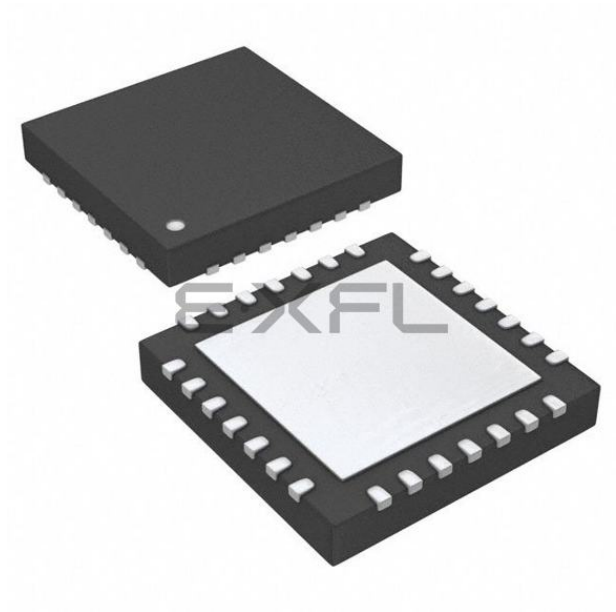

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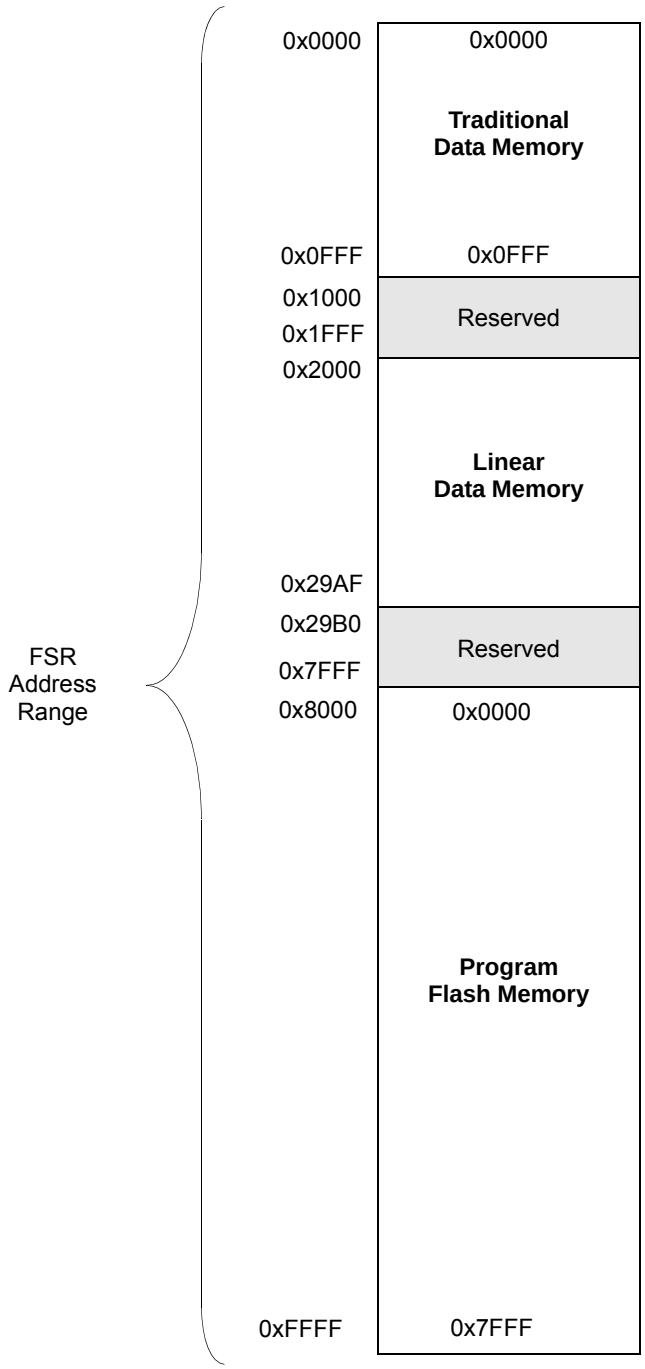
"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded"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

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	PIC
Core Size	8-Bit
Speed	20MHz
Connectivity	I²C, LINbus, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	25
Program Memory Size	7KB (4K x 14)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	256 x 8
Voltage - Supply (Vcc/Vdd)	1.8V ~ 3.6V
Data Converters	A/D 17x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	28-UFQFN Exposed Pad
Supplier Device Package	28-UQFN (4x4)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic16lf1513-i-mv

FIGURE 3-9: INDIRECT ADDRESSING



Note: Not all memory regions are completely implemented. Consult device memory tables for memory limits.

4.5 Device ID and Revision ID

The memory location 8006h is where the Device ID and Revision ID are stored. The upper nine bits hold the Device ID. The lower five bits hold the Revision ID. See **Section 11.4 "User ID, Device ID and Configuration Word Access"** for more information on accessing these memory locations.

Development tools, such as device programmers and debuggers, may be used to read the Device ID and Revision ID.

REGISTER 4-3: DEVICEID: DEVICE ID REGISTER

R	R	R	R	R	R
DEV<8:3>					
bit 13					bit 8

R	R	R	R	R	R	R	R
DEV<2:0>			REV<4:0>				
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '1'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	P = Programmable bit

bit 13-5 **DEV<8:0>:** Device ID bits

Device	DEVICEID<13:0> Values	
	DEV<8:0>	REV<4:0>
PIC16F1512	01 0111 000	x xxxx
PIC16F1513	01 0110 010	x xxxx
PIC16LF1512	01 0111 001	x xxxx
PIC16LF1513	01 0111 010	x xxxx

bit 4-0 **REV<4:0>:** Revision ID bits

These bits are used to identify the revision (see Table under DEV<8:0> above).

5.0 OSCILLATOR MODULE (WITH FAIL-SAFE CLOCK MONITOR)

5.1 Overview

The oscillator module has a wide variety of clock sources and selection features that allow it to be used in a wide range of applications while maximizing performance and minimizing power consumption. Figure 5-1 illustrates a block diagram of the oscillator module.

Clock sources can be supplied from external oscillators, quartz crystal resonators, ceramic resonators and Resistor-Capacitor (RC) circuits. In addition, the system clock source can be supplied from one of two internal oscillators, with a choice of speeds selectable via software. Additional clock features include:

- Selectable system clock source between external or internal sources via software.
- Two-Speed Start-up mode, which minimizes latency between external oscillator start-up and code execution.
- Fail-Safe Clock Monitor (FSCM) designed to detect a failure of the external clock source (LP, XT, HS, EC or RC modes) and switch automatically to the internal oscillator.
- Oscillator Start-up Timer (OST) ensures stability of crystal oscillator sources
- Fast start-up oscillator allows internal circuits to power up and stabilize before switching to the 16 MHz HFINTOSC

The oscillator module can be configured in one of eight clock modes.

1. ECL – External Clock Low-Power mode (0 MHz to 0.5 MHz)
2. ECM – External Clock Medium Power mode (0.5 MHz to 4 MHz)
3. ECH – External Clock High-Power mode (4 MHz to 20 MHz)
4. LP – 32 kHz Low-Power Crystal mode.
5. XT – Medium Gain Crystal or Ceramic Resonator Oscillator mode (up to 4 MHz)
6. HS – High Gain Crystal or Ceramic Resonator mode (4 MHz to 20 MHz)
7. RC – External Resistor-Capacitor (RC).
8. INTOSC – Internal oscillator (31 kHz to 16 MHz).

Clock Source modes are selected by the FOSC<2:0> bits in the Configuration Words. The FOSC bits determine the type of oscillator that will be used when the device is first powered.

The EC clock mode relies on an external logic level signal as the device clock source. The LP, XT and HS clock modes require an external crystal or resonator to be connected to the device. Each mode is optimized for a different frequency range. The RC clock mode requires an external resistor and capacitor to set the oscillator frequency.

The INTOSC internal oscillator block produces a low and high frequency clock source, designated LFINTOSC and HFINTOSC. (see Internal Oscillator Block, Figure 5-1). A wide selection of device clock frequencies may be derived from these two clock sources.

5.2.2 INTERNAL CLOCK SOURCES

The device may be configured to use the internal oscillator block as the system clock by performing one of the following actions:

- Program the FOSC<2:0> bits in Configuration Words to select the INTOSC clock source, which will be used as the default system clock upon a device Reset.
- Write the SCS<1:0> bits in the OSCCON register to switch the system clock source to the internal oscillator during run-time. See **Section 5.3 "Clock Switching"**for more information.

In **INTOSC** mode, OSC1/CLKIN is available for general purpose I/O. OSC2/CLKOUT is available for general purpose I/O or CLKOUT.

The function of the OSC2/CLKOUT pin is determined by the CLKOUTEN bit in Configuration Words.

The internal oscillator block has two independent oscillators that provides the internal system clock source.

1. The **HFINTOSC** (High-Frequency Internal Oscillator) is factory calibrated and operates at 16 MHz.
2. The **LFINTOSC** (Low-Frequency Internal Oscillator) is uncalibrated and operates at 31 kHz.

5.2.2.1 HFINTOSC

The High-Frequency Internal Oscillator (HFINTOSC) is a factory calibrated 16 MHz internal clock source.

The output of the HFINTOSC connects to a postscaler and multiplexer (see Figure 5-1). The frequency derived from the HFINTOSC can be selected via software using the IRCF<3:0> bits of the OSCCON register. See **Section 5.2.2.4 "Internal Oscillator Clock Switch Timing"** for more information.

The HFINTOSC is enabled by:

- Configure the IRCF<3:0> bits of the OSCCON register for the desired HF frequency, and
- FOSC<2:0> = 100, or
- Set the System Clock Source (SCS) bits of the OSCCON register to '1x'.

A fast start-up oscillator allows internal circuits to power up and stabilize before switching to HFINTOSC.

The High-Frequency Internal Oscillator Ready bit (HFIOFR) of the OSCSTAT register indicates when the HFINTOSC is running.

The High-Frequency Internal Oscillator Stable bit (HFIOFS) of the OSCSTAT register indicates when the HFINTOSC is running within 0.5% of its final value.

5.2.2.2 LFINTOSC

The Low-Frequency Internal Oscillator (LFINTOSC) is an uncalibrated 31 kHz internal clock source.

The output of the LFINTOSC connects to a postscaler and multiplexer (see Figure 5-1). Select 31 kHz, via software, using the IRCF<3:0> bits of the OSCCON register. See **Section 5.2.2.4 "Internal Oscillator Clock Switch Timing"** for more information. The LFINTOSC is also the frequency for the Power-up Timer (PWRT), Watchdog Timer (WDT) and Fail-Safe Clock Monitor (FSCM).

The LFINTOSC is enabled by selecting 31 kHz (IRCF<3:0> bits of the OSCCON register = 000) as the system clock source (SCS bits of the OSCCON register = 1x), or when any of the following are enabled:

- Configure the IRCF<3:0> bits of the OSCCON register for the desired LF frequency, and
- FOSC<2:0> = 100, or
- Set the System Clock Source (SCS) bits of the OSCCON register to '1x'

Peripherals that use the LFINTOSC are:

- Power-up Timer (PWRT)
- Watchdog Timer (WDT)
- Fail-Safe Clock Monitor (FSCM)

The Low-Frequency Internal Oscillator Ready bit (LFIOFR) of the OSCSTAT register indicates when the LFINTOSC is running.

FIGURE 5-7: INTERNAL OSCILLATOR SWITCH TIMING

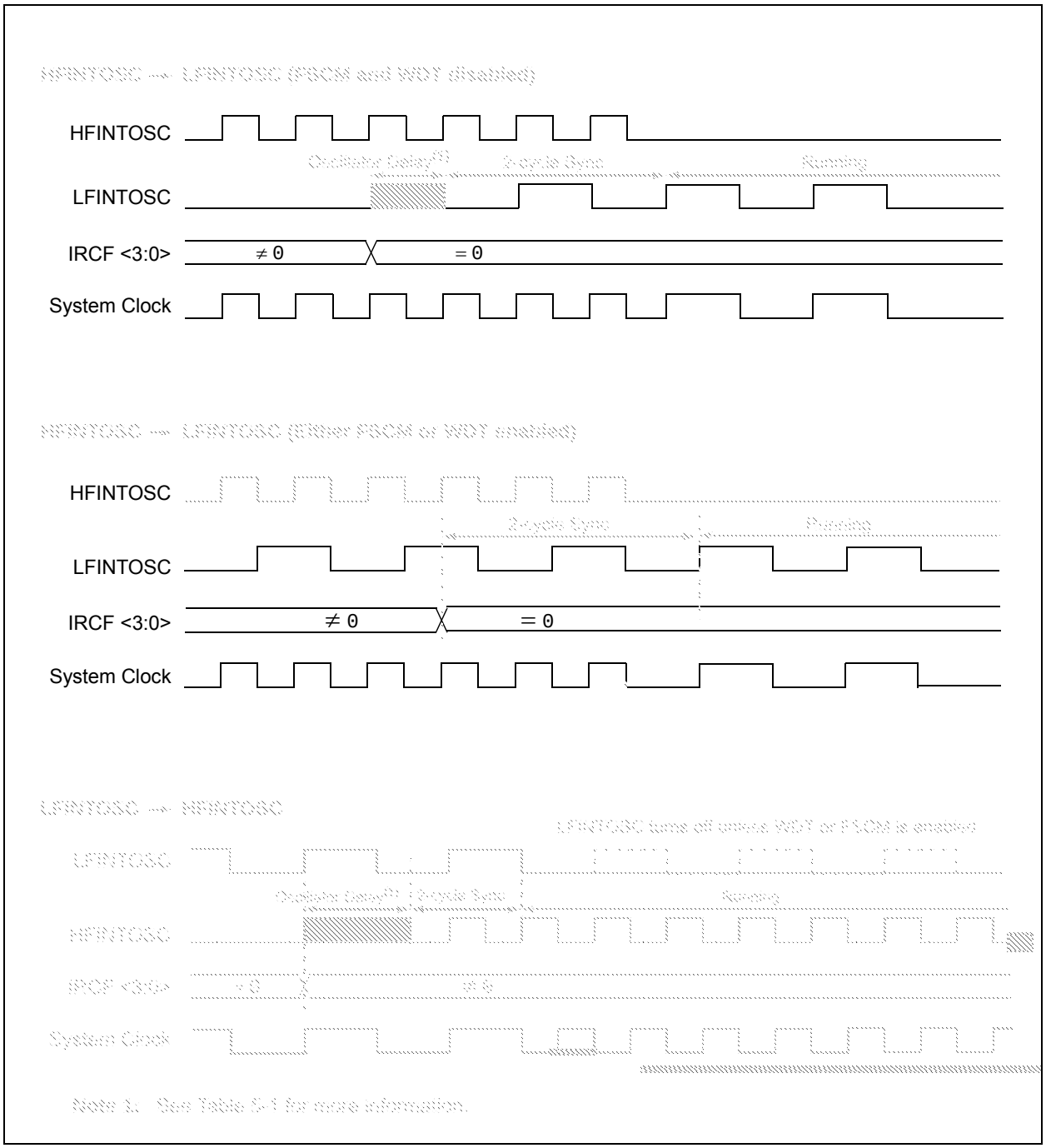


TABLE 6-5: SUMMARY OF REGISTERS ASSOCIATED WITH RESETS

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BORCON	SBOREN	BORFS	—	—	—	—	—	BORRDY	58
PCON	STKOVF	STKUNF	—	$\overline{\text{RWDT}}$	$\overline{\text{RMCLR}}$	$\overline{\text{RI}}$	$\overline{\text{POR}}$	$\overline{\text{BOR}}$	62
STATUS	—	—	—	$\overline{\text{TO}}$	$\overline{\text{PD}}$	Z	DC	C	18
WDTCON	—	—	WDTPS<4:0>					SWDTEN	82

Legend: — = unimplemented, reads as '0'. Shaded cells are not used by Resets.

Note 1: Other (non Power-up) Resets include $\overline{\text{MCLR}}$ Reset and Watchdog Timer Reset during normal operation.

8.2 Low-Power Sleep Mode

The PIC16F1512/3 device contains an internal Low Dropout (LDO) voltage regulator, which allows the device I/O pins to operate at voltages up to 5.5V while the internal device logic operates at a lower voltage. The LDO and its associated reference circuitry must remain active when the device is in Sleep mode. The PIC16F1512/3 allows the user to optimize the operating current in Sleep, depending on the application requirements.

A Low-Power Sleep mode can be selected by setting the VREGPM bit of the VREGCON register. With this bit set, the LDO and reference circuitry are placed in a low-power state when the device is in Sleep.

8.2.1 SLEEP CURRENT VS. WAKE-UP TIME

In the default operating mode, the LDO and reference circuitry remain in the normal configuration while in Sleep. The device is able to exit Sleep mode quickly since all circuits remain active. In Low-Power Sleep mode, when waking up from Sleep, an extra delay time is required for these circuits to return to the normal configuration and stabilize.

The Low-Power Sleep mode is beneficial for applications that stay in Sleep mode for long periods of time. The normal mode is beneficial for applications that need to wake from Sleep quickly and frequently.

8.2.2 PERIPHERAL USAGE IN SLEEP

Some peripherals that can operate in Sleep mode will not operate properly with the Low-Power Sleep mode selected. The LDO will remain in the Normal Power mode when those peripherals are enabled. The Low-Power Sleep mode is intended for use with these peripherals:

- Brown-Out Reset (BOR)
- Watchdog Timer (WDT)
- External interrupt pin/interrupt-on-change pins
- Timer1 (with external clock source)
- CCP (Capture mode)

Note:	The PIC16LF1512/3 does not have a configurable Low-Power Sleep mode. PIC16LF1512/3 is an unregulated device and is always in the lowest power state when in Sleep, with no wake-up time penalty. This device has a lower maximum V_{DD} and I/O voltage than the PIC16F1512/3. See **Section 25.0 "Electrical Specifications"** for more information.

8.3 Power Control Registers

REGISTER 8-1: VREGCON: VOLTAGE REGULATOR CONTROL REGISTER(1)

U-0	U-0	U-0	U-0	U-0	U-0	R/W-0/0	R/W-1/1
—	—	—	—	—	—	VREGPM	Reserved
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7-2 **Unimplemented:** Read as '0'

bit 1 **VREGPM:** Voltage Regulator Power Mode Selection bit
- 1 = Low-Power Sleep mode enabled in Sleep(2)
  Draws lowest current in Sleep, slower wake-up
- 0 = Normal-Power mode enabled in Sleep(2)
  Draws higher current in Sleep, faster wake-up

bit 0 **Reserved:** Read as '1'. Maintain this bit set.

Note 1: PIC16F1512/3 only.
2: See **Section 25.0 "Electrical Specifications"**.

14.3 FVR Control Registers

REGISTER 14-1: FVRCON: FIXED VOLTAGE REFERENCE CONTROL REGISTER

R/W-0/0	R-q/q	R/W-0/0	R/W-0/0	U-0	U-0	R/W-0/0	R/W-0/0
FVREN	FVRRDY(1)	TSEN	TSRNG	—	—	ADFVR<1:0>	
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	q = Value depends on condition

bit 7 **FVREN:** Fixed Voltage Reference Enable bit
0 = Fixed Voltage Reference is disabled
1 = Fixed Voltage Reference is enabled

bit 6 **FVRRDY:** Fixed Voltage Reference Ready Flag bit(1)
0 = Fixed Voltage Reference output is not ready or not enabled
1 = Fixed Voltage Reference output is ready for use

bit 5 **TSEN:** Temperature Indicator Enable bit
0 = Temperature Indicator is disabled
1 = Temperature Indicator is enabled

bit 4 **TSRNG:** Temperature Indicator Range Selection bit
0 = $V_{OUT} = V_{DD} - 2V_T$ (Low Range)
1 = $V_{OUT} = V_{DD} - 4V_T$ (High Range)

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

bit 1-0 **ADFVR<1:0>:** ADC Fixed Voltage Reference Selection bits
00 = ADC Fixed Voltage Reference Peripheral output is off
01 = ADC Fixed Voltage Reference Peripheral output is 1x (1.024V)
10 = ADC Fixed Voltage Reference Peripheral output is 2x (2.048V)(2)
11 = ADC Fixed Voltage Reference Peripheral output is 4x (4.096V)(2)

Note 1: FVRRDY is always '1' on PIC16F1512/3 only.
2: Fixed Voltage Reference output cannot exceed V_{DD}.

TABLE 14-2: SUMMARY OF REGISTERS ASSOCIATED WITH THE FIXED VOLTAGE REFERENCE

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on page
FVRCON	FVREN	FVRRDY	TSEN	TSRNG	—	—	ADFVR<1:0>		120

Legend: Shaded cells are unused by the Fixed Voltage Reference module.

REGISTER 16-16: AADRESxH: HARDWARE CVD RESULT REGISTER MSB ADFM = 0(1)

R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u
ADRESx<9:2>							
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7-0 **AD<9:2>:** Most Significant ADC results

Note 1: See **Section 16.6.11 "Hardware CVD Register Mapping"** for more information.

REGISTER 16-17: AADRESxL: HARDWARE CVD RESULT REGISTER LSL ADFM = 0(1)

R/W-x/u	R/W-x/u	U-0	U-0	U-0	U-0	U-0	U-0
ADRESx<1:0>		—	—	—	—	—	—
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7-6 **AD<1:0>:** ADC Result Register bits
Lower two bits of 10-bit conversion result

bit 5-0 **Reserved:** Do not use.

Note 1: See **Section 16.6.11 "Hardware CVD Register Mapping"** for more information.

17.2 Option and Timer0 Control Register

REGISTER 17-1: OPTION_REG: OPTION REGISTER

R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1
$\overline{\text{WPUEN}}$	INTEDG	TMR0CS	TMR0SE	PSA	PS<2:0>		
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

bit 7 **$\overline{\text{WPUEN}}$:** Weak Pull-up Enable bit
1 = All weak pull-ups are disabled (except $\overline{\text{MCLR}}$, if it is enabled)
0 = Weak pull-ups are enabled by individual WPUx latch values

bit 6 **INTEDG:** Interrupt Edge Select bit
1 = Interrupt on rising edge of INT pin
0 = Interrupt on falling edge of INT pin

bit 5 **TMR0CS:** Timer0 Clock Source Select bit
1 = Transition on T0CKI pin
0 = Internal instruction cycle clock (FOSC/4)

bit 4 **TMR0SE:** 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:** Prescaler Assignment bit
1 = Prescaler is not assigned to the Timer0 module
0 = Prescaler is assigned to the Timer0 module

bit 2-0 **PS<2:0>:** Prescaler Rate Select bits

Bit Value	Timer0 Rate
000	1 : 2
001	1 : 4
010	1 : 8
011	1 : 16
100	1 : 32
101	1 : 64
110	1 : 128
111	1 : 256

TABLE 17-1: SUMMARY OF REGISTERS ASSOCIATED WITH TIMER0

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	69
OPTION_REG	$\overline{\text{WPUEN}}$	INTEDG	TMR0CS	TMR0SE	PSA	PS<2:0>			159
TMR0	Timer0 Module Register								157*
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	103

Legend: — = Unimplemented locations, read as '0'. Shaded cells are not used by the Timer0 module.
* Page provides register information.

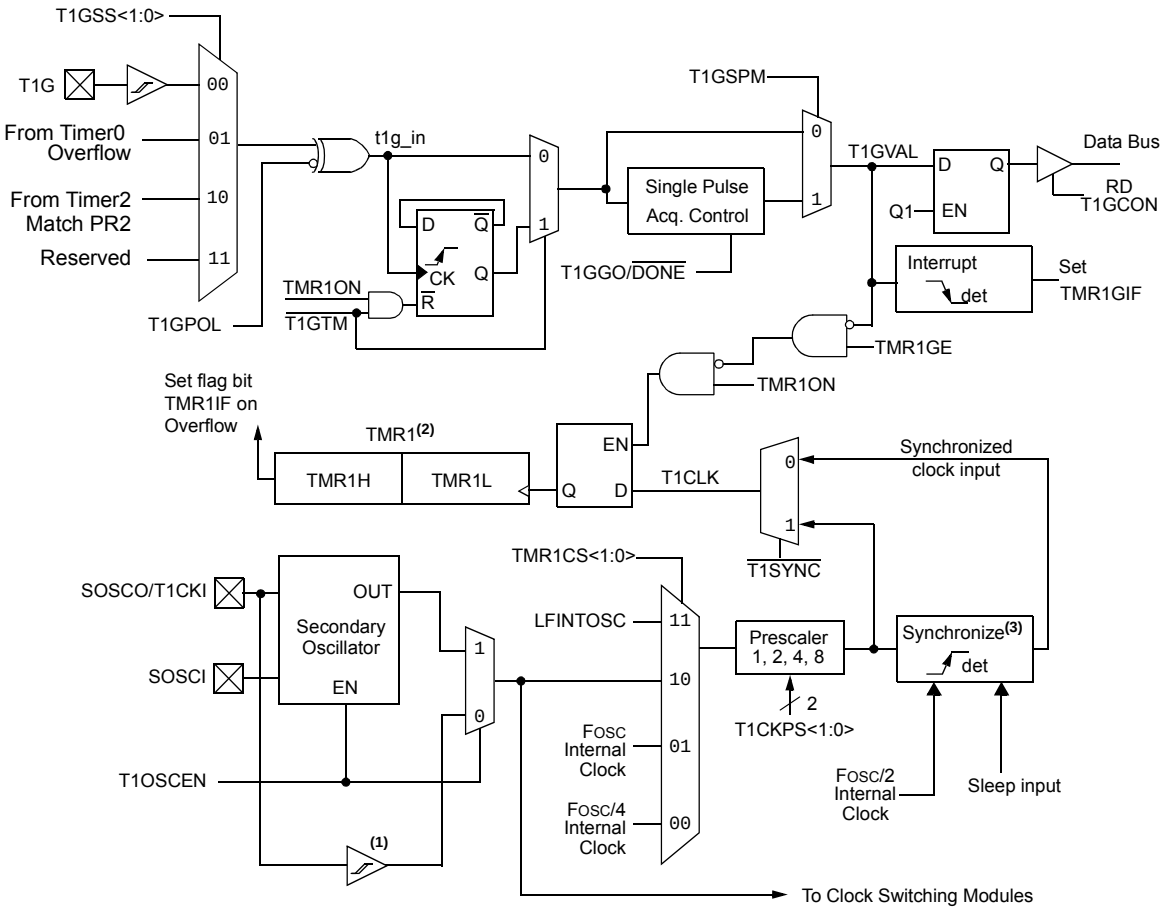
18.0 TIMER1 MODULE WITH GATE CONTROL

The Timer1 module is a 16-bit timer/counter with the following features:

- 16-bit timer/counter register pair (TMR1H:TMR1L)
- Programmable internal or external clock source
- 2-bit prescaler
- 32 kHz secondary oscillator circuit
- Optionally synchronized comparator out
- Multiple Timer1 gate (count enable) sources
- Interrupt on overflow
- Wake-up on overflow (external clock, Asynchronous mode only)
- Time base for the Capture/Compare function
- Special Event Trigger (with CCP)
- Selectable Gate Source Polarity
- Gate Toggle mode
- Gate Single-pulse mode
- Gate Value Status
- Gate Event Interrupt

Figure 18-1 is a block diagram of the Timer1 module.

FIGURE 18-1: TIMER1 BLOCK DIAGRAM



Note 1: ST Buffer is high speed type when using T1CKI.
2: Timer1 register increments on rising edge.
3: Synchronize does not operate while in Sleep.

20.5.3.3 7-bit Transmission with Address Hold Enabled

Setting the AHEN bit of the SSPCON3 register enables additional clock stretching and interrupt generation after the 8th falling edge of a received matching address. Once a matching address has been clocked in, CKP is cleared and the SSPIF interrupt is set.

Figure 20-18 displays a standard waveform of a 7-bit Address Slave Transmission with AHEN enabled.

1. Bus starts Idle.
2. Master sends Start condition; the S bit of SSPSTAT is set; SSPIF is set if interrupt on Start detect is enabled.
3. Master sends matching address with R/$\overline{W}$ bit set. After the 8th falling edge of the SCL line the CKP bit is cleared and SSPIF interrupt is generated.
4. Slave software clears SSPIF.
5. Slave software reads ACKTIM bit of SSPCON3 register, and R/$\overline{W}$ and D/$\overline{A}$ of the SSPSTAT register to determine the source of the interrupt.
6. Slave reads the address value from the SSPBUF register clearing the BF bit.
7. Slave software decides from this information if it wishes to $\overline{ACK}$ or not $\overline{ACK}$ and sets ACKDT bit of the SSPCON2 register accordingly.
8. Slave sets the CKP bit releasing SCL.
9. Master clocks in the $\overline{ACK}$ value from the slave.
10. Slave hardware automatically clears the CKP bit and sets SSPIF after the $\overline{ACK}$ if the R/$\overline{W}$ bit is set.
11. Slave software clears SSPIF.
12. Slave loads value to transmit to the master into SSPBUF setting the BF bit.

Note: SSPBUF cannot be loaded until after the $\overline{ACK}$.

13. Slave sets CKP bit releasing the clock.
14. Master clocks out the data from the slave and sends an $\overline{ACK}$ value on the 9th SCL pulse.
15. Slave hardware copies the $\overline{ACK}$ value into the ACKSTAT bit of the SSPCON2 register.
16. Steps 10-15 are repeated for each byte transmitted to the master from the slave.
17. If the master sends a not $\overline{ACK}$ the slave releases the bus allowing the master to send a Stop and end the communication.

Note: Master must send a not $\overline{ACK}$ on the last byte to ensure that the slave releases the SCL line to receive a Stop.

20.6.8 ACKNOWLEDGE SEQUENCE TIMING

An Acknowledge sequence is enabled by setting the Acknowledge Sequence Enable bit, ACKEN bit of the SSPCON2 register. 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 20-29).

20.6.8.1 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 does not occur).

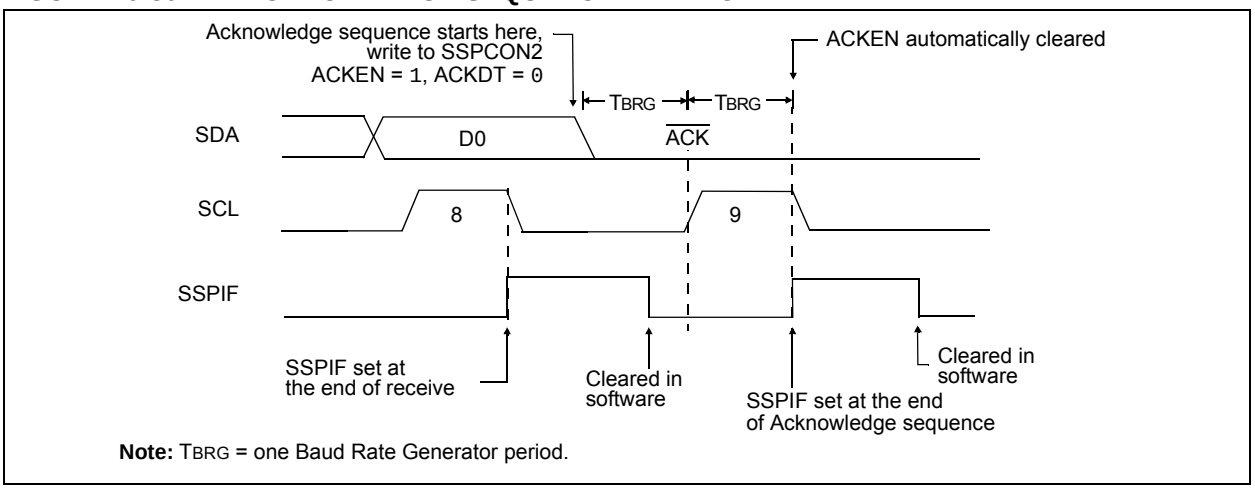
20.6.9 STOP CONDITION TIMING

A Stop bit is asserted on the SDA pin at the end of a receive/transmit by setting the Stop Sequence Enable bit, PEN bit of the SSPCON2 register. 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 of the SSPSTAT register is set. A TBRG later, the PEN bit is cleared and the SSPIF bit is set (Figure 20-30).

20.6.9.1 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 does not occur).

FIGURE 20-30: ACKNOWLEDGE SEQUENCE WAVEFORM



Note: TBRG = one Baud Rate Generator period.

21.3.2 SETUP FOR PWM OPERATION

The following steps should be taken when configuring the CCP module for standard PWM operation:

1. Disable the CCPx pin output driver by setting the associated TRIS bit.
2. Load the PR2 register with the PWM period value.
3. Configure the CCP module for the PWM mode by loading the CCPxCON register with the appropriate values.
4. Load the CCPRxL register and the DCxBx bits of the CCPxCON register, with the PWM duty cycle value.
5. Configure and start Timer2:
   - Clear the TMR2IF interrupt flag bit of the PIRx register. See Note below.
   - Configure the T2CKPS bits of the T2CON register with the Timer prescale value.
   - Enable the Timer by setting the TMR2ON bit of the T2CON register.
6. Enable PWM output pin:
   - Wait until the Timer overflows and the TMR2IF bit of the PIR1 register is set. See Note below.
   - Enable the CCPx pin output driver by clearing the associated TRIS bit.

Note:	In order to send a complete duty cycle and period on the first PWM output, the above steps must be included in the setup sequence. If it is not critical to start with a complete PWM signal on the first output, then step 6 may be ignored.

21.3.3 TIMER2 TIMER RESOURCE

The PWM standard mode makes use of the 8-bit Timer2 timer resources to specify the PWM period.

21.3.4 PWM PERIOD

The PWM period is specified by the PR2 register of Timer2. The PWM period can be calculated using the formula of Equation 21-1.

EQUATION 21-1: PWM PERIOD

$$PWM\ Period = [(PR2) + 1] \bullet 4 \bullet T_{OSC} \bullet (TMR2\ Prescale\ Value)$$

Note 1: TOSC = 1/FOSC

When TMR2 is equal to PR2, the following three events occur on the next increment cycle:

- TMR2 is cleared
- The CCPx pin is set. (Exception: If the PWM duty cycle = 0%, the pin will not be set.)
- The PWM duty cycle is latched from CCPRxL into CCPRxH.

Note:	The Timer postscaler (see **Section 19.1 "Timer2 Operation"**) is not used in the determination of the PWM frequency.

21.3.5 PWM DUTY CYCLE

The PWM duty cycle is specified by writing a 10-bit value to multiple registers: CCPRxL register and DCxB<1:0> bits of the CCPxCON register. The CCPRxL contains the eight MSbs and the DCxB<1:0> bits of the CCPxCON register contain the two LSbs. CCPRxL and DCxB<1:0> bits of the CCPxCON register can be written to at any time. The duty cycle value is not latched into CCPRxH until after the period completes (i.e., a match between PR2 and TMR2 registers occurs). While using the PWM, the CCPRxH register is read-only.

Equation 21-2 is used to calculate the PWM pulse width.

Equation 21-3 is used to calculate the PWM duty cycle ratio.

EQUATION 21-2: PULSE WIDTH

$$Pulse\ Width = (CCPRxL:CCPxCON\langle 5:4\rangle) \bullet T_{OSC} \bullet (TMR2\ Prescale\ Value)$$

EQUATION 21-3: DUTY CYCLE RATIO

$$Duty\ Cycle\ Ratio = \frac{(CCPRxL:CCPxCON\langle 5:4\rangle)}{4(PR2 + 1)}$$

The CCPRxH 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.

The 8-bit timer TMR2 register is concatenated with either the 2-bit internal system clock (FOSC), or two bits of the prescaler, to create the 10-bit time base. The system clock is used if the Timer2 prescaler is set to 1:1.

When the 10-bit time base matches the CCPRxH and 2-bit latch, then the CCPx pin is cleared (see Figure 21-4).

TABLE 22-2: SUMMARY OF REGISTERS ASSOCIATED WITH ASYNCHRONOUS RECEPTION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUDCON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	249
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	69
PIE1	TMR1GIE	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE	70
PIR1	TMR1GIF	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF	72
RCREG	EUSART Receive Data Register								242*
RCSTA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	248
SPBRGL	BRG<7:0>								250*
SPBRGH	BRG<15:8>								250*
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	110
TXSTA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	247

Legend: — = unimplemented, read as '0'. Shaded cells are not used for asynchronous reception.

* Page provides register information.

REGISTER 22-2: RCSTA: RECEIVE STATUS AND CONTROL REGISTER

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R-0/0	R-0/0	R-x/x
SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D
bit 7							bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
u = Bit is unchanged	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

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

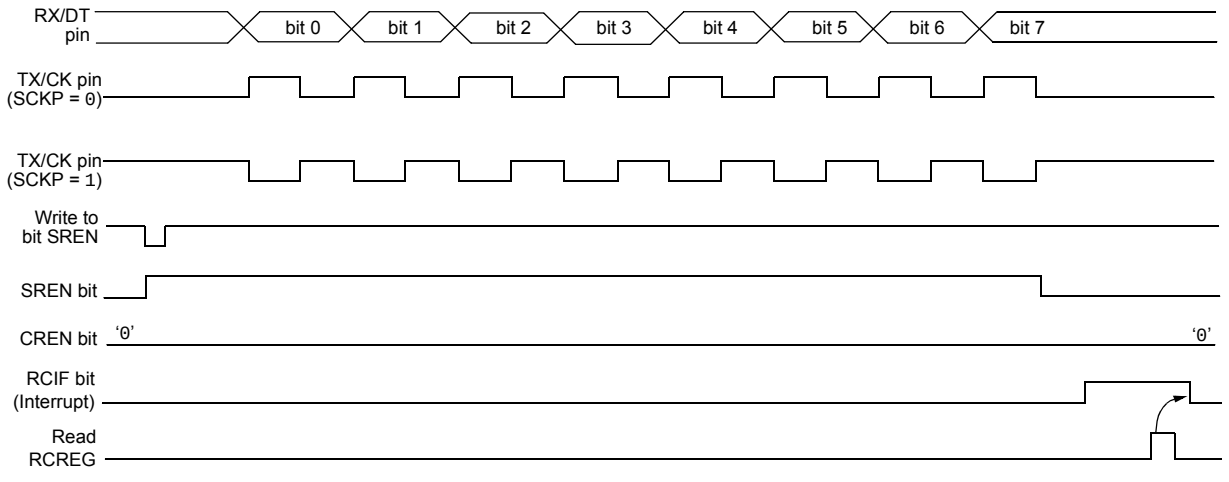
bit 3 **ADDEN:** Address Detect Enable bit
Asynchronous mode 9-bit (RX9 = 1):
1 = Enables address detection, enable interrupt and load the receive buffer when RSR<8> is set
0 = Disables address detection, all bytes are received and ninth bit can be used as parity bit
Asynchronous mode 8-bit (RX9 = 0):
Don't care

bit 2 **FERR:** Framing Error bit
1 = Framing error (can be updated by reading RCREG register and receive 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:** Ninth bit of Received Data
This can be address/data bit or a parity bit and must be calculated by user firmware.

FIGURE 22-12: SYNCHRONOUS RECEPTION (MASTER MODE, SREN)



Note: Timing diagram demonstrates Sync Master mode with bit SREN = 1 and bit BRGH = 0.

TABLE 22-7: SUMMARY OF REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER RECEPTION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUDCON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	249
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	69
PIE1	TMR1GIE	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE	70
PIR1	TMR1GIF	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF	72
RCREG	EUSART Receive Data Register								242*
RCSTA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	248
SPBRGL	BRG<7:0>								250*
SPBRGH	BRG<15:8>								250*
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	110
TXSTA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	247

Legend: — = unimplemented, read as '0'. Shaded cells are not used for synchronous master reception.

* Page provides register information.

24.0 INSTRUCTION SET SUMMARY

Each instruction is a 14-bit word containing the operation code (opcode) and all required operands. The opcodes are broken into three broad categories.

- Byte Oriented
- Bit Oriented
- Literal and Control

The literal and control category contains the most varied instruction word format.

Table 24-1 lists the instructions recognized by the MPASM™ assembler.

All instructions are executed within a single instruction cycle, with the following exceptions, which may take two or three cycles:

- Subroutine takes two cycles (CALL, CALLW)
- Returns from interrupts or subroutines take two cycles (RETURN, RETLW, RETFIE)
- Program branching takes two cycles (GOTO, BRA, BRW, BTFSS, BTFSC, DECFSZ, INCSFZ)
- One additional instruction cycle will be used when any instruction references an indirect file register and the file select register is pointing to program memory.

One instruction cycle consists of four oscillator cycles; for an oscillator frequency of 4 MHz, this gives a nominal instruction execution rate of 1 MHz.

All instruction examples use the format '0xhh' to represent a hexadecimal number, where 'h' signifies a hexadecimal digit.

24.1 Read-Modify-Write Operations

Any instruction that specifies a file register as part of the instruction performs a Read-Modify-Write (R-M-W) operation. The register is read, the data is modified, and the result is stored according to either the instruction, or the destination designator 'd'. A read operation is performed on a register even if the instruction writes to that register.

TABLE 24-1: OPCODE FIELD DESCRIPTIONS

Field	Description
f	Register file address (0x00 to 0x7F)
W	Working register (accumulator)
b	Bit address within an 8-bit file register
k	Literal field, constant data or label
x	Don't care location (= 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.
d	Destination select; d = 0: store result in W, d = 1: store result in file register f. Default is d = 1.
n	FSR or INDF number. (0-1)
mm	Pre-post increment-decrement mode selection

TABLE 24-2: ABBREVIATION DESCRIPTIONS

Field	Description
PC	Program Counter
$\overline{TO}$	Time-out bit
C	Carry bit
DC	Digit carry bit
Z	Zero bit
$\overline{PD}$	Power-down bit

FIGURE 26-11: IDD TYPICAL, EC OSCILLATOR, MEDIUM-POWER MODE, PIC16LF1512/3 ONLY

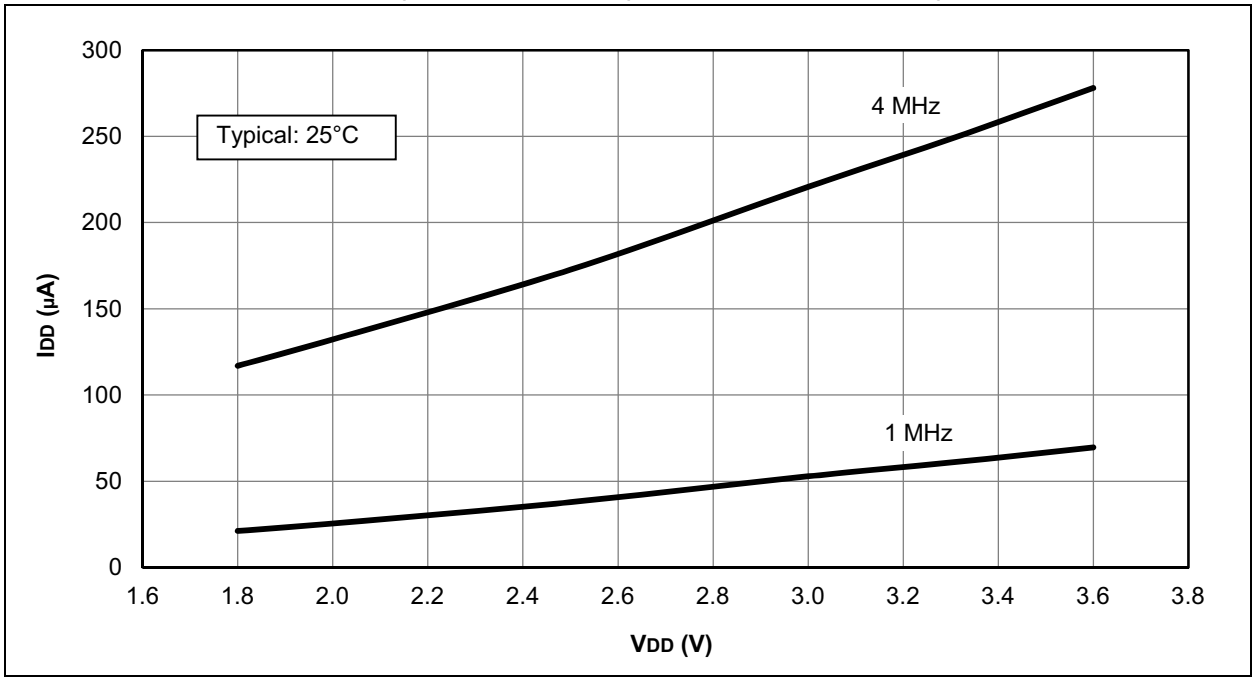
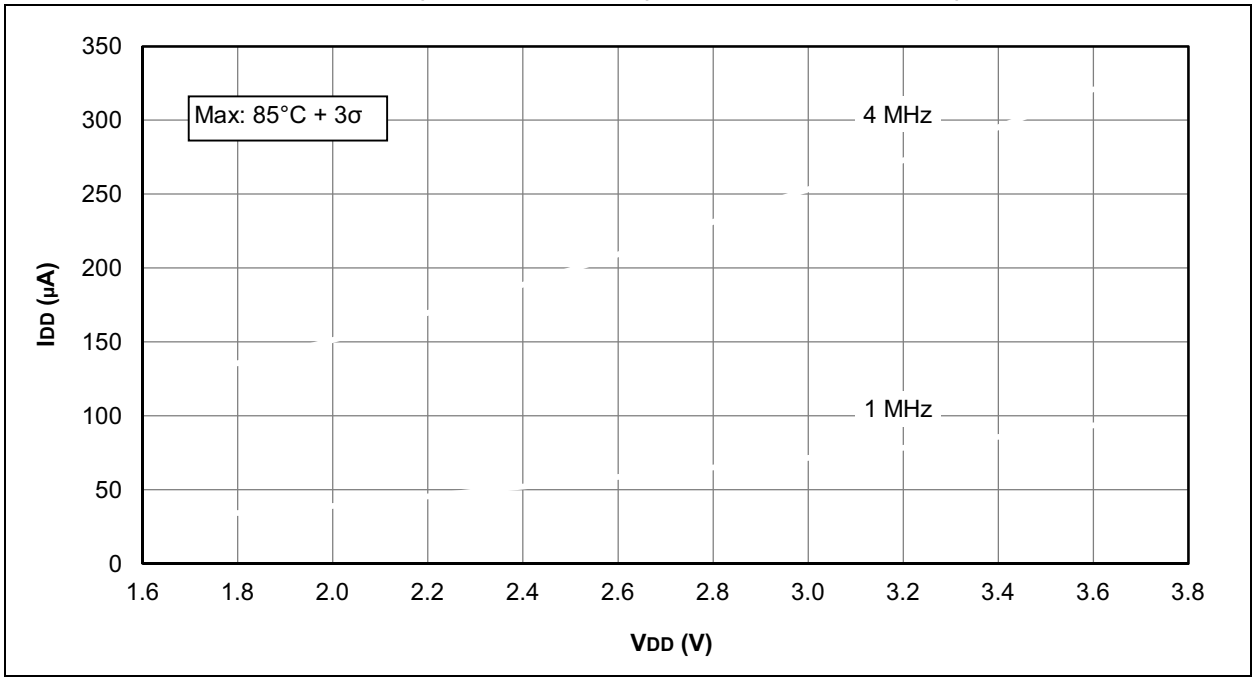
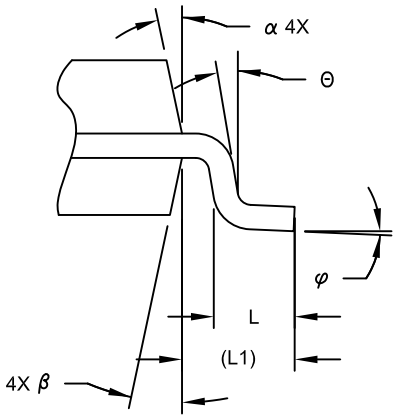


FIGURE 26-12: IDD MAXIMUM, EC OSCILLATOR, MEDIUM-POWER MODE, PIC16LF1512/3 ONLY

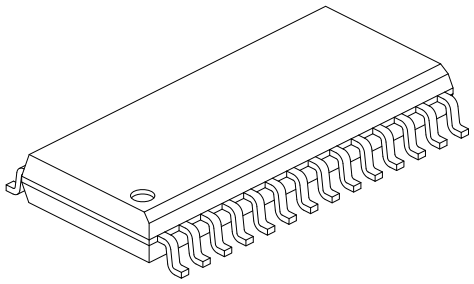


28-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



VIEW C



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		28	
Pitch	e		1.27 BSC	
Overall Height	A	-	-	2.65
Molded Package Thickness	A2	2.05	-	-
Standoff §	A1	0.10	-	0.30
Overall Width	E		10.30 BSC	
Molded Package Width	E1		7.50 BSC	
Overall Length	D		17.90 BSC	
Chamfer (Optional)	h	0.25	-	0.75
Foot Length	L	0.40	-	1.27
Footprint	L1		1.40 REF	
Lead Angle	Θ	0°	-	-
Foot Angle	φ	0°	-	8°
Lead Thickness	c	0.18	-	0.33
Lead Width	b	0.31	-	0.51
Mold Draft Angle Top	α	5°	-	15°
Mold Draft Angle Bottom	β	5°	-	15°

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic
3. Dimension D does not include mold flash, protrusions or gate burrs, which shall not exceed 0.15 mm per end. Dimension E1 does not include interlead flash or protrusion, which shall not exceed 0.25 mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

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

   REF: Reference Dimension, usually without tolerance, for information purposes only.
5. Datums A & B to be determined at Datum H.

Microchip Technology Drawing C04-052C Sheet 2 of 2