\text{SS}} = 7 \text{ k}\Omega\)
- Temperature = 50°C (system max.)
- \(V_{\text{HOLD}} = 0 \text{ V at time = 0}\)

**EQUATION 19-1: A/D ACQUISITION TIME**

\[
T_{\text{ACQ}} = \text{Amplifier Settling Time} + \text{Holding Capacitor Charging Time} + \text{Temperature Coefficient}
\]

\[
T_{\text{ACQ}} = T_{\text{AMP}} + T_{C} + T_{\text{COFF}}
\]

**EQUATION 19-2: A/D MINIMUM CHARGING TIME**

\[
V_{\text{HOLD}} = (V_{\text{REF}} - (V_{\text{REF}}/2048)) \cdot (1 - e^{-T_{C}/C_{\text{HOLD}}(R_{\text{IC}} + R_{\text{SS}} + R_s)})
\]

or

\[
T_c = -(C_{\text{HOLD}})(R_{\text{IC}} + R_{\text{SS}} + R_s) \ln(1/2048)
\]

**EQUATION 19-3: CALCULATING THE MINIMUM REQUIRED A/D ACQUISITION TIME**

\[
T_{\text{ACQ}} = T_{\text{AMP}} + T_{C} + T_{\text{COFF}}
\]

\[
T_{\text{AMP}} = 5 \mu s
\]

\[
T_{C} = -(C_{\text{HOLD}})(R_{\text{IC}} + R_{\text{SS}} + R_s) \ln(1/2048) \mu s
\]

\[
= -(120 \text{ pF})(1 \text{ k}\Omega + 7 \text{ k}\Omega + 2.5 \text{ k}\Omega) \ln(0.0004883) \mu s
\]

\[
= 9.61 \mu s
\]

Temperature coefficient is only required for temperatures > 25°C. Below 25°C, \(T_{\text{COFF}} = 0 \text{ ms}\).

\[
T_{\text{COFF}} = (\text{Temp} - 25 ^\circ \text{C})(0.05 \mu s/\circ \text{C})
\]

\[
= (50 ^\circ \text{C} - 25 ^\circ \text{C})(0.05 \mu s/\circ \text{C})
\]

\[
= 1.25 \mu s
\]

\[
T_{\text{COFF}} = (50 ^\circ \text{C} - 25 ^\circ \text{C})(0.05 \mu s/\circ \text{C})
\]

\[
= 1.25 \mu s
\]

\[
T_{\text{ACQ}} = 5 \mu s + 1.25 \mu s + 9.61 \mu s
\]

\[
= 12.86 \mu s
\]
19.2 Selecting and Configuring Automatic Acquisition Time

The ADCON2 register allows the user to select an acquisition time that occurs each time the GO/DONE bit is set.

When the GO/DONE bit is set, sampling is stopped and a conversion begins. The user is responsible for ensuring the required acquisition time has passed between selecting the desired input channel and setting the GO/DONE bit. This occurs when the ACQT2:ACQT0 bits (ADCON2<5:3>) remain in their Reset state ('000') and is compatible with devices that do not offer programmable acquisition times.

If desired, the ACQT bits can be set to select a programmable acquisition time for the A/D module. When the GO/DONE bit is set, the A/D module continues to sample the input for the selected acquisition time, then automatically begins a conversion. Since the acquisition time is programmed, there may be no need to wait for an acquisition time between selecting a channel and setting the GO/DONE bit.

In either case, when the conversion is completed, the GO/DONE bit is cleared, the ADIF flag is set and the A/D begins sampling the currently selected channel again. If an acquisition time is programmed, there is nothing to indicate if the acquisition time has ended or if the conversion has begun.

19.3 Selecting the A/D Conversion Clock

The A/D conversion time per bit is defined as TAD. The A/D conversion requires 11 TAD per 10-bit conversion. The source of the A/D conversion clock is software selectable. There are seven possible options for TAD:

- 2 Tosc
- 4 Tosc
- 8 Tosc
- 16 Tosc
- 32 Tosc
- 64 Tosc
- Internal RC Oscillator

For correct A/D conversions, the A/D conversion clock (TAD) must be as short as possible, but greater than the minimum TAD (approximately 2 μs, see parameter 130 for more information).

Table 19-1 shows the resultant TAD times derived from the device operating frequencies and the A/D clock source selected.

<table>
<thead>
<tr>
<th>AD Clock Source (TAD)</th>
<th>Maximum Device Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>ADCS2:ADCS0</td>
</tr>
<tr>
<td>2 Tosc</td>
<td>000</td>
</tr>
<tr>
<td>4 Tosc</td>
<td>100</td>
</tr>
<tr>
<td>8 Tosc</td>
<td>001</td>
</tr>
<tr>
<td>16 Tosc</td>
<td>101</td>
</tr>
<tr>
<td>32 Tosc</td>
<td>010</td>
</tr>
<tr>
<td>64 Tosc</td>
<td>110</td>
</tr>
<tr>
<td>RC&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>x11</td>
</tr>
</tbody>
</table>

**Note**

1: The RC source has a typical TAD time of 1.2 μs.
2: The RC source has a typical TAD time of 2.5 μs.
3: For device frequencies above 1 MHz, the device must be in Sleep for the entire conversion or the A/D accuracy may be out of specification.
4: Low-power (PIC18LFXXXX) devices only.
19.4 Operation in Power-Managed Modes

The selection of the automatic acquisition time and A/D conversion clock is determined in part, by the clock source and frequency while in a power-managed mode. If the A/D is expected to operate while the device is in a power-managed mode, the ACQT2:ACQT0 and ADCS2:ADCS0 bits in ADCON2 should be updated in accordance with the clock source to be used in that mode. After entering the mode, an A/D acquisition or conversion may be started. Once started, the device should continue to be clocked by the same clock source until the conversion has been completed.

If desired, the device may be placed into the corresponding Idle mode during the conversion. If the device clock frequency is less than 1 MHz, the A/D RC clock source should be selected.

Operation in the Sleep mode requires the A/D FRC clock to be selected. If the ACQT2:ACQT0 bits are set to '000' and a conversion is started, the conversion will be delayed one instruction cycle to allow execution of the SLEEP instruction and entry to Sleep mode. The IDLEN bit (OSCCON<7>) must have already been cleared prior to starting the conversion.

19.5 Configuring Analog Port Pins

The ADCON1, TRISA, TRISB and TRISE registers all configure the A/D port pins. The port pins needed as analog inputs must have their corresponding TRIS bits set (input). If the TRIS bit is cleared (output), the digital output level (VOH or VOL) will be converted.

The A/D operation is independent of the state of the CHS3:CHS0 bits and the TRIS bits.

**Note 1:** When reading the PORT register, all pins configured as analog input channels will read as cleared (a low level). Pins configured as digital inputs will convert an analog input. Analog levels on a digitally configured input will be accurately converted.

2: Analog levels on any pin defined as a digital input may cause the digital input buffer to consume current out of the device’s specification limits.

3: The PBADEN bit in Configuration Register 3H configures PORTB pins to reset as analog or digital pins by controlling how the PCFG0 bits in ADCON1 are reset.
19.6 A/D Conversions

Figure 19-3 shows the operation of the A/D converter after the GO/DONE bit has been set and the ACQT2:ACQT0 bits are cleared. A conversion is started after the following instruction to allow entry into Sleep mode before the conversion begins.

Figure 19-4 shows the operation of the A/D converter after the GO/DONE bit has been set, the ACQT2:ACQT0 bits are set to '010' and a 4 TAD acquisition time is selected before the conversion starts.

Clearing the GO/DONE bit during a conversion will abort the current conversion. The A/D Result register pair will NOT be updated with the partially completed A/D conversion sample. This means the ADRESH:ADRESL registers will continue to contain the value of the last completed conversion (or the last value written to the ADRESH:ADRESL registers).

After the A/D conversion is completed or aborted, a 2 TAD wait is required before the next acquisition can be started. After this wait, acquisition on the selected channel is automatically started.

**Note:** The GO/DONE bit should **NOT** be set in the same instruction that turns on the A/D.

**FIGURE 19-3:** A/D CONVERSION TAD CYCLES (ACQT<2:0> = 000, TACQ = 0)

**FIGURE 19-4:** A/D CONVERSION TAD CYCLES (ACQT<2:0> = 010, TACQ = 4 TAD)
19.7 Use of the ECCP1 Trigger

An A/D conversion can be started by the “Special Event Trigger” of the ECCP1 module. This requires that the ECCP1M3:ECCP1M0 bits (ECCP1CON<3:0>) be programmed as '1011' and that the A/D module is enabled (ADON bit is set). When the trigger occurs, the GO/DONE bit will be set, starting the A/D acquisition and conversion and the Timer1 (or Timer3) counter will be reset to zero. Timer1 (or Timer3) is reset to automatically repeat the A/D acquisition period with minimal software overhead (moving ADRESH/ADRESL to the desired location). The appropriate analog input channel must be selected and the minimum acquisition period is either timed by the user, or an appropriate TACQ time selected before the “Special Event Trigger” sets the GO/DONE bit (starts a conversion).

If the A/D module is not enabled (ADON is cleared), the “Special Event Trigger” will be ignored by the A/D module, but will still reset the Timer1 (or Timer3) counter.

### TABLE 19-2: REGISTERS ASSOCIATED WITH A/D OPERATION

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMROIE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMROIF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>IPR1</td>
<td>PSPiP(1)</td>
<td>ADIP</td>
<td>RCIP</td>
<td>TXIP</td>
<td>SSPiP</td>
<td>CCP1IP</td>
<td>TMR2IP</td>
<td>TMR1IP</td>
<td>54</td>
</tr>
<tr>
<td>PIR1</td>
<td>PSPiF(1)</td>
<td>ADIF</td>
<td>RCIF</td>
<td>TXIF</td>
<td>SSPiF</td>
<td>CCP1IF</td>
<td>TMR2IF</td>
<td>TMR1IF</td>
<td>54</td>
</tr>
<tr>
<td>PIE1</td>
<td>PSPiE(1)</td>
<td>ADIE</td>
<td>RCIE</td>
<td>TXIE</td>
<td>SSPiE</td>
<td>CCP1IE</td>
<td>TMR2IE</td>
<td>TMR1IE</td>
<td>54</td>
</tr>
<tr>
<td>IPR2</td>
<td>OSCFiP</td>
<td>CMiP(1)</td>
<td></td>
<td>EEIP</td>
<td>BCLiP</td>
<td>HLVDiP</td>
<td>TMR3iP</td>
<td>ECCP1iP(4)</td>
<td>53</td>
</tr>
<tr>
<td>PIR2</td>
<td>OSCFiF</td>
<td>CMiF(1)</td>
<td></td>
<td>EEIF</td>
<td>BCLIF</td>
<td>HLVDIF</td>
<td>TMR3IF</td>
<td>ECCP1iF(1)</td>
<td>54</td>
</tr>
<tr>
<td>PIE2</td>
<td>OSCFiE</td>
<td>CMiE(1)</td>
<td></td>
<td>EEIE</td>
<td>BCLIE</td>
<td>HLVDIE</td>
<td>TMR3IE</td>
<td>ECCP1iE(4)</td>
<td>54</td>
</tr>
<tr>
<td>ADRESH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>ADRESL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>ADCON0</td>
<td></td>
<td></td>
<td>CHS3</td>
<td>CHS2</td>
<td>CHS1</td>
<td>CHS0</td>
<td>GO/DONE</td>
<td>ADON</td>
<td>52</td>
</tr>
<tr>
<td>ADCON1</td>
<td></td>
<td>VCFG1</td>
<td>VCFG0</td>
<td>PCFG3</td>
<td>PCFG2</td>
<td>PCFG1</td>
<td>PCFG0</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>ADCON2</td>
<td>ADFM</td>
<td></td>
<td>ACQT2</td>
<td>ACQT1</td>
<td>ACQT0</td>
<td>ADCS2</td>
<td>ADCS1</td>
<td>ADCS0</td>
<td>53</td>
</tr>
<tr>
<td>PORTA</td>
<td>RA7(2)</td>
<td>RA6(2)</td>
<td>RA5</td>
<td>RA4</td>
<td>RA3</td>
<td>RA2</td>
<td>RA1</td>
<td>RA0</td>
<td>54</td>
</tr>
<tr>
<td>TRISA</td>
<td>TRISA7(2)</td>
<td>TRISA6(2)</td>
<td>PORTA Data Direction Register</td>
<td></td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PORTB</td>
<td>RB7</td>
<td>RB6</td>
<td>RB5</td>
<td>RB4</td>
<td>RB3</td>
<td>RB2</td>
<td>RB1</td>
<td>RB0</td>
<td>54</td>
</tr>
<tr>
<td>TRISB</td>
<td>PORTB Data Direction Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>LATB</td>
<td>LATB Data Output Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>PORTE(4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RE3(3)</td>
<td>RE2(1)</td>
<td>RE1(1)</td>
<td>RE0(1)</td>
<td>54</td>
</tr>
<tr>
<td>TRISE(4)</td>
<td>IBF</td>
<td>OBF</td>
<td>IBOV</td>
<td>PSPMODE</td>
<td></td>
<td>TRISE2</td>
<td>TRISE1</td>
<td>TRISE0</td>
<td>54</td>
</tr>
<tr>
<td>LATE(4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LATB Data Output Register</td>
<td></td>
<td>54</td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used for A/D conversion.

**Note 1:** These bits are unimplemented on PIC18F2682/2685 devices; always maintain these bits clear.

**Note 2:** These pins may be configured as port pins depending on the oscillator mode selected.

**Note 3:** RE3 port bit is available only as an input pin when the MCLRE Configuration bit is ‘0’.

**Note 4:** These registers are not implemented on PIC18F2682/2685 devices.
20.0 COMPARATOR MODULE

The analog comparator module contains two comparators that can be configured in a variety of ways. The inputs can be selected from the analog inputs multiplexed with pins RA0 through RA5, as well as the on-chip voltage reference (see Section 21.0 “Comparator Voltage Reference Module”). The digital outputs (normal or inverted) are available at the pin level and can also be read through the control register.

The CMCON register (Register 20-1) selects the comparator input and output configuration. Block diagrams of the various comparator configurations are shown in Figure 20-1.

REGISTER 20-1: CMCON: COMPARATOR CONTROL REGISTER

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>CIS</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
</tr>
</tbody>
</table>

Legend:

- R = Readable bit
- W = Writable 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  C2OUT: Comparator 2 Output bit

When C2INV = 0:
1 = C2 VIN+ > C2 VIN-
0 = C2 VIN+ < C2 VIN-

When C2INV = 1:
1 = C2 VIN+ < C2 VIN-
0 = C2 VIN+ > C2 VIN-

bit 6  C1OUT: Comparator 1 Output bit

When C1INV = 0:
1 = C1 VIN+ > C1 VIN-
0 = C1 VIN+ < C1 VIN-

When C1INV = 1:
1 = C1 VIN+ < C1 VIN-
0 = C1 VIN+ > C1 VIN-

bit 5  C2INV: Comparator 2 Output Inversion bit

1 = C2 output inverted
0 = C2 output not inverted

bit 4  C1INV: Comparator 1 Output Inversion bit

1 = C1 output inverted
0 = C1 output not inverted

bit 3  CIS: Comparator Input Switch bit

When CM2:CM0 = 110:
1 = C1 VIN- connects to RD0/PSP0/C1IN+
   C2 VIN- connects to RD2/PSP2/C2IN+
0 = C1 VIN- connects to RD1/PSP1/C1IN-
   C2 VIN- connects to RD3/PSP3/C2IN-

bit 2-0  CM2:CM0: Comparator Mode bits

Figure 20-1 shows the Comparator modes and the CM2:CM0 bit settings.
20.1 Comparator Configuration

There are eight modes of operation for the comparators, shown in Figure 20-1. Bits CM2:CM0 of the CMCON register are used to select these modes. The TRISA register controls the data direction of the comparator pins for each mode. If the Comparator mode is changed, the comparator output level may not be valid for the specified mode change delay shown in Section 27.0 “Electrical Characteristics”.

Note: Comparator interrupts should be disabled during a Comparator mode change; otherwise, a false interrupt may occur.

A = Analog Input, port reads zeros always
D = Digital Input
CIS (CMCON<3>) is the Comparator Input Switch

* Setting the TRISA<5:4> bits will disable the comparator outputs by configuring the pins as inputs.
20.2 Comparator Operation

A single comparator is shown in Figure 20-2, along with the relationship between the analog input levels and the digital output. When the analog input at \( V_{IN^+} \) is less than the analog input \( V_{IN^-} \), the output of the comparator is a digital low level. When the analog input at \( V_{IN^+} \) is greater than the analog input \( V_{IN^-} \), the output of the comparator is a digital high level. The shaded areas of the output of the comparator in Figure 20-2 represent the uncertainty, due to input offsets and response time.

20.3 Comparator Reference

Depending on the comparator operating mode, either an external or internal voltage reference may be used. The analog signal present at \( V_{IN^-} \) is compared to the signal at \( V_{IN^+} \) and the digital output of the comparator is adjusted accordingly (Figure 20-2).

**FIGURE 20-2: SINGLE COMPARATOR**

![Comparator Diagram]

20.3.1 EXTERNAL REFERENCE SIGNAL

When external voltage references are used, the comparator module can be configured to have the comparators operate from the same or different reference sources. However, threshold detector applications may require the same reference. The reference signal must be between \( V_{SS} \) and \( V_{DD} \) and can be applied to either pin of the comparator(s).

20.3.2 INTERNAL REFERENCE SIGNAL

The comparator module also allows the selection of an internally generated voltage reference from the comparator voltage reference module. This module is described in more detail in Section 21.0 “Comparator Voltage Reference Module”.

The internal reference is only available in the mode where four inputs are multiplexed to two comparators (CM2:CM0 = 110). In this mode, the internal voltage reference is applied to the \( V_{IN^+} \) pin of both comparators.

20.4 Comparator Response Time

Response time is the minimum time, after selecting a new reference voltage or input source, before the comparator output has a valid level. If the internal reference is changed, the maximum delay of the internal voltage reference must be considered when using the comparator outputs. Otherwise, the maximum delay of the comparators should be used (see Section 27.0 “Electrical Characteristics”).

20.5 Comparator Outputs

The comparator outputs are read through the CMCON register. These bits are read-only. The comparator outputs may also be directly output to the RE1 and RE2 I/O pins. When enabled, multiplexors in the output path of the RE1 and RE2 pins will switch and the output of each pin will be the unsynchronized output of the comparator. The uncertainty of each of the comparators is related to the input offset voltage and the response time given in the specifications. Figure 20-3 shows the comparator output block diagram.

The TRISE bits will still function as an output enable/disable for the RE1 and RE2 pins while in this mode. The polarity of the comparator outputs can be changed using the C2INV and C1INV bits (CMCON<5:4>).

**Note 1:** When reading the PORT register, all pins configured as analog inputs will read as a ‘0’. Pins configured as digital inputs will convert an analog input according to the Schmitt Trigger input specification.

**Note 2:** Analog levels on any pin defined as a digital input may cause the input buffer to consume more current than is specified.
20.6 Comparator Interrupts

The comparator interrupt flag is set whenever there is a change in the output value of either comparator. Software will need to maintain information about the status of the output bits, as read from CMCON<7:6>, to determine the actual change that occurred. The CMIF bit (PIR2<6>) is the Comparator Interrupt Flag. The CMIF bit must be reset by clearing it. Since it is also possible to write a '1' to this register, a simulated interrupt may be initiated.

Both the CMIE bit (PIE2<6>) and the PEIE bit (INTCON<6>) must be set to enable the interrupt. In addition, the GIE bit (INTCON<7>) must also be set. If any of these bits are clear, the interrupt is not enabled, though the CMIF bit will still be set if an interrupt condition occurs.

Note: If a change in the CMCON register (C1OUT or C2OUT) should occur when a read operation is being executed (start of the Q2 cycle), then the CMIF (PIR registers) interrupt flag may not get set.

The user, in the Interrupt Service Routine, can clear the interrupt in the following manner:

a) Any read or write of CMCON will end the mismatch condition.

b) Clear flag bit CMIF.

A mismatch condition will continue to set flag bit CMIF. Reading CMCON will end the mismatch condition and allow flag bit CMIF to be cleared.

20.7 Comparator Operation During Sleep

When a comparator is active and the device is placed in Sleep mode, the comparator remains active and the interrupt is functional if enabled. This interrupt will wake-up the device from Sleep mode, when enabled. While the comparator is powered up, higher Sleep currents than shown in the power-down current specification will occur. Each operational comparator will consume additional current, as shown in the comparator specifications. To minimize power consumption while in Sleep mode, turn off the comparators (CM2:CM0 = 111) before entering Sleep. If the device wakes up from Sleep, the contents of the CMCON register are not affected.

20.8 Effects of a Reset

A device Reset forces the CMCON register to its Reset state, causing the comparator module to be in the Comparator Reset mode (CM2:CM0 = 000). This ensures that all potential inputs are analog inputs. Device current is minimized when analog inputs are present at Reset time. The comparators are powered down during the Reset interval.
20.9 Analog Input Connection Considerations

A simplified circuit for an analog input is shown in Figure 20-4. Since the analog pins are connected to a digital output, they have reverse biased diodes to VDD and VSS. The analog input, therefore, must be between VSS and VDD. If the input voltage deviates from this range by more than 0.6V in either direction, one of the diodes is forward biased and a latch-up condition may occur. A maximum source impedance of 10 kΩ is recommended for the analog sources. Any external component connected to an analog input pin, such as a capacitor or a Zener diode, should have very little leakage current.

**FIGURE 20-4: COMPARATOR ANALOG INPUT MODEL**

![Comparator Analog Input Model Diagram]

**TABLE 20-1: REGISTERS ASSOCIATED WITH COMPARATOR MODULE**

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMCON[3]</td>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>CIS</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
<td>53</td>
</tr>
<tr>
<td>CVRCON[3]</td>
<td>CVREN</td>
<td>CVROE</td>
<td>CVRR</td>
<td>CVRSS</td>
<td>CVR3</td>
<td>CVR2</td>
<td>CVR1</td>
<td>CVR0</td>
<td>53</td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE/GIEL</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INTOIE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INTOF</td>
<td>RBIF</td>
<td>54</td>
</tr>
<tr>
<td>PORTA</td>
<td>RA7[1]</td>
<td>RA6[1]</td>
<td>RA5</td>
<td>RA4</td>
<td>RA3</td>
<td>RA2</td>
<td>RA1</td>
<td>RA0</td>
<td>54</td>
</tr>
<tr>
<td>LATA</td>
<td>LATA7[1]</td>
<td>LATA6[1]</td>
<td>LATA Data Output Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRISA</td>
<td>TRISA7[1]</td>
<td>TRISA6[1]</td>
<td>PORTA Data Direction Register</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:** — = unimplemented, read as ‘0’. Shaded cells are unused by the comparator module.

**Note:**
1: PORTA pins are enabled based on oscillator configuration.
2: These bits are available in PIC18F4682/4685 devices and reserved in PIC18F2682/2685 devices.
3: These registers are unimplemented on PIC18F2682/2685 devices.
21.0 COMPARATOR VOLTAGE REFERENCE MODULE

The comparator voltage reference is a 16-tap resistor ladder network that provides a selectable reference voltage. Although its primary purpose is to provide a reference for the analog comparators, it may also be used independently of them.

A block diagram of the module shown in Figure 21-1. The resistor ladder is segmented to provide two ranges of CVREF values and has a power-down function to conserve power when the reference is not being used. The module’s supply reference can be provided from either device VDD/VSS or an external voltage reference.

21.1 Configuring the Comparator Voltage Reference

The voltage reference module is controlled through the CVRCON register (Register 21-1). The comparator voltage reference provides two ranges of output voltage, each with 16 distinct levels. The range to be used is selected by the CVRR bit (CVRCON<5>). The primary difference between the ranges is the size of the steps selected by the CVREF selection bits (CVR3:CVR0), with one range offering finer resolution. The equations used to calculate the output of the comparator voltage reference are as follows:

If CVRR = 1:
\[
\text{CVREF} = ((\text{CVR3:CVR0})/24) \times \text{CVRSRC}
\]

If CVRR = 0:
\[
\text{CVREF} = (\text{VDD} \times 1/4) + (((\text{CVR3:CVR0})/32) \times \text{CVRSRC})
\]

The comparator reference supply voltage can come from either VDD and VSS, or the external VREF+ and VREF- that are multiplexed with RA2 and RA3. The voltage source is selected by the CVRSS bit (CVRCON<4>).

The settling time of the comparator voltage reference must be considered when changing the CVREF output (see Table 27-3 in Section 27.0 “Electrical Characteristics”).

**Note:** Comparators are only available in 40/44-pin devices (PIC18F4682/4685).

**REGISTER 21-1: CVRCON: COMPARATOR VOLTAGE REFERENCE CONTROL REGISTER**

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVREN</td>
<td>CVROE(1)</td>
<td>CVRR</td>
<td>CVRSS</td>
<td>CVR3</td>
<td>CVR2</td>
<td>CVR1</td>
<td>CVR0</td>
</tr>
</tbody>
</table>

**Legend:**
R = Readable bit  W = Writable 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  **CVREN**: Comparator Voltage Reference Enable bit

1 = CVREF circuit powered on
0 = CVREF circuit powered down

bit 6  **CVROE**: Comparator VREF Output Enable bit(1)

1 = CVREF voltage level is also output on the RA0/AN0/CVREF pin
0 = CVREF voltage is disconnected from the RA0/AN0/CVREF pin

bit 5  **CVRR**: Comparator VREF Range Selection bit

1 = CVRSRC to 0.75 CVRSRC, with CVRSRC/24 step size
0 = CVRSRC to 0.75 CVRSRC, with CVRSRC/32 step size

bit 4  **CVRSS**: Comparator VREF Source Selection bit

1 = Comparator reference source, CVRSSRC = (VREF+) – (VREF–)
0 = Comparator reference source, CVRSSRC = VDD – VSS

bit 3-0  **CVR3:CVR0**: Comparator VREF Value Selection bits (0 ≤ (CVR3:CVR0) ≤ 15)

When CVRR = 1:
\[
\text{CVREF} = ((\text{CVR3:CVR0})/24) \times \text{CVRSRC}
\]

When CVRR = 0:
\[
\text{CVREF} = ((\text{CVR3:CVR0})/32) \times \text{CVRSRC}
\]

**Note 1:** CVROE overrides the TRISA<0> bit setting. If enabled for output, RA2 must also be configured as an input by setting TRISA<2> to ‘1’.
21.2 Voltage Reference Accuracy/Error

The full range of voltage reference cannot be realized due to the construction of the module. The transistors on the top and bottom of the resistor ladder network (Figure 21-1) keep CVREF from approaching the reference source rails. The voltage reference is derived from the reference source; therefore, the CVREF output changes with fluctuations in that source. The tested absolute accuracy of the voltage reference can be found in Section 27.0 “Electrical Characteristics”.

21.3 Operation During Sleep

When the device wakes up from Sleep through an interrupt or a Watchdog Timer time-out, the contents of the CVRCON register are not affected. To minimize current consumption in Sleep mode, the voltage reference should be disabled.

21.4 Effects of a Reset

A device Reset disables the voltage reference by clearing bit CVREN (CVRCON<7>). This Reset also disconnects the reference from the RA0 pin by clearing bit, CVROE (CVRCON<6>), and selects the high-voltage range by clearing bit, CVRR (CVRCON<5>). The CVR value select bits are also cleared.

21.5 Connection Considerations

The voltage reference module operates independently of the comparator module. The output of the reference generator may be connected to the RA0 pin if the TRISA<0> bit and the CVROE bit are both set. Enabling the voltage reference output onto the RA0 pin, with an input signal present, will increase current consumption. Connecting RA0 as a digital output with CVRSS enabled will also increase current consumption.

The RA0 pin can be used as a simple D/A output with limited drive capability. Due to the limited current drive capability, a buffer must be used on the voltage reference output for external connections to VREF. Figure 21-2 shows an example buffering technique.
**FIGURE 21-2: COMPARATOR VOLTAGE REFERENCE OUTPUT BUFFER EXAMPLE**

![Comparator Voltage Reference Output Buffer Diagram](image)

**Note 1:** R is dependent upon the voltage reference configuration bits, CVRCON<3:0> and CVRCON<5>.

---

**TABLE 21-1: REGISTERS ASSOCIATED WITH COMPARATOR VOLTAGE REFERENCE**

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVRCON[2]</td>
<td>CVREN</td>
<td>CVROE</td>
<td>CVRR</td>
<td>CVRSS</td>
<td>CVR3</td>
<td>CVR2</td>
<td>CVR1</td>
<td>CVR0</td>
<td>53</td>
</tr>
<tr>
<td>CMCON[2]</td>
<td>C2OUT</td>
<td>C1OUT</td>
<td>C2INV</td>
<td>C1INV</td>
<td>CIS</td>
<td>CM2</td>
<td>CM1</td>
<td>CM0</td>
<td>53</td>
</tr>
<tr>
<td>TRISA</td>
<td>TRISA7[1]</td>
<td>TRISA6[1]</td>
<td>PORTA Data Direction Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
</tbody>
</table>

**Legend:** Shaded cells are not used with the comparator voltage reference.

**Note 1:** PORTA pins are enabled based on oscillator configuration.

**2:** These registers are unimplemented on PIC18F2682/2685 devices.
22.0 HIGH/LOW-VOLTAGE DETECT (HLVD)

PIC18F2682/2685/4682/4685 devices have a High/Low-Voltage Detect module (HLVD). This is a programmable circuit that allows the user to specify both a device voltage trip point and the direction of change from that point. If the device experiences an excursion past the trip point in that direction, an interrupt flag is set. If the interrupt is enabled, the program execution will branch to the interrupt vector address and the software can then respond to the interrupt.

The High/Low-Voltage Detect Control register (Register 22-1) completely controls the operation of the HLVD module. This allows the circuitry to be “turned off” by the user under software control, which minimizes the current consumption for the device.

The block diagram for the HLVD module is shown in Figure 22-1.

REGISTER 22-1: HLVDCON: HIGH/LOW-VOLTAGE DETECT CONTROL REGISTER

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>U-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDIRMAG</td>
<td>IRVST</td>
<td>HLVDEN</td>
<td>HLVDL3(1)</td>
<td>HLVDL2(1)</td>
<td>HLVDL1(1)</td>
<td>HLVDL0(1)</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- W = Writable 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 VDIRMAG: Voltage Direction Magnitude Select bit
0 = Event occurs when voltage equals or falls below trip point (HLVDL3:HLVDL0)
1 = Event occurs when voltage equals or exceeds trip point (HLVDL3:HLVDL0)

bit 6 Unimplemented: Read as ‘0’

bit 5 IRVST: Internal Reference Voltage Stable Flag bit
0 = Indicates that the voltage detect logic will not generate the interrupt flag at the specified voltage range and the HLVD interrupt should not be enabled
1 = Indicates that the voltage detect logic will generate the interrupt flag at the specified voltage range

bit 4 HLVDEN: High/Low-Voltage Detect Power Enable bit
0 = HLVD disabled
1 = HLVD enabled

bit 3-0 HLVDL3:HLVDL0: High/Low-Voltage Detection Limit bits(1)
0111 = 3.31V-3.47V
0110 = 3.05V-3.19V
0101 = 2.82V-2.95V
0100 = 2.72V-2.85V
0011 = 2.38V-2.49V
0010 = 2.31V-2.42V
0001 = 2.18V-2.28V
0000 = 2.12V-2.22V

Note 1: HLVDL3:HLVDL0 modes that result in a trip point below the valid operating voltage of the device are not tested.
The module is enabled by setting the HLVDEN bit. Each time that the HLVD module is enabled, the circuitry requires some time to stabilize. The IRVST bit is a read-only bit and is used to indicate when the circuit is stable. The module can only generate an interrupt after the circuit is stable and IRVST is set.

The VDIRMAG bit determines the overall operation of the module. When VDIRMAG is cleared, the module monitors for drops in VDD below a predetermined set point. When the bit is set, the module monitors for rises in VDD above the set point.

22.1 Operation

When the HLVD module is enabled, a comparator uses an internally generated reference voltage as the set point. The set point is compared with the trip point, where each node in the resistor divider represents a trip point voltage. The “trip point” voltage is the voltage level at which the device detects a high or low-voltage event, depending on the configuration of the module. When the supply voltage is equal to the trip point, the voltage tapped off of the resistor array is equal to the internal reference voltage generated by the voltage reference module. The comparator then generates an interrupt signal by setting the HLVDIF bit.

The trip point voltage is software programmable to any one of sixteen values. The trip point is selected by programming the HLVDL3:HLVDL0 bits (HLVDCON<3:0>).

The HLVD module has an additional feature that allows the user to supply the trip voltage to the module from an external source. This mode is enabled when bits HLVDL3:HLVDL0 are set to ‘1111’. In this state, the comparator input is multiplexed from the external input pin, HLVDIN. This gives users flexibility because it allows them to configure the High/Low-Voltage Detect interrupt to occur at any voltage in the valid operating range.
22.2 HLVD Setup

The following steps are needed to set up the HLVD module:

1. Disable the module by clearing the HLVDEN bit (HLVDCON<4>).
2. Write the value to the HLVDL3:HLVDL0 bits that select the desired HLVD trip point.
3. Set the VDIRMAG bit to detect high voltage (VDIRMAG = 1) or low voltage (VDIRMAG = 0).
4. Enable the HLVD module by setting the HLVDEN bit.
5. Clear the HLVD interrupt flag (PIR2<2>), which may have been set from a previous interrupt.
6. Enable the HLVD interrupt if interrupts are desired by setting the HLVDIE and GIE bits (PIE<2> and INTCON<7>). An interrupt will not be generated until the IRVST bit is set.

22.3 Current Consumption

When the module is enabled, the HLVD comparator and voltage divider are enabled and will consume static current. The total current consumption, when enabled, is specified in electrical specification parameter D022B. Depending on the application, the HLVD module does not need to be operating constantly. To decrease the current requirements, the HLVD circuitry may only need to be enabled for short periods where the voltage is checked. After doing the check, the HLVD module may be disabled.

22.4 HLVD Start-up Time

The internal reference voltage of the HLVD module, specified in electrical specification parameter D420, may be used by other internal circuitry, such as the Programmable Brown-out Reset. If the HLVD or other circuits using the voltage reference are disabled to lower the device’s current consumption, the reference voltage circuit will require time to become stable before a low or high-voltage condition can be reliably detected. This start-up time, TIRVST, is an interval that is independent of device clock speed. It is specified in electrical specification parameter 36.

The HLVD interrupt flag is not enabled until TIRVST has expired and a stable reference voltage is reached. For this reason, brief excursions beyond the set point may not be detected during this interval. Refer to Figure 22-2 or Figure 22-3.

**FIGURE 22-2: LOW-VOLTAGE DETECT OPERATION (VDIRMAG = 0)**

<table>
<thead>
<tr>
<th>CASE 1:</th>
<th>CASE 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>VDD</td>
</tr>
<tr>
<td>HLVDF</td>
<td>HLVDF</td>
</tr>
<tr>
<td>Enable HLVD</td>
<td>Enable HLVD</td>
</tr>
<tr>
<td>IRVST</td>
<td>IRVST</td>
</tr>
<tr>
<td>Internal Reference is stable</td>
<td>Internal Reference is stable</td>
</tr>
<tr>
<td>HLVDF cleared in software</td>
<td>HLVDF cleared in software</td>
</tr>
<tr>
<td>HLVDF may not be set</td>
<td>HLVDF cleared in software, HLVDF remains set since HLVD condition still exists</td>
</tr>
</tbody>
</table>

Internal Reference is stable
22.5 Applications

In many applications, the ability to detect a drop below, or rise above a particular threshold is desirable. For example, the HLVD module could be periodically enabled to detect Universal Serial Bus (USB) attach or detach. This assumes the device is powered by a lower voltage source than the USB when detached. An attach would indicate a high-voltage detect from, for example, 3.3V to 5V (the voltage on USB) and vice versa for a detach. This feature could save a design a few extra components and an attach signal (input pin).

For general battery applications, Figure 22-4 shows a possible voltage curve. Over time, the device voltage decreases. When the device voltage reaches voltage $V_a$, the HLVD logic generates an interrupt at time $T_A$. The interrupt could cause the execution of an ISR, which would allow the application to perform "housekeeping tasks" and perform a controlled shutdown before the device voltage exits the valid operating range at $T_B$. The HLVD, thus, would give the application a time window, represented by the difference between $T_A$ and $T_B$, to safely exit.

Legend:
- $V_a$ = HLVD trip point
- $V_b$ = Minimum valid device operating voltage
22.6 Operation During Sleep

When enabled, the HLVD circuitry continues to operate during Sleep. If the device voltage crosses the trip point, the HLVDIF bit will be set and the device will wake-up from Sleep. Device execution will continue from the interrupt vector address if interrupts have been globally enabled.

22.7 Effects of a Reset

A device Reset forces all registers to their Reset state. This forces the HLVD module to be turned off.

### TABLE 22-1: REGISTERS ASSOCIATED WITH HIGH/LOW-VOLTAGE DETECT MODULE

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLVDCON</td>
<td>VDIRMAG</td>
<td>—</td>
<td>IRVST</td>
<td>HLVDEN</td>
<td>HLVDL3</td>
<td>HLVDL2</td>
<td>HLVDL1</td>
<td>HLVDL0</td>
<td>52</td>
</tr>
<tr>
<td>INTCON</td>
<td>GIE/GIEH</td>
<td>PEIE/GIEL</td>
<td>TMR0IE</td>
<td>INT0IE</td>
<td>RBIE</td>
<td>TMR0IF</td>
<td>INT0IF</td>
<td>RBIF</td>
<td>51</td>
</tr>
<tr>
<td>PIR2</td>
<td>OSCFIF</td>
<td>CMIF(1)</td>
<td>—</td>
<td>EEIF</td>
<td>BCLIF</td>
<td>HLVDIF</td>
<td>TMR3IF</td>
<td>ECCP1IF(1)</td>
<td>54</td>
</tr>
<tr>
<td>PIE2</td>
<td>OSCFIE</td>
<td>CMIE(1)</td>
<td>—</td>
<td>EEIE</td>
<td>BCLI E</td>
<td>HLVDIE</td>
<td>TMR3IE</td>
<td>ECCP1IE(1)</td>
<td>54</td>
</tr>
<tr>
<td>IPR2</td>
<td>OSCFIP</td>
<td>CMIP(1)</td>
<td>—</td>
<td>EEIP</td>
<td>BCLIP</td>
<td>HLVDIP</td>
<td>TMR3IP</td>
<td>ECCP1IP(1)</td>
<td>53</td>
</tr>
</tbody>
</table>

**Legend:**  — = unimplemented, read as ‘0’. Shaded cells are unused by the HLVD module.

**Note 1:** These bits are available in PIC18F4682/4685 devices and reserved in PIC18F2682/2685 devices.
23.0 ECAN™ TECHNOLOGY

PIC18F2682/2685/4682/4685 devices contain an Enhanced Controller Area Network (ECAN) module. The ECAN module is fully backward compatible with the CAN module available in PIC18CXX8 and PIC18FXX8 devices.

The Controller Area Network (CAN) module is a serial interface which is useful for communicating with other peripherals or microcontroller devices. This interface, or protocol, was designed to allow communications within noisy environments.

The ECAN module is a communication controller, implementing the CAN 2.0A or B protocol as defined in the BOSCH specification. The module will support CAN 1.2, CAN 2.0A, CAN 2.0B Passive and CAN 2.0B Active versions of the protocol. The module implementation is a full CAN system; however, the CAN specification is not covered within this data sheet. Refer to the BOSCH CAN specification for further details.

The module features are as follows:

• Implementation of the CAN protocol CAN 1.2, CAN 2.0A and CAN 2.0B
• DeviceNet™ data bytes filter support
• Standard and extended data frames
• 0-8 bytes data length
• Programmable bit rate up to 1 Mbit/sec
• Fully backward compatible with PIC18XXX8 CAN module
• Three modes of operation:
  - Mode 0 – Legacy mode
  - Mode 1 – Enhanced Legacy mode with DeviceNet support
  - Mode 2 – FIFO mode with DeviceNet support
• Support for remote frames with automated handling
• Double-buffered receiver with two prioritized received message storage buffers
• Six buffers programmable as RX and TX message buffers
• 16 full (standard/extended identifier) acceptance filters that can be linked to one of four masks
• Two full acceptance filter masks that can be assigned to any filter
• One full acceptance filter that can be used as either an acceptance filter or acceptance filter mask
• Three dedicated transmit buffers with application specified prioritization and abort capability
• Programmable wake-up functionality with integrated low-pass filter
• Programmable Loopback mode supports self-test operation
• Signaling via interrupt capabilities for all CAN receiver and transmitter error states
• Programmable clock source
• Programmable link to timer module for time-stamping and network synchronization
• Low-power Sleep mode

23.1 Module Overview

The CAN bus module consists of a protocol engine and message buffering and control. The CAN protocol engine automatically handles all functions for receiving and transmitting messages on the CAN bus. Messages are transmitted by first loading the appropriate data registers. Status and errors can be checked by reading the appropriate registers. Any message detected on the CAN bus is checked for errors and then matched against filters to see if it should be received and stored in one of the two receive registers.

The CAN module supports the following frame types:

• Standard Data Frame
• Extended Data Frame
• Remote Frame
• Error Frame
• Overload Frame Reception
• Interframe Space Generation/Detection

The CAN module uses the RB2/CANTX and RB3/CANRX pins to interface with the CAN bus. In normal mode, the CAN module automatically overrides TRISB<2>. The user must ensure that TRISB<3> is set.

23.1.1 MODULE FUNCTIONALITY

The CAN bus module consists of a protocol engine, message buffering and control (see Figure 23-1). The protocol engine can best be understood by defining the types of data frames to be transmitted and received by the module.

The following sequence illustrates the necessary initialization steps before the ECAN module can be used to transmit or receive a message. Steps can be added or removed depending on the requirements of the application.

1. Ensure that the ECAN module is in Configuration mode.
2. Select ECAN operational mode.
3. Set up the baud rate registers.
4. Set up the filter and mask registers.
5. Set the ECAN module to normal mode or any other mode required by the application logic.
FIGURE 23-1: CAN BUFFERS AND PROTOCOL ENGINE BLOCK DIAGRAM

BUFFERS

PROTOCOL ENGINE

MESSAGE BUFFERS

Acceptance Filters
(RXF0-RXF05)
MODE 0

Acceptance Filters
(RXF06-RXF15)
MODE 1, 2

16 – 4 to 1 MUXs

Acceptance Mask
RXM10

Acceptance Mask
RXM1

Rcv Byte

RX

Configuration Registers

Shift<14:0>
(Transmit<5:0>, Receive<8:0>)

Comparator

CRC<14:0>

Bit Timing Logic

Clock Generator

Protocol Finite State Machine

Transmit Error Counter

Bus-Off

Message Queue Control

Transmit Byte Sequencer

Transmit Option

MODE 0
2 RX Buffers

MODE 1, 2
6 TX/RX Buffers

Receive Error Counter

REC

TEC

Error-Pas

Shift<14:0>

Receive<8:0>

Transmit<7:0>

Transmit Logic

TX

RX
23.2 CAN Module Registers

Note: Not all CAN registers are available in the Access Bank.

There are many control and data registers associated with the CAN module. For convenience, their descriptions have been grouped into the following sections:

- Control and Status Registers
- Dedicated Transmit Buffer Registers
- Dedicated Receive Buffer Registers
- Programmable TX/RX and Auto RTR Buffers
- Baud Rate Control Registers
- I/O Control Register
- Interrupt Status and Control Registers

Detailed descriptions of each register and their usage are described in the following sections.

23.2.1 CAN CONTROL AND STATUS REGISTERS

The registers described in this section control the overall operation of the CAN module and show its operational status.
## REGISTER 23-1: CANCON: CAN CONTROL REGISTER

<table>
<thead>
<tr>
<th>Mode</th>
<th>R/W-1</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/S-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>U-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode 0</td>
<td>REQOP2</td>
<td>REQOP1</td>
<td>REQOP0</td>
<td>ABAT</td>
<td>WIN2</td>
<td>WIN1</td>
<td>WIN0</td>
<td>—</td>
</tr>
<tr>
<td>Mode 1</td>
<td>R/W-1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/S-0</td>
<td>U0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
</tr>
<tr>
<td>Mode 2</td>
<td>R/W-1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/S-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
</tr>
</tbody>
</table>

### Legend:
- **S** = Settable bit
- **R** = Readable bit
- **W** = Writable bit
- **U** = Unimplemented bit, read as ‘0’
- -n = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

### Bit 7-5
**REQOP2:REQOP0**: Request CAN Operation Mode bits
- 1xx = Request Configuration mode
- 011 = Request Listen Only mode
- 010 = Request Loopback mode
- 001 = Request Disable mode
- 000 = Request Normal mode

### Bit 4
**ABAT**: Abort All Pending Transmissions bit
- 1 = Abort all pending transmissions (in all transmit buffers)
- 0 = Transmissions proceeding as normal

### Bit 3-1
**WIN2:WIN0**: Window Address bits
These bits select which of the CAN buffers to switch into the access bank area. This allows access to the buffer registers from any data memory bank. After a frame has caused an interrupt, the ICODE3:ICODE0 bits can be copied to the WIN3:WIN0 bits to select the correct buffer. See Example 23-2 for a code example.
- 111 = Receive Buffer 0
- 110 = Receive Buffer 0
- 101 = Receive Buffer 1
- 100 = Transmit Buffer 0
- 011 = Transmit Buffer 1
- 010 = Transmit Buffer 2
- 001 = Receive Buffer 0
- 000 = Receive Buffer 0

### Bit 0
**Unimplemented**: Read as ‘0’

### Bit 4-0
**Unimplemented**: Read as ‘0’

### Mode 1:
**Unimplemented**: Read as ‘0’

### Mode 2:
**FP3:FP0**: FIFO Read Pointer bits
These bits point to the message buffer to be read.
- 0111:0000 = Message buffer to be read
- 1111:1000 = Reserved
REGISTER 23-2: CANSTAT: CAN STATUS REGISTER

<table>
<thead>
<tr>
<th>Mode</th>
<th>R-1</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>U-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 1,2</td>
<td>R-1</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **W** = Writable 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 **OPMODE2:OPMODE0**: Operation Mode Status bits⁽¹⁾

- 111 = Reserved
- 110 = Reserved
- 101 = Reserved
- 100 = Configuration mode
- 011 = Listen Only mode
- 010 = Loopback mode
- 001 = Disable/Sleep mode
- 000 = Normal mode

bit 4 Mode 0:
**Unimplemented**: Read as ‘0’

bit 3-1 **ICODE3:ICODE1**: Interrupt Code bits

When an interrupt occurs, a prioritized coded interrupt value will be present in these bits. This code indicates the source of the interrupt. By copying ICODE3:ICODE1 to WIN2:WIN0 (Mode 0) or EICODE4:EICODE0 to EWIN4:EWIN0 (Mode 1 and 2), it is possible to select the correct buffer to map into the Access Bank area. See Example 23-2 for a code example. To simplify the description, the following table lists all five bits.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mode 0</th>
<th>Mode 1</th>
<th>Mode 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No interrupt</td>
<td>00000</td>
<td>00000</td>
<td>00000</td>
</tr>
<tr>
<td>Error interrupt</td>
<td>00010</td>
<td>00010</td>
<td>00010</td>
</tr>
<tr>
<td>TXB2 interrupt</td>
<td>00100</td>
<td>00100</td>
<td>00100</td>
</tr>
<tr>
<td>TXB1 interrupt</td>
<td>00110</td>
<td>00110</td>
<td>00110</td>
</tr>
<tr>
<td>TXB0 interrupt</td>
<td>01000</td>
<td>01000</td>
<td>01000</td>
</tr>
<tr>
<td>RXB1 interrupt</td>
<td>01010</td>
<td>10010</td>
<td>------</td>
</tr>
<tr>
<td>RXB0 interrupt</td>
<td>01100</td>
<td>10010</td>
<td>10000</td>
</tr>
<tr>
<td>Wake-up interrupt</td>
<td>00010</td>
<td>01110</td>
<td>01110</td>
</tr>
<tr>
<td>RXB0 interrupt</td>
<td>------</td>
<td>10000</td>
<td>10000</td>
</tr>
<tr>
<td>RXB1 interrupt</td>
<td>------</td>
<td>10001</td>
<td>10000</td>
</tr>
<tr>
<td>RX/TX B0 interrupt</td>
<td>------</td>
<td>10010</td>
<td>10010</td>
</tr>
<tr>
<td>RX/TX B1 interrupt</td>
<td>------</td>
<td>10011</td>
<td>10011⁽²⁾</td>
</tr>
<tr>
<td>RX/TX B2 interrupt</td>
<td>------</td>
<td>10100</td>
<td>10100⁽²⁾</td>
</tr>
<tr>
<td>RX/TX B3 interrupt</td>
<td>------</td>
<td>10101</td>
<td>10101⁽²⁾</td>
</tr>
<tr>
<td>RX/TX B4 interrupt</td>
<td>------</td>
<td>10110</td>
<td>10110⁽²⁾</td>
</tr>
<tr>
<td>RX/TX B5 interrupt</td>
<td>------</td>
<td>10111</td>
<td>10111⁽²⁾</td>
</tr>
</tbody>
</table>

bit 0 **Unimplemented**: Read as ‘0’

bit 4-0 Mode 1, 2:
**EICODE4:EICODE0**: Interrupt Code bits

See ICODE3:ICODE1 above.

**Note 1**: To achieve maximum power saving and/or able to wake-up on CAN bus activity, switch CAN module in Disable mode before putting device to Sleep.

**2**: If buffer is configured as receiver, EICODE bits will contain ‘10000’ upon interrupt.
EXAMPLE 23-1: CHANGING TO CONFIGURATION MODE

; Request Configuration mode.
MOVlw B’10000000’ ; Set to Configuration Mode.
MOVF CANCON
; A request to switch to Configuration mode may not be immediately honored.
; Module will wait for CAN bus to be idle before switching to Configuration Mode.
; Request for other modes such as Loopback, Disable etc. may be honored immediately.
; It is always good practice to wait and verify before continuing.

ConfigWait:
MOVF CANSTAT, W ; Read current mode state.
ANDlw B’10000000’ ; Interested in OPMODE bits only.
TSTFSZ WREG ; Is it Configuration mode yet?
Bra ConfigWait ; No. Continue to wait...
; Module is in Configuration mode now.
; Modify configuration registers as required.
; Switch back to Normal mode to be able to communicate.

EXAMPLE 23-2: WIN AND ICODE BITS USAGE IN INTERRUPT SERVICE ROUTINE TO ACCESS TX/RX BUFFERS

; Save application required context.
; Poll interrupt flags and determine source of interrupt
; TempCANCON and TempCANSTAT are variables defined in Access Bank low
MOVFF CANCON, TempCANCON ; Save CANCON.WIN bits
; This is required to prevent CANCON from corrupting CAN buffer access
; in-progress while this interrupt occurred

MOVFF CANSTAT, TempCANSTAT ; Save CANSTAT register
; This is required to make sure that we use same CANSTAT value rather than one changed by another CAN interrupt.

MOVF TempCANSTAT, W ; Retrieve ICODE bits
ANDlw B’00001110’ ; Perform computed GOTO
ADDWF FCL, F ; to corresponding interrupt cause
Bra NoInterrupt ; 000 = No interrupt
Bra ErrorInterrupt ; 001 = Error interrupt
Bra TXB2Interrupt ; 010 = TXB2 interrupt
Bra TXB1Interrupt ; 011 = TXB1 interrupt
Bra TXB0Interrupt ; 100 = TXB0 interrupt
Bra RXB1Interrupt ; 101 = RXB1 interrupt
Bra RXB0Interrupt ; 110 = RXB0 interrupt
Bra 111 = Wake-up on interrupt

WakeupInterrupt
BCF PIR3, WAKIF ; Clear the interrupt flag
; User code to handle wake-up procedure
; Continue checking for other interrupt source or return from here

NoInterrupt
; FC should never vector here. User may place a trap such as infinite loop or pin/port indication to catch this error.
EXAMPLE 23-2: WIN AND ICODE BITS USAGE IN INTERRUPT SERVICE ROUTINE TO ACCESS TX/RX BUFFERS (CONTINUED)

```
ErrorInterrupt
   BCF PIR3, ERRIF ; Clear the interrupt flag
   ; Handle error.
   RETFIE

TXB2Interrupt
   BCF PIR3, TXB2IF ; Clear the interrupt flag
   GOTO AccessBuffer

TXB1Interrupt
   BCF PIR3, TXB1IF ; Clear the interrupt flag
   GOTO AccessBuffer

TXB0Interrupt
   BCF PIR3, TXB0IF ; Clear the interrupt flag
   GOTO AccessBuffer

RXB1Interrupt
   BCF PIR3, RXB1IF ; Clear the interrupt flag
   GOTO AccessBuffer

RXB0Interrupt
   BCF PIR3, RXB0IF ; Clear the interrupt flag
   GOTO AccessBuffer

AccessBuffer ; This is either TX or RX interrupt
   ; Copy CANSTAT.ICODE bits to CANCON.WIN bits
   MOVF TempCANCON, W ; Clear CANCON.WIN bits before copying
                     ; new ones.
   ANDLW B’11110001’ ; Use previously saved CANCON value to
                     ; make sure same value.
   MOVWF TempCANCON ; Copy masked value back to TempCANCON

   MOVF TempCANSTAT, W ; Retrieve ICODE bits
   ANDLW B’00001110’ ; Use previously saved CANSTAT value
                     ; to make sure same value.
   IORWF TempCANCON ; Copy ICODE bits to WIN bits.

   MOVFF TempCANCON, CANCON ; Copy the result to actual CANCON
   ; Access current buffer...
   ; User code
   ; Restore CANCON.WIN bits
   MOVF CANCON, W        ; Preserve current non WIN bits
   ANDLW B’11110001’    ; Restore original WIN bits
   IORWF TempCANCON     ; Do not need to restore CANSTAT - it is read-only register.
   ; Return from interrupt or check for another module interrupt source
```
REGISTER 23-3: ECANCON: ENHANCED CAN CONTROL REGISTER

<table>
<thead>
<tr>
<th>Bit 7-6</th>
<th>MDSEL1:MDSEL0: Mode Select bits⁽¹⁾</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Legacy mode (Mode 0, default)</td>
</tr>
<tr>
<td>01</td>
<td>Enhanced Legacy mode (Mode 1)</td>
</tr>
<tr>
<td>10</td>
<td>Enhanced FIFO mode (Mode 2)</td>
</tr>
<tr>
<td>11</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 5</th>
<th>FIFOWM: FIFO High Water Mark bit⁽²⁾</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Will cause FIFO interrupt when one receive buffer remains⁽³⁾</td>
</tr>
<tr>
<td>0</td>
<td>Will cause FIFO interrupt when four receive buffers remain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 4-0</th>
<th>EWIN4:EWIN0: Enhanced Window Address bits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>These bits map the group of 16 banked CAN SFRs into access bank addresses 0F60-0F6Dh. Exact group of registers to map is determined by binary value of these bits.</td>
</tr>
<tr>
<td>Mode 0:</td>
<td>Unimplemented: Read as ‘0’</td>
</tr>
<tr>
<td>Mode 1, 2:</td>
<td></td>
</tr>
<tr>
<td>00000</td>
<td>Acceptance Filters 0, 1, 2 and BRGCON2, 3</td>
</tr>
<tr>
<td>00001</td>
<td>Acceptance Filters 3, 4, 5 and BRGCON1, CIOCON</td>
</tr>
<tr>
<td>00010</td>
<td>Acceptance Filter Masks, Error and Interrupt Control</td>
</tr>
<tr>
<td>00011</td>
<td>Transmit Buffer 0</td>
</tr>
<tr>
<td>00100</td>
<td>Transmit Buffer 1</td>
</tr>
<tr>
<td>00101</td>
<td>Transmit Buffer 2</td>
</tr>
<tr>
<td>00110</td>
<td>Acceptance Filters 6, 7, 8</td>
</tr>
<tr>
<td>00111</td>
<td>Acceptance Filters 9, 10, 11</td>
</tr>
<tr>
<td>01000</td>
<td>Acceptance Filters 12, 13, 14</td>
</tr>
<tr>
<td>01001</td>
<td>Acceptance Filters 15</td>
</tr>
<tr>
<td>01010-01110</td>
<td>Reserved</td>
</tr>
<tr>
<td>01111</td>
<td>RXINT0, RXINT1</td>
</tr>
<tr>
<td>10000</td>
<td>Receive Buffer 0</td>
</tr>
<tr>
<td>10001</td>
<td>Receive Buffer 1</td>
</tr>
<tr>
<td>10010</td>
<td>TX/RX Buffer 0</td>
</tr>
<tr>
<td>10011</td>
<td>TX/RX Buffer 1</td>
</tr>
<tr>
<td>10100</td>
<td>TX/RX Buffer 2</td>
</tr>
<tr>
<td>10101</td>
<td>TX/RX Buffer 3</td>
</tr>
<tr>
<td>10110</td>
<td>TX/RX Buffer 4</td>
</tr>
<tr>
<td>10111</td>
<td>TX/RX Buffer 5</td>
</tr>
<tr>
<td>11000-11111</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

**Note 1:** These bits can only be changed in Configuration mode. See Register 23-1 to change to Configuration mode.

**Note 2:** This bit is used in Mode 2 only.

**Note 3:** FIFO length of 4 or less will cause this bit to be set.
## REGISTER 23-4: COMSTAT: COMMUNICATION STATUS REGISTER

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/C-0</th>
<th>R/C-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RXB0OVFL</td>
<td>RXB1OVFL</td>
<td>TXBO</td>
<td>TXBP</td>
<td>RXBP</td>
<td>TXWARN</td>
<td>RXWARN</td>
<td>EWARN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 1</th>
<th>R/C-0</th>
<th>R/C-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>—</td>
<td>RXBnOVFL</td>
<td>TXB0</td>
<td>TXBP</td>
<td>RXBP</td>
<td>TXWARN</td>
<td>RXWARN</td>
<td>EWARN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 2</th>
<th>R/C-0</th>
<th>R/C-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FIFOEMPTY</td>
<td>RXBnOVFL</td>
<td>TXBO</td>
<td>TXBP</td>
<td>RXBP</td>
<td>TXWARN</td>
<td>RXWARN</td>
<td>EWARN</td>
</tr>
</tbody>
</table>

Legend:

- R = Readable bit
- C = Clearable bit
- U = Unimplemented bit, read as ‘0’
- -n = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

<table>
<thead>
<tr>
<th>bit 7</th>
<th>Mode 0: RXB0OVFL: Receive Buffer 0 Overflow bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Receive Buffer 0 overflowed</td>
</tr>
<tr>
<td></td>
<td>0 = Receive Buffer 0 has not overflowed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 6</th>
<th>Mode 1: Unimplemented: Read as ‘0’</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>bit 5</th>
<th>Mode 2: FIFOEMPTY: FIFO Not Empty bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Receive FIFO is not empty</td>
</tr>
<tr>
<td></td>
<td>0 = Receive FIFO is empty</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 4</th>
<th>Mode 0: RXB1OVFL: Receive Buffer 1 Overflow bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Receive Buffer 1 overflowed</td>
</tr>
<tr>
<td></td>
<td>0 = Receive Buffer 1 has not overflowed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 3</th>
<th>Mode 1, 2: RXBnOVFL: Receive Buffer n Overflow bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Receive Buffer n has overflowed</td>
</tr>
<tr>
<td></td>
<td>0 = Receive Buffer n has not overflowed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 2</th>
<th>TXBO: Transmitter Bus-Off bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Transmit error counter &gt; 255</td>
</tr>
<tr>
<td></td>
<td>0 = Transmit error counter ≤ 255</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1</th>
<th>TXBP: Transmitter Bus Passive bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Transmit error counter &gt; 127</td>
</tr>
<tr>
<td></td>
<td>0 = Transmit error counter ≤ 127</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 0</th>
<th>RXBP: Receiver Bus Passive bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Receive error counter &gt; 127</td>
</tr>
<tr>
<td></td>
<td>0 = Receive error counter ≤ 127</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 2</th>
<th>TXWARN: Transmitter Warning bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = Transmit error counter &gt; 95</td>
</tr>
<tr>
<td></td>
<td>0 = Transmit error counter ≤ 95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1</th>
<th>RXWARN: Receiver Warning bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = 127 ≥ Receive error counter &gt; 95</td>
</tr>
<tr>
<td></td>
<td>0 = Receive error counter ≤ 95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 0</th>
<th>EWARN: Error Warning bit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This bit is a flag of the RXWARN and TXWARN bits.</td>
</tr>
<tr>
<td></td>
<td>1 = The RXWARN or the TXWARN bits are set</td>
</tr>
<tr>
<td></td>
<td>0 = Neither the RXWARN or the TXWARN bits are set</td>
</tr>
</tbody>
</table>
23.2.2  DEDICATED CAN TRANSMIT BUFFER REGISTERS

This section describes the dedicated CAN Transmit Buffer registers and their associated control registers.

REGISTER 23-5:  TXBnCON: TRANSMIT BUFFER n CONTROL REGISTERS [0 ≤ n ≤ 2]

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/C-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TXBIF</td>
<td>TXABT(1)</td>
<td>TXLARB(1)</td>
<td>TXERR(1)</td>
<td>TXREQ(2)</td>
<td>—</td>
<td>TXPRI1(3)</td>
<td>TXPRI0(3)</td>
</tr>
<tr>
<td>Mode 1,2</td>
<td>R/C-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R/W-0</td>
<td>U-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>TXBIF</td>
<td>TXABT(1)</td>
<td>TXLARB(1)</td>
<td>TXERR(1)</td>
<td>TXREQ(2)</td>
<td>—</td>
<td>TXPRI1(3)</td>
<td>TXPRI0(3)</td>
</tr>
</tbody>
</table>

bit 7  TXBIF: Transmit Buffer Interrupt Flag bit
1 = Transmit buffer has completed transmission of message and may be reloaded
0 = Transmit buffer has not completed transmission of a message

bit 6  TXABT: Transmission Aborted Status bit(1)
1 = Message was aborted
0 = Message was not aborted

bit 5  TXLARB: Transmission Lost Arbitration Status bit(1)
1 = Message lost arbitration while being sent
0 = Message did not lose arbitration while being sent

bit 4  TXERR: Transmission Error Detected Status bit(1)
1 = A bus error occurred while the message was being sent
0 = A bus error did not occur while the message was being sent

bit 3  TXREQ: Transmit Request Status bit(2)
1 = Requests sending a message. Clears the TXABT, TXLARB and TXERR bits.
0 = Automatically cleared when the message is successfully sent

bit 2  Unimplemented: Read as ‘0’

bit 1-0  TXPRI1:TXPRI0: Transmit Priority bits(3)
11 = Priority Level 3 (highest priority)
10 = Priority Level 2
01 = Priority Level 1
00 = Priority Level 0 (lowest priority)

Note 1:  This bit is automatically cleared when TXREQ is set.
2:  While TXREQ is set, Transmit Buffer registers remain read-only. Clearing this bit in software while the bit is set will request a message abort.
3:  These bits define the order in which transmit buffers will be transferred. They do not alter the CAN message identifier.
REGISTER 23-6: TXBnSIDH: TRANSMIT BUFFER n STANDARD IDENTIFIER REGISTERS, HIGH BYTE [0 ≤ n ≤ 2]

<table>
<thead>
<tr>
<th>Bit</th>
<th>SID10</th>
<th>SID9</th>
<th>SID8</th>
<th>SID7</th>
<th>SID6</th>
<th>SID5</th>
<th>SID4</th>
<th>SID3</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

bit 7-0  **SID10:**SID3: Standard Identifier bits (if EXIDE (TXBnSIDL<3>) = 0)
Extended Identifier bits EID28:EID21 (if EXIDE = 1).

REGISTER 23-7: TXBnSIDL: TRANSMIT BUFFER n STANDARD IDENTIFIER REGISTERS, LOW BYTE [0 ≤ n ≤ 2]

<table>
<thead>
<tr>
<th>Bit</th>
<th>SID2</th>
<th>SID1</th>
<th>SID0</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **W** = Writable 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  **SID2:**SID0: Standard Identifier bits (if EXIDE (TXBnSIDL<3>) = 0)
Extended Identifier bits EID20:EID18 (if EXIDE = 1).

bit 4  **Unimplemented:** Read as ‘0’

bit 3  **EXIDE:** Extended Identifier Enable bit

- 1 = Message will transmit extended ID, SID10:SID0 become EID28:EID18
- 0 = Message will transmit standard ID, EID17:EID0 are ignored

bit 2  **Unimplemented:** Read as ‘0’

bit 1-0  **EID17:**EID16: Extended Identifier bits

REGISTER 23-8: TXBnEIDH: TRANSMIT BUFFER n EXTENDED IDENTIFIER REGISTERS, HIGH BYTE [0 ≤ n ≤ 2]

<table>
<thead>
<tr>
<th>Bit</th>
<th>EID15</th>
<th>EID14</th>
<th>EID13</th>
<th>EID12</th>
<th>EID11</th>
<th>EID10</th>
<th>EID9</th>
<th>EID8</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

bit 7-0  **EID15:**EID8: Extended Identifier bits (not used when transmitting standard identifier message)
REGISTER 23-9: TXBnEIDL: TRANSMIT BUFFER n EXTENDED IDENTIFIER REGISTERS, LOW BYTE [0 \leq n \leq 2]

| R/W-x | EID7 | R/W-x | EID6 | R/W-x | EID5 | R/W-x | EID4 | R/W-x | EID3 | R/W-x | EID2 | R/W-x | EID1 | R/W-x | EID0 |
|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|
|       |      |       |      |       |      |       |      |       |      |       |      |       |      |       |      |

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

bit 7-0 EID7:EID0: Extended Identifier bits (not used when transmitting standard identifier message)

REGISTER 23-10: TXBnDm: TRANSMIT BUFFER n DATA FIELD BYTE m REGISTERS [0 \leq n \leq 2, 0 \leq m \leq 7]

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>TXBnDm7</th>
<th>R/W-x</th>
<th>TXBnDm6</th>
<th>R/W-x</th>
<th>TXBnDm5</th>
<th>R/W-x</th>
<th>TXBnDm4</th>
<th>R/W-x</th>
<th>TXBnDm3</th>
<th>R/W-x</th>
<th>TXBnDm2</th>
<th>R/W-x</th>
<th>TXBnDm1</th>
<th>R/W-x</th>
<th>TXBnDm0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TXBnDm7</td>
<td></td>
<td>TXBnDm6</td>
<td></td>
<td>TXBnDm5</td>
<td></td>
<td>TXBnDm4</td>
<td></td>
<td>TXBnDm3</td>
<td></td>
<td>TXBnDm2</td>
<td></td>
<td>TXBnDm1</td>
<td></td>
<td>TXBnDm0</td>
</tr>
</tbody>
</table>

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

bit 7-0 TXBnDm7:TXBnDm0: Transmit Buffer n Data Field Byte m bits (where 0 \leq n < 3 and 0 \leq m < 8)

Each transmit buffer has an array of registers. For example, Transmit Buffer 0 has 7 registers: TXB0D0 to TXB0D7.
REGISTER 23-11: TXBnDLC: TRANSMIT BUFFER n DATA LENGTH CODE REGISTERS [0 ≤ n ≤ 2]

<table>
<thead>
<tr>
<th>U-0</th>
<th>R/W-x</th>
<th>U-0</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- W = Writable 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  **Unimplemented**: Read as ‘0’

bit 6  **TXRTR**: Transmit Remote Frame Transmission Request bit

| 1   | Transmitted message will have TXRTR bit set |
| 0   | Transmitted message will have TXRTR bit cleared |

bit 5-4  **Unimplemented**: Read as ‘0’

bit 3-0  **DLC3:DLC0**: Data Length Code bits

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1111</td>
<td>Reserved</td>
</tr>
<tr>
<td>1110</td>
<td>Reserved</td>
</tr>
<tr>
<td>1101</td>
<td>Reserved</td>
</tr>
<tr>
<td>1100</td>
<td>Reserved</td>
</tr>
<tr>
<td>1011</td>
<td>Reserved</td>
</tr>
<tr>
<td>1010</td>
<td>Reserved</td>
</tr>
<tr>
<td>1001</td>
<td>Reserved</td>
</tr>
<tr>
<td>1000</td>
<td>Data length = 8 bytes</td>
</tr>
<tr>
<td>0111</td>
<td>Data length = 7 bytes</td>
</tr>
<tr>
<td>0110</td>
<td>Data length = 6 bytes</td>
</tr>
<tr>
<td>0101</td>
<td>Data length = 5 bytes</td>
</tr>
<tr>
<td>0100</td>
<td>Data length = 4 bytes</td>
</tr>
<tr>
<td>0011</td>
<td>Data length = 3 bytes</td>
</tr>
<tr>
<td>0010</td>
<td>Data length = 2 bytes</td>
</tr>
<tr>
<td>0001</td>
<td>Data length = 1 bytes</td>
</tr>
<tr>
<td>0000</td>
<td>Data length = 0 bytes</td>
</tr>
</tbody>
</table>

REGISTER 23-12: TXERRCNT: TRANSMIT ERROR COUNT REGISTER

<table>
<thead>
<tr>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEC7</td>
<td>TEC6</td>
<td>TEC5</td>
<td>TEC4</td>
<td>TEC3</td>
<td>TEC2</td>
<td>TEC1</td>
<td>TEC0</td>
</tr>
</tbody>
</table>

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

bit 7-0  **TEC7:TEC0**: Transmit Error Counter bits

This register contains a value which is derived from the rate at which errors occur. When the error count overflows, the bus-off state occurs. When the bus has 128 occurrences of 11 consecutive recessive bits, the counter value is cleared.
EXAMPLE 23-3: TRANSMITTING A CAN MESSAGE USING BANKED METHOD

; Need to transmit Standard Identifier message 123h using TXB0 buffer.
; To successfully transmit, CAN module must be either in Normal or Loopback mode.
; TXB0 buffer is not in access bank. And since we want banked method, we need to make sure
; that correct bank is selected.
BANKSEL TXB0CON ; One BANKSEL in beginning will make sure that we are
; in correct bank for rest of the buffer access.
; Now load transmit data into TXB0 buffer.
MOVLW MY_DATA_BYTE1 ; Load first data byte into buffer
MOVWF TXB0D0 ; Compiler will automatically set “BANKED” bit
; Load rest of data bytes - up to 8 bytes into TXB0 buffer.
...
; Load message identifier
MOVLW 60H ; Load SID2:SID0, EXIDE = 0
MOVWF TXB0SIDL
MOVLW 24H ; Load SID10:SID3
MOVWF TXB0SIDH
; No need to load TXB0EIDL:TXB0EIDH, as we are transmitting Standard Identifier Message only.
; Now that all data bytes are loaded, mark it for transmission.
MOVLW B'00001000' ; Normal priority; Request transmission
MOVWF TXB0CON
; If required, wait for message to get transmitted
BTFSC TXB0CON, TXREQ ; Is it transmitted?
BRA $-2 ; No. Continue to wait...
; Message is transmitted.
EXAMPLE 23-4: TRANSMITTING A CAN MESSAGE USING WIN BITS

; Need to transmit Standard Identifier message 123h using TXB0 buffer.
; To successfully transmit, CAN module must be either in Normal or Loopback mode.
; TXB0 buffer is not in access bank. Use WIN bits to map it to RXB0 area.
MOVF CANCON, W ; WIN bits are in lower 4 bits only. Read CANCON
; register to preserve all other bits. If operation
; mode is already known, there is no need to preserve
; other bits.
ANDLW B’11110000’ ; Clear WIN bits.
IORLW B’00001000’ ; Select Transmit Buffer 0
MOVWF CANCON ; Apply the changes.
; Now TXB0 is mapped in place of RXB0. All future access to RXB0 registers will actually
; yield TXB0 register values.

; Load transmit data into TXB0 buffer.
MOVWF RXB0D0 ; Access TXB0D0 via RXB0D0 address.
; Load rest of the data bytes - up to 8 bytes into “TXB0” buffer using RXB0 registers.
... ; Load message identifier
MOVLW 60H ; Load SID2:SID0, EXIDE = 0
MOVWF RXB0SIDL
MOVLW 24H ; Load SID10:SID3
MOVWF RXB0SIDH
; No need to load RXB0EIDL:RXB0EIDH, as we are transmitting Standard Identifier Message only.

; Now that all data bytes are loaded, mark it for transmission.
MOVWF RXB0CON ; Normal priority; Request transmission

; If required, wait for message to get transmitted
BTSC RXB0CON, TXREQ ; Is it transmitted?
BRA $-2 ; No. Continue to wait...

; Message is transmitted.
; If required, reset the WIN bits to default state.
23.2.3 DEDICATED CAN RECEIVE BUFFER REGISTERS

This section shows the dedicated CAN Receive Buffer registers with their associated control registers.

REGISTER 23-13: RXB0CON: RECEIVE BUFFER 0 CONTROL REGISTER

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/C-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RXFUL(1)</td>
<td>RXM1</td>
<td>RXM0</td>
<td>—</td>
<td>RXRTRRO</td>
<td>RXB0DBEN</td>
<td>JTOFF(2)</td>
<td>FILHIT0</td>
</tr>
<tr>
<td>Mode 1, 2</td>
<td>R/C-0</td>
<td>R/W-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
<td>R-0</td>
</tr>
<tr>
<td></td>
<td>RXFUL(1)</td>
<td>RXM1</td>
<td>RTRRO</td>
<td>FILHIT4</td>
<td>FILHIT3</td>
<td>FILHIT2</td>
<td>FILHIT1</td>
<td>FILHIT0</td>
</tr>
</tbody>
</table>

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 **RXFUL**: Receive Full Status bit(1)
- 1 = Receive buffer contains a received message
- 0 = Receive buffer is open to receive a new message

bit 6 Mode 0:
**RXM1**: Receive Buffer Mode bit 1 (combines with RXM0 to form RXM<1:0> bits, see bit 5)
- 11 = Receive all messages (including those with errors); filter criteria is ignored
- 10 = Receive only valid messages with extended identifier; EXIDEN in RXFnSIDL must be ‘1’
- 01 = Receive only valid messages with standard identifier; EXIDEN in RXFnSIDL must be ‘0’
- 00 = Receive all valid messages as per EXIDEN bit in RXFnSIDL register

Mode 1, 2:
**RXM1**: Receive Buffer Mode bit 1
- 1 = Receive all messages (including those with errors); acceptance filters are ignored
- 0 = Receive all valid messages as per acceptance filters

bit 5 Mode 0:
**RXM0**: Receive Buffer Mode bit 0 (combines with RXM1 to form RXM<1:0> bits, see bit 6)

Mode 1, 2:
**RTRRO**: Remote Transmission Request bit for Received Message (read-only)
- 1 = A remote transmission request is received
- 0 = A remote transmission request is not received

bit 4 Mode 0:
**Unimplemented**: Read as ‘0’

Mode 1, 2:
**FILHIT4**: Filter Hit bit 4
This bit combines with other bits to form filter acceptance bits <4:0>.

bit 3 Mode 0:
**RXRTRRO**: Remote Transmission Request bit for Received Message (read-only)
- 1 = A remote transmission request is received
- 0 = A remote transmission request is not received

Mode 1, 2:
**FILHIT3**: Filter Hit bit 3
This bit combines with other bits to form filter acceptance bits <4:0>.

Note 1: This bit is set by the CAN module upon receiving a message and must be cleared by software after the buffer is read. As long as RXFUL is set, no new message will be loaded and buffer will be considered full. After clearing the RXFUL flag, the PIR3 bit, RXB0IF, can be cleared. If RXB0IF is cleared, but RXFUL is not cleared, then RXB0IF is set again.

2: This bit allows same filter jump table for both RXB0CON and RXB1CON.
REGISTER 23-13: RXB0CON: RECEIVE BUFFER 0 CONTROL REGISTER (CONTINUED)

bit 2  Mode 0:
RXB0DBEN: Receive Buffer 0 Double-Buffer Enable bit
1 = Receive Buffer 0 overflow will write to Receive Buffer 1
0 = No Receive Buffer 0 overflow to Receive Buffer 1

Mode 1, 2:
FILHIT2: Filter Hit bit 2
This bit combines with other bits to form filter acceptance bits <4:0>.

bit 1  Mode 0:
JTOFF: Jump Table Offset bit (read-only copy of RXB0DBEN)\(^{(2)}\)
1 = Allows jump table offset between 6 and 7
0 = Allows jump table offset between 1 and 0

Mode 1, 2:
FILHIT1: Filter Hit bit 1
This bit combines with other bits to form filter acceptance bits <4:0>.

bit 0  Mode 0:
FILHIT0: Filter Hit bit 0
This bit indicates which acceptance filter enabled the message reception into Receive Buffer 0.
1 = Acceptance Filter 1 (RXF1)
0 = Acceptance Filter 0 (RXF0)

Mode 1, 2:
FILHIT0: Filter Hit bit 0
This bit, in combination with FILHIT<4:1>, indicates which acceptance filter enabled the message reception into this receive buffer.
01111 = Acceptance Filter 15 (RXF15)
01110 = Acceptance Filter 14 (RXF14)
...
00000 = Acceptance Filter 0 (RXF0)

Note 1: This bit is set by the CAN module upon receiving a message and must be cleared by software after the buffer is read. As long as RXFUL is set, no new message will be loaded and buffer will be considered full. After clearing the RXFUL flag, the PIR3 bit, RXB0IF, can be cleared. If RXB0IF is cleared, but RXFUL is not cleared, then RXB0IF is set again.

2: This bit allows same filter jump table for both RXB0CON and RXB1CON.
REGISTER 23-14: RXB1CON: RECEIVE BUFFER 1 CONTROL REGISTER

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/C-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXFUL&lt;1&gt;</td>
<td>RXM1</td>
<td>RXM0</td>
<td>—</td>
<td>RXRTRRO</td>
<td>FILHIT2</td>
<td>FILHIT1</td>
<td>FILHIT0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 1, 2</th>
<th>R/C-0</th>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXFUL&lt;1&gt;</td>
<td>RXM1</td>
<td>RTRRO</td>
<td>FILHIT4</td>
<td>FILHIT3</td>
<td>FILHIT2</td>
<td>FILHIT1</td>
<td>FILHIT0</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- C = Clearable bit
- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as ‘0’
- -n = Value at POR

bit 7
- RXFUL: Receive Full Status bit<sup>(1)</sup>
  
  1 = Receive buffer contains a received message
  0 = Receive buffer is open to receive a new message

bit 6
Mode 0:
- RXM1: Receive Buffer Mode bit 1 (combines with RXM0 to form RXM<1:0> bits, see bit 5)
  
  11 = Receive all messages (including those with errors); filter criteria is ignored
  10 = Receive only valid messages with extended identifier; EXIDEN in RXFnSIDL must be ‘1’
  01 = Receive only valid messages with standard identifier, EXIDEN in RXFnSIDL must be ‘0’
  00 = Receive all valid messages as per EXIDEN bit in RXFnSIDL register

Mode 1, 2:
- RXM1: Receive Buffer Mode bit
  
  1 = Receive all messages (including those with errors); acceptance filters are ignored
  0 = Receive all valid messages as per acceptance filters

bit 5
Mode 0:
- RXM0: Receive Buffer Mode bit 0 (combines with RXM1 to form RXM<1:0> bits, see bit 6)

Mode 1, 2:
- RTRRO: Remote Transmission Request bit for Received Message (read-only)
  
  1 = A remote transmission request is received
  0 = A remote transmission request is not received

bit 4
Mode 0:
- Unimplemented: Read as ‘0’

Mode 1, 2:
- FILHIT4: Filter Hit bit 4
  
  This bit combines with other bits to form filter acceptance bits <4:0>.

bit 3
Mode 0:
- RXRTRRO: Remote Transmission Request bit for Received Message (read-only)
  
  1 = A remote transmission request is received
  0 = A remote transmission request is not received

Mode 1, 2:
- FILHIT3: Filter Hit bit 3
  
  This bit combines with other bits to form filter acceptance bits <4:0>.

Note 1:
- This bit is set by the CAN module upon receiving a message and must be cleared by software after the buffer is read. As long as RXFUL is set, no new message will be loaded and buffer will be considered full.
REGISTER 23-14: RXB1CON: RECEIVE BUFFER 1 CONTROL REGISTER (CONTINUED)

bit 2-0  Mode 0:
FILHIT2:FILHIT0: Filter Hit bits
These bits indicate which acceptance filter enabled the last message reception into Receive Buffer 1.

- 111 = Reserved
- 110 = Reserved
- 101 = Acceptance Filter 5 (RXF5)
- 100 = Acceptance Filter 4 (RXF4)
- 011 = Acceptance Filter 3 (RXF3)
- 010 = Acceptance Filter 2 (RXF2)
- 001 = Acceptance Filter 1 (RXF1), only possible when RXB0DBEN bit is set
- 000 = Acceptance Filter 0 (RXF0), only possible when RXB0DBEN bit is set

Mode 1, 2:
FILHIT2:FILHIT0 Filter Hit bits <2:0>
These bits, in combination with FILHIT<4:3>, indicate which acceptance filter enabled the message reception into this receive buffer.

- 01111 = Acceptance Filter 15 (RXF15)
- 01110 = Acceptance Filter 14 (RXF14)
- ...
- 00000 = Acceptance Filter 0 (RXF0)

Note 1: This bit is set by the CAN module upon receiving a message and must be cleared by software after the buffer is read. As long as RXFUL is set, no new message will be loaded and buffer will be considered full.

REGISTER 23-15: RXBnSIDH: RECEIVE BUFFER n STANDARD IDENTIFIER REGISTERS, HIGH BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th>bit 7</th>
<th>SID10</th>
<th>SID9</th>
<th>SID8</th>
<th>SID7</th>
<th>SID6</th>
<th>SID5</th>
<th>SID4</th>
<th>SID3</th>
</tr>
</thead>
</table>

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

bit 7-0  SID10:SID3: Standard Identifier bits (if EXID (RXBnSIDL<3>) = 0)
Extended Identifier bits EID28:EID21 (if EXID = 1).
REGISTER 23-16: RXBnSIDL: RECEIVE BUFFER n STANDARD IDENTIFIER REGISTERS, LOW BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th></th>
<th>SID2</th>
<th>SID1</th>
<th>SID0</th>
<th>SRR</th>
<th>EXID</th>
<th>—</th>
<th>EID17</th>
<th>EID16</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

- **SID2:SID0**: Standard Identifier bits (if EXID = 0)
  - Extended Identifier bits EID20:EID18 (if EXID = 1).
- **SRR**: Substitute Remote Request bit
  - This bit is always '0' when EXID = 1 or equal to the value of RXRTRRO (RBXnCON<3>) when EXID = 0.
- **EXID**: Extended Identifier bit
  - 1 = Received message is an extended data frame, SID10:SID0 are EID28:EID18
  - 0 = Received message is a standard data frame
- **Unimplemented**: Read as ‘0’

bit 1-0  **EID17:EID16**: Extended Identifier bits

REGISTER 23-17: RXBnEIDH: RECEIVE BUFFER n EXTENDED IDENTIFIER REGISTERS, HIGH BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th></th>
<th>EID15</th>
<th>EID14</th>
<th>EID13</th>
<th>EID12</th>
<th>EID11</th>
<th>EID10</th>
<th>EID9</th>
<th>EID8</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

- **EID15:EID8**: Extended Identifier bits

REGISTER 23-18: RXBnEIDL: RECEIVE BUFFER n EXTENDED IDENTIFIER REGISTERS, LOW BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th></th>
<th>EID7</th>
<th>EID6</th>
<th>EID5</th>
<th>EID4</th>
<th>EID3</th>
<th>EID2</th>
<th>EID1</th>
<th>EID0</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

- **EID7:EID0**: Extended Identifier bits
REGISTER 23-19: RXBnDLC: RECEIVE BUFFER n DATA LENGTH CODE REGISTERS \([0 \leq n \leq 1]\)

<table>
<thead>
<tr>
<th>U-0</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RXRTR</td>
<td>RB1</td>
<td>RB0</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
</tr>
</tbody>
</table>

Legend:

- \(R\) = Readable bit
- \(W\) = Writable 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**
  - **Unimplemented**: Read as ‘0’

- **bit 6**
  - **RXRTR**: Receiver Remote Transmission Request bit
    - 1 = Remote transfer request
    - 0 = No remote transfer request

- **bit 5**
  - **RB1**: Reserved bit 1
    - Reserved by CAN Spec and read as ‘0’.

- **bit 4**
  - **RB0**: Reserved bit 0
    - Reserved by CAN Spec and read as ‘0’.

- **bit 3-0**
  - **DLC3:DLC0**: Data Length Code bits
    - 1111 = Invalid
    - 1110 = Invalid
    - 1101 = Invalid
    - 1100 = Invalid
    - 1011 = Invalid
    - 1010 = Invalid
    - 1001 = Invalid
    - 1000 = Data length = 8 bytes
    - 0111 = Data length = 7 bytes
    - 0110 = Data length = 6 bytes
    - 0101 = Data length = 5 bytes
    - 0100 = Data length = 4 bytes
    - 0011 = Data length = 3 bytes
    - 0010 = Data length = 2 bytes
    - 0001 = Data length = 1 bytes
    - 0000 = Data length = 0 bytes

REGISTER 23-20: RXBnDm: RECEIVE BUFFER n DATA FIELD BYTE m REGISTERS
\([0 \leq n \leq 1, 0 \leq m \leq 7]\)

<table>
<thead>
<tr>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXBnDm7</td>
<td>RXBnDm6</td>
<td>RXBnDm5</td>
<td>RXBnDm4</td>
<td>RXBnDm3</td>
<td>RXBnDm2</td>
<td>RXBnDm1</td>
<td>RXBnDm0</td>
</tr>
</tbody>
</table>

Legend:

- \(R\) = Readable bit
- \(W\) = Writable bit
- \(U\) = Unimplemented bit, read as ‘0’
- \(-n\) = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- \(x\) = Bit is unknown

- **bit 7-0**
  - **RXBnDm7:RXBnDm0**: Receive Buffer n Data Field Byte m bits (where \(0 \leq n < 1\) and \(0 < m < 7\))
    - Each receive buffer has an array of registers. For example, Receive Buffer 0 has 8 registers: RXB0D0 to RXB0D7.

© 2009 Microchip Technology Inc.  DS39761C-page 295
EXAMPLE 23-5: READING A CAN MESSAGE

; Need to read a pending message from RXB0 buffer.
; To receive any message, filter, mask and RXM1:RXM0 bits in RXB0CON registers must be
; programmed correctly.
;
; Make sure that there is a message pending in RXB0.
BTFSS RXB0CON, RXFUL ; Does RXB0 contain a message?
BRA NoMessage ; No. Handle this situation...
;
; We have verified that a message is pending in RXB0 buffer.
; If this buffer can receive both Standard or Extended Identifier messages,
; identify type of message received.
BTFSS RXB0SIDL, EXID ; Is this Extended Identifier?
BRA StandardMessage ; No. This is Standard Identifier message.
;
; Yes. This is Extended Identifier message.
;
; Read all 29-bits of Extended Identifier message.

... ; Now read all data bytes
MOVFF RXB0DO, MY_DATA_BYTE1
...

; Once entire message is read, mark the RXB0 that it is read and no longer FULL.
BCF RXB0CON, RXFUL ; This will allow CAN Module to load new messages
; into this buffer.

...
23.2.3.1 Programmable TX/RX and Auto-RTR Buffers

The ECAN module contains 6 message buffers that can be programmed as transmit or receive buffers. Any of these buffers can also be programmed to automatically handle RTR messages.

**Note:** These registers are not used in Mode 0.

### REGISTER 23-22: BnCON: TX/RX BUFFER n CONTROL REGISTERS IN RECEIVE MODE

\[0 \leq n \leq 5, \text{TXnEN} (\text{BSEL<n>}) = 0\]^{(1)}

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>RXFUL(^{(2)}): Receive Full Status bit</td>
</tr>
<tr>
<td>6</td>
<td>RXM1: Receive Buffer Mode bit</td>
</tr>
<tr>
<td>5</td>
<td>RXRTRRO: Read-Only Remote Transmission Request for Received Message bit</td>
</tr>
<tr>
<td>4-0</td>
<td>FILHIT4:FILHIT0: Filter Hit bits</td>
</tr>
</tbody>
</table>

Legend:
- \(R\) = Readable bit
- \(W\) = Writable bit
- \(U\) = Unimplemented bit, read as ‘0’
- \(-n\) = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- \(x\) = Bit is unknown

**Note 1:** These registers are available in Mode 1 and 2 only.

2: This bit is set by the CAN module upon receiving a message and must be cleared by software after the buffer is read. As long as RXFUL is set, no new message will be loaded and the buffer will be considered full.
REGISTER 23-23: BnCON: TX/RX BUFFER n CONTROL REGISTERS IN TRANSMIT MODE
[0 ≤ n ≤ 5, TXnEN (BSEL0<n>) = 1](1)

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R-0</th>
<th>R-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXBIF(3)</td>
<td>TXABT(3)</td>
<td>TXLABR(3)</td>
<td>TXERR(3)</td>
<td>TXREQ(2,4)</td>
<td>RTREN</td>
<td>TXPRI1(5)</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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  TXBIF: Transmit Buffer Interrupt Flag bit(3)
1 = A message is successfully transmitted
0 = No message was transmitted

bit 6  TXABT: Transmission Aborted Status bit(3)
1 = Message was aborted
0 = Message was not aborted

bit 5  TXLABR: Transmission Lost Arbitration Status bit(3)
1 = Message lost arbitration while being sent
0 = Message did not lose arbitration while being sent

bit 4  TXERR: Transmission Error Detected Status bit(3)
1 = A bus error occurred while the message was being sent
0 = A bus error did not occur while the message was being sent

bit 3  TXREQ: Transmit Request Status bit(2,4)
1 = Requests sending a message; clears the TXABT, TXLABR and TXERR bits
0 = Automatically cleared when the message is successfully sent

bit 2  RTREN: Automatic Remote Transmission Request Enable bit
1 = When a remote transmission request is received, TXREQ will be automatically set
0 = When a remote transmission request is received, TXREQ will be unaffected

bit 1-0  TXPRI1:TXPRI0: Transmit Priority bits(5)
11 = Priority Level 3 (highest priority)
10 = Priority Level 2
01 = Priority Level 1
00 = Priority Level 0 (lowest priority)

Note 1: These registers are available in Mode 1 and 2 only.
2: Clearing this bit in software while the bit is set will request a message abort.
3: This bit is automatically cleared when TXREQ is set.
4: While TXREQ is set or transmission is in progress, transmit buffer registers remain read-only.
5: These bits set the order in which the transmit buffer will be transferred. They do not alter the CAN message identifier.
REGISTER 23-24: BnSIDH: TX/RX BUFFER n STANDARD IDENTIFIER REGISTERS, 
HIGH BYTE IN RECEIVE MODE [0 ≤ n ≤ 5, TXnEN (BSEL0<n>) = 0](1)

<table>
<thead>
<tr>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
</tr>
</tbody>
</table>

bit 7-0  SID10:SID3: Standard Identifier bits (if EXIDE (BnSIDL<3>) = 0)
        Extended Identifier bits EID28:EID21 (if EXIDE = 1).

Note 1:  These registers are available in Mode 1 and 2 only.

REGISTER 23-25: BnSIDH: TX/RX BUFFER n STANDARD IDENTIFIER REGISTERS, 
HIGH BYTE IN TRANSMIT MODE [0 ≤ n ≤ 5, TXnEN (BSEL0<n>) = 1](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
</tr>
</tbody>
</table>

bit 7-0  SID10:SID3: Standard Identifier bits (if EXIDE (BnSIDL<3>) = 0)
        Extended Identifier bits EID28:EID21 (if EXIDE = 1).

Note 1:  These registers are available in Mode 1 and 2 only.

Legend:
R = Readable bit  W = Writable bit  U = Unimplemented bit, read as ‘0’
-n = Value at POR ‘1’ = Bit is set ‘0’ = Bit is cleared  x = Bit is unknown
REGISTER 23-26: BnSIDL: TX/RX BUFFER n STANDARD IDENTIFIER REGISTERS, LOW BYTE IN RECEIVE MODE [0 ≤ n ≤ 5, TXnEN (BSEL0<n>) = 0](1)

<table>
<thead>
<tr>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>U-0</th>
<th>R-x</th>
<th>R-x</th>
<th>bit 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>SRR</td>
<td>EXID</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **W** = Writable 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  
**SID2:SID0**: Standard Identifier bits (if EXID = 0)  
Extended Identifier bits EID20:EID18 (if EXID = 1).

bit 4  
**SRR**: Substitute Remote Transmission Request bit (only when EXID = 1)
- 1 = Remote transmission request occurred
- 0 = No remote transmission request occurred

bit 3  
**EXID**: Extended Identifier Enable bit
- 1 = Received message is an extended identifier frame (SID10:SID0 are EID28:EID18)
- 0 = Received message is a standard identifier frame

bit 2  
Unimplemented: Read as ‘0’

bit 1-0  
**EID17:EID16**: Extended Identifier bits

**Note 1**: These registers are available in Mode 1 and 2 only.

REGISTER 23-27: BnSIDL: TX/RX BUFFER n STANDARD IDENTIFIER REGISTERS, LOW BYTE IN RECEIVE MODE [0 ≤ n ≤ 5, TXnEN (BSEL0<n>) = 1](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>U-0</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>bit 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDE</td>
<td>—</td>
<td>EID17</td>
<td>EID16</td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **W** = Writable 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  
**SID2:SID0**: Standard Identifier bits (if EXIDE = 0)  
Extended Identifier bits EID20:EID18 (if EXIDE = 1).

bit 4  
Unimplemented: Read as ‘0’

bit 3  
**EXIDE**: Extended Identifier Enable bit
- 1 = Received message is an extended identifier frame (SID10:SID0 are EID28:EID18)
- 0 = Received message is a standard identifier frame

bit 2  
Unimplemented: Read as ‘0’

bit 1-0  
**EID17:EID16**: Extended Identifier bits

**Note 1**: These registers are available in Mode 1 and 2 only.
REGISTER 23-28: BnEIDH: TX/RX BUFFER n EXTENDED IDENTIFIER REGISTERS, HIGH BYTE IN RECEIVE MODE \([0 \leq n \leq 5, \ TXnEN (BSEL0<n>) = 0]\)^{(1)}

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7-0</td>
<td>EID15:EID8: Extended Identifier bits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: These registers are available in Mode 1 and 2 only.

---

REGISTER 23-29: BnEIDH: TX/RX BUFFER n EXTENDED IDENTIFIER REGISTERS, HIGH BYTE IN TRANSMIT MODE \([0 \leq n \leq 5, \ TXnEN (BSEL0<n>) = 1]\)^{(1)}

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7-0</td>
<td>EID15:EID8: Extended Identifier bits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: These registers are available in Mode 1 and 2 only.

---

REGISTER 23-30: BnEIDL: TX/RX BUFFER n EXTENDED IDENTIFIER REGISTERS, LOW BYTE IN RECEIVE MODE \([0 \leq n \leq 5, \ TXnEN (BSEL<n>) = 0]\)^{(1)}

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7-0</td>
<td>EID7:EID0: Extended Identifier bits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: These registers are available in Mode 1 and 2 only.
REGISTER 23-31: BnEIDL: TX/RX BUFFER n EXTENDED IDENTIFIER REGISTERS, 
LOW BYTE IN RECEIVE MODE [0 ≤ n ≤ 5, TXnEN (BSEL<n>) = 1](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
</tr>
</tbody>
</table>

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

bit 7-0 **EID7:EID0**: Extended Identifier bits

**Note 1**: These registers are available in Mode 1 and 2 only.

REGISTER 23-32: BnDm: TX/RX BUFFER n DATA FIELD BYTE m REGISTERS IN RECEIVE MODE
[0 ≤ n ≤ 5, 0 ≤ m ≤ 7, TXnEN (BSEL<n>) = 0](1)

<table>
<thead>
<tr>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
<th>R-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>BnDm7</td>
<td>BnDm6</td>
<td>BnDm5</td>
<td>BnDm4</td>
<td>BnDm3</td>
<td>BnDm2</td>
<td>BnDm1</td>
<td>BnDm0</td>
</tr>
</tbody>
</table>

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

bit 7-0 **BnDm7:BnDm0**: Receive Buffer n Data Field Byte m bits (where 0 ≤ n < 3 and 0 < m < 8)
Each receive buffer has an array of registers. For example, Receive Buffer 0 has 7 registers: B0D0 to B0D7.

**Note 1**: These registers are available in Mode 1 and 2 only.

REGISTER 23-33: BnDm: TX/RX BUFFER n DATA FIELD BYTE m REGISTERS IN TRANSMIT MODE
[0 ≤ n ≤ 5, 0 ≤ m ≤ 7, TXnEN (BSEL<n>) = 1](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>BnDm7</td>
<td>BnDm6</td>
<td>BnDm5</td>
<td>BnDm4</td>
<td>BnDm3</td>
<td>BnDm2</td>
<td>BnDm1</td>
<td>BnDm0</td>
</tr>
</tbody>
</table>

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

bit 7-0 **BnDm7:BnDm0**: Transmit Buffer n Data Field Byte m bits (where 0 ≤ n < 3 and 0 < m < 8)
Each transmit buffer has an array of registers. For example, Transmit Buffer 0 has 7 registers: TXB0D0 to TXB0D7.

**Note 1**: These registers are available in Mode 1 and 2 only.
REGISTER 23-34: BnDLC: TX/RX BUFFER n DATA LENGTH CODE REGISTERS IN RECEIVE MODE

\[0 \leq n \leq 5, \text{TXnEN (BSEL}<n>) = 0\] \(^{(1)}\)

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0</td>
<td>R-x</td>
<td>R-x</td>
<td>R-x</td>
<td>R-x</td>
<td>R-x</td>
<td>R-x</td>
<td>R-x</td>
</tr>
<tr>
<td>—</td>
<td>RXRTR</td>
<td>RB1</td>
<td>RB0</td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit   W = Writable 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 Unimplemented: Read as ‘0’
- bit 6 RXRTR: Receiver Remote Transmission Request bit
  1 = This is a remote transmission request
  0 = This is not a remote transmission request
- bit 5 RB1: Reserved bit 1
  Reserved by CAN Spec and read as ‘0’.
- bit 4 RB0: Reserved bit 0
  Reserved by CAN Spec and read as ‘0’.
- bit 3-0 DLC3:DLC0: Data Length Code bits
  1111 = Reserved
  1110 = Reserved
  1101 = Reserved
  1100 = Reserved
  1011 = Reserved
  1010 = Reserved
  1001 = Reserved
  1000 = Data length = 8 bytes
  0111 = Data length = 7 bytes
  0110 = Data length = 6 bytes
  0101 = Data length = 5 bytes
  0100 = Data length = 4 bytes
  0011 = Data length = 3 bytes
  0010 = Data length = 2 bytes
  0001 = Data length = 1 bytes
  0000 = Data length = 0 bytes

Note 1: These registers are available in Mode 1 and 2 only.
REGISTER 23-35: BnDLC: TX/RX BUFFER n DATA LENGTH CODE REGISTERS IN TRANSMIT MODE

\[0 \leq n \leq 5, \text{TXnEN (BSEL}<n>) = 1^{(1)}\]

<table>
<thead>
<tr>
<th></th>
<th>R/W-x</th>
<th>U-0</th>
<th>U-0</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td>TXRTR</td>
<td></td>
<td></td>
<td>DLC3</td>
<td>DLC2</td>
<td>DLC1</td>
<td>DLC0</td>
</tr>
</tbody>
</table>

Legend:
- \(R\) = Readable bit
- \(W\) = Writable 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  **Unimplemented**: Read as ‘0’
bit 6  **TXRTR**: Transmitter Remote Transmission Request bit
\(1\) = Transmitted message will have RTR bit set
\(0\) = Transmitted message will have RTR bit cleared
bit 5-4  **Unimplemented**: Read as ‘0’
bit 3-0  **DLC3:DLC0**: Data Length Code bits
\(1111\) - \(1001\) = Reserved
\(1000\) = Data length = 8 bytes
\(0111\) = Data length = 7 bytes
\(0110\) = Data length = 6 bytes
\(0101\) = Data length = 5 bytes
\(0100\) = Data length = 4 bytes
\(0011\) = Data length = 3 bytes
\(0010\) = Data length = 2 bytes
\(0001\) = Data length = 1 bytes
\(0000\) = Data length = 0 bytes

Note 1: These registers are available in Mode 1 and 2 only.

REGISTER 23-36: BSEL0: BUFFER SELECT REGISTER 0^{(1)}

<table>
<thead>
<tr>
<th></th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>U-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- \(R\) = Readable bit
- \(W\) = Writable bit
- \(U\) = Unimplemented bit, read as ‘0’
- \(-n\) = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- \(x\) = Bit is unknown

bit 7-2  **B5TXEN:B0TXEN**: Buffer 5 to Buffer 0 Transmit Enable bit
\(1\) = Buffer is configured in Transmit mode
\(0\) = Buffer is configured in Receive mode
bit 1-0  **Unimplemented**: Read as ‘0’

Note 1: These registers are available in Mode 1 and 2 only.
23.2.3.2 Message Acceptance Filters and Masks

This section describes the message acceptance filters and masks for the CAN receive buffers.

REGISTER 23-37: RXFnSIDH: RECEIVE ACCEPTANCE FILTER n STANDARD IDENTIFIER FILTER REGISTERS, HIGH BYTE [0 ≤ n ≤ 15](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
</tr>
<tr>
<td></td>
<td>SID4</td>
<td>SID3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Bit 7-0

SID10:SID3: Standard Identifier Filter bits (if EXIDEN = 0)
Extended Identifier Filter bits EID28:EID21 (if EXIDEN = 1).

Note 1: Registers RXF6SIDH:RXF15SIDH are available in Mode 1 and 2 only.

REGISTER 23-38: RXFnSIDL: RECEIVE ACCEPTANCE FILTER n STANDARD IDENTIFIER FILTER REGISTERS, LOW BYTE [0 ≤ n ≤ 15](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>U-0</th>
<th>R/W-x</th>
<th>U-0</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>EXIDEN(2)</td>
<td>—</td>
<td>EID17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EID16</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit
W = Writable 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

SID2:SID0: Standard Identifier Filter bits (if EXIDEN = 0)
Extended Identifier Filter bits EID20:EID18 (if EXIDEN = 1).

bit 4
Unimplemented: Read as ‘0’

bit 3
EXIDEN: Extended Identifier Filter Enable bit(2)
1 = Filter will only accept extended ID messages
0 = Filter will only accept standard ID messages

bit 2
Unimplemented: Read as ‘0’

bit 1-0
EID17:EID16: Extended Identifier Filter bits

Note 1: Registers RXF6SIDL:RXF15SIDL are available in Mode 1 and 2 only.
2: In Mode 0, this bit must be set/cleared as required, irrespective of corresponding mask register value.
REGISTER 23-39: RXFnEIDH: RECEIVE ACCEPTANCE FILTER n EXTENDED IDENTIFIER
REGISTERS, HIGH BYTE [0 ≤ n ≤ 15](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
</tr>
</tbody>
</table>

**Legend:**
- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as '0'
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

bit 7-0

EID15:EID8: Extended Identifier Filter bits

**Note 1:** Registers RXF6EIDH:RXF15EIDH are available in Mode 1 and 2 only.

REGISTER 23-40: RXFnEIDL: RECEIVE ACCEPTANCE FILTER n EXTENDED IDENTIFIER
REGISTERS, LOW BYTE [0 ≤ n ≤ 15](1)

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
</tr>
</tbody>
</table>

**Legend:**
- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as '0'
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

bit 7-0

EID7:EID0: Extended Identifier Filter bits

**Note 1:** Registers RXF6EIDL:RXF15EIDL are available in Mode 1 and 2 only.

REGISTER 23-41: RXMnSIDH: RECEIVE ACCEPTANCE MASK n STANDARD IDENTIFIER MASK
REGISTERS, HIGH BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID10</td>
<td>SID9</td>
<td>SID8</td>
<td>SID7</td>
<td>SID6</td>
<td>SID5</td>
<td>SID4</td>
<td>SID3</td>
</tr>
</tbody>
</table>

**Legend:**
- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as '0'
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

bit 7-0

SID10:SID3: Standard Identifier Mask bits or Extended Identifier Mask bits EID28:EID21
REGISTER 23-42: RXMnSIDL: RECEIVE ACCEPTANCE MASK n STANDARD IDENTIFIER MASK REGISTERS, LOW BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>U-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>SID2</td>
<td>SID1</td>
<td>SID0</td>
<td>—</td>
<td>—</td>
<td>EXIDEN(1)</td>
<td>—</td>
<td>EID17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EID16</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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  SID2:SID0: Standard Identifier Mask bits or Extended Identifier Mask bits EID20:EID18
bit 4  Unimplemented: Read as ‘0’
bit 3  Mode 0:
Unimplemented: Read as ‘0’
Mode 1, 2:
EXIDEN: Extended Identifier Filter Enable Mask bit(1)
1 = Messages selected by the EXIDEN bit in RXFnSIDL will be accepted
0 = Both standard and extended identifier messages will be accepted
bit 2  Unimplemented: Read as ‘0’
bit 1-0  EID17:EID16: Extended Identifier Mask bits

Note 1: This bit is available in Mode 1 and 2 only.

REGISTER 23-43: RXMnEIDH: RECEIVE ACCEPTANCE MASK n EXTENDED IDENTIFIER MASK REGISTERS, HIGH BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>EID15</td>
<td>EID14</td>
<td>EID13</td>
<td>EID12</td>
<td>EID11</td>
<td>EID10</td>
<td>EID9</td>
<td>EID8</td>
</tr>
</tbody>
</table>

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

bit 7-0  EID15:EID8: Extended Identifier Mask bits

REGISTER 23-44: RXMnEIDL: RECEIVE ACCEPTANCE MASK n EXTENDED IDENTIFIER MASK REGISTERS, LOW BYTE [0 ≤ n ≤ 1]

<table>
<thead>
<tr>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
<th>R/W-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>EID7</td>
<td>EID6</td>
<td>EID5</td>
<td>EID4</td>
<td>EID3</td>
<td>EID2</td>
<td>EID1</td>
<td>EID0</td>
</tr>
</tbody>
</table>

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

bit 7-0  EID7:EID0: Extended Identifier Mask bits
REGISTER 23-45: RXFCONn: RECEIVE FILTER CONTROL REGISTER n [0 ≤ n ≤ 1](1)

<table>
<thead>
<tr>
<th></th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXF0EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF1EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF2EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF3EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF4EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF5EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF6EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXF7EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: This register is available in Mode 1 and 2 only.

Note: Register 23-46 through Register 23-51 are writable in Configuration mode only.

REGISTER 23-46: SDFLC: STANDARD DATA BYTES FILTER LENGTH COUNT REGISTER(1)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLC0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLC1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLC2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLC3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLC4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Note 1: This register is available in Mode 1 and 2 only.
<table>
<thead>
<tr>
<th>RXFBCON0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1BP_3</td>
<td>F1BP_2</td>
<td>F1BP_1</td>
<td>F1BP_0</td>
<td>F0BP_3</td>
<td>F0BP_2</td>
<td>F0BP_1</td>
<td>F0BP_0</td>
</tr>
<tr>
<td>RXFBCON1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-1</td>
</tr>
<tr>
<td></td>
<td>F3BP_3</td>
<td>F3BP_2</td>
<td>F3BP_1</td>
<td>F3BP_0</td>
<td>F2BP_3</td>
<td>F2BP_2</td>
<td>F2BP_1</td>
<td>F2BP_0</td>
</tr>
<tr>
<td>RXFBCON2</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-1</td>
</tr>
<tr>
<td></td>
<td>F5BP_3</td>
<td>F5BP_2</td>
<td>F5BP_1</td>
<td>F5BP_0</td>
<td>F4BP_3</td>
<td>F4BP_2</td>
<td>F4BP_1</td>
<td>F4BP_0</td>
</tr>
<tr>
<td>RXFBCON3</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>F7BP_3</td>
<td>F7BP_2</td>
<td>F7BP_1</td>
<td>F7BP_0</td>
<td>F6BP_3</td>
<td>F6BP_2</td>
<td>F6BP_1</td>
<td>F6BP_0</td>
</tr>
<tr>
<td>RXFBCON4</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>F9BP_3</td>
<td>F9BP_2</td>
<td>F9BP_1</td>
<td>F9BP_0</td>
<td>F8BP_3</td>
<td>F8BP_2</td>
<td>F8BP_1</td>
<td>F8BP_0</td>
</tr>
<tr>
<td>RXFBCON5</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>F11BP_3</td>
<td>F11BP_2</td>
<td>F11BP_1</td>
<td>F11BP_0</td>
<td>F10BP_3</td>
<td>F10BP_2</td>
<td>F10BP_1</td>
<td>F10BP_0</td>
</tr>
<tr>
<td>RXFBCON6</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>F13BP_3</td>
<td>F13BP_2</td>
<td>F13BP_1</td>
<td>F13BP_0</td>
<td>F12BP_3</td>
<td>F12BP_2</td>
<td>F12BP_1</td>
<td>F12BP_0</td>
</tr>
<tr>
<td>RXFBCON7</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>F15BP_3</td>
<td>F15BP_2</td>
<td>F15BP_1</td>
<td>F15BP_0</td>
<td>F14BP_3</td>
<td>F14BP_2</td>
<td>F14BP_1</td>
<td>F14BP_0</td>
</tr>
</tbody>
</table>

Legend:

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

bit 7-0  
**FnBP_3:FnBP_0**: Filter n Buffer Pointer Nibble bits

- 0000 = Filter n is associated with RXB0
- 0001 = Filter n is associated with RXB1
- 0010 = Filter n is associated with B0
- 0011 = Filter n is associated with B1
- ...
- 0111 = Filter n is associated with B5
- 1111-1000 = Reserved

**Note 1:** This register is available in Mode 1 and 2 only.
### REGISTER 23-48: MSEL0: MASK SELECT REGISTER 0\(^{(1)}\)

<table>
<thead>
<tr>
<th>FIL3_1</th>
<th>FIL3_0</th>
<th>FIL2_1</th>
<th>FIL2_0</th>
<th>FIL1_1</th>
<th>FIL1_0</th>
<th>FIL0_1</th>
<th>FIL0_0</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/W-0</td>
<td>R/W-1</td>
<td>R/W-0</td>
<td>R/W-1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>bit 7-6</th>
<th>FIL3_1:FIL3_0: Filter 3 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 5-4</th>
<th>FIL2_1:FIL2_0: Filter 2 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 3-2</th>
<th>FIL1_1:FIL1_0: Filter 1 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1-0</th>
<th>FIL0_1:FIL0_0: Filter 0 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

**Note 1:** This register is available in Mode 1 and 2 only.
REGISTER 23-49: MSEL1: MASK SELECT REGISTER 1

<table>
<thead>
<tr>
<th>bit 7-6</th>
<th>FIL7_1:FIL7_0: Filter 7 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 5-4</th>
<th>FIL6_1:FIL6_0: Filter 6 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 3-2</th>
<th>FIL5_1:FIL5_0: Filter 5 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1-0</th>
<th>FIL4_1:FIL4_0: Filter 4 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

**Note 1:** This register is available in Mode 1 and 2 only.
## REGISTER 23-50: MSEL2: MASK SELECT REGISTER 2\(^{(1)}\)

<table>
<thead>
<tr>
<th>Bit 7-6</th>
<th>FIL11_1: FIL11_0: Filter 11 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 5-4</th>
<th>FIL10_1: FIL10_0: Filter 10 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 3-2</th>
<th>FIL9_1: FIL9_0: Filter 9 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit 1-0</th>
<th>FIL8_1: FIL8_0: Filter 8 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

**Note 1:** This register is available in Mode 1 and 2 only.
REGISTER 23-51: MSEL3: MASK SELECT REGISTER 3(1)

<table>
<thead>
<tr>
<th>bit 7-6</th>
<th>FIL15_1:FIL15_0: Filter 15 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 5-4</th>
<th>FIL14_1:FIL14_0: Filter 14 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 3-2</th>
<th>FIL13_1:FIL13_0: Filter 13 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 1-0</th>
<th>FIL12_1:FIL12_0: Filter 12 Select bits 1 and 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>No mask</td>
</tr>
<tr>
<td>10</td>
<td>Filter 15</td>
</tr>
<tr>
<td>01</td>
<td>Acceptance Mask 1</td>
</tr>
<tr>
<td>00</td>
<td>Acceptance Mask 0</td>
</tr>
</tbody>
</table>

**Note 1:** This register is available in Mode 1 and 2 only.
23.2.4 CAN BAUD RATE REGISTERS

This section describes the CAN Baud Rate registers.

**Note:** These registers are writable in Configuration mode only.

### REGISTER 23-52: BRGCON1: BAUD RATE CONTROL REGISTER 1

<table>
<thead>
<tr>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJW1</td>
<td>SJW0</td>
<td>BRP5</td>
<td>BRP4</td>
<td>BRP3</td>
<td>BRP2</td>
<td>BRP1</td>
<td>BRP0</td>
</tr>
</tbody>
</table>

**Legend:**

- **R** = Readable bit
- **W** = Writable 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**

**SJW1:** Synchronized Jump Width bits

- **11** = Synchronization jump width time = 4 x Tq
- **10** = Synchronization jump width time = 3 x Tq
- **01** = Synchronization jump width time = 2 x Tq
- **00** = Synchronization jump width time = 1 x Tq

**bit 5-0**

**BRP5:** Baud Rate Prescaler bits

- **111111** = Tq = (2 x 64)/Fosc
- **111110** = Tq = (2 x 63)/Fosc
- **:**
- **000001** = Tq = (2 x 2)/Fosc
- **000000** = Tq = (2 x 1)/Fosc
REGISTER 23-53: BRGCON2: BAUD RATE CONTROL REGISTER 2

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5-3</th>
<th>bit 2-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEG2PHTS: Phase Segment 2 Time Select bit</td>
<td>SAM: Sample of the CAN bus Line bit</td>
<td>SEG1PH2:SEG1PH0: Phase Segment 1 bits</td>
<td>PRSEG2:PRSEG0: Propagation Time Select bits</td>
</tr>
<tr>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td>SEG2PHTS</td>
<td>SAM</td>
<td>SEG1PH2</td>
<td>SEG1PH1</td>
</tr>
<tr>
<td>bit 0</td>
<td>bit 0</td>
<td>bit 0</td>
<td>bit 0</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- W = Writable 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: SEG2PHTS: Phase Segment 2 Time Select bit
- 1 = Freely programmable
- 0 = Maximum of PHEG1 or Information Processing Time (IPT), whichever is greater

bit 6: SAM: Sample of the CAN bus Line bit
- 1 = Bus line is sampled three times prior to the sample point
- 0 = Bus line is sampled once at the sample point

bit 5-3: SEG1PH2:SEG1PH0: Phase Segment 1 bits
- 111 = Phase Segment 1 time = 8 x Tq
- 110 = Phase Segment 1 time = 7 x Tq
- 101 = Phase Segment 1 time = 6 x Tq
- 100 = Phase Segment 1 time = 5 x Tq
- 011 = Phase Segment 1 time = 4 x Tq
- 010 = Phase Segment 1 time = 3 x Tq
- 001 = Phase Segment 1 time = 2 x Tq
- 000 = Phase Segment 1 time = 1 x Tq

bit 2-0: PRSEG2:PRSEG0: Propagation Time Select bits
- 111 = Propagation time = 8 x Tq
- 110 = Propagation time = 7 x Tq
- 101 = Propagation time = 6 x Tq
- 100 = Propagation time = 5 x Tq
- 011 = Propagation time = 4 x Tq
- 010 = Propagation time = 3 x Tq
- 001 = Propagation time = 2 x Tq
- 000 = Propagation time = 1 x Tq
## REGISTER 23-54: BRGCON3: BAU D RATE CONTROL REGISTER 3

<table>
<thead>
<tr>
<th></th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAKDIS</td>
<td></td>
<td>WAKFIL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 7</td>
<td>WAKDIS: Wake-up Disable bit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 = Disable CAN bus activity wake-up feature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 = Enable CAN bus activity wake-up feature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 6</td>
<td>WAKFIL: Selects CAN bus Line Filter for Wake-up bit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 = Use CAN bus line filter for wake-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 = CAN bus line filter is not used for wake-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 5-3</td>
<td>Unimplemented: Read as '0'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 2-0</td>
<td>SEG2PH2:SEG2PH0: Phase Segment 2 Time Select bits(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>111 = Phase Segment 2 time = 8 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>110 = Phase Segment 2 time = 7 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>101 = Phase Segment 2 time = 6 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 = Phase Segment 2 time = 5 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>011 = Phase Segment 2 time = 4 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>010 = Phase Segment 2 time = 3 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>001 = Phase Segment 2 time = 2 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>000 = Phase Segment 2 time = 1 x Tq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Ignored if SEG2PHTS bit (BRGCON2<7>) is '0'.
23.2.5 CAN MODULE I/O CONTROL REGISTER

This register controls the operation of the CAN module’s I/O pins in relation to the rest of the microcontroller.

REGISTER 23-55: CIOCON: CAN I/O CONTROL REGISTER

<table>
<thead>
<tr>
<th>bit 7-6</th>
<th>Unimplemented: Read as ‘0’</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 5</td>
<td>ENDRHI: Enable Drive High bit(1)</td>
</tr>
<tr>
<td>1 = CANTX pin will drive VDD when recessive</td>
<td></td>
</tr>
<tr>
<td>0 = CANTX pin will be tri-state when recessive</td>
<td></td>
</tr>
<tr>
<td>bit 4</td>
<td>CANCAP: CAN Message Receive Capture Enable bit</td>
</tr>
<tr>
<td>1 = Enable CAN capture, CAN message receive signal replaces input on RC2/CCP1</td>
<td></td>
</tr>
<tr>
<td>0 = Disable CAN capture, RC2/CCP1 input to CCP1 module</td>
<td></td>
</tr>
<tr>
<td>bit 3-0</td>
<td>Unimplemented: Read as ‘0’</td>
</tr>
</tbody>
</table>

Note 1: Always set this bit when using differential bus to avoid signal crosstalk in CANTX from other nearby pins.
23.2.6 CAN INTERRUPT REGISTERS

Register 23-56 through Register 23-58 in this section are the same as described in Section 9.0 "Interrupts". They are duplicated here for convenience.

REGISTER 23-56: PIR3: PERIPHERAL INTERRUPT REQUEST (FLAG) REGISTER 3

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td>IRXIF</td>
<td>WAKIF</td>
<td>ERRIF</td>
<td>TXB2IF</td>
<td>TXB1IF</td>
<td>TXB0IF</td>
<td>RXB1IF</td>
</tr>
<tr>
<td>bit 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bit 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mode 1,2

<table>
<thead>
<tr>
<th>Mode 1,2</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit 7</td>
<td>IRXIF</td>
<td>WAKIF</td>
<td>ERRIF</td>
<td>TXBnIF</td>
<td>TXB1IF</td>
<td>TXB0IF</td>
<td>RXBnIF</td>
</tr>
<tr>
<td>bit 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  W = Writable 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  IRXIF: CAN Invalid Received Message Interrupt Flag bit
       1 = An invalid message has occurred on the CAN bus
       0 = No invalid message on CAN bus

bit 6  WAKIF: CAN bus Activity Wake-up Interrupt Flag bit
       1 = Activity on CAN bus has occurred
       0 = No activity on CAN bus

bit 5  ERRIF: CAN bus Error Interrupt Flag bit
       1 = An error has occurred in the CAN module (multiple sources)
       0 = No CAN module errors

bit 4  When CAN is in Mode 0:
       TXB2IF: CAN Transmit Buffer 2 Interrupt Flag bit
       1 = Transmit Buffer 2 has completed transmission of a message and may be reloaded
       0 = Transmit Buffer 2 has not completed transmission of a message

       When CAN is in Mode 1 or 2:
       TXBnIF: Any Transmit Buffer Interrupt Flag bit
       1 = One or more transmit buffers have completed transmission of a message and may be reloaded
       0 = No transmit buffer is ready for reload

bit 3  TXB1IF: CAN Transmit Buffer 1 Interrupt Flag bit
       1 = Transmit Buffer 1 has completed transmission of a message and may be reloaded
       0 = Transmit Buffer 1 has not completed transmission of a message

bit 2  TXB0IF: CAN Transmit Buffer 0 Interrupt Flag bit
       1 = Transmit Buffer 0 has completed transmission of a message and may be reloaded
       0 = Transmit Buffer 0 has not completed transmission of a message

bit 1  When CAN is in Mode 0:
       RXB1IF: CAN Receive Buffer 1 Interrupt Flag bit
       1 = Receive Buffer 1 has received a new message
       0 = Receive Buffer 1 has not received a new message

       When CAN is in Mode 1 or 2:
       RXBnIF: Any Receive Buffer Interrupt Flag bit
       1 = One or more receive buffers has received a new message
       0 = No receive buffer has received a new message

bit 0  When CAN is in Mode 0:
       RXB0IF: CAN Receive Buffer 0 Interrupt Flag bit
       1 = Receive Buffer 0 has received a new message
       0 = Receive Buffer 0 has not received a new message

       When CAN is in Mode 1:
       Unimplemented: Read as ‘0’

       When CAN is in Mode 2:
       FIFOWMIF: FIFO Watermark Interrupt Flag bit
       1 = FIFO high watermark is reached
       0 = FIFO high watermark is not reached

Note 1: In CAN Mode 1 and 2, these bits are forced to ‘0’.
### REGISTER 23-57: PIE3: PERIPHERAL INTERRUPT ENABLE REGISTER 3

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IRXIE</td>
<td>WAKIE</td>
<td>ERRIE</td>
<td>TXB2IE</td>
<td>TXB1IE(1)</td>
<td>TXB0IE(1)</td>
<td>RXB1IE</td>
<td>RXB0IE</td>
</tr>
<tr>
<td>Mode 1</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
<td>R/W-0</td>
</tr>
<tr>
<td></td>
<td>IRXIE</td>
<td>WAKIE</td>
<td>ERRIE</td>
<td>TXBnIE</td>
<td>TXB1IE(1)</td>
<td>TXB0IE(1)</td>
<td>RXBnIE</td>
<td>FIFOWMIE</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Mode 0</th>
<th>Mode 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>IRXIE: CAN Invalid Received Message Interrupt Enable bit</td>
<td>1 = Enable invalid message received interrupt</td>
<td>1 = Enable invalid message received interrupt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Disable invalid message received interrupt</td>
<td>0 = Disable invalid message received interrupt</td>
</tr>
<tr>
<td>6</td>
<td>WAKIE: CAN bus Activity Wake-up Interrupt Enable bit</td>
<td>1 = Enable bus activity wake-up interrupt</td>
<td>1 = Enable bus activity wake-up interrupt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Disable bus activity wake-up interrupt</td>
<td>0 = Disable bus activity wake-up interrupt</td>
</tr>
<tr>
<td>5</td>
<td>ERRIE: CAN bus Error Interrupt Enable bit</td>
<td>1 = Enable CAN bus error interrupt</td>
<td>1 = Enable CAN bus error interrupt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Disable CAN bus error interrupt</td>
<td>0 = Disable CAN bus error interrupt</td>
</tr>
<tr>
<td>4</td>
<td>When CAN is in Mode 0:</td>
<td>1 = Enable Transmit Buffer 2 interrupt</td>
<td>1 = Enable Transmit Buffer 2 interrupt</td>
</tr>
<tr>
<td></td>
<td>TXB2IE: CAN Transmit Buffer 2 Interrupt Enable bit</td>
<td>0 = Disable Transmit Buffer 2 interrupt</td>
<td>0 = Disable Transmit Buffer 2 interrupt</td>
</tr>
<tr>
<td></td>
<td>When CAN is in Mode 1 or 2:</td>
<td>1 = Enable transmit buffer interrupt; individual interrupt is enabled by TXBIE and BIE0</td>
<td>1 = Enable transmit buffer interrupt; individual interrupt is enabled by TXBIE and BIE0</td>
</tr>
<tr>
<td></td>
<td>TXBnIE: CAN Transmit Buffer Interrupts Enable bit</td>
<td>0 = Disable all transmit buffer interrupts</td>
<td>0 = Disable all transmit buffer interrupts</td>
</tr>
<tr>
<td>3</td>
<td>TXB1IE: CAN Transmit Buffer 1 Interrupt Enable bit(1)</td>
<td>1 = Enable Transmit Buffer 1 interrupt</td>
<td>1 = Enable Transmit Buffer 1 interrupt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Disable Transmit Buffer 1 interrupt</td>
<td>0 = Disable Transmit Buffer 1 interrupt</td>
</tr>
<tr>
<td>2</td>
<td>TXB0IE: CAN Transmit Buffer 0 Interrupt Enable bit(1)</td>
<td>1 = Enable Transmit Buffer 0 interrupt</td>
<td>1 = Enable Transmit Buffer 0 interrupt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Disable Transmit Buffer 0 interrupt</td>
<td>0 = Disable Transmit Buffer 0 interrupt</td>
</tr>
<tr>
<td>1</td>
<td>When CAN is in Mode 0:</td>
<td>1 = Enable Receive Buffer 1 interrupt</td>
<td>1 = Enable Receive Buffer 1 interrupt</td>
</tr>
<tr>
<td></td>
<td>RXB1IE: CAN Receive Buffer 1 Interrupt Enable bit</td>
<td>0 = Disable Receive Buffer 1 interrupt</td>
<td>0 = Disable Receive Buffer 1 interrupt</td>
</tr>
<tr>
<td></td>
<td>When CAN is in Mode 1 or 2:</td>
<td>1 = Enable receive buffer interrupt; individual interrupt is enabled by BIE0</td>
<td>1 = Enable receive buffer interrupt; individual interrupt is enabled by BIE0</td>
</tr>
<tr>
<td></td>
<td>RXBnIE: CAN Receive Buffer Interrupts Enable bit</td>
<td>0 = Disable all receive buffer interrupts</td>
<td>0 = Disable all receive buffer interrupts</td>
</tr>
<tr>
<td>0</td>
<td>When CAN is in Mode 0:</td>
<td>1 = Enable Receive Buffer 0 interrupt</td>
<td>1 = Enable Receive Buffer 0 interrupt</td>
</tr>
<tr>
<td></td>
<td>RXB0IE: CAN Receive Buffer 0 Interrupt Enable bit</td>
<td>0 = Disable Receive Buffer 0 interrupt</td>
<td>0 = Disable Receive Buffer 0 interrupt</td>
</tr>
<tr>
<td></td>
<td>When CAN is in Mode 1:</td>
<td>1 = Enable FIFO watermark interrupt</td>
<td>1 = Enable FIFO watermark interrupt</td>
</tr>
<tr>
<td></td>
<td>Unimplemented: Read as ‘0’</td>
<td>When CAN is in Mode 2:</td>
<td>0 = Disable FIFO watermark interrupt</td>
</tr>
<tr>
<td></td>
<td>FIFOWMIE: FIFO Watermark Interrupt Enable bit</td>
<td>When CAN is in Mode 2:</td>
<td>0 = Disable FIFO watermark interrupt</td>
</tr>
</tbody>
</table>

**Note 1:** In CAN Mode 1 and 2, these bits are forced to ‘0’. 

---

© 2009 Microchip Technology Inc. DS39761C-page 319
# REGISTER 23-58: IPR3: PERIPHERAL INTERRUPT PRIORITY REGISTER 3

<table>
<thead>
<tr>
<th>Mode 0</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRXIP</td>
<td>WAKIP</td>
<td>ERRIP</td>
<td>TXB2IP</td>
<td>TXB1IP</td>
<td>TXB0IP(f)</td>
<td>RXB1IP</td>
<td>RXB0IP</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode 1,2</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
<th>R/W-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRXIP</td>
<td>WAKIP</td>
<td>ERRIP</td>
<td>TXBnIP</td>
<td>TXB1IP</td>
<td>TXB0IP(f)</td>
<td>RXBnIP</td>
<td>FIFOWMIP</td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**

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

**Legend:**

- **IRXIP**: CAN Invalid Received Message Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **WAKIP**: CAN bus Activity Wake-up Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **ERRIP**: CAN bus Error Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **TXB2IP**: CAN Transmit Buffer 2 Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **TXB1IP**: CAN Transmit Buffer 1 Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **TXB0IP**: CAN Transmit Buffer 0 Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **RXB1IP**: CAN Receive Buffer 1 Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **RXB0IP**: CAN Receive Buffer 0 Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

- **FIFOWMIP**: FIFO Watermark Interrupt Priority bit
  - 1 = High priority
  - 0 = Low priority

**Note 1**: In CAN Mode 1 and 2, these bits are forced to ‘0’.
REGISTER 23-59: TXBIE: TRANSMIT BUFFERS INTERRUPT ENABLE REGISTER(1)

<table>
<thead>
<tr>
<th>bit 7-5</th>
<th>bit 4-2</th>
<th>bit 1-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXB2IE(2)</td>
<td>TXB1IE(2)</td>
<td>TXB0IE(2)</td>
</tr>
</tbody>
</table>

Legend:

- R = Readable bit
- W = Writable 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: Unimplemented: Read as ‘0’
bit 4-2: TXB2IE:TXB0IE: Transmit Buffer 2-0 Interrupt Enable bit(2)
  1 = Transmit buffer interrupt is enabled
  0 = Transmit buffer interrupt is disabled

bit 1-0: Unimplemented: Read as ‘0’

Note 1: This register is available in Mode 1 and 2 only.
2: TXBnIE in PIE3 register must be set to get an interrupt.

REGISTER 23-60: BIE0: BUFFER INTERRUPT ENABLE REGISTER 0(1)

<table>
<thead>
<tr>
<th>bit 7-2</th>
<th>bit 1-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5IE(2)</td>
<td>RXB1IE(2)</td>
</tr>
</tbody>
</table>

Legend:

- R = Readable bit
- W = Writable bit
- U = Unimplemented bit, read as ‘0’
- -n = Value at POR
- ‘1’ = Bit is set
- ‘0’ = Bit is cleared
- x = Bit is unknown

bit 7-2: B5IE:B0IE: Programmable Transmit/Receive Buffer 5-0 Interrupt Enable bit(2)
  1 = Interrupt is enabled
  0 = Interrupt is disabled

bit 1-0: RXB1IE:RXB0IE: Dedicated Receive Buffer 1-0 Interrupt Enable bit(2)
  1 = Interrupt is enabled
  0 = Interrupt is disabled

Note 1: This register is available in Mode 1 and 2 only.
2: Either TXBnIE or RXBnIE in PIE3 register must be set to get an interrupt.
### TABLE 23-1: CAN Controller Register Map

<table>
<thead>
<tr>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>F7Fh</td>
<td>SPBRGH(3)</td>
<td>F5Fh</td>
<td>CANCON_RO0</td>
<td>F3Fh</td>
<td>CANCON_RO2</td>
<td>F1Fh</td>
<td>RXM1EIDL</td>
</tr>
<tr>
<td>F7Eh</td>
<td>BAUDCON(3)</td>
<td>F5Eh</td>
<td>CANSTAT_RO0</td>
<td>F3Eh</td>
<td>CANSTAT_RO2</td>
<td>F1Eh</td>
<td>RXM1EIDH</td>
</tr>
<tr>
<td>F7Dh</td>
<td>—(4)</td>
<td>F5Dh</td>
<td>RXB1D7</td>
<td>F3Dh</td>
<td>TXB1D7</td>
<td>F1Dh</td>
<td>RXM1SIDL</td>
</tr>
<tr>
<td>F7Ch</td>
<td>—(4)</td>
<td>F5Ch</td>
<td>RXB1D6</td>
<td>F3Ch</td>
<td>TXB1D6</td>
<td>F1Ch</td>
<td>RXM1SIDH</td>
</tr>
<tr>
<td>F7Bh</td>
<td>—(4)</td>
<td>F5Bh</td>
<td>RXB1D5</td>
<td>F3Bh</td>
<td>TXB1D5</td>
<td>F1Bh</td>
<td>RXM0EIDL</td>
</tr>
<tr>
<td>F7Ah</td>
<td>—(4)</td>
<td>F5Ah</td>
<td>RXB1D4</td>
<td>F3Ah</td>
<td>TXB1D4</td>
<td>F1Ah</td>
<td>RXM0EIDH</td>
</tr>
<tr>
<td>F79h</td>
<td>ECCP1DEL(3)</td>
<td>F59h</td>
<td>RXB1D3</td>
<td>F39h</td>
<td>TXB1D3</td>
<td>F19h</td>
<td>RXM0SIDL</td>
</tr>
<tr>
<td>F78h</td>
<td>—(4)</td>
<td>F58h</td>
<td>RXB1D2</td>
<td>F38h</td>
<td>TXB1D2</td>
<td>F18h</td>
<td>RXM0SIDH</td>
</tr>
<tr>
<td>F77h</td>
<td>ECANCON</td>
<td>F57h</td>
<td>RXB1D1</td>
<td>F37h</td>
<td>TXB1D1</td>
<td>F17h</td>
<td>RXF5EIDL</td>
</tr>
<tr>
<td>F76h</td>
<td>TXERRCNT</td>
<td>F56h</td>
<td>RXB1D0</td>
<td>F36h</td>
<td>TXB1D0</td>
<td>F16h</td>
<td>RXF5EIDH</td>
</tr>
<tr>
<td>F75h</td>
<td>RXERRCNT</td>
<td>F55h</td>
<td>RXB1DLC</td>
<td>F35h</td>
<td>TXB1DLC</td>
<td>F15h</td>
<td>RXF5SIDL</td>
</tr>
<tr>
<td>F74h</td>
<td>COMSTAT</td>
<td>F54h</td>
<td>RXB1EIDL</td>
<td>F34h</td>
<td>TXB1EIDL</td>
<td>F14h</td>
<td>RXF5SIDH</td>
</tr>
<tr>
<td>F73h</td>
<td>CIOCON</td>
<td>F53h</td>
<td>RXB1EIDH</td>
<td>F33h</td>
<td>TXB1EIDH</td>
<td>F13h</td>
<td>RXF4EIDL</td>
</tr>
<tr>
<td>F72h</td>
<td>BRGCON3</td>
<td>F52h</td>
<td>RXB1SIDL</td>
<td>F32h</td>
<td>TXB1SIDL</td>
<td>F12h</td>
<td>RXF4EIDH</td>
</tr>
<tr>
<td>F71h</td>
<td>BRGCON2</td>
<td>F51h</td>
<td>RXB1SIDH</td>
<td>F31h</td>
<td>TXB1SIDH</td>
<td>F11h</td>
<td>RXF4SIDL</td>
</tr>
<tr>
<td>F70h</td>
<td>BRGCON1</td>
<td>F50h</td>
<td>RXB1CON</td>
<td>F30h</td>
<td>TXB1CON</td>
<td>F10h</td>
<td>RXF4SIDH</td>
</tr>
<tr>
<td>F6Fh</td>
<td>CANCON</td>
<td>F4Fh</td>
<td>CANCON_RO1(2)</td>
<td>F2Fh</td>
<td>CANCON_RO3(2)</td>
<td>F0Fh</td>
<td>RXF3EIDL</td>
</tr>
<tr>
<td>F6Eh</td>
<td>CANSTAT</td>
<td>F4Eh</td>
<td>CANSTAT_RO1(2)</td>
<td>F2Eh</td>
<td>CANSTAT_RO3(2)</td>
<td>F0Eh</td>
<td>RXF3EIDH</td>
</tr>
<tr>
<td>F6Dh</td>
<td>RXB0D7</td>
<td>F4Dh</td>
<td>TXB0D7</td>
<td>F2Dh</td>
<td>TXB2D7</td>
<td>F0Dh</td>
<td>RXF3SIDL</td>
</tr>
<tr>
<td>F6Ch</td>
<td>RXB0D6</td>
<td>F4Ch</td>
<td>TXB0D6</td>
<td>F2Ch</td>
<td>TXB2D6</td>
<td>F0Ch</td>
<td>RXF3SIDH</td>
</tr>
<tr>
<td>F6Bh</td>
<td>RXB0D5</td>
<td>F4Bh</td>
<td>TXB0D5</td>
<td>F2Bh</td>
<td>TXB2D5</td>
<td>F0Bh</td>
<td>RXF2EIDL</td>
</tr>
<tr>
<td>F6Ah</td>
<td>RXB0D4</td>
<td>F4Ah</td>
<td>TXB0D4</td>
<td>F2Ah</td>
<td>TXB2D4</td>
<td>F0Ah</td>
<td>RXF2EIDH</td>
</tr>
<tr>
<td>F69h</td>
<td>RXB0D3</td>
<td>F49h</td>
<td>TXB0D3</td>
<td>F29h</td>
<td>TXB2D3</td>
<td>F09h</td>
<td>RXF2SIDL</td>
</tr>
<tr>
<td>F68h</td>
<td>RXB0D2</td>
<td>F48h</td>
<td>TXB0D2</td>
<td>F28h</td>
<td>TXB2D2</td>
<td>F08h</td>
<td>RXF2SIDH</td>
</tr>
<tr>
<td>F67h</td>
<td>RXB0D1</td>
<td>F47h</td>
<td>TXB0D1</td>
<td>F27h</td>
<td>TXB2D1</td>
<td>F07h</td>
<td>RXF1EIDL</td>
</tr>
<tr>
<td>F66h</td>
<td>RXB0D0</td>
<td>F46h</td>
<td>TXB0D0</td>
<td>F26h</td>
<td>TXB2D0</td>
<td>F06h</td>
<td>RXF1EIDH</td>
</tr>
<tr>
<td>F65h</td>
<td>RXB0DLC</td>
<td>F45h</td>
<td>TXB0DLC</td>
<td>F25h</td>
<td>TXB2DLC</td>
<td>F05h</td>
<td>RXF1SIDL</td>
</tr>
<tr>
<td>F64h</td>
<td>RXB0EIDL</td>
<td>F44h</td>
<td>TXB0EIDL</td>
<td>F24h</td>
<td>TXB2EIDL</td>
<td>F04h</td>
<td>RXF1SIDH</td>
</tr>
<tr>
<td>F63h</td>
<td>RXB0EIDH</td>
<td>F43h</td>
<td>TXB0EIDH</td>
<td>F23h</td>
<td>TXB2EIDH</td>
<td>F03h</td>
<td>RXF0EIDL</td>
</tr>
<tr>
<td>F62h</td>
<td>RXB0SIDL</td>
<td>F42h</td>
<td>TXB0SIDL</td>
<td>F22h</td>
<td>TXB2SIDL</td>
<td>F02h</td>
<td>RXF0EIDH</td>
</tr>
<tr>
<td>F61h</td>
<td>RXB0SIDH</td>
<td>F41h</td>
<td>TXB0SIDH</td>
<td>F21h</td>
<td>TXB2SIDH</td>
<td>F01h</td>
<td>RXF0SIDL</td>
</tr>
<tr>
<td>F60h</td>
<td>RXB0CON</td>
<td>F40h</td>
<td>TXB0CON</td>
<td>F20h</td>
<td>TXB2CON</td>
<td>F00h</td>
<td>RXF0SIDH</td>
</tr>
</tbody>
</table>

**Note 1:** Shaded registers are available in Access Bank low area, while the rest are available in Bank 15.

**Note 2:** CANSTAT register is repeated in these locations to simplify application firmware. Unique names are given for each instance of the controller register due to the Microchip header file requirement.

**Note 3:** These registers are not CAN registers.

**Note 4:** Unimplemented registers are read as '0'.
### TABLE 23-1: CAN CONTROLLER REGISTER MAP (CONTINUED)

<table>
<thead>
<tr>
<th>Address(1)</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFBh</td>
<td>_</td>
<td>(4)</td>
<td>EDFh</td>
<td>_</td>
<td>(4)</td>
<td>EBFh</td>
<td>_</td>
</tr>
<tr>
<td>EFEh</td>
<td>_</td>
<td>(4)</td>
<td>EDEh</td>
<td>_</td>
<td>(4)</td>
<td>EBEh</td>
<td>_</td>
</tr>
<tr>
<td>EFDh</td>
<td>_</td>
<td>(4)</td>
<td>EDDh</td>
<td>_</td>
<td>(4)</td>
<td>EBDh</td>
<td>_</td>
</tr>
<tr>
<td>EFCh</td>
<td>_</td>
<td>(4)</td>
<td>EDCh</td>
<td>_</td>
<td>(4)</td>
<td>EBCh</td>
<td>_</td>
</tr>
<tr>
<td>EF Bh</td>
<td>_</td>
<td>(4)</td>
<td>EDBh</td>
<td>_</td>
<td>(4)</td>
<td>EBBh</td>
<td>_</td>
</tr>
<tr>
<td>EFAh</td>
<td>_</td>
<td>(4)</td>
<td>EDAh</td>
<td>_</td>
<td>(4)</td>
<td>EBAh</td>
<td>_</td>
</tr>
<tr>
<td>EFa</td>
<td>_</td>
<td>(4)</td>
<td>EDAh</td>
<td>_</td>
<td>(4)</td>
<td>EBAh</td>
<td>_</td>
</tr>
<tr>
<td>EF9h</td>
<td>_</td>
<td>(4)</td>
<td>ED9h</td>
<td>_</td>
<td>(4)</td>
<td>EB9h</td>
<td>_</td>
</tr>
<tr>
<td>EF8h</td>
<td>_</td>
<td>(4)</td>
<td>ED8h</td>
<td>_</td>
<td>(4)</td>
<td>EB8h</td>
<td>_</td>
</tr>
<tr>
<td>EF7h</td>
<td>_</td>
<td>(4)</td>
<td>ED7h</td>
<td>_</td>
<td>(4)</td>
<td>EB7h</td>
<td>_</td>
</tr>
<tr>
<td>EF6h</td>
<td>_</td>
<td>(4)</td>
<td>ED6h</td>
<td>_</td>
<td>(4)</td>
<td>EB6h</td>
<td>_</td>
</tr>
<tr>
<td>EF5h</td>
<td>_</td>
<td>(4)</td>
<td>ED5h</td>
<td>_</td>
<td>(4)</td>
<td>EB5h</td>
<td>_</td>
</tr>
<tr>
<td>EF4h</td>
<td>_</td>
<td>(4)</td>
<td>ED4h</td>
<td>_</td>
<td>(4)</td>
<td>EB4h</td>
<td>_</td>
</tr>
<tr>
<td>EF3h</td>
<td>_</td>
<td>(4)</td>
<td>ED3h</td>
<td>_</td>
<td>(4)</td>
<td>EB3h</td>
<td>_</td>
</tr>
<tr>
<td>EF2h</td>
<td>_</td>
<td>(4)</td>
<td>ED2h</td>
<td>_</td>
<td>(4)</td>
<td>EB2h</td>
<td>_</td>
</tr>
<tr>
<td>EF1h</td>
<td>_</td>
<td>(4)</td>
<td>ED1h</td>
<td>_</td>
<td>(4)</td>
<td>EB1h</td>
<td>_</td>
</tr>
<tr>
<td>EF0h</td>
<td>_</td>
<td>(4)</td>
<td>EDOh</td>
<td>_</td>
<td>(4)</td>
<td>EBOh</td>
<td>_</td>
</tr>
<tr>
<td>EEFh</td>
<td>_</td>
<td>(4)</td>
<td>ECFh</td>
<td>_</td>
<td>(4)</td>
<td>EAfh</td>
<td>_</td>
</tr>
<tr>
<td>EE Eh</td>
<td>_</td>
<td>(4)</td>
<td>ECEh</td>
<td>_</td>
<td>(4)</td>
<td>EAeh</td>
<td>_</td>
</tr>
<tr>
<td>EEDh</td>
<td>_</td>
<td>(4)</td>
<td>ECDh</td>
<td>_</td>
<td>(4)</td>
<td>EAdh</td>
<td>_</td>
</tr>
<tr>
<td>EECh</td>
<td>_</td>
<td>(4)</td>
<td>ECCh</td>
<td>_</td>
<td>(4)</td>
<td>EArch</td>
<td>_</td>
</tr>
<tr>
<td>EEBh</td>
<td>_</td>
<td>(4)</td>
<td>ECBh</td>
<td>_</td>
<td>(4)</td>
<td>EABh</td>
<td>_</td>
</tr>
<tr>
<td>EEAh</td>
<td>_</td>
<td>(4)</td>
<td>ECAh</td>
<td>_</td>
<td>(4)</td>
<td>EAh</td>
<td>_</td>
</tr>
<tr>
<td>EE9h</td>
<td>_</td>
<td>(4)</td>
<td>EC9h</td>
<td>_</td>
<td>(4)</td>
<td>E9h</td>
<td>_</td>
</tr>
<tr>
<td>EE8h</td>
<td>_</td>
<td>(4)</td>
<td>EC8h</td>
<td>_</td>
<td>(4)</td>
<td>E8h</td>
<td>_</td>
</tr>
<tr>
<td>EE7h</td>
<td>_</td>
<td>(4)</td>
<td>EC7h</td>
<td>_</td>
<td>(4)</td>
<td>E7h</td>
<td>_</td>
</tr>
<tr>
<td>EE6h</td>
<td>_</td>
<td>(4)</td>
<td>EC6h</td>
<td>_</td>
<td>(4)</td>
<td>E6h</td>
<td>_</td>
</tr>
<tr>
<td>EE5h</td>
<td>_</td>
<td>(4)</td>
<td>EC5h</td>
<td>_</td>
<td>(4)</td>
<td>E5h</td>
<td>_</td>
</tr>
<tr>
<td>EE4h</td>
<td>_</td>
<td>(4)</td>
<td>EC4h</td>
<td>_</td>
<td>(4)</td>
<td>E4h</td>
<td>_</td>
</tr>
<tr>
<td>EE3h</td>
<td>_</td>
<td>(4)</td>
<td>EC3h</td>
<td>_</td>
<td>(4)</td>
<td>E3h</td>
<td>_</td>
</tr>
<tr>
<td>EE2h</td>
<td>_</td>
<td>(4)</td>
<td>EC2h</td>
<td>_</td>
<td>(4)</td>
<td>E2h</td>
<td>_</td>
</tr>
<tr>
<td>EE1h</td>
<td>_</td>
<td>(4)</td>
<td>EC1h</td>
<td>_</td>
<td>(4)</td>
<td>E1h</td>
<td>_</td>
</tr>
<tr>
<td>EE0h</td>
<td>_</td>
<td>(4)</td>
<td>EC0h</td>
<td>_</td>
<td>(4)</td>
<td>E0h</td>
<td>_</td>
</tr>
</tbody>
</table>

**Note 1:** Shaded registers are available in Access Bank low area, while the rest are available in Bank 15.

**Note 2:** CANSTAT register is repeated in these locations to simplify application firmware. Unique names are given for each instance of the controller register due to the Microchip header file requirement.

**Note 3:** These registers are not CAN registers.

**Note 4:** Unimplemented registers are read as ‘0’.
### TABLE 23-1: CAN CONTROLLER REGISTER MAP (CONTINUED)

<table>
<thead>
<tr>
<th>Address(1)</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>E7Fh</td>
<td>CANCON_RO4(2)</td>
<td>E5Fh</td>
<td>CANCON_RO6(2)</td>
<td>E3Fh</td>
<td>CANSTAT_RO8(2)</td>
<td>E1Fh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E7Eh</td>
<td>B5D7</td>
<td>E5Dh</td>
<td>B3D7</td>
<td>E3Dh</td>
<td>B1D7</td>
<td>E1Dh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E7Dh</td>
<td>B5D6</td>
<td>E5Ch</td>
<td>B3D6</td>
<td>E3Ch</td>
<td>B1D6</td>
<td>E1Ch</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E7Bh</td>
<td>B5D5</td>
<td>E5Bh</td>
<td>B3D5</td>
<td>E3Bh</td>
<td>B1D5</td>
<td>E1Bh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E7Ah</td>
<td>B5D4</td>
<td>E5Ah</td>
<td>B3D4</td>
<td>E3Ah</td>
<td>B1D4</td>
<td>E1Ah</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E79h</td>
<td>B5D3</td>
<td>E59h</td>
<td>B3D3</td>
<td>E39h</td>
<td>B1D3</td>
<td>E19h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E78h</td>
<td>B5D2</td>
<td>E58h</td>
<td>B3D2</td>
<td>E38h</td>
<td>B1D2</td>
<td>E18h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E77h</td>
<td>B5D1</td>
<td>E57h</td>
<td>B3D1</td>
<td>E37h</td>
<td>B1D1</td>
<td>E17h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E76h</td>
<td>B5D0</td>
<td>E56h</td>
<td>B3D0</td>
<td>E36h</td>
<td>B1D0</td>
<td>E16h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E75h</td>
<td>B5DLC</td>
<td>E55h</td>
<td>B3DLC</td>
<td>E35h</td>
<td>B1DLC</td>
<td>E15h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E74h</td>
<td>B5EIDL</td>
<td>E54h</td>
<td>B3EIDL</td>
<td>E34h</td>
<td>B1EIDL</td>
<td>E14h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E73h</td>
<td>B5EIDH</td>
<td>E53h</td>
<td>B3EIDH</td>
<td>E33h</td>
<td>B1EIDH</td>
<td>E13h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E72h</td>
<td>B5SIDL</td>
<td>E52h</td>
<td>B3SIDL</td>
<td>E32h</td>
<td>B1SIDL</td>
<td>E12h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E71h</td>
<td>B5SIDH</td>
<td>E51h</td>
<td>B3SIDH</td>
<td>E31h</td>
<td>B1SIDH</td>
<td>E11h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E70h</td>
<td>B5CON</td>
<td>E50h</td>
<td>B3CON</td>
<td>E30h</td>
<td>B1CON</td>
<td>E10h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E6Fh</td>
<td>CANCON_RO5</td>
<td>E4Fh</td>
<td>CANCON_RO7</td>
<td>E2Fh</td>
<td>CANCON_RO9</td>
<td>E0Fh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E6Eh</td>
<td>CANSTAT_RO5</td>
<td>E4Eh</td>
<td>CANSTAT_RO7</td>
<td>E2Eh</td>
<td>CANSTAT_RO9</td>
<td>E0Eh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E6Dh</td>
<td>B4D7</td>
<td>E4Dh</td>
<td>B2D7</td>
<td>E2Dh</td>
<td>B0D7</td>
<td>E0Dh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E6Ch</td>
<td>B4D6</td>
<td>E4Ch</td>
<td>B2D6</td>
<td>E2Ch</td>
<td>B0D6</td>
<td>E0Ch</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E68h</td>
<td>B4D5</td>
<td>E4Bh</td>
<td>B2D5</td>
<td>E2Bh</td>
<td>B0D5</td>
<td>E0Bh</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E6Ah</td>
<td>B4D4</td>
<td>E4Ah</td>
<td>B2D4</td>
<td>E2Ah</td>
<td>B0D4</td>
<td>E0Ah</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E69h</td>
<td>B4D3</td>
<td>E49h</td>
<td>B2D3</td>
<td>E29h</td>
<td>B0D3</td>
<td>E09h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E68h</td>
<td>B4D2</td>
<td>E48h</td>
<td>B2D2</td>
<td>E28h</td>
<td>B0D2</td>
<td>E08h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E67h</td>
<td>B4D1</td>
<td>E47h</td>
<td>B2D1</td>
<td>E27h</td>
<td>B0D1</td>
<td>E07h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E66h</td>
<td>B4D0</td>
<td>E46h</td>
<td>B2D0</td>
<td>E26h</td>
<td>B0D0</td>
<td>E06h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E65h</td>
<td>B4DLC</td>
<td>E45h</td>
<td>B2DLC</td>
<td>E25h</td>
<td>B0DLC</td>
<td>E05h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E64h</td>
<td>B4EIDL</td>
<td>E44h</td>
<td>B2EIDL</td>
<td>E24h</td>
<td>B0EIDL</td>
<td>E04h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E63h</td>
<td>B4EIDH</td>
<td>E43h</td>
<td>B2EIDH</td>
<td>E23h</td>
<td>B0EIDH</td>
<td>E03h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E62h</td>
<td>B4SIDL</td>
<td>E42h</td>
<td>B2SIDL</td>
<td>E22h</td>
<td>B0SIDL</td>
<td>E02h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E61h</td>
<td>B4SIDH</td>
<td>E41h</td>
<td>B2SIDH</td>
<td>E21h</td>
<td>B0SIDH</td>
<td>E01h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>E60h</td>
<td>B4CON</td>
<td>E40h</td>
<td>B2CON</td>
<td>E20h</td>
<td>B0CON</td>
<td>E00h</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
</tbody>
</table>

**Note 1:** Shaded registers are available in Access Bank low area, while the rest are available in Bank 15.

**Note 2:** CANSTAT register is repeated in these locations to simplify application firmware. Unique names are given for each instance of the controller register due to the Microchip header file requirement.

**Note 3:** These registers are not CAN registers.

**Note 4:** Unimplemented registers are read as '0'.
<table>
<thead>
<tr>
<th>Address(1)</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFFh</td>
<td>...</td>
<td>DDFh</td>
<td>...</td>
<td>DBFh</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
</tr>
<tr>
<td>DFEh</td>
<td>...</td>
<td>DDEh</td>
<td>...</td>
<td>DDFh</td>
<td>...</td>
<td>D9Eh</td>
<td>...</td>
</tr>
<tr>
<td>DFDh</td>
<td>...</td>
<td>DDDh</td>
<td>...</td>
<td>DBFh</td>
<td>...</td>
<td>D9Dh</td>
<td>...</td>
</tr>
<tr>
<td>DFCh</td>
<td>TXBIE</td>
<td>DDCh</td>
<td>...</td>
<td>DBFh</td>
<td>...</td>
<td>D9Ch</td>
<td>...</td>
</tr>
<tr>
<td>DBFh</td>
<td>...</td>
<td>DBDh</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
<td>D9Bh</td>
<td>...</td>
</tr>
<tr>
<td>DFAh</td>
<td>BIE0</td>
<td>DDAh</td>
<td>...</td>
<td>DBFh</td>
<td>...</td>
<td>D9Ah</td>
<td>...</td>
</tr>
<tr>
<td>D9Fh</td>
<td>...</td>
<td>D9dh</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
<td>D99h</td>
<td>...</td>
</tr>
<tr>
<td>D9Eh</td>
<td>...</td>
<td>D9Dh</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
<td>D9Bh</td>
<td>...</td>
</tr>
<tr>
<td>D9Dh</td>
<td>...</td>
<td>D9Ch</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
<td>D9Ah</td>
<td>...</td>
</tr>
<tr>
<td>D9Ch</td>
<td>...</td>
<td>D9Bh</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
<td>D9Ah</td>
<td>...</td>
</tr>
<tr>
<td>D9Bh</td>
<td>...</td>
<td>D9Ah</td>
<td>...</td>
<td>D9Fh</td>
<td>...</td>
<td>D9Ah</td>
<td>...</td>
</tr>
</tbody>
</table>

**Note 1:** Shaded registers are available in Access Bank low area, while the rest are available in Bank 15.

**Note 2:** CANSTAT register is repeated in these locations to simplify application firmware. Unique names are given for each instance of the controller register due to the Microchip header file requirement.

**Note 3:** These registers are not CAN registers.

**Note 4:** Unimplemented registers are read as '0'.
TABLE 23-1: CAN CONTROLLER REGISTER MAP (CONTINUED)

<table>
<thead>
<tr>
<th>Address(1)</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>D7Fh</td>
<td>—(4)</td>
</tr>
<tr>
<td>D7Eh</td>
<td>—(4)</td>
</tr>
<tr>
<td>D7Dh</td>
<td>—(4)</td>
</tr>
<tr>
<td>D7Ch</td>
<td>—(4)</td>
</tr>
<tr>
<td>D7Bh</td>
<td>RXF11EIDL</td>
</tr>
<tr>
<td>D7Ah</td>
<td>RXF11EIDH</td>
</tr>
<tr>
<td>D79h</td>
<td>RXF11SIDL</td>
</tr>
<tr>
<td>D78h</td>
<td>RXF11SIDH</td>
</tr>
<tr>
<td>D77h</td>
<td>RXF10EIDL</td>
</tr>
<tr>
<td>D76h</td>
<td>RXF10EIDH</td>
</tr>
<tr>
<td>D75h</td>
<td>RXF10SIDL</td>
</tr>
<tr>
<td>D74h</td>
<td>RXF10SIDH</td>
</tr>
<tr>
<td>D73h</td>
<td>RXF9EIDL</td>
</tr>
<tr>
<td>D72h</td>
<td>RXF9EIDH</td>
</tr>
<tr>
<td>D71h</td>
<td>RXF9SIDL</td>
</tr>
<tr>
<td>D70h</td>
<td>RXF9SIDH</td>
</tr>
<tr>
<td>D6Fh</td>
<td>—(4)</td>
</tr>
<tr>
<td>D6Eh</td>
<td>—(4)</td>
</tr>
<tr>
<td>D6Dh</td>
<td>—(4)</td>
</tr>
<tr>
<td>D6Ch</td>
<td>—(4)</td>
</tr>
<tr>
<td>D6Bh</td>
<td>RXF8EIDL</td>
</tr>
<tr>
<td>D6Ah</td>
<td>RXF8EIDH</td>
</tr>
<tr>
<td>D69h</td>
<td>RXF8SIDL</td>
</tr>
<tr>
<td>D68h</td>
<td>RXF8SIDH</td>
</tr>
<tr>
<td>D67h</td>
<td>RXF7EIDL</td>
</tr>
<tr>
<td>D66h</td>
<td>RXF7EIDH</td>
</tr>
<tr>
<td>D65h</td>
<td>RXF7SIDL</td>
</tr>
<tr>
<td>D64h</td>
<td>RXF7SIDH</td>
</tr>
<tr>
<td>D63h</td>
<td>RXF6EIDL</td>
</tr>
<tr>
<td>D62h</td>
<td>RXF6EIDH</td>
</tr>
<tr>
<td>D61h</td>
<td>RXF6SIDL</td>
</tr>
<tr>
<td>D60h</td>
<td>RXF6SIDH</td>
</tr>
</tbody>
</table>

**Note 1:** Shaded registers are available in Access Bank low area while the rest are available in Bank 15.

**Note 2:** CANSTAT register is repeated in these locations to simplify application firmware. Unique names are given for each instance of the controller register due to the Microchip header file requirement.

**Note 3:** These registers are not CAN registers.

**Note 4:** Unimplemented registers are read as ‘0’.
23.3 CAN Modes of Operation

The PIC18F2682/2685/4682/4685 has six main modes of operation:

- Configuration mode
- Disable mode
- Normal Operation mode
- Listen Only mode
- Loopback mode
- Error Recognition mode

All modes, except Error Recognition, are requested by setting the REQOP bits (CANCON<7:5>). Error Recognition mode is requested through the RXM bits of the Receive Buffer register(s). Entry into a mode is acknowledged by monitoring the OPMODE bits.

When changing modes, the mode will not actually change until all pending message transmissions are complete. Because of this, the user must verify that the device has actually changed into the requested mode before further operations are executed.

23.3.1 CONFIGURATION MODE

The CAN module has to be initialized before the activation. This is only possible if the module is in the Configuration mode. The Configuration mode is requested by setting the REQOP2 bit. Only when the status bit, OPMODE2, has a high level can the initialization be performed. Afterwards, the Configuration registers, the Acceptance Mask registers and the Acceptance Filter registers can be written. The module is activated by setting the REQOP control bits to zero.

The module will protect the user from accidentally violating the CAN protocol through programming errors. All registers which control the configuration of the module can not be modified while the module is online. The CAN module will not be allowed to enter the Configuration mode while a transmission or reception is taking place. The Configuration mode serves as a lock to protect the following registers:

- Configuration Registers
- Functional Mode Selection Registers
- Bit Timing Registers
- Identifier Acceptance Filter Registers
- Identifier Acceptance Mask Registers
- Filter and Mask Control Registers
- Mask Selection Registers

In the Configuration mode, the module will not transmit or receive. The error counters are cleared and the interrupt flags remain unchanged. The programmer will have access to Configuration registers that are access restricted in other modes.

23.3.2 DISABLE MODE

In Disable mode, the module will not transmit or receive. The module has the ability to set the WAKIF bit due to bus activity; however, any pending interrupts will remain and the error counters will retain their value.

If the REQOP<2:0> bits are set to ‘001’, the module will enter the module Disable mode. This mode is similar to disabling other peripheral modules by turning off the module enables. This causes the module internal clock to stop unless the module is active (i.e., receiving or transmitting a message). If the module is active, the module will wait for 11 recessive bits on the CAN bus, detect that condition as an Idle bus, then accept the module disable command. OPMODE<2:0> = 001 indicates whether the module successfully went into the module Disable mode.

The WAKIF interrupt is the only module interrupt that is still active in the Disable mode. If the WAKDIS is cleared and WAKIE is set, the processor will receive an interrupt whenever the module detects recessive to dominant transition. On wake-up, the module will automatically be set to the previous mode of operation. For example, if the module was switched from Normal to Disable mode on bus activity wake-up, the module will automatically enter into Normal mode and the first message that caused the module to wake-up is lost. The module will not generate any error frame. Firmware logic must detect this condition and make sure that retransmission is requested. If the processor receives a wake-up interrupt while it is sleeping, more than one message may get lost. The actual number of messages lost would depend on the processor oscillator start-up time and incoming message bit rate.

The I/O pins will revert to normal I/O function when the module is in the Disable mode.

23.3.3 NORMAL MODE

This is the standard operating mode of the PIC18F2682/2685/4682/4685 devices. In this mode, the device actively monitors all bus messages and generates Acknowledge bits, error frames, etc. This is also the only mode in which the PIC18F2682/2685/4682/4685 devices will transmit messages over the CAN bus.
23.3.4 LISTEN ONLY MODE

Listen Only mode provides a means for the PIC18F2682/2685/4682/4685 devices to receive all messages, including messages with errors. This mode can be used for bus monitor applications or for detecting the baud rate in 'hot plugging' situations. For Auto-Baud Detection, it is necessary that there are at least two other nodes which are communicating with each other. The baud rate can be detected empirically by testing different values until valid messages are received. The Listen Only mode is a silent mode, meaning no messages will be transmitted while in this state, including error flags or Acknowledge signals. The filters and masks can be used to allow only particular messages to be loaded into the receive registers or the filter masks can be set to all zeros to allow a message with any identifier to pass. The error counters are reset and deactivated in this state. The Listen Only mode is activated by setting the mode request bits in the CANCON register.

23.3.5 LOOPBACK MODE

This mode will allow internal transmission of messages from the transmit buffers to the receive buffers without actually transmitting messages on the CAN bus. This mode can be used in system development and testing. In this mode, the ACK bit is ignored and the device will allow incoming messages from itself, just as if they were coming from another node. The Loopback mode is a silent mode, meaning no messages will be transmitted while in this state, including error flags or Acknowledge signals. The TXCAN pin will revert to port I/O while the device is in this mode. The filters and masks can be used to allow only particular messages to be loaded into the receive registers. The masks can be set to all zeros to provide a mode that accepts all messages. The Loopback mode is activated by setting the mode request bits in the CANCON register.

23.3.6 ERROR RECOGNITION MODE

The module can be set to ignore all errors and receive any message. In functional Mode 0, the Error Recognition mode is activated by setting the RXM<1:0> bits in the RXBnCON registers to '11'. In this mode, the data which is in the message assembly buffer until the error time, is copied in the receive buffer and can be read via the CPU interface.

23.4 ECAN Module Functional Modes

In addition to CAN modes of operation, the ECAN module offers a total of 3 functional modes. Each of these modes are identified as Mode 0, Mode 1 and Mode 2.

23.4.1 MODE 0 – LEGACY MODE

Mode 0 is designed to be fully compatible with CAN modules used in PIC18CXX8 and PIC18FXX8 devices. This is the default mode of operation on all Reset conditions. As a result, module code written for the PIC18XX8 CAN module may be used on the ECAN module without any code changes.

The following is the list of resources available in Mode 0:

- Three transmit buffers: TXB0, TXB1 and TXB2
- Two receive buffers: RXB0 and RXB1
- Two acceptance masks, one for each receive buffer: RXM0, RXM1
- Six acceptance filters, 2 for RXB0 and 4 for RXB1: RXF0, RXF1, RXF2, RXF3, RXF4, RXF5

23.4.2 MODE 1 – ENHANCED LEGACY MODE

Mode 1 is similar to Mode 0, with the exception that more resources are available in Mode 1. There are 16 acceptance filter registers and two acceptance mask registers. Acceptance Filter 15 can be used as either an acceptance filter or an acceptance mask register. In addition to three transmit and two receive buffers, there are six more message buffers. One or more of these additional buffers can be programmed as transmit or receive buffers. These additional buffers can also be programmed to automatically handle RTR messages.

Fourteen of sixteen acceptance filter registers can be dynamically associated to any receive buffer and acceptance mask register. One can use this capability to associate more than one filter to any one buffer.

When a receive buffer is programmed to use standard identifier messages, part of the full acceptance filter register can be used as a data byte filter. The length of the data byte filter is programmable from 0 to 18 bits. This functionality simplifies implementation of high-level protocols, such as the DeviceNet™ protocol.

The following is the list of resources available in Mode 1:

- Three transmit buffers: TXB0, TXB1 and TXB2
- Two receive buffers: RXB0 and RXB1
- Six buffers programmable as TX or RX: B0-B5
- Automatic RTR handling on B0-B5
- Sixteen dynamically assigned acceptance filters: RXF0-RXF15
- Two dedicated acceptance mask registers; RXF15 programmable as third mask: RXM0-RXM1, RXF15
- Programmable data filter on standard identifier messages: SDFLC
23.4.3 MODE 2 – ENHANCED FIFO MODE

In Mode 2, two or more receive buffers are used to form the receive FIFO (first in, first out) buffer. There is no one-to-one relationship between the receive buffer and acceptance filter registers. Any filter that is enabled and linked to any FIFO receive buffer can generate acceptance and cause FIFO to be updated.

FIFO length is user programmable, from 2-8 buffers deep. FIFO length is determined by the very first programmable buffer that is configured as a transmit buffer. For example, if Buffer 2 (B2) is programmed as a transmit buffer, FIFO consists of RXB0, RXB1, B0 and B1 – creating a FIFO length of 4. If all programmable buffers are configured as receive buffers, FIFO will have the maximum length of 8.

The following is the list of resources available in Mode 2:

- Three transmit buffers: TXB0, TXB1 and TXB2
- Two receive buffers: RXB0 and RXB1
- Six buffers programmable as TX or RX; receive buffers form FIFO: B0-B5
- Automatic RTR handling on B0-B5
- Sixteen acceptance filters: RXF0-RXF15
- Two dedicated acceptance mask registers; RXF15 programmable as third mask: RXM0-RXM1, RXF15
- Programmable data filter on standard identifier messages: SDFLC, useful for DeviceNet protocol

23.5 CAN Message Buffers

23.5.1 DEDICATED TRANSMIT BUFFERS

The PIC18F2682/2685/4682/4685 devices implement three dedicated transmit buffers – TXB0, TXB1 and TXB2. Each of these buffers occupies 14 bytes of SRAM and are mapped into the SFR memory map. These are the only transmit buffers available in Mode 0. Mode 1 and 2 may access these and other additional buffers.

Each transmit buffer contains one control register (TXBnCON), four identifier registers (TXBnSIDL, TXBnSIDH, TXBnEIDL, TXBnEIDH), one data length count register (TXBnDLC) and eight data byte registers (TXBnDm).

23.5.2 DEDICATED RECEIVE BUFFERS

The PIC18F2682/2685/4682/4685 devices implement two dedicated receive buffers – RXB0 and RXB1. Each of these buffers occupies 14 bytes of SRAM and are mapped into SFR memory map. These are the only receive buffers available in Mode 0. Mode 1 and 2 may access these and other additional buffers.

Each receive buffer contains one control register (RXBnCON), four identifier registers (RXBnSIDL, RXBnSIDH, RXBnEIDL, RXBnEIDH), one data length count register (RXBnDLC) and eight data byte registers (RXBnDm).

There is also a separate Message Assembly Buffer (MAB) which acts as an additional receive buffer. MAB is always committed to receiving the next message from the bus and is not directly accessible to user firmware. The MAB assembles all incoming messages one by one. A message is transferred to appropriate receive buffers only if the corresponding acceptance filter criteria is met.

23.5.3 PROGRAMMABLE TRANSMIT/RECEIVE BUFFERS

The ECAN module implements six new buffers: B0-B5. These buffers are individually programmable as either transmit or receive buffers. These buffers are available only in Mode 1 and 2. As with dedicated transmit and receive buffers, each of these programmable buffers occupies 14 bytes of SRAM and are mapped into SFR memory map.

Each buffer contains one control register (BnCON), four identifier registers (BnSIDL, BnSIDH, BnEIDL, BnEIDH), one data length count register (BnDLC) and eight data byte registers (BnDm). Each of these registers contains two sets of control bits. Depending on whether the buffer is configured as transmit or receive, one would use the corresponding control bit set. By default, all buffers are configured as receive buffers. Each buffer can be individually configured as a transmit or receive buffer by setting the corresponding TXENn bit in the BSEL0 register.

When configured as transmit buffers, user firmware may access transmit buffers in any order similar to accessing dedicated transmit buffers. In receive configuration with Mode 1 enabled, user firmware may also access receive buffers in any order required. But in Mode 2, all receive buffers are combined to form a single FIFO. Actual FIFO length is programmable by user firmware. Access to FIFO must be done through the FIFO Pointer bits (FP<4:0>) in the CANCON register. It must be noted that there is no hardware protection against out of order FIFO reads.
23.5.4 PROGRAMMABLE AUTO-RTR BUFFERS

In Mode 1 and 2, any of six programmable transmit/receive buffers may be programmed to automatically respond to predefined RTR messages without user firmware intervention. Automatic RTR handling is enabled by setting the TXnEN bit in the BSEL0 register and the RTREN bit in the BnCON register. After this setup, when an RTR request is received, the TXREQ bit is automatically set and the current buffer content is automatically queued for transmission as a RTR response. As with all transmit buffers, once the TXREQ bit is set, buffer registers become read-only and any writes to them will be ignored.

The following outlines the steps required to automatically handle RTR messages:

1. Set buffer to Transmit mode by setting TXnEN bit to ‘1’ in BSEL0 register.
2. At least one acceptance filter must be associated with this buffer and preloaded with expected RTR identifier.
3. Bit RTREN in BnCON register must be set to ‘1’.
4. Buffer must be preloaded with the data to be sent as a RTR response.

Normally, user firmware will keep buffer data registers up to date. If firmware attempts to update the buffer while an automatic RTR response is in the process of transmission, all writes to buffers are ignored.

23.6 CAN Message Transmission

23.6.1 INITIATING TRANSMISSION

For the MCU to have write access to the message buffer, the TXREQ bit must be clear, indicating that the message buffer is clear of any pending message to be transmitted. At a minimum, the SIDH, SIDL and DLC registers must be loaded. If data bytes are present in the message, the data registers must also be loaded. If the message is to use extended identifiers, the EIDH:EIDL registers must also be loaded and the EXIDE bit set.

To initiate message transmission, the TXREQ bit must be set for each buffer to be transmitted. When TXREQ is set, the TXABT, TXLARB and TXERR bits will be cleared. To successfully complete the transmission, there must be at least one node with matching baud rate on the network.

Setting the TXREQ bit does not initiate a message transmission; it merely flags a message buffer as ready for transmission. Transmission will start when the device detects that the bus is available. The device will then begin transmission of the highest priority message that is ready.

When the transmission has completed successfully, the TXREQ bit will be cleared, the TXBnIF bit will be set and an interrupt will be generated if the TXBnIE bit is set.

If the message transmission fails, the TXREQ will remain set, indicating that the message is still pending for transmission and one of the following condition flags will be set. If the message started to transmit but encountered an error condition, the TXERR and the IRXIF bits will be set and an interrupt will be generated. If the message lost arbitration, the TXLARB bit will be set.

23.6.2 ABORTING TRANSMISSION

The MCU can request to abort a message by clearing the TXREQ bit associated with the corresponding message buffer (TXBnCON<3> or BnCON<3>). Setting the ABAT bit (CANCON<4>) will request an abort of all pending messages. If the message has not yet started transmission, or if the message started but is interrupted by loss of arbitration or an error, the abort will be processed. The abort is indicated when the module sets the TXABT bit for the corresponding buffer (TXBnCON<6> or BnCON<6>). If the message has started to transmit, it will attempt to transmit the current message fully. If the current message is transmitted fully and is not lost to arbitration or an error, the TXABT bit will not be set because the message was transmitted successfully. Likewise, if a message is being transmitted during an abort request and the message is lost to arbitration or an error, the message will not be retransmitted and the TXABT bit will be set, indicating that the message was successfully aborted.

Once an abort is requested by setting the ABAT or TXABT bits, it cannot be cleared to cancel the abort request. Only CAN module hardware or a POR condition can clear it.
23.6.3 TRANSMIT PRIORITY

Transmit priority is a prioritization within the PIC18F2682/2685/4682/4685 devices of the pending transmittable messages. This is independent from and not related to any prioritization implicit in the message arbitration scheme built into the CAN protocol. Prior to sending the SOF, the priority of all buffers that are queued for transmission is compared. The transmit buffer with the highest priority will be sent first. If two buffers have the same priority setting, the buffer with the highest buffer number will be sent first. There are four levels of transmit priority. If TXP bits for a particular message buffer are set to '11', that buffer has the highest possible priority. If TXP bits for a particular message buffer are set to '00', that buffer has the lowest possible priority.

FIGURE 23-2: TRANSMIT BUFFERS
23.7 Message Reception

23.7.1 RECEIVING A MESSAGE

Of all receive buffers, the MAB is always committed to receiving the next message from the bus. The MCU can access one buffer while the other buffer is available for message reception or holding a previously received message.

Note: The entire contents of the MAB are moved into the receive buffer once a message is accepted. This means that regardless of the type of identifier (standard or extended) and the number of data bytes received, the entire receive buffer is overwritten with the MAB contents. Therefore, the contents of all registers in the buffer must be assumed to have been modified when any message is received.

When a message is moved into either of the receive buffers, the associated RXFUL bit is set. This bit must be cleared by the MCU when it has completed processing the message in the buffer in order to allow a new message to be received into the buffer. This bit provides a positive lockout to ensure that the firmware has finished with the message before the module attempts to load a new message into the receive buffer. If the receive interrupt is enabled, an interrupt will be generated to indicate that a valid message has been received.

Once a message is loaded into any matching buffer, user firmware may determine exactly what filter caused this reception by checking the filter hit bits in the RXBnCON or BnCON registers. In Mode 0, FILHIT<3:0> of RXBnCON serve as filter hit bits. In Mode 1 and 2, FILHIT<4:0> of BnCON serves as filter hit bits. The same registers also indicate whether the current message is an RTR frame or not. A received message is considered a standard identifier message if the EXID bit in the RXBnSIDL or the BnSIDL register is cleared. Conversely, a set EXID bit indicates an extended identifier message. If the received message is a standard identifier message, user firmware needs to read the SIDL and SIDH registers. In the case of an extended identifier message, firmware should read the SIDL, SIDH, EIDL and EIDH registers. If the RXBnDLC or BnDLC register contain non-zero data count, user firmware should also read the corresponding number of data bytes by accessing the RXBnDm or the BnDm registers. When a received message is an RTR and if the current buffer is not configured for automatic RTR handling, user firmware must take appropriate action and respond manually.

Each receive buffer contains RXM bits to set special Receive modes. In Mode 0, RXM<1:0> bits in RXBnCON define a total of four Receive modes. In Mode 1 and 2, RXM1 bit, in combination with the EXID mask and filter bit, define the same four Receive modes. Normally, these bits are set to ‘00’ to enable reception of all valid messages as determined by the appropriate acceptance filters. In this case, the determination of whether or not to receive standard or extended messages is determined by the EXIDE bit in the acceptance filter register. In Mode 0, if the RXM bits are set to ‘01’ or ‘10’, the receiver will accept only messages with standard or extended identifiers, respectively. If an acceptance filter has the EXIDE bit set such that it does not correspond with the RXM mode, that acceptance filter is rendered useless. In Mode 1 and 2, setting EXID in the SIDL Mask register will ensure that only standard or extended identifiers are received. These two modes of RXM bits can be used in systems where it is known that only standard or extended messages will be on the bus. If the RXM bits are set to ‘11’ (RXM1 = 1 in Mode 1 and 2), the buffer will receive all messages regardless of the values of the acceptance filters. Also, if a message has an error before the end of frame, that portion of the message assembled in the MAB before the error frame will be loaded into the buffer. This mode may serve as a valuable debugging tool for a given CAN network. It should not be used in an actual system environment as the actual system will always have some bus errors and all nodes on the bus are expected to ignore them.

In Mode 1 and 2, when a programmable buffer is configured as a transmit buffer and one or more acceptance filters are associated with it, all incoming messages matching this acceptance filter criteria will be discarded. To avoid this scenario, user firmware must make sure that there are no acceptance filters associated with a buffer configured as a transmit buffer.

23.7.2 RECEIVE PRIORITY

When in Mode 0, RXB0 is the higher priority buffer and has two message acceptance filters associated with it. RXB1 is the lower priority buffer and has four acceptance filters associated with it. The lower number of acceptance filters makes the match on RXB0 more restrictive and implies a higher priority for that buffer. Additionally, the RXB0CON register can be configured such that if RXB0 contains a valid message and another valid message is received, an overflow error will not occur and the new message will be moved into RXB1 regardless of the acceptance criteria of RXB1. There are also two programmable acceptance filter masks available, one for each receive buffer (see Section 23.5 “CAN Message Buffers”).

In Mode 1 and 2, there are a total of 16 acceptance filters available and each can be dynamically assigned to any of the receive buffers. A buffer with a lower number has higher priority. Given this, if an incoming message matches with two or more receive buffer acceptance criteria, the buffer with the lower number will be loaded with that message.
23.7.3  ENHANCED FIFO MODE

When configured for Mode 2, two of the dedicated receive buffers in combination with one or more programmable transmit/receive buffers, are used to create a maximum of an 8-buffer deep FIFO buffer. In this mode, there is no direct correlation between filters and receive buffer registers. Any filter that has been enabled can generate an acceptance. When a message has been accepted, it is stored in the next available Receive Buffer register and an Internal Write Pointer is incremented. The FIFO can be a maximum of 8 buffers deep. The entire FIFO must consist of contiguous receive buffers. The FIFO head begins at RXB0 buffer and its tail spans toward B5. The maximum length of the FIFO is limited by the presence or absence of the first transmit buffer starting from B0. If a buffer is configured as a transmit buffer, the FIFO length is reduced accordingly. For instance, if B3 is configured as a transmit buffer, the actual FIFO will consist of RXB0, RXB1, B0, B1 and B2, a total of 5 buffers. If B0 is configured as a transmit buffer, the FIFO will be 8 buffers deep. A system that requires more transmit buffers should try to locate transmit buffers at the very end of B0-B5 buffers to maximize available FIFO length.

When a message is received in FIFO mode, the interrupt flag code bits (EICODE<4:0>) in the CANSTAT register will have a value of '10000', indicating the FIFO has received a message. FIFO Pointer bits, FP<3:0> in the CANCON register, point to the buffer that contains data not yet read. The FIFO Pointer bits, in this sense, serve as the FIFO Read Pointer. The user should use FP bits and read corresponding buffer data. When receive data is no longer needed, the RXFUL bit in the current buffer must be cleared, causing FP<3:0> to be updated by the module.

To determine whether FIFO is empty or not, the user may use FP<3:0> bits to access the RXFUL bit in the current buffer. If RXFUL is cleared, the FIFO is considered to be empty. If it is set, the FIFO may contain one or more messages. In Mode 2, the module also provides a bit called FIFO High Water Mark (FIFOWM) in the ECANCON register. This bit can be used to cause an interrupt whenever the FIFO contains only one or four empty buffers. The FIFO high water mark interrupt can serve as an early warning to a full FIFO condition.

23.7.4  TIME-STAMPING

The CAN module can be programmed to generate a time-stamp for every message that is received. When enabled, the module generates a capture signal for CCP1, which in turn, captures the value of either Timer1 or Timer3. This value can be used as the message time-stamp.

To use the time-stamp capability, the CANCAP bit (CIOCAN<4>) must be set. This replaces the capture input for CCP1 with the signal generated from the CAN module. In addition, CCP1CON<3:0> must be set to '0011' to enable the CCP Special Event Trigger for CAN events.

23.8  Message Acceptance Filters and Masks

The message acceptance filters and masks are used to determine if a message in the Message Assembly Buffer should be loaded into any of the receive buffers. Once a valid message has been received into the MAB, the identifier fields of the message are compared to the filter values. If there is a match, that message will be loaded into the appropriate receive buffer. The filter masks are used to determine which bits in the identifier are examined with the filters. A truth table is shown below in Table 23-2 that indicates how each bit in the identifier is compared to the masks and filters to determine if a message should be loaded into a receive buffer. The mask essentially determines which bits to apply the acceptance filters to. If any mask bit is set to a zero, then that bit will automatically be accepted regardless of the filter bit.

<table>
<thead>
<tr>
<th>Mask bit n</th>
<th>Filter bit n</th>
<th>Message Identifier bit n001</th>
<th>Accept or Reject bit n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>x</td>
<td>Accept</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Accept</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Reject</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Reject</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Accept</td>
</tr>
</tbody>
</table>

Legend:  x = don’t care

In Mode 0, acceptance filters RXF0 and RXF1 and filter mask RXM0 are associated with RXB0. Filters RXF2, RXF3, RXF4 and RXF5 and mask RXM1 are associated with RXB1.
In Mode 1 and 2, there are an additional 10 acceptance filters, RXF6-RXF15, creating a total of 16 available filters. RXF15 can be used either as an acceptance filter or acceptance mask register. Each of these acceptance filters can be individually enabled or disabled by setting or clearing the RXFENn bit in the RXFCONn register. Any of these 16 acceptance filters can be dynamically associated with any of the receive buffers. Actual association is made by setting appropriate bits in the RXFBCONn register. Each RXFBCONn register contains a nibble for each filter. This nibble can be used to associate a specific filter to any of available receive buffers. User firmware may associate more than one filter to any one specific receive buffer.

In addition to dynamic filter to buffer association, in Mode 1 and 2, each filter can also be dynamically associated to available acceptance mask registers. The FILn_m bits in the MSELn register can be used to link a specific acceptance filter to an acceptance mask register. As with filter to buffer association, one can also associate more than one mask to a specific acceptance filter.

When a filter matches and a message is loaded into the receive buffer, the filter number that enabled the message reception is loaded into the FILHIT bit(s). In Mode 0 for RXB1, the RXB1CON register contains the FILHIT<2:0> bits. They are coded as follows:

- 101 = Acceptance Filter 5 (RXF5)
- 100 = Acceptance Filter 4 (RXF4)
- 011 = Acceptance Filter 3 (RXF3)
- 010 = Acceptance Filter 2 (RXF2)
- 001 = Acceptance Filter 1 (RXF1)
- 000 = Acceptance Filter 0 (RXF0)

The coding of the RXB0DBEN bit enables these three bits to be used similarly to the FILHIT bits and to distinguish a hit on filter RXF0 and RXF1, in either RXB0 or after a rollover into RXB1.

- 111 = Acceptance Filter 1 (RXF1)
- 110 = Acceptance Filter 0 (RXF0)
- 001 = Acceptance Filter 1 (RXF1)
- 000 = Acceptance Filter 0 (RXF0)

If the RXB0DBEN bit is clear, there are six codes corresponding to the six filters. If the RXB0DBEN bit is set, there are six codes corresponding to the six filters, plus two additional codes corresponding to RXF0 and RXF1 filters, that rollover into RXB1.

In Mode 1 and 2, each buffer control register contains 5 bits of filter hit bits (FILHIT<4:0>). A binary value of '0' indicates a hit from RXF0 and 15 indicates RXF15.

If more than one acceptance filter matches, the FILHIT bits will encode the binary value of the lowest numbered filter that matched. In other words, if filter RXF2 and filter RXF4 match, FILHIT will be loaded with the value for RXF2. This essentially prioritizes the acceptance filters with a lower number filter having higher priority. Messages are compared to filters in ascending order of filter number.

The mask and filter registers can only be modified when the PIC18F2682/2685/4682/4685 devices are in Configuration mode.
23.9 Baud Rate Setting

All nodes on a given CAN bus must have the same nominal bit rate. The CAN protocol uses Non-Return-to-Zero (NRZ) coding which does not encode a clock within the data stream. Therefore, the receive clock must be recovered by the receiving nodes and synchronized to the transmitter’s clock.

As oscillators and transmission time may vary from node to node, the receiver must have some type of Phase Lock Loop (PLL) synchronized to data transmission edges to synchronize and maintain the receiver clock. Since the data is NRZ coded, it is necessary to include bit stuffing to ensure that an edge occurs at least every six bit times to maintain the Digital Phase Lock Loop (DPLL) synchronization.

The bit timing of the PIC18F2682/2685/4682/4685 is implemented using a DPLL that is configured to synchronize to the incoming data and provides the nominal timing for the transmitted data. The DPLL breaks each bit time into multiple segments made up of minimal periods of time called the Time Quanta (TQ).

Bus timing functions executed within the bit time frame, such as synchronization to the local oscillator, network transmission delay compensation and sample point positioning, are defined by the programmable bit timing logic of the DPLL.

All devices on the CAN bus must use the same bit rate. However, all devices are not required to have the same master oscillator clock frequency. For the different clock frequencies of the individual devices, the bit rate has to be adjusted by appropriately setting the baud rate prescaler and number of Time Quanta in each segment.

The Nominal Bit Rate is the number of bits transmitted per second, assuming an ideal transmitter with an ideal oscillator, in the absence of resynchronization. The nominal bit rate is defined to be a maximum of 1 Mb/s.

The Nominal Bit Time is defined as:

**EQUATION 23-1:**

\[ T_{\text{BIT}} = \frac{1}{\text{Nominal Bit Rate}} \]

The Nominal Bit Time can be thought of as being divided into separate, non-overlapping time segments. These segments (Figure 23-4) include:

- Synchronization Segment (Sync_Seg)
- Propagation Time Segment (Prop_Seg)
- Phase Buffer Segment 1 (Phase_Seg1)
- Phase Buffer Segment 2 (Phase_Seg2)

The time segments (and thus the Nominal Bit Time) are in turn made up of integer units of time called Time Quanta or Tq (see Figure 23-4). By definition, the Nominal Bit Time is programmable from a minimum of 8 Tq to a maximum of 25 Tq. Also by definition, the minimum Nominal Bit Time is 1 μs, corresponding to a maximum 1 Mb/s rate. The actual duration is given by the following relationship.

**EQUATION 23-2:**

\[ \text{Nominal Bit Time} = T_q \times (\text{Sync}_\text{Seg} + \text{Prop}_\text{Seg} + \text{Phase}_\text{Seg1} + \text{Phase}_\text{Seg2}) \]

The Time Quantum is a fixed unit derived from the oscillator period. It is also defined by the programmable baud rate prescaler, with integer values from 1 to 64, in addition to a fixed divide-by-two for clock generation. Mathematically, this is:

**EQUATION 23-3:**

\[ T_q (\mu s) = \frac{2 \times (\text{BRP} + 1)}{\text{Fosc} (\text{MHz})} \]

or

\[ T_q (\mu s) = \frac{2 \times (\text{BRP} + 1) \times \text{Tosc} (\mu s)}{} \]

where Fosc is the clock frequency, Tosc is the corresponding oscillator period and BRP is an integer (0 through 63) represented by the binary values of BRGCON1<5:0>. The equation above refers to the effective clock frequency used by the microcontroller. If, for example, a 10 MHz crystal in HS mode is used, then the Fosc = 10 MHz and Tosc = 100 ns. If the same 10 MHz crystal is used in HSPLL mode, then the effective frequency is Fosc = 40 MHz and Tosc = 25 ns.
23.9.1 EXTERNAL CLOCK, INTERNAL CLOCK AND MEASURABLE JITTER IN HSPLL-BASED OSCILLATORS

The microcontroller clock frequency generated from a PLL circuit is subject to a jitter, also defined as Phase Jitter or Phase Skew. For its PIC18 Enhanced microcontrollers, Microchip specifies phase jitter \((P_{\text{jitter}})\) as being 2\% (Gaussian distribution, within 3 standard deviations, see parameter F13 in Table 27-7) and Total Jitter \((T_{\text{jitter}})\) as being \(2 \times P_{\text{jitter}}\).

The CAN protocol uses a bit-stuffing technique that inserts a bit of a given polarity following five bits with the opposite polarity. This gives a total of 10 bits transmitted without re-synchronization (compensation for jitter or phase error).

Given the random nature of the jitter error added, it can be shown that the total error caused by the jitter tends to cancel itself over time. For a period of 10 bits, it is necessary to add only two jitter intervals to correct for jitter-induced error: one interval in the beginning of the 10-bit period and another at the end. The overall effect is shown in Figure 23-5.

**FIGURE 23-5: EFFECTS OF PHASE JITTER ON THE MICROCONTROLLER CLOCK AND CAN BIT TIME**

Once these considerations are taken into account, it is possible to show that the relation between the jitter and the total frequency error can be defined as:

**EQUATION 23-4:**

\[
\Delta f = \frac{T_{\text{jitter}}}{10 \times \text{NBT}} = \frac{2 \times P_{\text{jitter}}}{10 \times \text{NBT}}
\]

where jitter is expressed in terms of time and NBT is the Nominal Bit Time.

For example, assume a CAN bit rate of 125 Kb/s, which gives an NBT of 8 \(\mu\)s. For a 16 MHz clock generated from a 4x PLL, the jitter at this clock frequency is:

**EQUATION 23-5:**

\[
2\% \times \frac{1}{16 \text{ MHz}} = \frac{0.02}{16 \times 10^6} = 1.25 \text{ ns}
\]

The resultant frequency error is:

**EQUATION 23-6:**

\[
\frac{2 \times (1.25 \times 10^{-9})}{10 \times (8 \times 10^{-6})} = 3.125 \times 10^{-5} = 0.0031\%
\]
Table 23-3 shows the relation between the clock generated by the PLL and the frequency error from jitter (measured jitter-induced error of 2%, Gaussian distribution, within 3 standard deviations), as a percentage of the nominal clock frequency. This is clearly smaller than the expected drift of a crystal oscillator, typically specified at 100 ppm or 0.01%. If we add jitter to oscillator drift, we have a total frequency drift of 0.0132%. The total oscillator frequency errors for common clock frequencies and bit rates, including both drift and jitter, are shown in Table 23-4.

**TABLE 23-3: FREQUENCY ERROR FROM JITTER AT VARIOUS PLL GENERATED CLOCK SPEEDS**

<table>
<thead>
<tr>
<th>PLL Output</th>
<th>$P_{jitter}$</th>
<th>$T_{jitter}$</th>
<th>Frequency Error at Various Nominal Bit Times (Bit Rates)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 $\mu$s (125 Kb/s)</td>
</tr>
<tr>
<td>40 MHz</td>
<td>0.5 ns</td>
<td>1 ns</td>
<td>0.00125%</td>
</tr>
<tr>
<td>24 MHz</td>
<td>0.83 ns</td>
<td>1.67 ns</td>
<td>0.00209%</td>
</tr>
<tr>
<td>16 MHz</td>
<td>1.25 ns</td>
<td>2.5 ns</td>
<td>0.00313%</td>
</tr>
</tbody>
</table>

**TABLE 23-4: TOTAL FREQUENCY ERROR AT VARIOUS PLL GENERATED CLOCK SPEEDS (100 PPM OSCILLATOR DRIFT, INCLUDING ERROR FROM JITTER)**

<table>
<thead>
<tr>
<th>Nominal PLL Output</th>
<th>Frequency Error at Various Nominal Bit Times (Bit Rates)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 $\mu$s (125 Kb/s)</td>
</tr>
<tr>
<td>40 MHz</td>
<td>0.01125%</td>
</tr>
<tr>
<td>24 MHz</td>
<td>0.01209%</td>
</tr>
<tr>
<td>16 MHz</td>
<td>0.01313%</td>
</tr>
</tbody>
</table>
23.9.2 TIME QUANTA
As already mentioned, the Time Quanta is a fixed unit derived from the oscillator period and baud rate prescaler. Its relationship to TBIT and the Nominal Bit Rate is shown in Example 23-6.

**EXAMPLE 23-6: CALCULATING TQ, NOMINAL BIT RATE AND NOMINAL BIT TIME**

| TQ (μs) | = (2 * (BRP + 1))/FOSC (MHz) |
| TBIT (μs) | = TQ (μs) * number of TQ per bit interval |
| Nominal Bit Rate (bits/s) | = 1/TBIT |

This frequency (FOSC) refers to the effective frequency used. If, for example, a 10 MHz external signal is used along with a PLL, then the effective frequency will be 4 x 10 MHz which equals 40 MHz.

**CASE 1:**
For FOSC = 16 MHz, BRP<5:0> = 00h and Nominal Bit Time = 8 Tq:
- TQ = (2 * 1)/16 = 0.125 μs (125 ns)
- TBIT = 8 * 0.125 = 1 μs (10^-6 s)
- Nominal Bit Rate = 1/10^-6 = 10^6 bits/s (1 Mb/s)

**CASE 2:**
For FOSC = 20 MHz, BRP<5:0> = 01h and Nominal Bit Time = 8 Tq:
- TQ = (2 * 2)/20 = 0.2 μs (200 ns)
- TBIT = 8 * 0.2 = 1.6 μs (1.6 * 10^-6 s)
- Nominal Bit Rate = 1/1.6 * 10^-6 = 625,000 bits/s (625 Kbps)

**CASE 3:**
For FOSC = 25 MHz, BRP<5:0> = 3Fh and Nominal Bit Time = 25 Tq:
- TQ = (2 * 64)/25 = 5.12 μs
- TBIT = 25 * 5.12 = 128 μs (1.28 * 10^-4 s)
- Nominal Bit Rate = 1/1.28 * 10^-4 = 7813 bits/s (7.8 Kbps)

The frequencies of the oscillators in the different nodes must be coordinated in order to provide a system wide specified nominal bit time. This means that all oscillators must have a Tosc that is an integral divisor of Tq. It should also be noted that although the number of Tq is programmable from 4 to 25, the usable minimum is 8 Tq. There is no assurance that a bit time of less than 8 Tq in length will operate correctly.

23.9.3 SYNCHRONIZATION SEGMENT
This part of the bit time is used to synchronize the various CAN nodes on the bus. The edge of the input signal is expected to occur during the sync segment. The duration is 1 Tq.

23.9.4 PROPAGATION SEGMENT
This part of the bit time is used to compensate for physical delay times within the network. These delay times consist of the signal propagation time on the bus line and the internal delay time of the nodes. The length of the Propagation Segment can be programmed from 1 Tq to 8 Tq by setting the PRSEG2:PRSEG0 bits.

23.9.5 PHASE BUFFER SEGMENTS
The phase buffer segments are used to optimally locate the sampling point of the received bit within the nominal bit time. The sampling point occurs between Phase Segment 1 and Phase Segment 2. These segments can be lengthened or shortened by the resynchronization process. The end of Phase Segment 1 determines the sampling point within a bit time. Phase Segment 1 is programmable from 1 Tq to 8 Tq in duration. Phase Segment 2 provides delay before the next transmitted data transition and is also programmable from 1 Tq to 8 Tq in duration. However, due to IPT requirements, the actual minimum length of Phase Segment 2 is 2 Tq, or it may be defined to be equal to the greater of Phase Segment 1 or the Information Processing Time (IPT). The sampling point should be as late as possible or approximately 80% of the bit time.

23.9.6 SAMPLE POINT
The sample point is the point of time at which the bus level is read and the value of the received bit is determined. The sampling point occurs at the end of Phase Segment 1. If the bit timing is slow and contains many Tq, it is possible to specify multiple sampling of the bus line at the sample point. The value of the received bit is determined to be the value of the majority decision of three values. The three samples are taken at the sample point and twice before, with a time of Tq/2 between each sample.

23.9.7 INFORMATION PROCESSING TIME
The Information Processing Time (IPT) is the time segment starting at the sample point that is reserved for calculation of the subsequent bit level. The CAN specification defines this time to be less than or equal to 2 Tq. The PIC18F2682/2685/4682/4685 devices define this time to be 2 Tq. Thus, Phase Segment 2 must be at least 2 Tq long.
23.10 Synchronization

To compensate for phase shifts between the oscillator frequencies of each of the nodes on the bus, each CAN controller must be able to synchronize to the relevant signal edge of the incoming signal. When an edge in the transmitted data is detected, the logic will compare the location of the edge to the expected time (Sync_Seg). The circuit will then adjust the values of Phase Segment 1 and Phase Segment 2 as necessary. There are two mechanisms used for synchronization.

23.10.1 HARD SYNCHRONIZATION

Hard synchronization is only done when there is a recessive to dominant edge during a bus Idle condition, indicating the start of a message. After hard synchronization, the bit time counters are restarted with Sync_Seg. Hard synchronization forces the edge which has occurred to lie within the synchronization segment of the restarted bit time. Due to the rules of synchronization, if a hard synchronization occurs, there will not be a resynchronization within that bit time.

23.10.2 RESYNCHRONIZATION

As a result of resynchronization, Phase Segment 1 may be lengthened or Phase Segment 2 may be shortened. The amount of lengthening or shortening of the phase buffer segments has an upper bound given by the Synchronization Jump Width (SJW). The value of the SJW will be added to Phase Segment 1 (see Figure 23-6) or subtracted from Phase Segment 2 (see Figure 23-7). The SJW is programmable between 1 TQ and 4 TQ.

Clocking information will only be derived from recessive to dominant transitions. The property, that only a fixed maximum number of successive bits have the same value, ensures resynchronization to the bit stream during a frame.

The phase error of an edge is given by the position of the edge relative to Sync_Seg, measured in TQ. The phase error is defined in magnitude of TQ as follows:

- $e = 0$ if the edge lies within Sync_Seg.
- $e > 0$ if the edge lies before the sample point.
- $e < 0$ if the edge lies after the sample point of the previous bit.

If the magnitude of the phase error is less than, or equal to, the programmed value of the Synchronization Jump Width, the effect of a resynchronization is the same as that of a hard synchronization.

If the magnitude of the phase error is larger than the Synchronization Jump Width and if the phase error is positive, then Phase Segment 1 is lengthened by an amount equal to the Synchronization Jump Width.

If the magnitude of the phase error is larger than the resynchronization jump width and if the phase error is negative, then Phase Segment 2 is shortened by an amount equal to the Synchronization Jump Width.

23.10.3 SYNCHRONIZATION RULES

- Only one synchronization within one bit time is allowed.
- An edge will be used for synchronization only if the value detected at the previous sample point (previously read bus value) differs from the bus value immediately after the edge.
- All other recessive to dominant edges fulfilling rules 1 and 2 will be used for resynchronization, with the exception that a node transmitting a dominant bit will not perform a resynchronization as a result of a recessive to dominant edge with a positive phase error.

---

**FIGURE 23-6: LENGTHENING A BIT PERIOD (ADDING SJW TO PHASE SEGMENT 1)**

<table>
<thead>
<tr>
<th>Bit Time Segments</th>
<th>TQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sync Prop Segment</td>
<td>Phase Segment 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Signal</th>
</tr>
</thead>
</table>

Nominal Bit Length → Actual Bit Length
23.11 Programming Time Segments

Some requirements for programming of the time segments:

- \( \text{Prop}_\text{Seg} + \text{Phase}_\text{Seg 1} \geq \text{Phase}_\text{Seg 2} \)
- \( \text{Phase}_\text{Seg 2} \geq \text{Sync Jump Width} \).

For example, assume that a 125 kHz CAN baud rate is desired, using 20 MHz for Fosc. With a Tosc of 50 ns, a baud rate prescaler value of 04h gives a To of 500 ns. To obtain a Nominal Bit Rate of 125 kHz, the Nominal Bit Time must be 8 \( \mu \)s or 16 To.

Using 1 To for the Sync_Seg, 2 To for the Prop_Seg and 7 To for Phase Segment 1 would place the sample point at 10 To after the transition. This leaves 6 To for Phase Segment 2.

By the rules above, the Sync Jump Width could be the maximum of 4 To. However, normally a large SJW is only necessary when the clock generation of the different nodes is inaccurate or unstable, such as using ceramic resonators. Typically, an SJW of 1 is enough.

23.12 Oscillator Tolerance

As a rule of thumb, the bit timing requirements allow ceramic resonators to be used in applications with transmission rates of up to 125 Kbit/sec. For the full bus speed range of the CAN protocol, a quartz oscillator is required. A maximum node-to-node oscillator variation of 1.7% is allowed.

23.13 Bit Timing Configuration Registers

The Baud Rate Control registers (BRGCON1, BRGCON2, BRGCON3) control the bit timing for the CAN bus interface. These registers can only be modified when the PIC18F2682/2685/4682/4685 devices are in Configuration mode.

23.13.1 BRGCON1

The BRP bits control the baud rate prescaler. The SJW<1:0> bits select the synchronization jump width in terms of multiples of To.

23.13.2 BRGCON2

The PRSEG bits set the length of the propagation segment in terms of To. The SEG1PH bits set the length of Phase Segment 1 in To. The SAM bit controls how many times the RXCAN pin is sampled. Setting this bit to a ‘1’ causes the bus to be sampled three times: twice at To/2 before the sample point and once at the normal sample point (which is at the end of Phase Segment 1). The value of the bus is determined to be the value read during at least two of the samples. If the SAM bit is set to a ‘0’, then the RXCAN pin is sampled only once at the sample point. The SEG2PHTS bit controls how the length of Phase Segment 2 is determined. If this bit is set to a ‘1’, then the length of Phase Segment 2 is determined by the SEG2PH bits of BRGCON3. If the SEG2PHTS bit is set to a ‘0’, then the length of Phase Segment 2 is the greater of Phase Segment 1 and the Information Processing Time (which is fixed at 2 To for the PIC18F2682/2685/4682/4685).

23.13.3 BRGCON3

The PHSEG2<2:0> bits set the length (in To) of Phase Segment 2 if the SEG2PHTS bit is set to a ‘1’. If the SEG2PHTS bit is set to a ‘0’, then the PHSEG2<2:0> bits have no effect.
23.14 Error Detection

The CAN protocol provides sophisticated error detection mechanisms. The following errors can be detected.

23.14.1 CRC ERROR
With the Cyclic Redundancy Check (CRC), the transmitter calculates special check bits for the bit sequence, from the start of a frame until the end of the data field. This CRC sequence is transmitted in the CRC field. The receiving node also calculates the CRC sequence using the same formula and performs a comparison to the received sequence. If a mismatch is detected, a CRC error has occurred and an error frame is generated. The message is repeated.

23.14.2 ACKNOWLEDGE ERROR
In the Acknowledge field of a message, the transmitter checks if the Acknowledge slot (which was sent out as a recessive bit) contains a dominant bit. If not, no other node has received the frame correctly. An Acknowledge error has occurred, an error frame is generated and the message will have to be repeated.

23.14.3 FORM ERROR
If a node detects a dominant bit in one of the four segments, including End-of-Frame, interframe space, Acknowledge delimiter or CRC delimiter, then a form error has occurred and an error frame is generated. The message is repeated.

23.14.4 BIT ERROR
A bit error occurs if a transmitter sends a dominant bit and detects a recessive bit, or if it sends a recessive bit and detects a dominant bit, when monitoring the actual bus level and comparing it to the just transmitted bit. In the case where the transmitter sends a recessive bit and a dominant bit is detected during the arbitration field and the Acknowledge slot, no bit error is generated because normal arbitration is occurring.

23.14.5 STUFF BIT ERROR
If, between the Start-of-Frame and the CRC delimiter, six consecutive bits with the same polarity are detected, the bit stuffing rule has been violated. A stuff bit error occurs and an error frame is generated. The message is repeated.

23.14.6 ERROR STATES
Detected errors are made public to all other nodes via error frames. The transmission of the erroneous message is aborted and the frame is repeated as soon as possible. Furthermore, each CAN node is in one of the three error states: “error-active”, “error-passive” or “bus-off”, according to the value of the internal error counters. The error-active state is the usual state where the bus node can transmit messages and activate error frames (made of dominant bits) without any restrictions. In the error-passive state, messages and passive error frames (made of recessive bits) may be transmitted. The bus-off state makes it temporarily impossible for the station to participate in the bus communication. During this state, messages can neither be received nor transmitted.

23.14.7 ERROR MODES AND ERROR COUNTERS
The PIC18F2682/2685/4682/4685 devices contain two error counters: the Receive Error Counter (RXERRCNT) and the Transmit Error Counter (TXERRCNT). The values of both counters can be read by the MCU. These counters are incremented or decremented in accordance with the CAN bus specification.

The PIC18F2682/2685/4682/4685 devices are error-active if both error counters are below the error-passive limit of 128. They are error-passive if at least one of the error counters equals or exceeds 128. They go to bus-off if the transmit error counter equals or exceeds the bus-off limit of 256. The devices remain in this state until the bus-off recovery sequence is received. The bus-off recovery sequence consists of 128 occurrences of 11 consecutive recessive bits (see Figure 23-8). Note that the CAN module, after going bus-off, will recover back to error-active without any intervention by the MCU if the bus remains Idle for 128 x 11 bit times. If this is not desired, the error Interrupt Service Routine should address this. The current Error mode of the CAN module can be read by the MCU via the COMSTAT register.

Additionally, there is an Error State Warning flag bit, EWARN, which is set if at least one of the error counters equals or exceeds the error warning limit of 96. EWARN is reset if both error counters are less than the error warning limit.
23.15 CAN Interrupts

The module has several sources of interrupts. Each of these interrupts can be individually enabled or disabled. The PIR3 register contains interrupt flags. The PIE3 register contains the enables for the 8 main interrupts. A special set of read-only bits in the CANSTAT register, the ICODE bits, can be used in combination with a jump table for efficient handling of interrupts.

All interrupts have one source, with the exception of the error interrupt and buffer interrupts in Mode 1 and 2. Any of the error interrupt sources can set the error interrupt flag. The source of the error interrupt can be determined by reading the Communication Status register, COMSTAT. In Mode 1 and 2, there are two interrupt enable/disable and flag bits – one for all transmit buffers and the other for all receive buffers.

The interrupts can be broken up into two categories: receive and transmit interrupts.

The receive related interrupts are:
- Receive Interrupts
- Wake-up Interrupt
- Receiver Overrun Interrupt
- Receiver Warning Interrupt
- Receiver Error-Passive Interrupt

The transmit related interrupts are:
- Transmit Interrupts
- Transmitter Warning Interrupt
- Transmitter Error-Passive Interrupt
- Bus-Off Interrupt
23.15.1 INTERRUPT CODE BITS
To simplify the interrupt handling process in user firmware, the ECAN module encodes a special set of bits. In Mode 0, these bits are ICODE<3:1> in the CANSTAT register. In Mode 1 and 2, these bits are EICODE<4:0> in the CANSTAT register. Interrupts are internally prioritized such that the higher priority interrupts are assigned lower values. Once the highest priority interrupt condition has been cleared, the code for the next highest priority interrupt that is pending (if any) will be reflected by the ICODE bits (see Table 23-5). Note that only those interrupt sources that have their associated interrupt enable bit set will be reflected in the ICODE bits.

In Mode 2, when a receive message interrupt occurs, the EICODE bits will always consist of '10000'. User firmware may use FIFO Pointer bits to actually access the next available buffer.

23.15.2 TRANSMIT INTERRUPT
When the transmit interrupt is enabled, an interrupt will be generated when the associated transmit buffer becomes empty and is ready to be loaded with a new message. In Mode 0, there are separate interrupt enable/disable and flag bits for each of the three dedicated transmit buffers. The TXBnIF bit will be set to indicate the source of the interrupt. The interrupt is cleared by the MCU, resetting the TXBnIF bit to a '0'. In Mode 1 and 2, all transmit buffers share one interrupt enable/disable and one flag bit. In Mode 1 and 2, TXBnIE in PIE3 and TXBnIF in PIR3 indicate when a transmit buffer has completed transmission of its message. TXBnIF, TXBnIE and TXBnIP in PIR3, PIE3 and IPR3, respectively, are not used in Mode 1 and 2. Individual transmit buffer interrupts can be enabled or disabled by setting or clearing TXBIE and BIE0 register bits. In Mode 1, when a shared transmit interrupt occurs, user firmware must poll the RXFUL bit of each receive buffer to detect the source of interrupt. In Mode 2, a receive interrupt indicates that the new message is loaded into FIFO. FIFO can be read by using FIFO Pointer bits, FP.

23.15.3 RECEIVE INTERRUPT
When the receive interrupt is enabled, an interrupt will be generated when a message has been successfully received and loaded into the associated receive buffer. This interrupt is activated immediately after receiving the End-Of-Frame (EOF) field.

In Mode 0, the RXBnIF bit is set to indicate the source of the interrupt. The interrupt is cleared by the MCU, resetting the RXBnIF bit to a '0'.

In Mode 1 and 2, all receive buffers share RXBIE, RXBIF and RXBIP in PIE3, PIR3 and IPR3, respectively. Bits RXBnIE, RXBnIF and RXBnIP are not used. Individual receive buffer interrupts can be controlled by the TXBIE and BIE0 registers. In Mode 1, when a shared receive interrupt occurs, user firmware must poll the RXFUL bit of each receive buffer to detect the source of interrupt. In Mode 2, a receive interrupt indicates that the new message is loaded into FIFO. FIFO can be read by using FIFO Pointer bits, FP.

<table>
<thead>
<tr>
<th>ICODE&lt;2:0&gt;</th>
<th>Interrupt</th>
<th>Boolean Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>None</td>
<td>ERR+WAK+TX0+TX1+TX2-RX0-RX1</td>
</tr>
<tr>
<td>001</td>
<td>Error</td>
<td>ERR</td>
</tr>
<tr>
<td>010</td>
<td>TXB2</td>
<td>ERR+TX0+TX1+TX2</td>
</tr>
<tr>
<td>011</td>
<td>TXB1</td>
<td>ERR+TX0+TX1</td>
</tr>
<tr>
<td>100</td>
<td>TXB0</td>
<td>ERR+TX0</td>
</tr>
<tr>
<td>101</td>
<td>RXB1</td>
<td>ERR+TX0+TX1+TX2+RX0-RX1</td>
</tr>
<tr>
<td>110</td>
<td>RXB0</td>
<td>ERR+TX0+TX1+TX2-RX0</td>
</tr>
<tr>
<td>111</td>
<td>Wake on Interrupt</td>
<td>ERR+TX0+TX1+TX2+RX0-RX1+WAKE</td>
</tr>
</tbody>
</table>

Legend:
ERR = ERRIF * ERRIE RX0 = RXB0IF * RXB0IE TX0 = TXB0IF * TXB0IE RX1 = RXB1IF * RXB1IE TX1 = TXB1IF * TXB1IE WAK = WAKIF * WAKIE TX2 = TXB2IF * TXB2IE

23.15.4 MESSAGE ERROR INTERRUPT
When an error occurs during transmission or reception of a message, the message error flag, IRXIF, will be set and if the IRXIE bit is set, an interrupt will be generated. This is intended to be used to facilitate baud rate determination when used in conjunction with Listen Only mode.
23.15.5 BUS ACTIVITY WAKE-UP
INTERRUPT
When the PIC18F2682/2685/4682/4685 devices are in Sleep mode and the bus activity wake-up interrupt is enabled, an interrupt will be generated and the WAKIF bit will be set when activity is detected on the CAN bus. This interrupt causes the PIC18F2682/2685/4682/4685 devices to exit Sleep mode. The interrupt is reset by the MCU, clearing the WAKIF bit.

23.15.6 ERROR INTERRUPT
When the error interrupt is enabled, an interrupt is generated if an overflow condition occurs or if the error state of the transmitter or receiver has changed. The error flags in COMSTAT will indicate one of the following conditions.

23.15.6.1 Receiver Overflow
An overflow condition occurs when the MAB has assembled a valid received message (the message meets the criteria of the acceptance filters) and the receive buffer associated with the filter is not available for loading of a new message. The associated RXBnOVFL bit in the COMSTAT register will be set to indicate the overflow condition. This bit must be cleared by the MCU.

23.15.6.2 Receiver Warning
The receive error counter has reached the MCU warning limit of 96.

23.15.6.3 Transmitter Warning
The transmit error counter has reached the MCU warning limit of 96.

23.15.6.4 Receiver Bus Passive
The receive error counter has exceeded the error-passive limit of 127 and the device has gone to error-passive state.

23.15.6.5 Transmitter Bus Passive
The transmit error counter has exceeded the error-passive limit of 127 and the device has gone to error-passive state.

23.15.6.6 Bus-Off
The transmit error counter has exceeded 255 and the device has gone to bus-off state.

23.15.6.7 Interrupt Acknowledge
Interrupts are directly associated with one or more status flags in the PIR register. Interrupts are pending as long as one of the flags is set. Once an interrupt flag is set by the device, the flag can not be reset by the microcontroller until the interrupt condition is removed.
24.0 SPECIAL FEATURES OF THE CPU

PIC18F2682/2685/4682/4685 devices include several features intended to maximize reliability and minimize cost through elimination of external components. These are:

- Oscillator Selection
- Resets:
  - Power-on Reset (POR)
  - Power-up Timer (PWRT)
  - Oscillator Start-up Timer (OST)
  - Brown-out Reset (BOR)
- Interrupts
- Watchdog Timer (WDT)
- Fail-Safe Clock Monitor
- Two-Speed Start-up
- Code Protection
- ID Locations
- In-Circuit Serial Programming

The oscillator can be configured for the application depending on frequency, power, accuracy and cost. All of the options are discussed in detail in Section 2.0 “Oscillator Configurations”.

A complete discussion of device Resets and interrupts is available in previous sections of this data sheet.

In addition to their Power-up and Oscillator Start-up Timers provided for Resets, PIC18F2682/2685/4682/4685 devices have a Watchdog Timer, which is either permanently enabled via the Configuration bits or software controlled (if configured as disabled).

24.1 Configuration Bits

The Configuration bits can be programmed (read as '0') or left unprogrammed (read as '1') to select various device configurations. These bits are mapped starting at program memory location 300000h.

The user will note that address 300000h is beyond the user program memory space. In fact, it belongs to the configuration memory space (300000h-3FFFFFh), which can only be accessed using table reads and table writes.

Programming the Configuration registers is done in a manner similar to programming the Flash memory. The WR bit in the EECON1 register starts a self-timed write to the Configuration register. In normal operation mode, a TBLWT instruction with the TBLPTR pointing to the Configuration register sets up the address and the data for the Configuration register write. Setting the WR bit starts a long write to the Configuration register. The Configuration registers are written a byte at a time. To write or erase a configuration cell, a TBLWT instruction can write a '1' or a '0' into the cell. For additional details on Flash programming, refer to Section 6.5 “Writing to Flash Program Memory”.

### TABLE 24-1: CONFIGURATION BITS AND DEVICE IDs

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Default/Unprogrammed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>300001h</td>
<td>CONFIG1H</td>
<td>IESO</td>
<td>FCMEN</td>
<td>—</td>
<td>—</td>
<td>FOSC3</td>
<td>FOSC2</td>
<td>FOSC1</td>
<td>FOSC0</td>
</tr>
<tr>
<td>300002h</td>
<td>CONFIG2L</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>BORV1</td>
<td>BORV0</td>
<td>BOREN1</td>
</tr>
<tr>
<td>300003h</td>
<td>CONFIG2H</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>WDTPS3</td>
<td>WDTPS2</td>
<td>WDTPS1</td>
</tr>
<tr>
<td>300005h</td>
<td>CONFIG3H</td>
<td>MCLRE</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>LPT1OSC</td>
<td>PBADEn</td>
<td>—</td>
</tr>
<tr>
<td>300006h</td>
<td>CONFIG4L</td>
<td>DEBUG</td>
<td>XINST</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>LVP</td>
<td>—</td>
<td>STVREN</td>
</tr>
<tr>
<td>300008h</td>
<td>CONFIG5L</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>CPS(1)</td>
<td>CP4</td>
<td>CP3</td>
<td>CP2</td>
<td>CP1</td>
</tr>
<tr>
<td>300009h</td>
<td>CONFIG5H</td>
<td>CPD</td>
<td>CPB</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>30000Ah</td>
<td>CONFIG6L</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>WRT5(1)</td>
<td>WRT4</td>
<td>WRT3</td>
<td>WRT2</td>
<td>WRT1</td>
</tr>
<tr>
<td>30000Bh</td>
<td>CONFIG6H</td>
<td>WRTD</td>
<td>WRTB</td>
<td>WRTC</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>30000Ch</td>
<td>CONFIG7L</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>EBTR5(1)</td>
<td>EBTR4</td>
<td>EBTR3</td>
<td>EBTR2</td>
<td>EBTR1</td>
</tr>
<tr>
<td>30000Dh</td>
<td>CONFIG7H</td>
<td>—</td>
<td>EBTRB</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3FFFFFFh</td>
<td>DEVID1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Legend:
- x = unknown
- u = unchanged
- = unimplemented
- q = value depends on condition.

Note 1:
- Unimplemented in PIC18F2682/4682 devices; maintain this bit set.

Note 2:
- See Register 24-12 and Register 24-13 for DEVID1 and DEVID2 values. DEVID registers are read-only and cannot be programmed by the user.
REGISTER 24-1: CONFIG1H: CONFIGURATION REGISTER 1 HIGH (BYTE ADDRESS 300001h)

<table>
<thead>
<tr>
<th>R/P-0</th>
<th>R/P-0</th>
<th>U-0</th>
<th>U-0</th>
<th>R/P-0</th>
<th>R/P-1</th>
<th>R/P-1</th>
<th>R/P-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IESO</td>
<td>FCMEN</td>
<td>—</td>
<td>—</td>
<td>FOSC3</td>
<td>FOSC2</td>
<td>FOSC1</td>
<td>FOSC0</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- P = Programmable bit
- U = Unimplemented bit, read as '0'
- -n = Value when device is unprogrammed
- u = Unchanged from programmed state

bit 7
IESO: Internal/External Oscillator Switchover bit
1 = Oscillator Switchover mode enabled
0 = Oscillator Switchover mode disabled

bit 6
FCMEN: Fail-Safe Clock Monitor Enable bit
1 = Fail-Safe Clock Monitor enabled
0 = Fail-Safe Clock Monitor disabled

bit 5-4
Unimplemented: Read as '0'

bit 3-0
FOSC3:FOSC0: Oscillator Selection bits
11xx = External RC oscillator, CLKO function on RA6
101x = External RC oscillator, CLKO function on RA6
1001 = Internal oscillator block, CLKO function on RA6, port function on RA7
1000 = Internal oscillator block, port function on RA6 and RA7
0111 = External RC oscillator, port function on RA6
0110 = HS oscillator, PLL enabled (Clock Frequency = 4 x FOSC1)
0101 = EC oscillator, port function on RA6
0100 = EC oscillator, CLKO function on RA6
0011 = External RC oscillator, CLKO function on RA6
0010 = HS oscillator
0001 = XT oscillator
0000 = LP oscillator
**REGISTER 24-2: CONFIG2L: CONFIGURATION REGISTER 2 LOW (BYTE ADDRESS 300002h)**

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>R/P-1</td>
<td>R/P-1</td>
<td>R/P-1</td>
<td>R/P-1</td>
<td>R/P-1</td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **P** = Programmable bit
- **U** = Unimplemented bit, read as '0'
- **-n** = Value when device is unprogrammed
- **u** = Unchanged from programmed state

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

**bit 4-3**  
**BORV1:BORV0:** Brown-out Reset Voltage bits
- **11** = Minimum setting
- **10** = Maximum setting

**bit 2-1**  
**BOREN1:BOREN0:** Brown-out Reset Enable bits<sup>(1)</sup>
- **11** = Brown-out Reset enabled in hardware only (SBOREN is disabled)
- **10** = Brown-out Reset enabled in hardware only and disabled in Sleep mode (SBOREN is disabled)
- **01** = Brown-out Reset enabled and controlled by software (SBOREN is enabled)
- **00** = Brown-out Reset disabled in hardware and software

**bit 0**  
**PWRTEN:** Power-up Timer Enable bit<sup>(1)</sup>
- **1** = PWRT disabled
- **0** = PWRT enabled

**Note 1:** The Power-up Timer is decoupled from Brown-out Reset, allowing these features to be independently controlled.
REGISTER 24-3: CONFIG2H: CONFIGURATION REGISTER 2 HIGH (BYTE ADDRESS 30003h)

<table>
<thead>
<tr>
<th>bit 7-5</th>
<th>bit 4-1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unimplemented: Read as '0'</td>
<td>WDTPS3:WDTPS0: Watchdog Timer Postscale Select bits</td>
<td>WDTEN: Watchdog Timer Enable bit</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- P = Programmable bit
- U = Unimplemented bit, read as '0'
- n = Value when device is unprogrammed
- u = Unchanged from programmed state

- WDTPS3: WDTPS0:
  - 1111 = 1:32,768
  - 1110 = 1:16,384
  - 1101 = 1:8,192
  - 1100 = 1:4,096
  - 1011 = 1:2,048
  - 1010 = 1:1,024
  - 1001 = 1:512
  - 1000 = 1:256
  - 0111 = 1:128
  - 0110 = 1:64
  - 0101 = 1:32
  - 0100 = 1:16
  - 0011 = 1:8
  - 0010 = 1:4
  - 0001 = 1:2
  - 0000 = 1:1

- WDTEN:
  - 1 = WDT enabled
  - 0 = WDT disabled (control is placed on the SWDTEN bit)
### REGISTER 24-4: CONFIG3H: CONFIGURATION REGISTER 3 HIGH (BYTE ADDRESS 300005h)

<table>
<thead>
<tr>
<th>R/P-1</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>R/P-0</th>
<th>R/P-1</th>
<th>U-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCLRE</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **P** = Programmable bit
- **U** = Unimplemented bit, read as '0'
- **-n** = Value when device is unprogrammed
- **u** = Unchanged from programmed state

- **bit 7**
  - MCLRE: MCLR Pin Enable bit
    - 1 = MCLR pin enabled; RE3 input pin disabled
    - 0 = RE3 input pin enabled; MCLR disabled

- **bit 6-3**
  - **Unimplemented**: Read as '0'

- **bit 2**
  - LPT1OSC: Low-Power Timer1 Oscillator Enable bit
    - 1 = Timer1 configured for low-power operation
    - 0 = Timer1 configured for higher power operation

- **bit 1**
  - PBADEN: PORTB A/D Enable bit
    - (Affects ADCON1 Reset state. ADCON1 controls PORTB<4:0> pin configuration.)
    - 1 = PORTB<4:0> pins are configured as analog input channels on Reset
    - 0 = PORTB<4:0> pins are configured as digital I/O on Reset

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

### REGISTER 24-5: CONFIG4L: CONFIGURATION REGISTER 4 LOW (BYTE ADDRESS 300006h)

<table>
<thead>
<tr>
<th>R/P-1</th>
<th>R/P-0</th>
<th>R/P-0</th>
<th>R/P-0</th>
<th>U-0</th>
<th>R/P-1</th>
<th>U-0</th>
<th>R/P-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEBUG</td>
<td>XINST</td>
<td>BBSIZ1</td>
<td>BBSIZ2</td>
<td>—</td>
<td>LVP</td>
<td>—</td>
<td>STVREN</td>
</tr>
</tbody>
</table>

Legend:
- **R** = Readable bit
- **P** = Programmable bit
- **U** = Unimplemented bit, read as '0'
- **-n** = Value when device is unprogrammed
- **u** = Unchanged from programmed state

- **bit 7**
  - DEBUG: Background Debugger Enable bit
    - 1 = Background debugger disabled, RB6 and RB7 configured as general purpose I/O pins
    - 0 = Background debugger enabled, RB6 and RB7 dedicated to In-Circuit Debug

- **bit 6**
  - XINST: Extended Instruction Set Enable bit
    - 1 = Instruction set extension and Indexed Addressing mode enabled
    - 0 = Instruction set extension and Indexed Addressing mode disabled (Legacy mode)

- **bit 5**
  - BBSIZ1: Boot Block Size Select Bit 1
    - 11 = 4K words (8 Kbytes) boot block
    - 10 = 4K words (8 Kbytes) boot block

- **bit 4**
  - BBSIZ2: Boot Block Size Select Bit 0
    - 01 = 2K words (4 Kbytes) boot block
    - 00 = 1K words (2 Kbytes) boot block

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

- **bit 2**
  - LVP: Single-Supply ICSP™ Enable bit
    - 1 = Single-Supply ICSP enabled
    - 0 = Single-Supply ICSP disabled

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

- **bit 0**
  - STVREN: Stack Full/Underflow Reset Enable bit
    - 1 = Stack full/underflow will cause Reset
    - 0 = Stack full/underflow will not cause Reset

© 2009 Microchip Technology Inc.
REGISTER 24-6: CONFIG5L: CONFIGURATION REGISTER 5 LOW (BYTE ADDRESS 300008h)

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0</td>
<td>U-0</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  
C = Clearable bit  
U = Unimplemented bit, read as '0'  
-n = Value when device is unprogrammed  
u = Unchanged from programmed state

bit 7-6 Unimplemented: Read as '0'

bit 5 CP5: Code Protection bit(1)
1 = Block 5 (014000-017FFFh) not code-protected
0 = Block 5 (014000-017FFFh) code-protected

bit 4 CP4: Code Protection bit
1 = Block 4 (010000-013FFFh) not code-protected
0 = Block 4 (010000-013FFFh) code-protected

bit 3 CP3: Code Protection bit
1 = Block 3 (00C000-00FFFFh) not code-protected
0 = Block 3 (00C000-00FFFFh) code-protected

bit 2 CP2: Code Protection bit
1 = Block 2 (008000-00BFFFh) not code-protected
0 = Block 2 (008000-00BFFFh) code-protected

bit 1 CP1: Code Protection bit
1 = Block 1 (004000-007FFFh) not code-protected
0 = Block 1 (004000-007FFFh) code-protected

bit 0 CP0: Code Protection bit
1 = Block 0 (000800-003FFFh) not code-protected
0 = Block 0 (000800-003FFFh) code-protected

Note 1: Unimplemented in PIC18F2682/4682 devices; maintain this bit set.

REGISTER 24-7: CONFIG5H: CONFIGURATION REGISTER 5 HIGH (BYTE ADDRESS 300009h)

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 6</th>
<th>bit 5</th>
<th>bit 4</th>
<th>bit 3</th>
<th>bit 2</th>
<th>bit 1</th>
<th>bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/C-1</td>
<td>R/C-1</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
</tr>
<tr>
<td>CPD</td>
<td>CPB</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
<td>U-0</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit  
C = Clearable bit  
U = Unimplemented bit, read as '0'  
-n = Value when device is unprogrammed  
u = Unchanged from programmed state

bit 7 CPD: Data EEPROM Code Protection bit
1 = Data EEPROM not code-protected
0 = Data EEPROM code-protected

bit 6 CPB: Boot Block Code Protection bit
1 = Boot Block (000000-0007FFFFh) not code-protected
0 = Boot Block (000000-0007FFFFh) code-protected

bit 5-0 Unimplemented: Read as '0'
### REGISTER 24-8: CONFIG6L: CONFIGURATION REGISTER 6 LOW (BYTE ADDRESS 30000Ah)

<table>
<thead>
<tr>
<th>bit 7-6</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0</td>
<td>U-0</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
<td>R/C-1</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>WRT5&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>WRT4</td>
<td>WRT3</td>
<td>WRT2</td>
<td>WRT1</td>
</tr>
<tr>
<td>bit 7</td>
<td>bit 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Legend:
- **R** = Readable bit
- **C** = Clearable bit
- **U** = Unimplemented bit, read as ‘0’
- **-n** = Value when device is unprogrammed
- **u** = Unchanged from programmed state

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

#### bit 5
- **WRT5**: Write Protection bit<sup>(1)</sup>
  - 1 = Block 5 (014000-017FFFh) not write-protected
  - 0 = Block 5 (014000-017FFFh) write-protected

#### bit 4
- **WRT4**: Write Protection bit
  - 1 = Block 4 (010000-013FFFh) not write-protected
  - 0 = Block 4 (010000-013FFFh) write-protected

#### bit 3
- **WRT3**: Write Protection bit
  - 1 = Block 3 (00C000-00FFFFh) not write-protected
  - 0 = Block 3 (00C000-00FFFFh) write-protected

#### bit 2
- **WRT2**: Write Protection bit
  - 1 = Block 2 (008000-00BFFFh) not write-protected
  - 0 = Block 2 (008000-00BFFFh) write-protected

#### bit 1
- **WRT1**: Write Protection bit
  - 1 = Block 1 (004000-007FFFh) not write-protected
  - 0 = Block 1 (004000-007FFFh) write-protected

#### bit 0
- **WRT0**: Write Protection bit
  - 1 = Block 0 (000800-003FFFh) not write-protected
  - 0 = Block 0 (000800-003FFFh) write-protected

**Note 1**: Unimplemented in PIC18F2682/4682 devices; maintain this bit set.
## REGISTER 24-9: CONFIG6H: CONFIGURATION REGISTER 6 HIGH (BYTE ADDRESS 30000Bh)

<table>
<thead>
<tr>
<th></th>
<th>R/C-1</th>
<th>R/C-1</th>
<th>R-1</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRTD</td>
<td>WRTB</td>
<td>WRTC$^{(1)}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bit 7</th>
<th>bit 0</th>
</tr>
</thead>
</table>

### Legend:
- **R** = Readable bit
- **C** = Clearable bit
- **U** = Unimplemented bit, read as '0'
- **-n** = Value when device is unprogrammed
- **u** = Unchanged from programmed state

### bit 7: WRTD
- **WRTD**: Data EEPROM Write Protection bit
  - 1 = Data EEPROM not write-protected
  - 0 = Data EEPROM write-protected

### bit 6: WRTB
- **WRTB**: Boot Block Write Protection bit
  - 1 = Boot Block (000000-0007FFh) not write-protected
  - 0 = Boot Block (000000-0007FFh) write-protected

### bit 5: WRTC
- **WRTC**: Configuration Register Write Protection bit$^{(1)}$
  - 1 = Configuration registers (300000-3000FFh) not write-protected
  - 0 = Configuration registers (300000-3000FFh) write-protected

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

### Note 1:
This bit is read-only in normal execution mode; it can be written only in Program mode.
REGISTER 24-10: CONFIG7L: CONFIGURATION REGISTER 7 LOW (BYTE ADDRESS 30000Ch)

<table>
<thead>
<tr>
<th></th>
<th>U-0</th>
<th>U-0</th>
<th>R/C-1</th>
<th>R/C-1</th>
<th>R/C-1</th>
<th>R/C-1</th>
<th>R/C-1</th>
<th>EBTR0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>U-0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>R/C-1</td>
<td>EBTR5(1)</td>
<td>EBTR4</td>
<td>EBTR3</td>
<td>EBTR2</td>
<td>EBTR1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- C = Clearable bit
- U = Unimplemented bit, read as ‘0’
- u = Unchanged from programmed state
- -n = Value when device is unprogrammed

bit 7-6 Unimplemented: Read as ‘0’

bit 5  EBTR5: Table Read Protection bit(1)
1 = Block 5 (014000-017FFFh) not protected from table reads executed in other blocks
0 = Block 5 (014000-017FFFh) protected from table reads executed in other blocks

bit 4  EBTR4: Table Read Protection bit
1 = Block 4 (010000-013FFFh) not protected from table reads executed in other blocks
0 = Block 4 (010000-013FFFh) protected from table reads executed in other blocks

bit 3  EBTR3: Table Read Protection bit
1 = Block 3 (00C000-00FFFFh) not protected from table reads executed in other blocks
0 = Block 3 (00C000-00FFFFh) protected from table reads executed in other blocks

bit 2  EBTR2: Table Read Protection bit(1)
1 = Block 2 (008000-00BFFFh) not protected from table reads executed in other blocks
0 = Block 2 (008000-00BFFFh) protected from table reads executed in other blocks

bit 1  EBTR1: Table Read Protection bit
1 = Block 1 (004000-007FFFh) not protected from table reads executed in other blocks
0 = Block 1 (004000-007FFFh) protected from table reads executed in other blocks

bit 0  EBTR0: Table Read Protection bit
1 = Block 0 (000800-003FFFh) not protected from table reads executed in other blocks
0 = Block 0 (000800-003FFFh) protected from table reads executed in other blocks

Note 1: Unimplemented in PIC18F2682/4682 devices; maintain this bit set.

REGISTER 24-11: CONFIG7H: CONFIGURATION REGISTER 7 HIGH (BYTE ADDRESS 30000Dh)

<table>
<thead>
<tr>
<th></th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
<th>U-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>U-0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>R/C-1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>EBTRB</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Legend:
- R = Readable bit
- C = Clearable bit
- U = Unimplemented bit, read as ‘0’
- u = Unchanged from programmed state
- -n = Value when device is unprogrammed

bit 7 Unimplemented: Read as ‘0’

bit 6  EBTRB: Boot Block Table Read Protection bit
1 = Boot Block (000000-0007FFFh) not protected from table reads executed in other blocks
0 = Boot Block (000000-0007FFFh) protected from table reads executed in other blocks

bit 5-0 Unimplemented: Read as ‘0’
REGISTER 24-12: DEVID1: DEVICE ID REGISTER 1 FOR PIC18F2682/2685/4682/4685

<table>
<thead>
<tr>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEV2</td>
<td>DEV1</td>
<td>DEV0</td>
<td>REV4</td>
<td>REV3</td>
<td>REV2</td>
<td>REV1</td>
<td>REV0</td>
</tr>
</tbody>
</table>

Legend:
- R = Read-only bit
- P = Programmable bit
- U = Unimplemented bit, read as '0'
- -n = Value when device is unprogrammed
- u = Unchanged from programmed state

bit 7-5  DEV2:DEV0: Device ID bits
- 000 = PIC18F2682
- 001 = PIC18F2685
- 010 = PIC18F4682
- 011 = PIC18F4685

bit 4-0  REV3:REV0: Revision ID bits
These bits are used to indicate the device revision.

REGISTER 24-13: DEVID2: DEVICE ID REGISTER 2 FOR PIC18F2682/2685/4682/4685

<table>
<thead>
<tr>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEV10</td>
<td>DEV9</td>
<td>DEV8</td>
<td>DEV7</td>
<td>DEV6</td>
<td>DEV5</td>
<td>DEV4</td>
<td>DEV3</td>
</tr>
</tbody>
</table>

Legend:
- R = Read-only bit
- P = Programmable bit
- U = Unimplemented bit, read as '0'
- -n = Value when device is unprogrammed
- u = Unchanged from programmed state

bit 7-0  DEV10:DEV3: Device ID bits
These bits are used with the DEV2:DEV0 bits in Device ID Register 1 to identify the part number.
- 0010 0111 = PIC18F2682/2685/4682/4685 devices

Note 1: These values for DEV10:DEV3 may be shared with other devices. The specific device is always identified by using the entire DEV10:DEV0 bit sequence.
24.2 Watchdog Timer (WDT)

For PIC18F2682/2685/4682/4685 devices, the WDT is driven by the INTRC source. When the WDT is enabled, the clock source is also enabled. The nominal WDT period is 4 ms and has the same stability as the INTRC oscillator.

The 4 ms period of the WDT is multiplied by a 16-bit postscaler. Any output of the WDT postscaler is selected by a multiplexer, controlled by bits in Configuration Register 2H. Available periods range from 4 ms to 131.072 seconds (2.18 minutes). The WDT and postscaler are cleared when any of the following events occur: a SLEEP or CLRWDT instruction is executed, the IRCF bits (OSCCON<6:4>) are changed or a clock failure has occurred.

Note 1: The CLRWDT and SLEEP instructions clear the WDT and postscaler counts when executed.

Note 2: Changing the setting of the IRCF bits (OSCCON<6:4>) clears the WDT and postscaler counts.

Note 3: When a CLRWDT instruction is executed, the postscaler count will be cleared.

24.2.1 CONTROL REGISTER

Register 24-14 shows the WDTCON register. This is a readable and writable register which contains a control bit that allows software to override the WDT enable Configuration bit, but only if the Configuration bit has disabled the WDT.
REGISTER 24-14: WDTCN: WATCHDOG TIMER CONTROL REGISTER

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>SWDTEN(1)</td>
</tr>
</tbody>
</table>

Legend:
R = Readable bit
W = Writable bit
U = Unimplemented bit, read as ‘0’

-n = Value at POR
‘1’ = Bit is set
‘0’ = Bit is cleared
x = Bit is unknown

bit 7-1: Unimplemented: Read as ‘0’
bit 0: SWDTEN: Software Controlled Watchdog Timer Enable bit(1)

1 = Watchdog Timer is on
0 = Watchdog Timer is off

Note 1: This bit has no effect if the Configuration bit, WDTEN, is enabled.

TABLE 24-2: SUMMARY OF WATCHDOG TIMER REGISTERS

<table>
<thead>
<tr>
<th>Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
<th>Reset Values on page</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCON</td>
<td>IPEN</td>
<td>SBOREN</td>
<td>—</td>
<td>RI</td>
<td>TO</td>
<td>PD</td>
<td>POR</td>
<td>BOR</td>
<td>50</td>
</tr>
<tr>
<td>WDTCN</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>SWDTEN</td>
<td>52</td>
</tr>
</tbody>
</table>

Legend: — = unimplemented, read as ‘0’. Shaded cells are not used by the Watchdog Timer.
24.3 Two-Speed Start-up

The Two-Speed Start-up feature helps to minimize the latency period from oscillator start-up to code execution by allowing the microcontroller to use the INTRC oscillator as a clock source until the primary clock source is available. It is enabled by setting the IESO Configuration bit.

Two-Speed Start-up should be enabled only if the primary oscillator mode is LP, XT, HS or HSPLL (Crystal-based modes). Other sources do not require an OST start-up delay; for these, Two-Speed Start-up should be disabled.

When enabled, Resets and wake-ups from Sleep mode cause the device to configure itself to run from the internal oscillator block as the clock source, following the time-out of the Power-up Timer after a Power-on Reset is enabled. This allows almost immediate code execution while the primary oscillator starts and the OST is running. Once the OST times out, the device automatically switches to PRI_RUN mode.

Because the OSCCON register is cleared on Reset events, the INTOSC (or postscaler) clock source is not initially available after a Reset event; the INTRC clock is used directly at its base frequency. To use a higher clock speed on wake-up, the INTOSC or postscaler clock sources can be selected to provide a higher clock speed by setting bits, IRCF2:IRCF0, immediately after Reset. For wake-ups from Sleep, the INTOSC or postscaler clock sources can be selected by setting the IRCF2:IRCF0 bits prior to entering Sleep mode.

In all other power-managed modes, Two-Speed Start-up is not used. The device will be clocked by the currently selected clock source until the primary clock source becomes available. The setting of the IESO bit is ignored.

24.3.1 SPECIAL CONSIDERATIONS FOR USING TWO-SPEED START-UP

While using the INTRC oscillator in Two-Speed Start-up, the device still obeys the normal command sequences for entering power-managed modes, including serial SLEEP instructions (refer to Section 3.1.4 “Multiple Sleep Commands”). In practice, this means that user code can change the SCS1:SCS0 bit settings or issue SLEEP instructions before the OST times out. This would allow an application to briefly wake-up, perform routine “housekeeping” tasks and return to Sleep before the device starts to operate from the primary oscillator.

User code can also check if the primary clock source is currently providing the device clocking by checking the status of the OSTS bit (OSCCON<3>). If the bit is set, the primary oscillator is providing the clock. Otherwise, the internal oscillator block is providing the clock during wake-up from Reset or Sleep mode.

FIGURE 24-2: TIMING TRANSITION FOR TWO-SPEED START-UP (INTOSC TO HSPLL)

Note 1: TOST = 1024 TOSC; TPLL = 2 ms (approx). These intervals are not shown to scale.
24.4 Fail-Safe Clock Monitor

The Fail-Safe Clock Monitor (FSCM) allows the microcontroller to continue operation in the event of an external oscillator failure by automatically switching the device clock to the internal oscillator block. The FSCM function is enabled by setting the FCMEN Configuration bit.

When FSCM is enabled, the INTRC oscillator runs at all times to monitor clocks to peripherals and provide a backup clock in the event of a clock failure. Clock monitoring (shown in Figure 24-3) is accomplished by creating a sample clock signal, which is the INTRC output divided by 64. This allows ample time between FSCM sample clocks for a peripheral clock edge to occur. The peripheral device clock and the sample clock are presented as inputs to the Clock Monitor latch (CM). The CM is set on the falling edge of the device clock source, but cleared on the rising edge of the sample clock.

FIGURE 24-3: FSCM BLOCK DIAGRAM

Clock failure is tested for on the falling edge of the sample clock. If a sample clock falling edge occurs while CM is still set, a clock failure has been detected (Figure 24-4). This causes the following:

- the FSCM generates an oscillator fail interrupt by setting bit, OSCFIF (PIR2<7>);
- the device clock source is switched to the internal oscillator block (OSCCON is not updated to show the current clock source – this is the fail-safe condition); and
- the WDT is reset.

During switchover, the postscaler frequency from the internal oscillator block may not be sufficiently stable for timing sensitive applications. In these cases, it may be desirable to select another clock configuration and enter an alternate power-managed mode. This can be done to attempt a partial recovery or execute a controlled shutdown. See Section 3.1.4 “Multiple Sleep Commands” and Section 24.3.1 “Special Considerations for Using Two-Speed Start-up” for more details.

To use a higher clock speed on wake-up, the INTOSC or postscaler clock sources can be selected to provide a higher clock speed by setting bits, IRCF2:IRCF0, immediately after Reset. For wake-ups from Sleep, the INTOSC or postscaler clock sources can be selected by setting the IRCF2:IRCF0 bits prior to entering Sleep mode.

The FSCM will detect failures of the primary or secondary clock sources only. If the internal oscillator block fails, no failure would be detected, nor would any action be possible.

24.4.1 FSCM AND THE WATCHDOG TIMER

Both the FSCM and the WDT are clocked by the INTRC oscillator. Since the WDT operates with a separate divider and counter, disabling the WDT has no effect on the operation of the INTRC oscillator when the FSCM is enabled.

As already noted, the clock source is switched to the INTOSC clock when a clock failure is detected. Depending on the frequency selected by the IRCF2:IRCF0 bits, this may mean a substantial change in the speed of code execution. If the WDT is enabled with a small prescale value, a decrease in clock speed allows a WDT time-out to occur and a subsequent device Reset. For this reason, fail-safe clock events also reset the WDT and postscaler, allowing it to start timing from when execution speed was changed and decreasing the likelihood of an erroneous time-out.

24.4.2 EXITING FAIL-SAFE OPERATION

The fail-safe condition is terminated by either a device Reset or by entering a power-managed mode. On Reset, the controller starts the primary clock source specified in Configuration Register 1H (with any required start-up delays that are required for the oscillator mode, such as OST or PLL timer). The INTOSC multiplexer provides the device clock until the primary clock source becomes ready (similar to a Two-Speed Start-up). The clock source is then switched to the primary clock (indicated by the OSTS bit in the OSCCON register becoming set). The Fail-Safe Clock Monitor then resumes monitoring the peripheral clock.

The primary clock source may never become ready during start-up. In this case, operation is clocked by the INTOSC multiplexer. The OSCCON register will remain in its Reset state until a power-managed mode is entered.
24.4.3 FSCM INTERRUPTS IN POWER-MANAGED MODES

By entering a power-managed mode, the clock multiplexer selects the clock source selected by the OSCCON register. Fail-Safe Monitoring of the power-managed clock source resumes in the power-managed mode.

If an oscillator failure occurs during power-managed operation, the subsequent events depend on whether or not the oscillator failure interrupt is enabled. If enabled (OSCFIF = 1), code execution will be clocked by the INTOSC multiplexer. An automatic transition back to the failed clock source will not occur.

If the interrupt is disabled, subsequent interrupts while in Idle mode will cause the CPU to begin executing instructions while being clocked by the INTOSC source.

24.4.4 POR OR WAKE-UP FROM SLEEP

The FSCM is designed to detect oscillator failure at any point after the device has exited Power-on Reset (POR) or low-power Sleep mode. When the primary device clock is EC, RC or INTRC, monitoring can begin immediately following these events.

For oscillator modes involving a crystal or resonator (HS, HSPLL, LP or XT), the situation is somewhat different. Since the oscillator may require a start-up time considerably longer than the FCSM sample clock time, a false clock failure may be detected. To prevent this, the internal oscillator block is automatically configured as the device clock and functions until the primary clock is stable (the OST and PLL timers have timed out). This is identical to Two-Speed Start-up mode. Once the primary clock is stable, the INTRC returns to its role as the FSCM source.

As noted in Section 24.3.1 “Special Considerations for Using Two-Speed Start-up”, it is also possible to select another clock configuration and enter an alternate power-managed mode while waiting for the primary clock to become stable. When the new power-managed mode is selected, the primary clock is disabled.
24.5 Program Verification and Code Protection

The overall structure of the code protection on the PIC18 Flash devices differs significantly from other PIC devices.

The user program memory is divided into five blocks. One of these is a boot block of 2 Kbytes. The remainder of the memory is divided into four blocks on binary boundaries.

Each of the five blocks has three code protection bits associated with them. They are:
- Code-Protect bit (CPn)
- Write-Protect bit (WRTn)
- External Block Table Read bit (EBTRn)

Figure 24-5 shows the program memory organization for 80- and 96-Kbyte devices and the specific code protection bit associated with each block. The actual locations of the bits are summarized in Table 24-3.
TABLE 24-3: SUMMARY OF CODE PROTECTION REGISTERS

<table>
<thead>
<tr>
<th>File Name</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>300008h</td>
<td>CONFIG5L</td>
<td>—</td>
<td>—</td>
<td>CP5&lt;sup&gt;(f)&lt;/sup&gt;</td>
<td>CP4</td>
<td>CP3</td>
<td>CP2</td>
<td>CP1</td>
</tr>
<tr>
<td>300009h</td>
<td>CONFIG5H</td>
<td>CPD</td>
<td>CPB</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>30000Ah</td>
<td>CONFIG6L</td>
<td>—</td>
<td>—</td>
<td>WRT5&lt;sup&gt;(f)&lt;/sup&gt;</td>
<td>WRT4</td>
<td>WRT3</td>
<td>WRT2</td>
<td>WRT1</td>
</tr>
<tr>
<td>30000Bh</td>
<td>CONFIG6H</td>
<td>WRTD</td>
<td>WRTB</td>
<td>WRTC</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>30000Ch</td>
<td>CONFIG7L</td>
<td>—</td>
<td>—</td>
<td>EBTR5&lt;sup&gt;(f)&lt;/sup&gt;</td>
<td>EBTR4</td>
<td>EBTR3</td>
<td>EBTR2</td>
<td>EBTR1</td>
</tr>
<tr>
<td>30000Dh</td>
<td>CONFIG7H</td>
<td>—</td>
<td>—</td>
<td>EBTRB</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Legend: Shaded cells are unimplemented.

Note 1: Unimplemented in PIC18F2682/4682 devices; maintain this bit set.

24.5.1 PROGRAM MEMORY CODE PROTECTION

The program memory may be read to or written from any location using the table read and table write instructions. The Device ID may be read with table reads. The Configuration registers may be read and written with the table read and table write instructions.

In normal execution mode, the CPn bits have no direct effect. CPn bits inhibit external reads and writes. A block of user memory may be protected from table writes if the WRTn Configuration bit is ‘0’. The EBTRn bits control table reads. For a block of user memory with the EBTRn bit set to ‘0’, a table read instruction that executes from within that block is allowed to read.

A table read instruction that executes from a location outside of that block is not allowed to read and will result in reading ‘0’ s. Figures 24-6 through 24-8 illustrate table write and table read protection.

Note: Code protection bits may only be written to a ‘0’ from a ‘1’ state. It is not possible to write a ‘1’ to a bit in the ‘0’ state. Code protection bits are only set to ‘1’ by a full Chip Erase or Block Erase function. The full Chip Erase and Block Erase functions can only be initiated via ICSP or an external programmer.
FIGURE 24-6: TABLE WRITE (WRTn) DISALLOWED

```
Register Values
TBLPTR = 0008FFh
PC = 003FFEh
PC = 00BFFEh

Program Memory
000000h
0007FFh
000800h
003FFFh
004000h
007FFFh
008000h
00BFFFh
00C000h
00FFFFh
0010000h
0014000h
0017FFh

WRTB, EBTRB = 11
WRT0, EBTR0 = 01
WRT1, EBTR1 = 11
WRT2, EBTR2 = 11
WRT3, EBTR3 = 11
WRT4, EBTR3 = 11
WRT5, EBTR3 = 11
```

Results: All table writes disabled to Blockn whenever WRTn = 0.

FIGURE 24-7: EXTERNAL BLOCK TABLE READ (EBTRn) DISALLOWED

```
Register Values
TBLPTR = 0008FFh
PC = 007FFEh

Program Memory
000000h
0007FFh
000800h
003FFFh
004000h
007FFFh
008000h
00BFFFh
00C000h
00FFFFh
0010000h
0014000h
0017FFh

WRTB, EBTRB = 11
WRT0, EBTR0 = 01
WRT1, EBTR1 = 11
WRT2, EBTR2 = 11
WRT3, EBTR3 = 11
WRT4, EBTR3 = 11
WRT5, EBTR3 = 11
```

Results: All table reads from external blocks to Blockn are disabled whenever EBTRn = 0. TABLAT register returns a value of '0'.
**FIGURE 24-8: EXTERNAL BLOCK TABLE READ (EBTRn) ALLOWED**

<table>
<thead>
<tr>
<th>Register Values</th>
<th>Program Memory</th>
<th>Configuration Bit Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBLPTR = 0008FFh</td>
<td></td>
<td>WRTB, EBTRB = 11</td>
</tr>
<tr>
<td>PC = 003FFEh</td>
<td>000000h</td>
<td>WRT0, EBTR0 = 01</td>
</tr>
<tr>
<td></td>
<td>0007FFh</td>
<td>WRT1, EBTR1 = 11</td>
</tr>
<tr>
<td></td>
<td>000800h</td>
<td>WRT2, EBTR2 = 11</td>
</tr>
<tr>
<td></td>
<td>003FFFh</td>
<td>WRT3, EBTR3 = 11</td>
</tr>
<tr>
<td></td>
<td>004000h</td>
<td>WRT4, EBTR3 = 11</td>
</tr>
<tr>
<td></td>
<td>007FFFh</td>
<td>WRT5, EBTR3 = 11</td>
</tr>
<tr>
<td></td>
<td>008000h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>00BFFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>00C000h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>00FFFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>010000h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>013FFFh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>014000h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>017FFFh</td>
<td></td>
</tr>
</tbody>
</table>

**Results:** Table reads permitted within Blockn, even when EBTRBn = 0. TABLAT register returns the value of the data at the location TBLPTR.
24.5.2  DATA EEPROM
CODE PROTECTION
The entire data EEPROM is protected from external
reads and writes by two bits: CPD and WRTD. CPD
inhibits external reads and writes to data EEPROM.
WRTD inhibits internal and external writes to data
EEPROM. The CPU can continue to read and write
data EEPROM regardless of the protection bit settings.

24.5.3  CONFIGURATION REGISTER
PROTECTION
The Configuration registers can be write-protected.
The WRTC bit controls protection of the Configuration
registers. In normal execution mode, the WRTC bit is
readable only. WRTC can only be written via ICSP or
an external programmer.

24.6  ID Locations
Eight memory locations (200000h-200007h) are
designated as ID locations, where the user can store
checksum or other code identification numbers. These
locations are both readable and writable during normal
execution through the TBLRD and TBLWT instructions
or during program/verify. The ID locations can be read
when the device is code-protected.

24.7  In-Circuit Serial Programming
PIC18F2682/2685/4682/4685 microcontrollers can be
serially programmed while in the end application circuit.
This is simply done with two lines for clock and data
and three other lines for power, ground and the
programming voltage. This allows customers to
manufacture boards with unprogrammed devices and
then program the microcontroller just before shipping
the product. This also allows the most recent firmware
or a custom firmware to be programmed.

24.8  In-Circuit Debugger
When the DEBUG Configuration bit is programmed to
a ‘0’, the In-Circuit Debugger functionality is enabled.
This function allows simple debugging functions when
used with MPLAB® IDE. When the microcontroller has
this feature enabled, some resources are not available
for general use. Table 24-4 shows which resources are
required by the background debugger.

<table>
<thead>
<tr>
<th>TABLE 24-4: DEBUGGER RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O pins:</td>
</tr>
<tr>
<td>Stack:</td>
</tr>
</tbody>
</table>

Note: Memory sources listed in MPLAB® IDE.

To use the In-Circuit Debugger function of the micro-
controller, the design must implement In-Circuit Serial
Programming connections to MCLR/VPP/RE3, Vdd,
Vss, RB7 and RB6. This will interface to the In-Circuit
Debugger module available from Microchip or one of
the third party development tool companies.

24.9  Single-Supply ICSP Programming
The LVP Configuration bit enables Single-Supply ICSP
programming (formerly known as Low-Voltage ICSP
Programming or LVP). When Single-Supply Program-
ing is enabled, the microcontroller can be programmed
without requiring high voltage being applied to the
MCLR/VPP/RE3 pin, but the RB5/KBI1/PGM pin is then
dedicated to controlling Program mode entry and is not
available as a general purpose I/O pin.

While programming using Single-Supply Programming,
Vdd is applied to the MCLR/VPP/RE3 pin as in normal
execution mode. To enter Programming mode, Vdd is
applied to the PGM pin.

Note 1: High-voltage programming is always avail-
able, regardless of the state of the LVP bit,
by applying Vih to the MCLR pin.

2: While in Low-Voltage ICSP Programming
mode, the RB5 pin can no longer be used
as a general purpose I/O pin and should
be held low during normal operation.

3: When using Low-Voltage ICSP Program-
ing (LVP) and the pull-ups on PORTB
are enabled, bit 5 in the TRISB register
must be cleared to disable the pull-up on
RB5 and ensure the proper operation of
the device.

4: If the device Master Clear is disabled,
verify that either of the following is done
to ensure proper entry into ICSP mode:
a)  disable Low-Voltage Programming
CONFIG4L<2> = 0; or
b)  make certain that RB5/KBI1/PGM
is held low during entry into ICSP.

If Single-Supply ICSP Programming mode will not be
used, the LVP bit can be cleared. RB5/KBI1/PGM then
becomes available as the digital I/O pin, RB5. The LVP
bit may be set or cleared only when using standard
high-voltage programming (Vih applied to the MCLR/
VPP/RE3 pin). Once LVP has been disabled, only the
standard high-voltage programming is available and
must be used to program the device.

Memory that is not code-protected can be erased using
either a block erase, or erased row by row, then written
at any specified Vdd. If code-protected memory is to be
erased, a block erase is required. If a block erase is to
be performed when using Low-Voltage Programming,
the device must be supplied with Vdd of 4.5V to 5.5V.
25.0 INSTRUCTION SET SUMMARY

PIC18F2682/2685/4682/4685 devices incorporate the standard set of 75 PIC18 core instructions, as well as an extended set of 8 new instructions, for the optimization of code that is recursive or that utilizes a software stack. The extended set is discussed later in this section.

25.1 Standard Instruction Set

The standard PIC18 instruction set adds many enhancements to the previous PIC® MCU instruction sets, while maintaining an easy migration from these PIC MCU instruction sets. Most instructions are a single program memory word (16 bits), but there are four instructions that require two program memory locations.

Each single-word instruction is a 16-bit word divided into an 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 four basic categories:

- **Byte-oriented** operations
- **Bit-oriented** operations
- **Literal** operations
- **Control** operations

The PIC18 instruction set summary in Table 25-2 lists byte-oriented, bit-oriented, literal and control operations. Table 25-1 shows the opcode field descriptions.

Most byte-oriented instructions have three operands:
1. The file register (specified by 'f')
2. The destination of the result (specified by 'd')
3. The accessed memory (specified by 'a')

The file register designator 'f' specifies which file register is to be used by the instruction. The destination designator 'd' specifies where the result of the operation is to be placed. If 'd' is zero, the result is placed in the WREG register. If 'd' is one, the result is placed in the file register specified in the instruction.

All bit-oriented instructions have three operands:
1. The file register (specified by 'f')
2. The bit in the file register (specified by 'b')
3. The accessed memory (specified by 'a')

The bit field designator 'b' selects the number of the bit affected by the operation, while the file register designator 'f' represents the number of the file in which the bit is located.

The literal instructions may use some of the following operands:
- A literal value to be loaded into a file register (specified by 'k')
- The desired FSR register to load the literal value into (specified by 'f')
- No operand required (specified by ‘—’)

The control instructions may use some of the following operands:
- A program memory address (specified by 'n')
- The mode of the CALL or RETURN instructions (specified by 's')
- The mode of the table read and table write instructions (specified by 'm')
- No operand required (specified by ‘—’)

All instructions are a single word, except for four double-word instructions. These instructions were made double-word to contain the required information in 32 bits. In the second word, the 4 MSBs are ‘1’s. If this second word is executed as an instruction (by itself), it will execute as a NOP.

All 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. In these cases, the execution takes two instruction cycles with the additional instruction cycle(s) executed as a NOP.

The double-word instructions execute in two instruction cycles.

One instruction cycle consists of four oscillator periods. Thus, for an oscillator frequency of 4 MHz, the normal instruction execution time is 1 μs. If a conditional test is true, or the program counter is changed as a result of an instruction, the instruction execution time is 2 μs.

Two-word branch instructions (if true) would take 3 μs.

Figure 25-1 shows the general formats that the instructions can have. All examples use the convention ‘nnh’ to represent a hexadecimal number.

The Instruction Set Summary, shown in Table 25-2, lists the standard instructions recognized by the Microchip MPASM™ Assembler.

Section 25.1.1 “Standard Instruction Set” provides a description of each instruction.
## Table 25-1: Opcode Field Descriptions

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
</table>
| `a`   | RAM access bit  
|       | \( a = 0 \): RAM location in Access RAM (BSR register is ignored)  
|       | \( a = 1 \): RAM bank is specified by BSR register |
| `bbb` | Bit address within an 8-bit file register (0 to 7). |
| `BSR` | Bank Select Register. Used to select the current RAM bank. |
| `C, DC, Z, OV, N` | ALU Status bits: Carry, Digit Carry, Zero, Overflow, Negative. |
| `d`   | Destination select bit  
|       | \( d = 0 \): store result in WREG  
|       | \( d = 1 \): store result in file register \( f \) |
| `dest` | Destination: either the WREG register or the specified register file location. |
| `f`   | 8-bit Register file address (00h to FFh), or 2-bit FSR designator (0h to 3h). |
| `\( f_{i} \)` | 12-bit Register file address (000h to FFFh). This is the source address. |
| `\( f_{d} \)` | 12-bit Register file address (000h to FFFh). This is the destination address. |
| `GIE` | Global Interrupt Enable bit. |
| `k`   | Literal field, constant data or label (may be either an 8-bit, 12-bit or a 20-bit value) |
| `label` | Label name |
| `mm`  | The mode of the TBLPTR register for the table read and table write instructions.  
|       | Only used with table read and table write instructions:  
|       | \* No change to register (such as TBLPTR with table reads and writes)  
|       | \*+ Post-Increment register (such as TBLPTR with table reads and writes)  
|       | \*- Post-Decrement register (such as TBLPTR with table reads and writes)  
|       | \*\* Pre-Increment register (such as TBLPTR with table reads and writes) |
| `n`   | The relative address (2’s complement number) for relative branch instructions or the direct address for Call/Branch and Return instructions |
| `PC`  | Program Counter. |
| `PCL` | Program Counter Low Byte. |
| `PCH` | Program Counter High Byte. |
| `PCLATH` | Program Counter High Byte Latch. |
| `PCLATU` | Program Counter Upper Byte Latch. |
| `PD`  | Power-down bit. |
| `PRODH` | Product of Multiply High Byte. |
| `PRODL` | Product of Multiply Low Byte. |
| `s`   | Fast Call/Return mode select bit  
|       | \( s = 0 \): do not update into/from shadow registers  
|       | \( s = 1 \): certain registers loaded into/from shadow registers (Fast mode) |
| `TBLPTR` | 21-bit Table Pointer (points to a Program Memory location). |
| `TABLAT` | 8-bit Table Latch. |
| `TU`  | Time-out bit. |
| `TOS` | Top-of-Stack. |
| `u`   | Unused or unchanged. |
| `WDT` | Watchdog Timer. |
| `WREG` | Working register (accumulator). |
| `x`   | Don’t care (‘0’ or ‘1’). The assembler will generate code with \( x = 0 \). It is the recommended form of use for compatibility with all Microchip software tools. |
| `\( z_{s} \)` | 7-bit offset value for indirect addressing of register files (source). |
| `\( z_{d} \)` | 7-bit offset value for indirect addressing of register files (destination). |
| `{ }` | Optional argument. |
| `[text]` | Indicates an indexed address. |
| `(text)` | The contents of text. |
| `[expr]<n>` | Specifies bit \( n \) of the register indicated by the pointer `expr`. |
| \( \rightarrow \) | Assigned to. |
| `< >` | Register bit field. |
| `∈`   | In the set of. |

*italics* | User defined term (font is Courier).
### FIGURE 25-1: GENERAL FORMAT FOR INSTRUCTIONS

#### Byte-oriented file register operations

<table>
<thead>
<tr>
<th>15</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>d</td>
<td>a</td>
<td>f (FILE #)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **d** = 0 for result destination to be WREG register
- **d** = 1 for result destination to be file register (f)
- **a** = 0 to force Access Bank
- **a** = 1 for BSR to select bank
- **f** = 8-bit file register address

#### Byte to Byte move operations (2-word)

<table>
<thead>
<tr>
<th>15</th>
<th>12</th>
<th>11</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>f (Source FILE #)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Bit-oriented file register operations

<table>
<thead>
<tr>
<th>15</th>
<th>12</th>
<th>11</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>b (BIT #)</td>
<td>a</td>
<td>f (FILE #)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **b** = 3-bit position of bit in file register (f)
- **a** = 0 to force Access Bank
- **a** = 1 for BSR to select bank
- **f** = 8-bit file register address

#### Literal operations

<table>
<thead>
<tr>
<th>15</th>
<th>8</th>
<th>7</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>k (literal)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **k** = 8-bit immediate value

#### Control operations

**CALL, GOTO and Branch** operations

<table>
<thead>
<tr>
<th>15</th>
<th>8</th>
<th>7</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>n&lt;7:0&gt; (literal)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **n** = 20-bit immediate value

**CALL**

<table>
<thead>
<tr>
<th>15</th>
<th>12</th>
<th>11</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>S</td>
<td>n&lt;7:0&gt; (literal)</td>
<td></td>
</tr>
</tbody>
</table>

- **S** = Fast bit

**BRA**

<table>
<thead>
<tr>
<th>15</th>
<th>11</th>
<th>10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>n&lt;10:0&gt; (literal)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BC**

<table>
<thead>
<tr>
<th>15</th>
<th>8</th>
<th>7</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>n&lt;7:0&gt; (literal)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GOTO**

<table>
<thead>
<tr>
<th>15</th>
<th>12</th>
<th>11</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPCODE</strong></td>
<td>n&lt;19:8&gt; (literal)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## TABLE 25-2: PIC18FXXXX INSTRUCTION SET

<table>
<thead>
<tr>
<th>Mnemonic, Operands</th>
<th>Description</th>
<th>Cycles</th>
<th>16-Bit Instruction Word</th>
<th>Status Bits Affected</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MSb</td>
<td>LSb</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADDWF f, d, a</td>
<td>Add WREG and f</td>
<td>1</td>
<td>1001 01da ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>ADDWFC f, d, a</td>
<td>Add WREG and Carry bit to f</td>
<td>1</td>
<td>1000 00da ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>ANDWF f, d, a</td>
<td>AND WREG with f</td>
<td>1</td>
<td>0001 01da ffff ffff</td>
<td>Z, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>CLRF f, a</td>
<td>Clear f</td>
<td>1</td>
<td>0110 101a ffff ffff</td>
<td>Z</td>
<td>2</td>
</tr>
<tr>
<td>COMF f, d, a</td>
<td>Complement f</td>
<td>1</td>
<td>0001 11da ffff ffff</td>
<td>Z, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>CPFSEQ f, a</td>
<td>Compare f with WREG, skip =</td>
<td>1 (2 or 3)</td>
<td>0110 001a ffff ffff</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>CPFSGT f, a</td>
<td>Compare f with WREG, skip &gt;</td>
<td>1 (2 or 3)</td>
<td>0110 010a ffff ffff</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>CPFSLT f, a</td>
<td>Compare f with WREG, skip &lt;</td>
<td>1 (2 or 3)</td>
<td>0110 000a ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>DECF f, d, a</td>
<td>Decrement f</td>
<td>1</td>
<td>0000 01da ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>DECF f, d, a</td>
<td>Decrement f, Skip if 0</td>
<td>1 (2 or 3)</td>
<td>0110 11da ffff ffff</td>
<td>None</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>DCFSNZ f, d, a</td>
<td>Decrement f, Skip if Not 0</td>
<td>1 (2 or 3)</td>
<td>0100 11da ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>INCF f, d, a</td>
<td>Increment f</td>
<td>1</td>
<td>0110 010a ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>INCFSZ f, d, a</td>
<td>Increment f, Skip if 0</td>
<td>1 (2 or 3)</td>
<td>0111 11da ffff ffff</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>INFSNZ f, d, a</td>
<td>Increment f, Skip if Not 0</td>
<td>1 (2 or 3)</td>
<td>0100 10da ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>IORWF f, d, a</td>
<td>Inclusive OR WREG with f</td>
<td>1</td>
<td>0001 00da ffff ffff</td>
<td>Z, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>MOVF f, d, a</td>
<td>Move f</td>
<td>1</td>
<td>0110 01da ffff ffff</td>
<td>Z</td>
<td>1</td>
</tr>
<tr>
<td>MOVFF fₛ, fₜ</td>
<td>Move fₛ (source) to 1st word fₜ (destination)</td>
<td>2</td>
<td>1100 ffff ffff ffff</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOVWF f, a</td>
<td>Move WREG to f</td>
<td>1</td>
<td>0110 011a ffff ffff</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>MULWF f, a</td>
<td>Multiply WREG with f</td>
<td>1</td>
<td>0000 001a ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>NEGF f, a</td>
<td>Negate f</td>
<td>1</td>
<td>0110 110a ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>RLCF f, d, a</td>
<td>Rotate Left f through Carry</td>
<td>1</td>
<td>0011 01da ffff ffff</td>
<td>C, Z, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>RLNCF f, d, a</td>
<td>Rotate Left f (No Carry)</td>
<td>1</td>
<td>0100 01da ffff ffff</td>
<td>Z</td>
<td>N</td>
</tr>
<tr>
<td>RRCF f, d, a</td>
<td>Rotate Right f through Carry</td>
<td>1</td>
<td>0011 00da ffff ffff</td>
<td>C, Z, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>RRNCF f, d, a</td>
<td>Rotate Right f (No Carry)</td>
<td>1</td>
<td>0100 00da ffff ffff</td>
<td>Z</td>
<td>N</td>
</tr>
<tr>
<td>SETF f, a</td>
<td>Set f</td>
<td>1</td>
<td>0110 100a ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>SUBFWB f, d, a</td>
<td>Subtract f from WREG with borrow</td>
<td>1</td>
<td>0101 01da ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>SUBWF f, d, a</td>
<td>Subtract WREG from f</td>
<td>1</td>
<td>0110 10da ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>SUBWFB f, d, a</td>
<td>Subtract WREG from f with borrow</td>
<td>1</td>
<td>0110 10da ffff ffff</td>
<td>C, DC, Z, OV, N</td>
<td>1, 2</td>
</tr>
<tr>
<td>SWAPF f, d, a</td>
<td>Swap nibbles in f</td>
<td>1</td>
<td>0110 10da ffff ffff</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>TSTFSZ f, a</td>
<td>Test f, skip if 0</td>
<td>1 (2 or 3)</td>
<td>0110 011a ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>XORWF f, d, a</td>
<td>Exclusive OR WREG with f</td>
<td>1</td>
<td>0001 10da ffff ffff</td>
<td>Z, N</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** When a PORT register is modified as a function of itself (e.g., MOVF PORTB, 1, 0), the value used will be that value present on the pins themselves. For example, if the data latch is ‘1’ for a pin configured as input and is driven low by an external device, the data will be written back with a ‘0’.

2: If this instruction is executed on the TMR0 register (and where applicable, ‘d’ ≠ 1), the prescaler will be cleared if assigned.

3: If Program Counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

4: Some instructions are two-word instructions. The second word of these instructions will be executed as a NOP unless the first word of the instruction retrieves the information embedded in these 16 bits. This ensures that all program memory locations have a valid instruction.

5: If the table write starts the write cycle to internal memory, the write will continue until terminated.
### BIT-ORIENTED OPERATIONS

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Operands</th>
<th>Description</th>
<th>Cycles</th>
<th>16-Bit Instruction Word</th>
<th>Status Bits Affected</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCF</td>
<td>f, b, a</td>
<td>Bit Clear f</td>
<td>1</td>
<td>1001 bbba ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>BSF</td>
<td>f, b, a</td>
<td>Bit Set f</td>
<td>1</td>
<td>1000 bbba ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
<tr>
<td>BTFSC</td>
<td>f, b, a</td>
<td>Bit Test f, Skip if Clear</td>
<td>1 (2 or 3)</td>
<td>1011 bbba ffff ffff</td>
<td>None</td>
<td>3, 4</td>
</tr>
<tr>
<td>BTFSS</td>
<td>f, b, a</td>
<td>Bit Test f, Skip if Set</td>
<td>1 (2 or 3)</td>
<td>1010 bbba ffff ffff</td>
<td>None</td>
<td>3, 4</td>
</tr>
<tr>
<td>BTG</td>
<td>f, b, a</td>
<td>Bit Toggle f</td>
<td>1</td>
<td>0111 bbba ffff ffff</td>
<td>None</td>
<td>1, 2</td>
</tr>
</tbody>
</table>

### CONTROL OPERATIONS

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Operands</th>
<th>Description</th>
<th>Cycles</th>
<th>16-Bit Instruction Word</th>
<th>Status Bits Affected</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>n</td>
<td>Branch if Carry</td>
<td>1 (2)</td>
<td>1110 0010 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BN</td>
<td>n</td>
<td>Branch if Negative</td>
<td>1 (2)</td>
<td>1110 0110 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BNC</td>
<td>n</td>
<td>Branch if Not Carry</td>
<td>1 (2)</td>
<td>1110 0011 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BNN</td>
<td>n</td>
<td>Branch if Not Negative</td>
<td>1 (2)</td>
<td>1110 0111 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BNOV</td>
<td>n</td>
<td>Branch if Not Overflow</td>
<td>1 (2)</td>
<td>1110 0101 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BNZ</td>
<td>n</td>
<td>Branch if Not Zero</td>
<td>1 (2)</td>
<td>1110 0001 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BOV</td>
<td>n</td>
<td>Branch if Overflow</td>
<td>1 (2)</td>
<td>1110 0100 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BRA</td>
<td>n</td>
<td>Branch Unconditionally</td>
<td>2</td>
<td>1101 0nnn nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>BZ</td>
<td>n</td>
<td>Branch if Zero</td>
<td>1 (2)</td>
<td>1110 0000 nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>CALL</td>
<td>n, s</td>
<td>Call subroutine 1st word</td>
<td>2</td>
<td>1110 110s kkkk kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd word</td>
<td></td>
<td>1111 kkkk kkkk kkkk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLRWDT</td>
<td>—</td>
<td>Clear Watchdog Timer</td>
<td>1</td>
<td>0000 0000 0000 0100</td>
<td>TO, PD</td>
<td></td>
</tr>
<tr>
<td>DAW</td>
<td>—</td>
<td>Decimal Adjust WREG</td>
<td>1</td>
<td>0000 0000 0000 0111</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>GOTO</td>
<td>n</td>
<td>Go to address 1st word</td>
<td>2</td>
<td>1110 1111 kkkk kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd word</td>
<td></td>
<td>1111 kkkk kkkk kkkk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOP</td>
<td>—</td>
<td>No Operation</td>
<td>1</td>
<td>0000 0000 0000 0000</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>NOP</td>
<td>—</td>
<td>No Operation</td>
<td>1</td>
<td>1111 xxxx xxxx xxxx</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>POP</td>
<td>—</td>
<td>Pop top of return stack (TOS)</td>
<td>1</td>
<td>0000 0000 0000 0110</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>PUSH</td>
<td>—</td>
<td>Push top of return stack (TOS)</td>
<td>1</td>
<td>0000 0000 0000 0110</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>RCALL</td>
<td>n</td>
<td>Relative Call</td>
<td>2</td>
<td>1101 lnnn nnnn nnnn</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>RESET</td>
<td>—</td>
<td>Software device Reset</td>
<td>1</td>
<td>0000 0000 1111 1111</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>RETFIE</td>
<td>s</td>
<td>Return from interrupt enable</td>
<td>2</td>
<td>0000 0000 0001 000s</td>
<td>GIE/GIEH, PEIE/PEIEL</td>
<td></td>
</tr>
<tr>
<td>RETLW</td>
<td>k</td>
<td>Return with literal in WREG</td>
<td>2</td>
<td>0000 1100 kkkk kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>RETURN</td>
<td>s</td>
<td>Return from Subroutine</td>
<td>2</td>
<td>0000 0000 0001 001s</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>SLEEP</td>
<td>—</td>
<td>Go into Standby mode</td>
<td>1</td>
<td>0000 0000 0000 0011</td>
<td>TO, PD</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** When a PORT register is modified as a function of itself (e.g., MOVF PORTB, 1, 0), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

2: If this instruction is executed on the TMR0 register (and where applicable, 'd' = 1), the prescaler will be cleared if assigned.

3: If Program Counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

4: Some instructions are two-word instructions. The second word of these instructions will be executed as a NOP unless the first word of the instruction retrieves the information embedded in these 16 bits. This ensures that all program memory locations have a valid instruction.

5: If the table write starts the write cycle to internal memory, the write will continue until terminated.
### TABLE 25-2: PIC18FXXXX INSTRUCTION SET (CONTINUED)

<table>
<thead>
<tr>
<th>Mnemonic, Operands</th>
<th>Description</th>
<th>Cycles</th>
<th>16-Bit Instruction Word</th>
<th>Status Bits Affected</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MSb</td>
<td>LSb</td>
<td></td>
</tr>
<tr>
<td><strong>LITERAL OPERATIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADDLW k</td>
<td>Add literal and WREG</td>
<td>1</td>
<td>0000 1111 kkkk kkkk</td>
<td>C, DC, Z, OV, N</td>
<td></td>
</tr>
<tr>
<td>ANDLW k</td>
<td>AND literal with WREG</td>
<td>1</td>
<td>0000 1011 kkkk kkkk</td>
<td>Z, N</td>
<td></td>
</tr>
<tr>
<td>IORLW k</td>
<td>Inclusive OR literal with WREG</td>
<td>1</td>
<td>0000 1001 kkkk kkkk</td>
<td>Z, N</td>
<td></td>
</tr>
<tr>
<td>LFSR f, k</td>
<td>Move literal (12-bit) 2nd word to FSR(f) 1st word</td>
<td>2</td>
<td>1111 1110 00ff kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>MOVLB k</td>
<td>Move literal to BSR&lt;3:0&gt;</td>
<td>1</td>
<td>0000 0001 0000 kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>MOVLW k</td>
<td>Move literal to WREG</td>
<td>1</td>
<td>0000 1110 kkkk kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>MULLW k</td>
<td>Multiply literal with WREG</td>
<td>1</td>
<td>0000 1101 kkkk kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>RETLW k</td>
<td>Return with literal in WREG</td>
<td>2</td>
<td>0000 1100 kkkk kkkk</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>SUBLW k</td>
<td>Subtract WREG from literal</td>
<td>1</td>
<td>0000 1000 kkkk kkkk</td>
<td>C, DC, Z, OV, N</td>
<td></td>
</tr>
<tr>
<td>XORLW k</td>
<td>Exclusive OR literal with WREG</td>
<td>1</td>
<td>0000 1010 kkkk kkkk</td>
<td>Z, N</td>
<td></td>
</tr>
<tr>
<td><strong>DATA MEMORY ↔ PROGRAM MEMORY OPERATIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBLRD*</td>
<td>Table Read</td>
<td>2</td>
<td>0000 0000 0000 1000</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLRD*+</td>
<td>Table Read with post-increment</td>
<td>2</td>
<td>0000 0000 0000 1001</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLRD*-</td>
<td>Table Read with post-decrement</td>
<td>2</td>
<td>0000 0000 0000 1010</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLRD+*</td>
<td>Table Read with pre-increment</td>
<td>2</td>
<td>0000 0000 0000 1011</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLWT*</td>
<td>Table Write</td>
<td>2</td>
<td>0000 0000 0000 1100</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLWT*+</td>
<td>Table Write with post-increment</td>
<td>2</td>
<td>0000 0000 0000 1101</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLWT*-</td>
<td>Table Write with post-decrement</td>
<td>2</td>
<td>0000 0000 0000 1110</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TBLWT+*</td>
<td>Table Write with pre-increment</td>
<td>2</td>
<td>0000 0000 0000 1111</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** When a PORT register is modified as a function of itself (e.g., MOVF PORTB, 1, 0), the value used will be that value present on the pins themselves. For example, if the data latch is ‘1’ for a pin configured as input and is driven low by an external device, the data will be written back with a ‘0’.

**Note 2:** If this instruction is executed on the TMR0 register (and where applicable, ‘d’ = 1), the prescaler will be cleared if assigned.

**Note 3:** If Program Counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

**Note 4:** Some instructions are two-word instructions. The second word of these instructions will be executed as a NOP unless the first word of the instruction retrieves the information embedded in these 16 bits. This ensures that all program memory locations have a valid instruction.

**Note 5:** If the table write starts the write cycle to internal memory, the write will continue until terminated.
25.1.1 STANDARD INSTRUCTION SET

### ADDLW ADD Literal to W

- **Syntax:** `ADDLW k`
- **Operands:** `0 ≤ k ≤ 255`
- **Operation:** `(W) + k → W`
- **Status Affected:** N, OV, C, DC, Z
- **Encoding:**
  - **Description:** The contents of W are added to the 8-bit literal ‘k’ and the result is placed in W.
- **Words:** 1
- **Cycles:** 1
- **Q Cycle Activity:**
  - **Example:** `ADDLW 15h`
  - **Before Instruction:**
    - W = 10h
  - **After Instruction:**
    - W = 25h

### ADDWF ADD W to f

- **Syntax:** `ADDWF {f,d,a} {,d,a}
- **Operands:** `0 ≤ f ≤ 255`
- **d ∈ [0,1]
- **a ∈ [0,1]
- **Operation:** `(W) + (f) → dest`
- **Status Affected:** N, OV, C, DC, Z
- **Encoding:**
  - **Description:** Add W to register ‘f’. If ‘d’ is ‘0’, the result is stored in W. If ‘d’ is ‘1’, the result is stored back in register ‘f’ (default).
  - **If ‘a’ is ‘0’, the Access Bank is selected. If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).**
  - **If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.
- **Words:** 1
- **Cycles:** 1
- **Q Cycle Activity:**
  - **Example:** `ADDWF REG, 0, 0`
  - **Before Instruction:**
    - W = 17h
    - REG = 0C2h
  - **After Instruction:**
    - W = 0D9h
    - REG = 0C2h

**Note:** All PIC18 instructions may take an optional label argument preceding the instruction mnemonic for use in symbolic addressing. If a label is used, the instruction format then becomes: `{label} instruction argument(s).
ADDWFC  ADD W and Carry bit to f

Syntax: ADDWFC  f { , d {a}}

Operands: 0 ≤ f ≤ 255
          d ∈ [0,1]
          a ∈ [0,1]

Operation: (W) + (f) + (C) → dest

Status Affected: N, OV, C, DC, Z

Encoding: 0010 00da ffff ffff

Description: Add W, the Carry flag and data memory
              location 'f'. If 'd' is '0', the result is
              placed in W. If 'd' is '1', the result is
              placed in data memory
              location 'f'.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select
the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates
in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See
Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed
Literal Offset Mode” for details.

Words: 1

Cycles: 1

Q Cycle Activity:

Example: ADDWFC  REG, 0, 1

Before Instruction
  Carry bit = 1
  REG = 02h
  W = 4Dh

After Instruction
  Carry bit = 0
  REG = 02h
  W = 50h

ANDLW  AND Literal with W

Syntax:  ANDLW  k

Operands: 0 ≤ k ≤ 255
Operation: (W).AND. k → W

Status Affected: N, Z

Encoding: 0000 1011 kkkk kkkk

Description: The contents of W are ANDed with the
8-bit literal 'k'. The result is placed in W.

Words: 1

Cycles: 1

Q Cycle Activity:

Example: ANDLW 05Fh

Before Instruction
  W = A3h

After Instruction
  W = 03h
**ANDWF**

Syntax: `ANDWF f{,d{,a}}`

Operands: 
- `0 ≤ f ≤ 255`
- `d ∈ [0,1]`
- `a ∈ [0,1]`

Operation: `(W).AND. (f) → dest`

Status Affected: `N, Z`

Encoding: 
- `0001 01da ffff ffff`

Description: The contents of W are ANDed with register ‘f’. If ‘d’ is ‘0’, the result is stored in W. If ‘d’ is ‘1’, the result is stored back in register ‘f’ (default).

If ‘a’ is ‘0’, the Access Bank is selected. If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).

If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever `f ≤ 95 (5Fh)`. See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1

Cycles: 1

Example: `ANDWF REG, 0, 0`

Before Instruction  
- `W = 17h`
- `REG = C2h`

After Instruction  
- `W = 02h`
- `REG = C2h`

**BC**

Syntax: `BC n`

Operands: `-128 ≤ n ≤ 127`

Operation: 
- If Carry bit is ‘1’  
  
  `(PC) + 2 + 2n → PC`

Status Affected: `None`

Encoding: 
- `1110 0010 nnnn nnnn`

Description: If the Carry bit is ‘1’, then the program will branch.

The 2's complement number ‘2n’ is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be `PC + 2 + 2n`. This instruction is then a two-cycle instruction.

Words: 1

Cycles: 1(2)

Example: `HERE BC 5`

Before Instruction  
- `PC = address (HERE)`

After Instruction  
- If Carry = 1:  
  
  `PC = address (HERE + 12)`
- If Carry = 0:  
  
  `PC = address (HERE + 2)`
### BCF (Bit Clear f)

**Syntax:** \( \text{BCF} \ f, b \{.a\} \)

- **Operands:** \( 0 \leq f \leq 255 \)
  \( 0 \leq b \leq 7 \)
  \( a \in [0,1] \)

- **Operation:** \( 0 \rightarrow f{<b>} \)

- **Status Affected:** None

- **Encoding:**
  
<table>
<thead>
<tr>
<th>0</th>
<th>bba</th>
<th>fff</th>
<th>ffff</th>
</tr>
</thead>
</table>

- **Description:** Bit 'b' in register 'f' is cleared. If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default). If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \( f \leq 95 \) (5Fh). See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

- **Words:** 1
- **Cycles:** 1

#### Q Cycle Activity:

If Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write register 'f'</td>
</tr>
</tbody>
</table>

If No Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction

FLAG_REG = C7h

After Instruction

FLAG_REG = 47h

### BN (Branch if Negative)

**Syntax:** \( \text{BN} \ n \)

- **Operands:** \(-128 \leq n \leq 127\)

- **Operation:**
  
  If Negative bit is '1'
  
  \( (PC) + 2 + 2n \rightarrow PC \)

- **Status Affected:** None

- **Encoding:**
  
  | 1110 | 0110 | nnnn | nnnn |

- **Description:** If the Negative bit is '1', then the program will branch. The 2’s complement number ‘2n’ is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be \( PC + 2 + 2n \). This instruction is then a two-cycle instruction.

- **Words:** 1
- **Cycles:** 1(2)

#### Q Cycle Activity:

If Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
</tbody>
</table>

If No Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction

HERE BN Jump

After Instruction

PC = address (HERE)

If Negative = 1;

PC = address (Jump)

If Negative = 0;

PC = address (HERE + 2)
### BNC Branch if Not Carry

| Syntax: | BNC  
| Operands: | \(-128 \leq n \leq 127\)  
| Operation: | if Carry bit is '0' \((PC) + 2 + 2n \rightarrow PC\)  
| Status Affected: | None  
| Encoding: | \[
\begin{array}{cccc}
1110 & 0011 & \text{nnnn} & \text{nnnn}
\end{array}\]  
| Description: | If the Carry bit is '0', then the program will branch. The 2's complement number '2n' is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is then a two-cycle instruction.  
| Words: | 1  
| Cycles: | 1(2)  
| Q Cycle Activity: |  

#### If Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

#### If No Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction | Address: \((HERE)\)  
After Instruction |  
If Carry | 0;  
PC | \((Jump)\)  
If Carry | 1;  
PC | \((HERE + 2)\)

### BNN Branch if Not Negative

| Syntax: | BNN  
| Operands: | \(-128 \leq n \leq 127\)  
| Operation: | if Negative bit is '0' \((PC) + 2 + 2n \rightarrow PC\)  
| Status Affected: | None  
| Encoding: | \[
\begin{array}{cccc}
1110 & 0111 & \text{nnnn} & \text{nnnn}
\end{array}\]  
| Description: | If the Negative bit is '0', then the program will branch. The 2's complement number '2n' is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is then a two-cycle instruction.  
| Words: | 1  
| Cycles: | 1(2)  
| Q Cycle Activity: |  

#### If Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

#### If No Jump:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction | Address: \((HERE)\)  
After Instruction |  
If Negative | 0;  
PC | \((Jump)\)  
If Negative | 1;  
PC | \((HERE + 2)\)
### BNOV  
**Branch if Not Overflow**

**Syntax:**  
BNOV n

**Operands:**  
-128 ≤ n ≤ 127

**Operation:**  
If Overflow bit is ‘0’  
(\(PC + 2\) + 2n → PC)

**Status Affected:**  
None

**Encoding:**  
1110 0101 nnnn nnnn

**Description:**  
If the Overflow bit is ‘0’, then the program will branch.  
The 2’s complement number ‘2n’ is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is then a two-cycle instruction.

**Words:** 1

**Cycles:** 1(2)

**Q Cycle Activity:**
- If Jump:
  - Q1: Decode
  - Q2: Read literal 'n'
  - Q3: Process Data
  - Q4: Write to PC
  - No operation

- If No Jump:
  - Q1: Decode
  - Q2: Read literal 'n'
  - Q3: Process Data
  - Q4: No operation

**Example:**  
Before Instruction:
- BNOV Jump

PC = address (HERE)

After Instruction:
- If Overflow = 0;  
  - PC = address (Jump)
- If Overflow = 1;  
  - PC = address (HERE + 2)

---

### BNZ  
**Branch if Not Zero**

**Syntax:**  
BNZ n

**Operands:**  
-128 ≤ n ≤ 127

**Operation:**  
If Zero bit is ‘0’  
(\(PC + 2\) + 2n → PC)

**Status Affected:**  
None

**Encoding:**  
1110 0001 nnnn nnnn

**Description:**  
If the Zero bit is ‘0’, then the program will branch.  
The 2’s complement number ‘2n’ is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is then a two-cycle instruction.

**Words:** 1

**Cycles:** 1(2)

**Q Cycle Activity:**
- If Jump:
  - Q1: Decode
  - Q2: Read literal 'n'
  - Q3: Process Data
  - Q4: Write to PC
  - No operation

- If No Jump:
  - Q1: Decode
  - Q2: Read literal 'n'
  - Q3: Process Data
  - Q4: No operation

**Example:**  
Before Instruction:
- BNZ Jump

PC = address (HERE)

After Instruction:
- If Zero = 0;  
  - PC = address (Jump)
- If Zero = 1;  
  - PC = address (HERE + 2)
### BRA Unconditional Branch

**Syntax:** BRA n

**Operands:** -1024 ≤ n ≤ 1023

**Operation:** (PC) + 2 + 2n → PC

**Status Affected:** None

**Encoding:**

```
1101 0nnn nnnn nnnn
```

**Description:** Add the 2's complement number '2n' to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is a two-cycle instruction.

**Words:** 1

**Cycles:** 2

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction

- PC = address (HERE)

After Instruction

- PC = address (Jump)

### BSF Bit Set f

**Syntax:** BSF f, b {,a}

**Operands:**

- 0 ≤ f ≤ 255
- 0 ≤ b ≤ 7
- a ∈ {0,1}

**Operation:** 1 → f<b>

**Status Affected:** None

**Encoding:**

```
1000 bbba ffff ffff
```

**Description:** Bit 'b' in register 'f' is set. If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default). If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write register 'f'</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

BSF FLAG_REG, 7, 1

Before Instruction

- FLAG_REG = 0Ah

After Instruction

- FLAG_REG = 8Ah
BTFSC  Bit Test File, Skip if Clear

Syntax: BTFSC f, b {,a}
Operands: 0 ≤ f ≤ 255
          0 ≤ b ≤ 7
          a ∈ [0,1]
Operation: skip if (f<b>) = 0
Status Affected: None
Encoding: 1011 bbba ffff ffff
Description: If bit 'b' in register 'f' is '0', then the next instruction is skipped. If bit 'b' is '0', then the next instruction fetched during the current instruction execution is discarded and a NOP is executed instead, making this a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh).

See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1(2)

Note: 3 cycles if skip and followed by a 2-word instruction.

Q Cycle Activity:

    Q1          Q2          Q3          Q4
Decoded      Read        Process      No
register 'f' register 'f' Data       operation

If skip:

    Q1          Q2          Q3          Q4
No          No          No          No
operation  operation  operation  operation

If skip and followed by 2-word instruction:

    Q1          Q2          Q3          Q4
No          No          No          No
operation  operation  operation  operation

Example:

Before Instruction
PC = address (HERE)
If FLAG<1> = 0:
   PC = address (TRUE)
If FLAG<1> = 1:
   PC = address (FALSE)

After Instruction
Before Instruction
PC = address (HERE)
If FLAG<1> = 0:
   PC = address (FALSE)
If FLAG<1> = 1:
   PC = address (TRUE)

BTFSS  Bit Test File, Skip if Set

Syntax: BTFSS f, b {,a}
Operands: 0 ≤ f ≤ 255
          0 ≤ b < 7
          a ∈ [0,1]
Operation: skip if (f<b>) = 1
Status Affected: None
Encoding: 1010 bbba ffff ffff
Description: If bit 'b' in register 'f' is '1', then the next instruction is skipped. If bit 'b' is '1', then the next instruction fetched during the current instruction execution is discarded and a NOP is executed instead, making this a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh).

See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1(2)

Note: 3 cycles if skip and followed by a 2-word instruction.

Q Cycle Activity:

    Q1          Q2          Q3          Q4
Decoded      Read        Process      No
register 'f' register 'f' Data       operation

If skip:

    Q1          Q2          Q3          Q4
No          No          No          No
operation  operation  operation  operation

If skip and followed by 2-word instruction:

    Q1          Q2          Q3          Q4
No          No          No          No
operation  operation  operation  operation

Example:

Before Instruction
PC = address (HERE)
If FLAG<1> = 0:
   PC = address (FALSE)
If FLAG<1> = 1:
   PC = address (TRUE)
BTG Bit Toggle

Syntax: BTG f, b {,a}
Operands: 0 ≤ f ≤ 255
0 ≤ b < 7
a ∈ [0,1]
Operation: (f<b>) → f<b>
Status Affected: None
Encoding: 0111 bbba ffff ffff
Description: Bit 'b' in data memory location 'f' is inverted.
If 'a' is '0', the Access Bank is selected.
If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Example:
Before Instruction:
PORTC = 0111 0101 [75h]
After Instruction:
PORTC = 0110 0101 [65h]

BOV Branch if Overflow

Syntax: BOV n
Operands: -128 ≤ n ≤ 127
Operation: if Overflow bit is '1'
(PC) + 2 + 2n → PC
Status Affected: None
Encoding: 1110 0100 nnnn nnnn
Description: If the Overflow bit is '1', then the program will branch.
The 2's complement number '2n' is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is then a two-cycle instruction.

Words: 1
Cycles: 1(2)
Q Cycle Activity:
If Jump:
<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>
If No Jump:
<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

Example:
Before Instruction:
HERE BOV Jump
Before Instruction:
PC = address (HERE)
After Instruction:
If Overflow = 1;
PC = address (Jump)
If Overflow = 0;
PC = address (HERE + 2)
**BZ**  
**Branch if Zero**

**Syntax:**  
BZ n

**Operands:**  
-128 ≤ n ≤ 127

**Operation:**  
if Zero bit is '1'  
(PC) + 2 + 2n → PC

**Status Affected:**  
None

**Encoding:**  
1110 0000 nnnn nnnn

**Description:**  
If the Zero bit is '1', then the program will branch.  
The 2's complement number '2n' is added to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is then a two-cycle instruction.

| Words: | 1 |
| Cycles: | 1(2) |

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**  
HERE BZ Jump

Before Instruction  
PC = address (HERE)

After Instruction  
If Zero = 1;  
PC = address (Jump)

If Zero = 0;  
PC = address (HERE + 2)

---

**CALL**  
**Subroutine Call**

**Syntax:**  
CALL k {.s}

**Operands:**  
0 ≤ k ≤ 1048575  
s ∈ [0,1]

**Operation:**  
(PC) + 4 → TOS,  
k → PC<20:1>;  
if s = 1,  
(W) → WS,  
(STATUS) → STATUSS,  
(BSR) → BSRS

**Status Affected:**  
None

**Encoding:**  
1st word (k<7:0>)  
1110 110s k,kkk kkkk0
2nd word (k<19:8>)  
1111 k1,kkk kkkk kkkk8

**Description:**  
Subroutine call of entire 2-Mbyte memory range. First, return address (PC + 4) is pushed onto the return stack. If 's' = 1, the W, STATUS and BSR registers are also pushed into their respective shadow registers, WS, STATUSS and BSRS. If 's' = 0, no update occurs (default). Then, the 20-bit value 'k' is loaded into PC<20:1>.  
CALL is a two-cycle instruction.

| Words: | 2 |
| Cycles: | 2 |

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'k'&lt;7:0&gt;,</td>
<td>Push PC to stack</td>
<td>Read literal 'k'&lt;19:8&gt;,</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**  
HERE CALL THERE, 1

Before Instruction  
PC = address (HERE)

After Instruction  
PC = address (THERE)  
TOS = address (HERE + 4)  
WS = W  
BSRS = BSR  
STATUSS = STATUS
### CLRF

**Syntax:**
```
CLRF f {,a}
```

**Operands:**
```
0 ≤ f ≤ 255
a ∈ [0,1]
```

**Operation:**
```
000h → f
1 → Z
```

**Status Affected:**
```
Z
```

**Encoding:**
```
0110 101a ffff ffff
```

**Description:**
Clears the contents of the specified register.
- If 'a' is '0', the Access Bank is selected.
- If 'a' is '1', the BSR is used to select the GPR bank (default).
- If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**
```
Q1  Q2  Q3  Q4
Decode  No operation  Process Data  No operation
Read register 'f'  
Write register 'f'  
```

**Example:**
```
CLRF FLAG_REG,1
```

Before Instruction
- `FLAG_REG` = 5Ah

After Instruction
- `FLAG_REG` = 00h

### CLRWDT

**Syntax:**
```
CLRWDT
```

**Operands:** None

**Operation:**
```
000h → WDT,
000h → WDT postscaler,
1 → TO,
1 → PD
```

**Status Affected:**
```
TO, PD
```

**Encoding:**
```
0000 0000 0000 0100
```

**Description:**
- CLRWDT instruction resets the Watchdog Timer. It also resets the postscaler of the WDT. Status bits TO and PD are set.
- Words: 1
- Cycles: 1

**Q Cycle Activity:**
```
Q1  Q2  Q3  Q4
Decode  No operation  Process Data  No operation
```

**Example:**
```
CLRWDT
```

Before Instruction
- WDT Counter = ?

After Instruction
- WDT Counter = 00h
- WDT Postscaler = 0
- TO = 1
- PD = 1
**COMF** Complement f

Syntax: \texttt{COMF \ } f \{d \{a\}\}

Operands: \[0 \leq f \leq 255\]
\[d \in \{0,1\}\]
\[a \in \{0,1\}\]

Operation: \((f) \rightarrow \text{dest}\)

Status Affected: \(N, Z\)

Encoding: \[0001 \quad \text{11da} \quad \text{fffe} \quad \text{fffe}\]

Description: The contents of register 'f' are complemented. If 'd' is '1', the result is stored in W. If 'd' is '0', the result is stored back in register 'f' (default).

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \(f \leq 95\) (5Fh). See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

Words: 1

Cycles: 1

Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

Example: \texttt{COMF REG, 0, 0}

Before Instruction

- REG = 13h

After Instruction

- REG = 13h
- W = ECh

**CPFSEQ** Compare f with W, Skip if f = W

Syntax: \texttt{CPFSEQ \ } f \{a\}

Operands: \[0 \leq f \leq 255\]
\[a \in \{0,1\}\]

Operation: \((f) - (W), \text{skip if } (f) = (W)\) (unsigned comparison)

Status Affected: None

Encoding: \[0110 \quad 001a \quad \text{fffe} \quad \text{fffe}\]

Description: Compares the contents of data memory location 'f' to the contents of W by performing an unsigned subtraction.

If 'f' = W, then the fetched instruction is discarded and a \texttt{NOP} is executed instead, making this a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \(f \leq 95\) (5Fh). See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

Words: 1

Cycles: 1(2)

Note: 3 cycles if skip and followed by a 2-word instruction.

Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

If skip:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

If skip and followed by 2-word instruction:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

Example: \texttt{HERE CPFSEQ REG, 0}

\texttt{NEQUAL}:

\texttt{EQUAL}:

Before Instruction

- PC Address = \texttt{HERE}
- W = ?
- REG = ?

After Instruction

If REG = W:

- PC = Address (\texttt{EQUAL})

If REG = W:

- PC = Address (\texttt{NEQUAL})
### CPFSGT

**Syntax:** CPFSGT \( f \{a\} \)

**Operands:**
- \( 0 \leq f \leq 255 \)
- \( a \in [0,1] \)

**Operation:**
- \((f) - (W),\) skip if \((f) > (W)\)
- (unsigned comparison)

**Status Affected:** None

**Encoding:**
- \(0110\) 010a ffff ffff

**Description:**
Compares the contents of data memory location ‘f’ to the contents of the W by performing an unsigned subtraction.

- If the contents of ‘f’ are greater than the contents of WREG, then the fetched instruction is discarded and a NOP is executed instead, making this a two-cycle instruction.
- If ‘a’ is ‘0’, the Access Bank is selected.
- If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).
- If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \( f \leq 95 \) (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1

**Cycles:** 1(2)

**Note:** 3 cycles if skip and followed by a 2-word instruction.

<table>
<thead>
<tr>
<th>Q Cycle Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>Decode</td>
</tr>
<tr>
<td>If skip:</td>
</tr>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>No operation</td>
</tr>
<tr>
<td>If skip and followed by 2-word instruction:</td>
</tr>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>No operation</td>
</tr>
<tr>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**
HERE CPFSGT REG, 0
NGREATER :
GREATER :

**Before Instruction**
- \( PC = \) Address (HERE)
- \( W = ? \)

**After Instruction**
- If REG \( > W; \) PC = Address (GREATER)
- If REG \( \leq W; \) PC = Address (NGREATER)

---

### CPFSLT

**Syntax:** CPFSLT \( f \{a\} \)

**Operands:**
- \( 0 \leq f \leq 255 \)
- \( a \in [0,1] \)

**Operation:**
- \((f) - (W),\) skip if \((f) < (W)\)
- (unsigned comparison)

**Status Affected:** None

**Encoding:**
- \(0110\) 000a ffff ffff

**Description:**
Compares the contents of data memory location ‘f’ to the contents of W by performing an unsigned subtraction.

- If the contents of ‘f’ are less than the contents of W, then the fetched instruction is discarded and a NOP is executed instead, making this a two-cycle instruction.
- If ‘a’ is ‘0’, the Access Bank is selected.
- If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).

**Words:** 1

**Cycles:** 1(2)

**Note:** 3 cycles if skip and followed by a 2-word instruction.

<table>
<thead>
<tr>
<th>Q Cycle Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>Decode</td>
</tr>
<tr>
<td>If skip:</td>
</tr>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>No operation</td>
</tr>
<tr>
<td>If skip and followed by 2-word instruction:</td>
</tr>
<tr>
<td>Q1</td>
</tr>
<tr>
<td>No operation</td>
</tr>
<tr>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**
HERE CPFSLT REG, 1
NLESS :
LESS :

**Before Instruction**
- \( PC = \) Address (HERE)
- \( W = ? \)

**After Instruction**
- If REG \( < W; \) PC = Address (LESS)
- If REG \( \geq W; \) PC = Address (NLESS)
DAW

**Decimal Adjust W Register**

**Syntax:**
DAW

**Operands:**
None

**Operation:**
If $[W<3:0> >9]$ or $[DC = 1]$ then
\[(W<3:0>) + 6 \rightarrow W<3:0>\];
else
\[(W<3:0>) \rightarrow W<3:0>\]

If $[W<7:4> >9]$ or $[C = 1]$ then
\[(W<7:4>) + 6 \rightarrow W<7:4>\];
else
\[(W<7:4>) \rightarrow W<7:4>\]

**Status Affected:**
C

**Encoding:**
```
0000 0000 0000 0111
```

**Description:**
DAW adjusts the eight-bit value in W, resulting from the earlier addition of two variables (each in packed BCD format) and produces a correct packed BCD result.

**Words:**
1

**Cycles:**
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register W</td>
<td>Process Data</td>
<td>Write W</td>
</tr>
</tbody>
</table>

**Example 1:**

Before Instruction
\[
W = A5h
C = 0
DC = 0
\]

After Instruction
\[
W = 05h
C = 1
DC = 0
\]

**Example 2:**

Before Instruction
\[
W = CEh
C = 0
DC = 0
\]

After Instruction
\[
W = 34h
C = 1
DC = 0
\]

DECF

**Decrement f**

**Syntax:**
DECF f,d,a

**Operands:**
0 ≤ f ≤ 255
d ∈ [0,1]
a ∈ [0,1]

**Operation:**
\[(f) – 1 \rightarrow \text{dest}\]

**Status Affected:**
C, DC, N, OV, Z

**Encoding:**
```
0000 01da ffff ffff
```

**Description:**
Decrement register 'f'. If 'd' is '0', the result is stored in W. If 'd' is '1', the result is stored back in register 'f' (default).

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever $f \leq 95$ (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:**
1

**Cycles:**
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction
\[
\text{DECF CNT, 1, 0}
\]

Before Instruction
\[
CNT = 01h
Z = 0
\]

After Instruction
\[
CNT = 00h
Z = 1
\]
DECFSZ Decrement f, Skip if 0

Syntax: DECFSZ  f {,d {,a}}

Operands: 0 ≤ f ≤ 255
d ∈ [0,1]
a ∈ [0,1]

Operation: (f) – 1 → dest, skip if result = 0

Status Affected: None

Encoding: 0010 lida ffff ffff

Description: The contents of register ‘f’ are decremented. If ‘d’ is ‘0’, the result is placed in W. If ‘d’ is ‘1’, the result is placed back in register ‘f’ (default).

If the result is ‘0’, the next instruction which is already fetched is discarded and a NOP is executed instead, making it a two-cycle instruction.

If ‘a’ is ‘0’, the Access Bank is selected. If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).

If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1(2)

Note: 3 cycles if skip and followed by a 2-word instruction.

Example: HERE DECFSZ CNT, 1, 1
CONTINUE

DCFSNZ Decrement f, Skip if Not 0

Syntax: DCFSNZ  f {,d {,a}}

Operands: 0 ≤ f ≤ 255
d ∈ [0,1]
a ∈ [0,1]

Operation: (f) – 1 → dest, skip if result ≠ 0

Status Affected: None

Encoding: 0100 lida ffff ffff

Description: The contents of register ‘f’ are decremented. If ‘d’ is ‘0’, the result is placed in W. If ‘d’ is ‘1’, the result is placed back in register ‘f’ (default).

If the result is not ‘0’, the next instruction which is already fetched is discarded and a NOP is executed instead, making it a two-cycle instruction.

If ‘a’ is ‘0’, the Access Bank is selected. If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).

If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1(2)

Note: 3 cycles if skip and followed by a 2-word instruction.

Example: HERE DCFSNZ TEMP, 1, 0
ZERO:
NZERO:

Before Instruction
PC = Address (HERE)

After Instruction
CNT = CNT – 1
If CNT = 0;
PC = Address (CONTINUE)
If CNT ≠ 0;
PC = Address (HERE + 2)
### GOTO

**Syntax:** GOTO k  
**Operands:** 0 ≤ k ≤ 1048575  
**Operation:** k → PC<20:1>  
**Status Affected:** None  
**Encoding:**

<table>
<thead>
<tr>
<th>1st word (k&lt;7:0&gt;)</th>
<th>2nd word (k&lt;19:8&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1110</td>
<td>1111 k,kkk kkkk kkkk0</td>
</tr>
</tbody>
</table>

**Description:** GOTO allows an unconditional branch anywhere within entire 2-Mbyte memory range. The 20-bit value 'k' is loaded into PC<20:1>. GOTO is always a two-cycle instruction.

Words: 2
Cycles: 2

#### Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'k'&lt;7:0&gt;</td>
<td>No operation</td>
<td>Read literal 'k'&lt;19:8&gt;, Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

GOTO THERE  

After Instruction  
PC = Address (THERE)

### INCF

**Syntax:** INCF f {,d {,a}}  
**Operands:** 0 ≤ f ≤ 255  
\( d \in [0,1] \)  
\( a \in [0,1] \)  
**Operation:** \( (f) + 1 \rightarrow \text{dest} \)  
**Status Affected:** C, DC, N, OV, Z  
**Encoding:**

| 0010 | 10da | ffff | ffff |

**Description:**

The contents of register 'f' are incremented. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is placed back in register 'f' (default).

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \( f \leq 95 \) (5Fh). See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

Words: 1
Cycles: 1

#### Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

**Example:**

INCF CNT, 1, 0  

Before Instruction  
CNT = FFh  
Z = 0  
C = ?  
DC = ?  

After Instruction  
CNT = 00h  
Z = 1  
C = 1  
DC = 1
### INCFSZ
Increment f, Skip if 0

**Syntax:**
```
INCFSZ f {,d {,a}}
```

**Operands:**
- `0 ≤ f ≤ 255`
- `d ∈ [0,1]`
- `a ∈ [0,1]`

**Operation:**
```
(f) + 1 → dest,
```
skip if result = 0

**Status Affected:** None

**Encoding:**
```
0011 11da ffff ffff
```

**Description:**
The contents of register 'f' are incremented. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is placed back in register 'f' (default).

If the result is '0', the next instruction which is already fetched is discarded and a NOP is executed instead, making it a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever `f ≤ 95 (5Fh)`. See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

If skip:
```
Q1 Q2 Q3 Q4
```
```
No operation | No operation | No operation | No operation |
```

If skip and followed by 2-word instruction:
```
Q1 Q2 Q3 Q4
```
```
No operation | No operation | No operation | No operation |
```

Example:
```
HERE INCFSZ CNT, 1, 0
NZERO :
ZERO :
```

Before Instruction
```
PC = Address (HERE)
CNT = CNT + 1
If CNT = 0; PC = Address (ZERO)
```

After Instruction
```
PC = Address (NZERO)
```

### INFSNZ
Increment f, Skip if Not 0

**Syntax:**
```
INFSNZ f {,d {,a}}
```

**Operands:**
- `0 ≤ f ≤ 255`
- `d ∈ [0,1]`
- `a ∈ [0,1]`

**Operation:**
```
(f) + 1 → dest,
```
skip if result ≠ 0

**Status Affected:** None

**Encoding:**
```
0100 10da ffff ffff
```

**Description:**
The contents of register 'f' are incremented. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is placed back in register 'f' (default).

If the result is not '0', the next instruction which is already fetched is discarded and a NOP is executed instead, making it a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever `f ≤ 95 (5Fh)`. See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

If skip:
```
Q1 Q2 Q3 Q4
```
```
No operation | No operation | No operation | No operation |
```

If skip and followed by 2-word instruction:
```
Q1 Q2 Q3 Q4
```
```
No operation | No operation | No operation | No operation |
```

Example:
```
HERE INFSNZ REG, 1, 0
ZERO :
NZERO :
```

Before Instruction
```
PC = Address (HERE)
REG = REG + 1
If REG = 0; PC = Address (NZERO)
```

After Instruction
```
PC = Address (ZERO)
```
IORLW  Inclusive OR Literal with W
Syntax: IORLW  k
Operands: 0 ≤ k ≤ 255
Operation: (W) .OR. k → W
Status Affected: N, Z
Encoding: 0000 1001 kkkk kkkk
Description: The contents of W are ORed with the eight-bit literal 'k'. The result is placed in W.
Words: 1
Cycles: 1
Q Cycle Activity:

| Q1 | Q2 | Q3 | Q4 |
|---------------------------|
| Decode | Read literal 'k' | Process Data | Write to W |

Example: IORLW 35h
Before Instruction
W = 9Ah
After Instruction
W = BFh

IORWF  Inclusive OR W with f
Syntax: IORWF f (d (a))
Operands: 0 ≤ f ≤ 255
d ∈ [0,1]
a ∈ [0,1]
Operation: (W) .OR. f → dest
Status Affected: N, Z
Encoding: 0001 00da ffff ffff
Description: Inclusive OR W with register 'f'. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is placed back in register 'f' (default).
If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.
Words: 1
Cycles: 1
Q Cycle Activity:

| Q1 | Q2 | Q3 | Q4 |
|---------------------------|
| Decode | Read register 'f' | Process Data | Write to destination |

Example: IORWF RESULT, 0, 1
Before Instruction
RESULT = 13h
W = 91h
After Instruction
RESULT = 13h
W = 93h
### LFSR Load FSR

**Syntax:**
LFSR  f, k

**Operands:**
0 ≤ f ≤ 2
0 ≤ k ≤ 4095

**Operation:**
k → FSRf

**Status Affected:**
None

**Encoding:**
<table>
<thead>
<tr>
<th>1110</th>
<th>1110</th>
<th>00ff</th>
<th>k1kkk</th>
<th>kkkk</th>
</tr>
</thead>
</table>

**Description:**
The 12-bit literal 'k' is loaded into the file select register pointed to by 'f'.

**Words:**
2

**Cycles:**
2

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Read literal 'k' MSB</td>
<td>Process Data</td>
<td>Write literal 'k' MSB to FSRfH</td>
</tr>
<tr>
<td></td>
<td>Read literal 'k' LSB</td>
<td>Process Data</td>
<td>Write literal 'k' to FSRfL</td>
</tr>
</tbody>
</table>

**Example:**
LFSR 2, 3ABh

After Instruction
FSR2H = 03h
FSR2L = ABh

### MOVF Move f

**Syntax:**
MOVF  f (.d, .a)

**Operands:**
0 ≤ f ≤ 255
d ∈ [0, 1]
a ∈ [0, 1]

**Operation:**
f → dest

**Status Affected:**
N, Z

**Encoding:**
| 0101 | 00da | ffff | ffff |

**Description:**
The contents of register 'f' are moved to a destination dependent upon the status of 'd'. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is placed back in register 'f' (default). Location 'f' can be anywhere in the 256-byte bank.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

**Words:**
1

**Cycles:**
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write W</td>
</tr>
</tbody>
</table>

**Example:**
MOVF  REG, 0, 0

Before Instruction
REG = 22h
W = FFh

After Instruction
REG = 22h
W = 22h
**MOVFF**

**Move f to f**

**Syntax:**

\[\text{MOVFF} \; f_s \rightarrow f_d\]

**Operands:**

\[0 \leq f_s \leq 4095\]
\[0 \leq f_d \leq 4095\]

**Operation:**

\[(f_s) \rightarrow f_d\]

**Status Affected:** none

**Encoding:**

<table>
<thead>
<tr>
<th>1st word (source)</th>
<th>2nd word (destin.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>ffff</td>
</tr>
<tr>
<td>1111</td>
<td>ffff</td>
</tr>
<tr>
<td></td>
<td>ffff</td>
</tr>
<tr>
<td></td>
<td>ffff</td>
</tr>
</tbody>
</table>

**Description:**

The contents of source register \(f_s\) are moved to destination register \(f_d\).

Location of source \(f_s\) can be anywhere in the 4096-byte data space (000h to FFFh) and location of destination \(f_d\) can also be anywhere from 000h to FFFh.

Either source or destination can be W (a useful special situation).

**MOVFF** is particularly useful for transferring a data memory location to a peripheral register (such as the transmit buffer or an I/O port).

The **MOVFF** instruction cannot use the PCL, TOSU, TOSH or TOSL as the destination register.

**Words:** 2

**Cycles:** 2 (3)

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register (f) (src)</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
<tr>
<td>Decode</td>
<td>No operation</td>
<td>No operation</td>
<td>Write register (f) (dest)</td>
</tr>
</tbody>
</table>

**Example:**

**MOVFF** REG1, REG2

Before Instruction

REG1 = 33h
REG2 = 11h

After Instruction

REG1 = 33h
REG2 = 33h

---

**MOVLB**

**Move Literal to Low Nibble in BSR**

**Syntax:**

\[\text{MOVLW} \; k\]

**Operands:**

\[0 \leq k \leq 255\]

**Operation:**

\[k \rightarrow \text{BSR}\]

**Status Affected:** None

**Encoding:**

| 0000 | 0001 | kkkk | kkkk |

**Description:**

The eight-bit literal \(k\) is loaded into the Bank Select Register (BSR). The value of BSR<7:4> always remains '0', regardless of the value of \(k_7:k_4\).

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal (k)</td>
<td>Process Data</td>
<td>Write literal (k) to BSR</td>
</tr>
</tbody>
</table>

**Example:**

**MOVLB** 5

Before Instruction

BSR Register = 02h

After Instruction

BSR Register = 05h

---

DS39761C-page 390 © 2009 Microchip Technology Inc.
**MOVLW**  
**Move Literal to W**

**Syntax:** 
MOVLW k

**Operands:** 
0 ≤ k ≤ 255

**Operation:** 
k → W

**Status Affected:** 
None

**Encoding:**

```
0000 1110 kkkk kkkk
```

**Description:** The eight-bit literal 'k' is loaded into W.

**Words:** 
1

**Cycles:** 
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'k'</td>
<td>Process Data</td>
<td>Write to W</td>
</tr>
</tbody>
</table>

**Example:**

MOVLW 5Ah

After Instruction

W = 5Ah

**MOVWF**  
**Move W to f**

**Syntax:** 
MOVWF f {,a}

**Operands:** 
0 ≤ f ≤ 255

**Operands:** 
a ∈ [0,1]

**Operation:** 
(W) → f

**Status Affected:** 
None

**Encoding:**

```
0110 111a ffff ffff
```

**Description:** Move data from W to register 'f'. Location 'f' can be anywhere in the 256-byte bank.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 
1

**Cycles:** 
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write register 'f'</td>
</tr>
</tbody>
</table>

**Example:**

MOVWF REG, 0

Before Instruction

W = 4Fh
REG = FFh

After Instruction

W = 4Fh
REG = 4Fh
### MULLW

**Multiply Literal with W**

<table>
<thead>
<tr>
<th>Syntax:</th>
<th>MULLW k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operands:</td>
<td>0 ≤ k ≤ 255</td>
</tr>
<tr>
<td>Operation:</td>
<td>(W) x k → PRODH:PRODL</td>
</tr>
<tr>
<td>Status Affected:</td>
<td>None</td>
</tr>
<tr>
<td>Encoding:</td>
<td>0000 1101 kkkk kkkk</td>
</tr>
<tr>
<td>Description:</td>
<td>An unsigned multiplication is carried out between the contents of W and the 8-bit literal 'k'. The 16-bit result is placed in the PRODH:PRODL register pair. PRODH contains the high byte. W is unchanged. None of the Status flags are affected. Note that neither Overflow nor Carry is possible in this operation. A Zero result is possible but not detected.</td>
</tr>
<tr>
<td>Words:</td>
<td>1</td>
</tr>
<tr>
<td>Cycles:</td>
<td>1</td>
</tr>
<tr>
<td>Q Cycle Activity:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal ‘k’</td>
<td>Process Data</td>
<td>Write registers PRODH:PRODL</td>
</tr>
</tbody>
</table>

**Example:** MULLW 0C4h

Before Instruction

<table>
<thead>
<tr>
<th>W</th>
<th>E2h</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODH</td>
<td>?</td>
</tr>
<tr>
<td>PRODL</td>
<td>?</td>
</tr>
</tbody>
</table>

After Instruction

<table>
<thead>
<tr>
<th>W</th>
<th>E2h</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODH</td>
<td>ADh</td>
</tr>
<tr>
<td>PRODL</td>
<td>08h</td>
</tr>
</tbody>
</table>

### MULWF

**Multiply W with f**

<table>
<thead>
<tr>
<th>Syntax:</th>
<th>MULWF f,a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operands:</td>
<td>0 ≤ f ≤ 255</td>
</tr>
<tr>
<td>a ∈ [0,1]</td>
<td></td>
</tr>
<tr>
<td>Operation:</td>
<td>(W) x (f) → PRODH:PRODL</td>
</tr>
<tr>
<td>Status Affected:</td>
<td>None</td>
</tr>
<tr>
<td>Encoding:</td>
<td>0000 001a ffff ffff</td>
</tr>
<tr>
<td>Description:</td>
<td>An unsigned multiplication is carried out between the contents of W and the register file location 'f'. The 16-bit result is stored in the PRODH:PRODL register pair. PRODH contains the high byte. Both W and 'f' are unchanged. None of the Status flags are affected. Note that neither Overflow nor Carry is possible in this operation. A Zero result is possible but not detected.</td>
</tr>
<tr>
<td>If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default). If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.</td>
<td></td>
</tr>
<tr>
<td>Words:</td>
<td>1</td>
</tr>
<tr>
<td>Cycles:</td>
<td>1</td>
</tr>
<tr>
<td>Q Cycle Activity:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register ‘f’</td>
<td>Process Data</td>
<td>Write registers PRODH:PRODL</td>
</tr>
</tbody>
</table>

**Example:** MULWF REG, 1

Before Instruction

<table>
<thead>
<tr>
<th>W</th>
<th>C4h</th>
</tr>
</thead>
<tbody>
<tr>
<td>REG</td>
<td>B5h</td>
</tr>
<tr>
<td>PRODH</td>
<td>?</td>
</tr>
<tr>
<td>PRODL</td>
<td>?</td>
</tr>
</tbody>
</table>

After Instruction

<table>
<thead>
<tr>
<th>W</th>
<th>C4h</th>
</tr>
</thead>
<tbody>
<tr>
<td>REG</td>
<td>B5h</td>
</tr>
<tr>
<td>PRODH</td>
<td>8Ah</td>
</tr>
<tr>
<td>PRODL</td>
<td>94h</td>
</tr>
</tbody>
</table>
NEG F Negate f

Syntax: NEGF f {a}
Operands: \(0 \leq f \leq 255\)
\(a \in [0,1]\)
Operation: \((\overline{f}) + 1 \rightarrow f\)
Status Affected: N, OV, DC, Z
Encoding: \[0110 110a ffff ffff\]
Description: Location 'f' is negated using two's complement. The result is placed in the data memory location 'f'.
If 'a' is '0', the Access Bank is selected.
If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \(f \leq 95\) (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1
Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

Example:

Before Instruction
REG = 0011 1010 [3Ah]
After Instruction
REG = 1100 0110 [C6h]

NOP No Operation

Syntax: NOP
Operands: None
Operation: No operation
Status Affected: None
Encoding: \[0000 0000 0000 0000\]
Description: No operation.
Words: 1
Cycles: 1
Q Cycle Activity:

Example:
None.
### POP
#### Pop Top of Return Stack

<table>
<thead>
<tr>
<th>Syntax:</th>
<th>POP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operands:</td>
<td>None</td>
</tr>
<tr>
<td>Operation:</td>
<td>(TOS) → bit bucket</td>
</tr>
<tr>
<td>Status Affected:</td>
<td>None</td>
</tr>
<tr>
<td>Encoding:</td>
<td>0000 0000 0000 0110</td>
</tr>
<tr>
<td>Description:</td>
<td>The TOS value is pulled off the return stack and is discarded. The TOS value then becomes the previous value that was pushed onto the return stack. This instruction is provided to enable the user to properly manage the return stack to incorporate a software stack.</td>
</tr>
<tr>
<td>Words:</td>
<td>1</td>
</tr>
<tr>
<td>Cycles:</td>
<td>1</td>
</tr>
<tr>
<td>Q Cycle Activity:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>No operation</td>
<td>POP TOS value</td>
<td>No operation</td>
</tr>
</tbody>
</table>

#### Example:

Before Instruction

<table>
<thead>
<tr>
<th>TOS</th>
<th>Stack (1 level down)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0031A2h</td>
<td>014332h</td>
</tr>
</tbody>
</table>

After Instruction

<table>
<thead>
<tr>
<th>TOS</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>014332h</td>
<td>NEW</td>
</tr>
</tbody>
</table>

### PUSH
#### Push Top of Return Stack

<table>
<thead>
<tr>
<th>Syntax:</th>
<th>PUSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operands:</td>
<td>None</td>
</tr>
<tr>
<td>Operation:</td>
<td>(PC + 2) → TOS</td>
</tr>
<tr>
<td>Status Affected:</td>
<td>None</td>
</tr>
<tr>
<td>Encoding:</td>
<td>0000 0000 0000 0101</td>
</tr>
<tr>
<td>Description:</td>
<td>The PC + 2 is pushed onto the top of the return stack. The previous TOS value is pushed down on the stack. This instruction allows implementing a software stack by modifying TOS and then pushing it onto the return stack.</td>
</tr>
<tr>
<td>Words:</td>
<td>1</td>
</tr>
<tr>
<td>Cycles:</td>
<td>1</td>
</tr>
<tr>
<td>Q Cycle Activity:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>PUSH PC + 2 onto return stack</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

#### Example:

Before Instruction

<table>
<thead>
<tr>
<th>TOS</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>345Ah</td>
<td>0124h</td>
</tr>
</tbody>
</table>

After Instruction

<table>
<thead>
<tr>
<th>TOS</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0126h</td>
<td>0126h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stack (1 level down)</th>
</tr>
</thead>
<tbody>
<tr>
<td>345Ah</td>
</tr>
</tbody>
</table>
RCALL Relative Call

Syntax: RCALL n
Operands: -1024 ≤ n ≤ 1023
Operation: (PC) + 2 → TOS, (PC) + 2 + 2n → PC
Status Affected: None
Encoding: 1101 1nnn nnnn nnnn
Description: Subroutine call with a jump up to 1K from the current location. First, return address (PC + 2) is pushed onto the stack. Then, add the 2's complement number '2n' to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 2 + 2n. This instruction is a two-cycle instruction.
Words: 1
Cycles: 2
Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal 'n'</td>
<td>Process Data</td>
<td>Write to PC</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

Example: HERE RCALL Jump

Before Instruction
PC = Address (HERE)
After Instruction
PC = Address (Jump)
TOS = Address (HERE + 2)

RESET Reset

Syntax: RESET
Operands: None
Operation: Reset all registers and flags that are affected by a MCLR Reset.
Status Affected: All
Encoding: 0000 0000 1111 1111
Description: This instruction provides a way to execute a MCLR Reset in software.
Words: 1
Cycles: 1
Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Start Reset</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

Example: RESET

After Instruction
Registers = Reset Value
Flags* = Reset Value

* Flags include: C, Z, V, N, and OV.
**RETFIE**  Return from Interrupt

<table>
<thead>
<tr>
<th>Syntax:</th>
<th>RETFIE  [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operands:</td>
<td>$s \in [0,1]$</td>
</tr>
</tbody>
</table>
| Operation:    | (TOS) $\rightarrow$ PC,  
                | 1 $\rightarrow$ GIE/GIEH or PEIE/GIEL;  
                | if $s = 1$,  
                | (WS) $\rightarrow$ W,  
                | (STATUSS) $\rightarrow$ STATUS,  
                | (BSRS) $\rightarrow$ BSR,  
                | PCLATU, PCLATH are unchanged |
| Status Affected: | GIE/GIEH, PEIE/GIEL. |
| Encoding:     | 0000 0000 0001 000s |
| Description: | Return from interrupt. Stack is popped and Top-of-Stack (TOS) is loaded into the PC. Interrupts are enabled by setting either the high or low priority global interrupt enable bit. If $s = 1$, the contents of the shadow registers, WS, STATUSUSS and BSRS, are loaded into their corresponding registers, W, STATUS and BSR. If $s = 0$, no update of these registers occurs (default). |
| Words:        | 1 |
| Cycles:       | 2 |
| Q Cycle Activity: | | | | |
| Q1 | Q2 | Q3 | Q4 |
| Decode | No operation | No operation | No operation |
| No operation | No operation | No operation | No operation |

**RETLW**  Return Literal to W

<table>
<thead>
<tr>
<th>Syntax:</th>
<th>RETLW  k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operands:</td>
<td>$0 \leq k \leq 255$</td>
</tr>
</tbody>
</table>
| Operation:    | $k \rightarrow$ W,  
                | (TOS) $\rightarrow$ PC,  
                | PCLATU, PCLATH are unchanged |
| Status Affected: | None |
| Encoding:     | 0000 1100 kkkk kkkk |
| Description: | W is loaded with the eight-bit literal 'k'. The program counter is loaded from the top of the stack (the return address). The high address latch (PCLATH) remains unchanged. |
| Words:        | 1 |
| Cycles:       | 2 |
| Q Cycle Activity: | | | | |
| Q1 | Q2 | Q3 | Q4 |
| Decode | Read literal 'k' | Process Data | POP PC from stack, Write to W |
| No operation | No operation | No operation | No operation |

**Example:**

```
CALL TABLE; W contains table  
    ; offset value  
    ; W now has  
    ; table value  

TABLE

ADDWF PCL; W = offset
RETLW k0; Begin table
RETLW k1;
:
RETLW kn; End of table
```

Before Instruction
```
W = 07h
```

After Instruction
```
W = value of kn
```
RETURN

Return from Subroutine

Syntax: RETURN {s}
Operands: s ∈ [0, 1]
Operation: (TOS) → PC;
            if s = 1, (WS) → W, (STATUSS) → STATUS, (BSRS) → BSR, PCLATU, PCLATH are unchanged
Status Affected: None
Encoding: 0000 0000 0001 001s
Description: Return from subroutine. The stack is popped and the top of the stack (TOS) is loaded into the program counter. If 's' = 1, the contents of the shadow registers, WS, STATUSS and BSRS, are loaded into their corresponding registers, W, STATUS and BSR. If 's' = 0, no update of these registers occurs (default).
Words: 1
Cycles: 2
Q Cycle Activity:

Example: RETURN
After Interrupt
PC = TOS

RLCF

Rotate Left f through Carry

Syntax: RLCF f (d, a)
Operands: 0 ≤ f ≤ 255, d ∈ [0, 1], a ∈ [0, 1]
Operation: (f<n>) → dest<n + 1>,
            if 'd' = 0, the result is placed in W. If 'd' = 1, the result is stored back in register 'f' (default).
            if 'a' = 0, the Access Bank is selected. If 'a' = 1, the BSR is used to select the GPR bank (default).
            if 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.
Status Affected: C, N, Z
Encoding: 0011 01da ffff ffff
Description: The contents of register 'f' are rotated one bit to the left through the Carry flag. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is stored back in register 'f' (default).
If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.
Words: 1
Cycles: 1
Q Cycle Activity:

Example: RLCF REG, 0, 0
Before Instruction
REG = 1110 0110
C = 0
After Instruction
REG = 1110 0110
W = 1100 1100
C = 1
### RLNCF Rotate Left f (No Carry)

**Syntax:**

\[ \text{RLNCF} \ f \{d, \{a\}\} \]

**Operands:**

\[ 0 \leq f \leq 255 \]

\[ d \in [0, 1] \]

\[ a \in [0, 1] \]

**Operation:**

\[ (f_{<n>}) \rightarrow \text{dest}_{<n + 1>} \]

\[ (f_{<7>}) \rightarrow \text{dest}_{<0>} \]

**Status Affected:**

N, Z

**Encoding:**

\[
\begin{array}{llll}
0100 & 01 \text{da} & \text{fff} & \text{fff} \\
\end{array}
\]

**Description:**

The contents of register 'f' are rotated one bit to the left. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is stored back in register 'f' (default).

If 'a' is '0', the Access Bank is selected.

If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \( f \leq 95 \) (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction

\[
\begin{align*}
\text{REG} &= 1010 \ 1011 \\
\text{C} &= 0
\end{align*}
\]

After Instruction

\[
\begin{align*}
\text{REG} &= 0101 \ 0111 \\
\text{C} &= 0
\end{align*}
\]

### RRCF Rotate Right f through Carry

**Syntax:**

\[ \text{RRCF} \ f \{d, \{a\}\} \]

**Operands:**

\[ 0 \leq f \leq 255 \]

\[ d \in [0, 1] \]

\[ a \in [0, 1] \]

**Operation:**

\[ (f_{<n>}) \rightarrow \text{dest}_{<n – 1>} \]

\[ (f_{<0>}) \rightarrow \text{C}, \]

\[ (C) \rightarrow \text{dest}_{<7>} \]

**Status Affected:**

C, N, Z

**Encoding:**

\[
\begin{array}{llll}
0011 & 00 \text{da} & \text{fff} & \text{fff} \\
\end{array}
\]

**Description:**

The contents of register 'f' are rotated one bit to the right through the Carry flag. If 'd' is '0', the result is placed in W.

If 'd' is '1', the result is placed back in register 'f' (default).

If 'a' is '0', the Access Bank is selected.

If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \( f \leq 95 \) (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction

\[
\begin{align*}
\text{REG} &= 1110 \ 0110 \\
\text{C} &= 0
\end{align*}
\]

After Instruction

\[
\begin{align*}
\text{REG} &= 1110 \ 0110 \\
\text{W} &= 0111 \ 0011 \\
\text{C} &= 0
\end{align*}
\]
RRNCF  Rotate Right f (No Carry)

Syntax: RRNCF f{,d{,a}}

Operands: 0 ≤ f ≤ 255
d ∈ [0,1]
a ∈ [0,1]

Operation: (f<n>) → dest<n – 1>,
(f<0>) → dest<7>

Status Affected: N, Z

Encoding: 0100 00da ffff ffff

Description: The contents of register ‘f’ are rotated one bit to the right. If ‘d’ is ‘0’, the result is placed in W. If ‘d’ is ‘1’, the result is placed back in register ‘f’ (default).

If ‘a’ is ‘0’, the Access Bank will be selected, overriding the BSR value. If ‘a’ is ‘1’, then the bank will be selected as per the BSR value (default).

If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1
Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register ‘f’</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

Example 1: RRNCF REG, 1, 0

Before Instruction
REG = 1101 0111

After Instruction
REG = 1110 1011

Example 2: RRNCF REG, 0, 0

Before Instruction
W = ?
REG = 1101 0111

After Instruction
W = 1110 1011
REG = 1101 0111

SETF  Set f

Syntax: SETF f{,a}

Operands: 0 ≤ f ≤ 255
a ∈ [0,1]

Operation: FFh → f

Status Affected: None

Encoding: 0110 100a ffff ffff

Description: The contents of the specified register are set to FFh.

If ‘a’ is ‘0’, the Access Bank is selected. If ‘a’ is ‘1’, the BSR is used to select the GPR bank (default).

If ‘a’ is ‘0’ and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1
Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register ‘f’</td>
<td>Process Data</td>
<td>Write register ‘f’</td>
</tr>
</tbody>
</table>

Example: SETF REG, 1

Before Instruction
REG = 5Ah

After Instruction
REG = FFh
**SLEEP**
Enter Sleep mode

**Syntax:**
SLEEP

**Operands:**
None

**Operation:**
00h → WDT,
0 → WDT postscaler,
1 → TO,
0 → PD

**Status Affected:**
TO, PD

**Encoding:**
0000 0000 0000 0011

**Description:**
The Power-Down status bit (PD) is cleared. The Time-out status bit (TO) is set. Watchdog Timer and its postscaler are cleared.
The processor is put into Sleep mode with the oscillator stopped.

**Words:**
1

**Cycles:**
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>No operation</td>
<td>Process Data</td>
<td>Go to Sleep</td>
</tr>
</tbody>
</table>

**Example:**
SLEEP

Before Instruction
TO = ?
PD = ?

After Instruction
TO = 1 †
PD = 0

† If WDT causes wake-up, this bit is cleared.

---

**SUBFWB**
Subtract f from W with Borrow

**Syntax:**
SUBFWB f, {d (a)}

**Operands:**
0 ≤ f ≤ 255
d ∈ [0, 1]
a ∈ [0, 1]

**Operation:**
(W) – (f) – (C) → dest

**Status Affected:**
N, OV, C, DC, Z

**Encoding:**
0101 01da ffff ffff

**Description:**
Subtract register 'f' and Carry flag (borrow) from W (2’s complement method). If ‘d’ is '0', the result is stored in W. If ‘d’ is '1', the result is stored in register 'f' (default).
If ‘a’ is '0', the Access Bank is selected. If ‘a’ is '1', the BSR is used to select the GPR bank (default).
If ‘a’ is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:**
1

**Cycles:**
1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

**Example 1:**
SUBFWB REG, 1, 0

Before Instruction
REG = 3
W = 2
C = 1

After Instruction
REG = FF
W = 2
C = 0
Z = 0
N = 1 ; result is negative

**Example 2:**
SUBFWB REG, 0, 0

Before Instruction
REG = 2
W = 5
C = 1

After Instruction
REG = 2
W = 3
C = 1
Z = 0
N = 0 ; result is positive

**Example 3:**
SUBFWB REG, 1, 0

Before Instruction
REG = 1
W = 2
C = 0

After Instruction
REG = 0
W = 2
C = 1
Z = 1
N = 0 ; result is zero
**SUBLW** Subtract W from Literal

**Syntax:**
SUBLW k

**Operands:**
\[0 \leq k \leq 255\]

**Operation:**
\[k - (W) \rightarrow W\]

**Status Affected:**
N, OV, C, DC, Z

**Encoding:**
```
0000 1000 kkkk kkkk
```

**Description:**
W is subtracted from the eight-bit literal 'k'. The result is placed in W.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Read</td>
<td>Write to W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>literal (k)</td>
<td>Data</td>
</tr>
</tbody>
</table>

**Example 1:**

Before Instruction
W = 02h
C = ?

After Instruction
W = 01h
C = 1; result is positive
Z = 0
N = 0

**Example 2:**

Before Instruction
W = 02h
C = ?

After Instruction
W = 00h
C = 1; result is zero
Z = 1
N = 0

**Example 3:**

Before Instruction
W = 03h
C = ?

After Instruction
W = FFh; (2's complement)
C = 0; result is negative
Z = 0
N = 1

**SUBWF** Subtract W from f

**Syntax:**
SUBWF f{,d {,a}}

**Operands:**
\[0 \leq f \leq 255\]
\[d \in [0,1]\]
\[a \in [0,1]\]

**Operation:**
\[(f) - (W) \rightarrow \text{dest}\]

**Status Affected:**
N, OV, C, DC, Z

**Encoding:**
```
0101 11da ffff ffff
```

**Description:**
Subtract W from register 'f' (2's complement method). If 'd' is '0', the result is stored in W. If 'd' is '1', the result is stored back in register 'f' (default).

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \[f \leq 95\] (5Fh). See Section 25.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode" for details.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Read</td>
<td>Write to destination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>register (f)</td>
<td>Data</td>
</tr>
</tbody>
</table>

**Example 1:**

Before Instruction
REG = 3
W = 2
C = ?

After Instruction
REG = 1
W = 2
C = 1; result is positive
Z = 0
N = 0

**Example 2:**

Before Instruction
REG = 2
W = 2
C = ?

After Instruction
REG = 2
W = 0
C = 1; result is zero
Z = 0
N = 0

**Example 3:**

Before Instruction
REG = 1
W = 2
C = ?

After Instruction
REG = FFh; (2's complement)
W = 2
C = 0; result is negative
Z = 0
N = 1
### SUBWFB
**Subtract W from f with Borrow**

**Syntax:**
\[
\text{SUBWFB } f\{,d\{,a\}\}
\]

**Operands:**
- \(0 \leq f \leq 255\)
- \(d \in [0,1]\)
- \(a \in [0,1]\)

**Operation:**
\[
(f) - (W) - (C) \to \text{dest}
\]

**Status Affected:**
- N, OV, C, DC, Z

**Encoding:**
0101 10da ffff ffff

**Description:** Subtract W and the Carry flag (borrow) from register 'f' (2's complement method). If 'd' is '0', the result is stored in W. If 'd' is '1', the result is stored back in register 'f' (default).

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \(f \leq 95\ (5F_{H})\). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1
**Cycles:** 1

<table>
<thead>
<tr>
<th>Q Cycle Activity:</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
<td></td>
</tr>
</tbody>
</table>

**Example 1:**

Before Instruction:
- \(\text{REG} = 19_{H}\) (0001 1001)
- \(\text{W} = 0\) (0000 0000)
- \(\text{C} = 1\)

After Instruction:
- \(\text{REG} = 0\) (0000 0000)
- \(\text{W} = 0\) (0000 0000)
- \(\text{C} = 1\)

; result is positive

**Example 2:**

Before Instruction:
- \(\text{REG} = 1B_{H}\) (0001 1011)
- \(\text{W} = 1\) (0001 0001)
- \(\text{C} = 0\)

After Instruction:
- \(\text{REG} = 1B_{H}\) (0001 1011)
- \(\text{W} = 0\) (0000 0000)
- \(\text{C} = 1\)

; result is zero

**Example 3:**

Before Instruction:
- \(\text{REG} = 03_{H}\) (0000 0011)
- \(\text{W} = 0\) (0000 0000)
- \(\text{C} = 1\)

After Instruction:
- \(\text{REG} = 5\) (1010 0101)
- \(\text{W} = 0\) (0000 0000)
- \(\text{C} = 1\)

; result is negative

### SWAPF
**Swap f**

**Syntax:**
\[
\text{SWAPF } f\{,d\{,a\}\}
\]

**Operands:**
- \(0 \leq f \leq 255\)
- \(d \in [0,1]\)
- \(a \in [0,1]\)

**Operation:**
\[
(f)_{<3:0>} \to \text{dest}<7:4>,
(f)_{<7:4>} \to \text{dest}<3:0>
\]

**Status Affected:** None

**Encoding:**
0011 10da ffff ffff

**Description:** The upper and lower nibbles of register 'f' are exchanged. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is placed in register 'f' (default).

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \(f \leq 95\ (5F_{H})\). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

**Words:** 1
**Cycles:** 1

<table>
<thead>
<tr>
<th>Q Cycle Activity:</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
<td></td>
</tr>
</tbody>
</table>

**Example:**

Before Instruction:
- \(\text{REG} = 53_{H}\)
- \(\text{W} = 0\) (0000 0000)

After Instruction:
- \(\text{REG} = 53_{H}\)
- \(\text{W} = 35_{H}\) (0011 0101)
TBLRD Table Read

Syntax: TBLRD (*; *+; *-; +*)
Operands: None
Operation: if TBLRD *,
(Prog Mem (TBLPTR)) → TABLAT,
TBLPTR – No Change;
if TBLRD *+,
(Prog Mem (TBLPTR)) → TABLAT,
(TBLPTR) + 1 → TBLPTR;
if TBLRD *-,
(Prog Mem (TBLPTR)) → TABLAT,
(TBLPTR) – 1 → TBLPTR;
if TBLRD +*,
(TBLPTR) + 1 → TBLPTR,
(Prog Mem (TBLPTR)) → TABLAT
Status Affected: None
Encoding:

<table>
<thead>
<tr>
<th>Encoding</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000 0000 0000 10nn</td>
<td>nn=0 * -1 0</td>
</tr>
</tbody>
</table>

Description: This instruction is used to read the contents of Program Memory (P.M.). To address the program memory, a pointer, called Table Pointer (TBLPTR), is used.
The TBLPTR (a 21-bit pointer) points to each byte in the program memory. TBLPTR has a 2-Mbyte address range.

TBLPTR[0] = 0: Least Significant Byte of Program Memory Word
TBLPTR[0] = 1: Most Significant Byte of Program Memory Word

The TBLRD instruction can modify the value of TBLPTR as follows:
• no change
• post-increment
• post-decrement
• pre-increment
Words: 1
Cycles: 2
Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation (Read Program Memory)</td>
<td>No operation</td>
<td>No operation (Write TABLAT)</td>
</tr>
</tbody>
</table>

Example 1: TBLRD *+ ;
Before Instruction
TABLAT = 55h
TBLPTR = 00A356h
MEMORY(00A356h) = 34h
After Instruction
TABLAT = 34h
TBLPTR = 00A357h

Example 2: TBLRD +* ;
Before Instruction
TABLAT = 0AAh
TBLPTR = 01A357h
MEMORY(01A357h) = 12h
MEMORY(01A358h) = 34h
After Instruction
TABLAT = 34h
TBLPTR = 01A358h
**TBLWT Table Write**

**Syntax:** TBLWT (*; *+; *-; +*)

**Operands:** None

**Operation:**
- if TBLWT*, (TABLAT) → Holding Register, TBLPTR – No Change;
- if TBLWT*+, (TABLAT) → Holding Register, (TBLPTR) + 1 → TBLPTR;
- if TBLWT*-., (TABLAT) → Holding Register, (TBLPTR) – 1 → TBLPTR;
- if TBLWT+*, (TBLPTR) + 1 → TBLPTR, (TABLAT) → Holding Register

**Status Affected:** None

**Encoding:**

<table>
<thead>
<tr>
<th>0000</th>
<th>0000</th>
<th>0000</th>
<th>11nn</th>
</tr>
</thead>
</table>

- nn=0 *=
- nn=1 *+=
- nn=2 *–
- nn=3 +*

**Description:**
This instruction uses the 3 LSBs of the TBLPTR to determine which of the 8 holding registers the TABLAT is written to. The holding registers are used to program the contents of Program Memory (P.M.). (Refer to Section 6.0 “Flash Program Memory” for additional details on programming Flash memory.)

The TBLPTR (a 21-bit pointer) points to each byte in the program memory. TBLPTR has a 2-MByte address range. The LSb of the TBLPTR selects which byte of the program memory location to access.

- TBLPTR[0] = 0: Least Significant Byte of Program Memory Word
- TBLPTR[0] = 1: Most Significant Byte of Program Memory Word

The TBLWT instruction can modify the value of TBLPTR as follows:
- no change
- post-increment
- post-decrement
- pre-increment

**Words:** 1

**Cycles:** 2

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation (Read TABLAT)</td>
<td>No operation</td>
<td>No operation (Write to Holding Register)</td>
</tr>
</tbody>
</table>

**Example 1:** TBLWT *+;

**Before Instruction**
- TABLAT = 55h
- TBLPTR = 00A356h
- HOLDING REGISTER (00A356h) = FFh

**After Instructions (table write completion)**
- TABLAT = 55h
- TBLPTR = 00A357h
- HOLDING REGISTER (00A356h) = 55h

**Example 2:** TBLWT +*;

**Before Instruction**
- TABLAT = 34h
- TBLPTR = 01389Ah
- HOLDING REGISTER (01389Ah) = FFh
- HOLDING REGISTER (01389Bh) = FFh

**After Instruction (table write completion)**
- TABLAT = 34h
- TBLPTR = 01389Bh
- HOLDING REGISTER (01389Ah) = FFh
- HOLDING REGISTER (01389Bh) = 34h
TSTFSZ Test f, Skip if 0

Syntax: TSTFSZ f {,a}
Operands: \(0 \leq f \leq 255\)
\(a \in [0,1]\)
Operation: skip if \(f = 0\)
Status Affected: None
Encoding: 0110 011a ffff ffff
Description: If \(f = 0\), the next instruction fetched during the current instruction execution is discarded and a \textit{NOP} is executed, making this a two-cycle instruction.
If \(a = 0\), the Access Bank is selected.
If \(a = 1\), the BSR is used to select the GPR bank (default).
If \(a = 0\) and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever \(f \leq 95\) (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.
Words: 1
Cycles: 1(2)
Note: 3 cycles if skip and followed by a 2-word instruction.

Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register (f)</td>
<td>Process Data</td>
<td>No operation</td>
</tr>
</tbody>
</table>

If skip:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

If skip and followed by 2-word instruction:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
<td>No operation</td>
</tr>
</tbody>
</table>

Example: HERE TSTFSZ CNT, 1
NZERO:
ZERO:

Before Instruction
PC = Address (HERE)

After Instruction
If CNT = 00h, PC = Address (ZERO)
If CNT = 00h, PC = Address (NZERO)

XORLW Exclusive OR Literal with W

Syntax: XORLW \(k\)
Operands: \(0 \leq k \leq 255\)
Operation: \((W) \text{XOR} \ k \rightarrow W\)
Status Affected: \(N, Z\)
Encoding: 0000 1010 kkkk kkkk
Description: The contents of \(W\) are XORed with the 8-bit literal \(k\). The result is placed in \(W\).
Words: 1
Cycles: 1

Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read literal (k)</td>
<td>Process Data</td>
<td>Write to W</td>
</tr>
</tbody>
</table>

Example:
XORLW 0AFh

Before Instruction
\(W = B5h\)
After Instruction
\(W = 1Ah\)
XORWF Exclusive OR W with f

Syntax: XORWF f {,d {,a}}

Operands: $0 \leq f \leq 255$
$\quad d \in [0,1]$
$\quad a \in [0,1]$

Operation: $(W) \cdot \text{XOR} \cdot (f) \rightarrow \text{dest}$

Status Affected: N, Z

Encoding:

<table>
<thead>
<tr>
<th></th>
<th>0001</th>
<th>10da</th>
<th>ffff</th>
<th>ffff</th>
</tr>
</thead>
</table>

Description: Exclusive OR the contents of W with register 'f'. If 'd' is '0', the result is stored in W. If 'd' is '1', the result is stored back in the register 'f' (default).
If 'a' is '0', the Access Bank is selected.
If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever $f \leq 95$ (5Fh). See Section 25.2.3 “Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode” for details.

Words: 1
Cycles: 1

Q Cycle Activity:

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

Example: XORWF REG, 1, 0

Before Instruction

<table>
<thead>
<tr>
<th>REG</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFh</td>
<td>B5h</td>
</tr>
</tbody>
</table>

After Instruction

<table>
<thead>
<tr>
<th>REG</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Ah</td>
<td>B5h</td>
</tr>
</tbody>
</table>
25.2 Extended Instruction Set

In addition to the standard 75 instructions of the PIC18 instruction set, PIC18F2682/2685/4682/4685 devices also provide an optional extension to the core CPU functionality. The added features include eight additional instructions that augment indirect and indexed addressing operations and the implementation of Indexed Literal Offset Addressing mode for many of the standard PIC18 instructions.

The additional features are disabled by default. To enable them, users must set the XINST Configuration bit.

The instructions in the extended set can all be classified as literal operations, which either manipulate the File Select Registers or use them for indexed addressing. Two of the instructions, ADDFSR and SUBFSR, each have an additional special instantiation for using FSR2. These versions (ADDFULNK and SUBULNK) allow for automatic return after execution.

The extended instructions are specifically implemented to optimize re-entrant program code (that is, code that is recursive or that uses a software stack) written in high-level languages, particularly C. Among other things, they allow users working in high-level languages to perform certain operations on data structures more efficiently. These include:

- Dynamic allocation and deallocation of software stack space when entering and leaving subroutines
- Function Pointer invocation
- Software Stack Pointer manipulation
- Manipulation of variables located in a software stack

A summary of the instructions in the extended instruction set is provided in Table 25-3. Detailed descriptions are provided in Section 25.2.2 “Extended Instruction Set”. The opcode field descriptions in Table 25-1 apply to both the standard and extended PIC18 instruction sets.

Note: The instruction set extension and the Indexed Literal Offset Addressing mode were designed for optimizing applications written in C; the user may likely never use these instructions directly in assembler. The syntax for these commands is provided as a reference for users who may be reviewing code that has been generated by a compiler.

25.2.1 EXTENDED INSTRUCTION SYNTAX

Most of the extended instructions use indexed arguments, using one of the File Select Registers and some offset to specify a source or destination register. When an argument for an instruction serves as part of indexed addressing, it is enclosed in square brackets (“[]”). This is done to indicate that the argument is used as an index or offset. MPASM™ Assembler will flag an error if it determines that an index or offset value is not bracketed.

When the extended instruction set is enabled, brackets are also used to indicate index arguments in bit-oriented and byte-oriented instructions. This is in addition to other changes in their syntax. For more details, see Section 25.2.3.1 “Extended Instruction Syntax with Standard PIC18 Commands”.

Note: In the past, square brackets have been used to denote optional arguments in the PIC18 and earlier instruction sets. In this text and going forward, optional arguments are denoted by braces (“{}”).

<table>
<thead>
<tr>
<th>Mnemonic, Operands</th>
<th>Description</th>
<th>Cycles</th>
<th>16-Bit Instruction Word</th>
<th>Status Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MSb</td>
<td>LSb</td>
</tr>
<tr>
<td>ADDFSR f, k</td>
<td>Add literal to FSR</td>
<td>1</td>
<td>1110 1110 ffkk kkkk</td>
<td>None</td>
</tr>
<tr>
<td>ADDULNK k</td>
<td>Add literal to FSR2 and return</td>
<td>2</td>
<td>1110 1110 11kk kkkk</td>
<td>None</td>
</tr>
<tr>
<td>CALLW z, f</td>
<td>Call subroutine using WREG</td>
<td>2</td>
<td>0000 0000 0010 0000</td>
<td>None</td>
</tr>
<tr>
<td>MOVFSF z, f</td>
<td>Move z (source) to 1st word f (destination) 2nd word</td>
<td>2</td>
<td>1110 1011 0zzz zzzz</td>
<td>None</td>
</tr>
<tr>
<td>MOVSF z, f</td>
<td>Move z (source) to 1st word f (destination) 2nd word</td>
<td>2</td>
<td>1111 fffe 1111 fffe</td>
<td>None</td>
</tr>
<tr>
<td>MOVSS z, z</td>
<td>Move z (source) to 1st word z (destination) 2nd word</td>
<td>2</td>
<td>1110 1011 1zzz zzzz</td>
<td>None</td>
</tr>
<tr>
<td>PUSHL k</td>
<td>Store literal at FSR2, decrement FSR2</td>
<td>1</td>
<td>1111 xxxx xxxz zzzz</td>
<td>None</td>
</tr>
<tr>
<td>SUBFSR f, k</td>
<td>Subtract literal from FSR</td>
<td>1</td>
<td>1110 1001 ffkk kkkk</td>
<td>None</td>
</tr>
<tr>
<td>SUBULNK k</td>
<td>Subtract literal from FSR2 and return</td>
<td>2</td>
<td>1110 1001 11kk kkkk</td>
<td>None</td>
</tr>
</tbody>
</table>
### 25.2.2 EXTENDED INSTRUCTION SET

<table>
<thead>
<tr>
<th>ADDFSR</th>
<th>Add Literal to FSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syntax:</td>
<td><code>ADDFSR f, k</code></td>
</tr>
</tbody>
</table>
| Operands: | `0 ≤ k ≤ 63`  
`f ∈ [0, 1, 2]` |
| Operation: | `FSR(f) + k → FSR(f)` |
| Status Affected: | None |
| Encoding: | ![Encoding](1110 1000 ffkk kkkk) |
| Description: | The 6-bit literal 'k' is added to the contents of the FSR specified by 'f'. |
| Words: | 1 |
| Cycles: | 1 |
| Q Cycle Activity: | ![Q Cycle Activity](Q1 Q2 Q3 Q4) |
| Example: | `ADDFSR 2, 23h` |

Before Instruction
- `FSR2 = 03FFh`

After Instruction
- `FSR2 = 0422h`

<table>
<thead>
<tr>
<th>ADDULNK</th>
<th>Add Literal to FSR2 and Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syntax:</td>
<td><code>ADDULNK k</code></td>
</tr>
<tr>
<td>Operands:</td>
<td><code>0 ≤ k ≤ 63</code></td>
</tr>
<tr>
<td>Operation:</td>
<td><code>FSR2 + k → FSR2, PC = (TOS)</code></td>
</tr>
<tr>
<td>Status Affected:</td>
<td>None</td>
</tr>
<tr>
<td>Encoding:</td>
<td>![Encoding](1110 1000 11kk kkkk)</td>
</tr>
<tr>
<td>Description:</td>
<td>The 6-bit literal 'k' is added to the contents of FSR2. A <code>RETURN</code> is then executed by loading the PC with the TOS. The instruction takes two cycles to execute; a <code>NOP</code> is performed during the second cycle. This may be thought of as a special case of the <code>ADDFSR</code> instruction, where <code>f = 3</code> (binary '11'); it operates only on FSR2.</td>
</tr>
<tr>
<td>Words:</td>
<td>1</td>
</tr>
<tr>
<td>Cycles:</td>
<td>2</td>
</tr>
<tr>
<td>Q Cycle Activity:</td>
<td>![Q Cycle Activity](Q1 Q2 Q3 Q4)</td>
</tr>
</tbody>
</table>

Example: `ADDULNK 23h`

Before Instruction
- `FSR2 = 03FFh`
- `PC = 0100h`
- `TOS = 02AFh`

After Instruction
- `FSR2 = 0422h`
- `PC = 02AFh`
- `TOS = TOS – 1`

**Note:** All PIC18 instructions may take an optional label argument preceding the instruction mnemonic for use in symbolic addressing. If a label is used, the instruction syntax then becomes: `{label} instruction argument(s)."
CALLW Subroutine Call Using WREG

Syntax: CALLW
Operands: None
Operation: (PC + 2) → TOS,
          (W) → PCL,
          (PCLATH) → PCH,
          (PCLATU) → PCU
Status Affected: None
Encoding: 0000 0000 0001 0100
Description: First, the return address (PC + 2) is pushed onto the return stack. Next, the contents of W are written to PCL; the existing value is discarded. Then, the contents of PCLATH and PCLATU are latched into PCH and PCU, respectively. The second cycle is executed as a NOP instruction while the new next instruction is fetched. Unlike CALL, there is no option to update W, STATUS or BSR.

Words: 1
Cycles: 2
Q Cycle Activity:

Example: HERE CALLW
Before Instruction
   PC = address (HERE)
   PCLATH = 10h
   PCLATU = 00h
   W = 06h
After Instruction
   PC = 001006h
   TOS = address (HERE + 2)

MOVSF Move Indexed to f

Syntax: MOVSF [z_s], f_d
Operands: 0 ≤ z_s ≤ 127
          0 ≤ f_d ≤ 4095
Operation: ((FSR2) + z_s) → f_d
Status Affected: None
Encoding: 1st word (source) 1110 1111 1011 ffff ffff 0zzz zzzzz_s
          2nd word (destin.) 1111 1111 ffff ffff ffffd
Description: The contents of the source register are moved to destination register 'f_d'. The actual address of the source register is determined by adding the 7-bit literal offset 'z_s' in the first word to the value of FSR2. The address of the destination register is specified by the 12-bit literal 'f_d' in the second word. Both addresses can be anywhere in the 4096-byte data space (000h to FFFh).

The MOVSF instruction cannot use the PCL, TOSU, TOSH or TOSL as the destination register.
If the resultant source address points to an indirect addressing register, the value returned will be 00h.

Words: 2
Cycles: 2
Q Cycle Activity:

Example: MOVSF [05h], REG2
Before Instruction
   FSR2 = 80h
   Contents of 85h = 33h
   REG2 = 11h
After Instruction
   FSR2 = 80h
   Contents of 85h = 33h
   REG2 = 33h
### MOVSS  Move Indexed to Indexed

| Syntax: | MOVSS  \([z_s], [z_d]\) |
| Operands: | 0 ≤ \(z_s\) ≤ 127  
| | 0 ≤ \(z_d\) ≤ 127 |
| Operation: | ((FSR2) + \(z_s\)) → ((FSR2) + \(z_d\)) |
| Status Affected: | None |
| Encoding: | 1110 1111 1zzz zzzz |
| Description: | The contents of the source register are moved to the destination register. The addresses of the source and destination registers are determined by adding the 7-bit literal offsets 'zs' or 'zd', respectively, to the value of FSR2. Both registers can be located anywhere in the 4096-byte data memory space (000h to FFFh). |

The MOVSS instruction cannot use the PCL, TOSU, TOSH or TOSL as the destination register. If the resultant source address points to an indirect addressing register, the value returned will be 00h. If the resultant destination address points to an indirect addressing register, the instruction will execute as a NOP.

| Words: | 2 |
| Cycles: | 2 |
| Q Cycle Activity: | |
| Q1 | Q2 | Q3 | Q4 |
| Decode | Determine source addr | Determine source addr | Read source reg |
| Decode | Determine dest addr | Determine dest addr | Write to dest reg |

**Example:** MOVSS  \([05h], [06h]\)

Before Instruction
- FSR2: 80h
- Contents of 85h: 33h
- Contents of 86h: 11h

After Instruction
- FSR2: 80h
- Contents of 85h: 33h
- Contents of 86h: 33h

### PUSHL  Store Literal at FSR2, Decrement FSR2

| Syntax: | PUSHL  \(k\) |
| Operands: | 0 ≤ \(k\) ≤ 255 |
| Operation: | \(k → (FSR2), FSR2 - 1 → FSR2\) |
| Status Affected: | None |
| Encoding: | 1111 1010 kkkk kkkk |
| Description: | The 8-bit literal 'k' is written to the data memory address specified by FSR2. FSR2 is decremented by 1 after the operation. This instruction allows users to push values onto a software stack. |

| Words: | 1 |
| Cycles: | 1 |
| Q Cycle Activity: | |
| Q1 | Q2 | Q3 | Q4 |
| Decode | Read 'k' | Process data | Write to destination |

**Example:** PUSHL 08h

Before Instruction
- FSR2H:FSR2L = 01ECh
- Memory (01ECh) = 00h

After Instruction
- FSR2H:FSR2L = 01EBh
- Memory (01ECh) = 08h
### SUBFSR
**Subtract Literal from FSR**

**Syntax:** `SUBFSR f, k`

**Operands:**
- `0 ≤ k ≤ 63`
- `f ∈ [0, 1, 2]`

**Operation:** `FSRf – k → FSRf`

**Status Affected:** None

**Encoding:**

<table>
<thead>
<tr>
<th></th>
<th>1110</th>
<th>1001</th>
<th>ffkk</th>
<th>kkkk</th>
</tr>
</thead>
</table>

**Description:** The 6-bit literal `k` is subtracted from the contents of the FSR specified by `f`.

**Words:** 1

**Cycles:** 1

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
</tbody>
</table>

**Example:** `SUBFSR 2, 23h`

**Before Instruction**
- `FSR2 = 03FFh`

**After Instruction**
- `FSR2 = 03DCh`

### SUBULNK
**Subtract Literal from FSR2 and Return**

**Syntax:** `SUBULNK k`

**Operands:**
- `0 ≤ k ≤ 63`

**Operation:**
- `FSR2 – k → FSR2`
- `(TOS) → PC`

**Status Affected:** None

**Encoding:**

<table>
<thead>
<tr>
<th></th>
<th>1110</th>
<th>1001</th>
<th>11kk</th>
<th>kkkk</th>
</tr>
</thead>
</table>

**Description:** The 6-bit literal `k` is subtracted from the contents of the FSR2. A `RETURN` is then executed by loading the PC with the TOS. The instruction takes two cycles to execute; a `NOP` is performed during the second cycle. This may be thought of as a special case of the `SUBFSR` instruction, where `f = 3` (binary ‘11’); it operates only on FSR2.

**Words:** 1

**Cycles:** 2

**Q Cycle Activity:**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decode</td>
<td>Read register 'f'</td>
<td>Process Data</td>
<td>Write to destination</td>
</tr>
<tr>
<td>No Operation</td>
<td>No Operation</td>
<td>No Operation</td>
<td>No Operation</td>
</tr>
</tbody>
</table>

**Example:** `SUBULNK 23h`

**Before Instruction**
- `FSR2 = 03FFh`
- `PC = 0100h`

**After Instruction**
- `FSR2 = 03DCh`
- `PC = (TOS)`
25.2.3 BYTE-ORIENTED AND BIT-ORIENTED INSTRUCTIONS IN INDEXED LITERAL OFFSET MODE

Note: Enabling the PIC18 instruction set extension may cause legacy applications to behave erratically or fail entirely.

In addition to eight new commands in the extended set, enabling the extended instruction set also enables Indexed Literal Offset Addressing mode (Section 5.6.1 “Indexed Addressing with Literal Offset”). This has a significant impact on the way that many commands of the standard PIC18 instruction set are interpreted.

When the extended set is disabled, addresses embedded in opcodes are treated as literal memory locations: either as a location in the Access Bank (a = 0), or in a GPR bank designated by the BSR (a = 1). When the extended instruction set is enabled and a = 0, however, a file register argument of 5Fh or less is interpreted as an offset from the pointer value in FSR2 and not as a literal address. For practical purposes, this means that all instructions that use the Access RAM bit as an argument – that is, all bit-oriented and byte-oriented instructions, or almost half of the core PIC18 instructions – may behave differently when the extended instruction set is enabled.

When the extended set is enabled, addresses in Indexed Literal Offset Addressing are interpreted as offsets from the register in FSR2 rather than as literal memory locations. This has implications for the way that certain instructions are executed, particularly those that use the Access RAM bit as an argument.

In the latest versions of the MPASM Assembler, language support for the extended instruction set must be explicitly invoked. This is done with either the command line option, /y, or the PE directive in the source listing.

25.2.4 CONSIDERATIONS WHEN ENABLING THE EXTENDED INSTRUCTION SET

It is important to note that the extensions to the instruction set may not be beneficial to all users. In particular, users who are not writing code that uses a software stack may not benefit from using the extensions to the instruction set.

Additionally, the Indexed Literal Offset Addressing mode may create issues with legacy applications written to the PIC18 assembler. This is because instructions in the legacy code may attempt to address registers in the Access Bank below 5Fh. Since these addresses are interpreted as literal offsets to FSR2 when the instruction set extension is enabled, the application may read or write to the wrong data addresses.

When porting an application to the PIC18F2682/2685/4682/4685, it is very important to consider the type of code. A large, re-entrant application that is written in 'C' and would benefit from efficient compilation will do well when using the instruction set extensions. Legacy applications that heavily use the Access Bank will most likely not benefit from using the extended instruction set.
ADDWF  ADD W to Indexed (Indexed Literal Offset mode)

Syntax:  ADDWF  [k] {,d}
Operands:  0 ≤ k ≤ 95  
           d ∈ [0,1]  
           a = 0
Operation:  (W) + ((FSR2) + k) → dest
Status Affected:  N, OV, C, DC, Z
Encoding:  0010 01d0 kkkk kkkk
Description:  The contents of W are added to the contents of the register indicated by FSR2, offset by the value ‘k’.

Words:  1
Cycles:  1
Q Cycle Activity:

Example:  ADDWF  [OFST], 0
Before Instruction  
W = 17h  
OFST = 2Ch  
FSR2 = 0A00h  
Contents of 0A2Ch = 00h
After Instruction  
W = 37h  
Contents of 0A2Ch = 20h

BSF  Bit Set Indexed (Indexed Literal Offset mode)

Syntax:  BSF  [k], b
Operands:  0 ≤ f ≤ 95
           0 ≤ b ≤ 7
           a = 0
Operation:  1 → ((FSR2) + k)<b>
Status Affected:  None
Encoding:  1000 bbb0 kkkk kkkk
Description:  Bit ‘b’ of the register indicated by FSR2, offset by the value ‘k’, is set.

Words:  1
Cycles:  1
Q Cycle Activity:

Example:  BSF  [FLAG_OFST], 7
Before Instruction  
FLAG_OFST = 0Ah  
FSR2 = 0A00h  
Contents of 0A0Ah = 55h
After Instruction  
Contents of 0A0Ah = D5h

SETF  Set Indexed (Indexed Literal Offset mode)

Syntax:  SETF  [k]
Operands:  0 ≤ k ≤ 95
Operation:  FFh → ((FSR2) + k)
Status Affected:  None
Encoding:  0110 1000 kkkk kkkk
Description:  The contents of the register indicated by FSR2, offset by ‘k’, are set to FFh.

Words:  1
Cycles:  1
Q Cycle Activity:

Example:  SETF  [OFST]
Before Instruction  
OFST = 2Ch  
FSR2 = 0A00h  
Contents of 0A2Ch = 00h
After Instruction  
Contents of 0A2Ch = FFh
25.2.5 SPECIAL CONSIDERATIONS WITH MICROCHIP MPLAB® IDE TOOLS

The latest versions of Microchip’s software tools have been designed to fully support the extended instruction set of the PIC18F2682/2685/4682/4685 family of devices. This includes the MPLAB C18 C compiler, MPASM assembly language and MPLAB Integrated Development Environment (IDE).

When selecting a target device for software development, MPLAB IDE will automatically set default Configuration bits for that device. The default setting for the XINST Configuration bit is ‘0’, disabling the extended instruction set and Indexed Literal Offset Addressing mode. For proper execution of applications developed to take advantage of the extended instruction set, XINST must be set during programming.

To develop software for the extended instruction set, the user must enable support for the instructions and the Indexed Addressing mode in their language tool(s). Depending on the environment being used, this may be done in several ways:

• A menu option, or dialog box within the environment, that allows the user to configure the language tool and its settings for the project
• A command line option
• A directive in the source code

These options vary between different compilers, assemblers and development environments. Users are encouraged to review the documentation accompanying their development systems for the appropriate information.
26.0 DEVELOPMENT SUPPORT

The PIC® microcontrollers and dsPIC® digital signal controllers are supported with a full range of software and hardware development tools:

- Integrated Development Environment
  - MPLAB® IDE Software
- Compilers/Assemblers/Linkers
  - MPLAB C Compiler for Various Device Families
  - HI-TECH C for Various Device Families
  - MPASM™ Assembler
  - MPLINK™ Object Linker/ MPLIB™ Object Librarian
  - MPLAB Assembler/Linker/Librarian for Various Device Families
- Simulators
  - MPLAB SIM Software Simulator
- Emulators
  - MPLAB REAL ICE™ In-Circuit Emulator
- In-Circuit Debuggers
  - MPLAB ICD 3
  - PICkit™ 3 Debug Express
- Device Programmers
  - PICkit™ 2 Programmer
  - MPLAB PM3 Device Programmer
- Low-Cost Demonstration/Development Boards, Evaluation Kits, and Starter Kits

26.1 MPLAB Integrated Development Environment Software

The MPLAB IDE software brings an ease of software development previously unseen in the 8/16/32-bit microcontroller market. The MPLAB IDE is a Windows® operating system-based application that contains:

- A single graphical interface to all debugging tools
  - Simulator
  - Programmer (sold separately)
  - In-Circuit Emulator (sold separately)
  - In-Circuit Debugger (sold separately)
- A full-featured editor with color-coded context
- A multiple project manager
- Customizable data windows with direct edit of contents
- High-level source code debugging
- Mouse over variable inspection
- Drag and drop variables from source to watch windows
- Extensive on-line help
- Integration of select third party tools, such as IAR C Compilers

The MPLAB IDE allows you to:

- Edit your source files (either C or assembly)
- One-touch compile or assemble, and download to emulator and simulator tools (automatically updates all project information)
- Debug using:
  - Source files (C or assembly)
  - Mixed C and assembly
  - Machine code

MPLAB IDE supports multiple debugging tools in a single development paradigm, from the cost-effective simulators, through low-cost in-circuit debuggers, to full-featured emulators. This eliminates the learning curve when upgrading to tools with increased flexibility and power.
26.2 MPLAB C Compilers for Various Device Families

The MPLAB C Compiler code development systems are complete ANSI C compilers for Microchip’s PIC18, PIC24 and PIC32 families of microcontrollers and the dsPIC30 and dsPIC33 families of digital signal controllers. These compilers provide powerful integration capabilities, superior code optimization and ease of use.

For easy source level debugging, the compilers provide symbol information that is optimized to the MPLAB IDE debugger.

26.3 HI-TECH C for Various Device Families

The HI-TECH C Compiler code development systems are complete ANSI C compilers for Microchip’s PIC family of microcontrollers and the dsPIC family of digital signal controllers. These compilers provide powerful integration capabilities, omniscient code generation and ease of use.

For easy source level debugging, the compilers provide symbol information that is optimized to the MPLAB IDE debugger.

The compilers include a macro assembler, linker, preprocessor, and one-step driver, and can run on multiple platforms.

26.4 MPASM Assembler

The MPASM Assembler is a full-featured, universal macro assembler for PIC10/12/16/18 MCUs.

The MPASM Assembler generates relocatable object files for the MPLINK Object Linker, Intel® standard HEX files, MAP files to detail memory usage and symbol reference, absolute LST files that contain source lines and generated machine code and COFF files for debugging.

The MPASM Assembler features include:

- Integration into MPLAB IDE projects
- User-defined macros to streamline assembly code
- Conditional assembly for multi-purpose source files
- Directives that allow complete control over the assembly process

26.5 MPLINK Object Linker/ MPLIB Object Librarian

The MPLINK Object Linker combines relocatable objects created by the MPASM Assembler and the MPLAB C18 C Compiler. It can link relocatable objects from precompiled libraries, using directives from a linker script.

The MPLIB Object Librarian manages the creation and modification of library files of precompiled code. When a routine from a library is called from a source file, only the modules that contain that routine will be linked in with the application. This allows large libraries to be used efficiently in many different applications.

The object linker/library features include:

- Efficient linking of single libraries instead of many smaller files
- Enhanced code maintainability by grouping related modules together
- Flexible creation of libraries with easy module listing, replacement, deletion and extraction

26.6 MPLAB Assembler, Linker and Librarian for Various Device Families

MPLAB Assembler produces relocatable machine code from symbolic assembly language for PIC24, PIC32 and dsPIC devices. MPLAB C Compiler uses the assembler to produce its object file. The assembler generates relocatable object files that can then be archived or linked with other relocatable object files and archives to create an executable file. Notable features of the assembler include:

- Support for the entire device instruction set
- Support for fixed-point and floating-point data
- Command line interface
- Rich directive set
- Flexible macro language
- MPLAB IDE compatibility
26.7 MPLAB SIM Software Simulator

The MPLAB SIM Software Simulator allows code development in a PC-hosted environment by simulating the PIC MCUs and dsPIC® DSCs on an instruction level. On any given instruction, the data areas can be examined or modified and stimuli can be applied from a comprehensive stimulus controller. Registers can be logged to files for further run-time analysis. The trace buffer and logic analyzer display extend the power of the simulator to record and track program execution, actions on I/O, most peripherals and internal registers.

The MPLAB SIM Software Simulator fully supports symbolic debugging using the MPLAB C Compilers, and the MPASM and MPLAB Assemblers. The software simulator offers the flexibility to develop and debug code outside of the hardware laboratory environment, making it an excellent, economical software development tool.

26.8 MPLAB REAL ICE In-Circuit Emulator System

MPLAB REAL ICE In-Circuit Emulator System is Microchip’s next generation high-speed emulator for Microchip Flash DSC and MCU devices. It debugs and programs PIC® Flash MCUs and dsPIC® Flash DSCs with the easy-to-use, powerful graphical user interface of the MPLAB Integrated Development Environment (IDE), included with each kit.

The emulator is connected to the design engineer’s PC using a high-speed USB 2.0 interface and is connected to the target with either a connector compatible with in-circuit debugger systems (RJ11) or with the new high-speed, noise tolerant, Low-Voltage Differential Signal (LVDS) interconnection (CAT5).

The emulator is field upgradable through future firmware downloads in MPLAB IDE. In upcoming releases of MPLAB IDE, new devices will be supported, and new features will be added. MPLAB REAL ICE offers significant advantages over competitive emulators including low-cost, full-speed emulation, run-time variable watches, trace analysis, complex breakpoints, a ruggedized probe interface and long (up to three meters) interconnection cables.

26.9 MPLAB ICD 3 In-Circuit Debugger System

MPLAB ICD 3 In-Circuit Debugger System is Microchip’s most cost effective high-speed hardware debugger/programmer for Microchip Flash Digital Signal Controller (DSC) and microcontroller (MCU) devices. It debugs and programs PIC® Flash microcontrollers and dsPIC® DSCs with the powerful, yet easy-to-use graphical user interface of MPLAB Integrated Development Environment (IDE).

The MPLAB ICD 3 In-Circuit Debugger probe is connected to the design engineer’s PC using a high-speed USB 2.0 interface and is connected to the target with a connector compatible with the MPLAB ICD 2 or MPLAB REAL ICE systems (RJ-11). MPLAB ICD 3 supports all MPLAB ICD 2 headers.

26.10 PICkit 3 In-Circuit Debugger/Programmer and PICkit 3 Debug Express

The MPLAB PICkit 3 allows debugging and programming of PIC® and dsPIC® Flash microcontrollers at a most affordable price point using the powerful graphical user interface of the MPLAB Integrated Development Environment (IDE). The MPLAB PICkit 3 is connected to the design engineer’s PC using a full speed USB interface and can be connected to the target via an Microchip debug (RJ-11) connector (compatible with MPLAB ICD 3 and MPLAB REAL ICE). The connector uses two device I/O pins and the reset line to implement in-circuit debugging and In-Circuit Serial Programming™.

The PICkit 3 Debug Express include the PICkit 3, demo board and microcontroller, hookup cables and CDROM with user’s guide, lessons, tutorial, compiler and MPLAB IDE software.
26.11 PICkit 2 Development Programmer/Debugger and PICkit 2 Debug Express

The PICkit™ 2 Development Programmer/Debugger is a low-cost development tool with an easy to use interface for programming and debugging Microchip’s Flash families of microcontrollers. The full featured Windows® programming interface supports baseline (PIC10F, PIC12F5xx, PIC16F5xx), midrange (PIC12F6xx, PIC16F), PIC18F, PIC24, dsPIC30, dsPIC33, and PIC32 families of 8-bit, 16-bit, and 32-bit microcontrollers, and many Microchip Serial EEPROM products. With Microchip’s powerful MPLAB Integrated Development Environment (IDE) the PICkit™ 2 enables in-circuit debugging on most PIC® microcontrollers. In-Circuit-Debugging runs, halts and single steps the program while the PIC microcontroller is embedded in the application. When halted at a breakpoint, the file registers can be examined and modified.

The PICkit 2 Debug Express include the PICkit 2, demo board and microcontroller, hookup cables and CDROM with user’s guide, lessons, tutorial, compiler and MPLAB IDE software.

26.12 MPLAB PM3 Device Programmer

The MPLAB PM3 Device Programmer is a universal, CE compliant device programmer with programmable voltage verification at VDDMIN and VDDMAX for maximum reliability. It features a large LCD display (128 x 64) for menus and error messages and a modular, detachable socket assembly to support various package types. The ICSP™ cable assembly is included as a standard item. In Stand-Alone mode, the MPLAB PM3 Device Programmer can read, verify and program PIC devices without a PC connection. It can also set code protection in this mode. The MPLAB PM3 connects to the host PC via an RS-232 or USB cable. The MPLAB PM3 has high-speed communications and optimized algorithms for quick programming of large memory devices and incorporates an MMC card for file storage and data applications.

26.13 Demonstration/Development Boards, Evaluation Kits, and Starter Kits

A wide variety of demonstration, development and evaluation boards for various PIC MCUs and dsPIC DSCs allows quick application development on fully functional systems. Most boards include prototyping areas for adding custom circuitry and provide application firmware and source code for examination and modification.

The boards support a variety of features, including LEDs, temperature sensors, switches, speakers, RS-232 interfaces, LCD displays, potentiometers and additional EEPROM memory.

The demonstration and development boards can be used in teaching environments, for prototyping custom circuits and for learning about various microcontroller applications.

In addition to the PICDEM™ and dsPICDEM™ demonstration/development board series of circuits, Microchip has a line of evaluation kits and demonstration software for analog filter design, Keeloq® security ICs, CAN, IrDA®, PowerSmart battery management, SEEVAL® evaluation system, Sigma-Delta ADC, flow rate sensing, plus many more.

Also available are starter kits that contain everything needed to experience the specified device. This usually includes a single application and debug capability, all on one board.

Check the Microchip web page (www.microchip.com) for the complete list of demonstration, development and evaluation kits.
27.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings (†)

Ambient temperature under bias............................................................................................................. -40°C to +125°C
Storage temperature .................................................................................................................................. -65°C to +150°C
Voltage on any pin with respect to VSS (except VDD and MCLR) ....................................................... -0.3V to (VDD + 0.3V)
Voltage on VDD with respect to VSS .......................................................................................................... -0.3V to +7.5V
Voltage on MCLR with respect to VSS (Note 2) .................................................................................... 0V to +13.25V
Total power dissipation (Note 1) ......................................................................................................... 1.0W
Maximum current out of VSS pin ................................................................................................................. 300 mA
Maximum current into VDD pin .................................................................................................................. 250 mA
Input clamp current, IIK (VI < 0 or VI > VDD) ..................................................................................... ±20 mA
Output clamp current, IOK (VO < 0 or VO > VDD) .................................................................................. ±20 mA
Maximum output current sunk by any I/O pin ......................................................................................... 25 mA
Maximum output current sourced by any I/O pin ..................................................................................... 25 mA
Maximum current sunk by all ports ......................................................................................................... 200 mA
Maximum current sourced by all ports .................................................................................................. 200 mA

Note 1: Power dissipation is calculated as follows:
\[ P_{\text{dis}} = VDD \times (IDD - \sum IOH) + \sum ((VDD - VOH) \times IOH) + \sum (VOL \times IOL) \]

2: Voltage spikes below VSS at the MCLR/VPP pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a “low” level to the MCLR/VPP/RE3 pin, rather than pulling this pin directly to VSS.

† NOTICE: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.
FIGURE 27-1: PIC18F2682/2685/4682/4685 VOLTAGE-FREQUENCY GRAPH (INDUSTRIAL)

FIGURE 27-2: PIC18LF2682/2685/4682/4685 VOLTAGE-FREQUENCY GRAPH (INDUSTRIAL)

F_{\text{MAX}} = (16.36 \text{ MHz/V}) (V_{\text{DDAPPMIN}} - 2.0V) + 4 \text{ MHz}

Note: V_{\text{DDAPPMIN}} is the minimum voltage of the PIC\textsuperscript{\textregistered} device in the application.
## 27.1 DC Characteristics: Supply Voltage
PIC18F2682/2685/4682/4685 (Industrial)
PIC18LF2682/2685/4682/4685 (Industrial)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>D001</td>
<td>VDD</td>
<td>Supply Voltage</td>
<td>2.0</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial</td>
</tr>
<tr>
<td>D002</td>
<td>VDR</td>
<td>RAM Data Retention Voltage(1)</td>
<td>1.5</td>
<td>—</td>
<td>—</td>
<td>V</td>
<td>Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial</td>
</tr>
<tr>
<td>D003</td>
<td>VPOR</td>
<td>VDD Start Voltage</td>
<td>—</td>
<td>—</td>
<td>0.7</td>
<td>V</td>
<td>See section on Power-on Reset for details</td>
</tr>
<tr>
<td>D004</td>
<td>SvDD</td>
<td>VDD Rise Rate</td>
<td>0.05</td>
<td>—</td>
<td>—</td>
<td>V/ms</td>
<td>See section on Power-on Reset for details</td>
</tr>
</tbody>
</table>

### Note 1:
This is the limit to which VDD can be lowered in Sleep mode, or during a device Reset, without losing RAM data.
27.2 DC Characteristics: Power-Down and Supply Current

### PIC18F2682/2685/4682/4685 (Industrial)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power-Down Current (IPD)(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/2685/4685 (Industrial)</td>
<td>Operating temperature</td>
<td>-40°C ≤ TA ≤ +85°C for industrial</td>
<td>VDD = 2.0V (Sleep mode)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/2685/4685 (Industrial, Extended)</td>
<td>Operating temperature</td>
<td>-40°C ≤ TA ≤ +125°C for extended</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>0.1</td>
<td>0.95</td>
<td>μA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.2</td>
<td>6</td>
<td>μA</td>
<td>+5°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>0.1</td>
<td>1</td>
<td>μA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.2</td>
<td>2</td>
<td>μA</td>
<td>+5°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>0.1</td>
<td>1.9</td>
<td>μA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
<td>15</td>
<td>μA</td>
<td>+5°C</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>0.1</td>
<td>120</td>
<td>μA</td>
<td>+125°C</td>
</tr>
</tbody>
</table>

### Notes:
1. The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).

2. The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption. The test conditions for all IDD measurements in active operation mode are:
   - OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD;
   - MCLR = VDD; WDT enabled/disabled as specified.

3. For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula \( I_r = \frac{VDD}{2 \times R_{EXT}} \) (mA) with \( R_{EXT} \) in kΩ.

4. Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
### 27.2 DC Characteristics: Power-Down and Supply Current

#### PIC18F2682/2685/4682/4685 (Industrial)

#### PIC18F2682/2685/4682/4685 (Industrial, Extended)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device Type</th>
<th>Supply Current (μA)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PIC18LF2682/2685/4682/4685 (Industrial)</td>
<td></td>
<td>Vdd = 2.0V</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>15 36 μA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>15 36 μA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>15 36 μA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>40 100 μA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>35 100 μA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>30 100 μA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>105 200 μA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>90 200 μA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>80 200 μA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>80 200 μA</td>
<td>+125°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.32 1 mA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.33 1 mA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.33 1 mA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.6 1.6 mA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.55 1.6 mA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.6 1.6 mA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>1.1 3 mA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>1.1 3 mA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>1 3 mA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>1 3 mA</td>
<td>+125°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.8 2.2 mA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.8 2.2 mA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>0.8 2.2 mA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>1.3 3 mA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>1.3 3 mA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>PIC18LF2682/468X</td>
<td>1.3 3 mA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>2.5 5.3 mA</td>
<td>-40°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>2.5 5.3 mA</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>2.5 5.3 mA</td>
<td>+85°C</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>2.5 8 mA</td>
<td>+125°C</td>
</tr>
</tbody>
</table>

**Legend:**

- **Shading of rows is to assist in readability of the table.**
- **Note 1:** The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).
- **Note 2:** The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.
- **Note 3:** The test conditions for all IDD measurements in active operation mode are:
  - OSC1 = external square wave, from rail-to-rail, all I/O pins tri-stated, pulled to VDD;
  - MCLR = VDD; WDT enabled/disabled as specified.
- **Note 4:** For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula \( I_r = \frac{Vdd}{2 \times REXT} \) (mA) with REXT in kΩ.
- **Note 5:** Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
### 27.2 DC Characteristics: Power-Down and Supply Current

PIC18F2682/2685/4682/4685 (Industrial)  
PIC18LF2682/2685/4682/4685 (Industrial) (Continued)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Standard Operating Conditions</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(unless otherwise stated)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Operating temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-40°C ≤ TA ≤ +85°C for industrial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>2.9</td>
<td>8 μA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>3.1</td>
<td>8 μA</td>
<td>+25°C</td>
<td>Fosc = 31 kHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>3.6</td>
<td>12 μA</td>
<td>+85°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>4.5</td>
<td>12 μA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>4.8</td>
<td>12 μA</td>
<td>+25°C</td>
<td>Fosc = 1 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>5.8</td>
<td>17 μA</td>
<td>+85°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>All devices</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>9.2</td>
<td>25 μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>9.8</td>
<td>25 μA</td>
<td>+25°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>11.4</td>
<td>36 μA</td>
<td>+85°C</td>
<td>Fosc = 4 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>Extended devices only</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>21</td>
<td>180 μA</td>
<td>+125°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>165</td>
<td>400 μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>175</td>
<td>400 μA</td>
<td>+25°C</td>
<td>Fosc = 4 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>190</td>
<td>400 μA</td>
<td>+85°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>250</td>
<td>600 μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>270</td>
<td>600 μA</td>
<td>+25°C</td>
<td>Fosc = 1 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>290</td>
<td>600 μA</td>
<td>+85°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td>All devices</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.5</td>
<td>1 mA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>Extended devices only</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.5</td>
<td>1 mA</td>
<td>+25°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.5</td>
<td>1 mA</td>
<td>+85°C</td>
<td>Fosc = 4 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.34</td>
<td>1.1 mA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.35</td>
<td>1.1 mA</td>
<td>+25°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.36</td>
<td>1.1 mA</td>
<td>+85°C</td>
<td>Fosc = 4 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.52</td>
<td>1.5 mA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.54</td>
<td>1.5 mA</td>
<td>+25°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>0.58</td>
<td>1.5 mA</td>
<td>+85°C</td>
<td>Fosc = 1 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>All devices</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>1</td>
<td>2.7 mA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>Extended devices only</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>1.1</td>
<td>2.7 mA</td>
<td>+25°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>1.1</td>
<td>2.7 mA</td>
<td>+85°C</td>
<td>Fosc = 4 MHz (\text{(RC}_\text{_IDLE mode, Internal oscillator source)})</td>
</tr>
<tr>
<td>PIC18LF2682/4682/4685 (Industrial, Extended)</td>
<td>Supply Current (Idd)(^{(2,3)})</td>
<td>1.1</td>
<td>3.6 mA</td>
<td>+125°C</td>
<td>VDD = 5.0V</td>
</tr>
</tbody>
</table>

**Legend:** Shading of rows is to assist in readability of the table.

**Note 1:** The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or Vss and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).

**Note 2:** The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.

The test conditions for all IDD measurements in active operation mode are:

- OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD; MCLR = VDD; WDT enabled/disabled as specified.
- Fosc = 31 kHz \(\text{(RC}_\text{_IDLE mode, Internal oscillator source)}\)

**Note 3:** For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula \(I_r = \frac{VDD}{2 \times R_{EXT}}\) (mA) with \(R_{EXT}\) in kΩ.

**Note 4:** Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
### 27.2 DC Characteristics: Power-Down and Supply Current

**PIC18F2682/2685/4682/4685 (Industrial)**  
**PIC18LF2682/2685/4682/4685 (Industrial) (Continued)**

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Conditions</th>
<th>Typ Max Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supply Current (Idd) (2,3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/2685/4682/4685 (Industrial)</td>
<td>Standard Operating Conditions (unless otherwise stated)</td>
<td>Operating temperature</td>
<td>-40°C ≤ Ta ≤ +85°C for industrial</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/2685/4682/4685 (Industrial, Extended)</td>
<td>Standard Operating Conditions (unless otherwise stated)</td>
<td>Operating temperature</td>
<td>-40°C ≤ Ta ≤ +85°C for industrial</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PIC18F2682/2685/4682/4685 (Industrial, Extended)</th>
<th>Supply Current (Idd) (2,3)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC18LF268X/468X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>600 μA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>600 μA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>600 μA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF268X/468X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>550</td>
<td>1.2 mA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
<td>Fosc = 1 MHz (PRI_RUN, EC oscillator)</td>
</tr>
<tr>
<td>480</td>
<td>1.2 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>460</td>
<td>1.2 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>1.2 mA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>3 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended devices only</td>
<td>1 mA</td>
<td>+125°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF268X/468X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.72</td>
<td>2.2 mA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>2.2 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.74</td>
<td>2.2 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF268X/468X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>3.3 mA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
<td>Fosc = 4 MHz (PRI_RUN, EC oscillator)</td>
</tr>
<tr>
<td>1.3</td>
<td>3.3 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>3.3 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>2.7 mA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>6.6 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>6.6 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended devices only</td>
<td>2.6 mA</td>
<td>+125°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended devices only</td>
<td>8.4 mA</td>
<td>+125°C</td>
<td>VDD = 4.2V</td>
<td>Fosc = 25 MHz (PRI_RUN, EC oscillator)</td>
</tr>
<tr>
<td>11</td>
<td>28 mA</td>
<td>+125°C</td>
<td>VDD = 5.0V</td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>15 mA</td>
<td>-40°C</td>
<td>VDD = 4.2V</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>38 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>38 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>21 mA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>44 mA</td>
<td>+25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>44 mA</td>
<td>+85°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- Shading of rows is to assist in readability of the table.

**Note 1:**
- The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).
- The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.
- The test conditions for all IDD measurements in active operation mode are:
  - OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD; MCLR = VDD; WDT enabled/disabled as specified.
- For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula \( I_{REXT} = \frac{VDD}{2REXT} \) (mA) with REXT in kΩ.

**Note 2:**
- Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
27.2 DC Characteristics: Power-Down and Supply Current

<table>
<thead>
<tr>
<th>PIC18F2682/2685/4682/4685 (Industrial)</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operating temperature</td>
<td>-40°C ≤ TA ≤ +85°C for industrial</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PIC18F2682/2685/4682/4685 (Industrial, Extended)</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operating temperature</td>
<td>-40°C ≤ TA ≤ +125°C for extended</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Current (Idd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>9.00</td>
<td>18.00</td>
<td>mA</td>
<td>-40°C</td>
<td>VDD = 4.2V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>8.90</td>
<td>17.00</td>
<td>mA</td>
<td>+25°C</td>
<td>VDD = 4.2V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>8.80</td>
<td>16.00</td>
<td>mA</td>
<td>+85°C</td>
<td>VDD = 4.2V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>12.00</td>
<td>24.00</td>
<td>mA</td>
<td>-40°C</td>
<td>VDD = 5.0V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>12.00</td>
<td>22.00</td>
<td>mA</td>
<td>+25°C</td>
<td>VDD = 5.0V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>12.00</td>
<td>21.00</td>
<td>mA</td>
<td>+85°C</td>
<td>VDD = 5.0V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>21.00</td>
<td>39.00</td>
<td>mA</td>
<td>-40°C</td>
<td>VDD = 4.2V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>21.00</td>
<td>39.00</td>
<td>mA</td>
<td>+25°C</td>
<td>VDD = 4.2V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>21.00</td>
<td>39.00</td>
<td>mA</td>
<td>+85°C</td>
<td>VDD = 4.2V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>28.00</td>
<td>44.00</td>
<td>mA</td>
<td>-40°C</td>
<td>VDD = 5.0V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>28.00</td>
<td>44.00</td>
<td>mA</td>
<td>+25°C</td>
<td>VDD = 5.0V (PRI_RUN HSPLL)</td>
</tr>
<tr>
<td>All devices</td>
<td>28.00</td>
<td>44.00</td>
<td>mA</td>
<td>+85°C</td>
<td>VDD = 5.0V (PRI_RUN HSPLL)</td>
</tr>
</tbody>
</table>

Legend: Shading of rows is to assist in readability of the table.

Note 1: The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).

Note 2: The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.

The test conditions for all Idd measurements in active operation mode are:

- OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD;
- MCLR = VDD; WDT enabled/disabled as specified.

Note 3: For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula Ir = VDD/2REXT (mA) with REXT in kΩ.

Note 4: Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
### 27.2 DC Characteristics: Power-Down and Supply Current

**PIC18F2682/2685/4682/4685 (Industrial)**  
**PIC18LF2682/2685/4682/4685 (Industrial) (Continued)**

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Supply Current (Idd)(2,3)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>120</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>130</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>300</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>240</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>320</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>260</td>
<td>760</td>
</tr>
<tr>
<td></td>
<td></td>
<td>255</td>
<td>760</td>
</tr>
<tr>
<td></td>
<td></td>
<td>270</td>
<td>760</td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>420</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>430</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>450</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>0.9</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Extended devices only</td>
<td>2.8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.3</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.6</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>All devices</td>
<td>8.1</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.1</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.3</td>
<td>22</td>
</tr>
</tbody>
</table>

**Legend:**  
Shading of rows is to assist in readability of the table.  

**Note 1:**  
The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).

**Note 2:**  
The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.

The test conditions for all Idd measurements in active operation mode are:  
- OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD;  
- MCLR = VDD;  
- WDT enabled/disabled as specified.

**Note 3:**  
For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula:  
\[ I_{REXT} = \frac{VDD}{2 \times REXT} \text{ (mA)} \]  
with REXT in kΩ.

**Note 4:**  
Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
## 27.2 DC Characteristics: Power-Down and Supply Current

### PIC18F2682/2685/4682/4685 (Industrial)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supply Current (ICC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>14</td>
<td>40</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>40</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>40</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>40</td>
<td>86</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>86</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>86</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>99</td>
<td>180</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td></td>
<td>81</td>
<td>180</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>180</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>2.5</td>
<td>20</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td></td>
<td>3.7</td>
<td>20</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>20</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>5</td>
<td>25</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td></td>
<td>5.4</td>
<td>25</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>25</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>8.5</td>
<td>30</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>30</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.5</td>
<td>30</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
</tbody>
</table>

### PIC18F2682/2685/4682/4685 (Industrial, Extended)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supply Current (ICC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>14</td>
<td>40</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>40</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>40</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>40</td>
<td>86</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>86</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>86</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>99</td>
<td>180</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td></td>
<td>81</td>
<td>180</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>180</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>2.5</td>
<td>20</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td></td>
<td>3.7</td>
<td>20</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>20</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>PIC18LF2682/468X</td>
<td>5</td>
<td>25</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 3.0V</td>
</tr>
<tr>
<td></td>
<td>5.4</td>
<td>25</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>25</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
<tr>
<td>All devices</td>
<td>8.5</td>
<td>30</td>
<td>μA</td>
<td>-40°C</td>
<td>VDD = 5.0V</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>30</td>
<td>μA</td>
<td>+25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.5</td>
<td>30</td>
<td>μA</td>
<td>+85°C</td>
<td></td>
</tr>
</tbody>
</table>

### Legend:

Shading of rows is to assist in readability of the table.

- **Note 1:** The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).
- **Note 2:** The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption. The test conditions for all ICC measurements in active operation mode are:
  - OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD;
  - MCLR = VDD; WDT enabled/disabled as specified.
- **Note 3:** Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
## 27.2 DC Characteristics: Power-Down and Supply Current

**PIC18F2682/2685/4682/4685 (Industrial)**

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>D022A</td>
<td>Brown-out Reset</td>
<td>(ΔIBOR)</td>
<td>35</td>
<td>65</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td>75</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55</td>
<td>75</td>
<td>μA</td>
</tr>
<tr>
<td>D022B</td>
<td>High/Low-Voltage Detect</td>
<td>(ΔILVD)</td>
<td>22</td>
<td>45</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>45</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29</td>
<td>55</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>55</td>
<td>μA</td>
</tr>
<tr>
<td>D025</td>
<td>Timer1 Oscillator</td>
<td>(ΔIOSCB)</td>
<td>2.1</td>
<td>4.5</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.8</td>
<td>4.5</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.2</td>
<td>4.5</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.6</td>
<td>6</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.9</td>
<td>6</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>8</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.2</td>
<td>8</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.4</td>
<td>8</td>
<td>μA</td>
</tr>
<tr>
<td>D026</td>
<td>A/D Converter</td>
<td>(ΔIAD)</td>
<td>1</td>
<td>2</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>8</td>
<td>μA</td>
</tr>
</tbody>
</table>

**Note 1:**

- Shading of rows is to assist in readability of the table.
- The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 Oscillator, BOR, etc.).
- The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.
- The test conditions for all IDD measurements in active operation mode are:
  - OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD; MCLR = VDD; WDT enabled/disabled as specified.
  - For RC oscillator configurations, current through REXT is not included. The current through the resistor can be estimated by the formula \( I_r = \frac{VDD}{2\times REXT} \) (mA) with REXT in kΩ.
- Standard low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.
27.3 DC Characteristics: PIC18F2682/2685/4682/4685 (Industrial)
PIC18LF2682/2685/4682/4685 (Industrial)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Input Low Voltage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D030</td>
<td>VIL</td>
<td>I/O ports:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with TTL buffer</td>
<td>Vss</td>
<td>0.15</td>
<td>VDD</td>
<td>V</td>
</tr>
<tr>
<td>D030A</td>
<td></td>
<td></td>
<td></td>
<td>0.8</td>
<td>V</td>
<td>VDD &lt; 4.5V</td>
</tr>
<tr>
<td>D031</td>
<td></td>
<td>with Schmitt Trigger buffer</td>
<td>Vss</td>
<td>0.2</td>
<td>VDD</td>
<td>V</td>
</tr>
<tr>
<td>D031A</td>
<td></td>
<td>RC3 and RC4</td>
<td>Vss</td>
<td>0.3</td>
<td>VDD</td>
<td>I^2C™ enabled</td>
</tr>
<tr>
<td>D031B</td>
<td></td>
<td></td>
<td>Vss</td>
<td>0.8</td>
<td>V</td>
<td>SMBus enabled</td>
</tr>
<tr>
<td>D032</td>
<td></td>
<td>MCLR</td>
<td>Vss</td>
<td>0.2</td>
<td>VDD</td>
<td>V</td>
</tr>
<tr>
<td>D033</td>
<td></td>
<td>OSC1</td>
<td>Vss</td>
<td>0.3</td>
<td>VDD</td>
<td>HS, HSPLL modes</td>
</tr>
<tr>
<td>D033A</td>
<td></td>
<td>OSC1</td>
<td>Vss</td>
<td>0.2</td>
<td>VDD</td>
<td>RC, EC modes (1)</td>
</tr>
<tr>
<td>D033B</td>
<td></td>
<td>OSC1</td>
<td>Vss</td>
<td>0.3</td>
<td>V</td>
<td>XT, LP modes</td>
</tr>
<tr>
<td>D034</td>
<td></td>
<td>T13CKI</td>
<td>Vss</td>
<td>0.3</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Input High Voltage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D040</td>
<td>VIH</td>
<td>I/O ports:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with TTL buffer</td>
<td>0.25</td>
<td>VDD+0.8V</td>
<td>VDD</td>
<td>V</td>
</tr>
<tr>
<td>D040A</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td>VDD</td>
<td>VDD &lt; 4.5V</td>
</tr>
<tr>
<td>D041</td>
<td></td>
<td>with Schmitt Trigger buffer</td>
<td>0.8</td>
<td>VDD</td>
<td>V</td>
<td>VDD &lt; 4.5V</td>
</tr>
<tr>
<td>D041A</td>
<td></td>
<td>RC3 and RC4</td>
<td>0.7</td>
<td>VDD</td>
<td>V</td>
<td>I^2C™ enabled</td>
</tr>
<tr>
<td>D041B</td>
<td></td>
<td></td>
<td>2.1</td>
<td>VDD</td>
<td>V</td>
<td>SMBus enabled</td>
</tr>
<tr>
<td>D042</td>
<td></td>
<td>MCLR</td>
<td>0.8</td>
<td>VDD</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>D043</td>
<td></td>
<td>OSC1</td>
<td>0.7</td>
<td>VDD</td>
<td>V</td>
<td>HS, HSPLL modes</td>
</tr>
<tr>
<td>D043A</td>
<td></td>
<td>OSC1</td>
<td>0.8</td>
<td>VDD</td>
<td>V</td>
<td>EC mode</td>
</tr>
<tr>
<td>D043B</td>
<td></td>
<td>OSC1</td>
<td>0.9</td>
<td>VDD</td>
<td>V</td>
<td>RC mode (1)</td>
</tr>
<tr>
<td>D043C</td>
<td></td>
<td>OSC1</td>
<td>1.6</td>
<td>VDD</td>
<td>V</td>
<td>XT, LP modes</td>
</tr>
<tr>
<td>D044</td>
<td></td>
<td>T13CKI</td>
<td>1.6</td>
<td>VDD</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Input Leakage Current</strong> (2,3)</td>
<td></td>
<td></td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>D060</td>
<td></td>
<td>I/O ports</td>
<td></td>
<td>±1</td>
<td></td>
<td>VSS ≤ VPIN ≤ VDD, Pin at high-impedance</td>
</tr>
<tr>
<td>D061</td>
<td></td>
<td>MCLR</td>
<td></td>
<td>±5</td>
<td>μA</td>
<td>VSS ≤ VPIN ≤ VDD</td>
</tr>
<tr>
<td>D063</td>
<td></td>
<td>OSC1</td>
<td></td>
<td>±5</td>
<td>μA</td>
<td>VSS ≤ VPIN ≤ VDD</td>
</tr>
<tr>
<td>D070</td>
<td></td>
<td>PORTB weak pull-up current</td>
<td>50</td>
<td>400</td>
<td>μA</td>
<td>VDD = 5V, VPIN = VSS</td>
</tr>
</tbody>
</table>

**Note:**
1: In RC oscillator configuration, the OSC1/CLKI pin is a Schmitt Trigger input. It is not recommended that the PIC® device be driven with an external clock while in RC mode.
2: The leakage current on the MCLR pin is strongly dependent on the applied voltage level. The specified levels represent normal operating conditions. Higher leakage current may be measured at different input voltages.
3: Negative current is defined as current sourced by the pin.
4: Parameter is characterized but not tested.
## DC Characteristics: PIC18F2682/2685/4682/4685 (Industrial)

### Capacitive Loading Specs on Output Pins

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>D100(4)</td>
<td>Cosc2</td>
<td>OSC2 pin</td>
<td>—</td>
<td>15</td>
<td>pF</td>
<td>In XT, HS and LP modes when external clock is used to drive OSC1</td>
</tr>
<tr>
<td>D101</td>
<td>ClO</td>
<td>All I/O pins and OSC2 (in RC mode)</td>
<td>—</td>
<td>50</td>
<td>pF</td>
<td>To meet the AC timing specifications</td>
</tr>
<tr>
<td>D102</td>
<td>Cb</td>
<td>SCL, SDA</td>
<td>—</td>
<td>400</td>
<td>pF</td>
<td>I2C™ specification</td>
</tr>
</tbody>
</table>

### Notes:
1: In RC oscillator configuration, the OSC1/CLKI pin is a Schmitt Trigger input. It is not recommended that the PIC® device be driven with an external clock while in RC mode.
2: The leakage current on the MCLR pin is strongly dependent on the applied voltage level. The specified levels represent normal operating conditions. Higher leakage current may be measured at different input voltages.
3: Negative current is defined as current sourced by the pin.
4: Parameter is characterized but not tested.
### TABLE 27-1: MEMORY PROGRAMMING REQUIREMENTS

<table>
<thead>
<tr>
<th>DC Characteristics</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operating temperature $-40^\circ C \leq T_A \leq +85^\circ C$ for industrial</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Min</th>
<th>Typ†</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Internal Program MemoryProgramming Specifications(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D110</td>
<td>VPP</td>
<td>Voltage on MCLR/VPP/RE3 pin</td>
<td>9.00</td>
<td>—</td>
<td>13.25</td>
<td>V</td>
<td>(Note 3)</td>
</tr>
<tr>
<td>D113</td>
<td>IDD</td>
<td>Supply Current during Programming</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data EEPROM Memory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D120</td>
<td>ED</td>
<td>Byte Endurance</td>
<td>100K</td>
<td>1M</td>
<td>—</td>
<td>E/W</td>
<td>-40°C to +85°C</td>
</tr>
<tr>
<td>D121</td>
<td>VDRW</td>
<td>VDD for Read/Write</td>
<td>VMIN</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>Using EECON to read/write</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>VMIN</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>V_MIN = Minimum operating voltage</td>
</tr>
<tr>
<td>D122</td>
<td>TDEW</td>
<td>Erase/Write Cycle Time</td>
<td>—</td>
<td>4</td>
<td>—</td>
<td>ms</td>
<td>Provided no other specifications</td>
</tr>
<tr>
<td>D123</td>
<td>TRET</td>
<td>Characteristic Retention</td>
<td>40</td>
<td>—</td>
<td>—</td>
<td>Year</td>
<td>Provided no other specifications</td>
</tr>
<tr>
<td>D124</td>
<td>TREF</td>
<td>Number of Total Erase/Write Cycles before Refresh(2)</td>
<td>1M</td>
<td>10M</td>
<td>—</td>
<td>E/W</td>
<td>-40°C to +85°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Program Flash Memory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D130</td>
<td>EP</td>
<td>Cell Endurance</td>
<td>10K</td>
<td>100K</td>
<td>—</td>
<td>E/W</td>
<td>-40°C to +85°C</td>
</tr>
<tr>
<td>D131</td>
<td>VPR</td>
<td>VDD for Read</td>
<td>VMIN</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>V_MIN = Minimum operating voltage</td>
</tr>
<tr>
<td>D132</td>
<td>VIE</td>
<td>VDD for Block Erase</td>
<td>4.5</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>Using ICSP™ port</td>
</tr>
<tr>
<td>D132A</td>
<td>ViW</td>
<td>VDD for Externally Timed Erase or Write</td>
<td>4.5</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>Using ICSP port</td>
</tr>
<tr>
<td>D132B</td>
<td>VPEW</td>
<td>VDD for Self-timed Write</td>
<td>VMIN</td>
<td>—</td>
<td>5.5</td>
<td>V</td>
<td>V_MIN = Minimum operating voltage</td>
</tr>
<tr>
<td>D133</td>
<td>TIE</td>
<td>ICSP™ Block Erase Cycle Time</td>
<td>—</td>
<td>4</td>
<td>—</td>
<td>ms</td>
<td>VDD &gt; 4.5V</td>
</tr>
<tr>
<td>D133A</td>
<td>TiW</td>
<td>ICSP Erase or Write Cycle Time (externally timed)</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td>VDD &gt; 4.5V</td>
</tr>
<tr>
<td>D133A</td>
<td>TiW</td>
<td>Self-timed Write Cycle Time</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>D134</td>
<td>TRET</td>
<td>Characteristic Retention</td>
<td>40</td>
<td>100</td>
<td>—</td>
<td>Year</td>
<td>Provided no other specifications</td>
</tr>
</tbody>
</table>

† Data in "Typ" column is at 5.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

**Note 1:** These specifications are for programming the on-chip program memory through the use of table write instructions.

**Note 2:** Refer to Section 7.8 “Using the Data EEPROM” for a more detailed discussion on data EEPROM endurance.

**Note 3:** Required only if Single-Supply Programming is disabled.
### TABLE 27-2: COMPARATOR SPECIFICATIONS

**Operating Conditions:** 3.0V < VDD < 5.5V, -40°C < TA < +85°C (unless otherwise stated).

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristics</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>D300</td>
<td>VIOFF</td>
<td>Input Offset Voltage</td>
<td></td>
<td>±5.0</td>
<td>±10</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>D301</td>
<td>VICM</td>
<td>Input Common Mode Voltage*</td>
<td>0</td>
<td>—</td>
<td>VDD − 1.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>D302</td>
<td>CMRR</td>
<td>Common Mode Rejection Ratio*</td>
<td>55</td>
<td>—</td>
<td>—</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>TRESP</td>
<td>Response Time(1)*</td>
<td></td>
<td>150</td>
<td>400</td>
<td>ns</td>
<td>PIC18FXXXX</td>
</tr>
<tr>
<td>300A</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
<td>600</td>
<td>ns</td>
<td>PIC18LFXXXXX,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>301</td>
<td>MC2OV</td>
<td>Comparator Mode Change to Output Valid*</td>
<td></td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>μs</td>
</tr>
</tbody>
</table>

* These parameters are characterized but not tested.

**Note 1:** Response time measured with one comparator input at (VDD − 1.5)/2 while the other input transitions from VSS to VDD.

### TABLE 27-3: VOLTAGE REFERENCE SPECIFICATIONS

**Operating Conditions:** 3.0V < VDD < 5.5V, -40°C < TA < +85°C (unless otherwise stated).

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristics</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>D310</td>
<td>VRES</td>
<td>Resolution</td>
<td>VDD/24</td>
<td>—</td>
<td>VDD/32</td>
<td>LSb</td>
<td></td>
</tr>
<tr>
<td>D311</td>
<td>VRAA</td>
<td>Absolute Accuracy</td>
<td></td>
<td>—</td>
<td>—</td>
<td>1/4</td>
<td>LSb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>—</td>
<td>—</td>
<td>1/2</td>
<td>LSb</td>
</tr>
<tr>
<td>D312</td>
<td>VRUR</td>
<td>Unit Resistor Value (R)*</td>
<td>—</td>
<td>2k</td>
<td>—</td>
<td>Ω</td>
<td></td>
</tr>
<tr>
<td>310</td>
<td>TSET</td>
<td>Settling Time(1)*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>μs</td>
</tr>
</tbody>
</table>

* These parameters are characterized but not tested.

**Note 1:** Settling time measured while CVRR = 1 and CVR3:CVR0 transitions from '0000' to '1111'.
**FIGURE 27-3: HIGH/LOW-VOLTAGE DETECT CHARACTERISTICS**

![Diagram of voltage detect characteristics](image)

**TABLE 27-4: HIGH/LOW-VOLTAGE DETECT CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ†</td>
</tr>
<tr>
<td>D420</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HLVDL Voltage on VDD Transition High-to-Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0000</td>
<td></td>
<td>2.12</td>
<td>2.17</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0001</td>
<td></td>
<td>2.18</td>
<td>2.23</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0010</td>
<td></td>
<td>2.31</td>
<td>2.36</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0011</td>
<td></td>
<td>2.38</td>
<td>2.44</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0100</td>
<td></td>
<td>2.54</td>
<td>2.60</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0101</td>
<td></td>
<td>2.72</td>
<td>2.79</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0110</td>
<td></td>
<td>2.82</td>
<td>2.89</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 0111</td>
<td></td>
<td>3.05</td>
<td>3.12</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1000</td>
<td></td>
<td>3.31</td>
<td>3.39</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1001</td>
<td></td>
<td>3.46</td>
<td>3.55</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1010</td>
<td></td>
<td>3.63</td>
<td>3.71</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1011</td>
<td></td>
<td>3.81</td>
<td>3.90</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1100</td>
<td></td>
<td>4.01</td>
<td>4.11</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1101</td>
<td></td>
<td>4.32</td>
<td>4.33</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1110</td>
<td></td>
<td>4.48</td>
<td>4.59</td>
</tr>
<tr>
<td>HLVDL&lt;3:0&gt; = 1111</td>
<td></td>
<td>1.14</td>
<td>1.20</td>
</tr>
</tbody>
</table>

† Production tested at TAMB = 25°C. Specifications over temperature limits ensured by characterization.
27.4 AC (Timing) Characteristics

27.4.1 TIMING PARAMETER SYMBOLOGY

The timing parameter symbols have been created using one of the following formats:

1. TppS2ppS
2. TppS
3. TCC:ST (I2C specifications only)
4. Ts (I2C specifications only)

<table>
<thead>
<tr>
<th>T</th>
<th>F Frequency</th>
<th>T</th>
<th>Time</th>
</tr>
</thead>
</table>

**Lowercase letters (pp) and their meanings:**

<table>
<thead>
<tr>
<th>pp</th>
<th>cc</th>
<th>CCP1</th>
<th>osc</th>
<th>OSC1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ck</td>
<td>CLKO</td>
<td>rd</td>
<td>RD</td>
</tr>
<tr>
<td></td>
<td>cs</td>
<td>CS</td>
<td>rw</td>
<td>RD or WR</td>
</tr>
<tr>
<td></td>
<td>di</td>
<td>SDI</td>
<td>sc</td>
<td>SCK</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>SDO</td>
<td>ss</td>
<td>SS</td>
</tr>
<tr>
<td></td>
<td>dt</td>
<td>Data in</td>
<td>t0</td>
<td>T0CKI</td>
</tr>
<tr>
<td></td>
<td>io</td>
<td>I/O port</td>
<td>t1</td>
<td>T13CKI</td>
</tr>
<tr>
<td></td>
<td>mc</td>
<td>MCLR</td>
<td>wr</td>
<td>WR</td>
</tr>
</tbody>
</table>

**Uppercase letters and their meanings:**

<table>
<thead>
<tr>
<th>S</th>
<th>F</th>
<th>Fall</th>
<th>P</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>High</td>
<td>R</td>
<td>Rise</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>Invalid (High-Impedance)</td>
<td>V</td>
<td>Valid</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>Low</td>
<td>Z</td>
<td>High-Impedance</td>
</tr>
</tbody>
</table>

**I2C only**

<table>
<thead>
<tr>
<th>AA</th>
<th>output access</th>
<th>High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUF</td>
<td>Bus free</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

**TCC:ST (I2C specifications only)**

<table>
<thead>
<tr>
<th>CC</th>
<th>HD</th>
<th>Hold</th>
<th>SU</th>
<th>Setup</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ST</td>
<td>DAT DATA input hold</td>
<td>STO</td>
<td>Stop condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STA Start condition</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
27.4.2 TIMING CONDITIONS
The temperature and voltages specified in Table 27-5 apply to all timing specifications unless otherwise noted. Figure 27-4 specifies the load conditions for the timing specifications.

Note: Because of space limitations, the generic terms "PIC18FXXXX" and "PIC18LFXXXX" are used throughout this section to refer to the PIC18F2682/2685/4682/4685 and PIC18LF2682/2685/4682/4685 families of devices specifically and only those devices.

TABLE 27-5: TEMPERATURE AND VOLTAGE SPECIFICATIONS – AC

<table>
<thead>
<tr>
<th>AC CHARACTERISTICS</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>-40°C ≤ TA ≤ +85°C  for industrial</td>
</tr>
<tr>
<td>Operating voltage VDD range</td>
<td>as described in DC spec Section 27.1 and Section 27.3. LF parts operate for industrial temperatures only.</td>
</tr>
</tbody>
</table>

FIGURE 27-4: LOAD CONDITIONS FOR DEVICE TIMING SPECIFICATIONS

<table>
<thead>
<tr>
<th>Load Condition 1</th>
<th>Load Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="load_condition1.png" alt="Diagram" /></td>
<td><img src="load_condition2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>VDD/2</td>
<td>Pin</td>
</tr>
<tr>
<td>RL</td>
<td>Vss</td>
</tr>
<tr>
<td>Pin</td>
<td>CL</td>
</tr>
<tr>
<td>CL = 50 pF for all pins except OSC2/CLKO and including D and E outputs as ports</td>
<td></td>
</tr>
</tbody>
</table>
### 27.4.3 TIMING DIAGRAMS AND SPECIFICATIONS

**FIGURE 27-5: EXTERNAL CLOCK TIMING (ALL MODES EXCEPT PLL)**

![External Clock Timing Diagram](image)

**TABLE 27-6: EXTERNAL CLOCK TIMING REQUIREMENTS**

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fosc</td>
<td>External CLKI Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>DC</td>
<td>1</td>
<td>MHz</td>
<td>XT, RC Oscillator modes</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>DC</td>
<td>25</td>
<td>MHz</td>
<td>HS Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>DC</td>
<td>31.25</td>
<td>kHz</td>
<td>LP Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>DC</td>
<td>40</td>
<td>MHz</td>
<td>EC Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>DC</td>
<td>4</td>
<td>MHz</td>
<td>RC Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>0.1</td>
<td>4</td>
<td>MHz</td>
<td>XT Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>4</td>
<td>25</td>
<td>MHz</td>
<td>HS Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>4</td>
<td>10</td>
<td>MHz</td>
<td>HSPLL Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>5</td>
<td>200</td>
<td>kHz</td>
<td>LP Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td>Tosc</td>
<td>External CLKI Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>1000</td>
<td>—</td>
<td>ns</td>
<td>XT, RC Oscillator modes</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>40</td>
<td>—</td>
<td>ns</td>
<td>HS Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>32</td>
<td>—</td>
<td>μs</td>
<td>LP Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>25</td>
<td>—</td>
<td>ns</td>
<td>EC Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>250</td>
<td>—</td>
<td>ns</td>
<td>RC Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>250</td>
<td>1</td>
<td>μs</td>
<td>XT Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>40</td>
<td>250</td>
<td>ns</td>
<td>HS Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>100</td>
<td>250</td>
<td>ns</td>
<td>HSPLL Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>5</td>
<td>200</td>
<td>μs</td>
<td>LP Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td>TCY</td>
<td>Instruction Cycle Time&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td>TCY = 4/Fosc</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>30</td>
<td>—</td>
<td>ns</td>
<td>XT Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>2.5</td>
<td>—</td>
<td>μs</td>
<td>LP Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>10</td>
<td>—</td>
<td>ns</td>
<td>HS Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>—</td>
<td>20</td>
<td>ns</td>
<td>XT Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>—</td>
<td>50</td>
<td>ns</td>
<td>LP Oscillator mode</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Oscillator Frequency&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>—</td>
<td>7.5</td>
<td>ns</td>
<td>HS Oscillator mode</td>
</tr>
</tbody>
</table>

**Note 1:** Instruction cycle period (TCy) equals four times the input oscillator time base period for all configurations except PLL. All specified values are based on characterization data for that particular oscillator type under standard operating conditions with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at “min.” values with an external clock applied to the OSC1/CLKI pin. When an external clock input is used, the “max.” cycle time limit is “DC” (no clock) for all devices.
### TABLE 27-7: PLL CLOCK TIMING SPECIFICATIONS (VDD = 4.2V TO 5.5V)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Min</th>
<th>Typ†</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>F10</td>
<td>FOSC</td>
<td>Oscillator Frequency Range</td>
<td>4</td>
<td></td>
<td>10</td>
<td>MHz</td>
<td>HS mode only</td>
</tr>
<tr>
<td>F11</td>
<td>FSYS</td>
<td>On-Chip VCO System Frequency</td>
<td>16</td>
<td></td>
<td>40</td>
<td>MHz</td>
<td>HS mode only</td>
</tr>
<tr>
<td>F12</td>
<td>trc</td>
<td>PLL Start-up Time (Lock Time)</td>
<td></td>
<td>—</td>
<td>2</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>F13</td>
<td>ΔCLK</td>
<td>CLKO Stability (Jitter)</td>
<td>-2</td>
<td></td>
<td>+2</td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>

† Data in “Typ” column is at 5V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

### TABLE 27-8: AC CHARACTERISTICS: INTERNAL RC ACCURACY

<table>
<thead>
<tr>
<th>PIC18F2682/2685/4682/4685 (Industrial)</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operating temperature -40°C ≤ Ta ≤ +85°C for industrial</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PIC18LF2682/2685/4682/4685 (Industrial)</th>
<th>Standard Operating Conditions (unless otherwise stated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operating temperature -40°C ≤ Ta ≤ +85°C for industrial</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Device</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INTOSC Accuracy @ Freq = 8 MHz, 4 MHz, 2 MHz, 1 MHz, 500 kHz, 250 kHz, 125 kHz(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>-2</td>
<td>+/-1</td>
<td>2</td>
<td>%</td>
<td>+25°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-5</td>
<td></td>
<td>5</td>
<td>%</td>
<td>-10°C to +85°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-10</td>
<td>+/-1</td>
<td>10</td>
<td>%</td>
<td>-40°C to +85°C</td>
</tr>
<tr>
<td></td>
<td>Vdd = 2.7-3.3V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTRC Accuracy @ Freq = 31 kHz(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PIC18LF268X/468X</td>
<td>26.562</td>
<td>—</td>
<td>35.938</td>
<td>kHz</td>
<td>-40°C to +85°C</td>
</tr>
</tbody>
</table>

**Legend:**
- Shading of rows is to assist in readability of the table.
- **Note 1:** Frequency calibrated at 25°C. OSCTUNE register can be used to compensate for temperature drift.
- **Note 2:** INTRC frequency after calibration.
TABLE 27-9: CLKO AND I/O TIMING REQUIREMENTS

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Tosh2ckL</td>
<td>OSC1 ↑ to CLKO ↓</td>
<td>—</td>
<td>75</td>
<td>200</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>11</td>
<td>Tosh2ckH</td>
<td>OSC1 ↑ to CLKO ↑</td>
<td>—</td>
<td>75</td>
<td>200</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>12</td>
<td>TckR</td>
<td>CLKO Rise Time</td>
<td>—</td>
<td>35</td>
<td>100</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>13</td>
<td>TckF</td>
<td>CLKO Fall Time</td>
<td>—</td>
<td>35</td>
<td>100</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>14</td>
<td>TckL2ioV</td>
<td>CLKO ↓ to Port Out Valid</td>
<td>—</td>
<td>—</td>
<td>0.5 Tcy + 20</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>15</td>
<td>TioV2ckH</td>
<td>Port In Valid before CLKO ↑</td>
<td>0.25 Tcy + 25</td>
<td>—</td>
<td>—</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>16</td>
<td>TckH2ioI</td>
<td>Port In Hold after CLKO ↑</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>17</td>
<td>Tosh2ioV</td>
<td>OSC1 ↑ (Q1 cycle) to Port Out Valid</td>
<td>—</td>
<td>50</td>
<td>150</td>
<td>ns</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>18</td>
<td>Tosh2ioI</td>
<td>OSC1 ↑ (Q2 cycle) to Port Input Invalid (I/O in hold time)</td>
<td>PIC18FXXXX</td>
<td>100</td>
<td>—</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>18A</td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>200</td>
<td>—</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>19</td>
<td>TioV2osH</td>
<td>Port Input Valid to OSC1 ↑ (I/O in setup time)</td>
<td>0</td>
<td>—</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>TioR</td>
<td>Port Output Rise Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>10</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td>20A</td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>—</td>
<td>60</td>
<td>ns</td>
</tr>
<tr>
<td>21</td>
<td>TioF</td>
<td>Port Output Fall Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>10</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td>21A</td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>—</td>
<td>60</td>
<td>ns</td>
</tr>
<tr>
<td>22†</td>
<td>TINP</td>
<td>INTx pin High or Low Time</td>
<td>Tcy</td>
<td>—</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>23†</td>
<td>TRBP</td>
<td>RB7:RB4 Change INTx High or Low Time</td>
<td>Tcy</td>
<td>—</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>24†</td>
<td>TRCP</td>
<td>RC7:RC4 Change INTx High or Low Time</td>
<td>20</td>
<td>—</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

† These parameters are asynchronous events not related to any internal clock edges.

Note 1: Measurements are taken in RC mode, where CLKO output is 4 x Tosc.

Note: Refer to Figure 27-4 for load conditions.
FIGURE 27-7:  
RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER TIMING

VDD
MCLR
Internal POR
PWRT Time-out
OSC Time-out
Internal Reset
Watchdog Timer Reset
I/O pins

Note: Refer to Figure 27-4 for load conditions.

FIGURE 27-8:  
BROWN-OUT RESET TIMING

VDD
BVDD
VIRVST
Enable Internal Reference Voltage
Internal Reference Voltage Stable

TABLE 27-10:  
RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER, POWER-UP TIMER AND BROWN-OUT RESET REQUIREMENTS

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>TMCL</td>
<td>MCLR Pulse Width (low)</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>TWDT</td>
<td>Watchdog Timer Time-out Period (no postscaler)</td>
<td>3.4</td>
<td>4.00</td>
<td>4.6</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>TOST</td>
<td>Oscillation Start-up Timer Period</td>
<td>1024 Tosc</td>
<td>—</td>
<td>1024 Tosc</td>
<td>—</td>
<td>Tosc = OSC1 period</td>
</tr>
<tr>
<td>33</td>
<td>TPWRT</td>
<td>Power-up Timer Period</td>
<td>55.6</td>
<td>65.5</td>
<td>75</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>TIOZ</td>
<td>I/O High-Impedance from MCLR Low or Watchdog Timer Reset</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>μs</td>
<td>VDD ≤ BVDD (see D005)</td>
</tr>
<tr>
<td>35</td>
<td>TBOR</td>
<td>Brown-out Reset Pulse Width</td>
<td>200</td>
<td>—</td>
<td>—</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>TIRVST</td>
<td>Time for Internal Reference Voltage to become stable</td>
<td>—</td>
<td>20</td>
<td>50</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>TLVD</td>
<td>High/Low-Voltage Detect Pulse Width</td>
<td>200</td>
<td>—</td>
<td>—</td>
<td>μs</td>
<td>VDD ≤ VLVD</td>
</tr>
<tr>
<td>38</td>
<td>TCSD</td>
<td>CPU Start-up Time</td>
<td>—</td>
<td>10</td>
<td>—</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>TIOBST</td>
<td>Time for INTOSC to stabilize</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>μs</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 27-9: TIMER0 AND TIMER1 EXTERNAL CLOCK TIMINGS

![Diagram of Timer0 and Timer1 External Clock Timings]

Note: Refer to Figure 27-4 for load conditions.

TABLE 27-11: TIMER0 AND TIMER1 EXTERNAL CLOCK REQUIREMENTS

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>T0H</td>
<td>T0CKI High Pulse Width</td>
<td>No prescaler</td>
<td>0.5 Tcy + 20</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With prescaler</td>
<td>10</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>41</td>
<td>T0L</td>
<td>T0CKI Low Pulse Width</td>
<td>No prescaler</td>
<td>0.5 Tcy + 20</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With prescaler</td>
<td>10</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>42</td>
<td>T0P</td>
<td>T0CKI Period</td>
<td>No prescaler</td>
<td>Tcy + 10</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With prescaler</td>
<td>Greater of: 20 ns or (Tcy + 40)/N</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N = prescale value (1, 2, 4, ..., 256)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>T1H</td>
<td>T13CKI High Time</td>
<td>Synchronous, no prescaler</td>
<td>0.5 Tcy + 20</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Synchronous, with prescaler</td>
<td>PIC18FXXXX</td>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>25</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asynchronous</td>
<td>PIC18FXXXXX</td>
<td>30</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXXX</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>46</td>
<td>T1L</td>
<td>T13CKI Low Time</td>
<td>Synchronous, no prescaler</td>
<td>0.5 Tcy + 5</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Synchronous, with prescaler</td>
<td>PIC18FXXXXX</td>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXXX</td>
<td>25</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asynchronous</td>
<td>PIC18FXXXXX</td>
<td>30</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXXX</td>
<td>50</td>
<td>—</td>
</tr>
<tr>
<td>47</td>
<td>T1P</td>
<td>T13CKI Input Period</td>
<td>Synchronous</td>
<td>Greater of: 20 ns or (Tcy + 40)/N</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asynchronous</td>
<td>60</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N = prescale value (1, 2, 4, 8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>TCE2TMR</td>
<td>Delay from External T13CKI Clock Edge to Timer Increment</td>
<td>2 Tosc</td>
<td>7 Tosc</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
FIGURE 27-10: CAPTURE/COMPARE/PWM TIMINGS (ALL CCP MODULES)

TABLE 27-12: CAPTURE/COMPARE/PWM REQUIREMENTS (ALL CCP MODULES)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>TcCL</td>
<td>CCPx Input Low Time</td>
<td>No prescaler</td>
<td>0.5 Tcy + 20</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With prescaler</td>
<td>PIC18FXXXX</td>
<td>10</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>51</td>
<td>TcCH</td>
<td>CCPx Input High Time</td>
<td>No prescaler</td>
<td>0.5 Tcy + 20</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>With prescaler</td>
<td>PIC18FXXXX</td>
<td>10</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>52</td>
<td>TcCP</td>
<td>CCPx Input Period</td>
<td>3 Tcy + 40</td>
<td>N</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N = prescale value (1, 4 or 16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>TcCR</td>
<td>CCPx Output Fall Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>45</td>
<td>ns</td>
</tr>
<tr>
<td>54</td>
<td>TcCF</td>
<td>CCPx Output Fall Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>45</td>
<td>ns</td>
</tr>
</tbody>
</table>

Note: Refer to Figure 27-4 for load conditions.
FIGURE 27-11: PARALLEL SLAVE PORT TIMING (PIC18F4682/4685)

TABLE 27-13: PARALLEL SLAVE PORT REQUIREMENTS (PIC18F4682/4685)

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>TDTV2WRH</td>
<td>Data In Valid before WR ↑ or CS ↑ (setup time)</td>
<td>20</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>TWRH2dtI</td>
<td>WR ↑ or CS ↑ to Data–In Invalid (hold time)</td>
<td>PIC18FXXX</td>
<td>20</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXX</td>
<td>35</td>
<td>—</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>64</td>
<td>TRL2dtV</td>
<td>RD ↓ and CS ↓ to Data–Out Valid</td>
<td>—</td>
<td>80</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>TRdH2dtI</td>
<td>RD ↑ or CS ↓ to Data–Out Invalid</td>
<td>10</td>
<td>30</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>TibFINH</td>
<td>Inhibit of the IBF Flag bit being Cleared from WR ↑ or CS ↑</td>
<td>—</td>
<td>3</td>
<td>TCY</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* Refer to Figure 27-4 for load conditions.
FIGURE 27-12: EXAMPLE SPI MASTER MODE TIMING (CKE = 0)

TABLE 27-14: EXAMPLE SPI MODE REQUIREMENTS (MASTER MODE, CKE = 0)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>TdI/V2sch, TdI/V2scL</td>
<td>Setup Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>Tsch2dIL, TscL2dIL</td>
<td>Hold Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>TdoR</td>
<td>SDO Data Output Rise Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>25 ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>45 ns</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>76</td>
<td>TdoF</td>
<td>SDO Data Output Fall Time</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>TscR</td>
<td>SCK Output Rise Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>25 ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>45 ns</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>79</td>
<td>TscF</td>
<td>SCK Output Fall Time</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Tsch2doV, TscL2doV</td>
<td>SDO Data Output Valid after SCK Edge</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>50 ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>100 ns</td>
<td>VDD = 2.0V</td>
</tr>
</tbody>
</table>

Note: Refer to Figure 27-4 for load conditions.
FIGURE 27-13: EXAMPLE SPI MASTER MODE TIMING (CKE = 1)

TABLE 27-15: EXAMPLE SPI MODE REQUIREMENTS (MASTER MODE, CKE = 1)

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>TdV2Sch, TdV2scL</td>
<td>Setup Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>TsCH2dIL, TsCL2dIL</td>
<td>Hold Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>TdOR</td>
<td>SDO Data Output Rise Time PIC18FXXXX</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>TdOF</td>
<td>SDO Data Output Fall Time</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>78</td>
<td>TscR</td>
<td>SCK Output Rise Time PIC18FXXXX</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>TscF</td>
<td>SCK Output Fall Time</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>TsCH2doV, TsCL2doV</td>
<td>SDO Data Output Valid after SCK Edge</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>50</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>81</td>
<td>TdOV2sch, TdOV2scL</td>
<td>SDO Data Output Setup to SCK Edge</td>
<td>TCY</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 27-14: EXAMPLE SPI SLAVE MODE TIMING (CKE = 0)

TABLE 27-16: EXAMPLE SPI MODE REQUIREMENTS (SLAVE MODE TIMING, CKE = 0)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>TssL2sCH, TssL2sCL</td>
<td>SS ↓ to SCK ↓ or SCK ↑ Input</td>
<td>Tcy</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>Tsch</td>
<td>SCK Input High Time</td>
<td>Continuous</td>
<td>1.25 Tcy + 30</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>71A</td>
<td></td>
<td>Single Byte</td>
<td>40</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>TscL</td>
<td>SCK Input Low Time</td>
<td>Continuous</td>
<td>1.25 Tcy + 30</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>72A</td>
<td></td>
<td>Single Byte</td>
<td>40</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>TdiV2sch, TdiV2scl</td>
<td>Setup Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>73A</td>
<td>Tb2b</td>
<td>Last Clock Edge of Byte1 to the First Clock Edge of</td>
<td>1.5 Tcy + 40</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>TschH2dIL, TschL2dIL</td>
<td>Hold Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>TdoR</td>
<td>SDO Data Output Rise Time</td>
<td>PIC18FXXXXX</td>
<td>—</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXXX</td>
<td>—</td>
<td>45</td>
<td>ns VDD = 2.0V</td>
</tr>
<tr>
<td>76</td>
<td>TdoF</td>
<td>SDO Data Output Fall Time</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>TssH2ooZ</td>
<td>SS ↑ to SDO Output High-Impedance</td>
<td>10</td>
<td>50</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>TschH2dOV, TschL2dOV</td>
<td>SDO Data Output Valid after SCK Edge</td>
<td>PIC18FXXXXX</td>
<td>—</td>
<td>50</td>
<td>ns VDD = 2.0V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXXX</td>
<td>—</td>
<td>100</td>
<td>ns VDD = 2.0V</td>
</tr>
<tr>
<td>83</td>
<td>TschH2ssH, TschL2ssH</td>
<td>SS ↑ after SCK Edge</td>
<td>1.5 Tcy + 40</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Note: Refer to Figure 27-4 for load conditions.

Note 1: Requires the use of parameter 73A.
Note 2: Only if parameter 71A and 72A are used.
FIGURE 27-15: EXAMPLE SPI SLAVE MODE TIMING (CKE = 1)

TABLE 27-17: EXAMPLE SPI SLAVE MODE REQUIREMENTS (CKE = 1)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>Tssl2scH, Tssl2scL</td>
<td>SS ↓ to SCK ↓ or SCK ↑ Input</td>
<td>TCY</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>TscH</td>
<td>SCK Input High Time</td>
<td>Continuous</td>
<td>1.25 TCY + 30</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>71A</td>
<td></td>
<td></td>
<td>Single Byte</td>
<td>40</td>
<td>—</td>
<td>ns (Note 1)</td>
</tr>
<tr>
<td>72</td>
<td>TscL</td>
<td>SCK Input Low Time</td>
<td>Continuous</td>
<td>1.25 TCY + 30</td>
<td>—</td>
<td>ns (Note 1)</td>
</tr>
<tr>
<td>72A</td>
<td></td>
<td></td>
<td>Single Byte</td>
<td>40</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>73A</td>
<td>Ts2b</td>
<td>Last Clock Edge of Byte 1 to the first Clock Edge of Byte 2</td>
<td>1.5 TCY + 40</td>
<td>—</td>
<td>ns (Note 2)</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>Tsch2diL, TscL2diL</td>
<td>Hold Time of SDI Data Input to SCK Edge</td>
<td>100</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>TdOR</td>
<td>SDO Data Output Rise Time</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>45</td>
<td>ns VDD = 2.0V</td>
</tr>
<tr>
<td>76</td>
<td>TdOF</td>
<td>SDO Data Output Fall Time</td>
<td>—</td>
<td>25</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>Tssh2ooZ</td>
<td>SS ↑ to SDO Output High-Impedance</td>
<td>10</td>
<td>50</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Tssh2ooV, TscL2ooV</td>
<td>SDO Data Output Valid after SCK Edge</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>50</td>
<td>ns VDD = 2.0V</td>
</tr>
<tr>
<td>82</td>
<td>Tssl2ooV</td>
<td>SDO Data Output Valid after SS ↓ Edge</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>50</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>100</td>
<td>ns VDD = 2.0V</td>
</tr>
<tr>
<td>83</td>
<td>Tsch2sshH, TscL2sshH</td>
<td>SS ↑ after SCK Edge</td>
<td>1.5 TCY + 40</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Requires the use of parameter 73A.
Note 2: Only if parameter 71A and 72A are used.
FIGURE 27-16: $\text{i}^{2}\text{C}$™ BUS START/STOP BITS TIMING

TABLE 27-18: $\text{i}^{2}\text{C}$™ BUS START/STOP BITS REQUIREMENTS (SLAVE MODE)

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>TSU:STA</td>
<td>Start Condition</td>
<td>4700</td>
<td>—</td>
<td>ns</td>
<td>Only relevant for Repeated Start condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Setup Time</td>
<td>600</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>THD:STA</td>
<td>Start Condition</td>
<td>4000</td>
<td>—</td>
<td>ns</td>
<td>After this period, the first clock pulse is generated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hold Time</td>
<td>600</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>TSU:STO</td>
<td>Stop Condition</td>
<td>4700</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Setup Time</td>
<td>600</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>THD:STO</td>
<td>Stop Condition</td>
<td>4000</td>
<td>—</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hold Time</td>
<td>600</td>
<td>—</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 27-17: $\text{i}^{2}\text{C}$™ BUS DATA TIMING

Note: Refer to Figure 27-4 for load conditions.
<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>THIGH</td>
<td>Clock High Time</td>
<td>100 kHz mode</td>
<td>4.0</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>0.6</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MSSP module</td>
<td>1.5 Tcy</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>101</td>
<td>TLOW</td>
<td>Clock Low Time</td>
<td>100 kHz mode</td>
<td>4.7</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>1.3</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MSSP module</td>
<td>1.5 Tcy</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>102</td>
<td>TR</td>
<td>SDA and SCL Rise Time</td>
<td>100 kHz mode</td>
<td>—</td>
<td>1000</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>20 + 0.1 Cs</td>
<td>300</td>
<td>ns</td>
</tr>
<tr>
<td>103</td>
<td>TF</td>
<td>SDA and SCL Fall Time</td>
<td>100 kHz mode</td>
<td>—</td>
<td>300</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>20 + 0.1 Cs</td>
<td>300</td>
<td>ns</td>
</tr>
<tr>
<td>90</td>
<td>TSU:STA</td>
<td>Start Condition Setup Time</td>
<td>100 kHz mode</td>
<td>4.7</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>0.6</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>91</td>
<td>THD:STA</td>
<td>Start Condition Hold Time</td>
<td>100 kHz mode</td>
<td>4.0</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>0.6</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>106</td>
<td>THD:DAT</td>
<td>Data Input Hold Time</td>
<td>100 kHz mode</td>
<td>0</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>0</td>
<td>0.9</td>
<td>µs</td>
</tr>
<tr>
<td>107</td>
<td>TSU:DAT</td>
<td>Data Input Setup Time</td>
<td>100 kHz mode</td>
<td>250</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>100</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>92</td>
<td>TSU:STO</td>
<td>Stop Condition Setup Time</td>
<td>100 kHz mode</td>
<td>4.7</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>0.6</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>109</td>
<td>TAA</td>
<td>Output Valid from Clock</td>
<td>100 kHz mode</td>
<td>—</td>
<td>3500</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>—</td>
<td>—</td>
<td>ns</td>
</tr>
<tr>
<td>110</td>
<td>TBUF</td>
<td>Bus Free Time</td>
<td>100 kHz mode</td>
<td>4.7</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>1.3</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>D102</td>
<td>Cb</td>
<td>Bus Capacitive Loading</td>
<td>—</td>
<td>400</td>
<td>pF</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** As a transmitter, the device must provide this internal minimum delay time to bridge the undefined region (min. 300 ns) of the falling edge of SCL to avoid unintended generation of Start or Stop conditions.

**Note 2:** A Fast mode **I²C™** bus device can be used in a Standard mode **I²C** bus system but the requirement, \( \text{TSU:DAT} \geq 250 \) ns, must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line, \( \text{Tr max.} + \text{TSU:DAT} = 1000 + 250 = 1250 \) ns (according to the Standard mode **I²C** bus specification), before the SCL line is released.

Note: As a transmitter, the device must provide this internal minimum delay time to bridge the undefined region (min. 300 ns) of the falling edge of SCL to avoid unintended generation of Start or Stop conditions.
**FIGURE 27-18:** MASTER SSP \( \text{I}^2\text{C} \text{™} \) BUS START/STOP BITS TIMING WAVEFORMS

![Waveform Diagram](image)

**TABLE 27-20:** MASTER SSP \( \text{I}^2\text{C} \text{™} \) BUS START/STOP BITS REQUIREMENTS

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>TSU:STA</td>
<td>Start condition Setup Time</td>
<td>100 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>— ns</td>
<td>Only relevant for Repeated Start condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 MHz mode(1)</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>THD:STA</td>
<td>Start Condition Hold Time</td>
<td>100 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>— ns</td>
<td>After this period, the first clock pulse is generated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 MHz mode(1)</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>TSU:STO</td>
<td>Stop Condition Setup Time</td>
<td>100 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>— ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 MHz mode(1)</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>THD:STO</td>
<td>Stop Condition Hold Time</td>
<td>100 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>— ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>400 kHz mode</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 MHz mode(1)</td>
<td>2((T_{OSC})(BRG + 1))</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Maximum pin capacitance = 10 pF for all \( \text{I}^2\text{C} \) pins.

**FIGURE 27-19:** MASTER SSP \( \text{I}^2\text{C} \text{™} \) BUS DATA TIMING

![Data Timing Diagram](image)

**Note:** Refer to Figure 27-4 for load conditions.
## TABLE 27-21: MASTER SSP I²C™ BUS DATA REQUIREMENTS

<table>
<thead>
<tr>
<th>Param. No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>100 kHz mode</th>
<th>400 kHz mode</th>
<th>1 MHz mode(1)</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>THIGH</td>
<td>Clock High Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>TLOW</td>
<td>Clock Low Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Tr</td>
<td>SDA and SCL Rise Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>Tf</td>
<td>SDA and SCL Fall Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>TSU:STA</td>
<td>Start Condition Setup Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td>Only relevant for Repeated Start condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>THD:STA</td>
<td>Start Condition Hold Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td>After this period, the first clock pulse is generated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>THD:DAT</td>
<td>Data Input Hold Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>TSU:DAT</td>
<td>Data Input Setup Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td>(Note 2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>TSU:STO</td>
<td>Stop Condition Setup Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>TAA</td>
<td>Output Valid from Clock</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>TBUF</td>
<td>Bus Free Time</td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2(Tosc)(BRG + 1)</td>
<td>—</td>
<td>—</td>
<td>ms</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Maximum pin capacitance = 10 pF for all I²C pins.

2: A Fast mode I²C™ bus device can be used in a Standard mode I²C bus system, but parameter 107 ≥ 250 ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line, parameter 102 + parameter 107 = 1000 + 250 = 1250 ns (for 100 kHz mode), before the SCL line is released.
FIGURE 27-20: EUSART SYNCHRONOUS TRANSMISSION (MASTER/SLAVE) TIMING

Note: Refer to Figure 27-4 for load conditions.

TABLE 27-22: EUSART SYNCHRONOUS TRANSMISSION REQUIREMENTS

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>TckH2DTV</td>
<td>SYNC XMIT (MASTER &amp; SLAVE) Clock High to Data Out Valid</td>
<td>PIC18FXXXX</td>
<td>40</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>100</td>
<td>ns</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>121</td>
<td>TCKRF</td>
<td>Clock Out Rise Time and Fall Time (Master mode)</td>
<td>PIC18FXXXX</td>
<td>20</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>50</td>
<td>ns</td>
<td>VDD = 2.0V</td>
</tr>
<tr>
<td>122</td>
<td>TDTRF</td>
<td>Data Out Rise Time and Fall Time</td>
<td>PIC18FXXXX</td>
<td>20</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>50</td>
<td>ns</td>
<td>VDD = 2.0V</td>
</tr>
</tbody>
</table>

FIGURE 27-21: EUSART SYNCHRONOUS RECEIVE (MASTER/SLAVE) TIMING

Note: Refer to Figure 27-4 for load conditions.

TABLE 27-23: EUSART SYNCHRONOUS RECEIVE REQUIREMENTS

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>TdTV2CKL</td>
<td>SYNC RCV (MASTER &amp; SLAVE) Data Hold before CK ↓ (DT hold time)</td>
<td>10</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>TckL2DTL</td>
<td>Data Hold after CK ↓ (DT hold time)</td>
<td>15</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>
## TABLE 27-24: A/D CONVERTER CHARACTERISTICS: PIC18F2682/2685/4682/4685 (INDUSTRIAL)

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Sym</th>
<th>Characteristic</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>NR</td>
<td>Resolution</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>bit</td>
<td>$\Delta V_{REF} \geq 3.0V$</td>
</tr>
<tr>
<td>A03</td>
<td>EIL</td>
<td>Integral Linearity Error</td>
<td>—</td>
<td>—</td>
<td>&lt;±1</td>
<td>LSb</td>
<td>$\Delta V_{REF} \geq 3.0V$</td>
</tr>
<tr>
<td>A04</td>
<td>EDL</td>
<td>Differential Linearity Error</td>
<td>—</td>
<td>—</td>
<td>&lt;±1</td>
<td>LSb</td>
<td>$\Delta V_{REF} \geq 3.0V$</td>
</tr>
<tr>
<td>A06</td>
<td>EOFF</td>
<td>Offset Error</td>
<td>—</td>
<td>—</td>
<td>&lt;±1</td>
<td>LSb</td>
<td>$\Delta V_{REF} \geq 3.0V$</td>
</tr>
<tr>
<td>A07</td>
<td>EGN</td>
<td>Gain Error</td>
<td>—</td>
<td>—</td>
<td>&lt;±1</td>
<td>LSb</td>
<td>$\Delta V_{REF} \geq 3.0V$</td>
</tr>
<tr>
<td>A10</td>
<td>—</td>
<td>Monotonicity</td>
<td>Guaranteed$^{(1)}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>A20</td>
<td>$\Delta V_{REF}$</td>
<td>Reference Voltage Range (VREFH – VREFL)</td>
<td>3</td>
<td>—</td>
<td>—</td>
<td>AVDD – AVSS</td>
<td>V</td>
</tr>
<tr>
<td>A21</td>
<td>VREFH</td>
<td>Reference Voltage High</td>
<td>AVSS + 3.0V</td>
<td>—</td>
<td>—</td>
<td>AVDD + 0.3V</td>
<td>V</td>
</tr>
<tr>
<td>A22</td>
<td>VREFL</td>
<td>Reference Voltage Low</td>
<td>AVSS – 0.3V</td>
<td>—</td>
<td>—</td>
<td>AVDD – 3.0V</td>
<td>V</td>
</tr>
<tr>
<td>A25</td>
<td>VAIN</td>
<td>Analog Input Voltage</td>
<td>VREFL</td>
<td>—</td>
<td>—</td>
<td>VREFH</td>
<td>V</td>
</tr>
<tr>
<td>A28</td>
<td>AVDD</td>
<td>Analog Supply Voltage</td>
<td>VDD – 0.3</td>
<td>—</td>
<td>—</td>
<td>VDD + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>A29</td>
<td>AVSS</td>
<td>Analog Supply Voltage</td>
<td>VSS – 0.3</td>
<td>—</td>
<td>—</td>
<td>VSS + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>A30</td>
<td>ZAIN</td>
<td>Recommended Impedance of Analog Voltage Source</td>
<td>—</td>
<td>—</td>
<td>2.5</td>
<td>kΩ</td>
<td></td>
</tr>
<tr>
<td>A40</td>
<td>IAD</td>
<td>A/D Conversion Current (VDD)</td>
<td>PIC18FXXXX</td>
<td>—</td>
<td>180</td>
<td>—</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXXX</td>
<td>—</td>
<td>90</td>
<td>—</td>
<td>μA</td>
</tr>
<tr>
<td>A50</td>
<td>IREF</td>
<td>VREF Input Current (Note 3)</td>
<td>—</td>
<td>—</td>
<td>±5</td>
<td>±150</td>
<td>μA</td>
</tr>
</tbody>
</table>

### Note 1: The A/D conversion result never decreases with an increase in the input voltage and has no missing codes.

### Note 2: When A/D is off, it will not consume any current other than minor leakage current. The power-down current spec includes any such leakage from the A/D module.

### Note 3: $V_{REFH}$ current is from RA3/AN3/VREF+ pin or AVDD, whichever is selected as the $V_{REFH}$ source. $V_{REFL}$ current is from RA2/AN2/VREF- pin or AVSS, whichever is selected as the $V_{REFL}$ source.
FIGURE 27-22: A/D CONVERSION TIMING

TABLE 27-25: A/D CONVERSION REQUIREMENTS

<table>
<thead>
<tr>
<th>Param No.</th>
<th>Symbol</th>
<th>Characteristic</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>TAD</td>
<td>A/D Clock Period</td>
<td>PIC18FXXX</td>
<td>0.7</td>
<td>25.0(1)</td>
<td>μs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXX</td>
<td>1.4</td>
<td>25.0(1)</td>
<td>μs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18FXXX</td>
<td>—</td>
<td>1</td>
<td>μs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PIC18LFXXX</td>
<td>—</td>
<td>3</td>
<td>μs</td>
</tr>
<tr>
<td>131</td>
<td>TCNV</td>
<td>Conversion Time (not including acquisition time) (Note 2)</td>
<td>11</td>
<td>12</td>
<td>μs</td>
<td>TAD</td>
</tr>
<tr>
<td>132</td>
<td>TACQ</td>
<td>Acquisition Time (Note 3)</td>
<td>1.4</td>
<td>—</td>
<td>μs</td>
<td>-40°C to +85°C</td>
</tr>
<tr>
<td>135</td>
<td>TSWC</td>
<td>Switching Time from Convert → Sample</td>
<td>—</td>
<td>(Note 4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>136</td>
<td>TAMP</td>
<td>Amplifier Settling Time (Note 5)</td>
<td>1</td>
<td>—</td>
<td>μs</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: The time of the A/D clock period is dependent on the device frequency and the TAD clock divider.

2: ADRES register may be read on the following TCY cycle.

3: The time for the holding capacitor to acquire the “New” input voltage when the voltage changes full scale after the conversion (AVDD to AVSS or AVSS to AVDD). The source impedance (Rs) on the input channels is 50Ω.

4: On the following cycle of the device clock.

5: See Section 19.0 “10-Bit Analog-to-Digital Converter (A/D) Module” for minimum conditions when input voltage has changed more than 1 LSb.
28.0  DC AND AC
CHARACTERISTICS GRAPHS
AND TABLES

Graphs and tables are not available at this time.
29.0 PACKAGING INFORMATION

29.1 Package Marking Information

Legend:
- **XX...X**  Customer-specific information
- **Y**  Year code (last digit of calendar year)
- **YY**  Year code (last 2 digits of calendar year)
- **WW**  Week code (week of January 1 is week ‘01’)
- **NNN**  Alphanumeric traceability code
- **e3**  Pb-free JEDEC designator for Matte Tin (Sn)
- *****  This package is Pb-free. The Pb-free JEDEC designator (*e3*) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.
29.1 Package Marking Information (Continued)

44-Lead TQFP

Example

```
XX...XX
YYWNNNN
```

PIC18F4685
-I/PT
0710017

44-Lead QFN

Example

```
XX...XX
YYWNNNN
```

PIC18F4685
-I/ML
0710017
29.2 Package Details

The following sections give the technical details of the packages.

28-Lead Skinny Plastic Dual In-Line (SP) – 300 mil Body [SPDIP]

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at [http://www.microchip.com/packaging](http://www.microchip.com/packaging)

<table>
<thead>
<tr>
<th>Units</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Limits</td>
<td>MIN</td>
</tr>
<tr>
<td>Number of Pins</td>
<td>N</td>
</tr>
<tr>
<td>Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Top to Seating Plane</td>
<td>A</td>
</tr>
<tr>
<td>Molded Package Thickness</td>
<td>A2</td>
</tr>
<tr>
<td>Base to Seating Plane</td>
<td>A1</td>
</tr>
<tr>
<td>Shoulder to Shoulder Width</td>
<td>E</td>
</tr>
<tr>
<td>Molded Package Width</td>
<td>E1</td>
</tr>
<tr>
<td>Overall Length</td>
<td>D</td>
</tr>
<tr>
<td>Tip to Seating Plane</td>
<td>L</td>
</tr>
<tr>
<td>Lead Thickness</td>
<td>c</td>
</tr>
<tr>
<td>Upper Lead Width</td>
<td>b1</td>
</tr>
<tr>
<td>Lower Lead Width</td>
<td>b</td>
</tr>
<tr>
<td>Overall Row Spacing §</td>
<td>eB</td>
</tr>
</tbody>
</table>

**Notes:**
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” per side.
4. Dimensioning and tolerancing per ASME Y14.5M.
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
28-Lead Plastic Small Outline (SO) – Wide, 7.50 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

<table>
<thead>
<tr>
<th>Units</th>
<th>Dimension Limits</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Pins</td>
<td>N</td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>Pitch</td>
<td>e</td>
<td></td>
<td></td>
<td>1.27 BSC</td>
</tr>
<tr>
<td>Overall Height</td>
<td>A</td>
<td></td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Molded Package Thickness</td>
<td>A2</td>
<td>2.05</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Standoff §</td>
<td>A1</td>
<td>0.10</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Overall Width</td>
<td>E</td>
<td></td>
<td></td>
<td>10.30 BSC</td>
</tr>
<tr>
<td>Molded Package Width</td>
<td>E1</td>
<td></td>
<td></td>
<td>7.50 BSC</td>
</tr>
<tr>
<td>Overall Length</td>
<td>D</td>
<td></td>
<td></td>
<td>17.90 BSC</td>
</tr>
<tr>
<td>Chamfer (optional)</td>
<td>h</td>
<td>0.25</td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>Foot Length</td>
<td>L</td>
<td>0.40</td>
<td>–</td>
<td>1.27</td>
</tr>
<tr>
<td>Footprint</td>
<td>L1</td>
<td></td>
<td></td>
<td>1.40 REF</td>
</tr>
<tr>
<td>Foot Angle Top</td>
<td>φ</td>
<td>0°</td>
<td>–</td>
<td>8°</td>
</tr>
<tr>
<td>Lead Thickness</td>
<td>c</td>
<td>0.18</td>
<td>–</td>
<td>0.33</td>
</tr>
<tr>
<td>Lead Width</td>
<td>b</td>
<td>0.31</td>
<td>–</td>
<td>0.51</td>
</tr>
<tr>
<td>Mold Draft Angle Top</td>
<td>α</td>
<td>5°</td>
<td>–</td>
<td>15°</td>
</tr>
<tr>
<td>Mold Draft Angle Bottom</td>
<td>β</td>
<td>5°</td>
<td>–</td>
<td>15°</td>
</tr>
</tbody>
</table>

Notes:
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

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

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-052B
40-Lead Plastic Dual In-Line (P) – 600 mil Body [PDIP]

**Notes:**
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
4. Dimensioning and tolerancing per ASME Y14.5M.
   
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

---

<table>
<thead>
<tr>
<th>Units</th>
<th>INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Limits</td>
<td>MIN</td>
</tr>
<tr>
<td>Number of Pins</td>
<td>N</td>
</tr>
<tr>
<td>Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Top to Seating Plane</td>
<td>A</td>
</tr>
<tr>
<td>Molded Package Thickness</td>
<td>A2</td>
</tr>
<tr>
<td>Base to Seating Plane</td>
<td>A1</td>
</tr>
<tr>
<td>Shoulder to Shoulder Width</td>
<td>E</td>
</tr>
<tr>
<td>Molded Package Width</td>
<td>E1</td>
</tr>
<tr>
<td>Overall Length</td>
<td>D</td>
</tr>
<tr>
<td>Tip to Seating Plane</td>
<td>L</td>
</tr>
<tr>
<td>Lead Thickness</td>
<td>c</td>
</tr>
<tr>
<td>Upper Lead Width</td>
<td>b1</td>
</tr>
<tr>
<td>Lower Lead Width</td>
<td>b</td>
</tr>
<tr>
<td>Overall Row Spacing §</td>
<td>eB</td>
</tr>
</tbody>
</table>

---

Microchip Technology Drawing C04-016B
44-Lead Plastic Thin Quad Flatpack (PT) – 10x10x1 mm Body, 2.00 mm Footprint [TQFP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

<table>
<thead>
<tr>
<th>Units</th>
<th>MILLIMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension Limits</td>
<td>MIN</td>
</tr>
<tr>
<td>Number of Leads</td>
<td>N</td>
</tr>
<tr>
<td>Lead Pitch</td>
<td>e</td>
</tr>
<tr>
<td>Overall Height</td>
<td>A</td>
</tr>
<tr>
<td>Molded Package Thickness</td>
<td>A2</td>
</tr>
<tr>
<td>Standoff</td>
<td>A1</td>
</tr>
<tr>
<td>Foot Length</td>
<td>L</td>
</tr>
<tr>
<td>Footprint</td>
<td>L1</td>
</tr>
<tr>
<td>Foot Angle</td>
<td>φ</td>
</tr>
<tr>
<td>Overall Width</td>
<td>E</td>
</tr>
<tr>
<td>Overall Length</td>
<td>D</td>
</tr>
<tr>
<td>Molded Package Width</td>
<td>E1</td>
</tr>
<tr>
<td>Molded Package Length</td>
<td>D1</td>
</tr>
<tr>
<td>Lead Thickness</td>
<td>c</td>
</tr>
<tr>
<td>Lead Width</td>
<td>b</td>
</tr>
<tr>
<td>Mold Draft Angle Top</td>
<td>α</td>
</tr>
<tr>
<td>Mold Draft Angle Bottom</td>
<td>β</td>
</tr>
</tbody>
</table>

Notes:
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Chamfers at corners are optional; size may vary.
3. Dimensions D1 and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-076B
Notes:
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated.
3. Dimensioning and tolerancing per ASME Y14.5M.

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.
APPENDIX A: REVISION HISTORY

Revision A (February 2006)
Original data sheet for PIC18F2682/2685/4682/4685 devices.

Revision B (January 2007)
Major edits to Section 27.0 “Electrical Characteristics”. Packaging diagrams have been updated and minor edits to text have been made throughout document.

Revision C (October 2009)
Updated to remove Preliminary status.

APPENDIX B: DEVICE DIFFERENCES

The differences between the devices listed in this data sheet are shown in Table B-1.

TABLE B-1: DEVICE DIFFERENCES

<table>
<thead>
<tr>
<th>Features</th>
<th>PIC18F2682</th>
<th>PIC18F2685</th>
<th>PIC18F4682</th>
<th>PIC18F4685</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program Memory (Bytes)</td>
<td>80K</td>
<td>96K</td>
<td>80K</td>
<td>96K</td>
</tr>
<tr>
<td>Program Memory (Instructions)</td>
<td>40960</td>
<td>49152</td>
<td>40960</td>
<td>49152</td>
</tr>
<tr>
<td>Interrupt Sources</td>
<td>27</td>
<td>27</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Capture/Compare/PWM Modules</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Enhanced Capture/Compare/PWM Modules</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Parallel Slave Port Communications (PSP)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10-Bit Analog-to-Digital Module</td>
<td>8 input channels</td>
<td>8 input channels</td>
<td>11 input channels</td>
<td>11 input channels</td>
</tr>
<tr>
<td>Packages</td>
<td>28-pin PDIP, 28-pin SOIC</td>
<td>28-pin PDIP, 28-pin SOIC</td>
<td>40-pin PDIP, 44-pin TQFP, 44-pin QFN</td>
<td>40-pin PDIP, 44-pin TQFP, 44-pin QFN</td>
</tr>
</tbody>
</table>
APPENDIX C: CONVERSION CONSIDERATIONS

This appendix discusses the considerations for converting from previous versions of a device to the ones listed in this data sheet. Typically, these changes are due to the differences in the process technology used. An example of this type of conversion is from a PIC16C74A to a PIC16C74B.

Not Applicable

APPENDIX D: MIGRATION FROM BASELINE TO ENHANCED DEVICES

This section discusses how to migrate from a Baseline device (i.e., PIC16C5X) to an Enhanced MCU device (i.e., PIC18FXXX).

The following are the list of modifications over the PIC16C5X microcontroller family:

Not Currently Available
APPENDIX E: MIGRATION FROM MID-RANGE TO ENHANCED DEVICES

A detailed discussion of the differences between the mid-range MCU devices (i.e., PIC16CXXX) and the enhanced devices (i.e., PIC18FXXX) is provided in AN716, "Migrating Designs from PIC16C74A/74B to PIC18C442." The changes discussed, while device specific, are generally applicable to all mid-range to enhanced device migrations.

This Application Note is available as Literature Number DS00716.

APPENDIX F: MIGRATION FROM HIGH-END TO ENHANCED DEVICES

A detailed discussion of the migration pathway and differences between the high-end MCU devices (i.e., PIC17CXXX) and the enhanced devices (i.e., PIC18FXXX) is provided in AN726, "PIC17CXXX to PIC18CXXX Migration." This Application Note is available as Literature Number DS00726.
INDEX

A

A/D ........................................................................ 249
ADCCON0 Register .................................................... 249
ADCCON1 Register .................................................... 249
ADCCON2 Register .................................................... 249
ADRESL Register .................................................... 249
ADRESH Register .................................................... 249, 252
ADRESL Register .................................................... 249
Analog Port Pins, Configuring .................................. 256
Associated Registers ................................................ 258
Automatic Acquisition Time ..................................... 255
Configuring the Module .......................................... 253
Conversion Clock (TAD) .......................................... 255
Conversion Requirements ....................................... 257
Conversion Status (GO/DONE Bit) ......................... 252
Conversions .......................................................... 257
Converter Characteristics ....................................... 453
Converter Interrupt, Configuring ......................... 253
Operation in Power-Managed Modes ................. 256
Special Event Trigger (ECCP1) ......................... 176, 258
Use of the ECCP1 Trigger ..................................... 258
Absolute Maximum Ratings ................................ 419
AC (Timing) Characteristics .................................... 435
Load Conditions for Device ..................................... 436
Timing Specifications ............................................. 436
Parameter Symbology ............................................. 436
Temperature and Voltage Specifications ............ 436
Timing Conditions .................................................. 436
ACKSTAT ............................................................. 219
ACKSTAT Status Flag ............................................. 219
ADCCON0 Register .................................................... 249
GO/DONE Bit ......................................................... 252
ADCCON1 Register .................................................... 249
ADCCON2 Register .................................................... 249
ADDFS R .............................................................. 408
ADLW ..................................................................... 371
ADDU L N K ............................................................ 408
ADDWF ............................................................... 371
ADDWFC .............................................................. 372
ADRESL Register .................................................... 249
ADRESL Register .................................................... 249, 252
Analog-to-Digital Converter. See A/D. .............. 372
ANDLW .............................................................. 372
ANDWF .............................................................. 373
Assembler .......................................................... 416

B

Baud Rate Generator ............................................... 215
BC ................................................................. 373
BCF ................................................................. 374
BF ........................................................................ 219
BF Status Flag ......................................................... 219
Bit Timing Configuration Registers
BRGCON1 ............................................................ 340
BRGCON2 ............................................................ 340
BRGCON3 ............................................................ 340
Block Diagrams
A/D .................................................................... 252
Analog Input Model ................................................. 253
Baud Rate Generator ............................................. 215
CAN Buffers and Protocol Engine ...................... 276
Capture Mode Operation ..................................... 168
Comparator Analog Input Model .......................... 263
Comparator I/O Operating Modes ....................... 260
Comparator Output ............................................... 262
Comparator Voltage Reference .......................... 266
Comparator Voltage Reference Output
  Buffer Example .................................................. 267
  Compare Mode Operation .................................. 169
  Device Clock ..................................................... 30
  Enhanced PWM ............................................... 177
  EUSART Receive ............................................. 240
  EUSART Transmit ............................................. 238
  External Power-on Reset Circuit
  (Slow VDD Power-up) ........................................ 45
  Fail-Safe Clock Monitor ...................................... 358
  Generic I/O Port Operation .............................. 131
High/Low-Voltage Detect with External Input ....... 270
Interrupt Logic ..................................................... 116
MSSP (I2C Master Mode) ....................................... 213
MSSP (I2C Mode) .................................................. 198
MSSP (SPI Mode) .................................................. 189
On-Chip Reset Circuit .......................................... 43
PIC18F2682/2685 ............................................... 12
PIC18F4682/4685 ............................................... 13
PLL (HS Mode) ..................................................... 27
PORTD and PORTE (Parallel Slave Port) .......... 146
PWM Operation (Simplified) ................................ 171
Reads from Flash Program Memory ................. 101
Single Comparator ................................................. 261
Table Read Operation .......................................... 97
Table Write Operation ......................................... 98
Table Writes to Flash Program Memory ............ 103
Timer0 in 16-Bit Mode .......................................... 150
Timer0 in 8-Bit Mode .......................................... 150
Timer1 ............................................................ 154
Timer1 (16-Bit Read/Write Mode) ..................... 154
Timer2 ............................................................ 160
Timer3 ............................................................ 162
Timer3 (16-Bit Read/Write Mode) ..................... 162
Watchdog Timer ................................................ 355
BN ..................................................................... 374
BNC ................................................................. 375
BNN ................................................................. 375
BNV ................................................................. 376
BNZ ................................................................. 376
BOR. See Brown-out Reset .................................. 379
BOV ................................................................. 379
BRA ................................................................. 377
BRG. See Baud Rate Generator ........................................
Brown-out Reset (BOR) ......................................... 46
  Detecting ......................................................... 46
  Disabling in Sleep Mode .................................. 46
  Software Enabled ............................................. 46
BSF ..................................................................... 377
BTFSC .............................................................. 378
BTFSS .............................................................. 378
BTG ................................................................. 379
BZ ....................................................................... 380
C

C Compilers
MPLAB C18 .......................................................... 416
CALL .............................................................. 380
CALLW .............................................................. 409
Capture (CCP1 Module) ................................................... 167
Associated Registers ..................................................... 170
CAN Message Time-Stampr ................................. 167
CCP1 Pin Configuration ........................................... 167
CCPR1H:CCPR1L Registers .................................... 167
Prescaler .................................................................. 167
Software Interrupt ............................................... 167
Timer1/Timer3 Mode Selection .............................. 167
Capture (ECCP1 Module) .............................................. 176
Capture/Compare/PWM (CCP1) .............................. 165
Capture Mode. See Capture.
CCP1 Mode and Timer Resources .......................... 166
CCPR1H or ECCPR1H Register .............................. 166
CCPR1L or ECCPR1L Register ............................... 166
Compare Mode. See Compare.
Interaction Between CCP1 and ECCP1 ................. 166
Module Configuration ............................................. 166
Clock Sources ......................................................... 30
Effects of Power-Managed Modes ..................... 33
Selecting the 31 kHz Source ................................ 31
Selection Using OSCCON Register ..................... 31
CLRF ...................................................................... 381
CLRWDT .............................................................. 381
Code Examples
16 x 16 Signed Multiply Routine ............................ 114
16 x 16 Unsigned Multiply Routine ................. 114
8 x 8 Signed Multiply Routine ............................... 113
8 x 8 Unsigned Multiply Routine ......................... 113
Changing Between Capture Prescalers ............... 167
Changing to Configuration Mode ....................... 280
Computed GOTO Using an Offset Value ............. 66
Data EEPROM Read .............................................. 109
Data EEPROM Refresh Routine ......................... 110
Data EEPROM Write ........................................... 109
Erasing a Flash Program Memory Row .............. 102
Fast Register Stack ............................................ 66
How to Clear RAM (Bank 1) Using
Indirect Addressing ............................................. 90
Implementing a Real-Time Clock Using
a Timer1 Interrupt Service ............................... 157
Initializing PORTA .............................................. 131
Initializing PORTB .............................................. 134
Initializing PORTC .............................................. 140
Initializing PORTD .............................................. 140
Initializing PORTE .............................................. 143
Loading the SSPBUF (SSPSR) Register ............ 192
Reading a CAN Message ...................................... 296
Reading a Flash Program Memory Word .......... 101
Saving STATUS, WREG and BSR
Registers in RAM ............................................... 130
Transmitting a CAN Message Using
Banked Method .................................................. 288
Transmitting a CAN Message Using WIN Bits ... 289
WIN and ICODE Bits Usage in Interrupt Service
Routine to Access TX/RX Buffers ..................... 280
Writing to Flash Program Memory .................... 104–105
Code Protection ................................................... 345
COMF ...................................................................... 382
Comparator .......................................................... 259
Analog Input Connection Considerations ......... 263
Associated Registers .......................................... 263
Configuration ...................................................... 260
Effects of a Reset ............................................... 262
Interrupts ......................................................... 262
Operation ......................................................... 261
Operation During Sleep .................................. 262
Outputs ............................................................ 261
Reference .......................................................... 261
External Signal .................................................... 261
Internal Signal ..................................................... 261
Response Time ...................................................... 261
Comparator Specifications ................................. 433
Comparator Voltage Reference ......................... 265
Accuracy and Error ............................................ 266
Associated Registers .......................................... 267
Configuring ....................................................... 265
Connection Considerations ......................... 266
Effects of a Reset ............................................... 266
Operation During Sleep .................................. 266
Compare (CCP1 Module) ............................................. 169
Associated Registers .......................................... 170
CCP1 Pin Configuration ....................................... 169
CCPR1 Register ................................................... 169
Software Interrupt ............................................. 169
Special Event Trigger ........................................ 169
Timer1/Timer3 Mode Selection ......................... 169
Compare (ECCP1 Module) ............................................. 176
Special Event Trigger ........................................ 163, 176, 258
Configuration Bits ............................................. 345
Configuration Mode ............................................ 327
Configuration Register
Protection .......................................................... 364
Context Saving During Interrupts ..................... 130
Conversion Considerations ................................. 466
CPFSEQ ............................................................ 382
CPSGT .............................................................. 383
CPFSLT ............................................................. 383
Crystal Oscillator/Ceramic Resonators ............... 25
Customer Change Notification Service ......... 481
Customer Notification Service ...................... 481
Customer Support ................................................ 481
D
Data Addressing Modes ......................................... 90
Comparing Addressing Options with the Extended Instruction Set Enabled .......................... 94
Direct .............................................................. 90
Indexed Literal Offset ........................................... 93
Affected Instructions ......................................... 93
BSR .................................................................. 95
Mapping the Access Bank ................................. 95
Indirect ............................................................. 90
Inherent and Literal .......................................... 90
Data EEPROM
Code Protection ................................................... 364
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data EEPROM Memory</td>
<td>107</td>
</tr>
<tr>
<td>Associated Registers</td>
<td>111</td>
</tr>
<tr>
<td>EEADR and EADDR Registers (EECON1 and EECON2 Registers</td>
<td>107</td>
</tr>
<tr>
<td>Operation During Code Protect</td>
<td>110</td>
</tr>
<tr>
<td>Protection Against Spurious Write</td>
<td>110</td>
</tr>
<tr>
<td>Reading</td>
<td>109</td>
</tr>
<tr>
<td>Use</td>
<td>110</td>
</tr>
<tr>
<td>Write Verify</td>
<td>109</td>
</tr>
<tr>
<td>Writing</td>
<td>109</td>
</tr>
<tr>
<td>Data Memory</td>
<td>69</td>
</tr>
<tr>
<td>Access Bank</td>
<td>71</td>
</tr>
<tr>
<td>Bank Select Register (BSR)</td>
<td>69</td>
</tr>
<tr>
<td>Extended Instruction Set</td>
<td>93</td>
</tr>
<tr>
<td>General Purpose Register File (GPRF)</td>
<td>71</td>
</tr>
<tr>
<td>Map for PIC18F268X/468X</td>
<td>70</td>
</tr>
<tr>
<td>Special Function Registers</td>
<td>72</td>
</tr>
<tr>
<td>DAV</td>
<td>384</td>
</tr>
<tr>
<td>DC and AC Characteristics</td>
<td>455</td>
</tr>
<tr>
<td>DC Characteristics</td>
<td>430</td>
</tr>
<tr>
<td>Power-Down and Supply Current</td>
<td>422</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>421</td>
</tr>
<tr>
<td>DCFSNZ</td>
<td>385</td>
</tr>
<tr>
<td>DECF</td>
<td>384</td>
</tr>
<tr>
<td>DECFNZ</td>
<td>385</td>
</tr>
<tr>
<td>Development Support</td>
<td>415</td>
</tr>
<tr>
<td>Device Differences</td>
<td>465</td>
</tr>
<tr>
<td>Device Overview</td>
<td>9</td>
</tr>
<tr>
<td>Features (table)</td>
<td>11</td>
</tr>
<tr>
<td>New Core Features</td>
<td>9</td>
</tr>
<tr>
<td>Device Reset Timers</td>
<td>47</td>
</tr>
<tr>
<td>Oscillator Start-up Timer (OST)</td>
<td>47</td>
</tr>
<tr>
<td>PLL Lock Time-out</td>
<td>47</td>
</tr>
<tr>
<td>Power-up Timer (PWRT)</td>
<td>47</td>
</tr>
<tr>
<td>Direct Addressing</td>
<td>91</td>
</tr>
<tr>
<td>Disable Mode</td>
<td>327</td>
</tr>
<tr>
<td>CAN Message Transmission</td>
<td>330</td>
</tr>
<tr>
<td>Aborting</td>
<td>330</td>
</tr>
<tr>
<td>Initiating</td>
<td>330</td>
</tr>
<tr>
<td>Priority</td>
<td>331</td>
</tr>
<tr>
<td>CAN Modes of Operation</td>
<td>327</td>
</tr>
<tr>
<td>CAN Registers</td>
<td>277</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>314</td>
</tr>
<tr>
<td>Control and Status</td>
<td>277</td>
</tr>
<tr>
<td>Controller Map</td>
<td>322</td>
</tr>
<tr>
<td>Dedicated Receive Buffers</td>
<td>290</td>
</tr>
<tr>
<td>Dedicated Transmit Buffers</td>
<td>284</td>
</tr>
<tr>
<td>I/O Control</td>
<td>317</td>
</tr>
<tr>
<td>Interrupt</td>
<td>318</td>
</tr>
<tr>
<td>Configuration Mode</td>
<td>327</td>
</tr>
<tr>
<td>Disable Mode</td>
<td>327</td>
</tr>
<tr>
<td>Error Detection</td>
<td>341</td>
</tr>
<tr>
<td>Acknowledge</td>
<td>341</td>
</tr>
<tr>
<td>Bit</td>
<td>341</td>
</tr>
<tr>
<td>CRC</td>
<td>341</td>
</tr>
<tr>
<td>Error States</td>
<td>341</td>
</tr>
<tr>
<td>Form</td>
<td>341</td>
</tr>
<tr>
<td>Modes and Counters</td>
<td>341</td>
</tr>
<tr>
<td>Stuff Bit</td>
<td>341</td>
</tr>
<tr>
<td>Error Modes State (diagram)</td>
<td>342</td>
</tr>
<tr>
<td>Error Recognition Mode</td>
<td>328</td>
</tr>
<tr>
<td>Filter-Mask Truth (table)</td>
<td>333</td>
</tr>
<tr>
<td>Functional Modes</td>
<td>328</td>
</tr>
<tr>
<td>Mode 0 (Legacy Mode)</td>
<td>328</td>
</tr>
<tr>
<td>Mode 1 (Enhanced Legacy Mode)</td>
<td>328</td>
</tr>
<tr>
<td>Mode 2 (Enhanced FIFO Mode)</td>
<td>329</td>
</tr>
<tr>
<td>Information Processing Time (IPT)</td>
<td>338</td>
</tr>
<tr>
<td>Lengthening a Bit Period</td>
<td>339</td>
</tr>
<tr>
<td>Listen Only Mode</td>
<td>328</td>
</tr>
<tr>
<td>Loopback Mode</td>
<td>328</td>
</tr>
<tr>
<td>Message Acceptance Filters and Masks</td>
<td>305, 333</td>
</tr>
<tr>
<td>Message Acceptance Mask and</td>
<td>334</td>
</tr>
<tr>
<td>Filter Operation</td>
<td>334</td>
</tr>
<tr>
<td>Message Reception</td>
<td>332</td>
</tr>
<tr>
<td>Enhanced FIFO Mode</td>
<td>333</td>
</tr>
<tr>
<td>Priority</td>
<td>332</td>
</tr>
<tr>
<td>Time-Stamping</td>
<td>333</td>
</tr>
<tr>
<td>Normal Mode</td>
<td>327</td>
</tr>
<tr>
<td>Oscillator Tolerance</td>
<td>340</td>
</tr>
<tr>
<td>Overview</td>
<td>275</td>
</tr>
<tr>
<td>Phase Buffer Segments</td>
<td>338</td>
</tr>
<tr>
<td>Programmable TX/RX and Auto-RTR Buffers</td>
<td>297</td>
</tr>
<tr>
<td>Programming Time Segments</td>
<td>340</td>
</tr>
<tr>
<td>Propagation Segment</td>
<td>338</td>
</tr>
<tr>
<td>Sample Point</td>
<td>338</td>
</tr>
<tr>
<td>Shortening a Bit Period</td>
<td>340</td>
</tr>
<tr>
<td>Synchronization</td>
<td>339</td>
</tr>
<tr>
<td>Hard</td>
<td>339</td>
</tr>
<tr>
<td>Resynchronization</td>
<td>339</td>
</tr>
<tr>
<td>Rules</td>
<td>339</td>
</tr>
<tr>
<td>Synchronization Segment</td>
<td>338</td>
</tr>
<tr>
<td>Time Quanta</td>
<td>338</td>
</tr>
<tr>
<td>Values for ICODE (table)</td>
<td>343</td>
</tr>
<tr>
<td>Effect on Standard PIC Instructions</td>
<td>412</td>
</tr>
<tr>
<td>Electrical Characteristics</td>
<td>419</td>
</tr>
</tbody>
</table>

© 2009 Microchip Technology Inc.
Fast Register Stack ........................................... 66
Firmware Instructions ................................................ 365
Flash Program Memory ................................................ 97
Associated Registers ............................................... 105
Control Registers ..................................................... 98
EECON1 ................................................................ 98
EECON2 ................................................................ 98
TABLET .............................................................. 98
TABLET (Table Latch) Register ............................. 100
TBLPTR ............................................................... 98
TBLPTR (Table Pointer) Register .......................... 100
Erase Sequence ..................................................... 102
Erasing ............................................................. 102
Operation During Code-Protection ................. 105
Reading ............................................................ 101
Table Pointer Boundary ......................................... 100
Table Pointer Boundaries ......................................... 100
Table Pointer Operations (table) ....................... 100
Table Reads and Table Writes ................................. 97
Write Sequence .................................................... 103
Write Verify ....................................................... 105
Writing ............................................................. 103
Protection Against Spurious Writes .................. 105
Unexpected Termination ....................................... 105
FSCM. See Fail-Safe Clock Monitor.

G
GOTO .................................................................. 386

H
Hardware Multiplier ................................................. 113
Introduction ....................................................... 113
Operation .......................................................... 113
Performance Comparison .................................... 113
High/Low-Voltage Detect ....................................... 269
Associated Registers ............................................... 273
Characteristics ...................................................... 434
Current Consumption .......................................... 271
Effects of a Reset .................................................. 273
Operation ............................................................ 270
Operation During Sleep .......................................... 273
Setup .............................................................. 271
Start-up Time ....................................................... 271
Typical Application ................................................. 272
HLVD. See High/Low-Voltage Detect. ............. 269

I
I/O Ports .......................................................... 131

I²C Mode (MSSP)
Acknowledgement Sequence Timing .................. 222
Baud Rate Generator .............................................. 215
Bus Collision ........................................................ 226
During a Repeated Start Condition .................... 226
During a Start Condition ....................................... 224
During a Stop Condition ......................................... 227
Clock Arbitration .................................................... 216
Clock Stretching ....................................................... 208
10-Bit Slave Transmit Mode ................................. 208
10-Bit Slave Receive Mode (SEN = 1) ............... 208
10-Bit Slave Transmit Mode ................................. 208
7-Bit Slave Receive Mode (SEN = 1) ............... 208
7-Bit Slave Transmit Mode ................................. 208
Clock Synchronization and the CKP Bit ........... 209
Effect of a Reset ...................................................... 223
General Call Address Support .......................... 212
I²C Clock Rate w/BRG ........................................... 215
Master Mode ................................................................. 213
Operation ................................................................. 214
Reception ................................................................. 219
Repeated Start Condition Timing ...................... 218
Start Condition ........................................................... 217
Transmission ............................................................. 219
Transmit Sequence .................................................... 214
Multi-Master Communication, Bus Collision and Arbitration 223
Multi-Master Mode ................................................... 223
Operation ................................................................. 202
Read/Write Bit Information (R/W Bit) ................. 202, 203
Registers ................................................................. 198
Serial Clock (RC3/SCK/SCL) ............................... 203
Slave Mode .............................................................. 202
Addressing .............................................................. 202
Reception .............................................................. 203
Transmission ............................................................ 203
Sleep Operation ......................................................... 223
Stop Condition Timing ............................................. 222
ID Locations ................................................................ 345, 364
INCF .......................................................................... 386
INCFSZ ..................................................................... 387
In-Circuit Debugger ................................................ 364
In-Circuit Serial Programming (ICSP) ................. 345, 364
Indexed Literal Offset Addressing Mode ............... 412
and Standard PIC18 Instructions ......................... 412
Indirect Addressing .................................................. 91
INFSNZ ................................................................. 387
Initialization Conditions for All Registers .......... 51–62
Instruction Cycle ..................................................... 67
Clocking Scheme ..................................................... 67
Flow/Pipelining ........................................................ 67
Instruction Set .......................................................... 365
ADDLW ................................................................... 371
ADDFW .................................................................... 371
ADDFWF (Indexed Literal Offset Mode) ............. 413
ADDFWCF ............................................................... 372
ANDLW ..................................................................... 372
ANDWF .................................................................... 373
BC .......................................................................... 373
BCF .......................................................................... 374
BN .......................................................................... 374
BNC ......................................................................... 375
BNN ......................................................................... 375
BNOV ........................................................................ 376
BNZ ......................................................................... 376
BOV ......................................................................... 379
BRA ......................................................................... 377
BSF .......................................................................... 377
BSF (Indexed Literal Offset Mode) ....................... 413
BTFSC .................................................................... 378
BTFFS .................................................................... 378
BTG ......................................................................... 379
BZ .......................................................................... 380
CALL ........................................................................ 380
CLKR ................................................................. 381
CLR .......................................................................... 381
CLRWDT ............................................................... 381
COMF ....................................................................... 382
CPFSEQ ................................................................. 382
CPFSGT ................................................................. 383
CFSLT ..................................................................... 383
DAW ........................................................................ 384
DCFSNZ ................................................................. 385
DECF ........................................................................ 384
DECFSZ ................................................................... 385
Extended Instructions ........................................... 407
and Using MPLAB Tools ......................................... 414
Considerations when Enabling ......................... 412
Syntax ..................................................................... 407
General Format ....................................................... 367
GOTO ....................................................................... 386
INCF ........................................................................ 386
INCFSZ ................................................................... 387
INFSNZ ................................................................. 387
IORLW ..................................................................... 388
IORWF ..................................................................... 388
LFSR ........................................................................ 389
MOVF ........................................................................ 389
MOVFF ..................................................................... 390
MOVLB ..................................................................... 390
MOVVLW ............................................................... 391
MOVWF ..................................................................... 391
MULLW ..................................................................... 392
MULWF ..................................................................... 392
NEG .......................................................................... 393
NOP .......................................................................... 393
Opcode Field Descriptions .................................. 366
POP .......................................................................... 394
PUSH ......................................................................... 394
RCALL ........................................................................ 395
RESET ....................................................................... 395
RET ............................................................................. 396
RETFIE ..................................................................... 396
RETLW ..................................................................... 396
RETURN ..................................................................... 397
RLCF ......................................................................... 397
RLNCF ....................................................................... 398
RRCF ......................................................................... 398
RRNCF ....................................................................... 399
SETF .......................................................................... 399
SLEEP ......................................................................... 400
Standard Instructions ............................................ 365
SUBFWB ..................................................................... 400
SUBLW ..................................................................... 401
SUBWF ..................................................................... 401
SUBWFB ..................................................................... 401
SWAPF ....................................................................... 402
TBLRD ....................................................................... 403
TBLWT ....................................................................... 404
TSTFSZ ..................................................................... 405
XOR ......................................................................... 405
XORLW ..................................................................... 405
XORWF ..................................................................... 406
Summary Table ....................................................... 368
INTCON Register .................................................... 369
RBIF Bit .................................................................... 134
INTCON Registers ................................................... 117
Inter-Integrated Circuit. See I2C. ..............................
Internal Oscillator Block .......................................... 28
Adjustment .............................................................. 28
Frequency Drift ....................................................... 28
INTIO Modes .......................................................... 28
INTOSC Output Frequency ..................................... 28
O SCTUNE Register ................................................... 28
Internal RC Oscillator ................................................
Use with WDT ........................................................... 355
Internet Address ....................................................... 481
Interrupt Sources .................................................. 345
A/D Conversion Complete ........................................... 253
Capture Complete (CCP1) ........................................... 167
Compare Complete (CCP1) ........................................... 169
ECAN Module .......................................................... 342
Interrupt-on-Change (RB7:RB4) ............................... 134
INTx Pin ................................................................ 130
PORTB, Interrupt-on-Change ..................................... 130
TMR0 ..................................................................... 130
TMR0 Overflow ...................................................... 151
TMR2 to PR2 Match (PWM) ........................................ 171
TMR3 Overflow ...................................................... 163
Interrupts .................................................................. 115
Interrupts, Flag Bits
Interrupt-on-Change (RB7:RB4) Flag 
(RBIF Bit) ................................................................ 134
INTOSC, INTRC. See Internal Oscillator Block.
IORTL .................................................................... 388
IOWRF .................................................................... 388
IPR Registers ............................................................ 126
I
LFSR ................................................................... 389
Listen Only Mode ...................................................... 327
Loopback Mode ......................................................... 327
Low-Voltage ICSP Programming. See 
Single-Supply ICSP Programming.

M
Master Clear Reset (MCLR) ....................................... 45
Master Synchronous Serial Port (MSSP). See MSSP.
Memory Organization ............................................. 63
Data Memory ............................................................ 69
Program Memory ...................................................... 63
Memory Programming Requirements ...................... 432
Microchip Internet Web Site .................................... 481
Migration from Baseline to Enhanced Devices .......... 466
Migration from High-End to Enhanced Devices ........ 467
Migration from Mid-Range to Enhanced Devices ........ 467
MOVF .................................................................... 389
MOVF .................................................................... 390
MOVF .................................................................... 390
MOVLW .................................................................... 391
MOVSF .................................................................... 409
MOVSS .................................................................... 410
MOVF .................................................................... 391
MPLAB ASM30 Assembler, Linker, Librarian .......... 416
MPLAB Integrated Development 
Environment Software ............................................ 415
MPLAB PM3 Device Programmer ............................ 418
MPLAB REAL ICE In-Circuit Emulator System ......... 417
MPLINK Object Linker/MPLIB Object Librarian ....... 416
MSSP
ACK Pulse ............................................................ 202, 203
Control Registers (general) ...................................... 189
I²C Mode. See I²C Mode.
Module Overview ..................................................... 189
SPI Master/Slave Connection ................................. 193
SSPBUF ................................................................... 194
SSPSR ................................................................... 194
MULLW .................................................................... 392
MULWF .................................................................... 392
N
NEGF .................................................................... 393
NOP .................................................................... 393
Normal Operation Mode ........................................... 327
O
Oscillator Configuration ........................................... 25
EC ...................................................................... 25
ECIO .................................................................... 25
HS .................................................................... 25
HSPLL .................................................................... 25
Internal Oscillator Block ........................................ 28
INTIO1 .................................................................. 25
INTIO2 .................................................................. 25
LP .................................................................... 25
RC .................................................................... 25
RCIO ................................................................... 25
XT ..................................................................... 25
Oscillator Selection ............................................... 345
Oscillator Start-up Timer (OST) ............................. 33, 47
Oscillator Switching ................................................. 30
Oscillator Transitions ............................................... 31
Oscillator, Timer1 .................................................. 163
Oscillator, Timer3 .................................................. 153, 161
P
Packaging Information .............................................. 457
Details .................................................................... 459
Marking ................................................................. 457
Parallel Slave Port (PSP) ........................................ 146
Associated Registers .............................................. 147
CS (Chip Select) ...................................................... 146
PORTD .................................................................... 146
RD (Read Input) ..................................................... 146
Select (PSPMODE Bit) ............................................. 140, 146
WR (Write Input) .................................................... 146
PIE Registers .......................................................... 123
Pin Functions
MCLR/VPP/RE3 ...................................................... 14, 18
OSC1/CLKI/RA7 ................................................. 14, 18
OSC2/CLKO/RA6 ............................................... 14, 18
RA0/AN0 ............................................................. 15
RA0/AN0/CVREF ................................................. 19
RA1/AN1 ............................................................. 15, 19
RA2/AN2/VREF* .................................................... 15, 19
RA3/AN3/VREF* .................................................... 15, 19
RA4/T0CK1 .......................................................... 15, 19
RA5/AN4/SS/HLVDIN .......................................... 15, 19
RB0/INT0/AN10 .................................................... 16
RB0/INT0/FLT0/AN10 .......................................... 20
RB1/INT1/AN8 ...................................................... 16, 20
RB2/INT2/CANTX ............................................... 16, 20
RB3/CANRX ........................................................ 16, 20
RB4/KB10/AN9 ...................................................... 16, 20
RB5/KB11/PGM ..................................................... 16, 20
RB6/KB12/PGC ..................................................... 16, 20
RB7/KB13/PGD ..................................................... 16, 20
RC0/T1SO/T13CKI .............................................. 17, 21
RC1/T1OSI .......................................................... 17, 21
RC2/CCP1 ............................................................ 17, 21
RC3/SCK/SCL ....................................................... 17, 21
RC4/SDI/SDA ....................................................... 17, 21
RC5/SDO ................................................................ 17, 21
RC6/TX/CK .......................................................... 17, 21
RC7/RX/DT .......................................................... 17, 21
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pins and I/O descriptions</td>
<td>13, 23</td>
</tr>
<tr>
<td>PIC18F2682/2685</td>
<td>14</td>
</tr>
<tr>
<td>PIC18F4682/4685</td>
<td>18</td>
</tr>
<tr>
<td>assignment (PSA bit)</td>
<td>151</td>
</tr>
<tr>
<td>TRISB Register</td>
<td>134</td>
</tr>
<tr>
<td>PORTA</td>
<td>131</td>
</tr>
<tr>
<td>associated registers</td>
<td>133</td>
</tr>
<tr>
<td>I/O summary</td>
<td>132</td>
</tr>
<tr>
<td>LATB Register</td>
<td>135</td>
</tr>
<tr>
<td>PORTA register</td>
<td>141</td>
</tr>
<tr>
<td>TRISA register</td>
<td>140</td>
</tr>
<tr>
<td>PORTB</td>
<td>131</td>
</tr>
<tr>
<td>associated registers</td>
<td>136</td>
</tr>
<tr>
<td>I/O summary</td>
<td>135</td>
</tr>
<tr>
<td>LATB register</td>
<td>134</td>
</tr>
<tr>
<td>PORTB register</td>
<td>140</td>
</tr>
<tr>
<td>RB7/RB4 interrupt-on-change flag (RBIF Bit)</td>
<td>134</td>
</tr>
<tr>
<td>TRISB register</td>
<td>134</td>
</tr>
<tr>
<td>PORTC</td>
<td>137</td>
</tr>
<tr>
<td>associated registers</td>
<td>139</td>
</tr>
<tr>
<td>I/O summary</td>
<td>138</td>
</tr>
<tr>
<td>LATC register</td>
<td>137</td>
</tr>
<tr>
<td>PORTC register</td>
<td>137</td>
</tr>
<tr>
<td>RC3/SCK/SCL pin</td>
<td>203</td>
</tr>
<tr>
<td>TRISC register</td>
<td>137</td>
</tr>
<tr>
<td>PORTD</td>
<td>134</td>
</tr>
<tr>
<td>associated registers</td>
<td>142</td>
</tr>
<tr>
<td>I/O summary</td>
<td>141</td>
</tr>
<tr>
<td>LATD register</td>
<td>140</td>
</tr>
<tr>
<td>Parallel Slave Port (PSP) function</td>
<td>140</td>
</tr>
<tr>
<td>PORTD register</td>
<td>140</td>
</tr>
<tr>
<td>TRISD register</td>
<td>140</td>
</tr>
<tr>
<td>PORTE</td>
<td>143</td>
</tr>
<tr>
<td>associated registers</td>
<td>145</td>
</tr>
<tr>
<td>I/O summary</td>
<td>145</td>
</tr>
<tr>
<td>LATD register</td>
<td>143</td>
</tr>
<tr>
<td>PORTE register</td>
<td>143</td>
</tr>
<tr>
<td>PSP Mode Select (PSPMODE Bit)</td>
<td>140</td>
</tr>
<tr>
<td>TRISD register</td>
<td>143</td>
</tr>
<tr>
<td>postscaler, WDT</td>
<td>151</td>
</tr>
<tr>
<td>assignment (PSA Bit)</td>
<td>151</td>
</tr>
<tr>
<td>rate select (TOPS2:TOPS0 Bites)</td>
<td>151</td>
</tr>
<tr>
<td>switching between timer0 and WDT</td>
<td>151</td>
</tr>
<tr>
<td>power-managed modes</td>
<td>35</td>
</tr>
<tr>
<td>clock sources</td>
<td>35</td>
</tr>
<tr>
<td>clock transitions and status indicators</td>
<td>36</td>
</tr>
<tr>
<td>entering</td>
<td>35</td>
</tr>
<tr>
<td>exiting idle and sleep modes</td>
<td>41</td>
</tr>
<tr>
<td>by interrupt</td>
<td>41</td>
</tr>
<tr>
<td>by reset</td>
<td>41</td>
</tr>
<tr>
<td>by WDT time-out</td>
<td>41</td>
</tr>
<tr>
<td>without an oscillator start-up delay</td>
<td>42</td>
</tr>
<tr>
<td>idle modes</td>
<td>39</td>
</tr>
<tr>
<td>PRI_IDLE</td>
<td>40</td>
</tr>
<tr>
<td>RC_IDLE</td>
<td>41</td>
</tr>
<tr>
<td>SEC_IDLE</td>
<td>40</td>
</tr>
<tr>
<td>multiple sleep commands</td>
<td>36</td>
</tr>
<tr>
<td>run modes</td>
<td>36</td>
</tr>
<tr>
<td>PRI_RUN</td>
<td>36</td>
</tr>
<tr>
<td>RC_RUN</td>
<td>37</td>
</tr>
<tr>
<td>SEC_RUN</td>
<td>36</td>
</tr>
<tr>
<td>selecting</td>
<td>35</td>
</tr>
<tr>
<td>sleep mode</td>
<td>39</td>
</tr>
<tr>
<td>summary (table)</td>
<td>35</td>
</tr>
<tr>
<td>power-on reset (POR)</td>
<td>45</td>
</tr>
<tr>
<td>power-up timer (PWRT)</td>
<td>47</td>
</tr>
<tr>
<td>time-out sequence</td>
<td>47</td>
</tr>
<tr>
<td>power-up delays</td>
<td>33</td>
</tr>
<tr>
<td>power-up timer (PWRT)</td>
<td>33, 47</td>
</tr>
<tr>
<td>prescaler</td>
<td>178</td>
</tr>
<tr>
<td>timer2</td>
<td>151</td>
</tr>
<tr>
<td>prescaler, Timer0</td>
<td>151</td>
</tr>
<tr>
<td>assignment (PSA Bit)</td>
<td>151</td>
</tr>
<tr>
<td>rate select (TOPS2:TOPS0 Bites)</td>
<td>151</td>
</tr>
<tr>
<td>switching between Timer0 and WDT</td>
<td>151</td>
</tr>
<tr>
<td>prescaler, Timer2</td>
<td>172</td>
</tr>
<tr>
<td>PRI_IDLE Mode</td>
<td>40</td>
</tr>
<tr>
<td>PRI_RUN Mode</td>
<td>36</td>
</tr>
<tr>
<td>program counter</td>
<td>64</td>
</tr>
<tr>
<td>PCL, PCH and PCU registers</td>
<td>64</td>
</tr>
<tr>
<td>PCLATH and PCLATU registers</td>
<td>64</td>
</tr>
<tr>
<td>program memory</td>
<td>361</td>
</tr>
<tr>
<td>code protection</td>
<td>361</td>
</tr>
<tr>
<td>extended instruction set</td>
<td>93</td>
</tr>
<tr>
<td>instructions</td>
<td>68</td>
</tr>
<tr>
<td>two-word</td>
<td>68</td>
</tr>
<tr>
<td>interrupt vector</td>
<td>63</td>
</tr>
<tr>
<td>look-up tables</td>
<td>66</td>
</tr>
<tr>
<td>map and stack (diagram)</td>
<td>63</td>
</tr>
<tr>
<td>reset vector</td>
<td>63</td>
</tr>
<tr>
<td>program verification and code protection</td>
<td>360</td>
</tr>
<tr>
<td>associated registers</td>
<td>361</td>
</tr>
<tr>
<td>programming, device instructions</td>
<td>365</td>
</tr>
<tr>
<td>ASDP, see parallel slave port</td>
<td>365</td>
</tr>
<tr>
<td>pulse-width modulation, see PWM (CCP1/ECCP1 Modules)</td>
<td>394</td>
</tr>
<tr>
<td>push hold</td>
<td>394</td>
</tr>
<tr>
<td>push and POP instructions</td>
<td>65</td>
</tr>
<tr>
<td>push and POP instructions</td>
<td>410</td>
</tr>
<tr>
<td>PWM (CCP1 Module)</td>
<td>173</td>
</tr>
<tr>
<td>associated registers</td>
<td>173</td>
</tr>
<tr>
<td>CCP11H:CCP11L registers</td>
<td>171</td>
</tr>
<tr>
<td>duty cycle</td>
<td>171</td>
</tr>
<tr>
<td>example frequencies/resolutions</td>
<td>172</td>
</tr>
<tr>
<td>period</td>
<td>171</td>
</tr>
<tr>
<td>setup for PWM operation</td>
<td>172</td>
</tr>
<tr>
<td>TMR2 to PR2 Match</td>
<td>171</td>
</tr>
</tbody>
</table>
PWM (ECCP1 Module) .................................................... 177
Auto-Shutdown .......................................................... 172
Direction Change in Full-Bridge Mode .................. 182
Output Mode ................................................................ 182
Duty Cycle ................................................................ 178
ECCPR1H:ECCPR1L Registers ........................................ 177
Effects of a Reset ......................................................... 187
Enhanced Mode ............................................................ 177
Enhanced PWM Auto-Shutdown .............................. 184
Example Frequencies/Resolutions ......................... 178
Full-Bridge Application Example ......................... 182
Full-Bridge Mode ......................................................... 181
Half-Bridge Mode ......................................................... 180
Half-Bridge Output Mode Applications Example ......... 180
Output Configurations .................................................. 178
Output Relationships (Active-High) ....................... 179
Output Relationships (Active-Low) ......................... 179
Period ........................................................................ 177
Programmable Dead-Band Delay ......................... 184
Setup ........................................................................ 187
Start-up Considerations ............................................. 186
TMR2 to PR2 Match ..................................................... 177

Q
Q Clock ........................................................................ 172, 178

R
RAM. See Data Memory.
RC Oscillator ............................................................ 27
RCIO Oscillator Mode ................................................. 27
RC_IDLE Mode ............................................................ 41
RC_RUN Mode ............................................................. 37
RCALL ................................................................. 395
RCON Register
Bit Status During Initialization ............................... 50
Reader Response ........................................................ 482
Register File Summary ............................................... 78–88
Registers
ADCON0 (A/D Control 0) ............................................ 249
ADCON1 (A/D Control 1) ............................................ 250
ADCON2 (A/D Control 2) ............................................ 251
BAUDCON (Baud Rate Control) .............................. 232
BIE0 (Buffer Interrupt Enable 0) ............................. 321
BnCON (TX/RX Buffer n Control, Receive Mode) ....... 297
BnCON (TX/RX Buffer n Control, Transmit Mode) .... 298
BnDLC (TX/RX Buffer n Data Length Code in Receive Mode) ......................... 303
BnDLC (TX/RX Buffer n Data Length Code in Transmit Mode) ................. 304
BnDm (TX/RX Buffer n Data Field Byte m in Receive Mode) ..................... 302
BnDm (TX/RX Buffer n Data Field Byte m in Transmit Mode) ................. 302
BnEIDH (TX/RX Buffer n Extended Identifier, High Byte in Receive Mode) ..... 301
BnEIDH (TX/RX Buffer n Extended Identifier, High Byte in Transmit Mode) .... 301
BnEIDL (TX/RX Buffer n Extended Identifier, Low Byte in Receive Mode) ... 301, 302
BnSIDH (TX/RX Buffer n Standard Identifier, High Byte in Receive Mode) ..... 299
BnSIDH (TX/RX Buffer n Standard Identifier, High Byte in Transmit Mode) .... 299
RXnEIDL (Receive Buffer n Extended Identifier, Low Byte) ............. 294
RXnSIDH (Receive Buffer n Standard Identifier, High Byte) .......... 293
RXnSIDIL (Receive Buffer n Standard Identifier, Low Byte) .......... 294
RXERRCNT (Receive Error Count) ................................................. 296
RXFCONn (Receive Filter Control n) ............................................. 309
RXFCONo (Receive Filter Control o) ............................................. 308
RXnEIDH (Receive Acceptance Filter n Extended Identifier, High Byte) ......................... 306
RXnEIDIL (Receive Acceptance Filter n Extended Identifier, Low Byte) .................... 306
RXnSIDH (Receive Acceptance Filter n Standard Identifier, High Byte) ..................... 305
RXnSIDIL (Receive Acceptance Filter n Standard Identifier, Low Byte) .................... 305
RXnMIDH (Receive Acceptance Mask n Extended Identifier, High Byte) ................. 307
RXnMIDIL (Receive Acceptance Mask n Extended Identifier, Low Byte) .................... 307
RXnMSIDH (Receive Acceptance Mask n Standard Identifier, High Byte) ................. 306
RXnMSIDIL (Receive Acceptance Mask n Standard Identifier, Low Byte) ................. 306
SDFLC (Standard Data Bytes Filter Length Count) .......................... 308
SSPCON1 (MSSP Control 1, I'C Mode) ........................................... 200
SSPCON1 (MSSP Control 1, SPI Mode) .......................................... 191
SSPCON2 (MSSP Control 2, I'C Mode) ........................................... 201
SSPSSTAT (MSSP Status, I'C Mode) ............................................. 199
SSPSSTAT (MSSP Status, SPI Mode) ............................................. 190
STATUS .................................................................................. 89
STKPTR (Stack Pointer) .............................................................. 65
TICON (Timer0 Control) .............................................................. 149
TICON (Timer1 Control) .............................................................. 153
T2CON (Timer2 Control) .............................................................. 159
T3CON (Timer3 Control) .............................................................. 161
TRISE (PORTE/PSP Control) ...................................................... 144
TXBIE (Transmit Buffers Interrupt Enable) ..................................... 321
TXBnCON (Transmit Buffer n Control) ........................................... 284
TXBnDLC (Transmit Buffer n Data Length Code) ............................ 287
TXBnDM (Transmit Buffer n Data Field Byte m) ............................ 286
TXBnEIDH (Transmit Buffer n Extended Identifier, High Byte) .......... 285
TXBnEIDL (Transmit Buffer n Extended Identifier, Low Byte) ............ 286
TXBnSIDH (Transmit Buffer n Standard Identifier, High Byte) .......... 285
TXBnSIDIL (Transmit Buffer n Standard Identifier, Low Byte) .......... 285
TXERRCNT (Transmit Error Count) ............................................. 287
TXSTA (Transmit Status and Control) .......................................... 230
WDTCON (Watchdog Timer Control) ........................................... 356
RESET .................................................................................. 395
Resets .................................................................................. 43, 345
Brown-out Reset (BOR) .............................................................. 345
Oscillator Start-up Timer (OST) ................................................... 345
Power-on Reset (POR) ............................................................... 345
Power-up Timer (PWRT) ............................................................. 345
RETIFIE ............................................................................. 396
RETLW .................................................................................. 396
RETURN .............................................................................. 397

Return Address Stack ................................................................. 64
Associated Registers .................................................................. 64
Return Stack Pointer (STKPTR) .................................................... 65
Revision History ...................................................................... 465
RLCF .................................................................................. 397
RLNCF .................................................................................. 398
RRCF .................................................................................. 398
RRNCF .................................................................................. 399

S
SCK .................................................................................. 189
SDI .................................................................................. 189
SDO .................................................................................. 189
SEC_IDLE Mode ........................................................................ 40
SEC_RUN Mode ........................................................................ 36
Serial Clock, SCK .................................................................... 189
Serial Data In (SDI) ................................................................. 189
Serial Data Out (SDO) ............................................................... 189
Serial Peripheral Interface. See SPI Mode. ................................. 189
SETF .................................................................................. 399
Slave Select (SS) .................................................................... 189
SLEEP .................................................................................. 400
Sleep

OSC1 and OSC2 Pin States ......................................................... 33
Software Simulator (MPLAB SIM) ............................................. 417
Special Event Trigger. See Compare (CCP1/CCP1 Module) ......... 417
Special Event Trigger. See Compare (CCP1 Module) ................. 417
Special Function Registers

Map .................................................................................. 72–77
Associated Registers .................................................................. 189
Bus Mode Compatibility .......................................................... 197
Effects of a Reset ..................................................................... 197
Enabling SPI I/O ..................................................................... 193
Master Mode ............................................................................ 194
Master/Slave Connection ....................................................... 193
Operation .............................................................................. 192
Operation in Power-Managed Modes ....................................... 197
Serial Clock .......................................................................... 189
Serial Data In .......................................................................... 189
Serial Data Out ....................................................................... 189
Slave Mode ............................................................................. 195
Slave Select ............................................................................ 189
Slave Select Synchronization .................................................. 195
SPI Clock .............................................................................. 194
Typical Connection .................................................................. 193

SS .................................................................................. 189
SSPOV .................................................................................. 219
SSPOV Status Flag .................................................................. 219
SSPSSTAT Register

R/W Bit .................................................................................. 202, 203
Stack Full/Underflow Resets ..................................................... 66
Status Register ........................................................................ 89
SUBFSR .................................................................................. 411
SUBFWB .................................................................................. 400
SUBLW .................................................................................. 401
SUBULNK ............................................................................... 411
SUBWF .................................................................................. 401
SUBWF .................................................................................. 402
SWAPF .................................................................................. 402

© 2009 Microchip Technology Inc.
PIC18F2682/2685/4682/4685

T

T0CON Register

PSA Bit .................................................................. 151
TOCS Bit ............................................................ 150
TOPS2:TOPS0 Bits .............................................. 151
TOSE Bit ............................................................ 150

Table Reads/Table Writes ..................................... 66

TBLRD ................................................................ 403
TBLWT ................................................................ 404

Time-out in Various Situations (table) ................. 47

Timer0 .................................................................. 149

Associated Registers .............................................. 151
Clock Source Edge Select (TOSE Bit) ................. 150
Clock Source Select (TOCS Bit) ......................... 150
Operation .......................................................... 150
Overflow Interrupt .............................................. 151
Prescaler. See Prescaler, Timer0.

Reads and Writes in 16-Bit Mode ......................... 150

Timer1 .................................................................. 153

16-Bit Read/Write Mode ....................................... 155
Associated Registers .............................................. 157
Interrupt ............................................................. 156
Operation ............................................................ 154

Oscillator ............................................................. 155

Layout Considerations ........................................ 156

Resetting, Using a Special Event Trigger

Output (CCP1) ...................................................... 156

Special Event Trigger (ECCP1) ............................ 176
Use as a Real-Time Clock ..................................... 156

Timer2 .................................................................. 159

Associated Registers .............................................. 160
Interrupt ............................................................. 160
Operation ............................................................ 159
Output ................................................................. 160

PR2 Register ........................................................ 171, 177

TMR2 to PR2 Match Interrupt .............................. 171

Timer3 .................................................................. 161

16-Bit Read/Write Mode ....................................... 163

Associated Registers .............................................. 163
Operation ............................................................ 162

Oscillator ............................................................. 153, 161, 163

Overflow Interrupt .............................................. 163

Special Event Trigger (ECCP1) ............................ 163

TMR3H Register .................................................... 153, 161

TMR3L Register .................................................... 153, 161

Timing Diagrams

A/D Conversion .................................................... 454

Acknowledge Sequence ....................................... 222

Asynchronous Reception ..................................... 241

Asynchronous Transmission ................................ 239

Asynchronous Transmission (Back-to-Back) ........ 239

Automatic Baud Rate Calculation ...................... 237

Auto-Wake-up Bit (WUE) During Normal Operation 242

Auto-Wake-up Bit (WUE) During Sleep ................. 242

Baud Rate Generator with Clock Arbitration ........ 216

BRG Overflow Sequence ..................................... 237

BRG Reset Due to SDA Arbitration

During Start Condition ....................................... 225

Brown-out Reset (BOR) ....................................... 440

Bus Collision During a Repeated Start Condition

(Case 1) ............................................................. 226

Bus Collision During a Repeated Start Condition

(Case 2) ............................................................. 226

Bus Collision During a Start Condition

(SCL = 0) ......................................................... 225

Bus Collision During a Start Condition

(SDA Only) ....................................................... 224

Bus Collision During a Stop Condition

(Case 1) ............................................................ 227

Bus Collision During a Stop Condition

(Case 2) ............................................................ 227

Bus Collision for Transmit and

Acknowledgment ................................................ 223

Capture/Compare/PWM (All CCP Modules) ........ 442

CLKO and I/O ...................................................... 439

Clock Synchronization ......................................... 209

Clock/Instruction Cycle ......................................... 67

EUSART Synchronous Receive

(Master/Slave) ................................................... 452

EUSART Synchronous Transmission

(Master/Slave) ................................................... 452

Example SPI Master Mode (CKE = 0) .................... 444

Example SPI Master Mode (CKE = 1) .................... 445

Example SPI Slave Mode (CKE = 0) ...................... 446

Example SPI Slave Mode (CKE = 1) ...................... 447

External Clock (All Modes Except PLL) ............... 437

Fail-Safe Clock Monitor ...................................... 359

First Start Bit Timing ........................................... 217

Full-Bridge PWM Output ..................................... 181

Half-Bridge PWM Output .................................... 180

High/Low-Voltage Detect Characteristics ............ 434

High-Voltage Detect (VDIRMAG = 1) ................. 272

I²C Bus Data ....................................................... 448

I²C Bus Start/Stop Bits ........................................ 448

I²C Master Mode (7 or 10-Bit Transmission) ........ 220

I²C Slave Mode (7-Bit Reception) ......................... 221

I²C Slave Mode (10-Bit Reception, SEN = 0) ........ 206

I²C Slave Mode (10-Bit Reception, SEN = 1) ....... 211

I²C Slave Mode (10-Bit Transmission) ................. 207

I²C Slave Mode (7-Bit Reception, SEN = 0) ........ 204

I²C Slave Mode (7-Bit Reception, SEN = 1) ....... 210

I²C Slave Mode (7-Bit Transmission) ................. 205

I²C Slave Mode General Call Address Sequence (7 or

10-Bit Address Mode) ....................................... 212

Low-Voltage Detect (VDIRMAG = 0) ................. 271

Master SSP I²C Bus Data .................................... 450

Master SSP I²C Bus Start/Stop Bits ....................... 450

Parallel Slave Port (PIC18F4682/4685) ............... 443

Parallel Slave Port (PSP) Read ......................... 147

Parallel Slave Port (PSP) Write ......................... 147

PWM Auto-Shutdown (PRSEN = 0, Auto-Restart Disabled) ........................................ 186

PWM Auto-Shutdown (PRSEN = 1, Auto- Restart Enabled) ........................................ 186

PWM Direction Change ....................................... 183

PWM Direction Change at Near 100% Duty Cycle .. 183

PWM Output ..................................................... 171

Repeated Start Condition .................................... 218

Reset, Watchdog Timer (WDT), Oscillator

Start-up Timer (OST) and

Power-up Timer (PWRT) .................................... 440

Send Break Character Sequence ....................... 243

Slave Synchronization ......................................... 195

Slow Rise Time (MCLR Tied to Vdd, VDD Rise > TPWRT) .............................................. 49

SPI Mode (Master Mode) ..................................... 194

DS39761C-page 478 © 2009 Microchip Technology Inc.
SPI Mode (Slave Mode with CKE = 0) ........................................ 196
SPI Mode (Slave Mode with CKE = 1) ........................................ 196
Stop Condition Receive or Transmit Mode .......................... 222
Synchronous Reception (Master Mode, SREN) .............. 246
Synchronous Transmission ................................................. 244
Synchronous Transmission
(Through TXEN) ......................................................... 245
Time-out Sequence on POR w/PLL Enabled
(MCLR Tied to Vdd) ......................................................... 49
Time-out Sequence on Power-up
(MCLR Not Tied to Vdd), Case 1 ................................. 48
Time-out Sequence on Power-up
(MCLR Not Tied to Vdd), Case 2 ................................. 48
Time-out Sequence on Power-up
(MCLR Tied to Vdd, Vdd Rise Tpwrt) .......................... 48
Timer0 and Timer1 External Clock .......................... 441
Transition for Entry to Idle Mode .................................. 40
Transition for Entry to SEC_RUN Mode ...................... 37
Transition for Entry to Sleep Mode ............................... 39
Transition for Two-Speed Start-up
(INTOSC to HSPLL) ...................................................... 357
Transition for Wake From Idle to Run Mode ............... 40
Transition for Wake From Sleep (HSPLL) .................. 39
Transition From RC_RUN Mode
to PRI_RUN Mode ......................................................... 38
Transition From SEC_RUN Mode
to PRI_RUN Mode (HSPLL) ............................................ 37
Transition to RC_RUN Mode ................................................. 38
Timing Diagrams and Specifications .......................... 437
AC Characteristics
Internal RC Accuracy .................................................. 438
Capture/Compare/PWM Requirements
(All CCP Modules) .......................................................... 442
CLKO and I/O Requirements ............................................. 439
EUSART Synchronous Receive Requirements ................ 452
EUSART Synchronous Transmission
Requirements .............................................................. 452
Example SPI Mode Requirements
(Master Mode, CKE = 0) .................................................. 444
Example SPI Mode Requirements
(Master Mode, CKE = 1) .................................................. 445
Example SPI Mode Requirements
(Slave Mode, CKE = 0) .................................................. 446
Example SPI Mode Requirements
(Slave Mode, CKE = 1) .................................................. 447
External Clock Requirements ............................................. 437
i2C Bus Data Requirements (Slave Mode) ............. 448
i2C Bus Start/Stop Bits Requirements
(Slave Mode) .............................................................. 449
Master SSP I2C Bus Data Requirements .................. 451
Master SSP I2C Bus Start/Stop Bits Requirements .... 450
Parallel Slave Port Requirements
(PIC18F4682/4685) .......................................................... 433
PLL Clock ................................................................. 443
Reset, Watchdog Timer, Oscillator Start-up
Timer, Power-up Timer and Brown-out
Reset Requirements ..................................................... 440
Timer0 and Timer1 External
Clock Requirements ...................................................... 441
Top-of-Stack Access ......................................................... 64
TRISE Register ............................................................... 140
TSTFSZ ................................................................. 405
Two-Speed Start-up ......................................................... 345, 357
Two-Word Instructions
Example Cases ............................................................... 68
TXSTA Register
BRGH Bit ................................................................. 233
V
Voltage Reference Specifications ........................................... 433
W
Watchdog Timer (WDT) ......................................................... 345, 355
Associated Registers ......................................................... 356
Control Register .............................................................. 355
Programming Considerations ............................................. 355
WCOL ................................................................. 217, 218, 219, 222
WCOL Status Flag ......................................................... 217, 218, 219, 222
WWW Address ............................................................... 481
WWW, On-Line Support ..................................................... 7
X
XORLW ................................................................. 405
XORWF ................................................................. 406
THE MICROCHIP WEB SITE

Microchip provides online support via our WWW site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

• **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user’s guides and hardware support documents, latest software releases and archived software

• **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing

• **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip’s customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at www.microchip.com, click on Customer Change Notification and follow the registration instructions.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

• Distributor or Representative
• Local Sales Office
• Field Application Engineer (FAE)
• Technical Support
• Development Systems Information Line

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://support.microchip.com
READER RESPONSE

It is our intention to provide you with the best documentation possible to ensure successful use of your Microchip product. If you wish to provide your comments on organization, clarity, subject matter, and ways in which our documentation can better serve you, please FAX your comments to the Technical Publications Manager at (480) 792-4150.

Please list the following information, and use this outline to provide us with your comments about this document.

To: Technical Publications Manager
RE: Reader Response

From: Name
Company ____________________________
Address ____________________________
City / State / ZIP / Country

Telephone: (_____ ) _______ - ________ FAX: (_____ ) _______ - ________

Application (optional):

Would you like a reply? Y N

Device: PIC18F2682/2685/4682/4685 Literature Number: DS39761C

Questions:

1. What are the best features of this document?

2. How does this document meet your hardware and software development needs?

3. Do you find the organization of this document easy to follow? If not, why?

4. What additions to the document do you think would enhance the structure and subject?

5. What deletions from the document could be made without affecting the overall usefulness?

6. Is there any incorrect or misleading information (what and where)?

7. How would you improve this document?
## PIC18F2682/2685/4682/4685 PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

### Table

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>X</th>
<th>/XX</th>
<th>XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device</td>
<td>Temperature Range</td>
<td>Package</td>
<td>Pattern</td>
</tr>
</tbody>
</table>

| Device | PIC18F2682/2685(1), PIC18F4682/4685(1), PIC18F2682/2685T(2), PIC18F4682/4685T(2), VDD range 4.2V to 5.5V |
|        | PIC18LF2682/2685(1), PIC18LF4682/4685(1), PIC18LF2682/2685T(2), PIC18LF4682/4685T(2), VDD range 2.0V to 5.5V |
| Temperature Range | I = -40°C to +85°C (Industrial) |
| Package | PT = TQFP (Thin Quad Flatpack) |
|          | SO = SOIC |
|          | SP = Skinny Plastic DIP |
|          | P = PDIP |
|          | ML = QFN |
| Pattern | QTP, SQTP, Code or Special Requirements |
|          | (blank otherwise) |

### Examples:

- **a)** PIC18LF4685-I/P 301 = Industrial temp., PDIP package, Extended VDD limits, QTP pattern #301.
- **b)** PIC18LF2685-I/SO = Industrial temp., SOIC package, Extended VDD limits.
- **c)** PIC18F4685-I/P = Industrial temp., PDIP package, normal VDD limits.

### Note:

1. **F** = Standard Voltage Range
   - **LF** = Wide Voltage Range
2. **T** = In tape and reel PLCC and TQFP packages only.
<table>
<thead>
<tr>
<th>AMERICAS</th>
<th>ASIA/PACIFIC</th>
<th>ASIA/PACIFIC</th>
<th>EUROPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Office&lt;br&gt;2355 West Chandler Blvd.&lt;br&gt;Chandler, AZ 85224-6199&lt;br&gt;Tel: 480-792-7200&lt;br&gt;Fax: 480-792-7277&lt;br&gt;Technical Support: <a href="http://support.microchip.com">http://support.microchip.com</a>&lt;br&gt;Web Address: <a href="http://www.microchip.com">www.microchip.com</a></td>
<td>Asia Pacific Office&lt;br&gt;Suites 3707-14, 37th Floor&lt;br&gt;Tower 6, The Gateway Harbour City, Kowloon&lt;br&gt;Hong Kong&lt;br&gt;Tel: 852-2401-1200&lt;br&gt;Fax: 852-2401-3431</td>
<td>India - Bangalore&lt;br&gt;Tel: 91-80-3090-4444&lt;br&gt;Fax: 91-80-3090-4080</td>
<td>Austria - Wels&lt;br&gt;Tel: 43-7242-2244-39&lt;br&gt;Fax: 43-7242-2244-393</td>
</tr>
<tr>
<td>Atlanta&lt;br&gt;Duluth, GA&lt;br&gt;Tel: 678-957-9614&lt;br&gt;Fax: 678-957-1455</td>
<td>Australia - Sydney&lt;br&gt;Tel: 61-2-9868-6733&lt;br&gt;Fax: 61-2-9868-6755</td>
<td>India - New Delhi&lt;br&gt;Tel: 91-11-4160-8631&lt;br&gt;Fax: 91-11-4160-8632</td>
<td>Denmark - Copenhagen&lt;br&gt;Tel: 45-4450-2828&lt;br&gt;Fax: 45-4485-2829</td>
</tr>
<tr>
<td>Boston&lt;br&gt;Westborough, MA&lt;br&gt;Tel: 774-760-0087&lt;br&gt;Fax: 774-760-0088</td>
<td>China - Beijing&lt;br&gt;Tel: 86-10-8528-2100&lt;br&gt;Fax: 86-10-8528-2104</td>
<td>India - Pune&lt;br&gt;Tel: 91-20-2566-1512&lt;br&gt;Fax: 91-20-2566-1513</td>
<td>France - Paris&lt;br&gt;Tel: 33-1-69-53-63-20&lt;br&gt;Fax: 33-1-69-30-90-79</td>
</tr>
<tr>
<td>Chicago&lt;br&gt;Itasca, IL&lt;br&gt;Tel: 630-285-0071&lt;br&gt;Fax: 630-285-0075</td>
<td>China - Chengdu&lt;br&gt;Tel: 86-28-8665-5511&lt;br&gt;Fax: 86-28-8665-7889</td>
<td>Japan - Yokohama&lt;br&gt;Tel: 81-45-471-6166&lt;br&gt;Fax: 81-45-471-6122</td>
<td>Germany - Munich&lt;br&gt;Tel: 49-89-627-144-0&lt;br&gt;Fax: 49-89-627-144-44</td>
</tr>
<tr>
<td>Cleveland&lt;br&gt;Independence, OH&lt;br&gt;Tel: 216-447-0464&lt;br&gt;Fax: 216-447-0643</td>
<td>China - Hong Kong SAR&lt;br&gt;Tel: 852-2401-1200&lt;br&gt;Fax: 852-2401-3431</td>
<td>Korea - Daegu&lt;br&gt;Tel: 82-53-744-4301&lt;br&gt;Fax: 82-53-744-4302</td>
<td>Italy - Milan&lt;br&gt;Tel: 39-0331-742611&lt;br&gt;Fax: 39-0331-466781</td>
</tr>
<tr>
<td>Dallas&lt;br&gt;Addison, TX&lt;br&gt;Tel: 972-818-7423&lt;br&gt;Fax: 972-818-2924</td>
<td>China - Nanjing&lt;br&gt;Tel: 86-25-8473-2460&lt;br&gt;Fax: 86-25-8473-2470</td>
<td>Korea - Seoul&lt;br&gt;Tel: 82-2-554-7200&lt;br&gt;Fax: 82-2-558-5932 or 82-2-558-5934</td>
<td>Netherlands - Drunen&lt;br&gt;Tel: 31-416-690399&lt;br&gt;Fax: 31-416-690340</td>
</tr>
<tr>
<td>Detroit&lt;br&gt;Farmington Hills, MI&lt;br&gt;Tel: 248-538-2250&lt;br&gt;Fax: 248-538-2260</td>
<td>China - Qingdao&lt;br&gt;Tel: 86-532-8502-7355&lt;br&gt;Fax: 86-532-8502-7205</td>
<td>Malaysia - Kuala Lumpur&lt;br&gt;Tel: 60-3-6201-9857&lt;br&gt;Fax: 60-3-6201-9859</td>
<td>Spain - Madrid&lt;br&gt;Tel: 34-91-708-08-90&lt;br&gt;Fax: 34-91-708-08-91</td>
</tr>
<tr>
<td>Kokomo&lt;br&gt;Kokomo, IN&lt;br&gt;Tel: 765-864-8360&lt;br&gt;Fax: 765-864-8387</td>
<td>China - Shanghai&lt;br&gt;Tel: 86-21-5407-5533&lt;br&gt;Fax: 86-21-5407-5066</td>
<td>Malaysia - Penang&lt;br&gt;Tel: 60-4-227-8870&lt;br&gt;Fax: 60-4-227-4068</td>
<td>UK - Wokingham&lt;br&gt;Tel: 44-118-921-5869&lt;br&gt;Fax: 44-118-921-5820</td>
</tr>
<tr>
<td>Los Angeles&lt;br&gt;Mission Viejo, CA&lt;br&gt;Tel: 949-462-9523&lt;br&gt;Fax: 949-462-9608</td>
<td>China - Shenyang&lt;br&gt;Tel: 86-24-2334-2829&lt;br&gt;Fax: 86-24-2334-2933</td>
<td>Philippines - Manila&lt;br&gt;Tel: 63-2-634-9065&lt;br&gt;Fax: 63-2-634-9069</td>
<td></td>
</tr>
<tr>
<td>Santa Clara&lt;br&gt;Santa Clara, CA&lt;br&gt;Tel: 408-961-6444&lt;br&gt;Fax: 408-961-6445</td>
<td>China - Shenzhen&lt;br&gt;Tel: 86-755-8203-2660&lt;br&gt;Fax: 86-755-8203-1760</td>
<td>Singapore&lt;br&gt;Tel: 65-6334-8870&lt;br&gt;Fax: 65-6334-8850</td>
<td></td>
</tr>
<tr>
<td>Toronto&lt;br&gt;Mississauga, Ontario, Canada&lt;br&gt;Tel: 905-673-0699&lt;br&gt;Fax: 905-673-6509</td>
<td>China - Wuhan&lt;br&gt;Tel: 86-27-5980-5300&lt;br&gt;Fax: 86-27-5980-5118</td>
<td>Taiwan - Hsin Chu&lt;br&gt;Tel: 886-3-6578-300&lt;br&gt;Fax: 886-3-6578-370</td>
<td></td>
</tr>
<tr>
<td></td>
<td>China - Xiamen&lt;br&gt;Tel: 86-592-2388138&lt;br&gt;Fax: 86-592-2388130</td>
<td>Taiwan - Kaohsiung&lt;br&gt;Tel: 886-7-536-4818&lt;br&gt;Fax: 886-7-536-4803</td>
<td></td>
</tr>
<tr>
<td></td>
<td>China - Xian&lt;br&gt;Tel: 86-29-8833-7252&lt;br&gt;Fax: 86-29-8833-7256</td>
<td>Taiwan - Taipei&lt;br&gt;Tel: 886-2-2500-6610&lt;br&gt;Fax: 886-2-2508-0102</td>
<td></td>
</tr>
<tr>
<td></td>
<td>China - Zhuhai&lt;br&gt;Tel: 86-756-3210040&lt;br&gt;Fax: 86-756-3210049</td>
<td>Thailand - Bangkok&lt;br&gt;Tel: 66-2-694-1351&lt;br&gt;Fax: 66-2-694-1350</td>
<td></td>
</tr>
</tbody>
</table>