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PIC16(L)F1526/27
Data Sheet

64-Pin Flash Microcontrollers
with nanoWatt XLP Technology

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ISBN: 978-1-61341-133-9

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64-Pin Flash Microcontrollers with nanoWatt Technology

High-Performance RISC CPU:

- C Compiler Optimized Architecture
- Only 49 Instructions
- Up to 28 Kbytes Linear Program Memory Addressing
- Up to 1536 Bytes Linear Data Memory Addressing
- Operating Speed:
 - DC – 20 MHz clock input @ 2.5V
 - DC – 16 MHz clock input @ 1.8V
 - DC – 200 ns instruction cycle
- Interrupt Capability with Automatic Context Saving
- 16-Level Deep Hardware Stack with Optional Overflow/Underflow Reset
- Direct, Indirect and Relative Addressing modes:
 - Two full 16-bit File Select Registers (FSRs)
 - FSRs can read program and data memory

Flexible Oscillator Structure:

- 16 MHz Internal Oscillator Block:
 - Software selectable frequency range from 16 MHz to 31 kHz
- 31 kHz Low-Power Internal Oscillator
- External Oscillator Block with:
 - Four crystal/resonator modes up to 20 MHz
 - Three external clock modes up to 20 MHz
- Fail-Safe Clock Monitor
 - Allows for safe shutdown if peripheral clock stops
- Two-Speed Oscillator Start-up
- Oscillator Start-up Timer (OST)

Special Microcontroller Features:

- Operating Voltage Range:
 - 1.8V to 3.6V (PIC16LF1526/27)
 - 2.3V to 5.5V (PIC16F1526/27)
- Self-Programmable under Software Control
- Power-on Reset (POR)
- Power-up Timer (PWRT)
- Programmable Low-Power Brown-Out Reset (LPBOR)
- Extended Watch-Dog Timer (WDT):
 - Programmable period from 1ms to 256s
- Programmable Code Protection
- In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via Two Pins
- Enhanced Low-Voltage Programming (LVP)
- Power-Saving Sleep mode

Extreme Low-Power Management PIC16LF1526/27 with nanoWatt XLP:

- Sleep mode: 20 nA @ 1.8V, typical
- Watchdog Timer: 300 nA @ 1.8V, typical
- Secondary Oscillator: 600 nA @ 32 kHz, 1.8V, typical

Analog Features:

- Analog-to-Digital Converter (ADC):
 - 10-bit resolution
 - 30 external channels
 - Two internal channels
 - Fixed Voltage Reference (FVR) channel
 - Temperature Indicator channel
 - Auto acquisition capability
 - Conversion available during Sleep
 - Dedicated ADC RC oscillator
 - Fixed Voltage Reference (FVR) as ADC positive reference
- Voltage Reference module:
 - Fixed Voltage Reference (FVR) with 1.024V, 2.048V and 4.096V output levels
 - Low-Power Sleep mode
 - Low-Power BOR (LPBOR)

Peripheral Features:

- 53 I/O Pins and 1 Input-only Pin:
 - High current sink/source 25 mA/25 mA
 - Individually programmable weak pull-ups
 - Individually programmable interrupt-on-change (IOC) pins
- Timer0: 8-Bit Timer/Counter with 8-Bit Programmable Prescaler
- Enhanced Timer1, 3, 5:
 - 16-bit timer/counter with prescaler
 - External Gate Input mode
 - Low-power 32 kHz secondary oscillator driver
- Timer2, 4, 6, 8, 10: 8-Bit Timer/Counter with 8-Bit Period Register, Prescaler and Postscaler
- Ten Capture/Compare/PWM (CCP) modules:
 - 16-bit Capture, 200 ns (max. resolution)
 - 16-bit Compare, 200 ns (max. resolution)
 - 10-bit PWM, 20 kHz @ 10 bits (max. frequency)
- Two Master Synchronous Serial Ports (MSSPs) with SPI and I²C™ with:
 - 7-bit address masking
 - SMBus/PMBus™ compatibility
 - Auto-wake-up on start
- Two Enhanced Universal Synchronous Asynchronous Receiver Transmitters (EUSART):
 - RS-232, RS-485 and LIN compatible
 - Auto-Baud Detect

PIC16(L)F1526/27

TABLE 1: PIC16(L)F1526/27 FAMILY TYPES

Device	Program Memory Flash (words)	SRAM (bytes)	I/Os	10-bit A/D (ch)	Timers 8/16-bit	EUSART	MSSP (I ² C™/SPI)	CCP
PIC16F1526 PIC16LF1526	8192	768	54	30	6/3	2	2	10
PIC16F1527 PIC16LF1527	16384	1536	54	30	6/3	2	2	10

FIGURE 1: 64-PIN TQFP (10MM X 10MM) PACKAGE DIAGRAM FOR PIC16(L)F1526/27

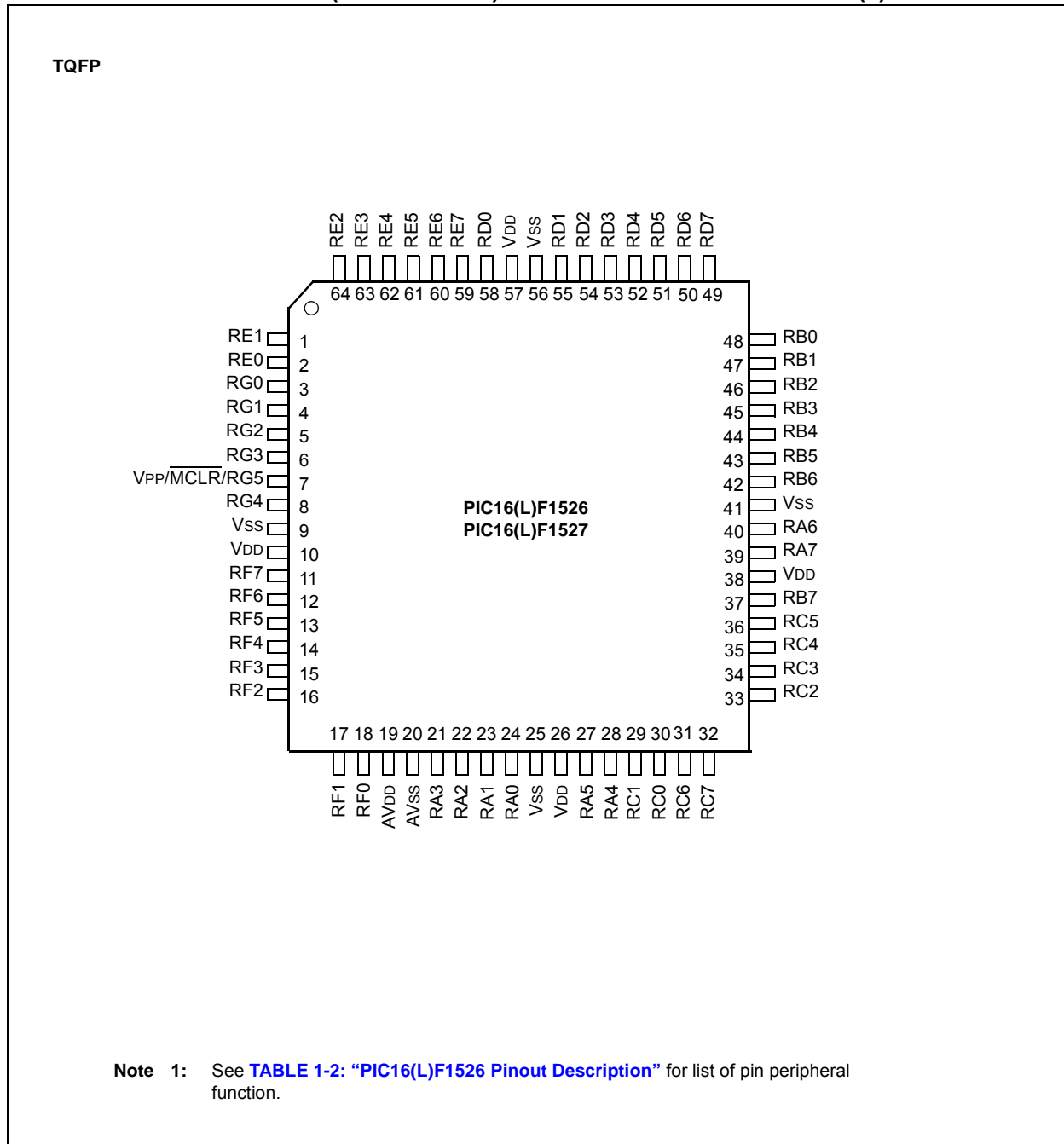
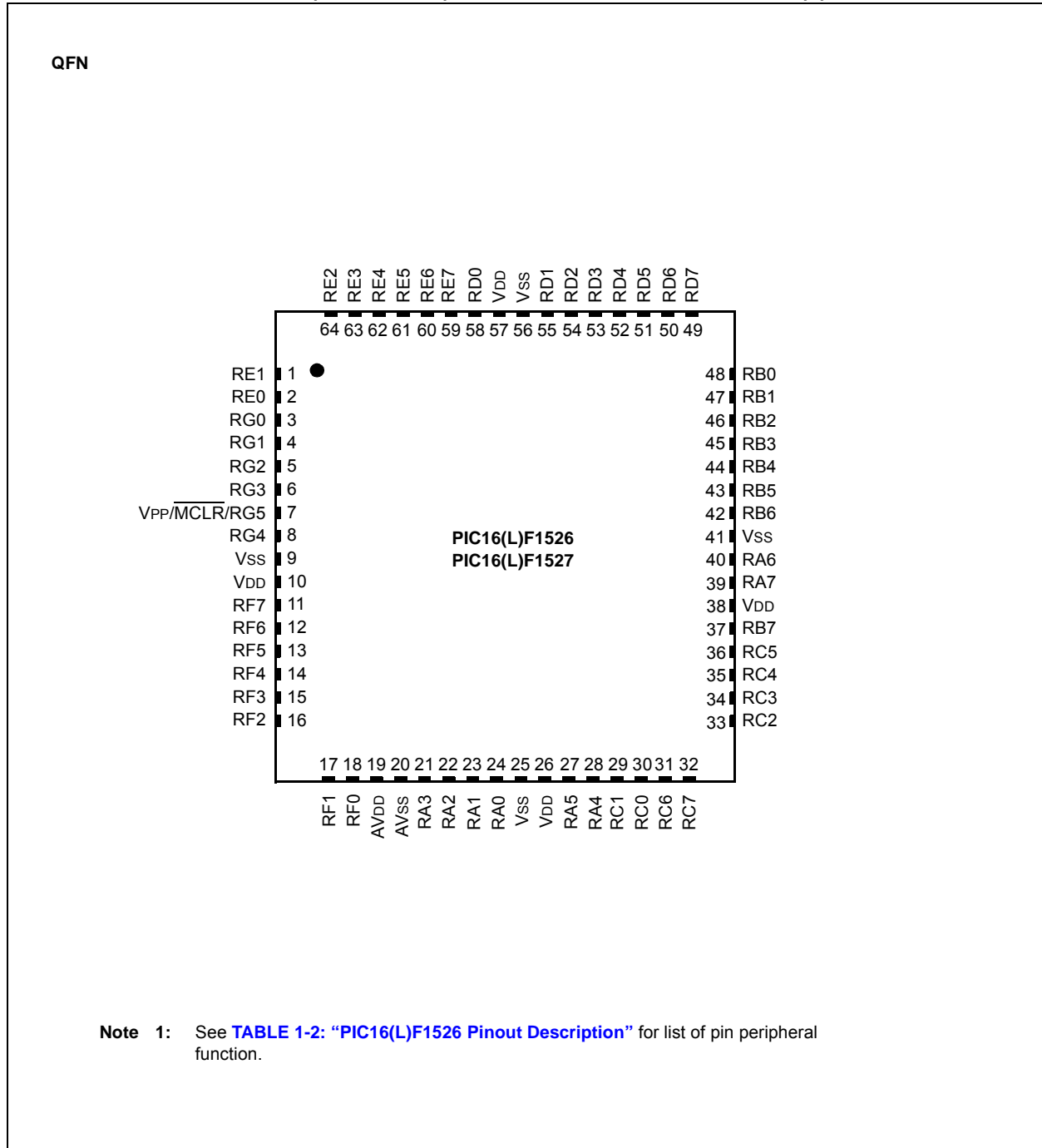


FIGURE 2: 64-PIN QFN (9MM X 9MM) PACKAGE DIAGRAM FOR PIC16(L)F1526/27



PIC16(L)F1526/27

TABLE 1: 64-PIN DEVICE ALLOCATION TABLE (PIC16(L)F1526/27)

I/O	64-Pin TQFP, QFN	A/D	Timers	CCP	USART	SSP	Interrupt	Pull-up	Basic
RA0	24	AN0	—	—	—	—	—	—	—
RA1	23	AN1	—	—	—	—	—	—	—
RA2	22	AN2	—	—	—	—	—	—	—
RA3	21	AN3	—	—	—	—	—	—	VREF+
RA4	28	—	T0CKI	—	—	—	—	—	—
RA5	27	AN4	T3G	—	—	—	—	—	—
RA6	40	—	—	—	—	—	—	—	OSC2/CLKOUT
RA7	39	—	—	—	—	—	—	—	OSC1/CLKIN
RB0	48	AN17	—	—	—	—	INT/ IOC	Y	—
RB1	47	AN18	—	—	—	—	IOC	Y	—
RB2	46	AN19	—	—	—	—	IOC	Y	—
RB3	45	AN20	—	—	—	—	IOC	Y	—
RB4	44	AN21	T3CKI ⁽²⁾	—	—	—	IOC	Y	—
RB5	43	AN22	T1G/T3CKI ⁽¹⁾	—	—	—	IOC	Y	—
RB6	42	—	—	—	—	—	IOC	Y	ICSPCLK/ICDCLK
RB7	37	—	—	—	—	—	IOC	Y	ICSPDAT/ICDDAT
RC0	30	—	SOSCO/T1CKI	—	—	—	—	—	—
RC1	29	—	SOSCI	CCP2 ⁽¹⁾	—	—	—	—	—
RC2	33	—	—	CCP1	—	—	—	—	—
RC3	34	—	—	—	—	SCK1/SCL1	—	—	—
RC4	35	—	—	—	—	SDI1/SDA1	—	—	—
RC5	36	—	—	—	—	SDO1	—	—	—
RC6	31	—	—	—	TX1/CK1	—	—	—	—
RC7	32	—	—	—	RX1/DT1	—	—	—	—
RD0	58	AN23	—	—	—	—	—	Y	—
RD1	55	AN24	T5CKI	—	—	—	—	Y	—
RD2	54	AN25	—	—	—	—	—	Y	—
RD3	53	AN26	—	—	—	—	—	Y	—
RD4	52	—	—	—	—	SDO2	—	Y	—
RD5	51	—	—	—	—	SDI2, SDA2	—	Y	—
RD6	50	—	—	—	—	SCK2, SCL2	—	Y	—
RD7	49	—	—	—	—	SS2	—	Y	—
RE0	2	AN27	—	—	—	—	—	Y	—
RE1	1	AN28	—	—	—	—	—	Y	—
RE2	64	AN29	—	CCP10	—	—	—	Y	—
RE3	63	—	—	CCP9	—	—	—	Y	—
RE4	62	—	—	CCP8	—	—	—	Y	—
RE5	61	—	—	CCP7	—	—	—	Y	—
RE6	60	—	—	CCP6	—	—	—	Y	—

Note 1: Peripheral pin location selected using APFCON register. Default Location.

2: Peripheral pin location selected using APFCON register. Alternate Location.

3: Weak pull-up is always enabled when MCLR is enabled, otherwise the pull-up is under user control.

PIC16(L)F1526/27

TABLE 1: 64-PIN DEVICE ALLOCATION TABLE (PIC16(L)F1526/27) (CONTINUED)

I/O	64-Pin TQFP, QFN	A/D	Timers	CCP	USART	SSP	Interrupt	Pull-up	Basic
RE7	59	—	—	CCP2 ⁽²⁾	—	—	—	Y	—
RF0	18	AN16	—	—	—	—	—	—	VCAP
RF1	17	AN6	—	—	—	—	—	—	—
RF2	16	AN7	—	—	—	—	—	—	—
RF3	15	AN8	—	—	—	—	—	—	—
RF4	14	AN9	—	—	—	—	—	—	—
RF5	13	AN10	—	—	—	—	—	—	—
RF6	12	AN11	—	—	—	—	—	—	—
RF7	11	AN5	—	—	—	SS1	—	—	—
RG0	3	—	—	CCP3	—	—	—	—	—
RG1	4	AN15	—	—	TX2/CK2	—	—	—	—
RG2	5	AN14	—	—	RX2/DT2	—	—	—	—
RG3	6	AN13	—	CCP4	—	—	—	—	—
RG4	8	AN12	T5G	CCP5	—	—	—	—	—
RG5	7	—	—	—	—	—	—	Y ⁽³⁾	MCLR/VPP
VDD	10, 26, 38, 57	—	—	—	—	—	—	—	VDD
VSS	9, 25, 41, 56	—	—	—	—	—	—	—	VSS
AVDD	19	—	—	—	—	—	—	—	AVDD
AVSS	20	—	—	—	—	—	—	—	AVSS

Note 1: Peripheral pin location selected using APFCON register. Default Location.

2: Peripheral pin location selected using APFCON register. Alternate Location.

3: Weak pull-up is always enabled when MCLR is enabled, otherwise the pull-up is under user control.

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PIC16(L)F1526/27

NOTES:

1.0 DEVICE OVERVIEW

The PIC16(L)F1526/27 are described within this data sheet. They are available in 64-pin packages. [Figure 1-1](#) shows a block diagram of the PIC16(L)F1526/27 devices.

[Table 1-2](#) shows the pinout descriptions.

Reference [Table 1-1](#) for peripherals available per device.

TABLE 1-1: DEVICE PERIPHERAL SUMMARY

Peripheral		PIC16F1526 PIC16LF1526	PIC16F1527 PIC16LF1527
ADC		•	•
EUSART		•	•
Fixed Voltage Reference (FVR)		•	•
Temperature Indicator		•	•
Capture/Compare/PWM Modules			
	CCP1	•	•
	CCP2	•	•
	CCP3	•	•
	CCP4	•	•
	CCP5	•	•
	CCP6	•	•
	CCP7	•	•
	CCP8	•	•
	CCP9	•	•
	CCP10	•	•
EUSARTs			
	EUSART1	•	•
	EUSART2	•	•
Master Synchronous Serial Ports			
	MSSP1	•	•
	MSSP2	•	•
Timers			
	Timer0	•	•
	Timer1/3/5	•	•
	Timer2/4/6 /8/10	•	•

PIC16(L)F1526/27

FIGURE 1-1: PIC16(L)F1526/27 BLOCK DIAGRAM

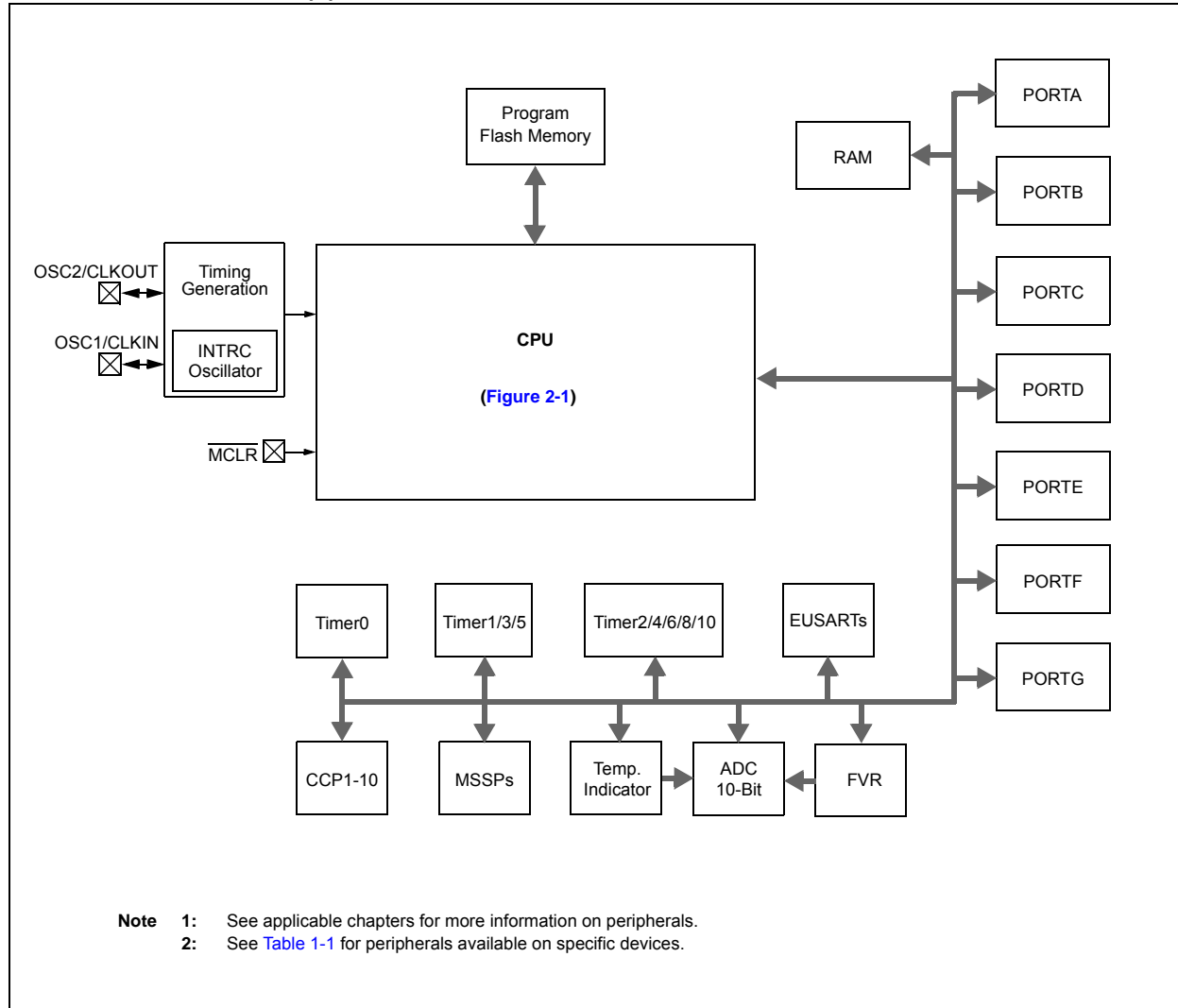


TABLE 1-2: PIC16(L)F1526 PINOUT DESCRIPTION

Name	Function	Input Type	Output Type	Description
RA0/AN0	RA0	TTL	CMOS	General purpose I/O.
	AN0	AN	—	A/D Channel 0 input.
RA1/AN1	RA1	TTL	CMOS	General purpose I/O.
	AN1	AN	—	A/D Channel 1 input.
RA2/AN2	RA2	TTL	CMOS	General purpose I/O.
	AN2	AN	—	A/D Channel 2 input.
RA3/AN3/VREF+	RA3	TTL	CMOS	General purpose I/O.
	AN3	AN	—	A/D Channel 3 input.
	VREF+	AN	—	A/D Positive Voltage Reference input.
RA4/T0CKI	RA4	TTL	CMOS	General purpose I/O.
	T0CKI	ST	—	Timer0 clock input.
RA5/AN4/T3G	RA5	TTL	CMOS	General purpose I/O.
	AN4	AN	—	A/D Channel 4 input.
	T3G	ST	—	Timer3 gate input.
RA6/OSC2/CLKOUT	RA6	TTL	CMOS	General purpose I/O.
	OSC2	—	XTAL	Crystal/Resonator (LP, XT, HS modes).
	CLKOUT	—	CMOS	Fosc/4 output.
RA7/OSC1/CLKIN	RA7	TTL	CMOS	General purpose I/O.
	OSC1	XTAL	—	Crystal/Resonator (LP, XT, HS modes).
	CLKIN	ST	—	External clock input (EC mode).
RB0/AN17/INT	RB0	TTL	CMOS	General purpose I/O with IOC and WPU.
	AN17	AN	—	A/D Channel 17 input.
	INT	ST	—	External interrupt.
RB1/AN18	RB1	TTL	CMOS	General purpose I/O with IOC and WPU.
	AN18	AN	—	A/D Channel 18 input.
RB2/AN19	RB2	TTL	CMOS	General purpose I/O with IOC and WPU.
	AN19	AN	—	A/D Channel 19 input.
RB3/AN20	RB3	TTL	CMOS	General purpose I/O with IOC and WPU.
	AN20	AN	—	A/D Channel 20 input.
RB4/AN21/T3CKI ⁽²⁾	RB4	TTL	CMOS	General purpose I/O with IOC and WPU.
	AN21	AN	—	A/D Channel 21 input.
	T3CKI	ST	—	Timer3 clock input.
RB5/AN22/T1G/T3CKI ⁽¹⁾	RB5	TTL	CMOS	General purpose I/O with IOC and WPU.
	AN22	AN	—	A/D Channel 22 input.
	T1G	ST	—	Timer1 gate input.
	T3CKI	ST	—	Timer3 clock input.
RB6/ICSPCLK/ICDCLK	RB6	TTL	CMOS	General purpose I/O with IOC and WPU.
	ICSPCLK	ST	—	Serial Programming Clock.
	ICDCLK	ST	—	In-Circuit Debug Clock.

Legend: AN = Analog input or output CMOS = CMOS compatible input or output OD = Open Drain
TTL = TTL compatible input ST = Schmitt Trigger input with CMOS levels I²C™ = Schmitt Trigger input with I²C levels
HV = High Voltage XTAL = Crystal

- Note** 1: Peripheral pin location selected using APFCON register. Default location.
2: Peripheral pin location selected using APFCON register. Alternate location.
3: RC3, RC4, RD5 and RD6 read the I²C ST input when I²C mode is enabled.

PIC16(L)F1526/27

TABLE 1-2: PIC16(L)F1526 PINOUT DESCRIPTION (CONTINUED)

Name	Function	Input Type	Output Type	Description
RB7/ICSPDAT/ICDDAT	RB7	TTL	CMOS	General purpose I/O with IOC and WPU.
	ICSPDAT	ST	CMOS	ICSP™ Data I/O.
	ICDDAT	ST	CMOS	In-Circuit Data I/O.
RC0/SOSCO/T1CKI	RC0	ST	CMOS	General purpose I/O.
	SOSCO	XTAL	XTAL	Timer1/3/5 oscillator connection.
	T1CKI	ST	—	Timer1/3/5 clock input.
RC1/SOSCI/CCP2 ⁽¹⁾	RC1	ST	CMOS	General purpose I/O.
	SOSCI	XTAL	XTAL	Timer1/3/5 oscillator connection.
	CCP2	ST	CMOS	Capture/Compare/PWM2.
RC2/CCP1	RC2	ST	CMOS	General purpose I/O.
	CCP1	ST	CMOS	Capture/Compare/PWM1.
RC3/SCK1/SCL1 ⁽³⁾	RC3	ST	CMOS	General purpose I/O.
	SCK1	ST	CMOS	SPI clock.
	SCL1	I ² C™	OD	I ² C™ clock.
RC4/SDI1/SDA1 ⁽³⁾	RC4	ST	CMOS	General purpose I/O.
	SDI1	ST	—	SPI data input.
	SDA1	I ² C™	OD	I ² C™ data input/output.
RC5/SDO1	RC5	ST	CMOS	General purpose I/O.
	SDO1	—	CMOS	SPI data output.
RC6/TX1/CK1	RC6	ST	CMOS	General purpose I/O.
	TX1	—	CMOS	USART1 asynchronous transmit.
	CK1	ST	CMOS	USART1 synchronous clock.
RC7/RX1/DT1	RC7	ST	CMOS	General purpose I/O.
	RX1	ST	—	USART1 asynchronous input.
	DT1	ST	CMOS	USART1 synchronous data.
RDO/AN23	RD0	ST	CMOS	General purpose I/O with WPU.
	AN23	AN	—	A/D Channel 23 input.
RD1/AN24/T5CKI	RD1	ST	CMOS	General purpose I/O with WPU.
	AN24	AN	—	A/D Channel 24 input.
	T5CKI	ST	—	Timer5 clock input.
RD2/AN25	RD2	ST	CMOS	General purpose I/O with WPU.
	AN25	AN	—	A/D Channel 25 input.
RD3/AN26	RD3	ST	CMOS	General purpose I/O with WPU.
	AN26	AN	—	A/D Channel 26 input.
RD4/SDO2	RD4	ST	CMOS	General purpose I/O with WPU.
	SDO2	—	CMOS	SPI data output.
RD5/SDI2/SDA2 ⁽³⁾	RD5	ST	CMOS	General purpose I/O with WPU.
	SDI2	ST	—	SPI data input.
	SDA2	I ² C	OD	I ² C™ data input/output.

Legend: AN = Analog input or output CMOS = CMOS compatible input or output OD = Open Drain
TTL = TTL compatible input ST = Schmitt Trigger input with CMOS levels I²C™ = Schmitt Trigger input with I²C levels
HV = High Voltage XTAL = Crystal

Note 1: Peripheral pin location selected using APFCON register. Default location.
2: Peripheral pin location selected using APFCON register. Alternate location.
3: RC3, RC4, RD5 and RD6 read the I²C ST input when I²C mode is enabled.

TABLE 1-2: PIC16(L)F1526 PINOUT DESCRIPTION (CONTINUED)

Name	Function	Input Type	Output Type	Description
RD6/SCK2/SCL2 ⁽³⁾	RD6	ST	CMOS	General purpose I/O with WPU.
	SCK2	ST	CMOS	SPI clock.
	SCL2	I ² C	OD	I ² C™ clock.
RD7/SS2	RD7	ST	CMOS	General purpose I/O with WPU.
	SS2	ST	—	Slave Select input.
RE0/AN27	RE0	ST	CMOS	General purpose I/O with WPU.
	AN27	AN	—	A/D Channel 27 input.
RE1/AN28	RE1	ST	CMOS	General purpose I/O with WPU.
	AN28	AN	—	A/D Channel 28 input.
RE2/AN29/CCP10	RE2	ST	CMOS	General purpose I/O with WPU.
	AN29	AN	—	A/D Channel 29 input.
	CCP10	ST	CMOS	Capture/Compare/PWM10.
RE3/CCP9	RE3	ST	CMOS	General purpose I/O with WPU.
	CCP9	ST	CMOS	Capture/Compare/PWM9.
RE4/CCP8	RE4	ST	CMOS	General purpose I/O with WPU.
	CCP8	ST	CMOS	Capture/Compare/PWM8.
RE5/CCP7	RE5	ST	CMOS	General purpose I/O with WPU.
	CCP7	ST	CMOS	Capture/Compare/PWM7.
RE6/CCP6	RE6	ST	CMOS	General purpose I/O with WPU.
	CCP6	ST	CMOS	Capture/Compare/PWM6.
RE7/CCP2 ⁽²⁾	RE7	ST	CMOS	General purpose I/O with WPU.
	CCP2	ST	CMOS	Capture/Compare/PWM2.
RF0/AN16/VCAP	RF0	ST	CMOS	General purpose I/O.
	AN16	AN	—	A/D Channel 16 input.
	VCAP	Power	Power	Filter capacitor for Voltage Regulator.
RF1/AN6	RF1	ST	CMOS	General purpose I/O.
	AN6	AN	—	A/D Channel 6 input.
RF2/AN7	RF2	ST	CMOS	General purpose I/O.
	AN7	AN	—	A/D Channel 7 input.
RF3/AN8	RF3	ST	CMOS	General purpose I/O.
	AN8	AN	—	A/D Channel 8 input.
RF4/AN9	RF4	ST	CMOS	General purpose I/O.
	AN9	AN	—	A/D Channel 9 input.
RF5/AN10	RF5	ST	CMOS	General purpose I/O.
	AN10	AN	—	A/D Channel 10 input.
RF6/AN11	RF6	ST	CMOS	General purpose I/O.
	AN11	AN	—	A/D Channel 11 input.
RF7/AN5/SS1	RF7	ST	CMOS	General purpose I/O.
	AN5	AN	—	A/D Channel 5 input.
	SS1	ST	—	Slave Select input.

Legend: AN = Analog input or output CMOS = CMOS compatible input or output OD = Open Drain
TTL = TTL compatible input ST = Schmitt Trigger input with CMOS levels I²C™ = Schmitt Trigger input with I²C levels
HV = High Voltage XTAL = Crystal

- Note** 1: Peripheral pin location selected using APFCON register. Default location.
2: Peripheral pin location selected using APFCON register. Alternate location.
3: RC3, RC4, RD5 and RD6 read the I²C ST input when I²C mode is enabled.

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TABLE 1-2: PIC16(L)F1526 PINOUT DESCRIPTION (CONTINUED)

Name	Function	Input Type	Output Type	Description
RG0/CCP3	RG0	ST	CMOS	General purpose I/O.
	CCP3	ST	CMOS	Capture/Compare/PWM3.
RG1/AN15/TX2/CK2	RG1	ST	CMOS	General purpose I/O.
	AN15	AN	—	A/D Channel 15 input.
	TX2	—	CMOS	USART2 asynchronous transmit.
	CK2	ST	CMOS	USART2 synchronous clock.
RG2/AN14/RX2/DT2	RG2	ST	CMOS	General purpose I/O.
	AN14	AN	—	A/D Channel 14 input.
	RX2	ST	—	USART2 asynchronous input.
	DT2	ST	CMOS	USART2 synchronous data.
RG3/AN13/CCP4	RG3	ST	CMOS	General purpose I/O.
	AN13	AN	—	A/D Channel 13 input.
	CCP4	ST	CMOS	Capture/Compare/PWM4.
RG4/AN12/T5G/CCP5	RG4	ST	—	General purpose input.
	AN12	AN	—	A/D Channel 12 input.
	T5G	ST	—	Timer5 gate input.
	CCP5	ST	CMOS	Capture/Compare/PWM5.
RG5/ $\overline{\text{MCLR}}$ /VPP	RG5	ST	—	General purpose input with WPU.
	$\overline{\text{MCLR}}$	ST	—	Master Clear with internal pull-up.
	VPP	HV	—	Programming voltage.
AVDD	AVDD	Power	—	Analog positive supply.
AVSS	AVSS	Power	—	Analog ground reference.
VDD	VDD	Power	—	Positive supply.
VSS	VSS	Power	—	Ground reference.

Legend: AN = Analog input or output CMOS = CMOS compatible input or output OD = Open Drain
 TTL = TTL compatible input ST = Schmitt Trigger input with CMOS levels I²C™ = Schmitt Trigger input with I²C levels
 HV = High Voltage XTAL = Crystal

- Note** 1: Peripheral pin location selected using APFCON register. Default location.
 2: Peripheral pin location selected using APFCON register. Alternate location.
 3: RC3, RC4, RD5 and RD6 read the I²C ST input when I²C mode is enabled.

2.0 ENHANCED MID-RANGE CPU

This family of devices contain an enhanced mid-range 8-bit CPU core. The CPU has 49 instructions. Interrupt capability includes automatic context saving. The hardware stack is 16 levels deep and has Overflow and Underflow Reset capability. Direct, Indirect, and Relative Addressing modes are available. Two File Select Registers (FSRs) provide the ability to read program and data memory.

- Automatic Interrupt Context Saving
- 16-level Stack with Overflow and Underflow
- File Select Registers
- Instruction Set

2.1 Automatic Interrupt Context Saving

During interrupts, certain registers are automatically saved in shadow registers and restored when returning from the interrupt. This saves stack space and user code. See [Section 7.5 “Automatic Context Saving”](#), for more information.

2.2 16-level Stack with Overflow and Underflow

These devices have an external stack memory 15 bits wide and 16 words deep. A Stack Overflow or Underflow will set the appropriate bit (STKOVF or STKUNF) in the PCON register, and if enabled will cause a software Reset. See [Section 3.4 “Stack”](#) for more details.

2.3 File Select Registers

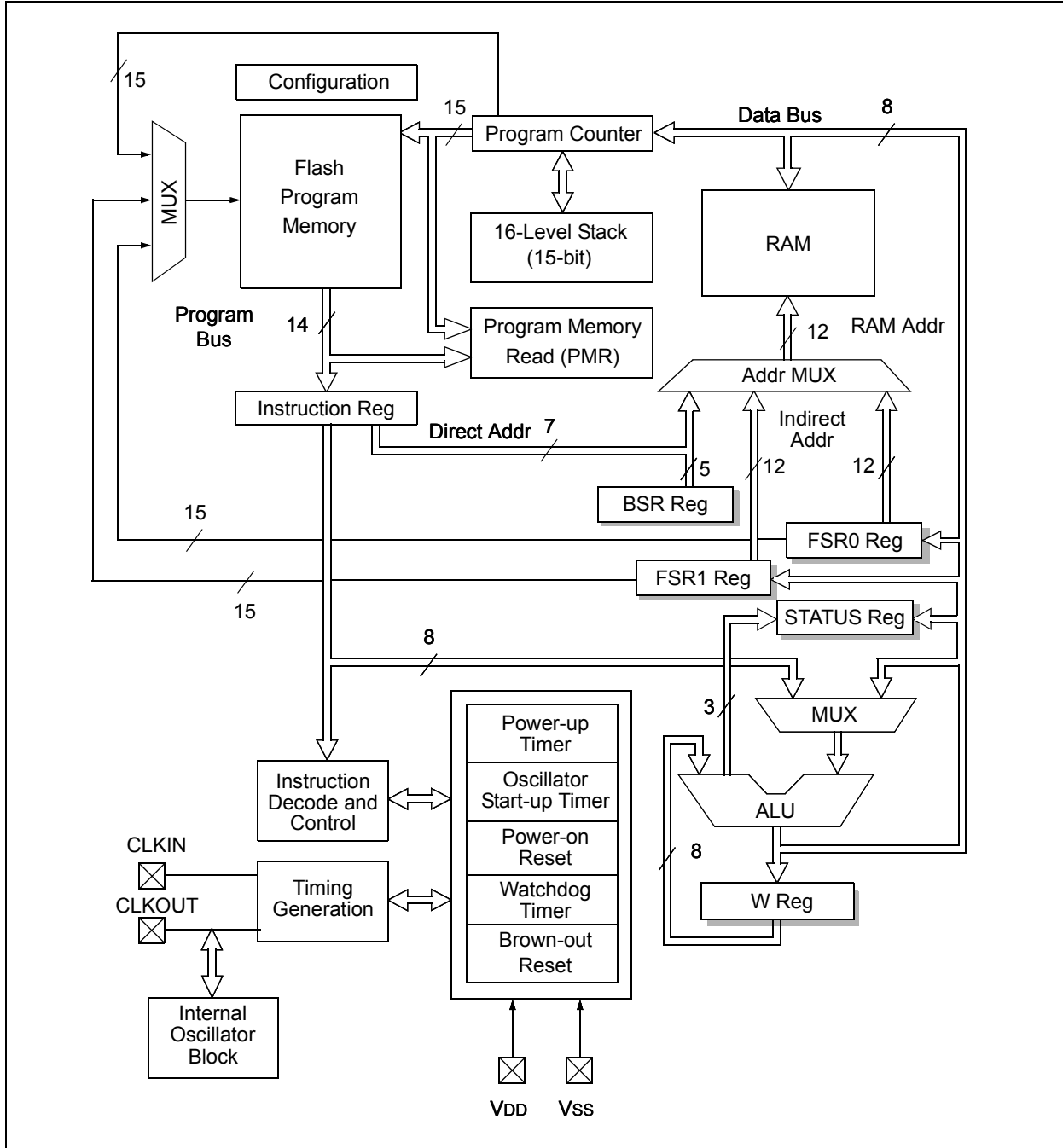
There are two 16-bit File Select Registers (FSR). FSRs can access all file registers and program memory, which allows one Data Pointer for all memory. When an FSR points to program memory, there is one additional instruction cycle in instructions using INDF to allow the data to be fetched. General purpose memory can now also be addressed linearly, providing the ability to access contiguous data larger than 80 bytes. There are also new instructions to support the FSRs. See [Section 3.5 “Indirect Addressing”](#) for more details.

2.4 Instruction Set

There are 49 instructions for the enhanced mid-range CPU to support the features of the CPU. See [Section 24.0 “Instruction Set Summary”](#) for more details.

PIC16(L)F1526/27

FIGURE 2-1: CORE BLOCK DIAGRAM



3.0 MEMORY ORGANIZATION

These devices contain the following types of memory:

- Program Memory
 - Configuration Words
 - Device ID
 - User ID
 - Flash Program Memory
- Data Memory
 - Core Registers
 - Special Function Registers
 - General Purpose RAM
 - Common RAM

The following features are associated with access and control of program memory and data memory:

- PCL and PCLATH
- Stack
- Indirect Addressing

3.1 Program Memory Organization

The enhanced mid-range core has a 15-bit program counter capable of addressing a 32K x 14 program memory space. [Table 3-1](#) shows the memory sizes implemented for the PIC16(L)F1526/27 family. Accessing a location above these boundaries will cause a wrap-around within the implemented memory space. The Reset vector is at 0000h and the interrupt vector is at 0004h (see [Figure 3-1](#) and [Figure 3-2](#)).

TABLE 3-1: DEVICE SIZES AND ADDRESSES

Device	Program Memory Space (Words)	Last Program Memory Address
PIC16F1526 PIC16LF1526	8,192	1FFFh
PIC16F1527 PIC16LF1527	16,384	3FFFh

PIC16(L)F1526/27

FIGURE 3-1: PROGRAM MEMORY MAP AND STACK FOR PIC16(L)F1526

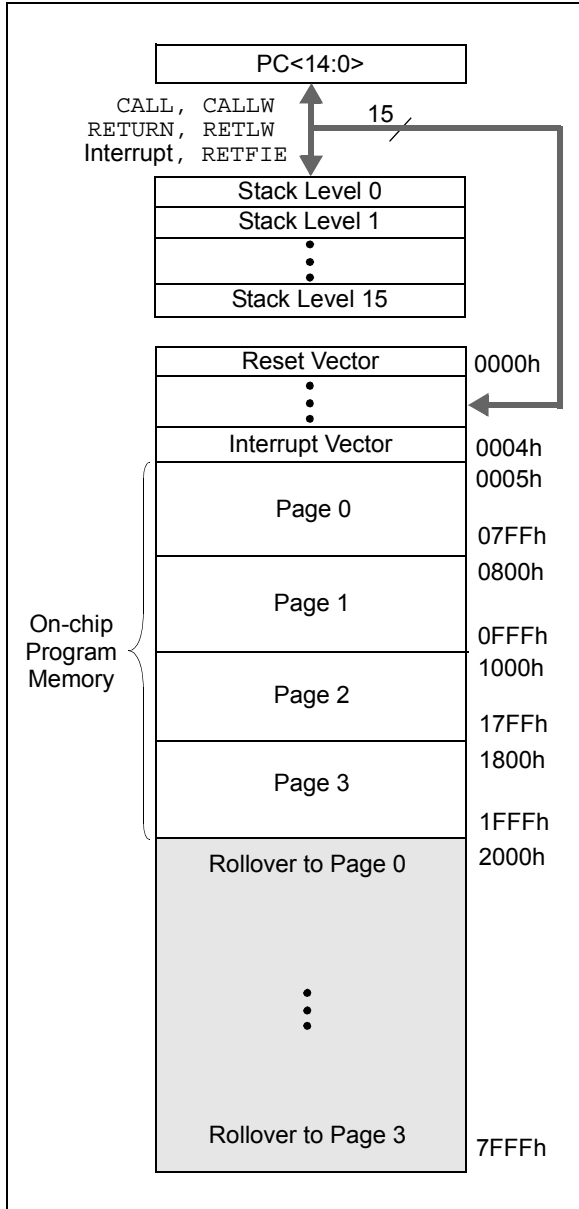
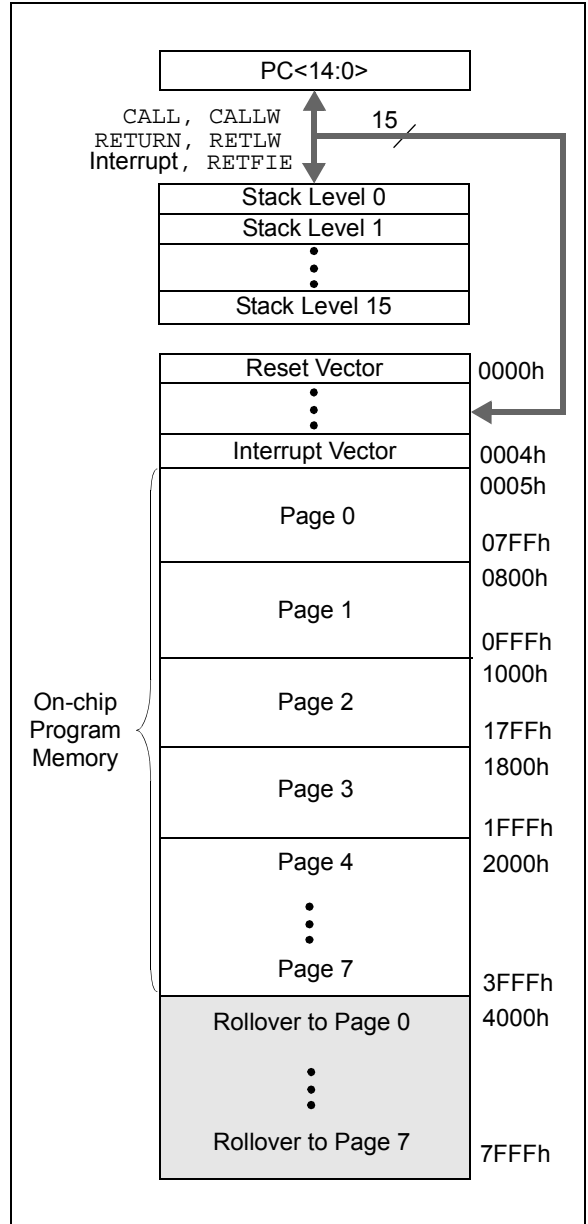


FIGURE 3-2: PROGRAM MEMORY MAP AND STACK FOR PIC16(L)F1527



3.1.1 READING PROGRAM MEMORY AS DATA

There are two methods of accessing constants in program memory. The first method is to use tables of RETLW instructions. The second method is to set an FSR to point to the program memory.

3.1.1.1 RETLW Instruction

The RETLW instruction can be used to provide access to tables of constants. The recommended way to create such a table is shown in [Example 3-1](#).

EXAMPLE 3-1: RETLW INSTRUCTION

```
constants
    BRW                ;Add Index in W to
                       ;program counter to
                       ;select data
    RETLW DATA0       ;Index0 data
    RETLW DATA1       ;Index1 data
    RETLW DATA2
    RETLW DATA3

my_function
    ;... LOTS OF CODE...
    MOVLW DATA_INDEX
    CALL constants
    ;... THE CONSTANT IS IN W
```

The BRW instruction makes this type of table very simple to implement. If your code must remain portable with previous generations of microcontrollers, then the BRW instruction is not available so the older table read method must be used.

3.1.1.2 Indirect Read with FSR

The program memory can be accessed as data by setting bit 7 of the FSRxH register and reading the matching INDFx register. The MOVIW instruction will place the lower 8 bits of the addressed word in the W register. Writes to the program memory cannot be performed via the INDF registers. Instructions that access the program memory via the FSR require one extra instruction cycle to complete. [Example 3-2](#) demonstrates accessing the program memory via an FSR.

The HIGH directive will set bit<7> if a label points to a location in program memory.

EXAMPLE 3-2: ACCESSING PROGRAM MEMORY VIA FSR

```
constants
    RETLW DATA0       ;Index0 data
    RETLW DATA1       ;Index1 data
    RETLW DATA2
    RETLW DATA3

my_function
    ;... LOTS OF CODE...
    MOVLW LOW constants
    MOVWF FSR1L
    MOVLW HIGH constants
    MOVWF FSR1H
    MOVIW 0[FSR1]
    ;THE PROGRAM MEMORY IS IN W
```

PIC16(L)F1526/27

3.2 Data Memory Organization

The data memory is partitioned in 32 memory banks with 128 bytes in a bank. Each bank consists of (Figure 3-3):

- 12 core registers
- 20 Special Function Registers (SFR)
- Up to 80 bytes of General Purpose RAM (GPR)
- 16 bytes of common RAM

The active bank is selected by writing the bank number into the Bank Select Register (BSR). Unimplemented memory will read as '0'. All data memory can be accessed either directly (via instructions that use the file registers) or indirectly via the two File Select Registers (FSR). See [Section 3.5 "Indirect Addressing"](#) for more information.

Data memory uses a 12-bit address. The upper 7-bit of the address define the Bank address and the lower 5-bits select the registers/RAM in that bank.

3.2.1 CORE REGISTERS

The core registers contain the registers that directly affect the basic operation. The core registers occupy the first 12 addresses of every data memory bank (addresses x00h/x08h through x0Bh/x8Bh). These registers are listed below in [Table 3-2](#). For detailed information, see [Table 3-4](#).

TABLE 3-2: CORE REGISTERS

Addresses	BANKx
x00h or x80h	INDF0
x01h or x81h	INDF1
x02h or x82h	PCL
x03h or x83h	STATUS
x04h or x84h	FSR0L
x05h or x85h	FSR0H
x06h or x86h	FSR1L
x07h or x87h	FSR1H
x08h or x88h	BSR
x09h or x89h	WREG
x0Ah or x8Ah	PCLATH
x0Bh or x8Bh	INTCON

3.2.1.1 STATUS Register

The STATUS register, shown in [Register 3-1](#), contains:

- the arithmetic status of the ALU
- the Reset status

The STATUS register can be the destination for any instruction, like any other register. If the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the $\overline{\text{TO}}$ and $\overline{\text{PD}}$ bits are not writable. Therefore, the result of an instruction with the STATUS register as destination may be different than intended.

For example, `CLRF STATUS` will clear the upper three bits and set the Z bit. This leaves the STATUS register as '000u u1uu' (where u = unchanged).

It is recommended, therefore, that only `BCF`, `BSF`, `SWAPF` and `MOVWF` instructions are used to alter the STATUS register, because these instructions do not affect any Status bits. For other instructions not affecting any Status bits (Refer to [Section 24.0 "Instruction Set Summary"](#)).

Note 1: The C and DC bits operate as Borrow and Digit Borrow out bits, respectively, in subtraction.

REGISTER 3-1: STATUS: STATUS REGISTER

U-0	U-0	U-0	R-1/q	R-1/q	R/W-0/u	R/W-0/u	R/W-0/u
—	—	—	$\overline{\text{TO}}$	$\overline{\text{PD}}$	Z	DC ⁽¹⁾	C ⁽¹⁾
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 7-5 **Unimplemented:** Read as '0'
- bit 4 **TO:** Time-out bit
1 = After power-up, `CLRWDT` instruction or `SLEEP` instruction
0 = A WDT time-out occurred
- bit 3 **PD:** Power-down bit
1 = After power-up or by the `CLRWDT` instruction
0 = By execution of the `SLEEP` instruction
- 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/Digit Borrow bit⁽¹⁾
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⁽¹⁾
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 two's complement of the second operand.

PIC16(L)F1526/27

3.2.2 SPECIAL FUNCTION REGISTER

The Special Function Registers are registers used by the application to control the desired operation of peripheral functions in the device. The Special Function Registers occupy the 20 bytes after the core registers of every data memory bank (addresses x0Ch/x8Ch through x1Fh/x9Fh). The registers associated with the operation of the peripherals are described in the appropriate peripheral chapter of this data sheet.

3.2.3 GENERAL PURPOSE RAM

There are up to 80 bytes of GPR in each data memory bank. The Special Function Registers occupy the 20 bytes after the core registers of every data memory bank (addresses x0Ch/x8Ch through x1Fh/x9Fh).

3.2.3.1 Linear Access to GPR

The general purpose RAM can be accessed in a non-banked method via the FSRs. This can simplify access to large memory structures. See [Section 3.5.2 “Linear Data Memory”](#) for more information.

3.2.4 COMMON RAM

There are 16 bytes of common RAM accessible from all banks.

FIGURE 3-3: BANKED MEMORY PARTITIONING



3.2.5 DEVICE MEMORY MAPS

The memory maps for PIC16(L)F1526/27 is shown in [Table 3-3](#).

TABLE 3-3: PIC16(L)F1526/27 MEMORY MAP

BANK 0		BANK 1		BANK 2		BANK 3		BANK 4		BANK 5		BANK 6		BANK 7	
000h	Core Registers (Table 3-2)	080h	Core Registers (Table 3-2)	100h	Core Registers (Table 3-2)	180h	Core Registers (Table 3-2)	200h	Core Registers (Table 3-2)	280h	Core Registers (Table 3-2)	300h	Core Registers (Table 3-2)	380h	Core Registers (Table 3-2)
00Bh		08Bh		10Bh		18Bh		20Bh		28Bh		30Bh		38Bh	
00Ch	PORTA	08Ch	TRISA	10Ch	LATA	18Ch	ANSELA	20Ch	—	28Ch	PORTF	30Ch	TRISF	38Ch	LATF
00Dh	PORTB	08Dh	TRISB	10Dh	LATB	18Dh	ANSELB	20Dh	WPUB	28Dh	PORTG	30Dh	TRISG	38Dh	LATG
00Eh	PORTC	08Eh	TRISC	10Eh	LATC	18Eh	—	20Eh	—	28Eh	—	30Eh	—	38Eh	—
00Fh	PORTD	08Fh	TRISD	10Fh	LATD	18Fh	ANSELD	20Fh	WPUD	28Fh	—	30Fh	—	38Fh	—
010h	PORTE	090h	TRISE	110h	LATE	190h	ANSELE	210h	WPUE	290h	—	310h	—	390h	—
011h	PIR1	091h	PIE1	111h	—	191h	PMADRL	211h	SSP1BUF	291h	CCPR1L	311h	CCPR3L	391h	—
012h	PIR2	092h	PIE2	112h	—	192h	PMADRH	212h	SSP1ADD	292h	CCPR1H	312h	CCPR3H	392h	—
013h	PIR3	093h	PIE3	113h	—	193h	PMDATL	213h	SSP1MSK	293h	CCP1CON	313h	CCP3CON	393h	—
014h	PIR4	094h	PIE4	114h	—	194h	PMDATH	214h	SSP1STAT	294h	—	314h	—	394h	IOCBP
015h	TMR0	095h	OPTION_REG	115h	—	195h	PMCON1	215h	SSP1CON1	295h	—	315h	—	395h	IOCBN
016h	TMR1L	096h	PCON	116h	BORCON	196h	PMCON2	216h	SSP1CON2	296h	—	316h	—	396h	IOCBF
017h	TMR1H	097h	WDTCON	117h	FVRCON	197h	VREGCON ⁽¹⁾	217h	SSP1CON3	297h	—	317h	—	397h	—
018h	T1CON	098h	—	118h	—	198h	—	218h	—	298h	CCPR2L	318h	CCPR4L	398h	—
019h	T1GCON	099h	OSCCON	119h	—	199h	RC1REG	219h	SSP2BUF	299h	CCPR2H	319h	CCPR4H	399h	—
01Ah	TMR2	09Ah	OSCSTAT	11Ah	—	19Ah	TX1REG	21Ah	SSP2ADD	29Ah	CCP2CON	31Ah	CCP4CON	39Ah	—
01Bh	PR2	09Bh	ADRESL	11Bh	—	19Bh	SP1BRG	21Bh	SSP2MSK	29Bh	—	31Bh	—	39Bh	—
01Ch	T2CON	09Ch	ADRESH	11Ch	—	19Ch	SP1BRGH	21Ch	SSP2STAT	29Ch	—	31Ch	CCPR5L	39Ch	—
01Dh	—	09Dh	ADCON0	11Dh	APFCON	19Dh	RC1STA	21Dh	SSP2CON1	29Dh	CCPTMRS0	31Dh	CCPR5H	39Dh	—
01Eh	—	09Eh	ADCON1	11Eh	—	19Eh	TX1STA	21Eh	SSP2CON2	29Eh	CCPTMRS1	31Eh	CCP5CON	39Eh	—
01Fh	—	09Fh	—	11Fh	—	19Fh	BAUD1CON	21Fh	SSP2CON3	29Fh	CCPTMRS2	31Fh	—	39Fh	—
020h	General Purpose Register 80 Bytes	0A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h	General Purpose Register 80 Bytes	220h	General Purpose Register 80 Bytes	2A0h	General Purpose Register 80 Bytes	320h	General Purpose Register 80 Bytes	3A0h	General Purpose Register 80 Bytes
06Fh		0EFh		16Fh		1EFh		26Fh		2EFh		36Fh		3EFh	
070h	Common RAM	0F0h	Common RAM (Accesses 70h – 7Fh)	170h	Common RAM (Accesses 70h – 7Fh)	1F0h	Common RAM (Accesses 70h – 7Fh)	270h	Common RAM (Accesses 70h – 7Fh)	2F0h	Common RAM (Accesses 70h – 7Fh)	370h	Common RAM (Accesses 70h – 7Fh)	3F0h	Common RAM (Accesses 70h – 7Fh)
07Fh		0FFh		17Fh		1FFh		27Fh		2FFh		37Fh		3FFh	

Legend: ■ = Unimplemented data memory locations, read as '0'.

Note 1: PIC16F1526/27 only.

TABLE 3-3: PIC16(L)F1526/27 MEMORY MAP (CONTINUED)

BANK 8		BANK 9		BANK 10		BANK 11		BANK 12		BANK 13		BANK 14		BANK 15	
400h	Core Registers (Table 3-2)	480h	Core Registers (Table 3-2)	500h	Core Registers (Table 3-2)	580h	Core Registers (Table 3-2)	600h	Core Registers (Table 3-2)	680h	Core Registers (Table 3-2)	700h	Core Registers (Table 3-2)	780h	Core Registers (Table 3-2)
40Bh	—	48Bh	—	50Bh	Unimplemented Read as '0'	58Bh	—	60Bh	—	68Bh	Unimplemented Read as '0'	70Bh	Unimplemented Read as '0'	78Bh	Unimplemented Read as '0'
40Ch	ANSELF	48Ch	—	50Ch		58Ch	—	60Ch	—	68Ch		70Ch		78Ch	
40Dh	ANSELG	48Dh	WPUFG	58Dh		—	60Dh	—	611h	CCPR6L		70Dh		78Dh	
40Eh	—	48Eh	—	58Eh		—	60Eh	—	612h	CCPR6H		70Eh		78Eh	
40Fh	—	48Fh	—	58Fh		—	60Fh	—	613h	CCP6CON		70Fh		78Fh	
410h	—	490h	—	590h		—	610h	—	614h	CCPR7L		710h		790h	
411h	TMR3L	491h	RC2REG	591h		—	611h	CCPR6L	615h	CCPR7H		711h		791h	
412h	TMR3H	492h	TX2REG	592h		—	612h	CCPR6H	616h	CCP7CON		712h		792h	
413h	T3CON	493h	SP2BRG	593h		—	613h	CCP6CON	617h	CCPR8L		713h		793h	
414h	T3GCON	494h	SP2BRGH	594h		—	614h	CCPR7L	618h	CCPR8H		714h		794h	
415h	TMR4	495h	RC2STA	595h		TMR8	615h	CCPR7H	619h	CCP8CON		715h		795h	
416h	PR4	496h	TX2STA	596h		PR8	616h	CCP7CON	61Ah	CCPR9L		716h		796h	
417h	T4CON	497h	BAUD2CON	597h		T8CON	617h	CCPR8L	61Bh	CCPR9H		717h		797h	
418h	TMR5L	498h	—	598h		—	618h	CCPR8H	61Ch	CCP9CON		718h		798h	
419h	TMR5H	499h	—	599h		—	619h	CCP8CON	61Dh	CCPR10L		719h		799h	
41Ah	T5CON	49Ah	—	59Ah		—	61Ah	CCPR9L	61Eh	CCPR10H		720h		800h	
41Bh	T5GCON	49Bh	—	59Bh	—	61Bh	CCPR9H	61Fh	CCP10CON	721h	801h				
41Ch	TMR6	49Ch	—	59Ch	TMR10	61Ch	CCP9CON	69Fh	General Purpose Register 80 Bytes ⁽¹⁾	722h	General Purpose Register 80 Bytes ⁽¹⁾				
41Dh	PR6	49Dh	—	59Dh	PR10	61Dh	CCPR10L	700h		General Purpose Register 80 Bytes ⁽¹⁾		723h	General Purpose Register 80 Bytes ⁽¹⁾		
41Eh	T6CON	49Eh	—	59Eh	T10CON	61Eh	CCPR10H	701h	General Purpose Register 80 Bytes ⁽¹⁾		724h	General Purpose Register 80 Bytes ⁽¹⁾			
41Fh	—	49Fh	—	59Fh	—	61Fh	CCP10CON	702h		General Purpose Register 80 Bytes ⁽¹⁾	725h		General Purpose Register 80 Bytes ⁽¹⁾		
420h	General Purpose Register 80 Bytes	4A0h	General Purpose Register 32 Bytes	520h	General Purpose Register 80 Bytes ⁽¹⁾	620h	General Purpose Register 80 Bytes ⁽¹⁾	703h	General Purpose Register 80 Bytes ⁽¹⁾		726h	General Purpose Register 80 Bytes ⁽¹⁾			
46Fh		4BFh		General Purpose Register 48 Bytes ⁽¹⁾		56Fh		5EFh		66Fh	6EFh		76Fh		
470h	Common RAM (Accesses 70h – 7Fh)	4F0h	Common RAM (Accesses 70h – 7Fh)		570h	Common RAM (Accesses 70h – 7Fh)	670h	Common RAM (Accesses 70h – 7Fh)	704h	Common RAM (Accesses 70h – 7Fh)	727h	Common RAM (Accesses 70h – 7Fh)			
47Fh		4FFh		57Fh	5FFh		67Fh		6FFh		77Fh				

Legend: = Unimplemented data memory locations, read as '0'.

Note 1: PIC16(L)F1527 only.

TABLE 3-3: PIC16(L)F1526/27 MEMORY MAP (CONTINUED)

BANK 16		BANK 17		BANK 18		BANK 19		BANK 20		BANK 21		BANK 22		BANK 23						
800h	Core Registers (Table 3-2)	880h	Core Registers (Table 3-2)	900h	Core Registers (Table 3-2)	980h	Core Registers (Table 3-2)	A00h	Core Registers (Table 3-2)	A80h	Core Registers (Table 3-2)	B00h	Core Registers (Table 3-2)	B80h	Core Registers (Table 3-2)					
80Bh	Unimplemented Read as '0'	88Bh	Unimplemented Read as '0'	90Bh	Unimplemented Read as '0'	98Bh	Unimplemented Read as '0'	A0Bh	Unimplemented Read as '0'	A8Bh	Unimplemented Read as '0'	B0Bh	Unimplemented Read as '0'	B8Bh	Unimplemented Read as '0'					
80Ch		88Ch		90Ch		98Ch		A0Ch		A8Ch		B0Ch		B8Ch						
81Fh	General Purpose Register 80 Bytes ⁽¹⁾	89Fh	General Purpose Register 80 Bytes ⁽¹⁾	91Fh	General Purpose Register 80 Bytes ⁽¹⁾	96Fh		Common RAM (Accesses 70h – 7Fh)		A6Fh		Common RAM (Accesses 70h – 7Fh)		AEFh		Common RAM (Accesses 70h – 7Fh)	B6Fh	Common RAM (Accesses 70h – 7Fh)	BEFh	Common RAM (Accesses 70h – 7Fh)
820h		8A0h		920h		9F0h				A70h				AF0h			B70h		BF0h	
86Fh	Common RAM (Accesses 70h – 7Fh)	8EFh	Common RAM (Accesses 70h – 7Fh)	96Fh	Common RAM (Accesses 70h – 7Fh)	9EFh	Common RAM (Accesses 70h – 7Fh)	A6Fh	Common RAM (Accesses 70h – 7Fh)	AEFh	Common RAM (Accesses 70h – 7Fh)	B6Fh	Common RAM (Accesses 70h – 7Fh)	BEFh	Common RAM (Accesses 70h – 7Fh)					
870h		8F0h		970h		9F0h		A70h		AF0h		B70h		BF0h						
87Fh		8FFh		97Fh		9FFh		A7Fh		AFh		B7Fh		BFh						
BANK 24		BANK 25		BANK 26		BANK 27		BANK 28		BANK 29		BANK 30								
C00h	Core Registers (Table 3-2)	C80h	Core Registers (Table 3-2)	D00h	Core Registers (Table 3-2)	D80h	Core Registers (Table 3-2)	E00h	Core Registers (Table 3-2)	E80h	Core Registers (Table 3-2)	F00h	Core Registers (Table 3-2)							
C0Bh	Unimplemented Read as '0'	C8Bh	Unimplemented Read as '0'	D0Bh	Unimplemented Read as '0'	D8Bh	Unimplemented Read as '0'	E0Bh	Unimplemented Read as '0'	E8Bh	Unimplemented Read as '0'	F0Bh	Unimplemented Read as '0'							
C0Ch		C8Ch		D0Ch		D8Ch		E0Ch		E8Ch		F0Ch								
C6Fh	Common RAM (Accesses 70h – 7Fh)	CEFh	Common RAM (Accesses 70h – 7Fh)	D6Fh	Common RAM (Accesses 70h – 7Fh)	DEFh	Common RAM (Accesses 70h – 7Fh)	E6Fh	Common RAM (Accesses 70h – 7Fh)	EEFh	Common RAM (Accesses 70h – 7Fh)	F6Fh	Common RAM (Accesses 70h – 7Fh)							
C70h		CF0h		D70h		DF0h		E70h		EF0h		F70h								
C7Fh		CFh		D7Fh		DFh		E7Fh		EFh		F7Fh								

Legend: ■ = Unimplemented data memory locations, read as '0'.

Note 1: PIC16(L)F1527 only.

TABLE 3-3: PIC16(L)F1526 MEMORY MAP (CONTINUED)

Bank 31	
F80h	Core Registers (Table 3-2)
F8Bh F8Ch	Unimplemented Read as '0'
FE3h	STATUS_SHAD
FE4h	WREG_SHAD
FE5h	BSR_SHAD
FE6h	PCLATH_SHAD
FE7h	FSROL_SHAD
FE8h	FSR0H_SHAD
FE9h	FSR1L_SHAD
FEAh	FSR1H_SHAD
FEBh	—
FECh	—
FEDh	STKPTR
FEEh	TOSL
FEFh	TOSH
FF0h	Common RAM (Accesses 70h – 7Fh)
FFFh	

Legend: = Unimplemented data memory locations, read as '0'.

3.2.6 CORE FUNCTION REGISTERS SUMMARY

The Core Function registers listed in [Table 3-4](#) can be addressed from any Bank.

TABLE 3-4: CORE FUNCTION REGISTERS SUMMARY

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets	
Bank 0-31												
x00h or x80h	INDF0	Addressing this location uses contents of FSR0H/FSR0L to address data memory (not a physical register)								xxxx xxxx	uuuu uuuu	
x01h or x81h	INDF1	Addressing this location uses contents of FSR1H/FSR1L to address data memory (not a physical register)								xxxx xxxx	uuuu uuuu	
x02h or x82h	PCL	Program Counter (PC) Least Significant Byte								0000 0000	0000 0000	
x03h or x83h	STATUS	—	—	—	\overline{TO}	\overline{PD}	Z	DC	C	---1 1000	---q ruuu	
x04h or x84h	FSR0L	Indirect Data Memory Address 0 Low Pointer								0000 0000	uuuu uuuu	
x05h or x85h	FSR0H	Indirect Data Memory Address 0 High Pointer								0000 0000	0000 0000	
x06h or x86h	FSR1L	Indirect Data Memory Address 1 Low Pointer								0000 0000	uuuu uuuu	
x07h or x87h	FSR1H	Indirect Data Memory Address 1 High Pointer								0000 0000	0000 0000	
x08h or x88h	BSR	—	—	—	BSR4	BSR3	BSR2	BSR1	BSR0	---0 0000	---0 0000	
x09h or x89h	WREG	Working Register								0000 0000	uuuu uuuu	
x0Ah or x8Ah	PCLATH	—	Write Buffer for the upper 7 bits of the Program Counter								-000 0000	-000 0000
x0Bh or x8Bh	INTCON	GIE	PEIE	TMR0IE	INTE	IOCF	TMR0IF	INTF	IOCF	0000 0000	0000 0000	

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

PIC16(L)F1526/27

TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets
Bank 0											
00Ch	PORTA	PORTA Data Latch when written: PORTA pins when read								xxxx xxxx	uuuu uuuu
00Dh	PORTB	PORTB Data Latch when written: PORTB pins when read								xxxx xxxx	uuuu uuuu
00Eh	PORTC	PORTC Data Latch when written: PORTC pins when read								xxxx xxxx	uuuu uuuu
00Fh	PORTD	PORTD Data Latch when written: PORTD pins when read								xxxx xxxx	uuuu uuuu
010h	PORTE	PORTE Data Latch when written: PORTE pins when read								xxxx xxxx	uuuu uuuu
011h	PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	0000 0000	0000 0000
012h	PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	000- 0000	000- 0000
013h	PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	0000 0000	0000 0000
014h	PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	0000 0000	0000 0000
015h	TMR0	Timer0 Module Register								xxxx xxxx	uuuu uuuu
016h	TMR1L	Holding Register for the Least Significant Byte of the 16-bit TMR1 Register								xxxx xxxx	uuuu uuuu
017h	TMR1H	Holding Register for the Most Significant Byte of the 16-bit TMR1 Register								xxxx xxxx	uuuu uuuu
018h	T1CON	TMR1CS<1:0>		T1CKPS<1:0>		SOSCEN	T1SYNC	—	TMR1ON	0000 00-0	uuuu uu-u
019h	T1GCON	TMR1GE	T1GPOL	T1GTM	T1GSPM	T1GGO/DONE	T1GVAL	T1GSS<1:0>		0000 0x00	uuuu uxuu
01Ah	TMR2	Timer 2 Module Register								0000 0000	0000 0000
01Bh	PR2	Timer 2 Period Register								1111 1111	1111 1111
01Ch	T2CON	—	T2OUTPS<3:0>				TMR2ON	T2CKPS<1:0>		-000 0000	-000 0000
01Dh	—	Unimplemented								—	—
01Eh	—	Unimplemented								—	—
01Fh	—	Unimplemented								—	—
Bank 1											
08Ch	TRISA	PORTA Data Direction Register								1111 1111	1111 1111
08Dh	TRISB	PORTB Data Direction Register								1111 1111	1111 1111
08Eh	TRISC	PORTC Data Direction Register								1111 1111	1111 1111
08Fh	TRISD	PORTD Data Direction Register								1111 1111	1111 1111
090h	TRISE	PORTE Data Direction Register								1111 1111	1111 1111
091h	PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	0000 0000	0000 0000
092h	PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	000- 0000	000- 0000
093h	PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	0000 0000	0000 0000
094h	PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	0000 0000	0000 0000
095h	OPTION_REG	WPUEN	INTEDG	TMR0CS	TMR0SE	PSA	PS<2:0>		1111 1111	1111 1111	
096h	PCON	STKOVF	STKUNF	—	RWDT	RMCLR	RI	POR	BOR	00-1 11qq	qq-q qquu
097h	WDTCON	—	—	WDTPS<4:0>				SWDTEN	--01 0110	--01 0110	
098h	—	Unimplemented								—	—
099h	OSCCON	—	IRCF<3:0>				—	SCS<1:0>		-011 1-00	-011 1-00
09Ah	OSCSTAT	SOSCR	—	OSTS	HFIOFR	—	—	LFIOFR	HFIOFS	0-q0 --00	q-qq --0q
09Bh	ADRESL	A/D Result Register Low								xxxx xxxx	uuuu uuuu
09Ch	ADRESH	A/D Result Register High								xxxx xxxx	uuuu uuuu
09Dh	ADCON0	—	CHS<4:0>				GO/DONE	ADON	-000 0000	-000 0000	
09Eh	ADCON1	ADFM	ADCS<2:0>		—	—	ADPREF<1:0>		0000 --00	0000 --00	
09Fh	—	Unimplemented								—	—

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

- Note 1:** PIC16F1526/7 only.
Note 2: Unimplemented, read as '1'.

PIC16(L)F1526/27

TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets
Bank 2											
10Ch	LATA	PORTA Data Latch								xxxx xxxx	uuuu uuuu
10Dh	LATB	PORTB Data Latch								xxxx xxxx	uuuu uuuu
10Eh	LATC	PORTC Data Latch								xxxx xxxx	uuuu uuuu
10Fh	LATD	PORTD Data Latch								xxxx xxxx	uuuu uuuu
110h	LATE	PORTE Data Latch								xxxx xxxx	uuuu uuuu
111h to 115h	—	Unimplemented								—	—
116h	BORCON	SBOREN	BORFS	—	—	—	—	—	BORRDY	10-- ---q	uu-- ---u
117h	FVRCON	FVREN	FVRRDY	TSEN	TSRNG	—	—	ADFVR<1:0>		0q00 0000	0q00 0000
118h to 11Ch	—	Unimplemented								—	—
11Dh	APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	---- --00	---- --00
11Eh	—	Unimplemented								—	—
11Fh	—	Unimplemented								—	—

Bank 3

18Ch	ANSELA	—	—	ANSA5	—	ANSA3	ANSA2	ANSA1	ANSA0	--1- 1111	--1- 1111		
18Dh	ANSELB	—	—	ANSB5	ANSB4	ANSB3	ANSB2	ANSB1	ANSB0	--11 1111	--11 1111		
18Eh	ANSELC	Unimplemented								—	—		
18Fh	ANSELD	—	—	—	—	ANDS3	ANDS2	ANDS1	ANDS0	---- 1111	---- 1111		
190h	ANSELE	—	—	—	—	—	ANSE2	ANSE1	ANSE0	---- -111	---- -111		
191h	PMADRL	Program Memory Address Register Low Byte								0000 0000	0000 0000		
192h	PMADRH	—	Program Memory Address Register High Byte								1000 0000	1000 0000	
193h	PMDATL	Program Memory Data Register Low Byte								xxxx xxxx	uuuu uuuu		
194h	PMDATH	—	—	Program Memory Data Register High Byte								--xx xxxx	--uu uuuu
195h	PMCON1	—	CFGS	LWLO	FREE	WRERR	WREN	WR	RD	-000 x000	-000 q000		
196h	PMCON2	Program Memory control register 2								0000 0000	0000 0000		
197h	VREGCON ⁽¹⁾	—	—	—	—	—	—	VREGPM	Reserved	---- --01	---- --01		
198h	—	Unimplemented								—	—		
199h	RC1REG	USART Receive Data Register								0000 0000	0000 0000		
19Ah	TX1REG	USART Transmit Data Register								0000 0000	0000 0000		
19Bh	SP1BRG	BRG<7:0>								0000 0000	0000 0000		
19Ch	SP1BRGH	BRG<15:8>								0000 0000	0000 0000		
19Dh	RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	0000 000x	0000 000x		
19Eh	TX1STA	CSRC	TX9	TXEN	SYNC	SENDER	BRGH	TRMT	TX9D	0000 0010	0000 0010		
19Fh	BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	01-0 0-00	01-0 0-00		

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

- Note** 1: PIC16F1526/7 only.
2: Unimplemented, read as '1'.

PIC16(L)F1526/27

TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets
Bank 4											
20Ch	—	Unimplemented								—	—
20Dh	WPUB	WPUB7	WPUB6	WPUB5	WPUB4	WPUB3	WPUB2	WPUB1	WPUB0	1111 1111	1111 1111
20Eh	—	Unimplemented								—	—
20Fh	WPUD	WPUD7	WPUD6	WPUD5	WPUD4	WPUD3	WPUD2	WPUD1	WPUD0	1111 1111	1111 1111
210h	WPUE	WPUE7	WPUE6	WPUE5	WPUE4	WPUE3	WPUE2	WPUE1	WPUE0	1111 1111	1111 1111
211h	SSP1BUF	Synchronous Serial Port Receive Buffer/Transmit Register								xxxx xxxx	uuuu uuuu
212h	SSP1ADD	Synchronous Serial Port (I ² C mode) Address Register								0000 0000	0000 0000
213h	SSP1MSK	Synchronous Serial Port (I ² C mode) Address Mask Register								1111 1111	1111 1111
214h	SSP1STAT	SMP	CKE	D/Ā	P	S	R/W	UA	BF	0000 0000	0000 0000
215h	SSP1CON1	WCOL	SSPOV	SSPEN	CKP	SSPM<3:0>				0000 0000	0000 0000
216h	SSP1CON2	GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN	0000 0000	0000 0000
217h	SSP1CON3	ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN	0000 0000	0000 0000
218h	—	Unimplemented								—	—
219h	SSP2BUF	Synchronous Serial Port Receive Buffer/Transmit Register								xxxx xxxx	uuuu uuuu
21Ah	SSP2ADD	Synchronous Serial Port (I ² C mode) Address Register								0000 0000	0000 0000
21Bh	SSP2MSK	Synchronous Serial Port (I ² C mode) Address Mask Register								1111 1111	1111 1111
21Ch	SSP2STAT	SMP	CKE	D/Ā	P	S	R/W	UA	BF	0000 0000	0000 0000
21Dh	SSP2CON1	WCOL	SSPOV	SSPEN	CKP	SSPM<3:0>				0000 0000	0000 0000
21Eh	SSP2CON2	GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN	0000 0000	0000 0000
21Fh	SSP2CON3	ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN	0000 0000	0000 0000
Bank 5											
28Ch	PORTF	RF7	RF6	RF5	RF4	RF3	RF2	RF1	RF0	xxxx xxxx	uuuu uuuu
28Dh	PORTG	—	—	RG5	RG4	RG3	RG2	RG1	RG0	--xx xxxx	--uu uuuu
28Eh	—	Unimplemented								—	—
28Fh	—	Unimplemented								—	—
290h	—	Unimplemented								—	—
291h	CCPR1L	Capture/Compare/PWM Register 1 (LSB)								xxxx xxxx	uuuu uuuu
292h	CCPR1H	Capture/Compare/PWM Register 1 (MSB)								xxxx xxxx	uuuu uuuu
293h	CCP1CON	—	—	DC1B<1:0>			CCP1M<3:0>			--00 0000	--00 0000
294h	—	Unimplemented								—	—
295h	—	Unimplemented								—	—
296h	—	Unimplemented								—	—
297h	—	Unimplemented								—	—
298h	CCPR2L	Capture/Compare/PWM Register 2 (LSB)								xxxx xxxx	uuuu uuuu
299h	CCPR2H	Capture/Compare/PWM Register 2 (MSB)								xxxx xxxx	uuuu uuuu
29Ah	CCP2CON	—	—	DC2B<1:0>			CCP2M<3:0>			--00 0000	--00 0000
29Bh	—	Unimplemented								—	—
29Ch	—	Unimplemented								—	—
29Dh	CCPTMRS0	C4TSEL<1:0>		C3TSEL<1:0>		C2TSEL<1:0>		C1TSEL<1:0>		0000 0000	0000 0000
29Eh	CCPTMRS1	C8TSEL<1:0>		C7TSEL<1:0>		C6TSEL<1:0>		C5TSEL<1:0>		0000 0000	0000 0000
29Fh	CCPTMRS2	—	—	—	—	C10TSEL<1:0>		C9TSEL<1:0>		---- 0000	---- 0000

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

- Note 1:** PIC16F1526/7 only.
Note 2: Unimplemented, read as '1'.

PIC16(L)F1526/27

TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets
Bank 6											
30Ch	TRISF	TRISF7	TRISF6	TRISF5	TRISF4	TRISF3	TRISF2	TRISF1	TRISF0	1111 1111	1111 1111
30Dh	TRISG	—	—	— ⁽²⁾	TRISG4	TRISG3	TRISG2	TRISG1	TRISG0	--11 1111	--11 1111
30Eh	—	Unimplemented								—	—
30Fh	—	Unimplemented								—	—
310h	—	Unimplemented								—	—
311h	CCPR3L	Capture/Compare/PWM Register 3 (LSB)								xxxx xxxx	uuuu uuuu
312h	CCPR3H	Capture/Compare/PWM Register 3 (MSB)								xxxx xxxx	uuuu uuuu
313h	CCP3CON	—	—	DC3B<1:0>	CCP3M<3:0>					--00 0000	--00 0000
314h	—	Unimplemented								—	—
315h	—	Unimplemented								—	—
316h	—	Unimplemented								—	—
317h	—	Unimplemented								—	—
318h	CCPR4L	Capture/Compare/PWM Register 4 (LSB)								xxxx xxxx	uuuu uuuu
319h	CCPR4H	Capture/Compare/PWM Register 4 (MSB)								xxxx xxxx	uuuu uuuu
31Ah	CCP4CON	—	—	DC4B<1:0>	CCP4M<3:0>					--00 0000	--00 0000
31Bh	—	Unimplemented								—	—
31Ch	CCPR5L	Capture/Compare/PWM Register 5 (LSB)								xxxx xxxx	uuuu uuuu
31Dh	CCPR5H	Capture/Compare/PWM Register 5 (MSB)								xxxx xxxx	uuuu uuuu
31Eh	CCP5CON	—	—	DC5B<1:0>	CCP5M<3:0>					--00 0000	--00 0000
31Fh	—	Unimplemented								—	—
Bank 7											
38Ch	LATF	LATF7	LATF6	LATF5	LATF4	LATF3	LATF2	LATF1	LATF0	xxxx xxxx	uuuu uuuu
38Dh	LATG	—	—	—	LATG4	LATG3	LATG2	LATG1	LATG0	---x xxxx	---u uuuu
38Eh to 393h	—	Unimplemented								—	—
394h	IOCBP	IOCBP7	IOCBP6	IOCBP5	IOCBP4	IOCBP3	IOCBP2	IOCBP1	IOCBP0	0000 0000	0000 0000
395h	IOCBN	IOCBN7	IOCBN6	IOCBN5	IOCBN4	IOCBN3	IOCBN2	IOCBN1	IOCBN0	0000 0000	0000 0000
396h	IOCBF	IOCBF7	IOCBF6	IOCBF5	IOCBF4	IOCBF3	IOCBF2	IOCBF1	IOCBF0	0000 0000	0000 0000
397h to 39Fh	—	Unimplemented								—	—

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

- Note 1:** PIC16F1526/7 only.
Note 2: Unimplemented, read as '1'.

PIC16(L)F1526/27

TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets
Bank 8											
40Ch	ANSELF	ANSF7	ANSF6	ANSF5	ANSF4	ANSF3	ANSF2	ANSF1	ANSF0	1111 1111	1111 1111
40Dh	ANSELG	—	—	—	ANSG4	ANSG3	ANSG2	ANSG1	—	---1 111-	---1 111-
40Eh	—	Unimplemented								—	—
40Fh	—	Unimplemented								—	—
410h	—	Unimplemented								—	—
411h	TMR3L	Holding Register for the Least Significant Byte of the 16-bit TMR3 Register								xxxx xxxx	uuuu uuuu
412h	TMR3H	Holding Register for the Most Significant Byte of the 16-bit TMR3 Register								xxxx xxxx	uuuu uuuu
413h	T3CON	TMR3CS<1:0>		T3CKPS<1:0>		SOSCEN	T3SYN \bar{C}	—	TMR3ON	0000 00-0	uuuu uu-u
414h	T3GCON	TMR3GE	T3GPOL	T3GTM	T3GSPM	T3GGO/DONE	T3GVAL	T3GSS<1:0>		0000 0x00	uuuu uxuu
415h	TMR4	Timer 4 Module Register								0000 0000	0000 0000
416h	PR4	Timer 4 Period Register								1111 1111	1111 1111
417h	T4CON	—	T4OUTPS<3:0>				TMR4ON	T4CKPS<1:0>		-000 0000	-000 0000
418h	TMR5L	Holding Register for the Least Significant Byte of the 16-bit TMR5 Register								xxxx xxxx	uuuu uuuu
419h	TMR5H	Holding Register for the Most Significant Byte of the 16-bit TMR5 Register								xxxx xxxx	uuuu uuuu
41Ah	T5CON	TMR5CS<1:0>		T5CKPS<1:0>		SOSCEN	T5SYN \bar{C}	—	TMR5ON	0000 00-0	uuuu uu-u
41Bh	T5GCON	TMR5GE	T5GPOL	T5GTM	T5GSPM	T5GGO/DONE	T5GVAL	T5GSS<1:0>		0000 0x00	uuuu uxuu
41Ch	TMR6	Timer 6 Module Register								0000 0000	0000 0000
41Dh	PR6	Timer 6 Period Register								1111 1111	1111 1111
41Eh	T6CON	—	T6OUTPS<3:0>				TMR6ON	T6CKPS<1:0>		-000 0000	-000 0000
41Fh	—	Unimplemented								—	—
Bank 9											
48Ch	—	Unimplemented								—	—
48Dh	WPUG	—	—	WPUG5	—	—	—	—	—	--1- ----	--1- ----
48Dh to 490h	—	Unimplemented								—	—
491h	RC2REG	USART Receive Data Register								0000 0000	0000 0000
492h	TX2REG	USART Transmit Data Register								0000 0000	0000 0000
493h	SP2BRG	BRG<7:0>								0000 0000	0000 0000
494h	SP2BRGH	BRG<15:8>								0000 0000	0000 0000
495h	RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	0000 000x	0000 000x
496h	TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	0000 0010	0000 0010
497h	BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	01-0 0-00	01-0 0-00
498h to 49Fh	—	Unimplemented								—	—

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

- Note 1:** PIC16F1526/7 only.
Note 2: Unimplemented, read as '1'.

PIC16(L)F1526/27

TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets	
Bank 10												
50Ch — 51Fh	—	Unimplemented								—	—	
Bank 11												
58Ch — 594h	—	Unimplemented								—	—	
595h	TMR8	Timer 8 Module Register								0000 0000	0000 0000	
596h	PR8	Timer 8 Period Register								1111 1111	1111 1111	
597h	T8CON	—	T8OUTPS<3:0>				TMR8ON	T8CKPS<1:0>			-000 0000	-000 0000
598h — 59Bh	—	Unimplemented								—	—	
59Ch	TMR10	Timer 10 Module Register								0000 0000	0000 0000	
59Dh	PR10	Timer 10 Period Register								1111 1111	1111 1111	
59Eh	T10CON	—	T10OUTPS<3:0>				TMR10ON	T10CKPS<1:0>			-000 0000	-000 0000
59Fh	—	Unimplemented								—	—	
Bank 12												
60Ch — 610h	—	Unimplemented								—	—	
611h	CCPR6L	Capture/Compare/PWM Register 6 (LSB)								xxxx xxxx	uuuu uuuu	
612h	CCPR6H	Capture/Compare/PWM Register 6 (MSB)								xxxx xxxx	uuuu uuuu	
613h	CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>			--00 0000	--00 0000		
614h	CCPR7L	Capture/Compare/PWM Register 7 (LSB)								xxxx xxxx	uuuu uuuu	
615h	CCPR7H	Capture/Compare/PWM Register 7 (MSB)								xxxx xxxx	uuuu uuuu	
616h	CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>			--00 0000	--00 0000		
617h	CCPR8L	Capture/Compare/PWM Register 8 (LSB)								xxxx xxxx	uuuu uuuu	
618h	CCPR8H	Capture/Compare/PWM Register 8 (MSB)								xxxx xxxx	uuuu uuuu	
619h	CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>			--00 0000	--00 0000		
61Ah	CCPR9L	Capture/Compare/PWM Register 9 (LSB)								xxxx xxxx	uuuu uuuu	
61Bh	CCPR9H	Capture/Compare/PWM Register 9 (MSB)								xxxx xxxx	uuuu uuuu	
61Ch	CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>			--00 0000	--00 0000		
61Dh	CCPR10L	Capture/Compare/PWM Register 10 (LSB)								xxxx xxxx	uuuu uuuu	
61Eh	CCPR10H	Capture/Compare/PWM Register 10 (MSB)								xxxx xxxx	uuuu uuuu	
61Fh	CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>			--00 0000	--00 0000		
Bank 13-30												
x0Ch or x8Ch to x1Fh or x9Fh	—	Unimplemented								—	—	

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

- Note 1:** PIC16F1526/7 only.
Note 2: Unimplemented, read as '1'.

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TABLE 3-2: SPECIAL FUNCTION REGISTER SUMMARY (CONTINUED)

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets	
Bank 31												
F8Ch — FE3h	—	Unimplemented								—	—	
FE4h	STATUS_SHAD	—	—	—	—	—	Z_SHAD	DC_SHAD	C_SHAD	---- -xxx	---- -uuu	
FE5h	WREG_SHAD	Working Register Normal (Non-ICD) Shadow								xxxx xxxx	uuuu uuuu	
FE6h	BSR_SHAD	—	—	—	Bank Select Register Normal (Non-ICD) Shadow					---x xxxx	---u uuuu	
FE7h	PCLATH_SHAD	—	Program Counter Latch High Register Normal (Non-ICD) Shadow								-xxx xxxx	uuuu uuuu
FE8h	FSR0L_SHAD	Indirect Data Memory Address 0 Low Pointer Normal (Non-ICD) Shadow								xxxx xxxx	uuuu uuuu	
FE9h	FSR0H_SHAD	Indirect Data Memory Address 0 High Pointer Normal (Non-ICD) Shadow								xxxx xxxx	uuuu uuuu	
FEAh	FSR1L_SHAD	Indirect Data Memory Address 1 Low Pointer Normal (Non-ICD) Shadow								xxxx xxxx	uuuu uuuu	
FEBh	FSR1H_SHAD	Indirect Data Memory Address 1 High Pointer Normal (Non-ICD) Shadow								xxxx xxxx	uuuu uuuu	
FECh	—	Unimplemented								—	—	
FEDh	STKPTR	—	—	—	Current Stack Pointer					---1 1111	---1 1111	
FEEh	TOSL	Top of Stack Low byte								xxxx xxxx	uuuu uuuu	
FEFh	TOSH	—	Top of Stack High byte								-xxx xxxx	-uuu uuuu

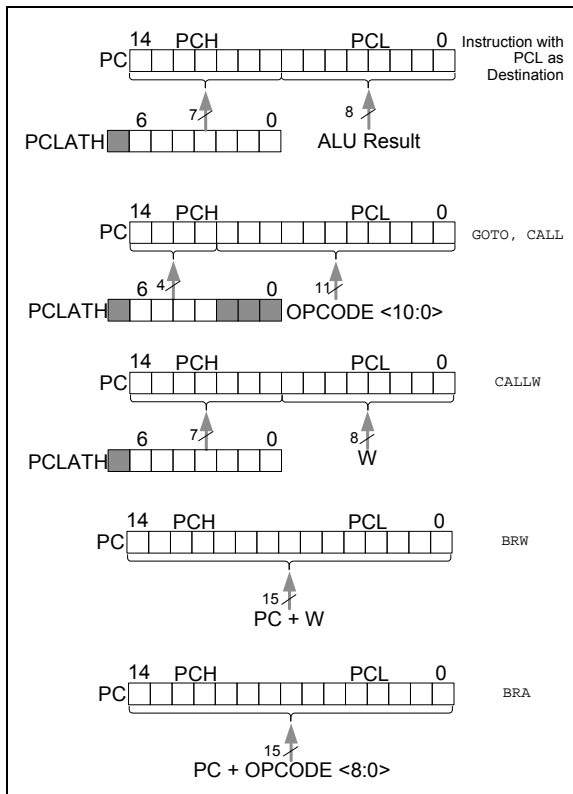
Legend: x = unknown, u = unchanged, q = value depends on condition, - = unimplemented, read as '0', r = reserved.
Shaded locations are unimplemented, read as '0'.

- Note 1:** PIC16F1526/7 only.
Note 2: Unimplemented, read as '1'.

3.3 PCL and PCLATH

The Program Counter (PC) is 15 bits wide. The low byte comes from the PCL register, which is a readable and writable register. The high byte (PC<14:8>) is not directly readable or writable and comes from PCLATH. On any Reset, the PC is cleared. Figure 3-4 shows the five situations for the loading of the PC.

FIGURE 3-4: LOADING OF PC IN DIFFERENT SITUATIONS



3.3.1 MODIFYING PCL

Executing any instruction with the PCL register as the destination simultaneously causes the Program Counter PC<14:8> bits (PCH) to be replaced by the contents of the PCLATH register. This allows the entire contents of the program counter to be changed by writing the desired upper 7 bits to the PCLATH register. When the lower 8 bits are written to the PCL register, all 15 bits of the program counter will change to the values contained in the PCLATH register and those being written to the PCL register.

3.3.2 COMPUTED GOTO

A computed GOTO is accomplished by adding an offset to the program counter (ADDWF PCL). When performing a table read using a computed GOTO method, care should be exercised if the table location crosses a PCL memory boundary (each 256-byte block). Refer to the Application Note AN556, "Implementing a Table Read" (DS00556).

3.3.3 COMPUTED FUNCTION CALLS

A computed function CALL allows programs to maintain tables of functions and provide another way to execute state machines or look-up tables. When performing a table read using a computed function CALL, care should be exercised if the table location crosses a PCL memory boundary (each 256-byte block).

If using the CALL instruction, the PCH<2:0> and PCL registers are loaded with the operand of the CALL instruction. PCH<6:3> is loaded with PCLATH<6:3>.

The CALLW instruction enables computed calls by combining PCLATH and W to form the destination address. A computed CALLW is accomplished by loading the W register with the desired address and executing CALLW. The PCL register is loaded with the value of W and PCH is loaded with PCLATH.

3.3.4 BRANCHING

The branching instructions add an offset to the PC. This allows relocatable code and code that crosses page boundaries. There are two forms of branching, BRW and BRA. The PC will have incremented to fetch the next instruction in both cases. When using either branching instruction, a PCL memory boundary may be crossed.

If using BRW, load the W register with the desired unsigned address and execute BRW. The entire PC will be loaded with the address PC + 1 + W.

If using BRA, the entire PC will be loaded with PC + 1 +, the signed value of the operand of the BRA instruction.

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3.4 Stack

All devices have a 16-level x 15-bit wide hardware stack (refer to Figures 3-5 through 3-8). The stack space is not part of either program or data space. The PC is PUSHed onto the stack when `CALL` or `CALLW` instructions are executed or an interrupt causes a branch. The stack is POPed in the event of a `RETURN`, `RETLW` or a `RETFIE` instruction execution. `PCLATH` is not affected by a `PUSH` or `POP` operation.

The stack operates as a circular buffer if the `STVREN` bit is programmed to '0' (Configuration Word 2). This means that after the stack has been PUSHed sixteen times, the seventeenth PUSH overwrites the value that was stored from the first PUSH. The eighteenth PUSH overwrites the second PUSH (and so on). The `STKOVF` and `STKUNF` flag bits will be set on an Overflow/Underflow, regardless of whether the Reset is enabled.

Note 1: There are no instructions/mnemonics called `PUSH` or `POP`. These are actions that occur from the execution of the `CALL`, `CALLW`, `RETURN`, `RETLW` and `RETFIE` instructions or the vectoring to an interrupt address.

3.4.1 ACCESSING THE STACK

The stack is available through the `TOSH`, `TOSL` and `STKPTR` registers. `STKPTR` is the current value of the Stack Pointer. `TOSH:TOSL` register pair points to the TOP of the stack. Both registers are read/writable. `TOS` is split into `TOSH` and `TOSL` due to the 15-bit size of the PC. To access the stack, adjust the value of `STKPTR`, which will position `TOSH:TOSL`, then read/write to `TOSH:TOSL`. `STKPTR` is 5 bits to allow detection of overflow and underflow.

Note: Care should be taken when modifying the `STKPTR` while interrupts are enabled.

During normal program operation, `CALL`, `CALLW` and Interrupts will increment `STKPTR` while `RETLW`, `RETURN`, and `RETFIE` will decrement `STKPTR`. At any time `STKPTR` can be inspected to see how much stack is left. The `STKPTR` always points at the currently used place on the stack. Therefore, a `CALL` or `CALLW` will increment the `STKPTR` and then write the PC, and a return will unload the PC and then decrement `STKPTR`.

Reference Figures 3-5 through 3-8 for examples of accessing the stack.

FIGURE 3-5: ACCESSING THE STACK EXAMPLE 1



FIGURE 3-6: ACCESSING THE STACK EXAMPLE 2



FIGURE 3-7: ACCESSING THE STACK EXAMPLE 3



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FIGURE 3-8: ACCESSING THE STACK EXAMPLE 4



3.4.2 OVERFLOW/UNDERFLOW RESET

If the STVREN bit in Configuration Word 2 is programmed to '1', the device will be reset if the stack is PUSHed beyond the sixteenth level or POPed beyond the first level, setting the appropriate bits (STKOVF or STKUNF, respectively) in the PCON register.

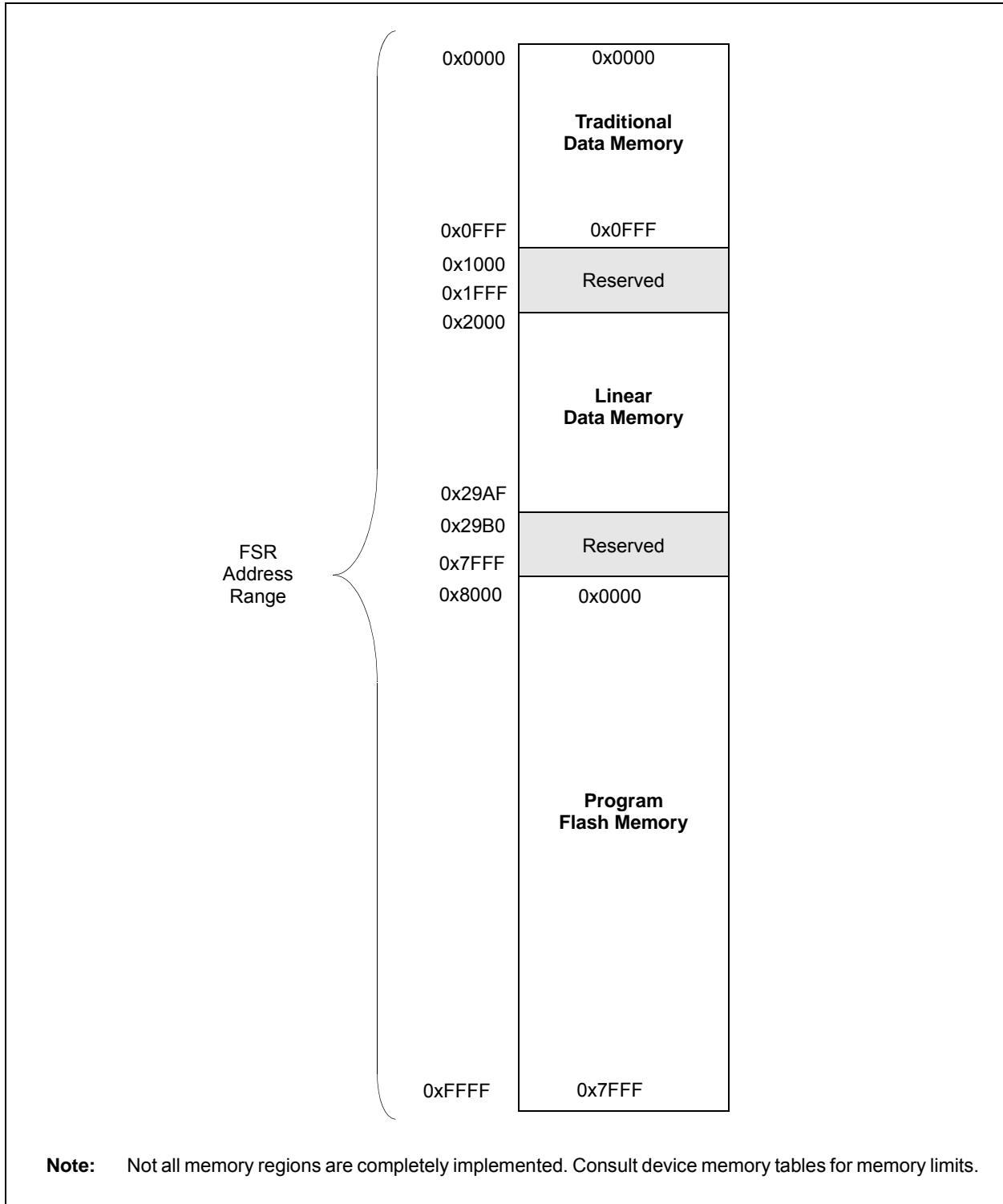
3.5 Indirect Addressing

The INDFn registers are not physical registers. Any instruction that accesses an INDFn register actually accesses the register at the address specified by the File Select Registers (FSR). If the FSRn address specifies one of the two INDFn registers, the read will return '0' and the write will not occur (though Status bits may be affected). The FSRn register value is created by the pair FSRnH and FSRnL.

The FSR registers form a 16-bit address that allows an addressing space with 65536 locations. These locations are divided into three memory regions:

- Traditional Data Memory
- Linear Data Memory
- Program Flash Memory

FIGURE 3-9: INDIRECT ADDRESSING

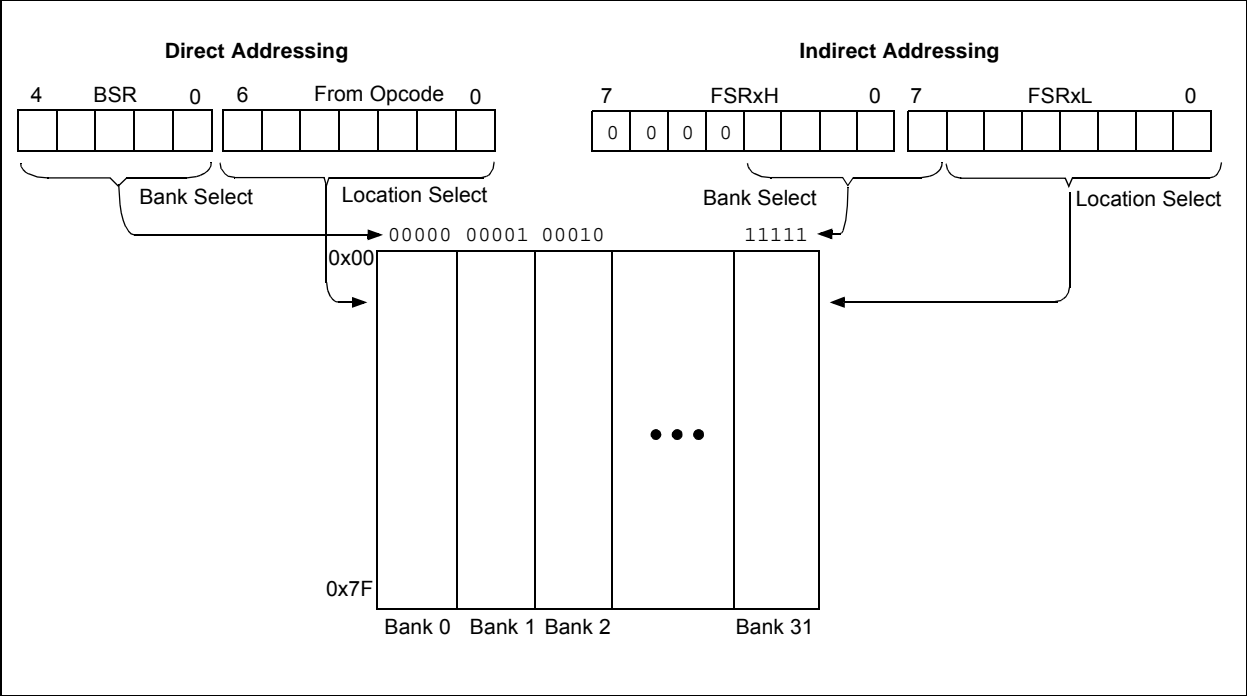


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3.5.1 TRADITIONAL DATA MEMORY

The traditional data memory is a region from FSR address 0x000 to FSR address 0xFFF. The addresses correspond to the absolute addresses of all SFR, GPR and common registers.

FIGURE 3-10: TRADITIONAL DATA MEMORY MAP



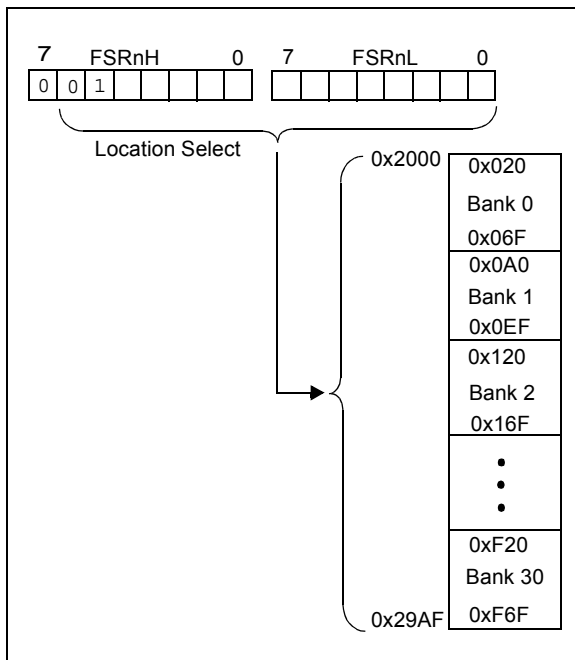
3.5.2 LINEAR DATA MEMORY

The linear data memory is the region from FSR address 0x2000 to FSR address 0x29AF. This region is a virtual region that points back to the 80-byte blocks of GPR memory in all the banks.

Unimplemented memory reads as 0x00. Use of the linear data memory region allows buffers to be larger than 80 bytes because incrementing the FSR beyond one bank will go directly to the GPR memory of the next bank.

The 16 bytes of common memory are not included in the linear data memory region.

FIGURE 3-11: LINEAR DATA MEMORY MAP



3.5.3 PROGRAM FLASH MEMORY

To make constant data access easier, the entire program Flash memory is mapped to the upper half of the FSR address space. When the MSB of FSRnH is set, the lower 15 bits are the address in program memory which will be accessed through INDF. Only the lower 8 bits of each memory location is accessible via INDF. Writing to the program Flash memory cannot be accomplished via the FSR/INDF interface. All instructions that access program Flash memory via the FSR/INDF interface will require one additional instruction cycle to complete.

FIGURE 3-12: PROGRAM FLASH MEMORY MAP



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NOTES:

4.0 DEVICE CONFIGURATION

Device Configuration consists of Configuration Word 1 and Configuration Word 2, Code Protection and Device ID.

4.1 Configuration Words

There are several Configuration Word bits that allow different oscillator and memory protection options. These are implemented as Configuration Word 1 at 8007h and Configuration Word 2 at 8008h.

<p>Note: The DEBUG bit in Configuration Word 2 is managed automatically by device development tools including debuggers and programmers. For normal device operation, this bit should be maintained as a '1'.</p>
--

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REGISTER 4-1: CONFIGURATION WORD 1

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	U-1
FCMEN	IESO	CLKOUTEN	BOREN<1:0>		—
bit 13					bit 8

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
CP	MCLRE	PWRTE	WDTE<1:0>		FOSC<2:0>		
bit 7							bit 0

Legend:

R = Readable bit P = Programmable bit U = Unimplemented bit, read as '1'
 '0' = Bit is cleared '1' = Bit is set -n = Value when blank or after Bulk Erase

- bit 13 **FCMEN:** Fail-Safe Clock Monitor Enable bit
 1 = Fail-Safe Clock Monitor is enabled
 0 = Fail-Safe Clock Monitor is disabled
- bit 12 **IESO:** Internal External Switchover bit
 1 = Internal/External Switchover mode is enabled
 0 = Internal/External Switchover mode is disabled
- bit 11 **CLKOUTEN:** Clock Out Enable bit
If FOSC configuration bits are set to LP, XT, HS modes:
 This bit is ignored, CLKOUT function is disabled. Oscillator function on the CLKOUT pin.
All other FOSC modes:
 1 = CLKOUT function is disabled. I/O function on the CLKOUT pin.
 0 = CLKOUT function is enabled on the CLKOUT pin
- bit 10-9 **BOREN<1:0>:** Brown-out Reset Enable bits
 11 = BOR enabled
 10 = BOR enabled during operation and disabled in Sleep
 01 = BOR controlled by SBOREN bit of the BORCON register
 00 = BOR disabled
- bit 8 **Unimplemented:** Read as '1'
- bit 7 **CP:** Code Protection bit
 1 = Program memory code protection is disabled
 0 = Program memory code protection is enabled
- bit 6 **MCLRE:** MCLR/VPP Pin Function Select bit
If LVP bit = 1:
 This bit is ignored.
If LVP bit = 0:
 1 = MCLR/VPP pin function is MCLR; Weak pull-up enabled.
 0 = MCLR/VPP pin function is digital input; MCLR internally disabled; Weak pull-up under control of WPUE3 bit.
- bit 5 **PWRTE:** Power-up Timer Enable bit
 1 = PWRT disabled
 0 = PWRT enabled
- bit 4-3 **WDTE<1:0>:** Watchdog Timer Enable bit
 11 = WDT enabled
 10 = WDT enabled while running and disabled in Sleep
 01 = WDT controlled by the SWDTEN bit in the WDTCN register
 00 = WDT disabled

REGISTER 4-1: CONFIGURATION WORD 1 (CONTINUED)

bit 2-0

FOSC<2:0>: Oscillator Selection bits

111 = ECH: External Clock, High-Power mode (4-20 MHz): device clock supplied to CLKIN pin

110 = ECM: External Clock, Medium-Power mode (0.5-4 MHz): device clock supplied to CLKIN pin

101 = ECL: External Clock, Low-Power mode (0-0.5 MHz): device clock supplied to CLKIN pin

100 = INTOSC oscillator: I/O function on CLKIN pin

011 = EXTRC oscillator: External RC circuit connected to CLKIN pin

010 = HS oscillator: High-speed crystal/resonator connected between OSC1 and OSC2 pins

001 = XT oscillator: Crystal/resonator connected between OSC1 and OSC2 pins

000 = LP oscillator: Low-power crystal connected between OSC1 and OSC2 pins

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REGISTER 4-2: CONFIGURATION WORD 2

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	U-1
LVP	DEBUG	LPBOR	BORV	STVREN	—
bit 13					bit 8

U-1	U-1	U-1	R/P-1	U-1	U-1	R/P-1	R/P-1
—	—	—	VCAPEN ⁽¹⁾	—	—	WRT<1:0>	
bit 7							bit 0

Legend:

R = Readable bit P = Programmable bit U = Unimplemented bit, read as '1'
 '0' = Bit is cleared '1' = Bit is set -n = Value when blank or after Bulk Erase

- bit 13 **LVP:** Low-Voltage Programming Enable bit
 1 = Low-voltage programming enabled
 0 = High-voltage on MCLR must be used for programming
- bit 12 **DEBUG:** In-Circuit Debugger Mode bit
 1 = In-Circuit Debugger disabled, ICSPCLK and ICSPDAT are general purpose I/O pins
 0 = In-Circuit Debugger enabled, ICSPCLK and ICSPDAT are dedicated to the debugger
- bit 11 **LPBOR:** Low-Power BOR bit
 1 = Low-Power BOR is disabled
 0 = Low-Power BOR is enabled
- bit 10 **BORV:** Brown-out Reset Voltage Selection bit
 1 = Brown-out Reset voltage set to 1.9V (typical)
 0 = Brown-out Reset voltage set to 2.5V (typical)
- bit 9 **STVREN:** Stack Overflow/Underflow Reset Enable bit
 1 = Stack Overflow or Underflow will cause a Reset
 0 = Stack Overflow or Underflow will not cause a Reset
- bit 8-5 **Unimplemented:** Read as '1'
- bit 4 **VCAPEN:** Voltage Regulator Capacitor Enable bits⁽¹⁾
If PIC16LF1526/27 (regulator disabled):
 These bits are ignored. All VCAP pin functions are disabled.
If PIC16F1526/27 (regulator enabled):
 0 = VCAP functionality is enabled on RF0.
 1 = All VCAP pin functions are disabled
- bit 3-2 **Unimplemented:** Read as '1'
- bit 1-0 **WRT<1:0>:** Flash Memory Self-Write Protection bits
8 kW Flash memory (PIC16(L)F1526 only):
 11 = Write protection off
 10 = 000h to 1FFh write-protected, 200h to 1FFFh may be modified by PMCON control
 01 = 000h to FFFh write-protected, 1000h to 1FFFh may be modified by PMCON control
 00 = 000h to 1FFFh write-protected, no addresses may be modified by PMCON control
16 kW Flash memory (PIC16(L)F1527 only):
 11 = Write protection off
 10 = 000h to 1FFh write-protected, 200h to 3FFFh may be modified by PMCON control
 01 = 000h to 1FFFh write-protected, 2000h to 3FFFh may be modified by PMCON control
 00 = 000h to 3FFFh write-protected, no addresses may be modified by PMCON control

Note 1: PIC16F1526/27 only.

4.2 Code Protection

Code protection allows the device to be protected from unauthorized access. Program memory protection is controlled independently. Internal access to the program memory is unaffected by any code protection setting.

4.2.1 PROGRAM MEMORY PROTECTION

The entire program memory space is protected from external reads and writes by the CP bit in Configuration Word 1. When $\overline{CP} = 0$, external reads and writes of program memory are inhibited and a read will return all '0's. The CPU can continue to read program memory, regardless of the protection bit settings. Writing the program memory is dependent upon the write protection setting. See [Section 4.3 "Write Protection"](#) for more information.

4.3 Write Protection

Write protection allows the device to be protected from unintended self-writes. Applications, such as bootloader software, can be protected while allowing other regions of the program memory to be modified.

The WRT<1:0> bits in Configuration Word 2 define the size of the program memory block that is protected.

4.4 User ID

Four memory locations (8000h-8003h) are designated as ID locations where the user can store checksum or other code identification numbers. These locations are readable and writable during normal execution. See [Section 11.5 "User ID, Device ID and Configuration Word Access"](#) for more information on accessing these memory locations. For more information on checksum calculation, see the *"PIC16F/LF151X/152X Memory Programming Specification"* (DS41422).

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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 11.5 “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>
PIC16F1526	01 0101 100	x xxxxx
PIC16F1527	01 0101 101	x xxxxx
PIC16LF1526	01 0101 110	x xxxxx
PIC16LF1527	01 0101 111	x xxxxx

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).

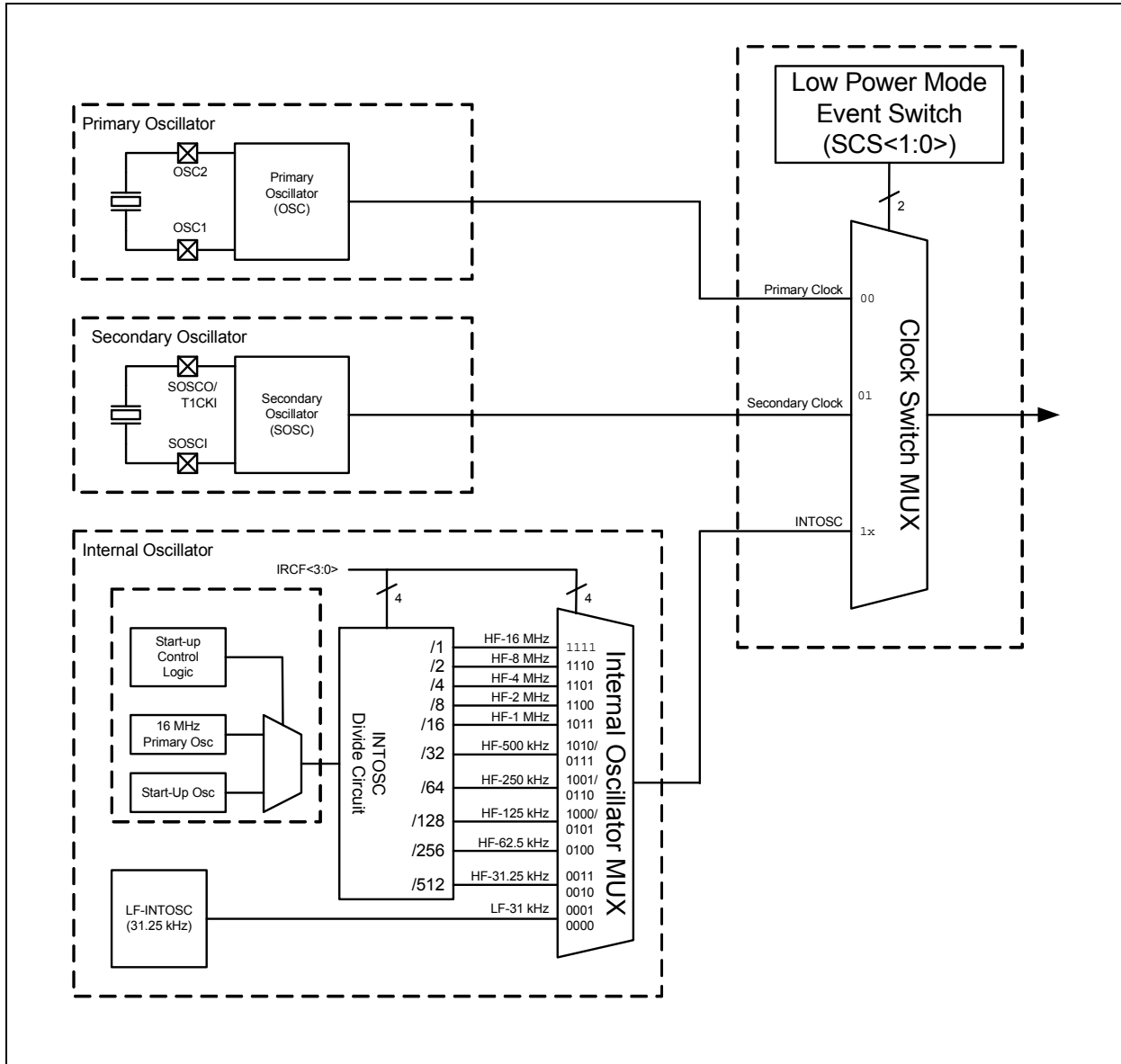
Clock Source modes are selected by the FOSC<2:0> bits in the Configuration Word 1. The FOSC bits determine the type of oscillator that will be used when the device is first powered.

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.

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FIGURE 5-1: SIMPLIFIED PIC[®] MCU CLOCK SOURCE BLOCK DIAGRAM



5.2 Clock Source Types

Clock sources can be classified as external or internal.

External clock sources rely on external circuitry for the clock source to function. Examples are: oscillator modules (EC mode), quartz crystal resonators or ceramic resonators (LP, XT and HS modes) and Resistor-Capacitor (RC) mode circuits.

Internal clock sources are contained internally within the oscillator module. The internal oscillator block has two internal oscillators that are used to generate the internal system clock sources: the 16 MHz High-Frequency Internal Oscillator and the 31 kHz Low-Frequency Internal Oscillator (LFINTOSC).

The system clock can be selected between external or internal clock sources via the System Clock Select (SCS) bits in the OSCCON register. See [Section 5.3 “Clock Switching”](#) for additional information.

5.2.1 EXTERNAL CLOCK SOURCES

An external clock source can be used as the device system clock by performing one of the following actions:

- Program the FOSC<2:0> bits in the Configuration Word 1 to select an external clock source that 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:
 - Secondary oscillator during run-time, or
 - An external clock source determined by the value of the FOSC bits.

See [Section 5.3 “Clock Switching”](#) for more information.

5.2.1.1 EC Mode

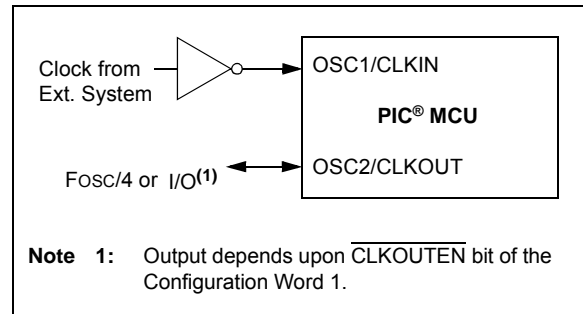
The External Clock (EC) mode allows an externally generated logic level signal to be the system clock source. When operating in this mode, an external clock source is connected to the OSC1 input. OSC2/CLKOUT is available for general purpose I/O or CLKOUT. [Figure 5-2](#) shows the pin connections for EC mode.

EC mode has three power modes to select from through Configuration Word 1:

- High power, 4-20 MHz (FOSC = 111)
- Medium power, 0.5-4 MHz (FOSC = 110)
- Low power, 0-0.5 MHz (FOSC = 101)

The Oscillator Start-up Timer (OST) is disabled when EC mode is selected. Therefore, there is no delay in operation after a Power-on Reset (POR) or wake-up from Sleep. Because the PIC® MCU design is fully static, stopping the external clock input will have the effect of halting the device while leaving all data intact. Upon restarting the external clock, the device will resume operation as if no time had elapsed.

FIGURE 5-2: EXTERNAL CLOCK (EC) MODE OPERATION



5.2.1.2 LP, XT, HS Modes

The LP, XT and HS modes support the use of quartz crystal resonators or ceramic resonators connected to OSC1 and OSC2 ([Figure 5-3](#)). The three modes select a low, medium or high gain setting of the internal inverter-amplifier to support various resonator types and speed.

LP Oscillator mode selects the lowest gain setting of the internal inverter-amplifier. LP mode current consumption is the least of the three modes. This mode is designed to drive only 32.768 kHz tuning-fork type crystals (watch crystals).

XT Oscillator mode selects the intermediate gain setting of the internal inverter-amplifier. XT mode current consumption is the medium of the three modes. This mode is best suited to drive resonators with a medium drive level specification.

HS Oscillator mode selects the highest gain setting of the internal inverter-amplifier. HS mode current consumption is the highest of the three modes. This mode is best suited for resonators that require a high drive setting.

[Figure 5-3](#) and [Figure 5-4](#) show typical circuits for quartz crystal and ceramic resonators, respectively.

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FIGURE 5-3: QUARTZ CRYSTAL OPERATION (LP, XT OR HS MODE)



Note 1: Quartz crystal characteristics vary according to type, package and manufacturer. The user should consult the manufacturer data sheets for specifications and recommended application.

- 2:** Always verify oscillator performance over the V_{DD} and temperature range that is expected for the application.
- 3:** For oscillator design assistance, reference the following Microchip Applications Notes:

- AN826, “Crystal Oscillator Basics and Crystal Selection for *rPIC*[®] and *PIC*[®] Devices” (DS00826)
- AN849, “Basic *PIC*[®] Oscillator Design” (DS00849)
- AN943, “Practical *PIC*[®] Oscillator Analysis and Design” (DS00943)
- AN949, “Making Your Oscillator Work” (DS00949)

FIGURE 5-4: CERAMIC RESONATOR OPERATION (XT OR HS MODE)



5.2.1.3 Oscillator Start-up Timer (OST)

If the oscillator module is configured for LP, XT or HS modes, the Oscillator Start-up Timer (OST) counts 1024 oscillations from OSC1. This occurs following a Power-on Reset (POR) and when the Power-up Timer (PWRT) has expired (if configured), or a wake-up from Sleep. During this time, the program counter does not increment and program execution is suspended. The OST ensures that the oscillator circuit, using a quartz crystal resonator or ceramic resonator, has started and is providing a stable system clock to the oscillator module.

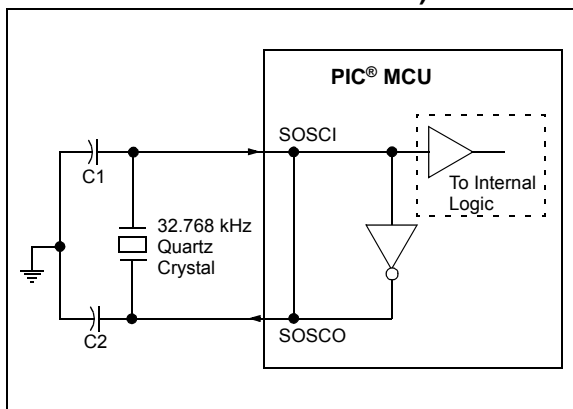
In order to minimize latency between external oscillator start-up and code execution, the Two-Speed Clock Start-up mode can be selected (see [Section 5.4 “Two-Speed Clock Start-up Mode”](#)).

5.2.1.4 Secondary Oscillator

The secondary oscillator is a separate crystal oscillator that is associated with the Timer1 peripheral. It is optimized for timekeeping operations with a 32.768 kHz crystal connected between the SOSCO and SOSCI device pins.

The secondary oscillator can be used as an alternate system clock source and can be selected during run-time using clock switching. Refer to [Section 5.3 "Clock Switching"](#) for more information.

FIGURE 5-5: QUARTZ CRYSTAL OPERATION (SECONDARY OSCILLATOR)



Note 1: Quartz crystal characteristics vary according to type, package and manufacturer. The user should consult the manufacturer data sheets for specifications and recommended application.

- 2: Always verify oscillator performance over the VDD and temperature range that is expected for the application.
- 3: For oscillator design assistance, reference the following Microchip Applications Notes:

- AN826, "Crystal Oscillator Basics and Crystal Selection for *rfPIC*® and *PIC*® Devices" (DS00826)
- AN849, "Basic *PIC*® Oscillator Design" (DS00849)
- AN943, "Practical *PIC*® Oscillator Analysis and Design" (DS00943)
- AN949, "Making Your Oscillator Work" (DS00949)
- TB097, "Interfacing a Micro Crystal MS1V-T1K 32.768 kHz Tuning Fork Crystal to a *PIC16F690/SS*" (DS91097)
- AN1288, "Design Practices for Low-Power External Oscillators" (DS01288)

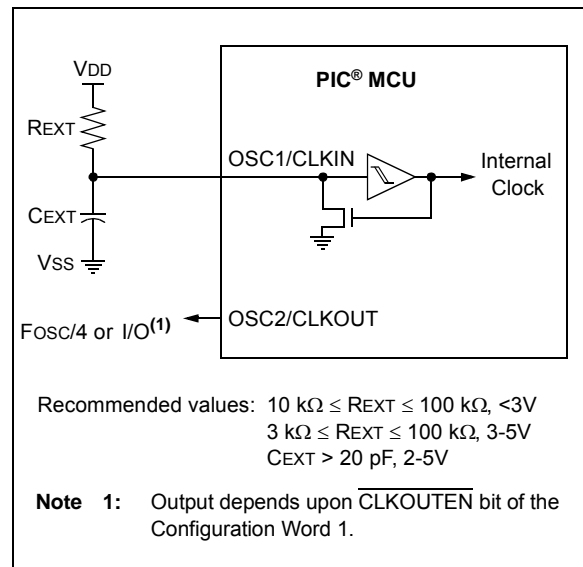
5.2.1.5 External RC Mode

The external Resistor-Capacitor (RC) modes support the use of an external RC circuit. This allows the designer maximum flexibility in frequency choice while keeping costs to a minimum when clock accuracy is not required.

The RC circuit connects to OSC1. OSC2/CLKOUT is available for general purpose I/O or CLKOUT. The function of the OSC2/CLKOUT pin is determined by the state of the CLKOUTEN bit in Configuration Word 1.

[Figure 5-6](#) shows the external RC mode connections.

FIGURE 5-6: EXTERNAL RC MODES



The RC oscillator frequency is a function of the supply voltage, the resistor (R_{EXT}) and capacitor (C_{EXT}) values and the operating temperature. Other factors affecting the oscillator frequency are:

- threshold voltage variation
- component tolerances
- packaging variations in capacitance

The user also needs to take into account variation due to tolerance of external RC components used.

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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 Word 1 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 state of the $\overline{\text{CLKOUTEN}}$ bit in Configuration Word 1.

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'.

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

The High-Frequency Internal Oscillator Status 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 and can be utilized.

5.2.2.3 Internal Oscillator Frequency Selection

The system clock speed can be selected via software using the Internal Oscillator Frequency Select bits IRCF<3:0> of the OSCCON register.

The output of the 16 MHz HFINTOSC and 31 kHz LFINTOSC connects to a postscaler and multiplexer (see [Figure 5-1](#)). The Internal Oscillator Frequency Select bits IRCF<3:0> of the OSCCON register select the frequency output of the internal oscillators. One of the following frequencies can be selected via software:

- 16 MHz
- 8 MHz
- 4 MHz
- 2 MHz
- 1 MHz
- 500 kHz (Default after Reset)
- 250 kHz
- 125 kHz
- 62.5 kHz
- 31.25 kHz
- 31 kHz (LFINTOSC)

Note: Following any Reset, the IRCF<3:0> bits of the OSCCON register are set to '0111' and the frequency selection is set to 500 kHz. The user can modify the IRCF bits to select a different frequency.

The IRCF<3:0> bits of the OSCCON register allow duplicate selections for some frequencies. These duplicate choices can offer system design trade-offs. Lower power consumption can be obtained when changing oscillator sources for a given frequency. Faster transition times can be obtained between frequency changes that use the same oscillator source.

5.2.2.4 Internal Oscillator Clock Switch Timing

When switching between the HFINTOSC and the LFINTOSC, the new oscillator may already be shut down to save power (see [Figure 5-7](#)). If this is the case, there is a delay after the IRCF<3:0> bits of the OSCCON register are modified before the frequency selection takes place. The OSCSTAT register will reflect the current active status of the HFINTOSC and LFINTOSC oscillators. The sequence of a frequency selection is as follows:

1. IRCF<3:0> bits of the OSCCON register are modified.
2. If the new clock is shut down, a clock start-up delay is started.
3. Clock switch circuitry waits for a falling edge of the current clock.
4. The current clock is held low and the clock switch circuitry waits for a rising edge in the new clock.
5. The new clock is now active.
6. The OSCSTAT register is updated as required.
7. Clock switch is complete.

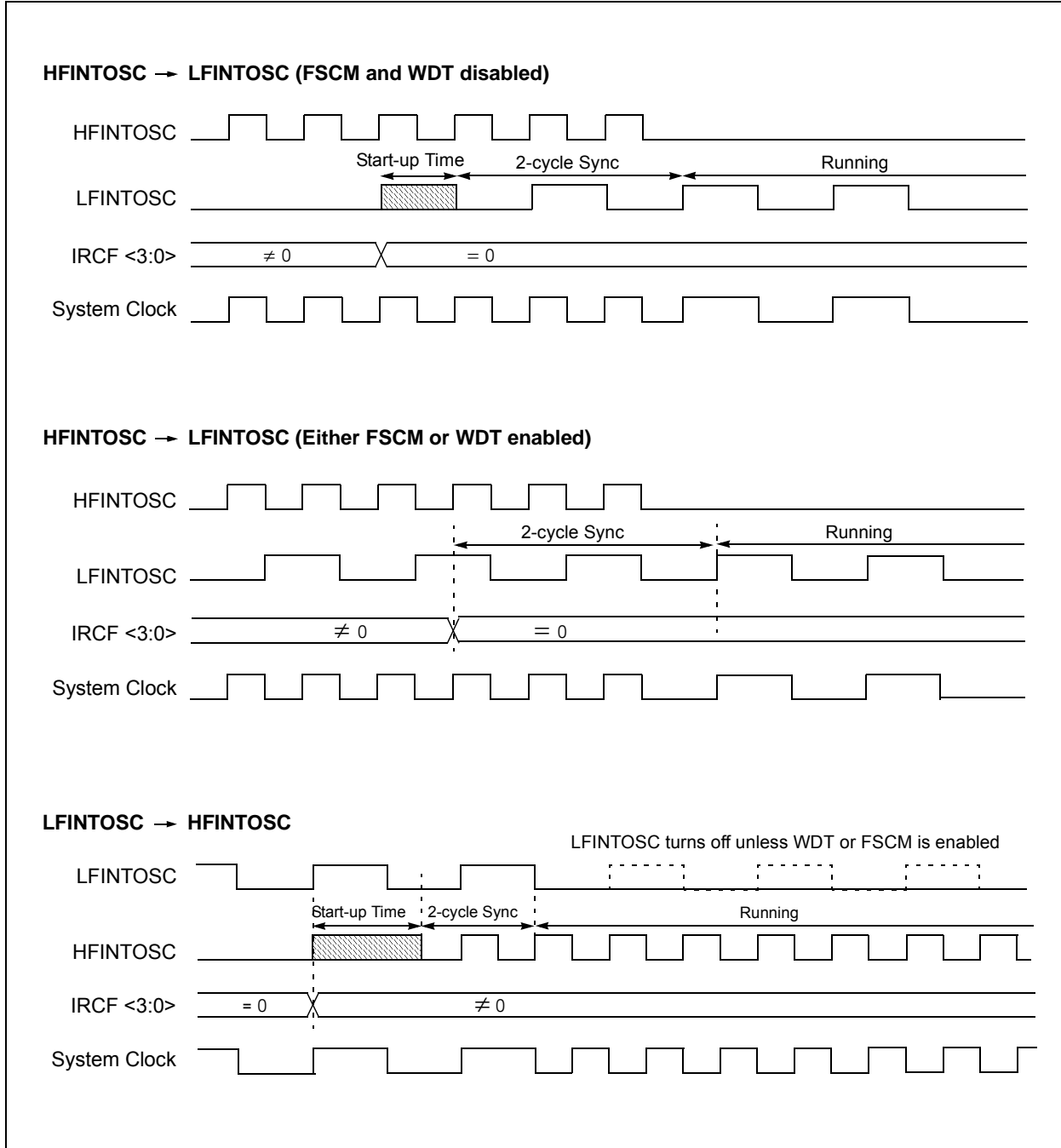
See [Figure 5-7](#) for more details.

If the internal oscillator speed is switched between two clocks of the same source, there is no start-up delay before the new frequency is selected. Clock switching time delays are shown in [Table 5-1](#).

Start-up delay specifications are located in the oscillator tables of **Section 25.0 “Electrical Specifications”**

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FIGURE 5-7: INTERNAL OSCILLATOR SWITCH TIMING



5.3 Clock Switching

The system clock source can be switched between external and internal clock sources via software using the System Clock Select (SCS) bits of the OSCCON register. The following clock sources can be selected using the SCS bits:

- Default system oscillator determined by FOSC bits in Configuration Word 1
- Secondary oscillator 32 kHz crystal
- Internal Oscillator Block (INTOSC)

5.3.1 SYSTEM CLOCK SELECT (SCS) BITS

The System Clock Select (SCS) bits of the OSCCON register selects the system clock source that is used for the CPU and peripherals.

- When the SCS bits of the OSCCON register = 00, the system clock source is determined by value of the FOSC<2:0> bits in the Configuration Word 1.
- When the SCS bits of the OSCCON register = 01, the system clock source is the secondary oscillator.
- When the SCS bits of the OSCCON register = 1x, the system clock source is chosen by the internal oscillator frequency selected by the IRCF<3:0> bits of the OSCCON register. After a Reset, the SCS bits of the OSCCON register are always cleared.

Note: Any automatic clock switch, which may occur from Two-Speed Start-up or Fail-Safe Clock Monitor, does not update the SCS bits of the OSCCON register. The user can monitor the OSTS bit of the OSCSTAT register to determine the current system clock source.

When switching between clock sources, a delay is required to allow the new clock to stabilize. These oscillator delays are shown in [Table 5-1](#).

5.3.2 OSCILLATOR START-UP TIME-OUT STATUS (OSTS) BIT

The Oscillator Start-up Time-out Status (OSTS) bit of the OSCSTAT register indicates whether the system clock is running from the external clock source, as defined by the FOSC<2:0> bits in the Configuration Word 1, or from the internal clock source. In particular, OSTS indicates that the Oscillator Start-up Timer (OST) has timed out for LP, XT or HS modes. The OST does not reflect the status of the secondary oscillator.

5.3.3 SECONDARY OSCILLATOR

The secondary oscillator is a separate crystal oscillator associated with the Timer1 peripheral. It is optimized for timekeeping operations with a 32.768 kHz crystal connected between the SOSCO and SOSCI device pins.

The secondary oscillator is enabled using the SOSSEN control bit in the TxCON register. See **Section 18.0 “Timer1 Module with Gate Control”** for more information about the Timer1 peripheral.

5.3.4 SECONDARY OSCILLATOR READY (SOSCR) BIT

The user must ensure that the secondary oscillator is ready to be used before it is selected as a system clock source. The Secondary Oscillator Ready (SOSCR) bit of the OSCSTAT register indicates whether the secondary oscillator is ready to be used. After the SOSCR bit is set, the SCS bits can be configured to select the secondary oscillator.

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5.4 Two-Speed Clock Start-up Mode

Two-Speed Start-up mode provides additional power savings by minimizing the latency between external oscillator start-up and code execution. In applications that make heavy use of the Sleep mode, Two-Speed Start-up will remove the external oscillator start-up time from the time spent awake and can reduce the overall power consumption of the device. This mode allows the application to wake-up from Sleep, perform a few instructions using the INTOSC internal oscillator block as the clock source and go back to Sleep without waiting for the external oscillator to become stable.

Two-Speed Start-up provides benefits when the oscillator module is configured for LP, XT or HS modes. The Oscillator Start-up Timer (OST) is enabled for these modes and must count 1024 oscillations before the oscillator can be used as the system clock source.

If the oscillator module is configured for any mode other than LP, XT or HS mode, then Two-Speed Start-up is disabled. This is because the external clock oscillator does not require any stabilization time after POR or an exit from Sleep.

If the OST count reaches 1024 before the device enters Sleep mode, the OSTS bit of the OSCSTAT register is set and program execution switches to the external oscillator. However, the system may never operate from the external oscillator if the time spent awake is very short.

Note: Executing a SLEEP instruction will abort the oscillator start-up time and will cause the OSTS bit of the OSCSTAT register to remain clear.

5.4.1 TWO-SPEED START-UP MODE CONFIGURATION

Two-Speed Start-up mode is configured by the following settings:

- IESO (of the Configuration Word 1) = 1; Internal/External Switchover bit (Two-Speed Start-up mode enabled).
- SCS (of the OSCCON register) = 00.
- FOSC<2:0> bits in the Configuration Word 1 configured for LP, XT or HS mode.

Two-Speed Start-up mode is entered after:

- Power-on Reset (POR) and, if enabled, after Power-up Timer (PWRT) has expired, or
- Wake-up from Sleep.

TABLE 5-1: OSCILLATOR SWITCHING DELAYS

Switch From	Switch To	Frequency	Oscillator Delay
Sleep/POR	LFINTOSC HFINTOSC	31 kHz 31.25 kHz-16 MHz	Oscillator Warm-up Delay (TWARM)
Sleep/POR	EC, RC	DC – 20 MHz	2 cycles
LFINTOSC	EC, RC	DC – 20 MHz	1 cycle of each
Sleep/POR	Secondary Oscillator, LP, XT, HS	32 kHz-20 MHz	1024 Clock Cycles (OST)
Any clock source	HFINTOSC	31.25 kHz-16 MHz	2 μ s (approx.)
Any clock source	LFINTOSC	31 kHz	1 cycle of each
Any clock source	Secondary Oscillator	32 kHz	1024 Clock Cycles (OST)

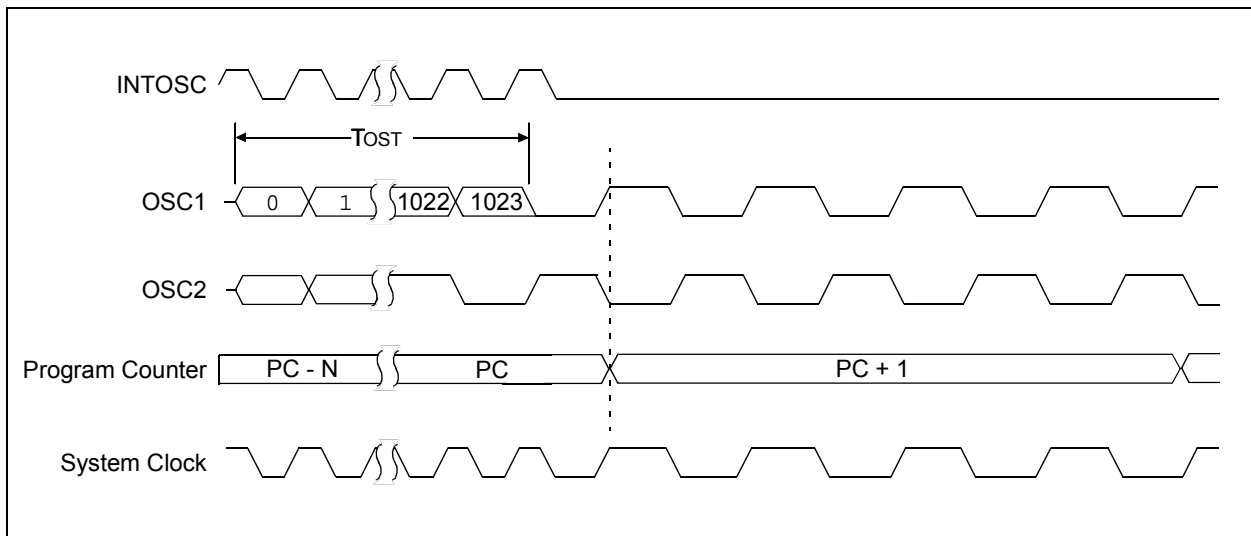
5.4.2 TWO-SPEED START-UP SEQUENCE

1. Wake-up from Power-on Reset or Sleep.
2. Instructions begin execution by the internal oscillator at the frequency set in the IRCF<3:0> bits of the OSCCON register.
3. OST enabled to count 1024 clock cycles.
4. OST timed out, wait for falling edge of the internal oscillator.
5. OSTS is set.
6. System clock held low until the next falling edge of new clock (LP, XT or HS mode).
7. System clock is switched to external clock source.

5.4.3 CHECKING TWO-SPEED CLOCK STATUS

Checking the state of the OSTS bit of the OSCSTAT register will confirm if the microcontroller is running from the external clock source, as defined by the FOSC<2:0> bits in the Configuration Word 1, or the internal oscillator.

FIGURE 5-8: TWO-SPEED START-UP

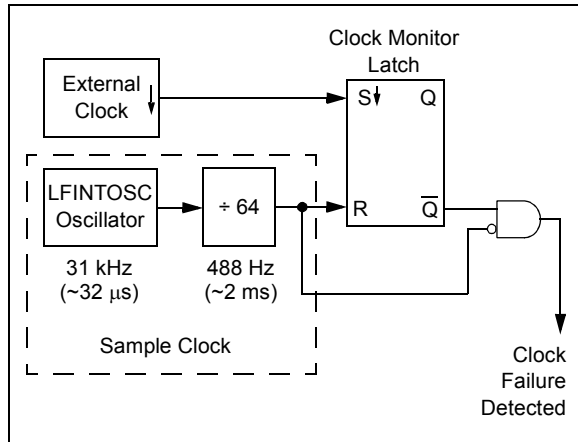


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5.5 Fail-Safe Clock Monitor

The Fail-Safe Clock Monitor (FSCM) allows the device to continue operating should the external oscillator fail. The FSCM can detect oscillator failure any time after the Oscillator Start-up Timer (OST) has expired. The FSCM is enabled by setting the FCMEN bit in the Configuration Word 1. The FSCM is applicable to all external Oscillator modes (LP, XT, HS, EC, RC and secondary oscillator).

FIGURE 5-9: FSCM BLOCK DIAGRAM



5.5.1 FAIL-SAFE DETECTION

The FSCM module detects a failed oscillator by comparing the external oscillator to the FSCM sample clock. The sample clock is generated by dividing the LFINTOSC by 64. See [Figure 5-9](#). Inside the fail detector block is a latch. The external clock sets the latch on each falling edge of the external clock. The sample clock clears the latch on each rising edge of the sample clock. A failure is detected when an entire half-cycle of the sample clock elapses before the external clock goes low.

5.5.2 FAIL-SAFE OPERATION

When the external clock fails, the FSCM switches the device clock to an internal clock source and sets the bit flag OSFIF of the PIR2 register. Setting this flag will generate an interrupt if the OSFIE bit of the PIE2 register is also set. The device firmware can then take steps to mitigate the problems that may arise from a failed clock. The system clock will continue to be sourced from the internal clock source until the device firmware successfully restarts the external oscillator and switches back to external operation.

The internal clock source chosen by the FSCM is determined by the IRCF<3:0> bits of the OSCCON register. This allows the internal oscillator to be configured before a failure occurs.

5.5.3 FAIL-SAFE CONDITION CLEARING

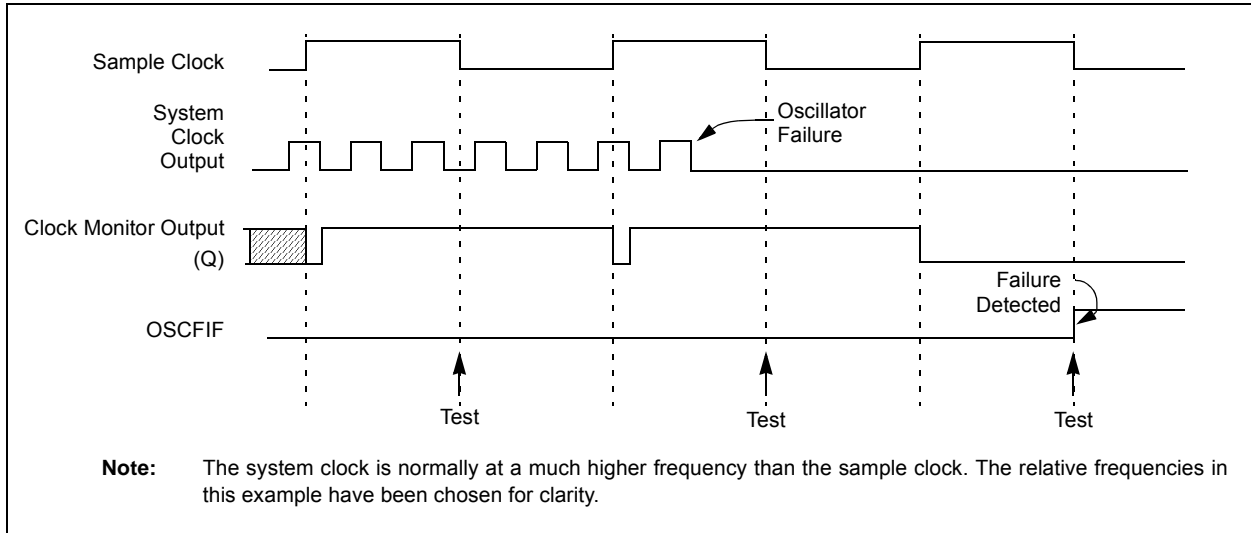
The Fail-Safe condition is cleared after a Reset, executing a SLEEP instruction or changing the SCS bits of the OSCCON register. When the SCS bits are changed, the OST is restarted. While the OST is running, the device continues to operate from the INTOSC selected in OSCCON. When the OST times out, the Fail-Safe condition is cleared and the device will be operating from the external clock source. The Fail-Safe condition must be cleared before the OSFIF flag can be cleared.

5.5.4 RESET OR WAKE-UP FROM SLEEP

The FSCM is designed to detect an oscillator failure after the Oscillator Start-up Timer (OST) has expired. The OST is used after waking up from Sleep and after any type of Reset. The OST is not used with the EC or RC Clock modes so that the FSCM will be active as soon as the Reset or wake-up has completed. When the FSCM is enabled, the Two-Speed Start-up is also enabled. Therefore, the device will always be executing code while the OST is operating.

Note: Due to the wide range of oscillator start-up times, the Fail-Safe circuit is not active during oscillator start-up (i.e., after exiting Reset or Sleep). After an appropriate amount of time, the user should check the Status bits in the OSCSTAT register to verify the oscillator start-up and that the system clock switchover has successfully completed.

FIGURE 5-10: FSCM TIMING DIAGRAM



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5.6 Oscillator Control Registers

REGISTER 5-1: OSCCON: OSCILLATOR CONTROL REGISTER

U-0	R/W-0/0	R/W-1/1	R/W-1/1	R/W-1/1	U-0	R/W-0/0	R/W-0/0
—	IRCF<3:0>				—	SCS<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 **Unimplemented:** Read as '0'

bit 6-3 **IRCF<3:0>:** Internal Oscillator Frequency Select bits

000x = 31 kHz LF

001x = 31.25 kHz

0100 = 62.5 kHz

0101 = 125 kHz

0110 = 250 kHz

0111 = 500 kHz (default upon Reset)

1000 = 125 kHz⁽¹⁾

1001 = 250 kHz⁽¹⁾

1010 = 500 kHz⁽¹⁾

1011 = 1 MHz

1100 = 2 MHz

1101 = 4 MHz

1110 = 8 MHz

1111 = 16 MHz

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

bit 1-0 **SCS<1:0>:** System Clock Select bits

1x = Internal oscillator block

01 = Secondary oscillator

00 = Clock determined by FOSC<2:0> in Configuration Word 1.

Note 1: Duplicate frequency derived from HFINTOSC.

REGISTER 5-2: OSCSTAT: OSCILLATOR STATUS REGISTER

R-1/q	U-0	R-q/q	R-0/q	U-0	U-0	R-0/0	R-0/q
SOSCR	—	OSTS	HFIOFR	—	—	LFIOFR	HFIOFS
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 = Conditional

- bit 7 **SOSCR:** Secondary Oscillator Ready bit
 If **SOSCEN = 1:**
 1 = Secondary oscillator is ready
 0 = Secondary oscillator is not ready
 If **SOSCEN = 0:**
 1 = Timer1 clock source is always ready
- bit 6 **Unimplemented:** Read as '0'
- bit 5 **OSTS:** Oscillator Start-up Time-out Status bit
 1 = Running from the clock defined by the FOSC<2:0> bits of the Configuration Word 1
 0 = Running from an internal oscillator (FOSC<2:0> = 100)
- bit 4 **HFIOFR:** High-Frequency Internal Oscillator Ready bit
 1 = HFINTOSC is ready
 0 = HFINTOSC is not ready
- bit 3-2 **Unimplemented:** Read as '0'
- bit 1 **LFIOFR:** Low-Frequency Internal Oscillator Ready bit
 1 = LFINTOSC is ready
 0 = LFINTOSC is not ready
- bit 0 **HFIOFS:** High-Frequency Internal Oscillator Stable bit
 1 = HFINTOSC 16 MHz Oscillator is stable and is driving the INTOSC
 0 = HFINTOSC 16 MHz is not stable, the 12 MHz Start-up Oscillator is driving INTOSC

TABLE 5-2: SUMMARY OF REGISTERS ASSOCIATED WITH CLOCK SOURCES

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
OSCCON	—	IRCF<3:0>			—	SCS<1:0>			64
OSCSTAT	SOSCR	—	OSTS	HFIOFR	—	—	LFIOFR	HFIOFS	65
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	83
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	85
T1CON	TMR1CS<1:0>		T1CKPS<1:0>		SOSCEN	T1SYNC	—	TMR1ON	165

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by clock sources.

TABLE 5-3: SUMMARY OF CONFIGURATION WORD WITH CLOCK SOURCES

Name	Bits	Bit -/7	Bit -/6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG1	13:8	—		FCMEN	IESO	CLKOUTEN	BOREN<1:0>		—	46
	7:0	CP	MCLRE	PWRTE	WDTE<1:0>		FOSC<2:0>			

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by clock sources.

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NOTES:

6.0 RESETS

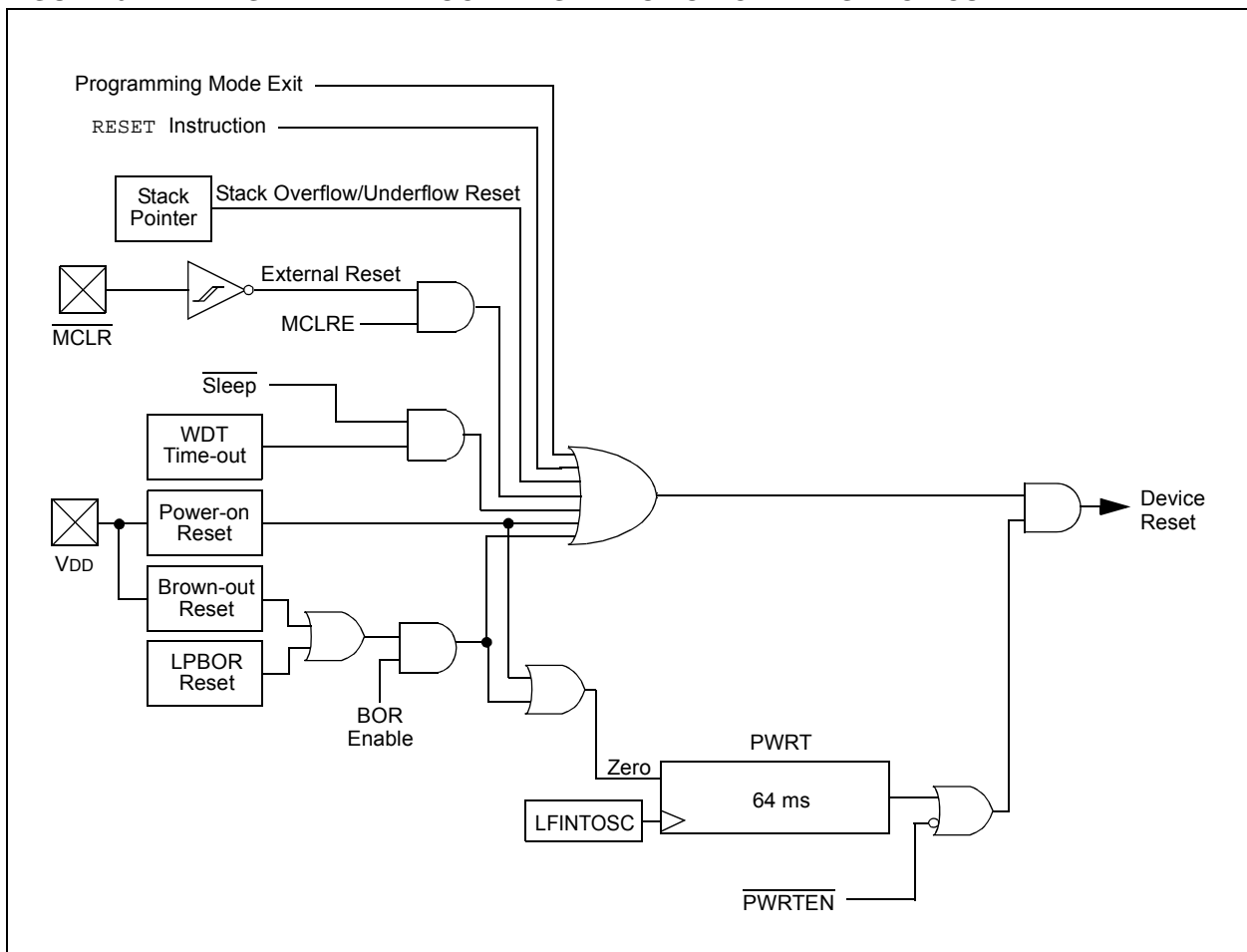
A simplified block diagram of the On-Chip Reset Circuit is shown in [Figure 6-1](#).

There are multiple ways to reset this device:

- Power-on Reset (POR)
- Brown-out Reset (BOR)
- Low-Power Brown-out Reset (LPBOR)
- MCLR Reset
- WDT Reset
- RESET instruction
- Stack Overflow
- Stack Underflow
- Programming mode exit

To allow VDD to stabilize, an optional power-up timer can be enabled to extend the Reset time after a BOR or POR event.

FIGURE 6-1: SIMPLIFIED BLOCK DIAGRAM OF ON-CHIP RESET CIRCUIT



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6.1 Power-on Reset (POR)

The POR circuit holds the device in Reset until VDD has reached an acceptable level for minimum operation. Slow rising VDD, fast operating speeds or analog performance may require greater than minimum VDD. The PWRT, BOR or MCLR features can be used to extend the start-up period until all device operation conditions have been met.

6.1.1 POWER-UP TIMER (PWRT)

The Power-up Timer provides a nominal 64 ms time-out on POR or Brown-out Reset.

The device is held in Reset as long as PWRT is active. The PWRT delay allows additional time for the VDD to rise to an acceptable level. The Power-up Timer is enabled by clearing the PWRTE bit in Configuration Word 1.

The Power-up Timer starts after the release of the POR and BOR.

For additional information, refer to Application Note AN607, "Power-up Trouble Shooting" (DS00607).

6.2 Brown-Out Reset (BOR)

The BOR circuit holds the device in Reset when VDD reaches a selectable minimum level. Between the POR and BOR, complete voltage range coverage for execution protection can be implemented.

The Brown-out Reset module has four operating modes controlled by the BOREN<1:0> bits in Configuration Word 1. The four operating modes are:

- BOR is always on
- BOR is off when in Sleep
- BOR is controlled by software
- BOR is always off

Refer to [Table 6-1](#) for more information.

The Brown-out Reset voltage level is selectable by configuring the BORV bit in Configuration Word 2.

A VDD noise rejection filter prevents the BOR from triggering on small events. If VDD falls below VBOR for a duration greater than parameter TBORDC, the device will reset. See [Figure 6-2](#) for more information.

TABLE 6-1: BOR OPERATING MODES

BOREN<1:0>	SBOREN	Device Mode	BOR Mode	Device Operation upon release of POR	Device Operation upon wake-up from Sleep
11	X	X	Active	Waits for BOR ready ⁽¹⁾	
10	X	Awake	Active	Waits for BOR ready	
		Sleep	Disabled		
01	1	X	Active	Begins immediately	
	0		Disabled	Begins immediately	
00	X	X	Disabled	Begins immediately	

Note 1: Even though this case specifically waits for the BOR, the BOR is already operating, so there is no delay in start-up.

6.2.1 BOR IS ALWAYS ON

When the BOREN bits of Configuration Word 1 are set to '11', the BOR is always on. The device start-up will be delayed until the BOR is ready and VDD is higher than the BOR threshold.

BOR protection is active during Sleep. The BOR does not delay wake-up from Sleep.

6.2.2 BOR IS OFF IN SLEEP

When the BOREN bits of Configuration Word 1 are set to '10', the BOR is on, except in Sleep. The device start-up will be delayed until the BOR is ready and VDD is higher than the BOR threshold.

BOR protection is not active during Sleep. The device wake-up will be delayed until the BOR is ready.

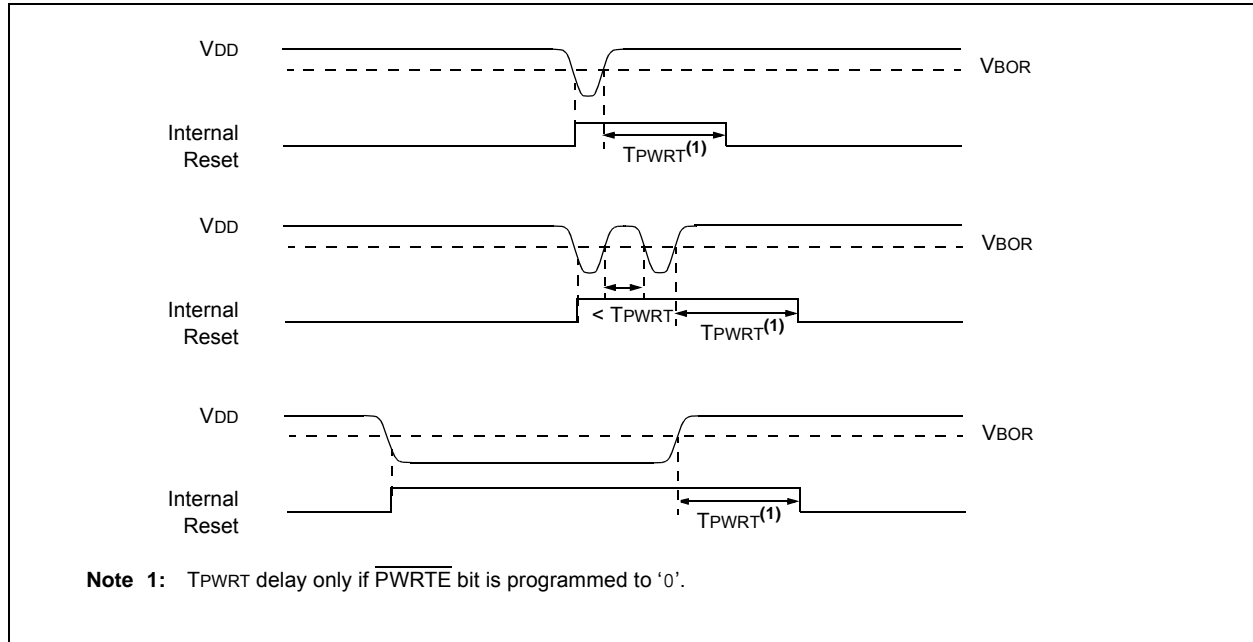
6.2.3 BOR CONTROLLED BY SOFTWARE

When the BOREN bits of Configuration Word 1 are set to '01', the BOR is controlled by the SBOREN bit of the BORCON register. The device start-up is not delayed by the BOR ready condition or the VDD level.

BOR protection begins as soon as the BOR circuit is ready. The status of the BOR circuit is reflected in the BORRDY bit of the BORCON register.

BOR protection is unchanged by Sleep.

FIGURE 6-2: BROWN-OUT SITUATIONS



REGISTER 6-1: BORCON: BROWN-OUT RESET CONTROL REGISTER

R/W-1/u	R/W-0/u	U-0	U-0	U-0	U-0	U-0	R-q/u
SBOREN	BORFS	—	—	—	—	—	BORRDY
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 **SBOREN:** Software Brown-out Reset Enable bit⁽¹⁾
If BOREN <1:0> ≠ 01:
SBOREN is read/write, but has no effect on the BOR.
If BOREN <1:0> = 01:
1 = BOR Enabled
0 = BOR Disabled
- bit 6 **BORFS:** Brown-out Reset Fast Start bit⁽¹⁾
If BOREN<1:0> = 11 (Always on) or BOREN<1:0> = 00 (Always off)
BORFS is Read/Write, but has no effect.
If BOREN <1:0> = 10 (Disabled in Sleep) or BOREN<1:0> = 01 (Under software control):
1 = Band gap is forced on always (covers sleep/wake-up/operating cases)
0 = Band gap operates normally, and may turn off
- bit 5-1 **Unimplemented:** Read as '0'
- bit 0 **BORRDY:** Brown-out Reset Circuit Ready Status bit
1 = The Brown-out Reset circuit is active
0 = The Brown-out Reset circuit is inactive

Note 1: BOREN<1:0> bits are located in Configuration Word 1.

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6.3 Low-Power Brown-out Reset (LPBOR)

The Low-Power Brown-Out Reset (LPBOR) is an essential part of the Reset subsystem. Refer to [Figure 6-1](#) to see how the BOR interacts with other modules.

The LPBOR is used to monitor the external VDD pin. When too low of a voltage is detected, the device is held in Reset. When this occurs, a register bit ($\overline{\text{BOR}}$) is changed to indicate that a BOR Reset has occurred. The same bit is set for both the BOR and the LPBOR. Refer to [Register 6-2](#).

6.3.1 ENABLING LPBOR

The LPBOR is controlled by the $\overline{\text{LPBOR}}$ bit of Configuration Word 2. When the device is erased, the LPBOR module defaults to disabled.

6.3.1.1 LPBOR Module Output

The output of the LPBOR module is a signal indicating whether or not a Reset is to be asserted. This signal is to be OR'd together with the Reset signal of the BOR module to provide the generic $\overline{\text{BOR}}$ signal which goes to the PCON register and to the power control block.

6.4 $\overline{\text{MCLR}}$

The $\overline{\text{MCLR}}$ is an optional external input that can reset the device. The MCLR function is controlled by the MCLRE bit of Configuration Word 1 and the LVP bit of Configuration Word 2 ([Register 4-2](#)).

TABLE 6-2: $\overline{\text{MCLR}}$ CONFIGURATION

MCLRE	LVP	$\overline{\text{MCLR}}$
0	0	Disabled
1	0	Enabled
x	1	Enabled

6.4.1 $\overline{\text{MCLR}}$ ENABLED

When $\overline{\text{MCLR}}$ is enabled and the pin is held low, the device is held in Reset. The $\overline{\text{MCLR}}$ pin is connected to VDD through an internal weak pull-up.

The device has a noise filter in the $\overline{\text{MCLR}}$ Reset path. The filter will detect and ignore small pulses.

Note: A Reset does not drive the $\overline{\text{MCLR}}$ pin low.

6.4.2 $\overline{\text{MCLR}}$ DISABLED

When $\overline{\text{MCLR}}$ is disabled, the pin functions as a general purpose input and the internal weak pull-up is under software control. See [Section 12.6 “PORTE Registers”](#) for more information.

6.5 Watchdog Timer (WDT) Reset

The Watchdog Timer generates a Reset if the firmware does not issue a $\overline{\text{CLRWDT}}$ instruction within the time-out period. The $\overline{\text{TO}}$ and $\overline{\text{PD}}$ bits in the STATUS register are changed to indicate the WDT Reset. See [Section 10.0 “Watchdog Timer”](#) for more information.

6.6 RESET Instruction

A $\overline{\text{RESET}}$ instruction will cause a device Reset. The $\overline{\text{R}}$ bit in the PCON register will be set to '0'. See [Table 6-4](#) for default conditions after a $\overline{\text{RESET}}$ instruction has occurred.

6.7 Stack Overflow/Underflow Reset

The device can reset when the Stack Overflows or Underflows. The STKOVF or STKUNF bits of the PCON register indicate the Reset condition. These Resets are enabled by setting the STVREN bit in Configuration Word 2. See [Section 3.4.2 “Overflow/Underflow Reset”](#) for more information.

6.8 Programming Mode Exit

Upon exit of Programming mode, the device will behave as if a POR had just occurred.

6.9 Power-Up Timer

The Power-up Timer optionally delays device execution after a BOR or POR event. This timer is typically used to allow VDD to stabilize before allowing the device to start running.

The Power-up Timer is controlled by the $\overline{\text{PWRT}}$ bit of Configuration Word 1.

6.10 Start-up Sequence

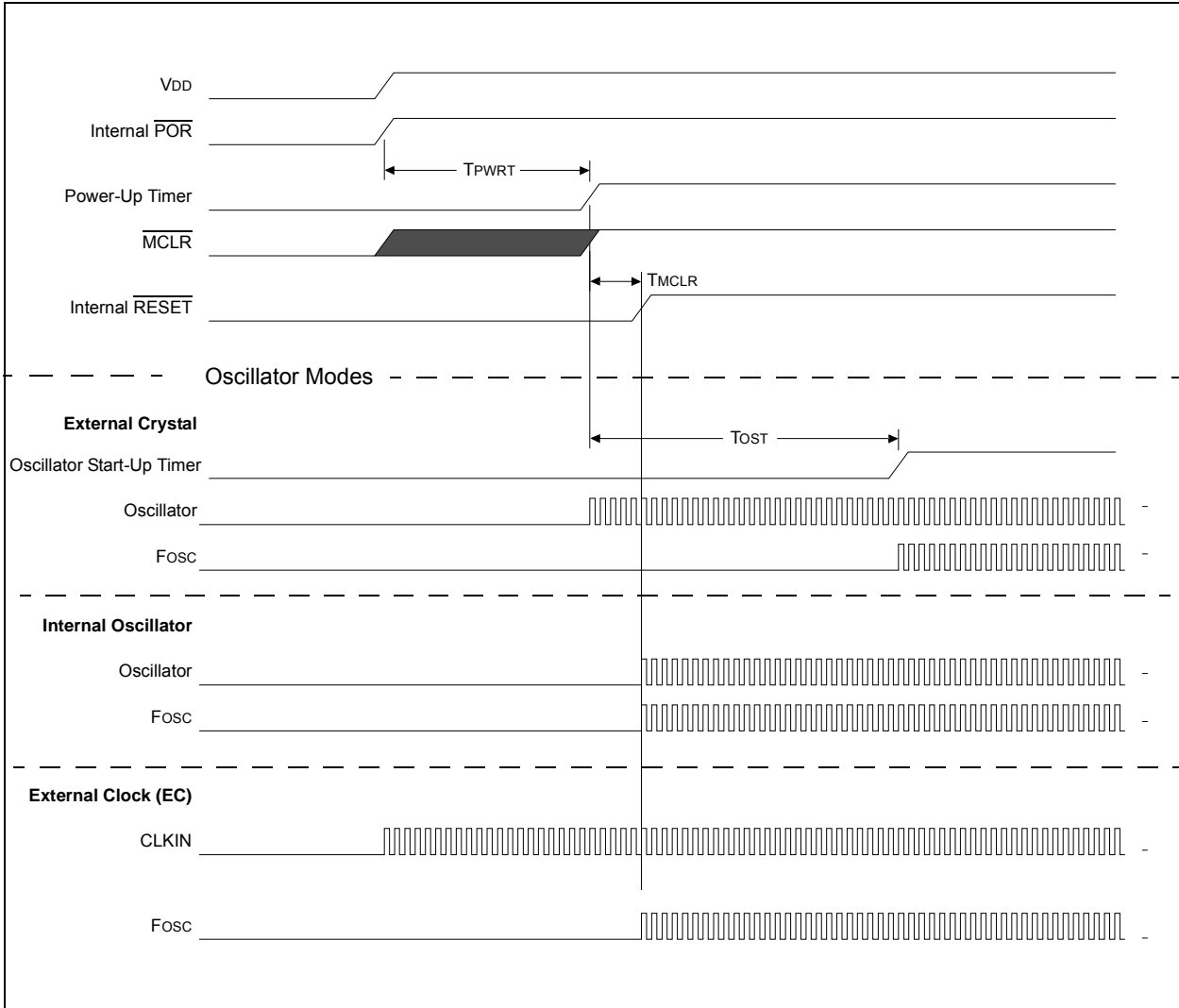
Upon the release of a POR or BOR, the following must occur before the device will begin executing:

1. Power-up Timer runs to completion (if enabled).
2. Oscillator start-up timer runs to completion (if required for oscillator source).
3. $\overline{\text{MCLR}}$ must be released (if enabled).

The total time-out will vary based on oscillator configuration and Power-up Timer configuration. See [Section 5.0 “Oscillator Module \(With Fail-Safe Clock Monitor\)”](#) for more information.

The Power-up Timer and oscillator start-up timer run independently of $\overline{\text{MCLR}}$ Reset. If $\overline{\text{MCLR}}$ is kept low long enough, the Power-up Timer and oscillator start-up timer will expire. Upon bringing $\overline{\text{MCLR}}$ high, the device will begin execution immediately (see [Figure 6-3](#)). This is useful for testing purposes or to synchronize more than one device operating in parallel.

FIGURE 6-3: RESET START-UP SEQUENCE



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6.11 Determining the Cause of a Reset

Upon any Reset, multiple bits in the STATUS and PCON register are updated to indicate the cause of the Reset. Table 6-3 and Table 6-4 show the Reset conditions of these registers.

TABLE 6-3: RESET STATUS BITS AND THEIR SIGNIFICANCE

STKOVF	STKUNF	RWD \overline{T}	RMCLR	RI	POR	BOR	TO	PD	Condition
0	0	1	1	1	0	x	1	1	Power-on Reset
0	0	1	1	1	0	x	0	x	Illegal, \overline{TO} is set on \overline{POR}
0	0	1	1	1	0	x	x	0	Illegal, \overline{PD} is set on \overline{POR}
0	0	u	1	1	u	0	1	1	Brown-out Reset
u	u	0	u	u	u	u	0	u	WDT Reset
u	u	u	u	u	u	u	0	0	WDT Wake-up from Sleep
u	u	u	u	u	u	u	1	0	Interrupt Wake-up from Sleep
u	u	u	0	u	u	u	u	u	\overline{MCLR} Reset during normal operation
u	u	u	0	u	u	u	1	0	\overline{MCLR} Reset during Sleep
u	u	u	u	0	u	u	u	u	RESET Instruction Executed
1	u	u	u	u	u	u	u	u	Stack Overflow Reset (STVREN = 1)
u	1	u	u	u	u	u	u	u	Stack Underflow Reset (STVREN = 1)

TABLE 6-4: RESET CONDITION FOR SPECIAL REGISTERS⁽²⁾

Condition	Program Counter	STATUS Register	PCON Register
Power-on Reset	0000h	---1 1000	00-1 110x
\overline{MCLR} Reset during normal operation	0000h	---u uuuu	uu-u 0uuu
\overline{MCLR} Reset during Sleep	0000h	---1 0uuu	uu-u 0uuu
WDT Reset	0000h	---0 uuuu	uu-0 uuuu
WDT Wake-up from Sleep	PC + 1	---0 0uuu	uu-u uuuu
Brown-out Reset	0000h	---1 1uuu	00-1 11u0
Interrupt Wake-up from Sleep	PC + 1 ⁽¹⁾	---1 0uuu	uu-u uuuu
RESET Instruction Executed	0000h	---u uuuu	uu-u u0uu
Stack Overflow Reset (STVREN = 1)	0000h	---u uuuu	1u-u uuuu
Stack Underflow Reset (STVREN = 1)	0000h	---u uuuu	u1-u uuuu

Legend: u = unchanged, x = unknown, - = unimplemented bit, reads as '0'.

Note 1: When the wake-up is due to an interrupt and Global Enable bit (GIE) is set, the return address is pushed on the stack and PC is loaded with the interrupt vector (0004h) after execution of PC + 1.

2: If a Status bit is not implemented, that bit will be read as '0'.

6.12 Power Control (PCON) Register

The Power Control (PCON) register contains flag bits to differentiate between a:

- Power-on Reset ($\overline{\text{POR}}$)
- Brown-out Reset ($\overline{\text{BOR}}$)
- Reset Instruction Reset ($\overline{\text{RI}}$)
- MCLR Reset ($\overline{\text{RMCLR}}$)
- Watchdog Timer Reset ($\overline{\text{RWDT}}$)
- Stack Underflow Reset (STKUNF)
- Stack Overflow Reset (STKOVF)

The PCON register bits are shown in [Register 6-2](#).

REGISTER 6-2: PCON: POWER CONTROL REGISTER

R/W/HS-0/q	R/W/HS-0/q	U-0	R/W/HC-1/q	R/W/HC-1/q	R/W/HC-1/q	R/W/HC-q/u	R/W/HC-q/u
STKOVF	STKUNF	—	$\overline{\text{RWDT}}$	$\overline{\text{RMCLR}}$	$\overline{\text{RI}}$	$\overline{\text{POR}}$	$\overline{\text{BOR}}$
bit 7							bit 0

Legend:

HC = Bit is cleared by hardware

HS = Bit is set by hardware

R = Readable bit

W = Writable bit

U = Unimplemented bit, read as '0'

u = Bit is unchanged

x = Bit is unknown

-m/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 **STKOVF:** Stack Overflow Flag bit
 1 = A Stack Overflow occurred
 0 = A Stack Overflow has not occurred or set to '0' by firmware
- bit 6 **STKUNF:** Stack Underflow Flag bit
 1 = A Stack Underflow occurred
 0 = A Stack Underflow has not occurred or set to '0' by firmware
- bit 5 **Unimplemented:** Read as '0'
- bit 4 **$\overline{\text{RWDT}}$:** Watchdog Timer Reset Flag bit
 1 = A Watchdog Timer Reset has not occurred or set to '1' by firmware
 0 = A Watchdog Timer Reset has occurred (set to '0' in hardware when a Watchdog Timer Reset)
- bit 3 **$\overline{\text{RMCLR}}$:** MCLR Reset Flag bit
 1 = A MCLR Reset has not occurred or set to '1' by firmware
 0 = A MCLR Reset has occurred (set to '0' in hardware when a MCLR Reset occurs)
- bit 2 **$\overline{\text{RI}}$:** RESET Instruction Flag bit
 1 = A RESET instruction has not been executed or set to '1' by firmware
 0 = A RESET instruction has been executed (set to '0' in hardware upon executing a RESET instruction)
- bit 1 **$\overline{\text{POR}}$:** Power-on Reset Status bit
 1 = No Power-on Reset occurred
 0 = A Power-on Reset occurred (must be set in software after a Power-on Reset occurs)
- bit 0 **$\overline{\text{BOR}}$:** Brown-out Reset Status bit
 1 = No Brown-out Reset occurred
 0 = A Brown-out Reset occurred (must be set in software after a Power-on Reset or Brown-out Reset occurs)

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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	69
PCON	STKOVF	STKUNF	—	\overline{RWDT}	\overline{RMCLR}	\overline{RI}	\overline{POR}	\overline{BOR}	73
STATUS	—	—	—	\overline{TO}	\overline{PD}	Z	DC	C	23
WDTCON	—	—	WDTPS<4:0>					SWDTEN	99

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

7.0 INTERRUPTS

The interrupt feature allows certain events to preempt normal program flow. Firmware is used to determine the source of the interrupt and act accordingly. Some interrupts can be configured to wake the MCU from Sleep mode.

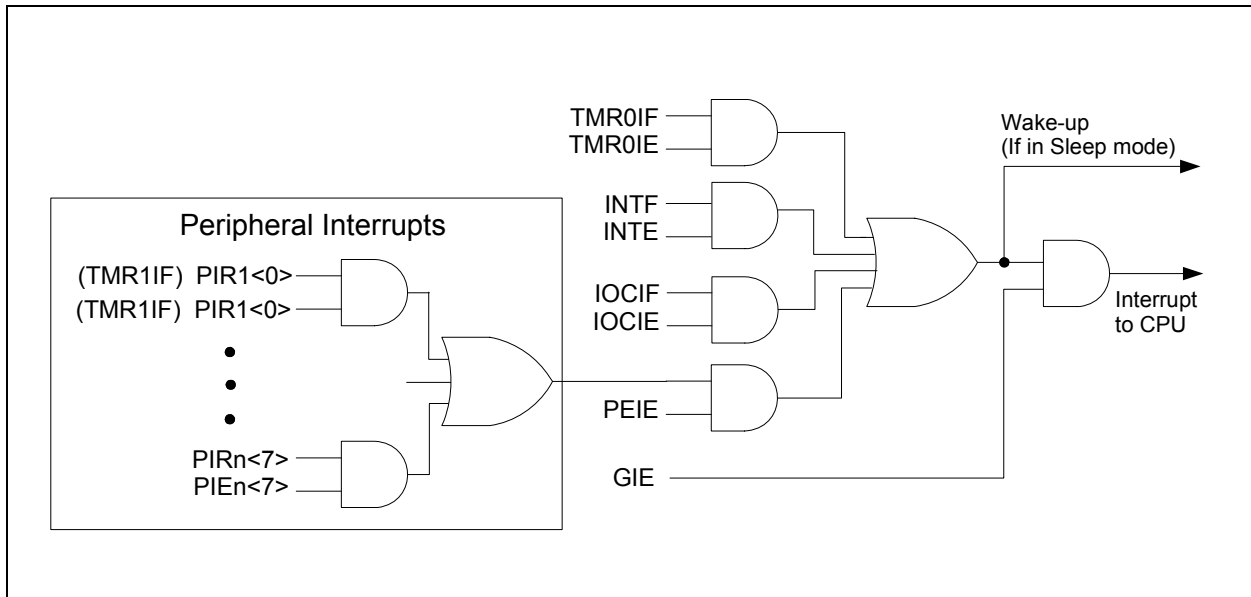
This chapter contains the following information for Interrupts:

- Operation
- Interrupt Latency
- Interrupts During Sleep
- INT Pin
- Automatic Context Saving

Many peripherals produce Interrupts. Refer to the corresponding chapters for details.

A block diagram of the interrupt logic is shown in [Figure 7-1](#).

FIGURE 7-1: INTERRUPT LOGIC



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7.1 Operation

Interrupts are disabled upon any device Reset. They are enabled by setting the following bits:

- GIE bit of the INTCON register
- Interrupt Enable bit(s) for the specific interrupt event(s)
- PEIE bit of the INTCON register (if the Interrupt Enable bit of the interrupt event is contained in the PEx register)

The INTCON and PIRx registers record individual interrupts via interrupt flag bits. Interrupt flag bits will be set, regardless of the status of the GIE, PEIE and individual interrupt enable bits.

The following events happen when an interrupt event occurs while the GIE bit is set:

- Current prefetched instruction is flushed
- GIE bit is cleared
- Current Program Counter (PC) is pushed onto the stack
- Critical registers are automatically saved to the shadow registers (See [Section 7.5 “Automatic Context Saving”](#))
- PC is loaded with the interrupt vector 0004h

The firmware within the Interrupt Service Routine (ISR) should determine the source of the interrupt by polling the interrupt flag bits. The interrupt flag bits must be cleared before exiting the ISR to avoid repeated interrupts. Because the GIE bit is cleared, any interrupt that occurs while executing the ISR will be recorded through its interrupt flag, but will not cause the processor to redirect to the interrupt vector.

The `RETFIE` instruction exits the ISR by popping the previous address from the stack, restoring the saved context from the shadow registers and setting the GIE bit.

For additional information on a specific interrupt's operation, refer to its peripheral chapter.

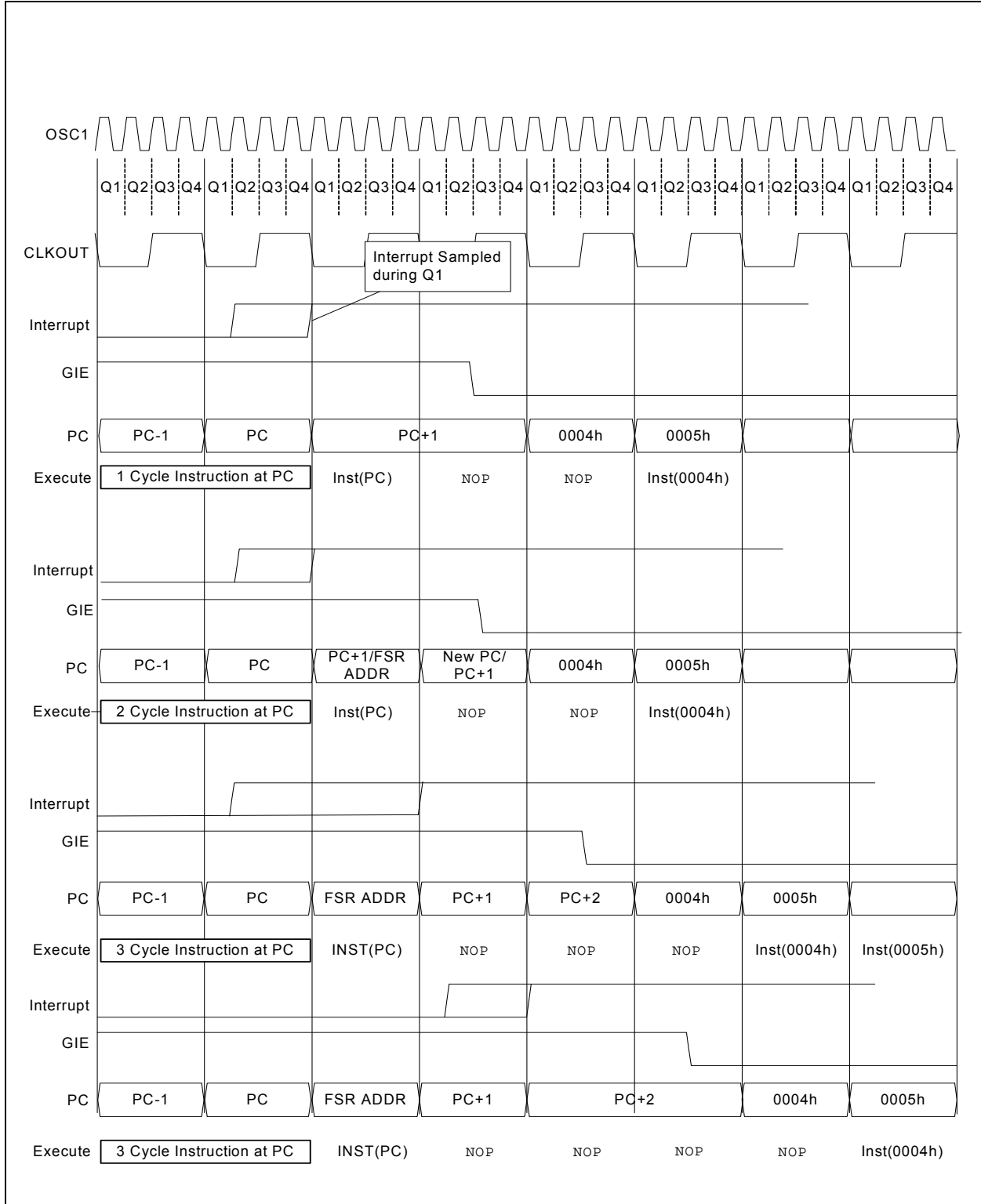
Note 1: Individual interrupt flag bits are set, regardless of the state of any other enable bits.

2: All interrupts will be ignored while the GIE bit is cleared. Any interrupt occurring while the GIE bit is clear will be serviced when the GIE bit is set again.

7.2 Interrupt Latency

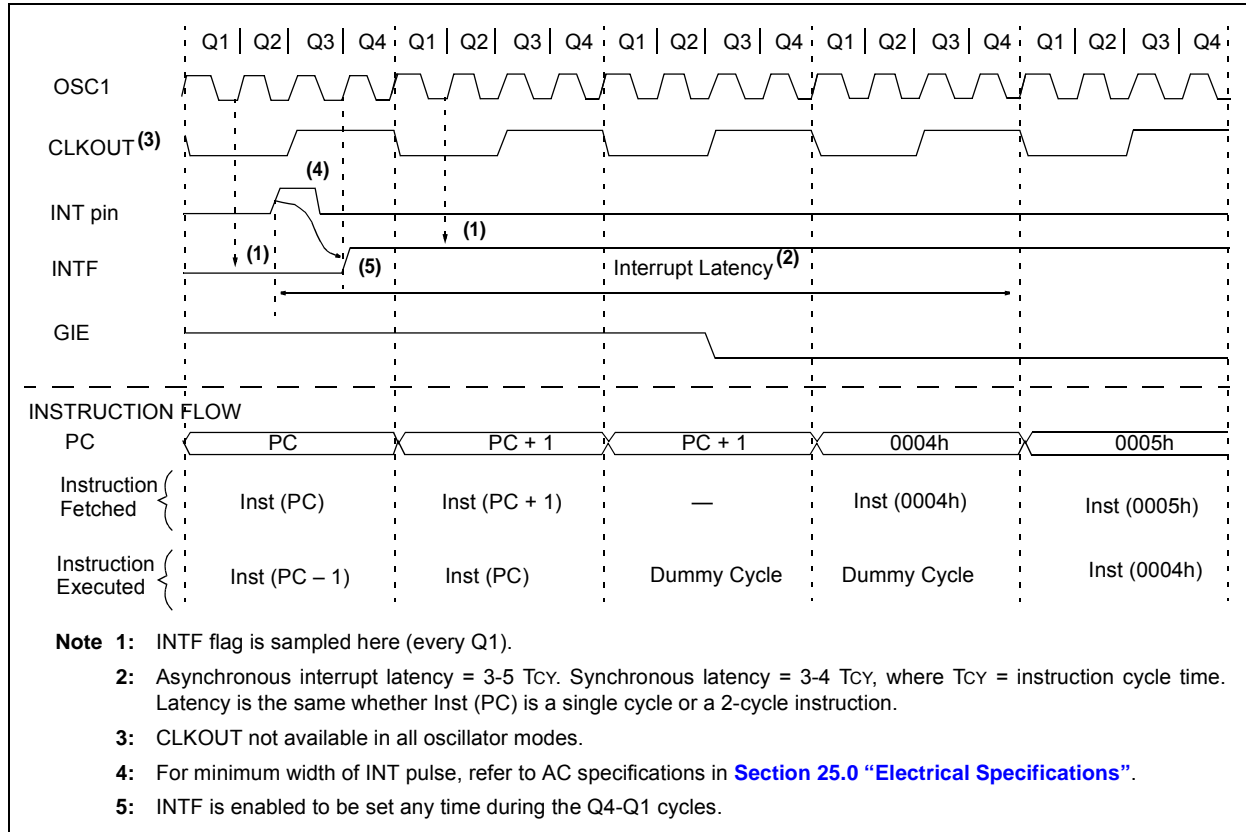
Interrupt latency is defined as the time from when the interrupt event occurs to the time code execution at the interrupt vector begins. The latency for synchronous interrupts is 3 or 4 instruction cycles. For asynchronous interrupts, the latency is 3 to 5 instruction cycles, depending on when the interrupt occurs. See [Figure 7-2](#) and [Figure 7-3](#) for more details.

FIGURE 7-2: INTERRUPT LATENCY



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FIGURE 7-3: INT PIN INTERRUPT TIMING



7.3 Interrupts During Sleep

Some interrupts can be used to wake from Sleep. To wake from Sleep, the peripheral must be able to operate without the system clock. The interrupt source must have the appropriate Interrupt Enable bit(s) set prior to entering Sleep.

On waking from Sleep, if the GIE bit is also set, the processor will branch to the interrupt vector. Otherwise, the processor will continue executing instructions after the `SLEEP` instruction. The instruction directly after the `SLEEP` instruction will always be executed before branching to the ISR. Refer to the [Section 8.0 “Power-Down Mode \(Sleep\)”](#) for more details.

7.4 INT Pin

The INT pin can be used to generate an asynchronous edge-triggered interrupt. This interrupt is enabled by setting the INTE bit of the INTCON register. The INTEDG bit of the OPTION_REG register determines on which edge the interrupt will occur. When the INTEDG bit is set, the rising edge will cause the interrupt. When the INTEDG bit is clear, the falling edge will cause the interrupt. The INTF bit of the INTCON register will be set when a valid edge appears on the INT pin. If the GIE and INTE bits are also set, the processor will redirect program execution to the interrupt vector.

7.5 Automatic Context Saving

Upon entering an interrupt, the return PC address is saved on the stack. Additionally, the following registers are automatically saved in the Shadow registers:

- W register
- STATUS register (except for $\overline{\text{TO}}$ and $\overline{\text{PD}}$)
- BSR register
- FSR registers
- PCLATH register

Upon exiting the Interrupt Service Routine, these registers are automatically restored. Any modifications to these registers during the ISR will be lost. If modifications to any of these registers are desired, the corresponding Shadow register should be modified and the value will be restored when exiting the ISR. The Shadow registers are available in Bank 31 and are readable and writable. Depending on the user's application, other registers may also need to be saved.

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7.6 Interrupt Control Registers

7.6.1 INTCON REGISTER

The INTCON register is a readable and writable register, which contains the various enable and flag bits for TMR0 register overflow, interrupt-on-change and external INT pin interrupts.

Note: Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the Global Enable bit, GIE, of the INTCON register. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 7-1: INTCON: INTERRUPT CONTROL REGISTER

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R-0/0
GIE	PEIE	TMR0IE	INTE	IOCFIE	TMR0IF	INTF	IOCFIF
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 **GIE:** Global Interrupt Enable bit
 1 = Enables all active interrupts
 0 = Disables all interrupts
- bit 6 **PEIE:** Peripheral Interrupt Enable bit
 1 = Enables all active peripheral interrupts
 0 = Disables all peripheral interrupts
- bit 5 **TMROIE:** Timer0 Overflow Interrupt Enable bit
 1 = Enables the Timer0 interrupt
 0 = Disables the Timer0 interrupt
- bit 4 **INTE:** INT External Interrupt Enable bit
 1 = Enables the INT external interrupt
 0 = Disables the INT external interrupt
- bit 3 **IOCFIE:** Interrupt-on-Change Interrupt Enable bit
 1 = Enables the interrupt-on-change interrupt
 0 = Disables the interrupt-on-change interrupt
- bit 2 **TMROIF:** Timer0 Overflow Interrupt Flag bit
 1 = TMR0 register has overflowed
 0 = TMR0 register did not overflow
- bit 1 **INTF:** INT External Interrupt Flag bit
 1 = The INT external interrupt occurred
 0 = The INT external interrupt did not occur
- bit 0 **IOCFIF:** Interrupt-on-Change Interrupt Flag bit⁽¹⁾
 1 = When at least one of the interrupt-on-change pins changed state
 0 = None of the interrupt-on-change pins have changed state

Note 1: The IOCFIF flag bit is read-only and cleared when all the Interrupt-on-Change flags in the IOCBF register have been cleared by software.

7.6.2 PIE1 REGISTER

The PIE1 register contains the interrupt enable bits, as shown in [Register 7-2](#).

Note: Bit PEIE of the INTCON register must be set to enable any peripheral interrupt.

REGISTER 7-2: PIE1: PERIPHERAL INTERRUPT ENABLE REGISTER 1

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE
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 **TMR1GIE:** Timer1 Gate Interrupt Enable bit
 1 = Enables the Timer1 Gate Acquisition interrupt
 0 = Disables the Timer1 Gate Acquisition interrupt

- bit 6 **ADIE:** A/D Converter (ADC) Interrupt Enable bit
 1 = Enables the ADC interrupt
 0 = Disables the ADC interrupt

- bit 5 **RC1IE:** USART1 Receive Interrupt Enable bit
 1 = Enables the USART1 receive interrupt
 0 = Disables the USART1 receive interrupt

- bit 4 **TX1IE:** USART1 Transmit Interrupt Enable bit
 1 = Enables the USART1 transmit interrupt
 0 = Disables the USART1 transmit interrupt

- bit 3 **SSP1IE:** Synchronous Serial Port (MSSP1) Interrupt Enable bit
 1 = Enables the MSSP1 interrupt
 0 = Disables the MSSP1 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 Timer2 to PR2 match interrupt
 0 = Disables the Timer2 to PR2 match interrupt

- bit 0 **TMR1IE:** Timer1 Overflow Interrupt Enable bit
 1 = Enables the Timer1 overflow interrupt
 0 = Disables the Timer1 overflow interrupt

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7.6.3 PIE2 REGISTER

The PIE2 register contains the interrupt enable bits, as shown in [Register 7-3](#).

Note: Bit PEIE of the INTCON register must be set to enable any peripheral interrupt.

REGISTER 7-3: PIE2: PERIPHERAL INTERRUPT ENABLE REGISTER 2

R/W-0/0	R/W-0/0	R/W-0/0	U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE
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 **OSFIE:** Oscillator Fail Interrupt Enable bit
1 = Enables the Oscillator Fail interrupt
0 = Disables the Oscillator Fail interrupt
- bit 6 **TMR5GIE:** Timer5 Gate Interrupt Enable bit
1 = Enables the Timer5 Gate Acquisition interrupt
0 = Disables the Timer5 Gate Acquisition interrupt
- bit 5 **TMR3GIE:** Timer3 Gate Interrupt Enable bit
1 = Enables the Timer3 Gate Acquisition interrupt
0 = Disables the Timer3 Gate Acquisition interrupt
- bit 4 **Unimplemented:** Read as '0'
- bit 3 **BCL1IE:** MSSP1 Bus Collision Interrupt Enable bit
1 = Enables the MSSP1 Bus Collision Interrupt
0 = Disables the MSSP1 Bus Collision Interrupt
- bit 2 **TMR10IE:** TMR10 to PR10 Match Interrupt Enable bit
1 = Enables the Timer10 to PR10 match interrupt
0 = Disables the Timer10 to PR10 match interrupt
- bit 1 **TMR8IE:** TMR8 to PR8 Match Interrupt Enable bit
1 = Enables the Timer8 to PR8 match interrupt
0 = Disables the Timer8 to PR8 match interrupt
- bit 0 **CCP2IE:** CCP2 Interrupt Enable bit
1 = Enables the CCP2 interrupt
0 = Disables the CCP2 interrupt

7.6.4 PIE3 REGISTER

The PIE3 register contains the interrupt enable bits, as shown in [Register 7-4](#).

Note: Bit PEIE of the INTCON register must be set to enable any peripheral interrupt.

REGISTER 7-4: PIE3: PERIPHERAL INTERRUPT ENABLE REGISTER 3

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE
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 **CCP6IE:** CCP6 Interrupt Enable bit
 1 = Enables the CCP6 interrupt
 0 = Disables the CCP6 interrupt

- bit 6 **CCP5IE:** CCP5 Interrupt Enable bit
 1 = Enables the CCP5 interrupt
 0 = Disables the CCP5 interrupt

- bit 5 **CCP4IE:** CCP4 Interrupt Enable bit
 1 = Enables the CCP4 interrupt
 0 = Disables the CCP4 interrupt

- bit 4 **CCP3IE:** CCP3 Interrupt Enable bit
 1 = Enables the CCP3 interrupt
 0 = Disables the CCP3 interrupt

- bit 3 **TMR6IE:** TMR6 to PR6 Match Interrupt Enable bit
 1 = Enables the TMR6 to PR6 Match interrupt
 0 = Disables the TMR6 to PR6 Match interrupt

- bit 2 **TMR5IE:** Timer5 Overflow Interrupt Enable bit
 1 = Enables the Timer5 overflow interrupt
 0 = Disables the Timer5 overflow interrupt

- bit 1 **TMR4IE:** TMR4 to PR4 Match Interrupt Enable bit
 1 = Enables the TMR4 to PR4 Match interrupt
 0 = Disables the TMR4 to PR4 Match interrupt

- bit 0 **TMR3IE:** Timer3 Overflow Interrupt Enable bit
 1 = Enables the Timer3 overflow interrupt
 0 = Disables the Timer3 overflow interrupt

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7.6.5 PIE4 REGISTER

The PIE4 register contains the interrupt enable bits, as shown in [Register 7-5](#).

Note: Bit PEIE of the INTCON register must be set to enable any peripheral interrupt.

REGISTER 7-5: PIE4: PERIPHERAL INTERRUPT ENABLE REGISTER 4

R/W-0/0	R/W-0/0	R-0/0	R-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE
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 **CCP10IE:** CCP10 Interrupt Enable bit
1 = Enables the CCP10 interrupt
0 = Disables the CCP10 interrupt
- bit 6 **CCP9IE:** CCP9 Interrupt Enable bit
1 = Enables the CCP9 interrupt
0 = Disables the CCP9 interrupt
- bit 5 **RC2IE:** USART2 Receive Interrupt Enable bit
1 = Enables the USART2 receive interrupt
0 = Disables the USART2 receive interrupt
- bit 4 **TX2IE:** USART2 Transmit Interrupt Enable bit
1 = Enables the USART2 transmit interrupt
0 = Disables the USART2 transmit interrupt
- bit 3 **CCP8IE:** CCP8 Interrupt Enable bit
1 = Enables the CCP8 interrupt
0 = Disables the CCP8 interrupt
- bit 2 **CCP7IE:** CCP7 Interrupt Enable bit
1 = Enables the CCP7 interrupt
0 = Disables the CCP7 interrupt
- bit 1 **BCL2IE:** MSSP2 Bus Collision Interrupt Enable bit
1 = Enables the MSSP2 Bus Collision Interrupt
0 = Disables the MSSP2 Bus Collision Interrupt
- bit 0 **SSP2IE:** Synchronous Serial Port (MSSP2) Interrupt Enable bit
1 = Enables the MSSP2 interrupt
0 = Disables the MSSP2 interrupt

7.6.6 PIR1 REGISTER

The PIR1 register contains the interrupt flag bits, as shown in [Register 7-6](#).

Note: Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the Global Enable bit, GIE, of the INTCON register. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 7-6: PIR1: PERIPHERAL INTERRUPT REQUEST REGISTER 1

R/W-0/0	R/W-0/0	R-0/0	R-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF
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 **TMR1GIF:** Timer1 Gate Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 6 **ADIF:** A/D Converter Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 5 **RC1IF:** USART1 Receive Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 4 **TX1IF:** USART1 Transmit Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 3 **SSP1IF:** Synchronous Serial Port (MSSP1) Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 2 **CCP1IF:** CCP1 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 1 **TMR2IF:** Timer2 to PR2 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

- bit 0 **TMR1IF:** Timer1 Overflow Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

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7.6.7 PIR2 REGISTER

The PIR2 register contains the interrupt flag bits, as shown in [Register 7-7](#).

Note: Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the Global Enable bit, GIE, of the INTCON register. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 7-7: PIR2: PERIPHERAL INTERRUPT REQUEST REGISTER 2

R/W-0/0	R/W-0/0	R/W-0/0	U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF
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 **OSFIF:** Oscillator Fail Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending
- bit 6 **TMR5GIF:** Timer5 Gate Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending
- bit 5 **TMR3GIF:** Timer3 Gate Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending
- bit 4 **Unimplemented:** Read as '0'
- bit 3 **BCL1IF:** MSSP1 Bus Collision Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending
- bit 2 **TMR10IF:** Timer10 to PR10 Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending
- bit 1 **TMR8IF:** Timer8 to PR8 Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending
- bit 0 **CCP2IF:** CCP2 Interrupt Flag bit
1 = Interrupt is pending
0 = Interrupt is not pending

7.6.8 PIR3 REGISTER

The PIR3 register contains the interrupt flag bits, as shown in [Register 7-8](#).

Note: Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the Global Enable bit, GIE, of the INTCON register. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 7-8: PIR3: PERIPHERAL INTERRUPT REQUEST REGISTER 3

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF
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 **CCP6IF:** CCP6 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 6 **CCP5IF:** CCP5 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 5 **CCP4IF:** CCP4 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 4 **CCP3IF:** CCP3 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 3 **TMR6IF:** TMR6 to PR6 Match Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 2 **TMR5IF:** Timer5 Overflow Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 1 **TMR4IF:** TMR4 to PR4 Match Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 0 **TMR3IF:** Timer3 Overflow Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

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7.6.9 PIR4 REGISTER

The PIR4 register contains the interrupt flag bits, as shown in [Register 7-9](#).

Note: Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the Global Enable bit, GIE, of the INTCON register. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

REGISTER 7-9: PIR4: PERIPHERAL INTERRUPT REQUEST REGISTER 4

R/W-0/0	R/W-0/0	R-0/0	R-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF
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 **CCP10IF:** CCP10 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 6 **CCP9IF:** CCP9 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 5 **RC2IF:** USART2 Receive Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 4 **TX2IF:** USART2 Transmit Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 3 **CCP8IF:** CCP8 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 2 **CCP7IF:** CCP7 Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 1 **BCL2IF:** MSSP2 Bus Collision Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending
- bit 0 **SSP2IF:** Synchronous Serial Port (MSSP2) Interrupt Flag bit
 1 = Interrupt is pending
 0 = Interrupt is not pending

TABLE 7-1: SUMMARY OF REGISTERS ASSOCIATED WITH INTERRUPTS

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	IOCFIE	TMR0IF	INTF	IOCFIF	80
IOCBF	IOCBF7	IOCBF6	IOCBF5	IOCBF4	IOCBF3	IOCBF2	IOCBF1	IOCBF0	143
IOCBN	IOCBN7	IOCBN6	IOCBN5	IOCBN4	IOCBN3	IOCBN2	IOCBN1	IOCBN0	143
IOCBP	IOCBP7	IOCBP6	IOCBP5	IOCBP4	IOCBP3	IOCBP2	IOCBP1	IOCBP0	143
OPTION_REG	$\overline{\text{WPUEN}}$	INTEDG	TMR0CS	TMR0SE	PSA	PS<2:0>			165
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCLIE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88

Legend: — = unimplemented locations read as '0'. Shaded cells are not used by Interrupts.

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NOTES:

8.0 POWER-DOWN MODE (SLEEP)

The Power-Down mode is entered by executing a `SLEEP` instruction.

Upon entering Sleep mode, the following conditions exist:

1. WDT will be cleared but keeps running, if enabled for operation during Sleep.
2. \overline{PD} bit of the STATUS register is cleared.
3. \overline{TO} bit of the STATUS register is set.
4. CPU clock is disabled.
5. 31 kHz LFINTOSC is unaffected and peripherals that operate from it may continue operation in Sleep.
6. Secondary oscillator is unaffected and peripherals that operate from it may continue operation in Sleep.
7. ADC is unaffected, if the dedicated FRC clock is selected.
8. I/O ports maintain the status they had before `SLEEP` was executed (driving high, low or high-impedance).
9. Resets other than WDT are not affected by Sleep mode.

Refer to individual chapters for more details on peripheral operation during Sleep.

To minimize current consumption, the following conditions should be considered:

- I/O pins should not be floating
- External circuitry sinking current from I/O pins
- Internal circuitry sourcing current from I/O pins
- Current draw from pins with internal weak pull-ups
- Modules using 31 kHz LFINTOSC
- Modules using Secondary oscillator

I/O pins that are high-impedance inputs should be pulled to V_{DD} or V_{SS} externally to avoid switching currents caused by floating inputs.

Examples of internal circuitry that might be sourcing current include modules such as the DAC and FVR modules. See [Section 8.0 “Digital-to-Analog Converter \(DAC\) Module”](#) and [Section 14.0 “Fixed Voltage Reference \(FVR\)”](#) for more information on these modules.

8.1 Wake-up from Sleep

The device can wake-up from Sleep through one of the following events:

1. External Reset input on \overline{MCLR} pin, if enabled
2. BOR Reset, if enabled
3. POR Reset
4. Watchdog Timer, if enabled
5. Any external interrupt
6. Interrupts by peripherals capable of running during Sleep (see individual peripheral for more information)

The first three events will cause a device Reset. The last three events are considered a continuation of program execution. To determine whether a device Reset or wake-up event occurred, refer to [Section 6.11 “Determining the Cause of a Reset”](#).

When the `SLEEP` instruction is being executed, the next instruction ($PC + 1$) is prefetched. For the device to wake-up through an interrupt event, the corresponding interrupt enable bit must be enabled. Wake-up will occur regardless of the state of the GIE bit. If the GIE bit is disabled, the device continues execution at the instruction after the `SLEEP` instruction. If the GIE bit is enabled, the device executes the instruction after the `SLEEP` instruction, the device will call the Interrupt Service Routine. In cases where the execution of the instruction following `SLEEP` is not desirable, the user should have a `NOP` after the `SLEEP` instruction.

The WDT is cleared when the device wakes up from Sleep, regardless of the source of wake-up.

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8.1.1 WAKE-UP USING INTERRUPTS

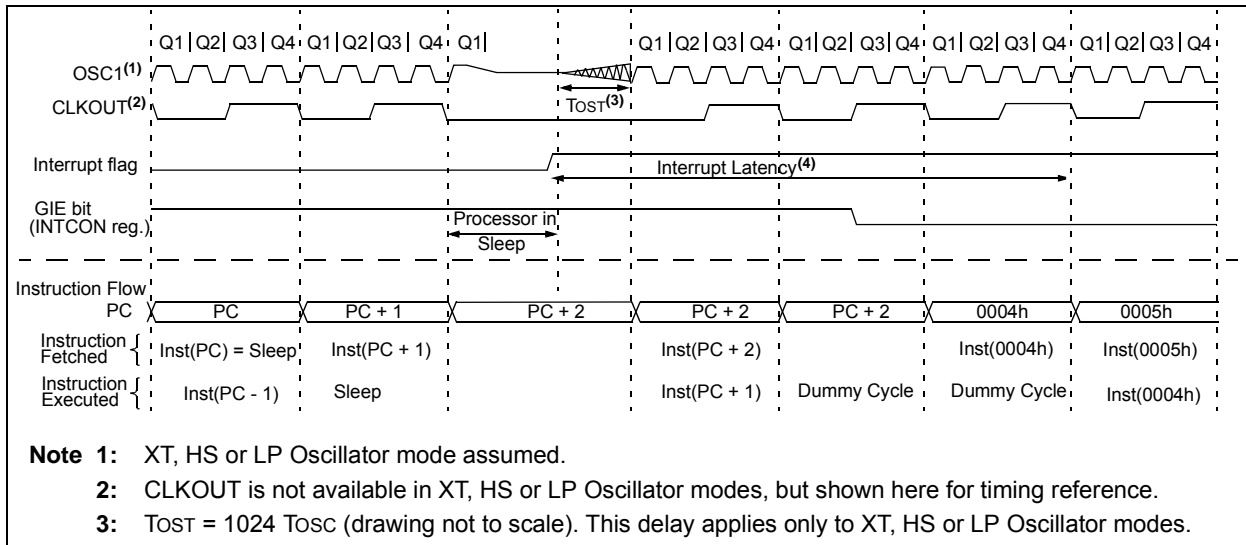
When global interrupts are disabled (GIE cleared) and any interrupt source has both its interrupt enable bit and interrupt flag bit set, one of the following will occur:

- If the interrupt occurs **before** the execution of a `SLEEP` instruction
 - `SLEEP` instruction will execute as a `NOP`.
 - `WDT` and `WDT` prescaler will not be cleared
 - \overline{TO} bit of the `STATUS` register will not be set
 - \overline{PD} bit of the `STATUS` register will not be cleared.
- If the interrupt occurs **during or after** the execution of a `SLEEP` instruction

- `SLEEP` instruction will be completely executed
- Device will immediately wake-up from Sleep
- `WDT` and `WDT` prescaler will be cleared
- \overline{TO} bit of the `STATUS` register will be set
- \overline{PD} bit of the `STATUS` register will be cleared.

Even if the flag bits were checked before executing a `SLEEP` instruction, it may be possible for flag bits to become set before the `SLEEP` instruction completes. To determine whether a `SLEEP` instruction executed, test the `PD` bit. If the `PD` bit is set, the `SLEEP` instruction was executed as a `NOP`.

FIGURE 8-1: WAKE-UP FROM SLEEP THROUGH INTERRUPT



8.2 Low-Power Sleep Mode

The PIC16F1526 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 PIC16F1526 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 PIC16LF1526/27 does not have a configurable Low-Power Sleep mode. PIC16LF1526/27 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 VDD and I/O voltage than the PIC16LF1526/27. See [Section 25.0 “Electrical Specifications”](#) for more information.

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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: PIC16F1526/27 only.
2: See Section 25.0 "Electrical Specifications".

TABLE 8-1: SUMMARY OF REGISTERS ASSOCIATED WITH POWER-DOWN MODE

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	IOCFIE	TMR0IF	INTF	IOCFIF	80
IOCBF	IOCBF7	IOCBF6	IOCBF5	IOCBF4	IOCBF3	IOCBF2	IOCBF1	IOCBF0	143
IOCBN	IOCBN7	IOCBN6	IOCBN5	IOCBN4	IOCBN3	IOCBN2	IOCBN1	IOCBN0	143
IOCBP	IOCBP7	IOCBP6	IOCBP5	IOCBP4	IOCBP3	IOCBP2	IOCBP1	IOCBP0	143
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCLIE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88
STATUS	—	—	—	TO	PD	Z	DC	C	23
VREGCON ⁽¹⁾	—	—	—	—	—	—	VREGPM	Reserved	94
WDTCON	—	—	WDTPS<4:0>					SWDTEN	99

Legend: — = unimplemented, read as '0'. Shaded cells are not used in Power-down mode.
Note 1: PIC16F1526/27 only.

9.0 LOW DROPOUT (LDO) VOLTAGE REGULATOR

The PIC16F1526/27 has an internal Low Dropout Regulator (LDO) which provides operation above 3.6V. The LDO regulates a voltage for the internal device logic while permitting the VDD and I/O pins to operate at a higher voltage. There is no user enable/disable control available for the LDO, it is always active. The PIC16LF1526/27 operates at a maximum VDD of 3.6V and does not incorporate an LDO.

A device I/O pin may be configured as the LDO voltage output, identified as the VCAP pin. Although not required, an external low-ESR capacitor may be connected to the VCAP pin for additional regulator stability.

The VCAPEN bit of Configuration Word 2 enables the VCAP pin. Refer to [Table 9-1](#).

On power-up, the external capacitor will load the LDO voltage regulator. To prevent erroneous operation, the device is held in Reset while a constant current source charges the external capacitor. After the cap is fully charged, the device is released from Reset. For more information on recommended capacitor values and the constant current rate, refer to the LDO Regulator Characteristics Table in **Section 25.0 “Electrical Specifications”**.

TABLE 9-1: VCAPEN SELECT BIT

VCAPEN	Pin
0	RF0
1	No Vcap

TABLE 9-2: SUMMARY OF CONFIGURATION WORD WITH LDO

Name	Bits	Bit -/7	Bit -/6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG2	13:8	—		LVP	DEBUG	LPBOR	BORV	STVREN	—	48
	7:0	—	—	—	VCAPEN ⁽¹⁾	—	—	WRT<1:0>		

Legend: — = unimplemented locations read as '0'. Shaded cells are not used by LDO.

Note 1: PIC16F1526/27 only.

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NOTES:

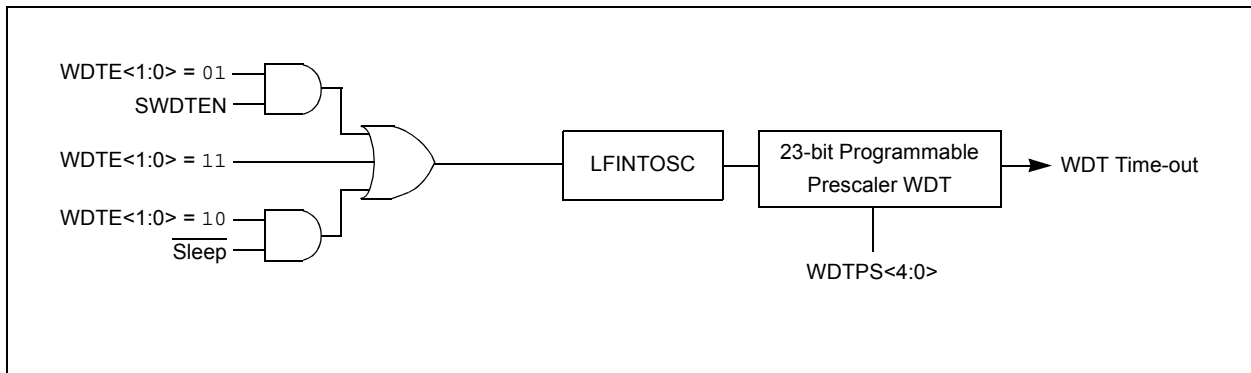
10.0 WATCHDOG TIMER

The Watchdog Timer is a system timer that generates a Reset if the firmware does not issue a `CLRWDT` instruction within the time-out period. The Watchdog Timer is typically used to recover the system from unexpected events.

The WDT has the following features:

- Independent clock source
- Multiple operating modes
 - WDT is always on
 - WDT is off when in Sleep
 - WDT is controlled by software
 - WDT is always off
- Configurable time-out period is from 1 ms to 256 seconds (typical)
- Multiple Reset conditions
- Operation during Sleep

FIGURE 10-1: WATCHDOG TIMER BLOCK DIAGRAM



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10.1 Independent Clock Source

The WDT derives its time base from the 31 kHz LFINTOSC internal oscillator. Time intervals in this chapter are based on a nominal interval of 1ms. See [Section 25.0 “Electrical Specifications”](#) for the LFINTOSC tolerances.

10.2 WDT Operating Modes

The Watchdog Timer module has four operating modes controlled by the WDTE<1:0> bits in Configuration Word 1. See [Table 10-1](#).

10.2.1 WDT IS ALWAYS ON

When the WDTE bits of Configuration Word 1 are set to ‘11’, the WDT is always on.

WDT protection is active during Sleep.

10.2.2 WDT IS OFF IN SLEEP

When the WDTE bits of Configuration Word 1 are set to ‘10’, the WDT is on, except in Sleep.

WDT protection is not active during Sleep.

10.2.3 WDT CONTROLLED BY SOFTWARE

When the WDTE bits of Configuration Word 1 are set to ‘01’, the WDT is controlled by the SWDTEN bit of the WDTCON register.

WDT protection is unchanged by Sleep. See [Table 10-1](#) for more details.

TABLE 10-1: WDT OPERATING MODES

WDTE<1:0>	SWDTEN	Device Mode	WDT Mode
11	X	X	Active
10	X	Awake	Active
		Sleep	Disabled
01	1	X	Active
	0		Disabled
00	X	X	Disabled

TABLE 10-2: WDT CLEARING CONDITIONS

Conditions	WDT
WDTE<1:0> = 00	Cleared
WDTE<1:0> = 01 and SWDTEN = 0	
WDTE<1:0> = 10 and enter Sleep	
CLRWDT Command	
Oscillator Fail Detected	
Exit Sleep + System Clock = SOSC, EXTRC, INTOSC, EXTCLK	
Exit Sleep + System Clock = XT, HS, LP	Cleared until the end of OST
Change INTOSC divider (IRCF bits)	Unaffected

10.3 Time-Out Period

The WDTPS bits of the WDTCON register set the time-out period from 1ms to 256 seconds (nominal). After a Reset, the default time-out period is 2 seconds.

10.4 Clearing the WDT

The WDT is cleared when any of the following conditions occur:

- Any Reset
- CLRWDT instruction is executed
- Device enters Sleep
- Device wakes up from Sleep
- Oscillator fail event
- WDT is disabled
- OST is running

See [Table 10-2](#) for more information.

10.5 Operation During Sleep

When the device enters Sleep, the WDT is cleared. If the WDT is enabled during Sleep, the WDT resumes counting.

When the device exits Sleep, the WDT is cleared again. The WDT remains clear until the OST, if enabled, completes. See [Section 5.0 “Oscillator Module \(With Fail-Safe Clock Monitor\)”](#) for more information on the OST.

When a WDT time-out occurs while the device is in Sleep, no Reset is generated. Instead, the device wakes up and resumes operation. The TO and PD bits in the STATUS register are changed to indicate the event. See [Section 3.0 “Memory Organization”](#) and The STATUS register ([Register 3-1](#)) for more information.

10.6 Watchdog Control Register

REGISTER 10-1: WDTCON: WATCHDOG TIMER CONTROL REGISTER

U-0	U-0	R/W-0/0	R/W-1/1	R/W-0/0	R/W-1/1	R/W-1/1	R/W-0/0
—	—	WDTPS<4:0>					SWDTEN
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	-m/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	

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

bit 5-1 **WDTPS<4:0>:** Watchdog Timer Period Select bits⁽¹⁾

Bit Value = Prescale Rate

- 00000 = 1:32 (Interval 1 ms nominal)
- 00001 = 1:64 (Interval 2 ms nominal)
- 00010 = 1:128 (Interval 4 ms nominal)
- 00011 = 1:256 (Interval 8 ms nominal)
- 00100 = 1:512 (Interval 16 ms nominal)
- 00101 = 1:1024 (Interval 32 ms nominal)
- 00110 = 1:2048 (Interval 64 ms nominal)
- 00111 = 1:4096 (Interval 128 ms nominal)
- 01000 = 1:8192 (Interval 256 ms nominal)
- 01001 = 1:16384 (Interval 512 ms nominal)
- 01010 = 1:32768 (Interval 1s nominal)
- 01011 = 1:65536 (Interval 2s nominal) (Reset value)
- 01100 = 1:131072 (2^{17}) (Interval 4s nominal)
- 01101 = 1:262144 (2^{18}) (Interval 8s nominal)
- 01110 = 1:524288 (2^{19}) (Interval 16s nominal)
- 01111 = 1:1048576 (2^{20}) (Interval 32s nominal)
- 10000 = 1:2097152 (2^{21}) (Interval 64s nominal)
- 10001 = 1:4194304 (2^{22}) (Interval 128s nominal)
- 10010 = 1:8388608 (2^{23}) (Interval 256s nominal)

10011 = Reserved. Results in minimum interval (1:32)

•
•
•

11111 =Reserved. Results in minimum interval (1:32)

bit 0 **SWDTEN:** Software Enable/Disable for Watchdog Timer bit

If WDTE<1:0> = 00:

This bit is ignored.

If WDTE<1:0> = 01:

1 = WDT is turned on

0 = WDT is turned off

If WDTE<1:0> = 1x:

This bit is ignored.

Note 1: Times are approximate. WDT time is based on 31 kHz LFINTOSC.

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TABLE 10-3: SUMMARY OF REGISTERS ASSOCIATED WITH WATCHDOG TIMER

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
OSCCON	—	IRCF<3:0>				—	SCS<1:0>		64
STATUS	—	—	—	\overline{TO}	\overline{PD}	Z	DC	C	23
WDTCON	—	—	WDTPS<4:0>					SWDTEN	99

Legend: x = unknown, u = unchanged, — = unimplemented locations read as '0'. Shaded cells are not used by Watchdog Timer.

TABLE 10-4: SUMMARY OF CONFIGURATION WORD WITH WATCHDOG TIMER

Name	Bits	Bit -/7	Bit -/6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG1	13:8	—		FCMEN	IESO	$\overline{CLKOUTEN}$	BOREN<1:0>		—	46
	7:0	\overline{CP}	MCLRE	\overline{PWRTE}	WDTE<1:0>		FOSC<2:0>			

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by Watchdog Timer.

11.0 FLASH PROGRAM MEMORY CONTROL

The Flash program memory is readable and writable during normal operation over the full VDD range. Program memory is indirectly addressed using Special Function Registers (SFRs). The SFRs used to access program memory are:

- PMCON1
- PMCON2
- PMDATL
- PMDATH
- PMADRL
- PMADRH

When accessing the program memory, the PMDATH:PMDATL register pair forms a 2-byte word that holds the 14-bit data for read/write, and the PMDATH:PMDATL register pair forms a 2-byte word that holds the 15-bit address of the program memory location being read.

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

The Flash program memory can be protected in two ways; by code protection (\overline{CP} bit in Configuration Word 1) and write protection (WRT<1:0> bits in Configuration Word 2).

Code protection ($\overline{CP} = 0$)⁽¹⁾, disables access, reading and writing, to the Flash program memory via external device programmers. Code protection does not affect the self-write and erase functionality. Code protection can only be reset by a device programmer performing a bulk erase to the device, clearing all Flash program memory, Configuration bits and User IDs.

Write protection prohibits self-write and erase to a portion or all of the Flash program memory as defined by the bits WRT<1:0>. Write protection does not affect a device programmers ability to read, write or erase the device.

Note 1: Code protection of the entire Flash program memory array is enabled by clearing the \overline{CP} bit of Configuration Word 1.

11.1 PMADRL and PMADRH Registers

The PMADRH:PMADRL register pair can address up to a maximum of 32K words of program memory. When selecting a program address value, the MSB of the address is written to the PMADRH register and the LSB is written to the PMADRL register.

11.1.1 PMCON1 AND PMCON2 REGISTERS

PMCON1 is the control register for Flash program memory accesses.

Control bits RD and WR initiate read and write, respectively. These bits cannot be cleared, only set, in software. They are cleared by hardware at completion of the read or write operation. The inability to clear the WR bit in software prevents the accidental, premature termination of a write operation.

The WREN bit, when set, will allow a write operation to occur. On power-up, the WREN bit is clear. The WRERR bit is set when a write operation is interrupted by a Reset during normal operation. In these situations, following Reset, the user can check the WRERR bit and execute the appropriate error handling routine.

The PMCON2 register is a write-only register. Attempting to read the PMCON2 register will return all '0's.

To enable writes to the program memory, a specific pattern (the unlock sequence), must be written to the PMCON2 register. The required unlock sequence prevents inadvertent writes to the program memory write latches and Flash program memory.

11.2 Flash Program Memory Overview

It is important to understand the Flash program memory structure for erase and programming operations. Flash program memory is arranged in rows. A row consists of a fixed number of 14-bit program memory words. A row is the minimum size that can be erased by user software.

After a row has been erased, the user can reprogram all or a portion of this row. Data to be written into the program memory row is written to 14-bit wide data write latches. These write latches are not directly accessible to the user, but may be loaded via sequential writes to the PMDATH:PMDATL register pair.

Note: If the user wants to modify only a portion of a previously programmed row, then the contents of the entire row must be read and saved in RAM prior to the erase. Then, new data and retained data can be written into the write latches to reprogram the row of Flash program memory. However, any unprogrammed locations can be written without first erasing the row. In this case, it is not necessary to save and rewrite the other previously programmed locations.

See [Table 11-1](#) for Erase Row size and the number of write latches for Flash program memory.

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TABLE 11-1: FLASH MEMORY ORGANIZATION BY DEVICE

Device	Row Erase (words)	Write Latches (words)
PIC16(L)F1526	32	32
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11.2.1 READING THE FLASH PROGRAM MEMORY

To read a program memory location, the user must:

1. Write the desired address to the PMADRH:PMADRL register pair.
2. Clear the CFGS bit of the PMCON1 register.
3. Then, set control bit RD of the PMCON1 register.

Once the read control bit is set, the program memory Flash controller will use the second instruction cycle to read the data. This causes the second instruction immediately following the "BSF PMCON1, RD" instruction to be ignored. The data is available in the very next cycle, in the PMDATH:PMDATL register pair; therefore, it can be read as two bytes in the following instructions.

PMDATH:PMDATL register pair will hold this value until another read or until it is written to by the user.

Note: The two instructions following a program memory read are required to be NOPs. This prevents the user from executing a two-cycle instruction on the next instruction after the RD bit is set.

FIGURE 11-1: FLASH PROGRAM MEMORY READ FLOWCHART

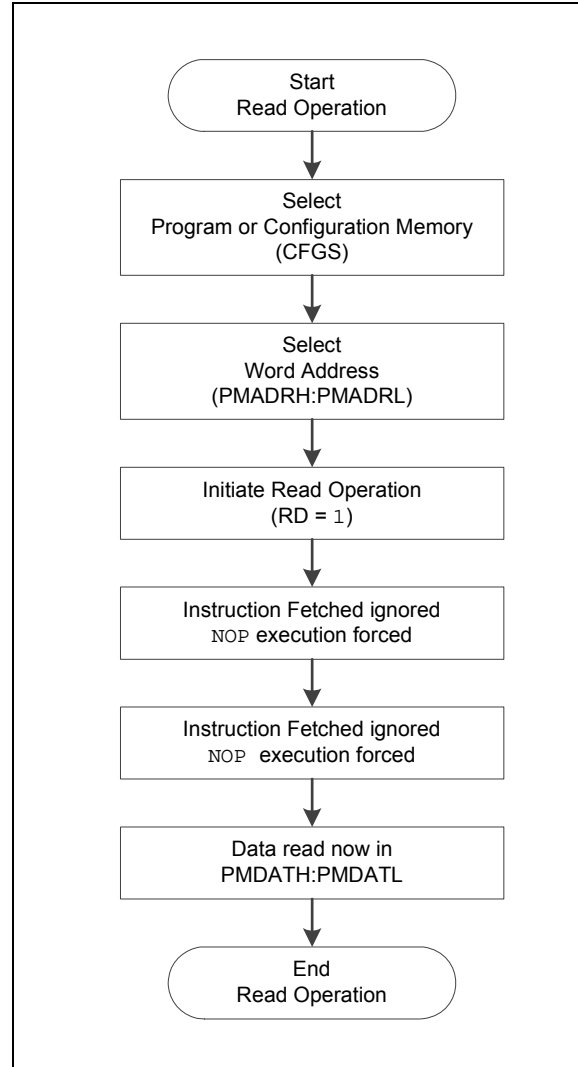
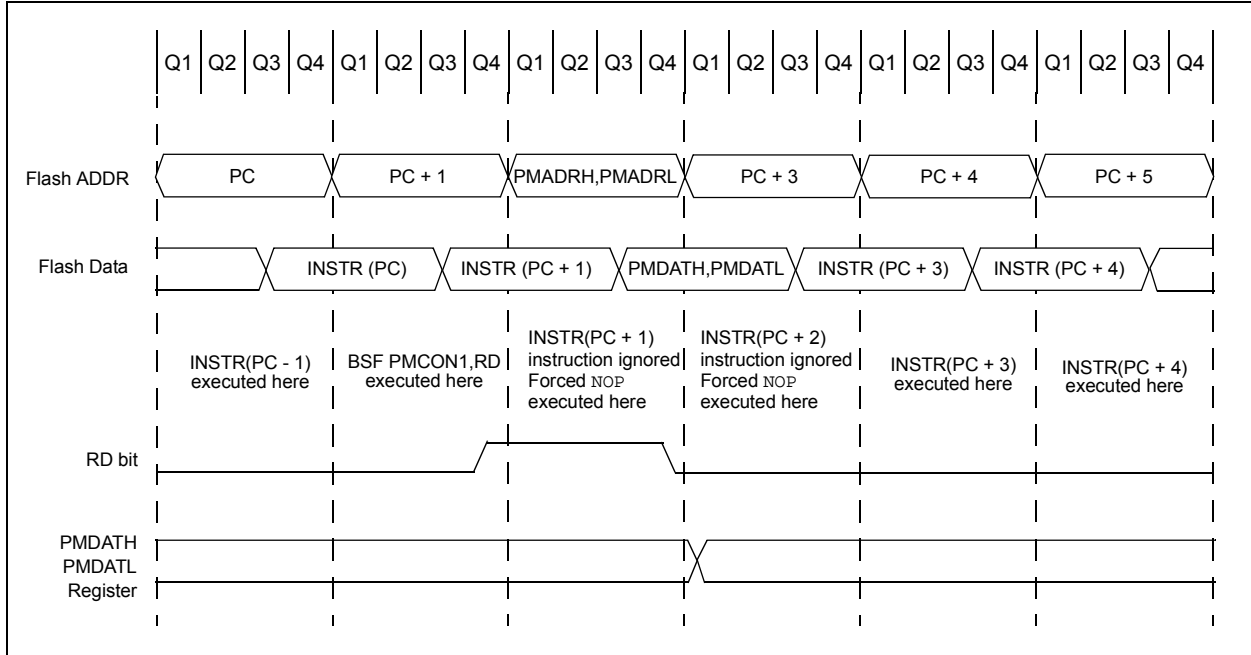


FIGURE 11-2: FLASH PROGRAM MEMORY READ CYCLE EXECUTION



EXAMPLE 11-1: FLASH PROGRAM MEMORY READ

```

* This code block will read 1 word of program
* memory at the memory address:
  PROG_ADDR_HI : PROG_ADDR_LO
* data will be returned in the variables;
*  PROG_DATA_HI, PROG_DATA_LO

  BANKSEL  PMADRL          ; Select Bank for PCON registers
  MOVLW   PROG_ADDR_LO    ;
  MOVWF   PMADRL          ; Store LSB of address
  MOVLW   PROG_ADDR_HI    ;
  MOVWF   PMADRH          ; Store MSB of address

  BCF     PMCON1,CFGSS    ; Do not select Configuration Space
  BSF     PMCON1,RD       ; Initiate read
  NOP     ; Ignored (Figure 11-2)
  NOP     ; Ignored (Figure 11-2)

  MOVF    PMDATL,W        ; Get LSB of word
  MOVWF   PROG_DATA_LO    ; Store in user location
  MOVF    PMDATH,W        ; Get MSB of word
  MOVWF   PROG_DATA_HI    ; Store in user location
    
```

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11.2.2 FLASH MEMORY UNLOCK SEQUENCE

The unlock sequence is a mechanism that protects the Flash program memory from unintended self-write programming or erasing. The sequence must be executed and completed without interruption to successfully complete any of the following operations:

- Row Erase
- Load program memory write latches
- Write of program memory write latches to program memory
- Write of program memory write latches to User IDs

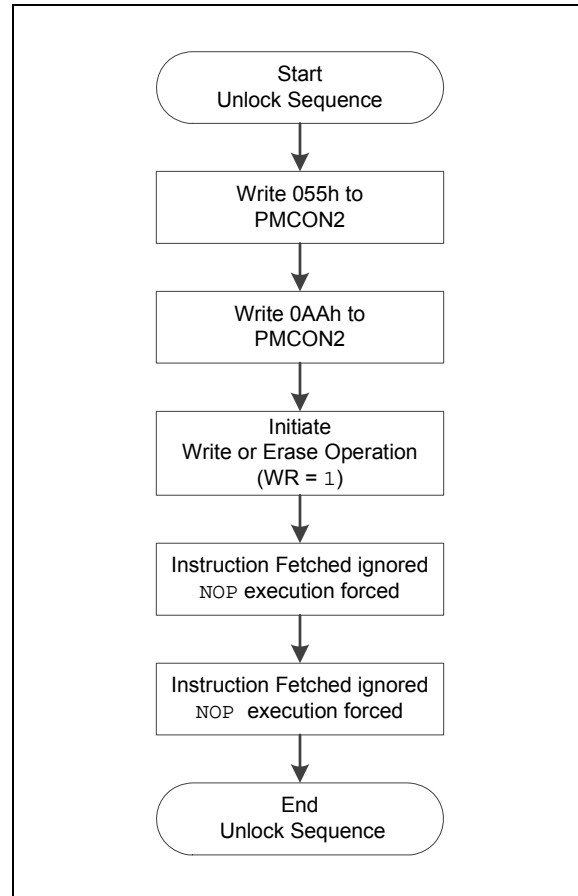
The unlock sequence consists of the following steps:

1. Write 55h to PMCON2
2. Write AAh to PMCON2
3. Set the WR bit in PMCON1
4. NOP instruction
5. NOP instruction

Once the WR bit is set, the processor will always force two NOP instructions. When an Erase Row or Program Row operation is being performed, the processor will stall internal operations (typical 2 ms), until the operation is complete and then resume with the next instruction. When the operation is loading the program memory write latches, the processor will always force the two NOP instructions and continue uninterrupted with the next instruction.

Since the unlock sequence must not be interrupted, global interrupts should be disabled prior to the unlock sequence and re-enabled after the unlock sequence is completed.

FIGURE 11-3: FLASH PROGRAM MEMORY UNLOCK SEQUENCE FLOWCHART



11.2.3 ERASING FLASH PROGRAM MEMORY

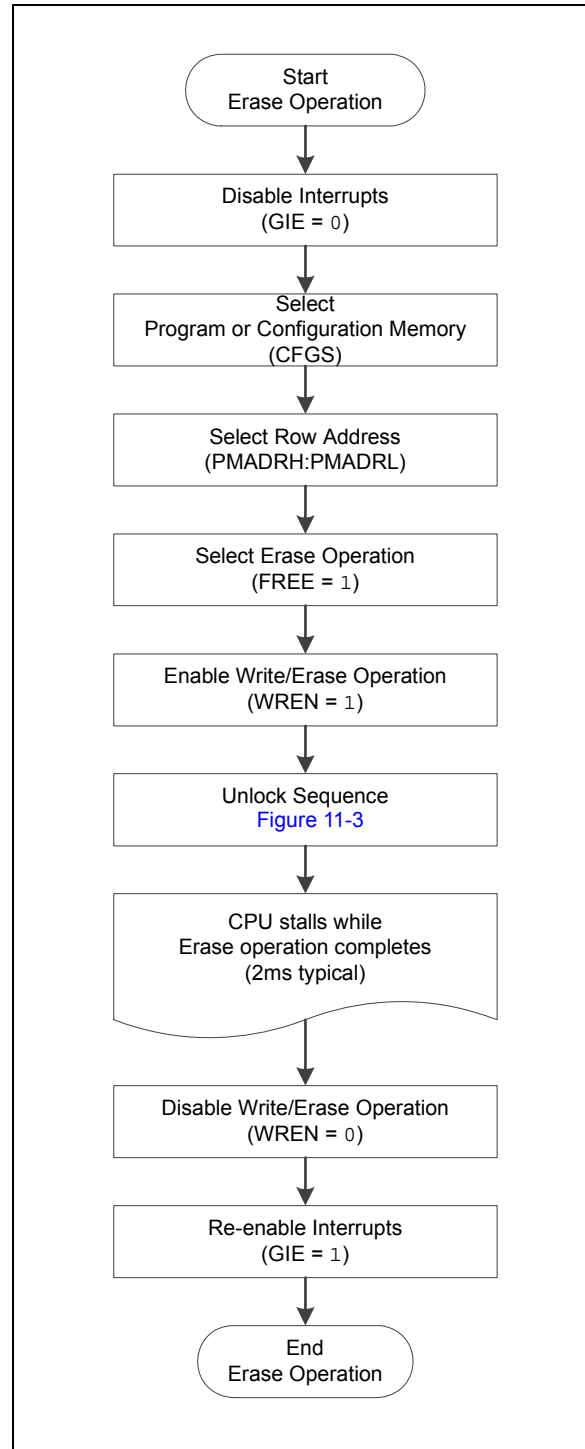
While executing code, program memory can only be erased by rows. To erase a row:

1. Load the PMADRH:PMADRL register pair with any address within the row to be erased.
2. Clear the CFGS bit of the PMCON1 register.
3. Set the FREE and WREN bits of the PMCON1 register.
4. Write 55h, then AAh, to PMCON2 (Flash programming unlock sequence).
5. Set control bit WR of the PMCON1 register to begin the erase operation.

See [Example 11-2](#).

After the “BSF PMCON1, WR” instruction, the processor requires two cycles to set up the erase operation. The user must place two NOP instructions after the WR bit is set. The processor will halt internal operations for the typical 2 ms erase time. This is not Sleep mode as the clocks and peripherals will continue to run. After the erase cycle, the processor will resume operation with the third instruction after the PMCON1 WRITE instruction.

FIGURE 11-4: FLASH PROGRAM MEMORY ERASE FLOWCHART



EXAMPLE 11-2: ERASING ONE ROW OF PROGRAM MEMORY

```

; This row erase routine assumes the following:
; 1. A valid address within the erase row is loaded in ADDRH:ADDRL
; 2. ADDRH and ADDRL are located in shared data memory 0x70 - 0x7F (common RAM)

      BCF      INTCON,GIE      ; Disable ints so required sequences will execute properly
      BANKSEL PMADRL
      MOVF    ADDRL,W         ; Load lower 8 bits of erase address boundary
      MOVWF   PMADRL
      MOVF    ADDRH,W        ; Load upper 6 bits of erase address boundary
      MOVWF   PMADRH
      BCF     PMCON1,CFGS     ; Not configuration space
      BSF     PMCON1,FREE     ; Specify an erase operation
      BSF     PMCON1,WREN     ; Enable writes

      MOVLW   55h             ; Start of required sequence to initiate erase
      MOVWF   PMCON2         ; Write 55h
      MOVLW   0AAh           ;
      MOVWF   PMCON2         ; Write AAh
      BSF     PMCON1,WR      ; Set WR bit to begin erase
      NOP     ; NOP instructions are forced as processor starts
      NOP     ; row erase of program memory.
      ;
      ; The processor stalls until the erase process is complete
      ; after erase processor continues with 3rd instruction

      BCF     PMCON1,WREN     ; Disable writes
      BSF     INTCON,GIE     ; Enable interrupts

```

11.2.4 WRITING TO FLASH PROGRAM MEMORY

Program memory is programmed using the following steps:

1. Load the address in PMADRH:PMADRL of the row to be programmed.
2. Load each write latch with data.
3. Initiate a programming operation.
4. Repeat steps 1 through 3 until all data is written.

Before writing to program memory, the word(s) to be written must be erased or previously unwritten. Program memory can only be erased one row at a time. No automatic erase occurs upon the initiation of the write.

Program memory can be written one or more words at a time. The maximum number of words written at one time is equal to the number of write latches. See [Figure 11-5](#) (row writes to program memory with 32 write latches) for more details.

The write latches are aligned to the Flash row address boundary defined by the upper 10-bits of PMADRH:PMADRL, (PMADRH<6:0>:PMADRL<7:5>) with the lower 5-bits of PMADRL, (PMADRL<4:0>) determining the write latch being loaded. Write operations do not cross these boundaries. At the completion of a program memory write operation, the data in the write latches is reset to contain 0x3FFF.

The following steps should be completed to load the write latches and program a row of program memory. These steps are divided into two parts. First, each write latch is loaded with data from the PMDATH:PMDATL using the unlock sequence with LWLO = 1. When the last word to be loaded into the write latch is ready, the LWLO bit is cleared and the unlock sequence executed. This initiates the programming operation, writing all the latches into Flash program memory.

Note: The special unlock sequence is required to load a write latch with data or initiate a Flash programming operation. If the unlock sequence is interrupted, writing to the latches or program memory will not be initiated.

1. Set the WREN bit of the PMCON1 register.
2. Clear the CFGS bit of the PMCON1 register.
3. Set the LWLO bit of the PMCON1 register. When the LWLO bit of the PMCON1 register is '1', the write sequence will only load the write latches and will not initiate the write to Flash program memory.
4. Load the PMADRH:PMADRL register pair with the address of the location to be written.
5. Load the PMDATH:PMDATL register pair with the program memory data to be written.
6. Execute the unlock sequence ([Section 11.2.2 "Flash Memory Unlock Sequence"](#)). The write latch is now loaded.
7. Increment the PMADRH:PMADRL register pair to point to the next location.
8. Repeat steps 5 through 7 until all but the last write latch has been loaded.
9. Clear the LWLO bit of the PMCON1 register. When the LWLO bit of the PMCON1 register is '0', the write sequence will initiate the write to Flash program memory.
10. Load the PMDATH:PMDATL register pair with the program memory data to be written.
11. Execute the unlock sequence ([Section 11.2.2 "Flash Memory Unlock Sequence"](#)). The entire program memory latch content is now written to Flash program memory.

Note: The program memory write latches are reset to the blank state (0x3FFF) at the completion of every write or erase operation. As a result, it is not necessary to load all the program memory write latches. Unloaded latches will remain in the blank state.

An example of the complete write sequence is shown in [Example 11-3](#). The initial address is loaded into the PMADRH:PMADRL register pair; the data is loaded using indirect addressing.

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FIGURE 11-5: BLOCK WRITES TO FLASH PROGRAM MEMORY WITH 32 WRITE LATCHES

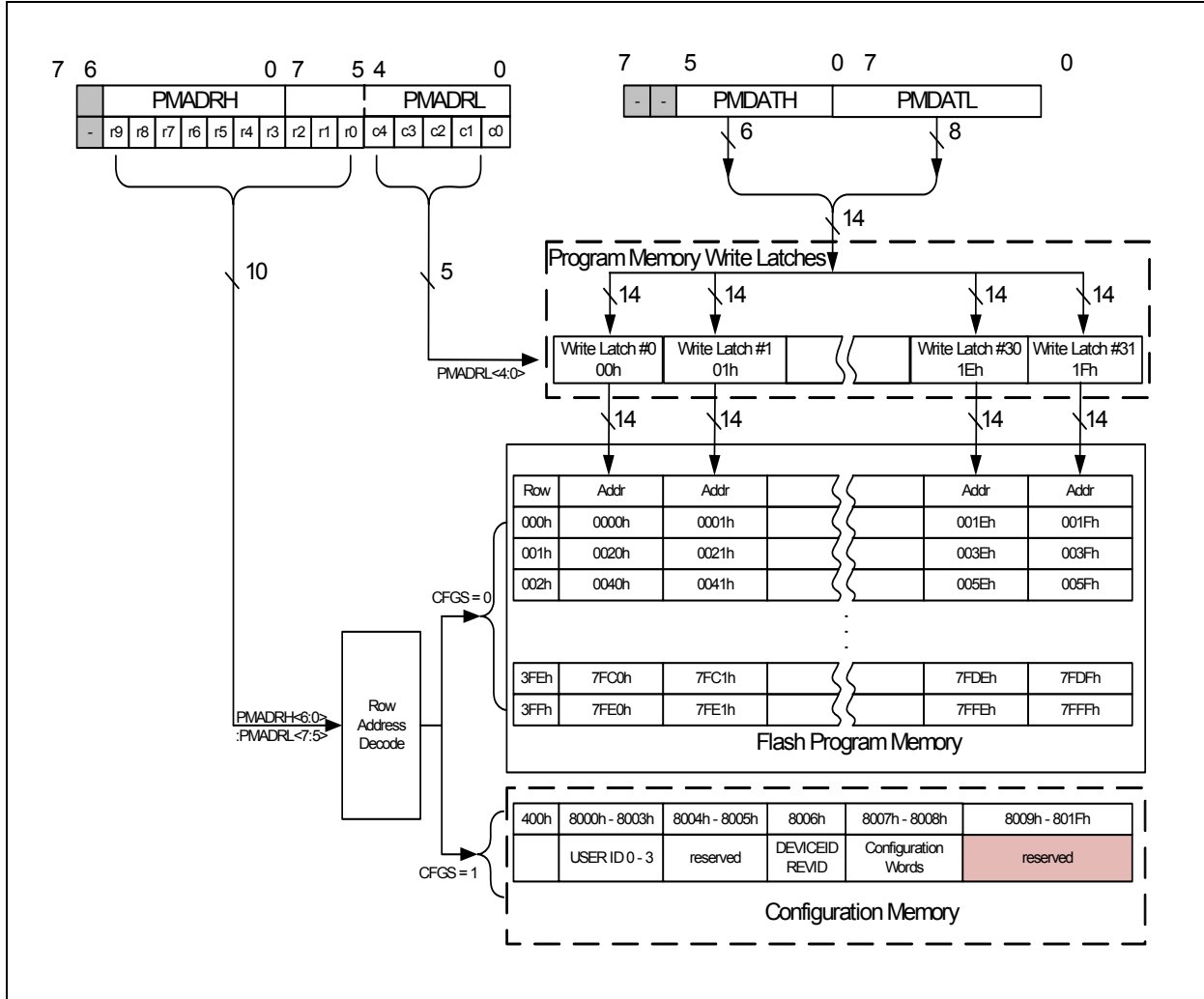
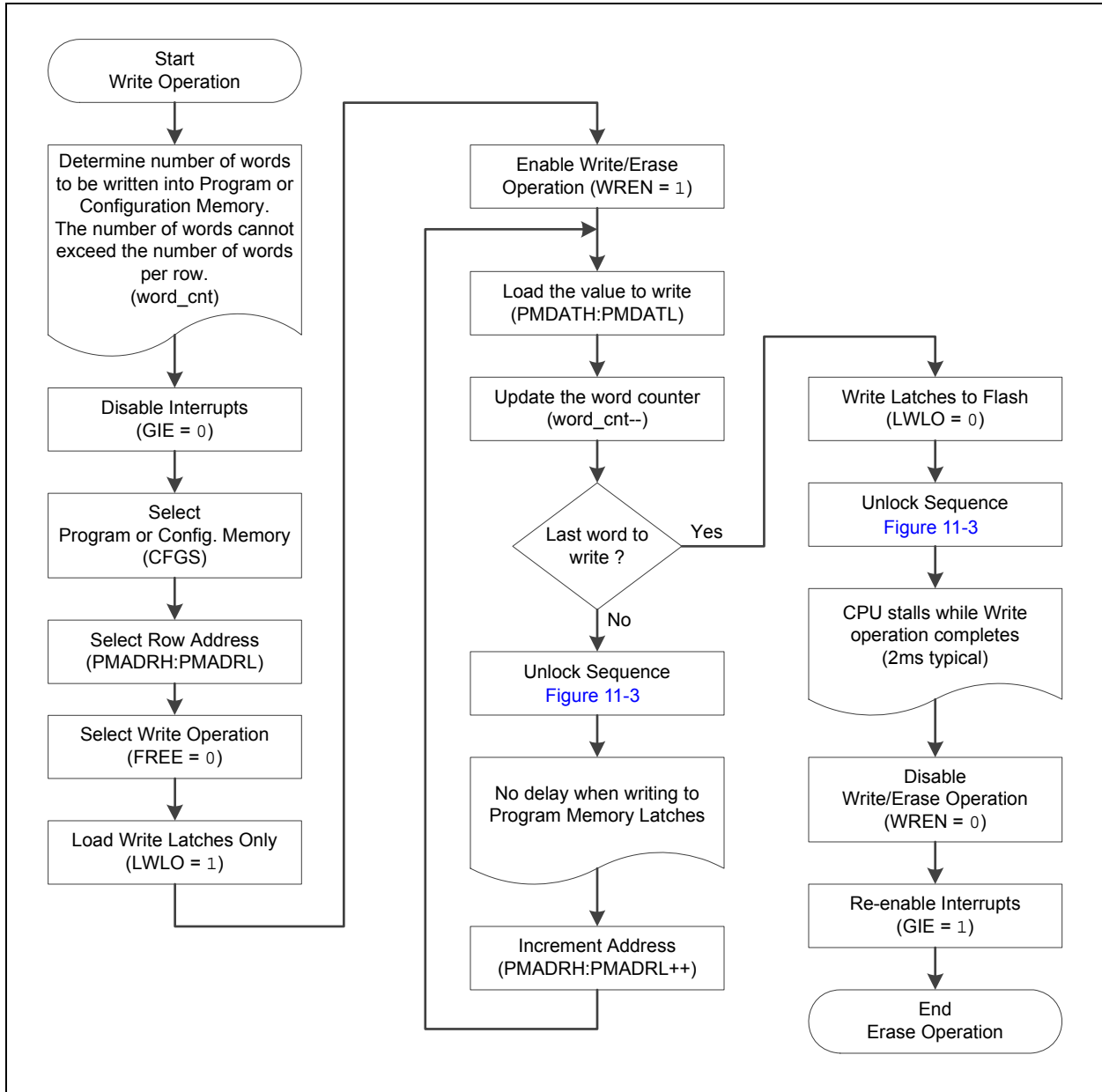


FIGURE 11-6: FLASH PROGRAM MEMORY WRITE FLOWCHART



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EXAMPLE 11-3: WRITING TO FLASH PROGRAM MEMORY

```
; This write routine assumes the following:
; 1. 64 bytes of data are loaded, starting at the address in DATA_ADDR
; 2. Each word of data to be written is made up of two adjacent bytes in DATA_ADDR,
; stored in little endian format
; 3. A valid starting address (the least significant bits = 00000) is loaded in ADDRH:ADDRL
; 4. ADDRH and ADDRL are located in shared data memory 0x70 - 0x7F (common RAM)
;
    BCF      INTCON,GIE      ; Disable ints so required sequences will execute properly
    BANKSEL PMADRH         ; Bank 3
    MOVF    ADDRH,W         ; Load initial address
    MOVWF   PMADRH         ;
    MOVF    ADDRH,W         ;
    MOVWF   PMADRL         ;
    MOVLW   LOW DATA_ADDR  ; Load initial data address
    MOVWF   FSR0L          ;
    MOVLW   HIGH DATA_ADDR ; Load initial data address
    MOVWF   FSR0H          ;
    BCF     PMCON1,CFGSS    ; Not configuration space
    BSF     PMCON1,WREN     ; Enable writes
    BSF     PMCON1,LWLO    ; Only Load Write Latches

LOOP
    MOVIW   FSR0++         ; Load first data byte into lower
    MOVWF   PMDATH         ;
    MOVIW   FSR0++         ; Load second data byte into upper
    MOVWF   PMDATH         ;

    MOVF    PMADRL,W       ; Check if lower bits of address are '00000'
    XORLW   0x1F           ; Check if we're on the last of 32 addresses
    ANDLW   0x1F           ;
    BTFSC   STATUS,Z       ; Exit if last of 32 words,
    GOTO    START_WRITE    ;

    [ Required Sequence
    MOVLW   55h             ; Start of required write sequence:
    MOVWF   PMCON2         ; Write 55h
    MOVLW   0AAh           ;
    MOVWF   PMCON2         ; Write AAh
    BSF     PMCON1,WR       ; Set WR bit to begin write
    NOP     ; NOP instructions are forced as processor
    ; loads program memory write latches
    NOP     ;

    INCF    PMADRL,F       ; Still loading latches Increment address
    GOTO    LOOP           ; Write next latches

START_WRITE
    BCF     PMCON1,LWLO    ; No more loading latches - Actually start Flash program
    ; memory write

    [ Required Sequence
    MOVLW   55h             ; Start of required write sequence:
    MOVWF   PMCON2         ; Write 55h
    MOVLW   0AAh           ;
    MOVWF   PMCON2         ; Write AAh
    BSF     PMCON1,WR       ; Set WR bit to begin write
    NOP     ; NOP instructions are forced as processor writes
    ; all the program memory write latches simultaneously
    NOP     ; to program memory.
    ; After NOPs, the processor
    ; stalls until the self-write process is complete
    ; after write processor continues with 3rd instruction

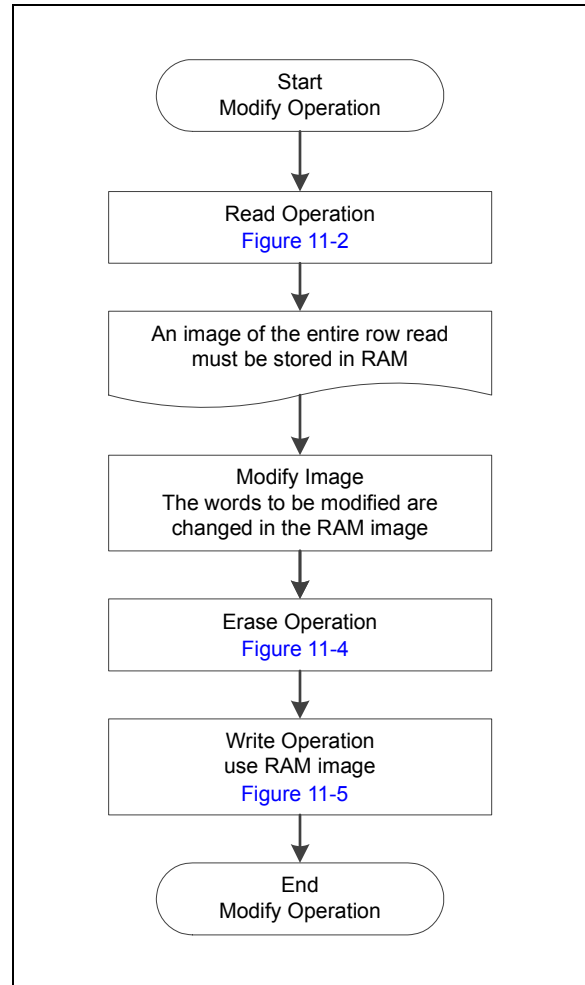
    BCF     PMCON1,WREN    ; Disable writes
    BSF     INTCON,GIE     ; Enable interrupts
```

11.3 Modifying Flash Program Memory

When modifying existing data in a program memory row, and data within that row must be preserved, it must first be read and saved in a RAM image. Program memory is modified using the following steps:

1. Load the starting address of the row to be modified.
2. Read the existing data from the row into a RAM image.
3. Modify the RAM image to contain the new data to be written into program memory.
4. Load the starting address of the row to be rewritten.
5. Erase the program memory row.
6. Load the write latches with data from the RAM image.
7. Initiate a programming operation.

FIGURE 11-7: FLASH PROGRAM MEMORY MODIFY FLOWCHART



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11.4 User ID, Device ID and Configuration Word Access

Instead of accessing program memory, the User ID's, Device ID/Revision ID and Configuration Words can be accessed when $CFG_{S} = 1$ in the $PMCON1$ register. This is the region that would be pointed to by $PC_{<15>} = 1$, but not all addresses are accessible. Different access may exist for reads and writes. Refer to [Table 11-2](#).

When read access is initiated on an address outside the parameters listed in [Table 11-2](#), the $PMDATH:PMDATL$ register pair is cleared, reading back '0's.

TABLE 11-2: USER ID, DEVICE ID AND CONFIGURATION WORD ACCESS ($CFG_{S} = 1$)

Address	Function	Read Access	Write Access
8000h-8003h	User IDs	Yes	Yes
8006h	Device ID/Revision ID	Yes	No
8007h-8008h	Configuration Words 1 and 2	Yes	No

EXAMPLE 11-4: CONFIGURATION WORD AND DEVICE ID ACCESS

```
* This code block will read 1 word of program memory at the memory address:
*   PROG_ADDR_LO (must be 00h-08h) data will be returned in the variables;
*   PROG_DATA_HI, PROG_DATA_LO

BANKSEL  PMADRL           ; Select correct Bank
MOVLW    PROG_ADDR_LO    ;
MOVWF    PMADRL          ; Store LSB of address
CLRF     PMADRH          ; Clear MSB of address

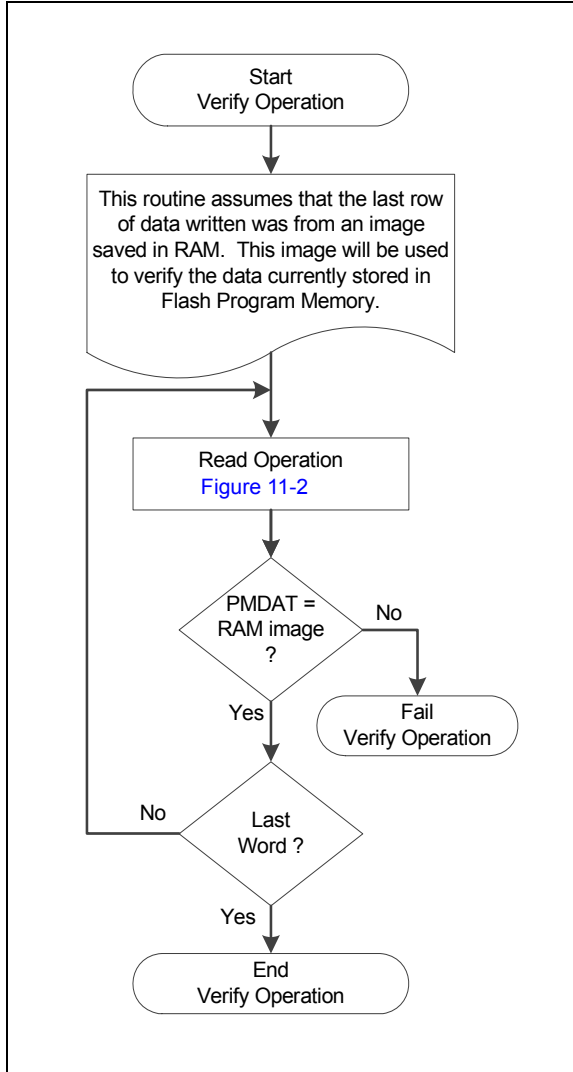
BSF      PMCON1,CFG_{S}  ; Select Configuration Space
BCF      INTCON,GIE      ; Disable interrupts
BSF      PMCON1,RD       ; Initiate read
NOP      ; Executed (See Figure 11-2)
NOP      ; Ignored (See Figure 11-2)
BSF      INTCON,GIE      ; Restore interrupts

MOVF     PMDATL,W        ; Get LSB of word
MOVWF    PROG_DATA_LO    ; Store in user location
MOVF     PMDATH,W        ; Get MSB of word
MOVWF    PROG_DATA_HI    ; Store in user location
```


11.5 Write Verify

It is considered good programming practice to verify that program memory writes agree with the intended value. Since program memory is stored as a full page then the stored program memory contents are compared with the intended data stored in RAM after the last write is complete.

FIGURE 11-8: FLASH PROGRAM MEMORY VERIFY FLOWCHART



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11.6 Flash Program Memory Control Registers

REGISTER 11-1: PMDATL: PROGRAM MEMORY DATA LOW BYTE REGISTER

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
PMDAT<7:0>							
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 7-0 **PMDAT<7:0>**: Read/write value for Least Significant bits of program memory

REGISTER 11-2: PMDATH: PROGRAM MEMORY DATA HIGH BYTE REGISTER

U-0	U-0	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u
—		PMDAT<13:8>					
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 **Unimplemented**: Read as '0'

bit 5-0 **PMDAT<13:8>**: Read/write value for Most Significant bits of program memory

REGISTER 11-3: PMADRL: PROGRAM MEMORY ADDRESS LOW BYTE REGISTER

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
PMADR<7:0>							
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 7-0 **PMADR<7:0>**: Specifies the Least Significant bits for program memory address

REGISTER 11-4: PMADRH: PROGRAM MEMORY ADDRESS HIGH BYTE REGISTER

U-1	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
—	PMADR<14:8>						
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 **Unimplemented**: Read as '1'

bit 6-0 **PMADR<14:8>**: Specifies the Most Significant bits for program memory address

REGISTER 11-5: PMCON1: PROGRAM MEMORY CONTROL 1 REGISTER

U-1 ⁽¹⁾	R/W-0/0	R/W-0/0	R/W/HC-0/0	R/W/HC-x/q ⁽²⁾	R/W-0/0	R/S/HC-0/0	R/S/HC-0/0
—	CFGS	LWLO	FREE	WRERR	WREN	WR	RD
bit 7							bit 0

Legend:

R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
S = Bit can only be set	x = Bit is unknown	-n/n = Value at POR and BOR/Value at all other Resets
'1' = Bit is set	'0' = Bit is cleared	HC = Bit is cleared by hardware

bit 7	Unimplemented: Read as '1'
bit 6	CFGS: Configuration Select bit 1 = Access Configuration, User ID and Device ID Registers 0 = Access Flash program memory
bit 5	LWLO: Load Write Latches Only bit ⁽³⁾ 1 = Only the addressed program memory write latch is loaded/updated on the next WR command 0 = The addressed program memory write latch is loaded/updated and a write of all program memory write latches will be initiated on the next WR command
bit 4	FREE: Program Flash Erase Enable bit 1 = Performs an erase operation on the next WR command (hardware cleared upon completion) 0 = Performs a write operation on the next WR command
bit 3	WRERR: Program/Erase Error Flag bit 1 = Condition indicates an improper program or erase sequence attempt or termination (bit is set automatically on any set attempt (write '1') of the WR bit). 0 = The program or erase operation completed normally.
bit 2	WREN: Program/Erase Enable bit 1 = Allows program/erase cycles 0 = Inhibits programming/erasing of program Flash
bit 1	WR: Write Control bit 1 = Initiates a program Flash program/erase operation. The operation is self-timed and the bit is cleared by hardware once operation is complete. The WR bit can only be set (not cleared) in software. 0 = Program/erase operation to the Flash is complete and inactive.
bit 0	RD: Read Control bit 1 = Initiates a program Flash read. Read takes one cycle. RD is cleared in hardware. The RD bit can only be set (not cleared) in software. 0 = Does not initiate a program Flash read.

- Note**
- 1: Unimplemented bit, read as '1'.
 - 2: The WRERR bit is automatically set by hardware when a program memory write or erase operation is started (WR = 1).
 - 3: The LWLO bit is ignored during a program memory erase operation (FREE = 1).

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REGISTER 11-6: PMCON2: PROGRAM MEMORY CONTROL 2 REGISTER

W-0/0	W-0/0	W-0/0	W-0/0	W-0/0	W-0/0	W-0/0	W-0/0
Program Memory Control Register 2							
bit 7							bit 0

Legend:

R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'
S = Bit can only be set	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 **Flash Memory Unlock Pattern bits**

To unlock writes, a 55h must be written first, followed by an AAh, before setting the WR bit of the PMCON1 register. The value written to this register is used to unlock the writes. There are specific timing requirements on these writes.

TABLE 11-3: SUMMARY OF REGISTERS ASSOCIATED WITH FLASH PROGRAM MEMORY

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
PMCON1	—	CFGFS	LWLO	FREE	WRERR	WREN	WR	RD	115
PMCON2	Program Memory Control Register 2								116
PMADRL	PMADRL<7:0>								114
PMADRH	—	PMADRH<6:0>							114
PMDATL	PMDATL<7:0>								114
PMDATH	—	—	PMDATH<5:0>						114
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	80

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by Flash program memory module.

TABLE 11-4: SUMMARY OF CONFIGURATION WORD WITH FLASH PROGRAM MEMORY

Name	Bits	Bit -/7	Bit -/6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG1	13:8	—	—	FCMEN	IESO	CLKOUTEN	BOREN<1:0>		—	46
	7:0	CP	MCLRE	PWRTE	WDTE<1:0>		FOSC<2:0>			
CONFIG2	13:8	—		LVP	DEBUG	LPBOR	BORV	STVREN	—	48
	7:0	—		—	VCAPEN ⁽¹⁾	—	—	WRT<1:0>		

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by Flash program memory.

12.0 I/O PORTS

In general, when a peripheral is enabled on a port pin, that pin cannot be used as a general purpose output. However, the pin can still be read.

Each port has three standard registers for its operation. These registers are:

- TRISx registers (data direction)
- PORTx registers (reads the levels on the pins of the device)
- LATx registers (output latch)

Some ports may have one or more of the following additional registers. These registers are:

- ANSELx (analog select)
- WPUx (weak pull-up)

TABLE 12-1: PORT AVAILABILITY PER DEVICE

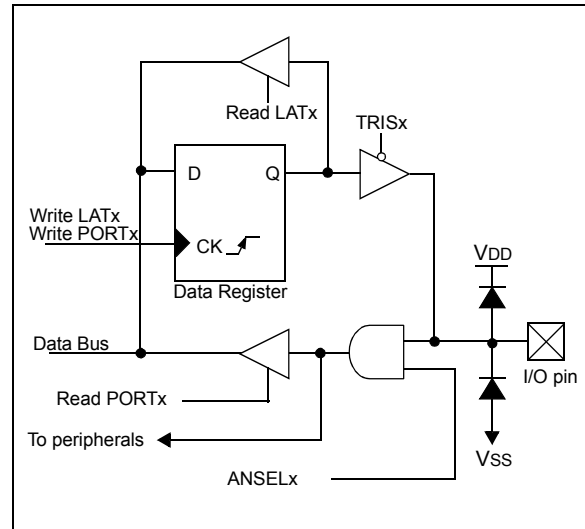
Device	PORTA	PORTB	PORTC	PORTD	PORTE	PORTF	PORTG
PIC16(L)F1526	•	•	•	•	•	•	•
PIC16(L)F1527	•	•	•	•	•	•	•

The Data Latch (LATA register) is useful for read-modify-write operations on the value that the I/O pins are driving.

A write operation to the LATA register has the same affect as a write to the corresponding PORTA register. A read of the LATA register reads of the values held in the I/O PORT latches, while a read of the PORTA register reads the actual I/O pin value.

The port has analog functions and has an ANSELA register which can disable the digital input and save power. A simplified model of a generic I/O port, without the interfaces to other peripherals, is shown in Figure 12-1.

FIGURE 12-1: GENERIC I/O PORT OPERATION



EXAMPLE 12-1: INITIALIZING PORTA

```

; This code example illustrates
; initializing the PORTA register. The
; other ports are initialized in the same
; manner.

BANKSEL PORTA      ;
CLRF   PORTA       ;Init PORTA
BANKSEL LATA       ;Data Latch
CLRF   LATA        ;
BANKSEL ANSELA    ;
CLRF   ANSELA     ;digital I/O
BANKSEL TRISA     ;
MOVLW  B'00111000' ;Set RA<5:3> as inputs
MOVWF  TRISA      ;and set RA<2:0> as
                    ;outputs
    
```

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12.1 Alternate Pin Function

The Alternate Pin Function Control (APFCON) registers are used to steer specific peripheral input and output functions between different pins. The APFCON registers are shown in [Register 12-1](#). For this device family, the following functions can be moved between different pins.

- Timer3
- CCP2

These bits have no effect on the values of any TRIS register. PORT and TRIS overrides will be routed to the correct pin. The unselected pin will be unaffected.

REGISTER 12-1: APFCON: ALTERNATE PIN FUNCTION CONTROL REGISTER

U-0	U-0	U-0	U-0	U-0	U-0	R/W-0/0	R/W-0/0
—	—	—	—	—	—	T3CKISEL	CCP2SEL
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 **T3CKISEL:** Timer3 Input Selection bit

0 = T3CKI function is on RB5

1 = T3CKI function is on RB4

bit 0 **CCP2SEL:** Pin Selection bit

0 = CCP2 function is on RC1

1 = CCP2 function is on RE7

12.2 PORTA Registers

PORTA is a 8-bit wide, bidirectional port. The corresponding data direction register is TRISA (Register 12-3). Setting a TRISA bit (= 1) will make the corresponding PORTA pin an input (i.e., disable the output driver). Clearing a TRISA bit (= 0) will make the corresponding PORTA pin an output (i.e., enables output driver and puts the contents of the output latch on the selected pin). Example 12-1 shows how to initialize an I/O port.

Reading the PORTA register (Register 12-2) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATA).

The TRISA register (Register 12-3) controls the PORTA pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISA register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.2.1 ANSELA REGISTER

The ANSELA register (Register 12-5) is used to configure the Input mode of an I/O pin to analog. Setting the appropriate ANSELA bit high will cause all digital reads on the pin to be read as '0' and allow analog functions on the pin to operate correctly.

The state of the ANSELA bits has no effect on digital output functions. A pin with TRIS clear and ANSEL set will still operate as a digital output, but the Input mode will be analog. This can cause unexpected behavior when executing read-modify-write instructions on the affected port.

Note: The ANSELA bits default to the Analog mode after Reset. To use any pins as digital general purpose or peripheral inputs, the corresponding ANSEL bits must be initialized to '0' by user software.

12.2.2 PORTA FUNCTIONS AND OUTPUT PRIORITIES

Each PORTA pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-2.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority.

Analog input functions, such as ADC, are not shown in the priority lists. These inputs are active when the I/O pin is set for Analog mode using the ANSELx registers. Digital output functions may control the pin when it is in Analog mode with the priority shown in Table 12-2.

TABLE 12-2: PORTA OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RA0	RA0
RA1	RA1
RA2	RA2
RA3	RA3
RA4	RA4
RA5	RA5
RA6	CLKOUT OSC2 RA6
RA7	RA7

Note 1: Priority listed from highest to lowest.

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REGISTER 12-2: PORTA: PORTA REGISTER

R/W-x/x	R/W-x/x	R/W-x/x	R/W-x/x	R/W-x/x	R/W-x/x	R/W-x/x	R/W-x/x
RA7	RA6	RA5	RA4	RA3	RA2	RA1	RA0
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 **RA<7:0>**: PORTA I/O Value bits⁽¹⁾
1 = Port pin is $\geq V_{IH}$
0 = Port pin is $\leq V_{IL}$

Note 1: Writes to PORTA are actually written to corresponding LATA register. Reads from PORTA register is return of actual I/O pin values.

REGISTER 12-3: TRISA: PORTA TRI-STATE 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
TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0
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 **TRISA<7:0>**: PORTA Tri-State Control bits
1 = PORTA pin configured as an input (tri-stated)
0 = PORTA pin configured as an output

REGISTER 12-4: LATA: PORTA DATA LATCH REGISTER

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
LATA7	LATA6	LATA5	LATA4	LATA3	LATA2	LATA1	LATA0
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 **LATA<7:0>**: RA<7:0> Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTA are actually written to corresponding LATA register. Reads from PORTA register is return of actual I/O pin values.

REGISTER 12-5: ANSELA: PORTA ANALOG SELECT REGISTER

U-0	U-0	R/W-1/1	U-0	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1
—	—	ANSA5	—	ANSA3	ANSA2	ANSA1	ANSA0
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 **Unimplemented:** Read as '0'

bit 5 **ANSA5:** Analog Select between Analog or Digital Function on pins RA5, respectively
 0 = Digital I/O. Pin is assigned to port or digital special function.
 1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

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

bit 3-0 **ANSA<3:0>:** Analog Select between Analog or Digital Function on pins RA<3:0>, respectively
 0 = Digital I/O. Pin is assigned to port or digital special function.
 1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

Note 1: When setting a pin to an analog input, the corresponding TRIS bit must be set to Input mode in order to allow external control of the voltage on the pin.

TABLE 12-3: SUMMARY OF REGISTERS ASSOCIATED WITH PORTA

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELA	—	—	ANSA5	—	ANSA3	ANSA2	ANSA1	ANSA0	121
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	118
LATA	LATA7	LATA6	LATA5	LATA4	LATA3	LATA2	LATA1	LATA0	120
OPTION_REG	WPUEN	INTEDG	TMR0CS	TMR0SE	PSA	PS<2:0>			165
PORTA	RA7	RA6	RA5	RA4	RA3	RA2	RA1	RA0	120
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120

Legend: x = unknown, u = unchanged, — = unimplemented locations read as '0'. Shaded cells are not used by PORTA.

TABLE 12-4: SUMMARY OF CONFIGURATION WORD WITH PORTA

Name	Bits	Bit -7	Bit -6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG1	13:8	—		FCMEN	IESO	CLKOUTEN	BOREN<1:0>		—	48
	7:0	CP	MCLRE	PWRTE	WDTE<1:0>		FOSC<2:0>			

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by PORTA.

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12.3 PORTB Registers

PORTB is a 8-bit wide, bidirectional port. The corresponding data direction register is TRISB (Register 12-7). 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., enable the output driver and put the contents of the output latch on the selected pin). Example 12-1 shows how to initialize an I/O port.

Reading the PORTB register (Register 12-6) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATB).

The TRISB register (Register 12-7) controls the PORTB pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISB register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.3.1 ANSELB REGISTER

The ANSELB register (Register 12-9) is used to configure the Input mode of an I/O pin to analog. Setting the appropriate ANSELB bit high will cause all digital reads on the pin to be read as '0' and allow analog functions on the pin to operate correctly.

The state of the ANSELB bits has no effect on digital output functions. A pin with TRIS clear and ANSELB set will still operate as a digital output, but the Input mode will be analog. This can cause unexpected behavior when executing read-modify-write instructions on the affected port.

Note: The ANSELB bits default to the Analog mode after Reset. To use any pins as digital general purpose or peripheral inputs, the corresponding ANSEL bits must be initialized to '0' by user software.

12.3.2 PORTB FUNCTIONS AND OUTPUT PRIORITIES

Each PORTB pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-5.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority. Analog input and some digital input functions are not included in the list below. These input functions can remain active when the pin is configured as an output. Certain digital input functions override other port functions and are included in Table 12-5.

TABLE 12-5: PORTB OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RB0	RB0
RB1	RB1
RB2	RB2
RB3	CCP2 RB3
RB4	RB4
RB5	RB5
RB6	ICDCLK RB6
RB7	ICDDAT RB7

Note 1: Priority listed from highest to lowest.

REGISTER 12-6: PORTB: PORTB REGISTER

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
RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0
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 **RB<7:0>**: PORTB General Purpose I/O Pin bits⁽¹⁾
 1 = Port pin is $\geq V_{IH}$
 0 = Port pin is $\leq V_{IL}$

Note 1: Writes to PORTB are actually written to corresponding LATB register. Reads from PORTB register is return of actual I/O pin values.

REGISTER 12-7: TRISB: PORTB TRI-STATE 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
TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0
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 **TRISB<7:0>**: PORTB Tri-State Control bits
 1 = PORTB pin configured as an input (tri-stated)
 0 = PORTB pin configured as an output

REGISTER 12-8: LATB: PORTB DATA LATCH REGISTER

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
LATB7	LATB6	LATB5	LATB4	LATB3	LATB2	LATB1	LATB0
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 **LATB<7:0>**: PORTB Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTB are actually written to corresponding LATB register. Reads from PORTB register is return of actual I/O pin values.

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REGISTER 12-9: ANSELB: PORTB ANALOG SELECT REGISTER

U-0	U-0	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1	R/W-1/1
—	—	ANSB5	ANSB4	ANSB3	ANSB2	ANSB1	ANSB0
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 **Unimplemented:** Read as '0'
bit 5-0 **ANSB<5:0>:** Analog Select between Analog or Digital Function on pins RB<5:0>, respectively
0 = Digital I/O. Pin is assigned to port or digital special function.
1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

Note 1: When setting a pin to an analog input, the corresponding TRIS bit must be set to Input mode in order to allow external control of the voltage on the pin.

REGISTER 12-10: WPUB: WEAK PULL-UP PORTB 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
WPUB7	WPUB6	WPUB5	WPUB4	WPUB3	WPUB2	WPUB1	WPUB0
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 **WPUB<7:0>:** Weak Pull-up Register bits
1 = Pull-up enabled
0 = Pull-up disabled

Note 1: Global $\overline{\text{WPUEN}}$ bit of the OPTION_REG register must be cleared for individual pull-ups to be enabled.
2: The weak pull-up device is automatically disabled if the pin is in configured as an output.

TABLE 12-6: SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	124
ANSELB	—	—	ANSB5	ANSB4	ANSB3	ANSB2	ANSB1	ANSB0	124
LATB	LATB7	LATB6	LATB5	LATB4	LATB3	LATB2	LATB1	LATB0	123
PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	123
TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0	123
WPUB	WPUB7	WPUB6	WPUB5	WPUB4	WPUB3	WPUB2	WPUB1	WPUB0	124

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTB.

12.4 PORTC Registers

PORTC is a 8-bit wide, bidirectional port. The corresponding data direction register is TRISC (Register 12-12). 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., enable the output driver and put the contents of the output latch on the selected pin). Example 12-1 shows how to initialize an I/O port.

Reading the PORTC register (Register 12-11) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATC).

The TRISC register (Register 12-12) controls the PORTC pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISC register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.4.1 PORTC FUNCTIONS AND OUTPUT PRIORITIES

Each PORTC pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-7.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority. Analog input and some digital input functions are not included in the list below. These input functions can remain active when the pin is configured as an output. Certain digital input functions override other port functions and are included in Table 12-7.

TABLE 12-7: PORTC OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RC0	SOSCO RC0
RC1	SOSCI CCP2 RC1
RC2	CCP1 RC2
RC3	SCL1 SCK1 RC3 ⁽²⁾
RC4	SDA1 RC4 ⁽²⁾
RC5	SDO1 RC5
RC6	CK1 TX1 RC6
RC7	DT1 RC7

Note 1: Priority listed from highest to lowest.

2: RC3 and RC4 read the I²C ST input when I²C mode is enabled.

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REGISTER 12-11: PORTC: PORTC REGISTER

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
RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0
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 **RC<7:0>**: PORTC General Purpose I/O Pin bits⁽¹⁾
1 = Port pin is $\geq V_{IH}$
0 = Port pin is $\leq V_{IL}$

Note 1: Writes to PORTC are actually written to corresponding LATC register. Reads from PORTC register is return of actual I/O pin values.

REGISTER 12-12: TRISC: PORTC TRI-STATE 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
TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0
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 **TRISC<7:0>**: PORTC Tri-State Control bits⁽¹⁾
1 = PORTC pin configured as an input (tri-stated)
0 = PORTC pin configured as an output

REGISTER 12-13: LATC: PORTC DATA LATCH REGISTER

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
LATC7	LATC6	LATC5	LATC4	LATC3	LATC2	LATC1	LATC0
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 **LATC<7:0>**: PORTC Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTC are actually written to corresponding LATC register. Reads from PORTC register is return of actual I/O pin values.

TABLE 12-8: SUMMARY OF REGISTERS ASSOCIATED WITH PORTC

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	124
LATC	LATC7	LATC6	LATC5	LATC4	LATC3	LATC2	LATC1	LATC0	123
PORTC	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	123
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	123

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTC.

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12.5 PORTD Registers

PORTD is a 8-bit wide, bidirectional port. The corresponding data direction register is TRISD (Register 12-15). 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., enable the output driver and put the contents of the output latch on the selected pin). Example 12-1 shows how to initialize an I/O port.

Reading the PORTD register (Register 12-14) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATD).

The TRISD register (Register 12-15) controls the PORTD pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISD register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.5.1 ANSEL D REGISTER

The ANSEL D register (Register 12-17) is used to configure the Input mode of an I/O pin to analog. Setting the appropriate ANSEL D bit high will cause all digital reads on the pin to be read as '0' and allow analog functions on the pin to operate correctly.

The state of the ANSEL D bits has no effect on digital output functions. A pin with TRIS clear and ANSEL D set will still operate as a digital output, but the Input mode will be analog. This can cause unexpected behavior when executing read-modify-write instructions on the affected port.

Note: The ANSEL D bits default to the Analog mode after Reset. To use any pins as digital general purpose or peripheral inputs, the corresponding ANSEL bits must be initialized to '0' by user software.

12.5.2 PORTD FUNCTIONS AND OUTPUT PRIORITIES

Each PORTD pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-9.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority. Analog input and some digital input functions are not included in the list below. These input functions can remain active when the pin is configured as an output. Certain digital input functions override other port functions and are included in Table 12-9.

TABLE 12-9: PORTD OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RD0	RD0
RD1	RD1
RD2	RD2
RD3	RD3
RD4	SDO2 RD4
RD5	SDA2 RD5 ⁽²⁾
RD6	SCL2 SCK2 RD6 ⁽²⁾
RD7	RD7

- Note 1:** Priority listed from highest to lowest.
2: RD5 and RD6 read the I²C ST input when I²C mode is enabled.

REGISTER 12-14: PORTD: PORTD REGISTER

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
RD7	RD6	RD5	RD4	RD3	RD2	RD1	RD0
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 **RD<7:0>**: PORTD General Purpose I/O Pin bits⁽¹⁾
 1 = Port pin is $\geq V_{IH}$
 0 = Port pin is $\leq V_{IL}$

Note 1: Writes to PORTD are actually written to corresponding LATD register. Reads from PORTD register is return of actual I/O pin values.

REGISTER 12-15: TRISD: PORTD TRI-STATE 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
TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0
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 **TRISD<7:0>**: PORTD Tri-State Control bits
 1 = PORTD pin configured as an input (tri-stated)
 0 = PORTD pin configured as an output

REGISTER 12-16: LATD: PORTB DATA LATCH REGISTER

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
LATD7	LATD6	LATD5	LATD4	LATD3	LATD2	LATD1	LATD0
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 **LATD<7:0>**: PORTD Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTD are actually written to corresponding LATD register. Reads from PORTD register is return of actual I/O pin values.

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REGISTER 12-17: ANSELD: PORTD ANALOG SELECT REGISTER

U-0	U-0	U-0	U-0	R/W-1	R/W-1	R/W-1	R/W-1
—	—	—	—	ANSD3	ANSD2	ANSD1	ANSD0
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 7-4 **Unimplemented:** Read as '0'
bit 3-0 **ANSD<3:0>:** Analog Select between Analog or Digital Function on pins RD<3:0>, respectively
0 = Digital I/O. Pin is assigned to port or digital special function.
1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

Note 1: When setting a pin to an analog input, the corresponding TRIS bit must be set to Input mode in order to allow external control of the voltage on the pin.

REGISTER 12-18: WPUD: WEAK PULL-UP PORTD 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
WPUD7	WPUD6	WPUD5	WPUD4	WPUD3	WPUD2	WPUD1	WPUD0
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 **WPUD<7:0>:** Weak Pull-up Register bits
1 = Pull-up enabled
0 = Pull-up disabled

Note 1: Global $\overline{\text{WPUEN}}$ bit of the OPTION_REG register must be cleared for individual pull-ups to be enabled.
2: The weak pull-up device is automatically disabled if the pin is in configured as an output.

TABLE 12-10: SUMMARY OF REGISTERS ASSOCIATED WITH PORTD

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELD	—	—	—	—	ANSD3	ANSD2	ANSD1	ANSD0	124
LATD	LATD7	LATD6	LATD5	LATD4	LATD3	LATD2	LATD1	LATD0	123
PORTD	RD7	RD6	RD5	RD4	RD3	RD2	RD1	RD0	123
TRISD	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0	123
WPUD	WPUD7	WPUD6	WPUD5	WPUD4	WPUD3	WPUD2	WPUD1	WPUD0	130

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTD.

12.6 PORTE Registers

PORTE is a 8-bit wide, bidirectional port. The corresponding data direction register is TRISE (Register 12-20). 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., enable the output driver and put the contents of the output latch on the selected pin). Example 12-1 shows how to initialize an I/O port.

Reading the PORTE register (Register 12-19) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATE).

The TRISE register (Register 12-20) controls the PORTE pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISE register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.6.1 ANSELE REGISTER

The ANSELE register (Register 12-22) is used to configure the Input mode of an I/O pin to analog. Setting the appropriate ANSELE bit high will cause all digital reads on the pin to be read as '0' and allow analog functions on the pin to operate correctly.

The state of the ANSELE bits has no effect on digital output functions. A pin with TRIS clear and ANSELE set will still operate as a digital output, but the Input mode will be analog. This can cause unexpected behavior when executing read-modify-write instructions on the affected port.

Note: The ANSELE bits default to the Analog mode after Reset. To use any pins as digital general purpose or peripheral inputs, the corresponding ANSEL bits must be initialized to '0' by user software.

12.6.2 PORTE FUNCTIONS AND OUTPUT PRIORITIES

Each PORTE pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-11.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority. Analog input and some digital input functions are not included in the list below. These input functions can remain active when the pin is configured as an output. Certain digital input functions override other port functions and are included in Table 12-11.

TABLE 12-11: PORTE OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RE0	RE0
RE1	RE1
RE2	CCP10 RE2
RE3	CCP9 RE3
RE4	CCP8 RE4
RE5	CCP7 RE5
RE6	CCP6 RE6
RE7	CCP2 RE7

Note 1: Priority listed from highest to lowest.

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REGISTER 12-19: PORTE: PORTE REGISTER

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
RE7	RE6	RE5	RE4	RE3	RE2	RE1	RE0
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 **RE<7:0>**: PORTE General Purpose I/O Pin bits⁽¹⁾
1 = Port pin is $\geq V_{IH}$
0 = Port pin is $\leq V_{IL}$

Note 1: Writes to PORTE are actually written to corresponding LATE register. Reads from PORTE register is return of actual I/O pin values.

REGISTER 12-20: TRISE: PORTE TRI-STATE 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
TRISE7	TRISE6	TRISE5	TRISE4	TRISE3	TRISE2	TRISE1	TRISE0
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 **TRISE<7:0>**: PORTE Tri-State Control bits
1 = PORTE pin configured as an input (tri-stated)
0 = PORTE pin configured as an output

REGISTER 12-21: LATE: PORTE DATA LATCH REGISTER

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
LATE7	LATE6	LATE5	LATE4	LATE3	LATE2	LATE1	LATE0
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 **LATE<7:0>**: PORTE Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTE are actually written to corresponding LATE register. Reads from PORTE register is return of actual I/O pin values.

REGISTER 12-22: ANSELE: PORTE ANALOG SELECT REGISTER

U-0	U-0	U-0	U-0	U-0	R/W-1	R/W-1	R/W-1
—	—	—	—	—	ANSE2	ANSE1	ANSE0
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 7-3 **Unimplemented:** Read as '0'
bit 2-0 **ANSE<2:0>:** Analog Select between Analog or Digital Function on pins RE<2:0>, respectively
0 = Digital I/O. Pin is assigned to port or digital special function.
1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

Note 1: When setting a pin to an analog input, the corresponding TRIS bit must be set to Input mode in order to allow external control of the voltage on the pin.

REGISTER 12-23: WPUE: WEAK PULL-UP PORTE 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
WPUE7	WPUE6	WPUE5	WPUE4	WPUE3	WPUE2	WPUE1	WPUE0
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 **WPUE<7:0>:** Weak Pull-up Register bits
1 = Pull-up enabled
0 = Pull-up disabled

Note 1: Global $\overline{\text{WPUEN}}$ bit of the OPTION_REG register must be cleared for individual pull-ups to be enabled.
2: The weak pull-up device is automatically disabled if the pin is in configured as an output.

TABLE 12-12: SUMMARY OF REGISTERS ASSOCIATED WITH PORTE

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	124
ANSELE	—	—	—	—	—	ANSE2	ANSE1	ANSE0	133
LATE	LATE7	LATE6	LATE5	LATE4	LATE3	LATE2	LATE1	LATE0	132
PORTE	RE7	RE6	RE5	RE4	RE3	RE2	RE1	RE0	132
TRISE	TRISE7	TRISE6	TRISE5	TRISE4	TRISE3	TRISE2	TRISE1	TRISE0	132
WPUE	WPUE7	WPUE6	WPUE5	WPUE4	WPUE3	WPUE2	WPUE1	WPUE0	133

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTE.

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12.7 PORTF Registers

PORTF is a 8-bit wide, bidirectional port. The corresponding data direction register is TRISF (Register 12-25). Setting a TRISF bit (= 1) will make the corresponding PORTF pin an input (i.e., put the corresponding output driver in a High-Impedance mode). Clearing a TRISF bit (= 0) will make the corresponding PORTF pin an output (i.e., enable the output driver and put the contents of the output latch on the selected pin). Example 12-1 shows how to initialize an I/O port.

Reading the PORTF register (Register 12-24) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATF).

The TRISF register (Register 12-25) controls the PORTF pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISF register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.7.1 ANSELF REGISTER

The ANSELF register (Register 12-27) is used to configure the Input mode of an I/O pin to analog. Setting the appropriate ANSELF bit high will cause all digital reads on the pin to be read as '0' and allow analog functions on the pin to operate correctly.

The state of the ANSELF bits has no effect on digital output functions. A pin with TRIS clear and ANSELF set will still operate as a digital output, but the Input mode will be analog. This can cause unexpected behavior when executing read-modify-write instructions on the affected port.

Note: The ANSELF bits default to the Analog mode after Reset. To use any pins as digital general purpose or peripheral inputs, the corresponding ANSEL bits must be initialized to '0' by user software.

12.7.2 PORTE FUNCTIONS AND OUTPUT PRIORITIES

Each PORTF pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-13.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority. Analog input and some digital input functions are not included in the list below. These input functions can remain active when the pin is configured as an output. Certain digital input functions override other port functions and are included in Table 12-13.

TABLE 12-13: PORTF OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RF0	VCAP ⁽²⁾ RF0
RF1	RF1
RF2	RF2
RF3	RF3
RF4	RF4
RF5	RF5
RF6	RF6
RF7	RF7

Note 1: Priority listed from highest to lowest.
2: PIC16F1526/27 only

REGISTER 12-24: PORTF: PORTF REGISTER

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
RF7	RF6	RF5	RF4	RF3	RF2	RF1	RF0
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 **RF<7:0>**: PORTF General Purpose I/O Pin bits⁽¹⁾
 1 = Port pin is $\geq V_{IH}$
 0 = Port pin is $\leq V_{IL}$

Note 1: Writes to PORTF are actually written to corresponding LATF register. Reads from PORTF register is return of actual I/O pin values.

REGISTER 12-25: TRISF: PORTF TRI-STATE 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
TRISF7	TRISF6	TRISF5	TRISF4	TRISF3	TRISF2	TRISF1	TRISF0
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 **TRISF<7:0>**: PORTF Tri-State Control bits
 1 = PORTF pin configured as an input (tri-stated)
 0 = PORTF pin configured as an output

REGISTER 12-26: LATF: PORTF DATA LATCH REGISTER

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
LATF7	LATF6	LATF5	LATF4	LATF3	LATF2	LATF1	LATF0
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 **LATF<7:0>**: PORTF Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTF are actually written to corresponding LATF register. Reads from PORTF register is return of actual I/O pin values.

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REGISTER 12-27: ANSELF: PORTF ANALOG SELECT REGISTER

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
ANSF7	ANSF6	ANSF5	ANSF4	ANSF3	ANSF2	ANSF1	ANSF0
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 **ANSF<7:0>**: Analog Select between Analog or Digital Function on pins RF<7:0>, respectively
0 = Digital I/O. Pin is assigned to port or digital special function.
1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

Note 1: When setting a pin to an analog input, the corresponding TRIS bit must be set to Input mode in order to allow external control of the voltage on the pin.

TABLE 12-14: SUMMARY OF REGISTERS ASSOCIATED WITH PORTF

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELF	ANSF7	ANSF6	ANSF5	ANSF4	ANSF3	ANSF2	ANSF1	ANSF0	136
LATF	LATF7	LATF6	LATF5	LATF4	LATF3	LATF2	LATF1	LATF0	135
PORTF	RF7	RF6	RF5	RF4	RF3	RF2	RF1	RF0	135
TRISF	TRISF7	TRISF6	TRISF5	TRISF4	TRISF3	TRISF2	TRISF1	TRISF0	135

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by PORTF.

TABLE 12-15: SUMMARY OF CONFIGURATION WORD WITH PORTF

Name	Bits	Bit -/7	Bit -/6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG2	13:8	—	—	LVP	DEBUG	LPBOR	BORV	STVREN	—	48
	7:0	—	—	—	VCAPEN ⁽¹⁾	—	—	WRT<1:0>	—	

Legend: — = unimplemented locations read as '0'. Shaded cells are not used by PORTF.

Note 1: PIC16F1526/27 only.

12.8 PORTG Registers

PORTG is a 6-bit wide, bidirectional port. The corresponding data direction register is TRISG (Register 12-29). Setting a TRISG bit (= 1) will make the corresponding PORTG pin an input (i.e., disable the output driver). Clearing a TRISG bit (= 0) will make the corresponding PORTG pin an output (i.e., enables output driver and puts the contents of the output latch on the selected pin). The exception is RG5, which is input only and its TRIS bit will always read as '1'. Example 12-1 shows how to initialize an I/O port.

Reading the PORTG register (Register 12-28) reads the status of the pins, whereas writing to it will write to the PORT latch. All write operations are read-modify-write operations. Therefore, a write to a port implies that the port pins are read, this value is modified and then written to the PORT data latch (LATG).

The TRISG register (Register 12-29) controls the PORTG pin output drivers, even when they are being used as analog inputs. The user should ensure the bits in the TRISG register are maintained set when using them as analog inputs. I/O pins configured as analog input always read '0'.

12.8.1 ANSELG REGISTER

The ANSELG register (Register 12-31) is used to configure the Input mode of an I/O pin to analog. Setting the appropriate ANSELG bit high will cause all digital reads on the pin to be read as '0' and allow analog functions on the pin to operate correctly.

The state of the ANSELG bits has no effect on digital output functions. A pin with TRIS clear and ANSEL set will still operate as a digital output, but the Input mode will be analog. This can cause unexpected behavior when executing read-modify-write instructions on the affected port.

Note: The ANSELG bits default to the Analog mode after Reset. To use any pins as digital general purpose or peripheral inputs, the corresponding ANSEL bits must be initialized to '0' by user software.

12.8.2 PORTG FUNCTIONS AND OUTPUT PRIORITIES

Each PORTG pin is multiplexed with other functions. The pins, their combined functions and their output priorities are shown in Table 12-16.

When multiple outputs are enabled, the actual pin control goes to the peripheral with the highest priority.

Analog input functions, such as ADC, are not shown in the priority lists. These inputs are active when the I/O pin is set for Analog mode using the ANSELx registers. Digital output functions may control the pin when it is in Analog mode with Table 12-16.

TABLE 12-16: PORTG OUTPUT PRIORITY

Pin Name	Function Priority ⁽¹⁾
RG0	CCP3 RG0
RG1	CK2 TX2 RG1
RG2	DT2 RG2
RG3	CCP4 RG3
RG4	CCP5 RG4
RG5	Input only pin

Note 1: Priority listed from highest to lowest.

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REGISTER 12-28: PORTG: PORTG REGISTER

U-0	U-0	R-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u
—	—	RG5	RG4	RG3	RG2	RG1	RG0
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 **Unimplemented:** Read as '0'
bit 5-0 **RG<5:0>:** PORTG I/O Pin bits⁽¹⁾
 1 = Port pin is > VIH
 0 = Port pin is < VIL

Note 1: Writes to PORTG are actually written to corresponding LATG register. Reads from PORTG register is return of actual I/O pin values.

REGISTER 12-29: TRISG: PORTG TRI-STATE REGISTER

U-0	U-0	U-1 ⁽¹⁾	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
—	—	—	TRISG4	TRISG3	TRISG2	TRISG1	TRISG0
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 **Unimplemented:** Read as '0'
bit 5 **Unimplemented:** Read as '1'
bit 4-0 **TRISG<4:0>:** RG<4:0> Tri-State Control bits⁽¹⁾
 1 = PORTG pin configured as an input (tri-stated)
 0 = PORTG pin configured as an output

Note 1: Unimplemented, read as '1'.

REGISTER 12-30: LATG: PORTG DATA LATCH REGISTER

U-0	U-0	U-0	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u	R/W-x/u
—	—	—	LATG4	LATG3	LATG2	LATG1	LATG0
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 7-5 **Unimplemented:** Read as '0'

bit 4-0 **LATG<4:0>:** PORTG Output Latch Value bits⁽¹⁾

Note 1: Writes to PORTG are actually written to corresponding LATG register. Reads from PORTG register is return of actual I/O pin values.

REGISTER 12-31: ANSELG: PORTG ANALOG SELECT REGISTER

U-0	U-0	U-0	R/W-1	R/W-1	R/W-1	R/W-1	U-0
—	—	—	ANSG4	ANSG3	ANSG2	ANSG1	—
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 7-5 **Unimplemented:** Read as '0'

bit 4-1 **ANSG<4:1>:** Analog Select between Analog or Digital Function on Pins RG<4:1>, respectively
 0 = Digital I/O. Pin is assigned to port or digital special function.
 1 = Analog input. Pin is assigned as analog input⁽¹⁾. Digital input buffer disabled.

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

Note 1: When setting a pin to an analog input, the corresponding TRIS bit must be set to Input mode in order to allow external control of the voltage on the pin.

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REGISTER 12-32: WPUG: WEAK PULL-UP PORTG REGISTER

U-0	U-0	R/W-1/1	U-0	U-0	U-0	U-0	U-0	
—	—	WPUG5	—	—	—	—	—	
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 **Unimplemented:** Read as '0'

bit 5 **WPUG5:** Weak Pull-up Register bit

1 = Pull-up enabled

0 = Pull-up disabled

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

Note 1: Global $\overline{\text{WPUEN}}$ bit of the OPTION_REG register must be cleared for individual pull-ups to be enabled.

Note 2: The weak pull-up device is automatically disabled if the pin is in configured as an output.

TABLE 12-17: SUMMARY OF REGISTERS ASSOCIATED WITH PORTG

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELG	—	—	—	ANSG4	ANSG3	ANSG2	ANSG1	—	139
LATG	—	—	—	LATG4	LATG3	LATG2	LATG1	LATG0	139
PORTG	—	—	RG5	RG4	RG3	RG2	RG1	RG0	138
TRISG	—	—	TRISG5	TRISG4	TRISG3	TRISG2	TRISG1	TRISG0	138
WPUG	—	—	WPUG5	—	—	—	—	—	140

Legend: x = unknown, u = unchanged, — = unimplemented locations read as '0'. Shaded cells are not used by PORTG.

TABLE 12-18: SUMMARY OF CONFIGURATION WORD WITH PORTG

Name	Bits	Bit -/7	Bit -/6	Bit 13/5	Bit 12/4	Bit 11/3	Bit 10/2	Bit 9/1	Bit 8/0	Register on Page
CONFIG1	13:8	—	—	FCMEN	IESO	$\overline{\text{CLKOUTEN}}$	BOREN<1:0>	—	—	48
	7:0	$\overline{\text{CP}}$	MCLRE	$\overline{\text{PWRTE}}$	WDTE<1:0>	—	FOSC<2:0>	—	—	

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by PORTG.

13.0 INTERRUPT-ON-CHANGE

The PORTB pins can be configured to operate as Interrupt-On-Change (IOC) pins. An interrupt can be generated by detecting a signal that has either a rising edge or a falling edge. Any individual PORTB pin, or combination of PORTB pins, can be configured to generate an interrupt. The interrupt-on-change module has the following features:

- Interrupt-on-Change enable (Master Switch)
- Individual pin configuration
- Rising and falling edge detection
- Individual pin interrupt flags

Figure 13-1 is a block diagram of the IOC module.

13.1 Enabling the Module

To allow individual PORTB pins to generate an interrupt, the IOCIE bit of the INTCON register must be set. If the IOCIE bit is disabled, the edge detection on the pin will still occur, but an interrupt will not be generated.

13.2 Individual Pin Configuration

For each PORTB pin, a rising edge detector and a falling edge detector are present. To enable a pin to detect a rising edge, the associated IOCBP_x bit of the IOCBP register is set. To enable a pin to detect a falling edge, the associated IOCBN_x bit of the IOCBN register is set.

A pin can be configured to detect rising and falling edges simultaneously by setting both the IOCBP_x bit and the IOCBN_x bit of the IOCBP and IOCBN registers, respectively.

13.3 Interrupt Flags

The IOCBF_x bits located in the IOCBF register are status flags that correspond to the Interrupt-on-change pins of PORTB. If an expected edge is detected on an appropriately enabled pin, then the status flag for that pin will be set, and an interrupt will be generated if the IOCIE bit is set. The IOCIF bit of the INTCON register reflects the status of all IOCBF_x bits.

13.4 Clearing Interrupt Flags

The individual status flags, (IOCBF_x bits), can be cleared by resetting them to zero. If another edge is detected during this clearing operation, the associated status flag will be set at the end of the sequence, regardless of the value actually being written.

In order to ensure that no detected edge is lost while clearing flags, only AND operations masking out known changed bits should be performed. The following sequence is an example of what should be performed.

EXAMPLE 13-1:

```
MOVLW    0xff
XORWF    IOCBF, W
ANDWF    IOCBF, F
```

13.5 Operation in Sleep

The interrupt-on-change interrupt sequence will wake the device from Sleep mode, if the IOCIE bit is set.

If an edge is detected while in Sleep mode, the IOCBF register will be updated prior to the first instruction executed out of Sleep.

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FIGURE 13-1: INTERRUPT-ON-CHANGE BLOCK DIAGRAM



13.6 Interrupt-On-Change Registers

REGISTER 13-1: IOCBP: INTERRUPT-ON-CHANGE PORTB POSITIVE EDGE REGISTER

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
IOCBP7	IOCBP6	IOCBP5	IOCBP4	IOCBP3	IOCBP2	IOCBP1	IOCBP0
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 **IOCBP<7:0>**: Interrupt-on-Change PORTB Positive Edge Enable bits
1 = Interrupt-on-Change enabled on the pin for a positive going edge. Associated Status bit and interrupt flag will be set upon detecting an edge.
0 = Interrupt-on-Change disabled for the associated pin

REGISTER 13-2: IOCBN: INTERRUPT-ON-CHANGE PORTB NEGATIVE EDGE REGISTER

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
IOCBN7	IOCBN6	IOCBN5	IOCBN4	IOCBN3	IOCBN2	IOCBN1	IOCBN0
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 **IOCBN<7:0>**: Interrupt-on-Change PORTB Negative Edge Enable bits
1 = Interrupt-on-Change enabled on the pin for a negative going edge. Associated Status bit and interrupt flag will be set upon detecting an edge.
0 = Interrupt-on-Change disabled for the associated pin

REGISTER 13-3: IOCBF: INTERRUPT-ON-CHANGE PORTB FLAG REGISTER

R/W/HS-0/0	R/W/HS-0/0	R/W/HS-0/0	R/W/HS-0/0	R/W/HS-0/0	R/W/HS-0/0	R/W/HS-0/0	R/W/HS-0/0
IOCBF7	IOCBF6	IOCBF5	IOCBF4	IOCBF3	IOCBF2	IOCBF1	IOCBF0
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 HS - Bit is set in hardware

bit 7-0 **IOCBF<7:0>**: Interrupt-on-Change PORTB Flag bits
1 = An enabled change was detected on the associated pin.
Set when IOCBPx = 1 and a rising edge was detected on RBx, or when IOCBNx = 1 and a falling edge was detected on RBx.
0 = No change was detected, or the user cleared the detected change.

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TABLE 13-1: SUMMARY OF REGISTERS ASSOCIATED WITH INTERRUPT-ON-CHANGE

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELB	—	—	ANSB5	ANSB4	ANSB3	ANSB2	ANSB1	ANSB0	124
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	80
IOCBP	IOCBP7	IOCBP6	IOCBP5	IOCBP4	IOCBP3	IOCBP2	IOCBP1	IOCBP0	143
IOCBN	IOCBN7	IOCBN6	IOCBN5	IOCBN4	IOCBN3	IOCBN2	IOCBN1	IOCBN0	143
IOCBF	IOCBF7	IOCBF6	IOCBF5	IOCBF4	IOCBF3	IOCBF2	IOCBF1	IOCBF0	143
TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0	123

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by Interrupt-on-Change.

14.0 FIXED VOLTAGE REFERENCE (FVR)

The Fixed Voltage Reference, or FVR, is a stable voltage reference, independent of V_{DD} , with 1.024V, 2.048V or 4.096V selectable output levels. The output of the FVR can be configured to supply a reference voltage to the following:

- ADC input channel
- ADC positive reference

The FVR can be enabled by setting the FVREN bit of the FVRCON register.

14.1 Independent Gain Amplifiers

The output of the FVR supplied to the ADC module is routed through two independent programmable gain amplifiers. Each amplifier can be configured to amplify the reference voltage by 1x, 2x or 4x, to produce the three possible voltage levels.

The ADFVR<1:0> bits of the FVRCON register are used to enable and configure the gain amplifier settings for the reference supplied to the ADC module. Reference [Section 16.0 “Analog-to-Digital Converter \(ADC\) Module”](#) for additional information.

14.2 FVR Stabilization Period

When the Fixed Voltage Reference module is enabled, it requires time for the reference and amplifier circuits to stabilize. Once the circuits stabilize and are ready for use, the FVRRDY bit of the FVRCON register will be set. See [Section 25.0 “Electrical Specifications”](#) for the minimum delay requirement.

FIGURE 14-1: VOLTAGE REFERENCE BLOCK DIAGRAM

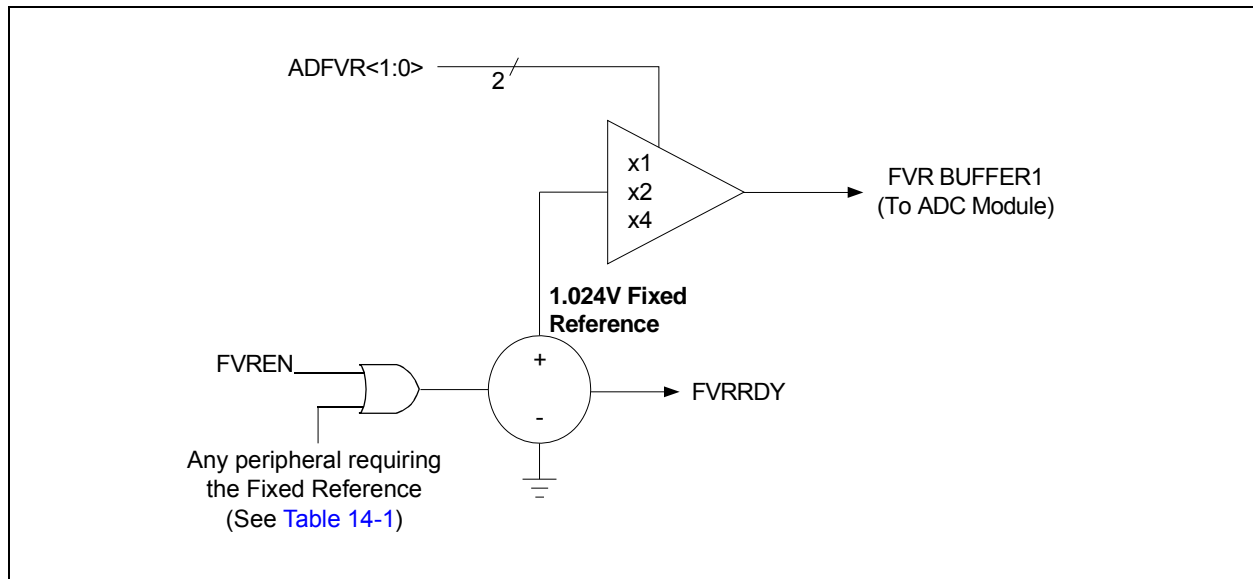


TABLE 14-1: PERIPHERALS REQUIRING THE FIXED VOLTAGE REFERENCE (FVR)

Peripheral	Conditions	Description
HFINTOSC	FOSC<2:0> = 100 and IRCF<3:0> = 000x	INTOSC is active and device is not in Sleep.
BOR	BOREN<1:0> = 11	BOR always enabled.
	BOREN<1:0> = 10 and BORFS = 1	BOR disabled in Sleep mode, BOR Fast Start enabled.
	BOREN<1:0> = 01 and BORFS = 1	BOR under software control, BOR Fast Start enabled.
LDO	All PIC16F1526/27 devices, when VREGPM = 1 and not in Sleep	The device runs off of the low-power regulator when in Sleep mode.

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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 = VOUT = VDD - 2VT (Low Range)
1 = VOUT = VDD - 4VT (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 PIC16F1526/27 only.
Note 2: Fixed Voltage Reference output cannot exceed VDD.

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>		146

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

15.0 TEMPERATURE INDICATOR MODULE

This family of devices is equipped with a temperature circuit designed to measure the operating temperature of the silicon die. The circuit's range of operating temperature falls between of -40°C and +85°C. The output is a voltage that is proportional to the device temperature. The output of the temperature indicator is internally connected to the device ADC.

The circuit may be used as a temperature threshold detector or a more accurate temperature indicator, depending on the level of calibration performed. A one-point calibration allows the circuit to indicate a temperature closely surrounding that point. A two-point calibration allows the circuit to sense the entire range of temperature more accurately. Reference Application Note AN1333, "Use and Calibration of the Internal Temperature Indicator" (DS01333) for more details regarding the calibration process.

15.1 Circuit Operation

Figure 15-1 shows a simplified block diagram of the temperature circuit. The proportional voltage output is achieved by measuring the forward voltage drop across multiple silicon junctions.

Equation 15-1 describes the output characteristics of the temperature indicator.

EQUATION 15-1: V_{OUT} RANGES

$$\text{High Range: } V_{OUT} = V_{DD} - 4V_T$$

$$\text{Low Range: } V_{OUT} = V_{DD} - 2V_T$$

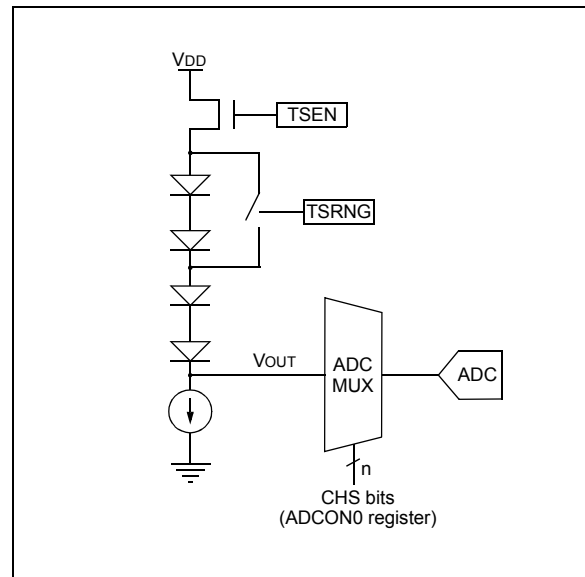
The temperature sense circuit is integrated with the Fixed Voltage Reference (FVR) module. See Section 14.0 "Fixed Voltage Reference (FVR)" for more information.

The circuit is enabled by setting the TSEN bit of the FVRCON register. When disabled, the circuit draws no current.

The circuit operates in either high or low range. The high range, selected by setting the TSRNG bit of the FVRCON register, provides a wider output voltage. This provides more resolution over the temperature range, but may be less consistent from part to part. This range requires a higher bias voltage to operate and thus, a higher V_{DD} is needed.

The low range is selected by clearing the TSRNG bit of the FVRCON register. The low range generates a lower voltage drop and thus, a lower bias voltage is needed to operate the circuit. The low range is provided for low voltage operation.

FIGURE 15-1: TEMPERATURE CIRCUIT DIAGRAM



15.2 Minimum Operating V_{DD} vs. Minimum Sensing Temperature

When the temperature circuit is operated in low range, the device may be operated at any operating voltage that is within specifications.

When the temperature circuit is operated in high range, the device operating voltage, V_{DD} , must be high enough to ensure that the temperature circuit is correctly biased.

Table 15-1 shows the recommended minimum V_{DD} vs. range setting.

TABLE 15-1: RECOMMENDED V_{DD} VS. RANGE

Min. V_{DD} , TSRNG = 1	Min. V_{DD} , TSRNG = 0
3.6V	1.8V

15.3 Temperature Output

The output of the circuit is measured using the internal analog-to-digital converter. A channel is reserved for the temperature circuit output. Refer to Section 16.0 "Analog-to-Digital Converter (ADC) Module" for detailed information.

15.4 ADC Acquisition Time

To ensure accurate temperature measurements, the user must wait at least 200 μ s after the ADC input multiplexer is connected to the temperature indicator output before the conversion is performed. In addition, the user must wait 200 μ s between sequential conversions of the temperature indicator output.

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NOTES:

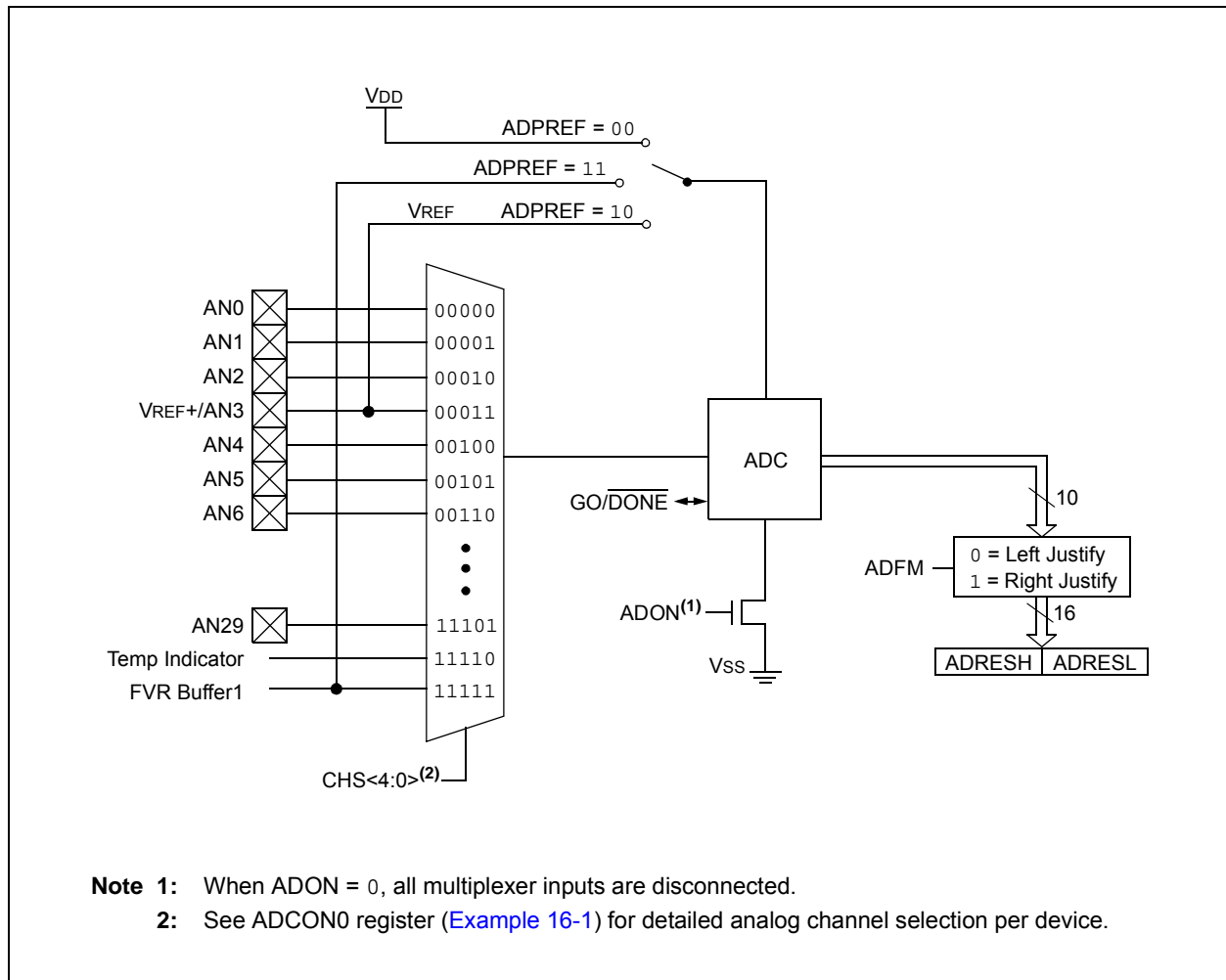
16.0 ANALOG-TO-DIGITAL CONVERTER (ADC) MODULE

The ADC can generate an interrupt upon completion of a conversion. This interrupt can be used to wake-up the device from Sleep.

The Analog-to-Digital Converter (ADC) allows conversion of an analog input signal to a 10-bit binary representation of that signal. This device uses analog inputs, which are multiplexed into a single sample and hold circuit. The output of the sample and hold is connected to the input of the converter. The converter generates a 10-bit binary result via successive approximation and stores the conversion result into the ADC result registers (ADRESH:ADRESL register pair). Figure 16-1 shows the block diagram of the ADC.

The ADC voltage reference is software selectable to be either internally generated or externally supplied.

FIGURE 16-1: ADC BLOCK DIAGRAM



- Note 1:** When ADON = 0, all multiplexer inputs are disconnected.
Note 2: See ADCON0 register (Example 16-1) for detailed analog channel selection per device.

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16.1 ADC Configuration

When configuring and using the ADC the following functions must be considered:

- Port configuration
- Channel selection
- ADC voltage reference selection
- ADC conversion clock source
- Interrupt control
- Result formatting

16.1.1 PORT CONFIGURATION

The ADC can be used to convert both analog and digital signals. When converting analog signals, the I/O pin should be configured for analog by setting the associated TRIS and ANSEL bits. Refer to [Section 12.0 “I/O Ports”](#) for more information.

Note: Analog voltages on any pin that is defined as a digital input may cause the input buffer to conduct excess current.

16.1.2 CHANNEL SELECTION

There are 32 channel selections available:

- AN<29:0> pins
- Temperature Indicator
- FVR (Fixed Voltage Reference) Output

Refer to [Section 14.0 “Fixed Voltage Reference \(FVR\)”](#) and [Section 15.0 “Temperature Indicator Module”](#) for more information on these channel selections.

The CHS bits of the ADCON0 register determine which channel is connected to the sample and hold circuit.

When changing channels, a delay is required before starting the next conversion. Refer to [Section 16.2 “ADC Operation”](#) for more information.

16.1.3 ADC VOLTAGE REFERENCE

The ADPREF bits of the ADCON1 register provides control of the positive voltage reference. The positive voltage reference can be:

- VREF+ pin
- VDD
- FVR 2.048V
- FVR 4.096V (Not available on LF devices)

See [Section 14.0 “Fixed Voltage Reference \(FVR\)”](#) for more details on the Fixed Voltage Reference.

16.1.4 CONVERSION CLOCK

The source of the conversion clock is software selectable via the ADCS bits of the ADCON1 register. There are seven possible clock options:

- Fosc/2
- Fosc/4
- Fosc/8
- Fosc/16
- Fosc/32
- Fosc/64
- FRC (dedicated internal oscillator)

The time to complete one bit conversion is defined as TAD. One full 10-bit conversion requires 11.5 TAD periods as shown in [Figure 16-2](#).

For correct conversion, the appropriate TAD specification must be met. Refer to the A/D conversion requirements in [Section 25.0 “Electrical Specifications”](#) for more information. [Table 16-1](#) gives examples of appropriate ADC clock selections.

Note: Unless using the FRC, any changes in the system clock frequency will change the ADC clock frequency, which may adversely affect the ADC result.

TABLE 16-1: ADC CLOCK PERIOD (TAD) Vs. DEVICE OPERATING FREQUENCIES

ADC Clock Period (TAD)		Device Frequency (Fosc)				
ADC Clock Source	ADCS<2:0>	20 MHz	16 MHz	8 MHz	4 MHz	1 MHz
Fosc/2	000	100 ns ⁽²⁾	125 ns ⁽²⁾	250 ns ⁽²⁾	500 ns ⁽²⁾	2.0 μs
Fosc/4	100	200 ns ⁽²⁾	250 ns ⁽²⁾	500 ns ⁽²⁾	1.0 μs	4.0 μs
Fosc/8	001	400 ns ⁽²⁾	0.5 μs ⁽²⁾	1.0 μs	2.0 μs	8.0 μs ⁽³⁾
Fosc/16	101	800 ns	1.0 μs	2.0 μs	4.0 μs	16.0 μs ⁽³⁾
Fosc/32	010	1.6 μs	2.0 μs	4.0 μs	8.0 μs ⁽³⁾	32.0 μs ⁽³⁾
Fosc/64	110	3.2 μs	4.0 μs	8.0 μs ⁽³⁾	16.0 μs ⁽³⁾	64.0 μs ⁽³⁾
FRC	x11	1.0-6.0 μs ^(1,4)	1.0-6.0 μs ^(1,4)	1.0-6.0 μs ^(1,4)	1.0-6.0 μs ^(1,4)	1.0-6.0 μs ^(1,4)

Legend: Shaded cells are outside of recommended range.

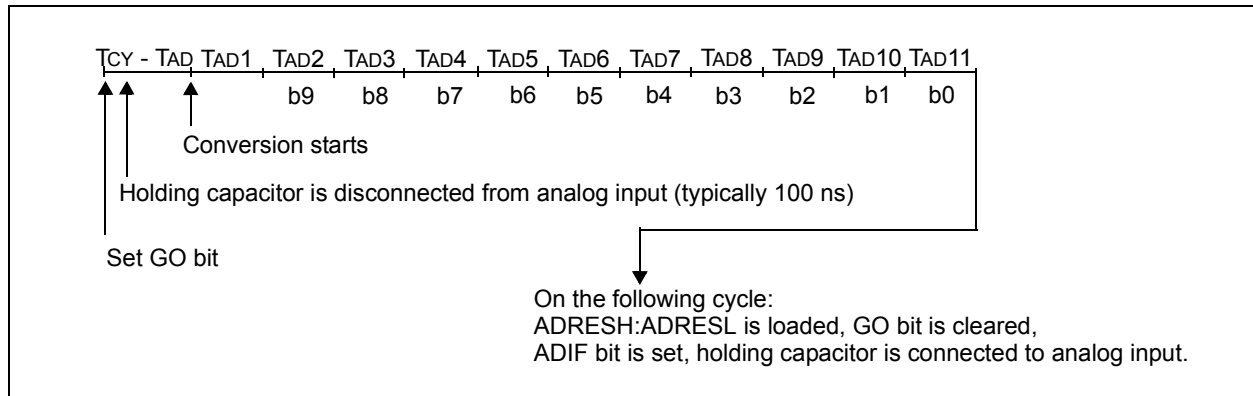
Note 1: The FRC source has a typical TAD time of 1.6 μs for VDD.

2: These values violate the minimum required TAD time.

3: For faster conversion times, the selection of another clock source is recommended.

4: The ADC clock period (TAD) and total ADC conversion time can be minimized when the ADC clock is derived from the system clock FOSC. However, the FRC clock source must be used when conversions are to be performed with the device in Sleep mode.

FIGURE 16-2: ANALOG-TO-DIGITAL CONVERSION TAD CYCLES



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16.1.5 INTERRUPTS

The ADC module allows for the ability to generate an interrupt upon completion of an Analog-to-Digital conversion. The ADC Interrupt Flag is the ADIF bit in the PIR1 register. The ADC Interrupt Enable is the ADIE bit in the PIE1 register. The ADIF bit must be cleared in software.

Note 1: The ADIF bit is set at the completion of every conversion, regardless of whether or not the ADC interrupt is enabled.

2: The ADC operates during Sleep only when the FRC oscillator is selected.

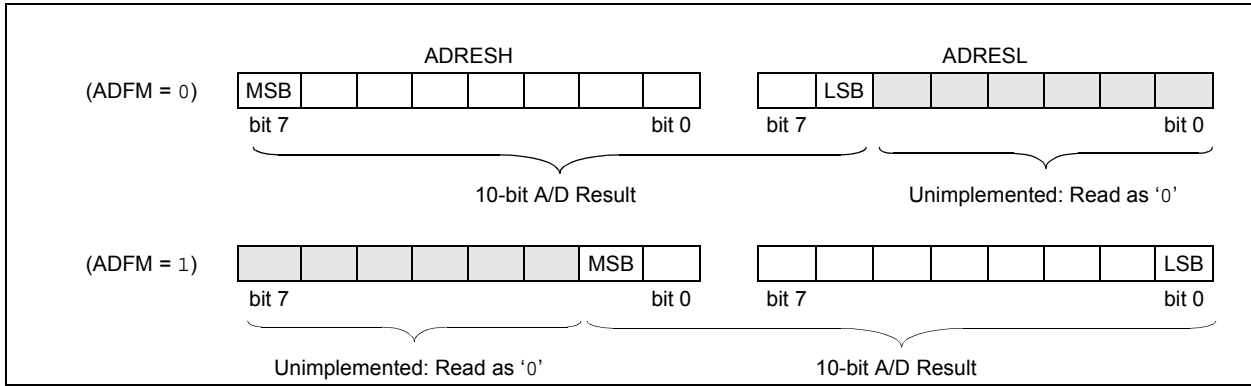
This interrupt can be generated while the device is operating or while in Sleep. If the device is in Sleep, the interrupt will wake-up the device. Upon waking from Sleep, the next instruction following the SLEEP instruction is always executed. If the user is attempting to wake-up from Sleep and resume in-line code execution, the GIE and PEIE bits of the INTCON register must be disabled. If the GIE and PEIE bits of the INTCON register are enabled, execution will switch to the Interrupt Service Routine.

16.1.6 RESULT FORMATTING

The 10-bit A/D conversion result can be supplied in two formats, left justified or right justified. The ADFM bit of the ADCON1 register controls the output format.

Figure 16-3 shows the two output formats.

FIGURE 16-3: 10-BIT A/D CONVERSION RESULT FORMAT



16.2 ADC Operation

16.2.1 STARTING A CONVERSION

To enable the ADC module, the ADON bit of the ADCON0 register must be set to a '1'. Setting the GO/DONE bit of the ADCON0 register to a '1' will start the Analog-to-Digital conversion.

Note: The GO/DONE bit should not be set in the same instruction that turns on the ADC. Refer to [Section 16.2.6 “A/D Conversion Procedure”](#).

16.2.2 COMPLETION OF A CONVERSION

When the conversion is complete, the ADC module will:

- Clear the GO/DONE bit
- Set the ADIF Interrupt Flag bit
- Update the ADRESH and ADRESL registers with new conversion result

16.2.3 TERMINATING A CONVERSION

If a conversion must be terminated before completion, the GO/DONE bit can be cleared in software. The ADRESH and ADRESL registers will be updated with the partially complete Analog-to-Digital conversion sample. Incomplete bits will match the last bit converted.

Note: A device Reset forces all registers to their Reset state. Thus, the ADC module is turned off and any pending conversion is terminated.

16.2.4 ADC OPERATION DURING SLEEP

The ADC module can operate during Sleep. This requires the ADC clock source to be set to the FRC option. When the FRC clock source is selected, the ADC waits one additional instruction before starting the conversion. This allows the SLEEP instruction to be executed, which can reduce system noise during the conversion. If the ADC interrupt is enabled, the device will wake-up from Sleep when the conversion completes. If the ADC interrupt is disabled, the ADC module is turned off after the conversion completes, although the ADON bit remains set.

When the ADC clock source is something other than FRC, a SLEEP instruction causes the present conversion to be aborted and the ADC module is turned off, although the ADON bit remains set.

16.2.5 SPECIAL EVENT TRIGGER

The Special Event Trigger of the CCPx module allows periodic ADC measurements without software intervention. When this trigger occurs, the GO/DONE bit is set by hardware and the Timer1 counter resets to zero.

TABLE 16-2: SPECIAL EVENT TRIGGER

Device	CCP
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Using the Special Event Trigger does not assure proper ADC timing. It is the user's responsibility to ensure that the ADC timing requirements are met.

Refer to [Section 20.0 “Capture/Compare/PWM Modules”](#) for more information.

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16.2.6 A/D CONVERSION PROCEDURE

This is an example procedure for using the ADC to perform an Analog-to-Digital conversion:

1. Configure Port:
 - Disable pin output driver (Refer to the TRIS register)
 - Configure pin as analog (Refer to the ANSEL register)
2. Configure the ADC module:
 - Select ADC conversion clock
 - Configure voltage reference
 - Select ADC input channel
 - Turn on ADC module
3. Configure ADC interrupt (optional):
 - Clear ADC interrupt flag
 - Enable ADC interrupt
 - Enable peripheral interrupt
 - Enable global interrupt⁽¹⁾
4. Wait the required acquisition time⁽²⁾.
5. Start conversion by setting the $\overline{\text{GO/DONE}}$ bit.
6. Wait for ADC conversion to complete by one of the following:
 - Polling the $\overline{\text{GO/DONE}}$ bit
 - Waiting for the ADC interrupt (interrupts enabled)
7. Read ADC Result.
8. Clear the ADC interrupt flag (required if interrupt is enabled).

Note 1: The global interrupt can be disabled if the user is attempting to wake-up from Sleep and resume in-line code execution.

2: Refer to [Section 16.4 “A/D Acquisition Requirements”](#).

EXAMPLE 16-1: A/D CONVERSION

```
;This code block configures the ADC
;for polling, Vdd and Vss references, Frc
;clock and AN0 input.
;
;Conversion start & polling for completion
; are included.
;
BANKSEL    ADCON1    ;
MOVLW     B'11110000' ;Right justify, Frc
                                ;clock
MOVWF     ADCON1    ;Vdd and Vss Vref
BANKSEL    TRISA     ;
BSF       TRISA,0    ;Set RA0 to input
BANKSEL    ANSEL     ;
BSF       ANSEL,0    ;Set RA0 to analog
BANKSEL    ADCON0    ;
MOVLW     B'00000001' ;Select channel AN0
MOVWF     ADCON0    ;Turn ADC On
CALL     SampleTime  ;Acquisition delay
BSF       ADCON0,ADGO ;Start conversion
BTFSC    ADCON0,ADGO ;Is conversion done?
GOTO     $-1         ;No, test again
BANKSEL    ADRESH    ;
MOVF     ADRESH,W    ;Read upper 2 bits
MOVWF    RESULTHI    ;store in GPR space
BANKSEL    ADRESL    ;
MOVF     ADRESL,W    ;Read lower 8 bits
MOVWF    RESULTLO    ;Store in GPR space
```

16.3 ADC Register Definitions

The following registers are used to control the operation of the ADC.

REGISTER 16-1: ADCON0: A/D CONTROL REGISTER 0

U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
—	CHS<4:0>					GO/DONE	ADON
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 **Unimplemented:** Read as '0'
- bit 6-2 **CHS<4:0>:** Analog Channel Select bits
 - 00000 = AN0
 - 00001 = AN1
 - 00010 = AN2
 - 00011 = AN3
 - 00100 = AN4
 - 00101 = AN5
 - 00110 = AN6
 -
 -
 -
 - 11101 = AN29
 - 11110 = Temperature Indicator⁽²⁾.
 - 11111 = FVR (Fixed Voltage Reference) Buffer 1 Output⁽¹⁾
- bit 1 **GO/DONE:** A/D Conversion Status bit
 - 1 = A/D conversion cycle in progress. Setting this bit starts an A/D conversion cycle. This bit is automatically cleared by hardware when the A/D conversion has completed.
 - 0 = A/D conversion completed/not in progress
- bit 0 **ADON:** ADC Enable bit
 - 1 = ADC is enabled
 - 0 = ADC is disabled and consumes no operating current

Note 1: See [Section 14.0 “Fixed Voltage Reference \(FVR\)”](#) for more information.
Note 2: See [Section 15.0 “Temperature Indicator Module”](#) for more information.

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REGISTER 16-2: ADCON1: A/D CONTROL REGISTER 1

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	U-0	U-0	R/W-0/0	R/W-0/0
ADFM	ADCS<2:0>			—	—	ADPREF<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 **ADFM:** A/D Result Format Select bit
1 = Right justified. Six Most Significant bits of ADRESH are set to '0' when the conversion result is loaded.
0 = Left justified. Six Least Significant bits of ADRESL are set to '0' when the conversion result is loaded.
- bit 6-4 **ADCS<2:0>:** A/D Conversion Clock Select bits
000 = FOSC/2
001 = FOSC/8
010 = FOSC/32
011 = FRC (clock supplied from a dedicated RC oscillator)
100 = FOSC/4
101 = FOSC/16
110 = FOSC/64
111 = FRC (clock supplied from a dedicated RC oscillator)
- bit 3-2 **Unimplemented:** Read as '0'
- bit 1-0 **ADPREF<1:0>:** A/D Positive Voltage Reference Configuration bits
00 = VREF is connected to VDD
01 = Reserved
10 = VREF is connected to external VREF pin⁽¹⁾
11 = VREF is connected to internal Fixed Voltage Reference (FVR) module⁽¹⁾

Note 1: When selecting the FVR or the VREF+ pin as the source of the positive reference, be aware that a minimum voltage specification exists. See [Section 25.0 "Electrical Specifications"](#) for details.

REGISTER 16-3: ADRESH: ADC RESULT REGISTER HIGH (ADRESH) ADFM = 0

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
ADRES<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 **ADRES<9:2>**: ADC Result Register bits
Upper 8 bits of 10-bit conversion result

REGISTER 16-4: ADRESL: ADC RESULT REGISTER LOW (ADRESL) ADFM = 0

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
ADRES<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 **ADRES<1:0>**: ADC Result Register bits
Lower 2 bits of 10-bit conversion result

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

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REGISTER 16-5: ADRESH: ADC RESULT REGISTER HIGH (ADRESH) ADFM = 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
—	—	—	—	—	—	ADRES<9:8>	
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 **Reserved:** Do not use.
bit 1-0 **ADRES<9:8>:** ADC Result Register bits
Upper 2 bits of 10-bit conversion result

REGISTER 16-6: ADRESL: ADC RESULT REGISTER LOW (ADRESL) ADFM = 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
ADRES<7:0>							
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 7-0 **ADRES<7:0>:** ADC Result Register bits
Lower 8 bits of 10-bit conversion result

16.4 A/D Acquisition Requirements

For the ADC to meet its specified accuracy, the charge holding capacitor (CHOLD) must be allowed to fully charge to the input channel voltage level. The Analog Input model is shown in Figure 16-4. The source impedance (RS) and the internal sampling switch (RSS) impedance directly affect the time required to charge the capacitor CHOLD. The sampling switch (RSS) impedance varies over the device voltage (VDD), refer to Figure 16-4. **The maximum recommended impedance for analog sources is 10 kΩ.** As the

source impedance is decreased, the acquisition time may be decreased. After the analog input channel is selected (or changed), an A/D acquisition must be done before the conversion can be started. To calculate the minimum acquisition time, Equation 16-1 may be used. This equation assumes that 1/2 LSB error is used (1,024 steps for the ADC). The 1/2 LSB error is the maximum error allowed for the ADC to meet its specified resolution.

EQUATION 16-1: ACQUISITION TIME EXAMPLE

Assumptions: Temperature = 50°C and external impedance of 10kΩ 5.0V VDD

$$\begin{aligned} T_{ACQ} &= \text{Amplifier Settling Time} + \text{Hold Capacitor Charging Time} + \text{Temperature Coefficient} \\ &= T_{AMP} + T_C + T_{COFF} \\ &= 2\mu s + T_C + [(Temperature - 25^\circ C)(0.05\mu s/^\circ C)] \end{aligned}$$

The value for TC can be approximated with the following equations:

$$V_{APPLIED} \left(1 - \frac{1}{(2^{n+1}) - 1} \right) = V_{CHOLD} \quad ;[1] \text{ } V_{CHOLD} \text{ charged to within } 1/2 \text{ lsb}$$

$$V_{APPLIED} \left(1 - e^{-\frac{T_C}{RC}} \right) = V_{CHOLD} \quad ;[2] \text{ } V_{CHOLD} \text{ charge response to } V_{APPLIED}$$

$$V_{APPLIED} \left(1 - e^{-\frac{T_C}{RC}} \right) = V_{APPLIED} \left(1 - \frac{1}{(2^{n+1}) - 1} \right) \quad ;\text{combining [1] and [2]}$$

Note: Where n = number of bits of the ADC.

Solving for TC:

$$\begin{aligned} T_C &= -CHOLD(RIC + RSS + RS) \ln(1/2047) \\ &= -10pF(1k\Omega + 7k\Omega + 10k\Omega) \ln(0.000488) \\ &= 1.37\mu s \end{aligned}$$

Therefore:

$$\begin{aligned} T_{ACQ} &= 2\mu s + 1.37\mu s + [(50^\circ C - 25^\circ C)(0.05\mu s/^\circ C)] \\ &= 4.62\mu s \end{aligned}$$

Note 1: The reference voltage (VREF) has no effect on the equation, since it cancels itself out.

2: The charge holding capacitor (CHOLD) is not discharged after each conversion.

3: The maximum recommended impedance for analog sources is 10 kΩ. This is required to meet the pin leakage specification.

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FIGURE 16-4: ANALOG INPUT MODEL

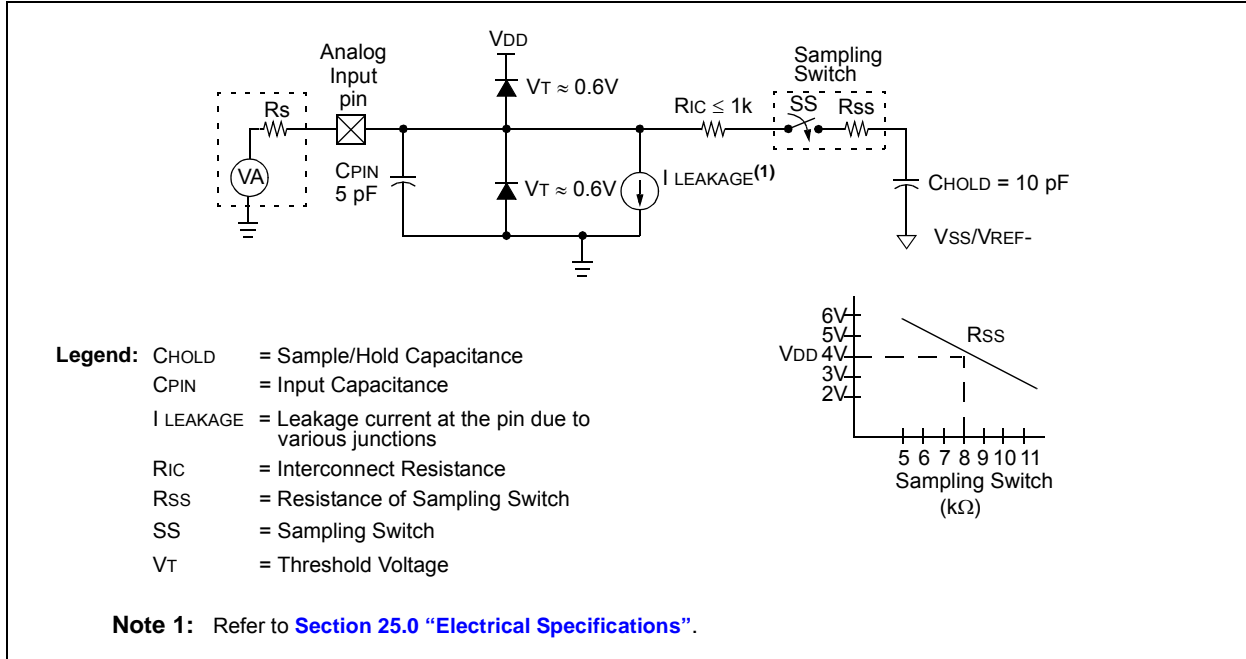


FIGURE 16-5: ADC TRANSFER FUNCTION

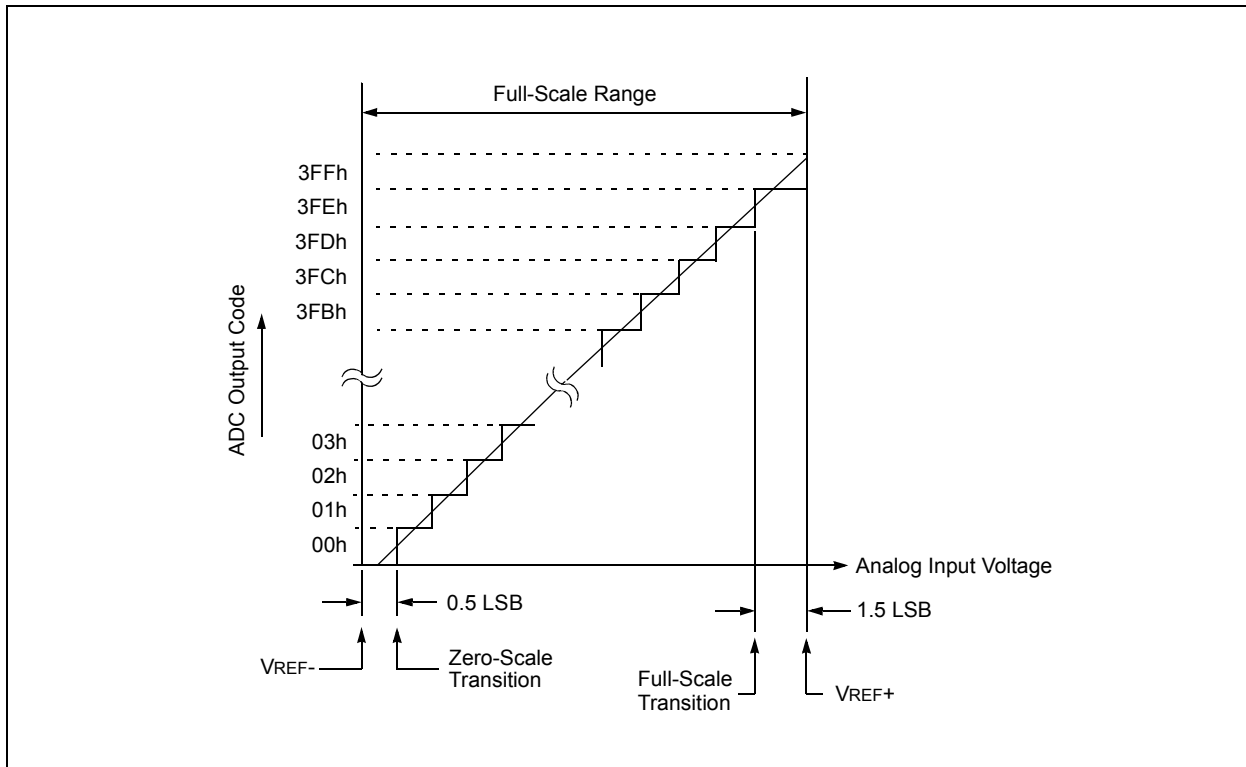


TABLE 16-3: SUMMARY OF REGISTERS ASSOCIATED WITH ADC

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ADCON0	—	CHS<4:0>				—	GO/DONE	ADON	155
ADCON1	ADFM	ADCS<2:0>			—	—	ADPREF<1:0>		156
ADRESH	A/D Result Register High								157, 158
ADRESL	A/D Result Register Low								157, 158
ANSELA	—	—	—	ANSA4	—	ANSA2	ANSA1	ANSA0	121
ANSELB	—	—	ANSB5	ANSB4	ANSB3	ANSB2	ANSB1	ANSB0	124
ANSELD	—	—	—	—	ANSD3	ANSD2	ANSD1	ANSD0	130
ANSELE	—	—	—	—	—	ANSE2	ANSE1	ANSE0	133
ANSELF	ANSF7	ANSF6	ANSF5	ANSF4	ANSF3	ANSF2	ANSF1	ANSF0	136
ANSELG	—	—	—	ANSG4	ANSG3	ANSG2	ANSG1	—	139
CCP1CON	—	—	DC1B<1:0>		CCP1M<3:0>				197
CCP2CON	—	—	DC2B<1:0>		CCP2M<3:0>				197
CCP3CON	—	—	DC3B<1:0>		CCP3M<3:0>				197
CCP4CON	—	—	DC4B<1:0>		CCP4M<3:0>				197
CCP5CON	—	—	DC5B<1:0>		CCP5M<3:0>				197
CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>				197
CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>				197
CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>				197
CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>				197
CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>				197
FVRCON	FVREN	FVRRDY	TSEN	TSRNG	CDAFVR<1:0>		ADFVR<1:0>		146
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120
TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0	123
TRISD	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0	129
TRISE	TRISE7	TRISE6	TRISE5	TRISE4	TRISE3	TRISE2	TRISE1	TRISE0	132
TRISF	TRISF7	TRISF6	TRISF5	TRISF4	TRISF3	TRISF2	TRISF1	TRISF0	135
TRISG	—	—	—	TRISG4	TRISG3	TRISG2	TRISG1	TRISG0	138

Legend: — = unimplemented read as '0'. Shaded cells are not used for ADC module.

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NOTES:

17.0 TIMER0 MODULE

The Timer0 module is an 8-bit timer/counter with the following features:

- 8-bit timer/counter register (TMR0)
- 8-bit prescaler (independent of Watchdog Timer)
- Programmable internal or external clock source
- Programmable external clock edge selection
- Interrupt on overflow
- TMR0 can be used to gate Timer1/3/5

Figure 17-1 is a block diagram of the Timer0 module.

17.1 Timer0 Operation

The Timer0 module can be used as either an 8-bit timer or an 8-bit counter.

17.1.1 8-BIT TIMER MODE

The Timer0 module will increment every instruction cycle, if used without a prescaler. 8-Bit Timer mode is selected by clearing the TMR0CS bit of the OPTION_REG register.

When TMR0 is written, the increment is inhibited for two instruction cycles immediately following the write.

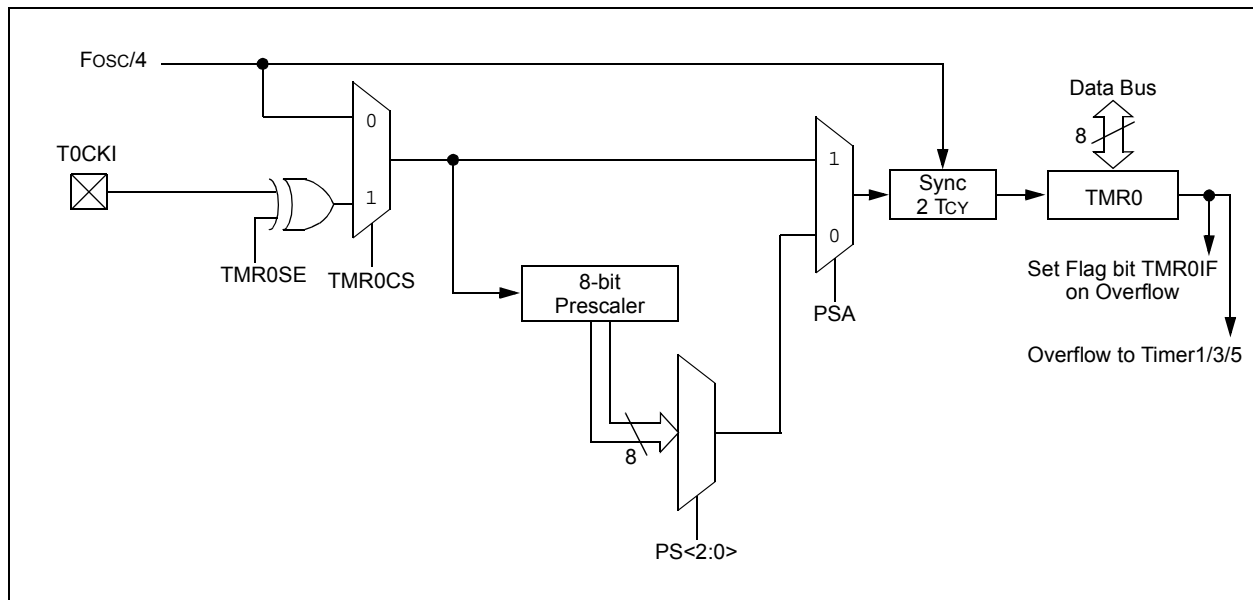
Note: The value written to the TMR0 register can be adjusted, in order to account for the two instruction cycle delay when TMR0 is written.

17.1.2 8-BIT COUNTER MODE

In 8-Bit Counter mode, the Timer0 module will increment on either the rising or falling edge of the T0CKI pin. The edge that increments the counter is determined by the TMR0SE bit in the OPTION_REG register. TMR0SE = 1 selects the falling edge.

The 8-bit Counter mode using the T0CKI pin is selected by setting the TMR0CS bit in the OPTION_REG register to '1'.

FIGURE 17-1: BLOCK DIAGRAM OF THE TIMER0



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17.1.3 SOFTWARE PROGRAMMABLE PRESCALER

A software programmable prescaler is available for exclusive use with Timer0. The prescaler is enabled by clearing the PSA bit of the OPTION_REG register.

Note: The Watchdog Timer (WDT) uses its own independent prescaler.

There are 8 prescaler options for the Timer0 module ranging from 1:2 to 1:256. The prescale values are selectable via the PS<2:0> bits of the OPTION_REG register. In order to have a 1:1 prescaler value for the Timer0 module, the prescaler must be disabled by setting the PSA bit of the OPTION_REG register.

The prescaler is not readable or writable. All instructions writing to the TMR0 register will clear the prescaler.

17.1.4 TIMER0 INTERRUPT

Timer0 will generate an interrupt when the TMR0 register overflows from FFh to 00h. The TMR0IF interrupt flag bit of the INTCON register is set every time the TMR0 register overflows, regardless of whether or not the Timer0 interrupt is enabled. The TMR0IF bit can only be cleared in software. The Timer0 interrupt enable is the TMR0IE bit of the INTCON register.

Note: The Timer0 interrupt cannot wake the processor from Sleep since the timer is frozen during Sleep.

17.1.5 8-BIT COUNTER MODE SYNCHRONIZATION

When in 8-Bit Counter mode, the incrementing edge on the T0CKI pin must be synchronized to the instruction clock. Synchronization can be accomplished by sampling the prescaler output on the Q2 and Q4 cycles of the instruction clock. The high and low periods of the external clocking source must meet the timing requirements as shown in [Section 25.0 “Electrical Specifications”](#).

17.1.6 OPERATION DURING SLEEP

Timer0 cannot operate while the processor is in Sleep mode. The contents of the TMR0 register will remain unchanged while the processor is in Sleep mode.

17.2 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
<u>WPUEN</u>	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 **WPUEN**: Weak Pull-up Enable bit
 1 = All weak pull-ups are disabled (except MCLR, if it is enabled)
 0 = Weak pull-ups are enabled by individual WPUA 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	IOCFIE	TMR0IF	INTF	IOCF	80
OPTION_REG	<u>WPUEN</u>	INTEDG	TMR0CS	TMR0SE	PSA	PS<2:0>			165
TMR0	Timer0 Module Register								163*
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120

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

* Page provides register information.

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NOTES:

18.0 TIMER1/3/5 MODULE WITH GATE CONTROL

The Timer1/3/5 module is a 16-bit timer/counter with the following features:

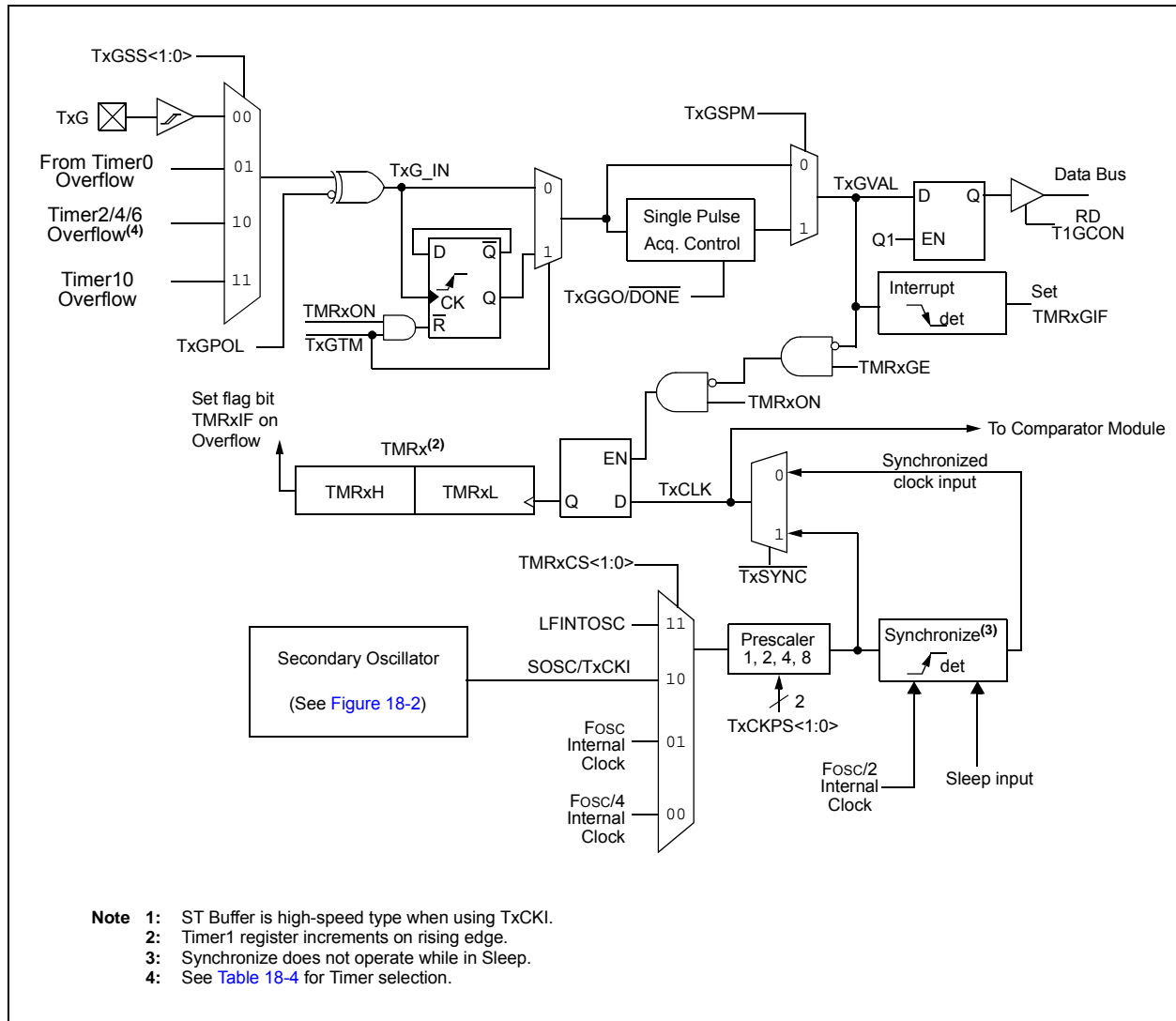
- 16-bit timer/counter register pair (TMRxH:TMRxL)
- Programmable internal or external clock source
- 2-bit prescaler
- Dedicated 32 kHz oscillator circuit
- Optionally synchronized comparator out
- Multiple Timer1/3/5 gate (count enable) sources
- Interrupt on overflow
- Wake-up on overflow (external 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 Timer1/3/5 module.

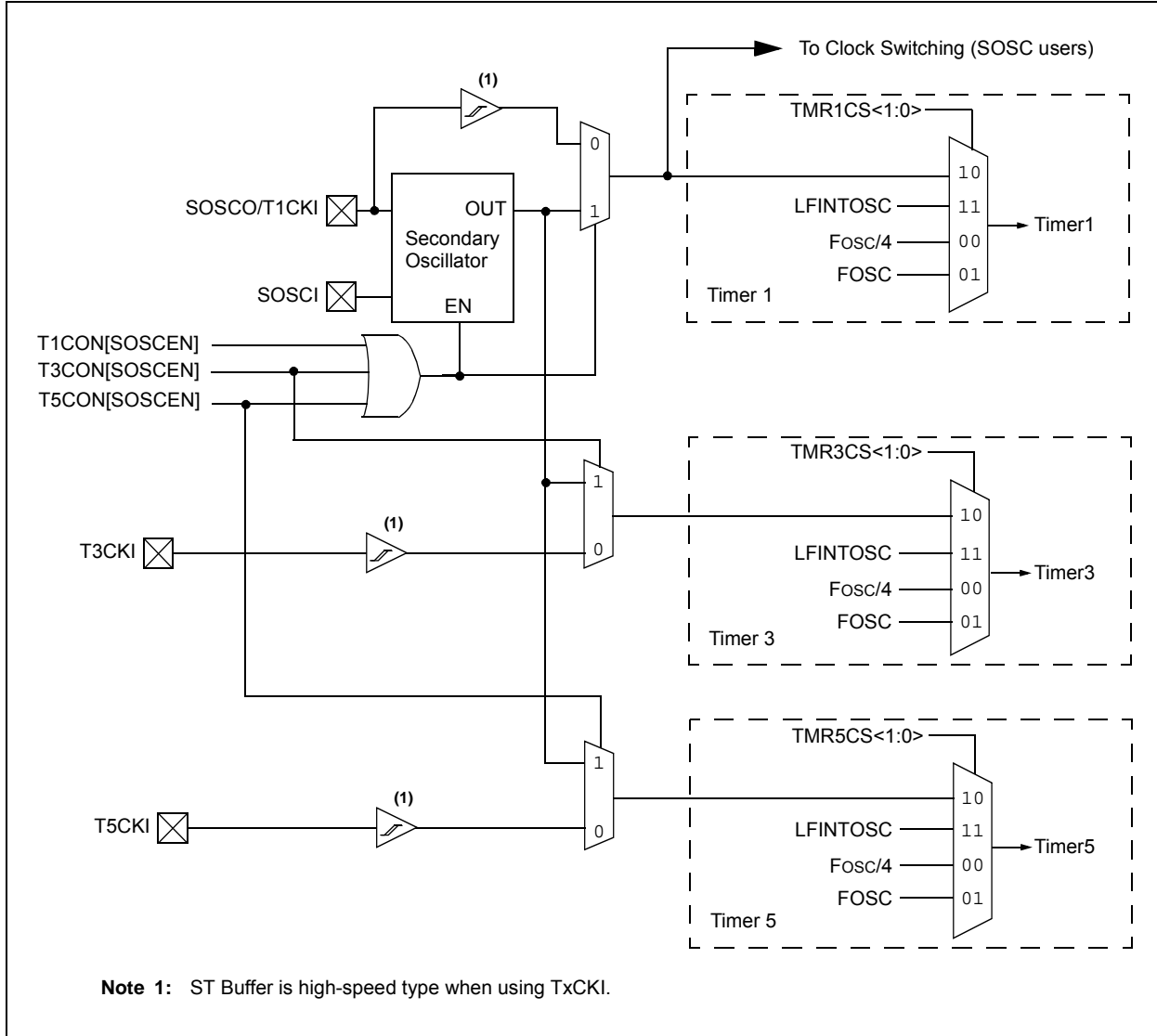
Note: The 'x' variable used in this section is used to designate Timer1, Timer3 or Timer5. For example, TxCON references T1CON, T3CON or T5CON. PRx references PR1, PR3 or PR5.

FIGURE 18-1: TIMER1/3/5 BLOCK DIAGRAM



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FIGURE 18-2: TIMER1/3/5 CLOCK SOURCE DIAGRAM



18.1 Timer1/3/5 Operation

The Timer1/3/5 module is a 16-bit incrementing counter which is accessed through the TMRxH:TMRxL register pair. Writes to TMRxH or TMRxL directly update the counter.

When used with an internal clock source, the module is a timer and increments on every instruction cycle. When used with an external clock source, the module can be used as either a timer or counter and increments on every selected edge of the external source.

Timer1/3/5 is enabled by configuring the TMRxON and TMRxGE bits in the TxCON and TxGCON registers, respectively. Table 18-1 displays the Timer1/3/5 enable selections.

TABLE 18-1: TIMER1/3/5 ENABLE SELECTIONS

TMRxON	TMRxGE	Timer1/3/5 Operation
0	0	Off
0	1	Off
1	0	Always On
1	1	Count Enabled

18.2 Clock Source Selection

The TMRxCS<1:0> and SOSSEN bits of the TxCON register are used to select the clock source for Timer1/3/5. Table 18-2 displays the clock source selections.

18.2.1 INTERNAL CLOCK SOURCE

When the internal clock source is selected the TMRxH:TMRxL register pair will increment on multiples of FOSC as determined by the Timer1/3/5 prescaler.

When the FOSC internal clock source is selected, the Timer1/3/5 register value will increment by four counts every instruction clock cycle. Due to this condition, a 2 LSB error in resolution will occur when reading the Timer1/3/5 value. To utilize the full resolution of Timer1/3/5, an asynchronous input signal must be used to gate the Timer1/3/5 clock input.

The following asynchronous sources may be used:

- Asynchronous event on the TxG pin to Timer1/3/5 gate

18.2.2 EXTERNAL CLOCK SOURCE

When the external clock source is selected, the Timer1/3/5 module may work as a timer or a counter.

When enabled to count, Timer1/3/5 is incremented on the rising edge of the external clock input TxCKI. These external clock inputs (TxCKI) can be synchronized to the microcontroller system clock or they can run asynchronously.

When used as a timer with a clock oscillator, an external 32.768 kHz crystal can be used in conjunction with the dedicated internal oscillator circuit.

Note: In Counter mode, a falling edge must be registered by the counter prior to the first incrementing rising edge after any one or more of the following conditions:

- Timer1/3/5 enabled after POR
- Write to TMRxH or TMRxL
- Timer1/3/5 is disabled
- Timer1/3/5 is disabled (TMRxON = 0) when TxCKI is high then Timer1/3/5 is enabled (TMRxON = 1) when TxCKI is low.

TABLE 18-2: CLOCK SOURCE SELECTIONS

TMRxCS<1:0>	SOSSEN	Clock Source
00	x	Instruction Clock (FOSC/4)
01	x	System Clock (FOSC)
10	0	External Clocking on TxCKI Pin
	1	Secondary Oscillator Circuit on SOSCI/SOSCO Pins
11	x	LFINTOSC

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18.3 Timer1/3/5 Prescaler

Timer1/3/5 has four prescaler options allowing 1, 2, 4 or 8 divisions of the clock input. The TxCKPS bits of the TxCON register control the prescale counter. The prescale counter is not directly readable or writable; however, the prescaler counter is cleared upon a write to TMRxH or TMRxL.

18.4 Timer1/3/5 Oscillator

A dedicated low-power 32.768 kHz oscillator circuit is built-in between pins SOSC1 (input) and SOSCO (amplifier output). This internal circuit is to be used in conjunction with an external 32.768 kHz crystal.

The oscillator circuit is enabled by setting the SOSSEN bit of the TxCON register. The oscillator will continue to run during Sleep.

Note: The oscillator requires a start-up and stabilization time before use. Thus, SOSSEN should be set and a suitable delay observed prior to enabling Timer1/3/5.

18.5 Timer1/3/5 Operation in Asynchronous Counter Mode

If control bit $\overline{\text{TxSYNC}}$ of the TxCON register is set, the external clock input is not synchronized. The timer increments asynchronously to the internal phase clocks. If the external clock source is selected then the timer will continue to run during Sleep and can generate an interrupt on overflow, which will wake-up the processor. However, special precautions in software are needed to read/write the timer (see [Section 18.5.1 “Reading and Writing Timer1/3/5 in Asynchronous Counter Mode”](#)).

Note: When switching from synchronous to asynchronous operation, it is possible to skip an increment. When switching from asynchronous to synchronous operation, it is possible to produce an additional increment.

18.5.1 READING AND WRITING TIMER1/3/5 IN ASYNCHRONOUS COUNTER MODE

Reading TMRxH or TMRxL while the timer is running from an external asynchronous clock will ensure a valid read (taken care of in hardware). However, the user should keep in mind that reading the 16-bit timer in two 8-bit values itself, poses certain problems, since the timer may overflow between the reads.

For writes, it is recommended that the user simply stop the timer and write the desired values. A write contention may occur by writing to the timer registers, while the register is incrementing. This may produce an unpredictable value in the TMRxH:TMRxL register pair.

18.6 Timer1/3/5 Gate

Timer1/3/5 can be configured to count freely or the count can be enabled and disabled using Timer1/3/5 gate circuitry. This is also referred to as Timer1/3/5 Gate Enable.

Timer1/3/5 gate can also be driven by multiple selectable sources.

18.6.1 TIMER1/3/5 GATE ENABLE

The Timer1/3/5 Gate Enable mode is enabled by setting the TMRxGE bit of the TxGCON register. The polarity of the Timer1/3/5 Gate Enable mode is configured using the TxGPOL bit of the TxGCON register.

When Timer1/3/5 Gate Enable mode is enabled, Timer1/3/5 will increment on the rising edge of the Timer1/3/5 clock source. When Timer1/3/5 Gate Enable mode is disabled, no incrementing will occur and Timer1/3/5 will hold the current count. See [Figure 18-4](#) for timing details.

TABLE 18-3: TIMER1/3/5 GATE ENABLE SELECTIONS

TxCLK	TxGPOL	TxG	Timer1/3/5 Operation
↑	0	0	Counts
↑	0	1	Holds Count
↑	1	0	Holds Count
↑	1	1	Counts

18.6.2 TIMER1/3/5 GATE SOURCE SELECTION

The Timer1/3/5 gate source can be selected from one of four different sources. Source selection is controlled by the TxGSS bits of the TxGCON register. The polarity for each available source is also selectable. Polarity selection is controlled by the TxGPOL bit of the TxGCON register.

TABLE 18-4: TIMER1/3/5 GATE SOURCES

T1GSS	Timer1 Gate Source	Timer3 Gate Source	Timer5 Gate Source
00	T1G Pin	T3G Pin	T5G Pin
01	Overflow of Timer0 (TMR0 increments from FFh to 00h)		
10	Timer2 match PR2 (TMR2 increments to match PR2)	Timer4 match PR4	Timer6 match PR6
11	Timer10 match PR10		

18.6.2.1 TxG Pin Gate Operation

The TxG pin is one source for Timer1/3/5 gate control. It can be used to supply an external source to the Timer1/3/5 gate circuitry.

18.6.2.2 Timer0 Overflow Gate Operation

When Timer0 increments from FFh to 00h, a low-to-high pulse will automatically be generated and internally supplied to the Timer1/3/5 gate circuitry.

18.6.3 TIMER1/3/5 GATE TOGGLE MODE

When Timer1/3/5 Gate Toggle mode is enabled, it is possible to measure the full-cycle length of a Timer1/3/5 gate signal, as opposed to the duration of a single level pulse.

The Timer1/3/5 gate source is routed through a flip-flop that changes state on every incrementing edge of the signal. See [Figure 18-5](#) for timing details.

Timer1/3/5 Gate Toggle mode is enabled by setting the TxGTM bit of the TxGCON register. When the TxGTM bit is cleared, the flip-flop is cleared and held clear. This is necessary in order to control which edge is measured.

Note: Enabling Toggle mode at the same time as changing the gate polarity may result in indeterminate operation.

18.6.4 TIMER1/3/5 GATE SINGLE-PULSE MODE

When Timer1/3/5 Gate Single-Pulse mode is enabled, it is possible to capture a single pulse gate event. Timer1/3/5 Gate Single-Pulse mode is first enabled by setting the TxGSPM bit in the TxGCON register. Next, the TxGGO/DONE bit in the TxGCON register must be set. The Timer1/3/5 will be fully enabled on the next incrementing edge. On the next trailing edge of the pulse, the TxGGO/DONE bit will automatically be cleared. No other gate events will be allowed to increment Timer1/3/5 until the TxGGO/DONE bit is once again set in software. See [Figure 18-6](#) for timing details.

If the Single Pulse Gate mode is disabled by clearing the TxGSPM bit in the TxGCON register, the TxGGO/DONE bit should also be cleared.

Enabling the Toggle mode and the Single-Pulse mode simultaneously will permit both sections to work together. This allows the cycle times on the Timer1/3/5 gate source to be measured. See [Figure 18-7](#) for timing details.

18.6.5 TIMER1/3/5 GATE VALUE STATUS

When Timer1/3/5 Gate Value Status is utilized, it is possible to read the most current level of the gate control value. The value is stored in the TxGVAL bit in the TxGCON register. The TxGVAL bit is valid even when the Timer1/3/5 gate is not enabled (TMRxGE bit is cleared).

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18.6.6 TIMER1/3/5 GATE EVENT INTERRUPT

When Timer1/3/5 Gate Event Interrupt is enabled, it is possible to generate an interrupt upon the completion of a gate event. When the falling edge of TxGVAL occurs, the TMRxGIF flag bit in the PIR1 register will be set. If the TMRxGIE bit in the PIE1 register is set, then an interrupt will be recognized.

The TMRxGIF flag bit operates even when the Timer1/3/5 gate is not enabled (TMRxGE bit is cleared).

18.7 Timer1/3/5 Interrupt

The Timer1/3/5 register pair (TMRxH:TMRxL) increments to FFFFh and rolls over to 0000h. When Timer1/3/5 rolls over, the Timer1/3/5 interrupt flag bit of the PIR1 register is set. To enable the interrupt on roll-over, you must set these bits:

- TMRxON bit of the TxCON register
- TMRxIE bit of the PIE1 register
- PEIE bit of the INTCON register
- GIE bit of the INTCON register

The interrupt is cleared by clearing the TMRxIF bit in the Interrupt Service Routine.

Note: The TMRxH:TMRxL register pair and the TMRxIF bit should be cleared before enabling interrupts.

18.8 Timer1/3/5 Operation During Sleep

Timer1/3/5 can only operate during Sleep when setup in Asynchronous Counter mode. In this mode, an external crystal or clock source can be used to increment the counter. To set up the timer to wake the device:

- TMRxON bit of the TxCON register must be set
- TMRxIE bit of the PIE1 register must be set
- PEIE bit of the INTCON register must be set
- TxSYNC bit of the TxCON register must be set
- TMRxCS bits of the TxCON register must be configured
- SOSSEN bit of the TxCON register must be configured

The device will wake-up on an overflow and execute the next instructions. If the GIE bit of the INTCON register is set, the device will call the Interrupt Service Routine.

Timer1/3/5 oscillator will continue to operate in Sleep regardless of the TxSYNC bit setting.

18.9 ECCP/CCP Capture/Compare Time Base

The CCP module uses the TMRxH:TMRxL register pair as the time base when operating in Capture or Compare mode.

In Capture mode, the value in the TMRxH:TMRxL register pair is copied into the CCPR1H:CCPR1L register pair on a configured event.

In Compare mode, an event is triggered when the value CCPR1H:CCPR1L register pair matches the value in the TMRxH:TMRxL register pair. This event can be a Special Event Trigger.

For more information, see [Section 20.0 “Capture/Compare/PWM Modules”](#).

18.10 ECCP/CCP Special Event Trigger

When the CCP is configured to trigger a special event, the trigger will clear the TMRxH:TMRxL register pair. This special event does not cause a Timer1/3/5 interrupt. The CCP module may still be configured to generate a CCP interrupt.

In this mode of operation, the CCPR1H:CCPR1L register pair becomes the period register for Timer1/3/5.

Timer1/3/5 should be synchronized and Fosc/4 should be selected as the clock source in order to utilize the Special Event Trigger. Asynchronous operation of Timer1/3/5 can cause a Special Event Trigger to be missed.

In the event that a write to TMRxH or TMRxL coincides with a Special Event Trigger from the CCP, the write will take precedence.

For more information, see [Section 16.2.5 “Special Event Trigger”](#).

FIGURE 18-3: TIMER1/3/5 INCREMENTING EDGE

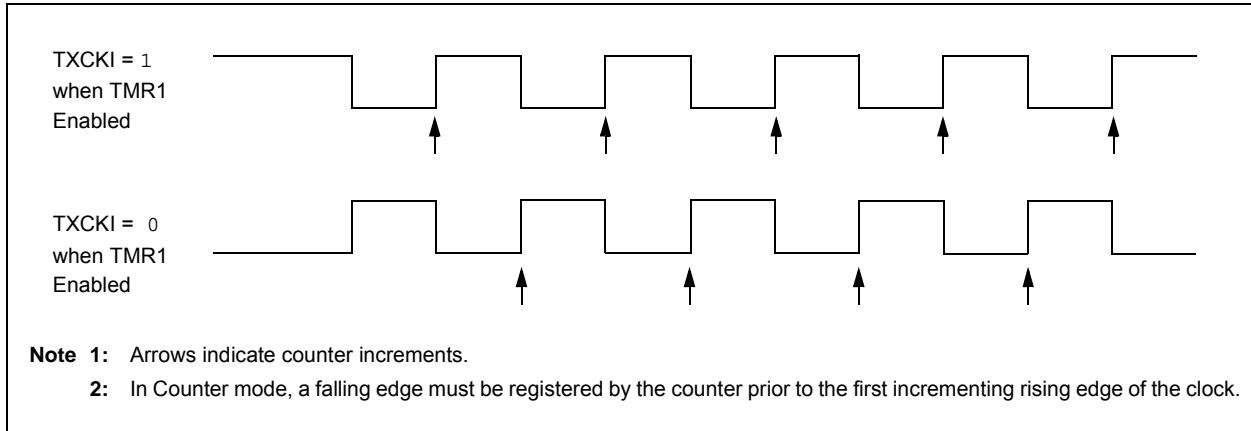
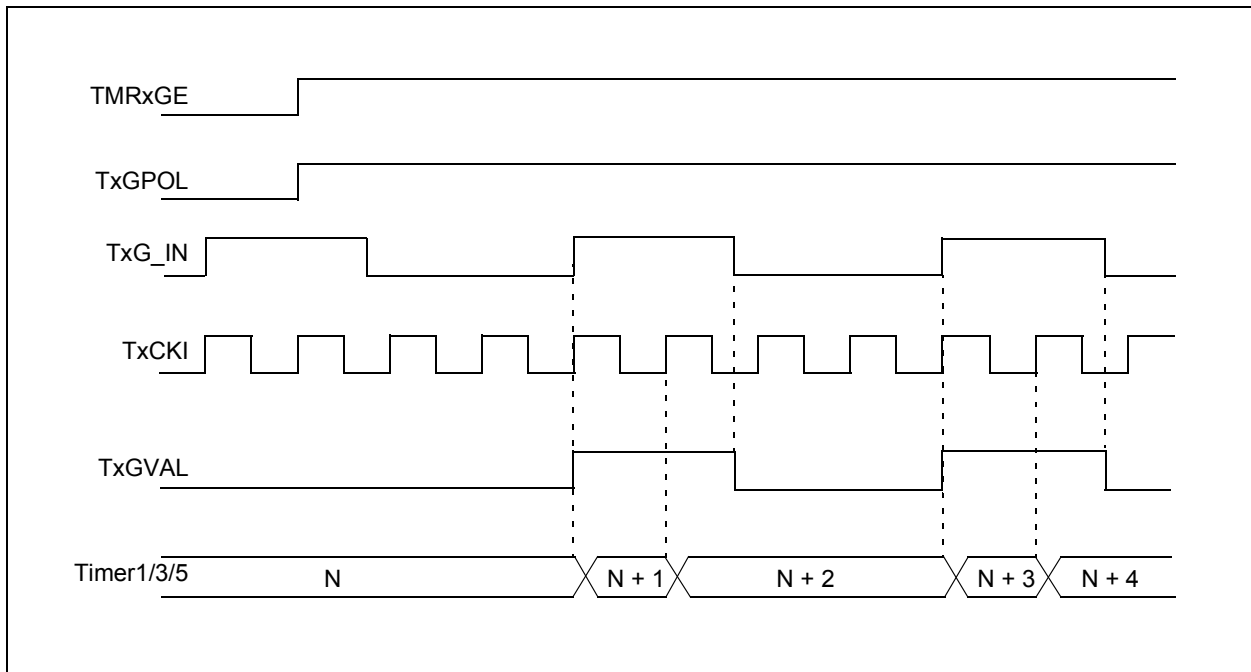


FIGURE 18-4: TIMER1/3/5 GATE ENABLE MODE



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FIGURE 18-5: TIMER1/3/5 GATE TOGGLE MODE

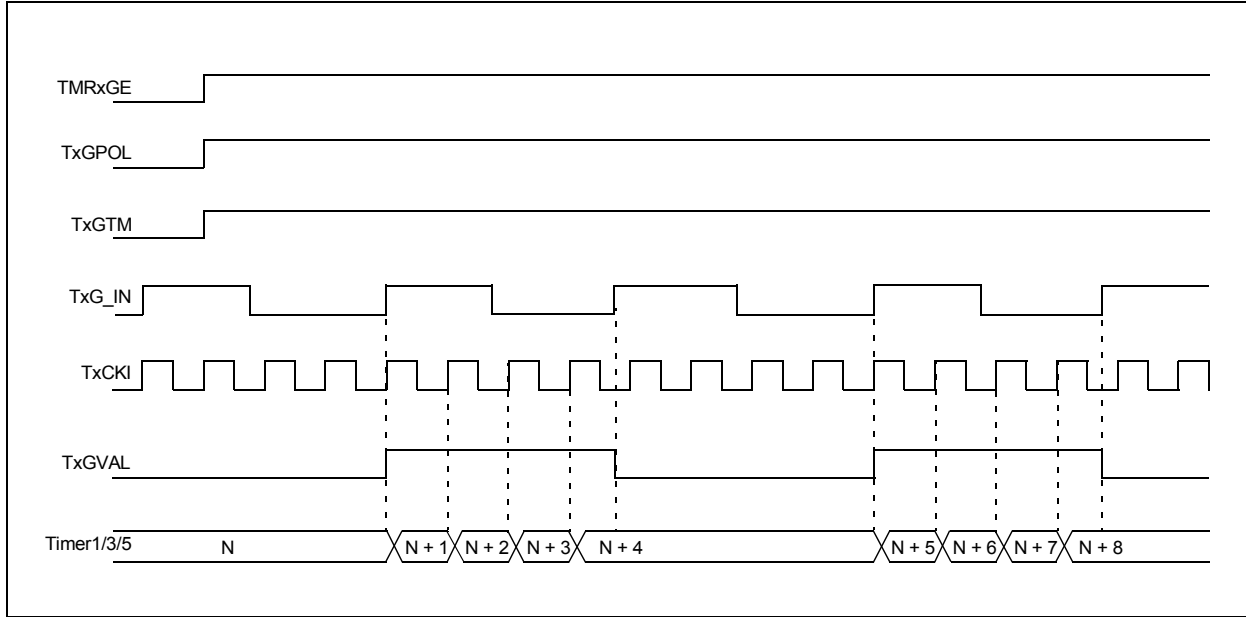


FIGURE 18-6: TIMER1/3/5 GATE SINGLE-PULSE MODE

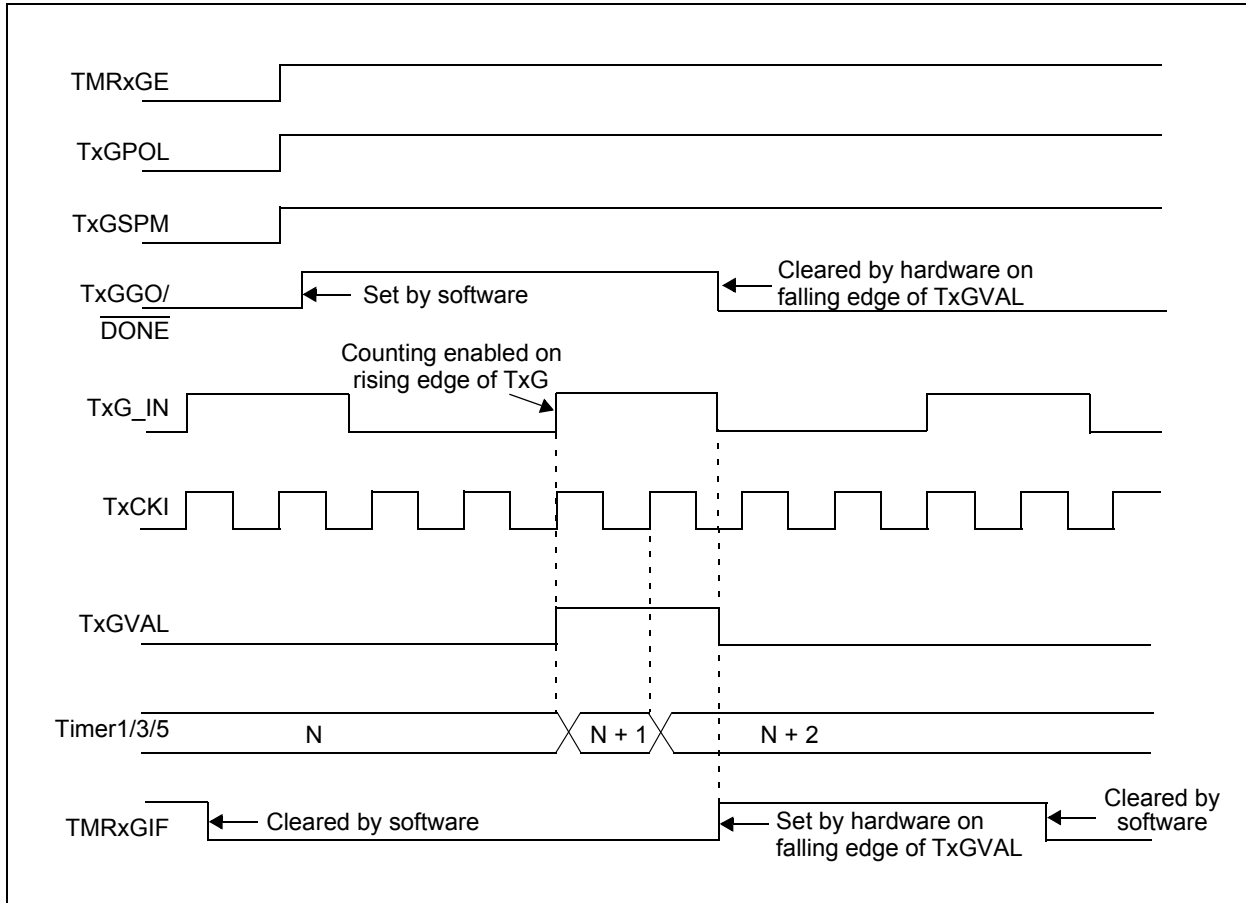
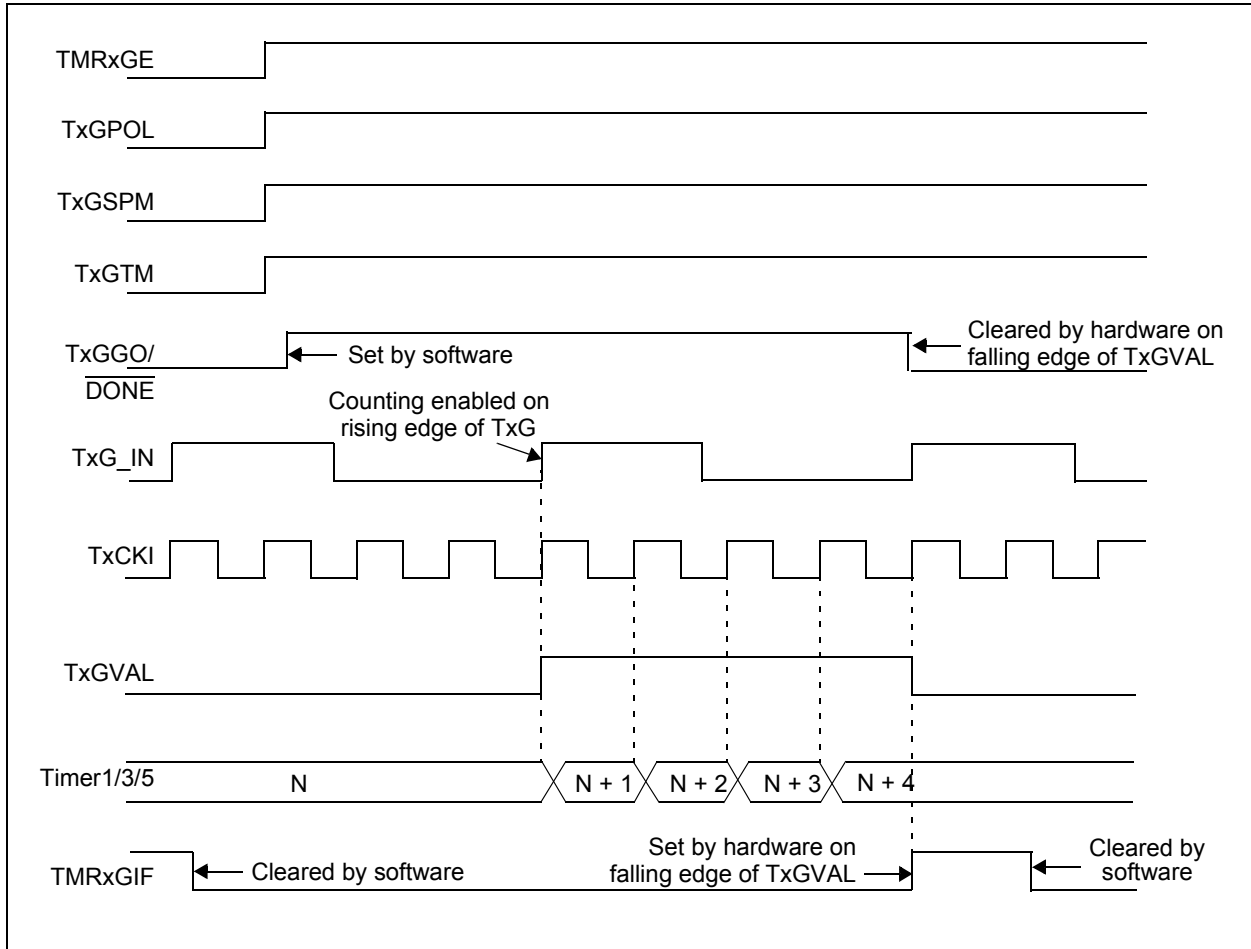


FIGURE 18-7: TIMER1/3/5 GATE SINGLE-PULSE AND TOGGLE COMBINED MODE



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18.11 Timer1/3/5 Control Register

The Timer1/3/5 Control register (TxCON), shown in [Register 18-1](#), is used to control Timer1/3/5 and select the various features of the Timer1/3/5 module.

REGISTER 18-1: TXCON: TIMER1/3/5 CONTROL REGISTER

R/W-0/u	R/W-0/u	R/W-0/u	R/W-0/u	R/W-0/u	R/W-0/u	U-0	R/W-0/u
TMRxCS<1:0>		TxCKPS<1:0>		SOSCEN	$\overline{\text{TxSYNC}}$	—	TMRxON
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 **TMRxCS<1:0>**: Timer1/3/5 Clock Source Select bits
11 = Timer1/3/5 clock source is LFINTOSC
10 = Timer1/3/5 clock source is pin or oscillator:
 If SOSCEN = 0:
 External clock from TxCKI pin (on the rising edge)
 If SOSCEN = 1:
 Crystal oscillator on SOSC1/SOSCO pins
01 = Timer1/3/5 clock source is system clock (Fosc)
00 = Timer1/3/5 clock source is instruction clock (Fosc/4)
- bit 5-4 **TxCKPS<1:0>**: Timer1/3/5 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 3 **SOSCEN**: LP Oscillator Enable Control bit
1 = Dedicated secondary oscillator circuit enabled
0 = Dedicated secondary oscillator circuit disabled
- bit 2 **TxSYNC**: Timer1/3/5 External Clock Input Synchronization Control bit
TMRxCS<1:0> = 1X:
1 = Do not synchronize external clock input
0 = Synchronize external clock input with system clock (Fosc)

TMRxCS<1:0> = 0X:
This bit is ignored.
- bit 1 **Unimplemented**: Read as '0'
- bit 0 **TMRxON**: Timer1/3/5 On bit
1 = Enables Timer1/3/5
0 = Stops Timer1/3/5
 Clears Timer1/3/5 gate flip-flop

18.12 Timer1/3/5 Gate Control Register

The Timer1/3/5 Gate Control register (TxGCON), shown in [Register 18-2](#), is used to control Timer1/3/5 Gate.

REGISTER 18-2: TXGCON: TIMER1/3/5 GATE CONTROL REGISTER

R/W-0/u	R/W-0/u	R/W-0/u	R/W-0/u	R/W/HC-0/u	R-x/x	R/W-0/u	R/W-0/u
TMRxGE	TxGPOL	TxGTM	TxGSPM	TxGGO/ DONE	TxGVAL	TxGSS<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	HC = Bit is cleared by hardware

- bit 7 **TMRxGE:** Timer1/3/5 Gate Enable bit
If TMRxON = 0:
This bit is ignored
If TMRxON = 1:
1 = Timer1/3/5 counting is controlled by the Timer1/3/5 gate function
0 = Timer1/3/5 counts regardless of Timer1/3/5 gate function
- bit 6 **TxGPOL:** Timer1/3/5 Gate Polarity bit
1 = Timer1/3/5 gate is active-high (Timer1/3/5 counts when gate is high)
0 = Timer1/3/5 gate is active-low (Timer1/3/5 counts when gate is low)
- bit 5 **TxGTM:** Timer1/3/5 Gate Toggle Mode bit
1 = Timer1/3/5 Gate Toggle mode is enabled
0 = Timer1/3/5 Gate Toggle mode is disabled and toggle flip-flop is cleared
Timer1/3/5 gate flip-flop toggles on every rising edge.
- bit 4 **TxGSPM:** Timer1/3/5 Gate Single-Pulse Mode bit
1 = Timer1/3/5 Gate Single-Pulse mode is enabled and is controlling Timer1/3/5 gate
0 = Timer1/3/5 Gate Single-Pulse mode is disabled
- bit 3 **TxGGO/DONE:** Timer1/3/5 Gate Single-Pulse Acquisition Status bit
1 = Timer1/3/5 gate single-pulse acquisition is ready, waiting for an edge
0 = Timer1/3/5 gate single-pulse acquisition has completed or has not been started
- bit 2 **TxGVAL:** Timer1/3/5 Gate Current State bit
Indicates the current state of the Timer1/3/5 gate that could be provided to TMRxH:TMRxL.
Unaffected by Timer1/3/5 Gate Enable (TMRxGE).
- bit 1-0 **TxGSS<1:0>:** Timer1/3/5 Gate Source Select bits
00 = Timer1/3/5 gate pin
01 = Timer0 overflow output
10 = Timer2/4/6/8 match PR2/PR4/PR6/PR8⁽¹⁾
11 = Timer10 match PR10

Note 1: See [Table 18-4](#) for Timer selection.

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18.12.1 ALTERNATE PIN LOCATIONS

This module incorporates I/O pins that can be moved to other locations with the use of the alternate pin function register, APFCON. To determine which pins can be moved and what their default locations are upon a Reset, see [Section 12.1 “Alternate Pin Function”](#) for more information.

TABLE 18-5: SUMMARY OF REGISTERS ASSOCIATED WITH TIMER1/3/5

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELA	—	—	ANSA5	—	ANSA3	ANSA2	ANSA1	ANSA0	121
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	118
CCP1CON	—	—	DC1B<1:0>		CCP1M<3:0>				197
CCP2CON	—	—	DC2B<1:0>		CCP2M<3:0>				197
CCP3CON	—	—	DC3B<1:0>		CCP3M<3:0>				197
CCP4CON	—	—	DC4B<1:0>		CCP4M<3:0>				197
CCP5CON	—	—	DC5B<1:0>		CCP5M<3:0>				197
CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>				197
CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>				197
CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>				197
CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>				197
CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>				197
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
TMR1H	Holding Register for the Most Significant Byte of the 16-bit TMR1 Register								172*
TMR3H	Holding Register for the Most Significant Byte of the 16-bit TMR3 Register								172*
TMR5H	Holding Register for the Most Significant Byte of the 16-bit TMR5 Register								172*
TMR1L	Holding Register for the Least Significant Byte of the 16-bit TMR1 Register								172*
TMR3L	Holding Register for the Least Significant Byte of the 16-bit TMR3 Register								172*
TMR5L	Holding Register for the Least Significant Byte of the 16-bit TMR5 Register								172*
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120
T1CON	TMR1CS<1:0>		T1CKPS<1:0>		SOSCEN	T1SYNC	—	TMR1ON	176
T3CON	TMR3CS<1:0>		T3CKPS<1:0>		SOSCEN	T3SYNC	—	TMR3ON	176
T5CON	TMR5CS<1:0>		T5CKPS<1:0>		SOSCEN	T5SYNC	—	TMR5ON	176
T1GCON	TMR1GE	T1GPOL	T1GTM	T1GSPM	T1GGO/ DONE	T1GVAL	T1GSS<1:0>		177
T3GCON	TMR3GE	T3GPOL	T3GTM	T3GSPM	T3GGO/ DONE	T3GVAL	T3GSS<1:0>		177
T5GCON	TMR5GE	T5GPOL	T5GTM	T5GSPM	T5GGO/ DONE	T5GVAL	T5GSS<1:0>		177

Legend: — = unimplemented, read as '0'. Shaded cells are not used by the Timer1/3/5 module.

* Page provides register information.

19.0 TIMER2/4/6/8/10 MODULES

There are up to five identical Timer2-type modules available. To maintain pre-existing naming conventions, the Timers are called Timer2, Timer4, Timer6, Timer8 and Timer10 (also Timer2/4/6/8/10).

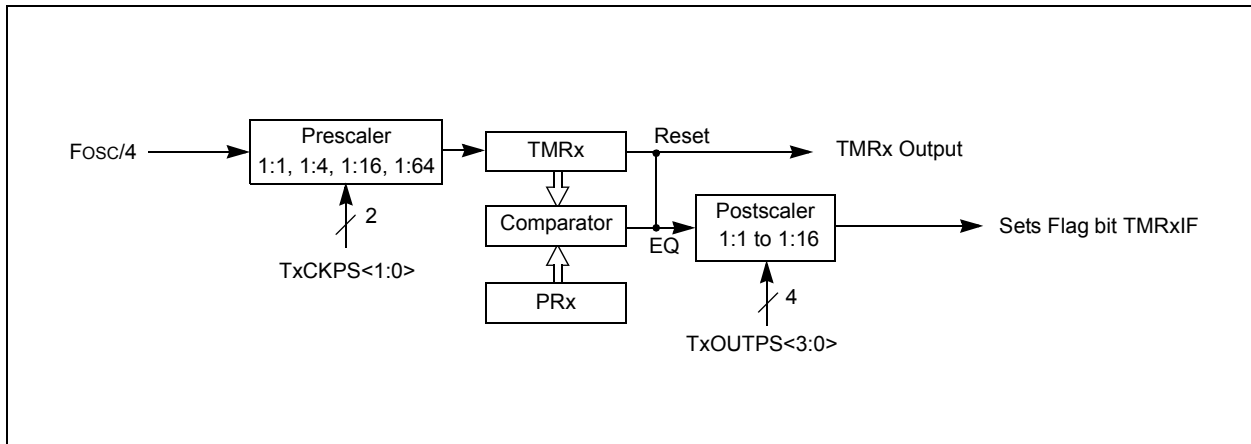
Note: The 'x' variable used in this section is used to designate Timer2, Timer4, Timer6, Timer8 or Timer10. For example, TxCON references T2CON, T4CON, T6CON, T8CON or T10CON. PRx references PR2, PR4, PR6, PR8 or PR10.

The Timer2/4/6/8/10 modules incorporate the following features:

- 8-bit Timer and Period registers (TMR2/4/6/8/10 and PR2/4/6/8/10, respectively)
- Readable and writable (both registers)
- Software programmable prescaler (1:1, 1:4, 1:16, and 1:64)
- Software programmable postscaler (1:1 to 1:16)
- Interrupt on TMR2/4/6/8/10 match with PR2/4/6/8/10, respectively
- Optional use as the shift clock for the MSSPx modules (Timer2 only)

See [Figure 19-1](#) for a block diagram of Timer2/4/6/8/10.

FIGURE 19-1: TIMER2/4/6/8/10 BLOCK DIAGRAM



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19.1 Timer2/4/6/8/10 Operation

The clock input to the Timer2/4/6/8/10 modules is the system instruction clock (Fosc/4).

TMR2/4/6/8/10 increments from 00h on each clock edge.

A 4-bit counter/prescaler on the clock input allows direct input, divide-by-4 and divide-by-16 prescale options. These options are selected by the prescaler control bits, TxCKPS<1:0> of the TxCON register. The value of TMR2/4/6/8/10 is compared to that of the Period register, PR2/4/6/8/10, 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 TMR2/4/6/8/10 to 00h on the next cycle and drives the output counter/postscaler (see [Section 19.2 “Timer2/4/6/8/10 Interrupt”](#)).

The TMR2/4/6/8/10 and PR2/4/6/8/10 registers are both directly readable and writable. The TMR2/4/6/8/10 register is cleared on any device Reset, whereas the PR2/4/6/8/10 register initializes to FFh. Both the prescaler and postscaler counters are cleared on the following events:

- a write to the TMR2/4/6/8/10 register
- a write to the TxCON register
- Power-on Reset (POR)
- Brown-out Reset (BOR)
- MCLR Reset
- Watchdog Timer (WDT) Reset
- Stack Overflow Reset
- Stack Underflow Reset
- RESET Instruction

Note: TMR2/4/6/8/10 is not cleared when TxCON is written.
--

19.2 Timer2/4/6/8/10 Interrupt

Timer2/4/6/8/10 can also generate an optional device interrupt. The Timer2/4/6/8/10 output signal (TMRx-to-PRx match) provides the input for the 4-bit counter/postscaler. This counter generates the TMRx match interrupt flag which is latched in TMRxIF of the PIRx register. The interrupt is enabled by setting the TMR2/4/6/8/10 Match Interrupt Enable bit, TMRxIE of the PIEx register.

A range of 16 postscale options (from 1:1 through 1:16 inclusive) can be selected with the postscaler control bits, TxOUTPS<3:0>, of the TxCON register.

19.3 Timer2/4/6/8/10 Output

The unscaled output of TMR2/4/6/8/10 is available primarily to the CCP 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 MSSPx modules operating in SPI mode. Additional information is provided in [Section X.X “SSP Module Overview”](#)

19.4 Timer2/4/6/8/10 Operation During Sleep

The Timer2/4/6/8/10 timers cannot be operated while the processor is in Sleep mode. The contents of the TMR2/4/6/8/10 and PR2/4/6/8/10 registers will remain unchanged while the processor is in Sleep mode.

19.5 Timer2/4/6/8/10 Control Register

REGISTER 19-1: TXCON: TIMER2/TIMER4/TIMER6/TIMER8/TIMER10 CONTROL REGISTER

U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
—	TxOUTPS<3:0>			TMRxON	TxCKPS<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 **Unimplemented:** Read as '0'
- bit 6-3 **TxOUTPS<3:0>:** Timerx Output Postscaler Select bits
 - 0000 = 1:1 Postscaler
 - 0001 = 1:2 Postscaler
 - 0010 = 1:3 Postscaler
 - 0011 = 1:4 Postscaler
 - 0100 = 1:5 Postscaler
 - 0101 = 1:6 Postscaler
 - 0110 = 1:7 Postscaler
 - 0111 = 1:8 Postscaler
 - 1000 = 1:9 Postscaler
 - 1001 = 1:10 Postscaler
 - 1010 = 1:11 Postscaler
 - 1011 = 1:12 Postscaler
 - 1100 = 1:13 Postscaler
 - 1101 = 1:14 Postscaler
 - 1110 = 1:15 Postscaler
 - 1111 = 1:16 Postscaler
- bit 2 **TMRxON:** Timerx On bit
 - 1 = Timer2/4/6 is on
 - 0 = Timer2/4/6 is off
- bit 1-0 **TxCKPS<1:0>:** Timer2-type Clock Prescale Select bits
 - 00 = Prescaler is 1
 - 01 = Prescaler is 4
 - 10 = Prescaler is 16
 - 11 = Prescaler is 64

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TABLE 19-1: SUMMARY OF REGISTERS ASSOCIATED WITH TIMER2/4/6/8/10

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
CCP1CON	—	—	DC1B<1:0>		CCP1M<3:0>				197
CCP2CON	—	—	DC2B<1:0>		CCP2M<3:0>				197
CCP3CON	—	—	DC3B<1:0>		CCP3M<3:0>				197
CCP4CON	—	—	DC4B<1:0>		CCP4M<3:0>				197
CCP5CON	—	—	DC5B<1:0>		CCP5M<3:0>				197
CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>				197
CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>				197
CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>				197
CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>				197
CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>				197
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
PR2	Timer2 Module Period Register								213*
PR4	Timer4 Module Period Register								213*
PR6	Timer6 Module Period Register								213*
PR8	Timer8 Module Period Register								213*
PR10	Timer10 Module Period Register								213*
T2CON	—	T2OUTPS<3:0>				TMR2ON	T2CKPS1	T2CKPS0	215
T4CON	—	T4OUTPS<3:0>				TMR4ON	T4CKPS1	T4CKPS0	215
T6CON	—	T6OUTPS<3:0>				TMR6ON	T6CKPS1	T6CKPS0	215
T8CON	—	T8OUTPS<3:0>				TMR8ON	T8CKPS1	T8CKPS0	215
T10CON	—	T10OUTPS<3:0>				TMR10ON	T10CKPS1	T10CKPS0	215
TMR2	Holding Register for the 8-bit TMR2 Register								213*
TMR4	Holding Register for the 8-bit TMR4 Register ⁽¹⁾								213*
TMR6	Holding Register for the 8-bit TMR6 Register ⁽¹⁾								213*
TMR8	Holding Register for the 8-bit TMR8 Register ⁽¹⁾								213*
TMR10	Holding Register for the 8-bit TMR10 Register ⁽¹⁾								213*

Legend: — = unimplemented location, read as '0'. Shaded cells are not used for Timer2/4/6/8/10 module.

* Page provides register information.

20.0 CAPTURE/COMPARE/PWM MODULES

The Capture/Compare/PWM module is a peripheral which allows the user to time and control different events, and to generate Pulse-Width Modulation (PWM) signals. In Capture mode, the peripheral allows the timing of the duration of an event. The Compare mode allows the user to trigger an external event when a predetermined amount of time has expired. The PWM mode can generate Pulse-Width Modulated signals of varying frequency and duty cycle.

This device contains ten standard Capture/Compare/PWM modules (CCP1 through CCP10).

The capture and compare functions are identical for all CCP modules.

Note 1: In devices with more than one CCP module, it is very important to pay close attention to the register names used. A number placed after the module acronym is used to distinguish between separate modules. For example, the CCP1CON and CCP2CON control the same operational aspects of two completely different CCP modules.

2: Throughout this section, generic references to a CCP module in any of its operating modes may be interpreted as being equally applicable to any CCPx module. Register names, module signals, I/O pins, and bit names may use the generic designator 'x' to indicate the use of a numeral to distinguish a particular module, when required.

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20.1 Capture Mode

The Capture mode function described in this section is available and identical for CCP modules.

Capture mode makes use of the 16-bit Timer1/3/5 resource. When an event occurs on the CCPx pin, the 16-bit CCPRxH:CCPRxL register pair captures and stores the 16-bit value of the TMRxH:TMRxL register pair, respectively. An event is defined as one of the following and is configured by the CCPxM<3:0> bits of the CCPxCON register:

- Every falling edge
- Every rising edge
- Every 4th rising edge
- Every 16th rising edge

When a capture is made, the Interrupt Request flag bit CCPxIF of the PIRx register is set. The interrupt flag must be cleared in software. If another capture occurs before the value in the CCPRxH, CCPRxL register pair is read, the old captured value is overwritten by the new captured value.

Figure 20-1 shows a simplified diagram of the Capture operation.

20.1.1 CCP PIN CONFIGURATION

In Capture mode, the CCPx pin should be configured as an input by setting the associated TRIS control bit.

Also, the CCP2x pin function can be moved to alternative pins using the APFCON register. Refer to Section 12.1 “Alternate Pin Function” for more details.

Note: If the CCPx pin is configured as an output, a write to the port can cause a capture condition.

20.1.2 TIMER1/3/5 MODE RESOURCE

Timer1/3/5 must be running in Timer mode or Synchronized Counter mode for the CCP module to use the capture feature. In Asynchronous Counter mode, the capture operation may not work.

See Section 18.0 “Timer1/3/5 Module with Gate Control” for more information on configuring Timer1/3/5.

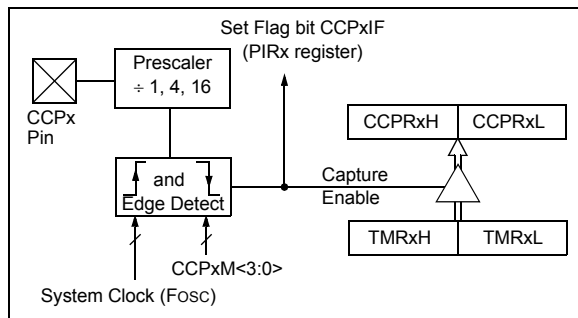
TABLE 20-1: CCPx CAPTURE TIMER1/3/5 RESOURCES

CCP	TMR1	TMR3	TMR5
CCP1	•	•	
CCP2	•	•	
CCP3	•	•	
CCP4	•	•	
CCP5	•	•	
CCP6	•		•
CCP7	•		•
CCP8	•		•
CCP9	•		•
CCP10	•		•

20.1.3 SOFTWARE INTERRUPT MODE

When the Capture mode is changed, a false capture interrupt may be generated. The user should keep the CCPxIE interrupt enable bit of the PIRx register clear to avoid false interrupts. Additionally, the user should clear the CCPxIF interrupt flag bit of the PIRx register following any change in Operating mode.

FIGURE 20-1: CAPTURE MODE OPERATION BLOCK DIAGRAM



20.1.4 CCP PRESCALER

There are four prescaler settings specified by the CCPxM<3:0> bits of the CCPxCON register. Whenever the CCP module is turned off, or the CCP module is not in Capture mode, the prescaler counter is cleared. Any Reset will clear the prescaler counter.

Switching from one capture prescaler to another does not clear the prescaler and may generate a false interrupt. To avoid this unexpected operation, turn the module off by clearing the CCPxCON register before changing the prescaler. [Equation 20-1](#) demonstrates the code to perform this function.

EXAMPLE 20-1: CHANGING BETWEEN CAPTURE PRESCALERS

```
BANKSEL CCPxCON    ;Set Bank bits to point
                   ;to CCPxCON
CLRF    CCPxCON    ;Turn CCP module off
MOVLW  NEW_CAPT_PS ;Load the W reg with
                   ;the new prescaler
                   ;move value and CCP ON
MOVWF  CCPxCON    ;Load CCPxCON with this
                   ;value
```

20.1.5 CAPTURE DURING SLEEP

Capture mode depends upon the Timer1/3/5 module for proper operation. There are two options for driving the Timer1/3/5 module in Capture mode. It can be driven by the instruction clock (FOSC/4), or by an external clock source.

When Timer1/3/5 is clocked by FOSC/4, Timer1/3/5 will not increment during Sleep. When the device wakes from Sleep, Timer1/3/5 will continue from its previous state.

Capture mode will operate during Sleep when Timer1/3/5 is clocked by an external clock source.

20.1.6 ALTERNATE PIN LOCATIONS

This module incorporates I/O pins that can be moved to other locations with the use of the alternate pin function register, APFCON. To determine which pins can be moved and what their default locations are upon a Reset, see [Section 12.1 “Alternate Pin Function”](#) for more information.

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TABLE 20-2: SUMMARY OF REGISTERS ASSOCIATED WITH CAPTURE

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	118
CCP1CON	—	—	DC1B<1:0>		CCP1M<3:0>				197
CCP2CON	—	—	DC2B<1:0>		CCP2M<3:0>				197
CCP3CON	—	—	DC3B<1:0>		CCP3M<3:0>				197
CCP4CON	—	—	DC4B<1:0>		CCP4M<3:0>				197
CCP5CON	—	—	DC5B<1:0>		CCP5M<3:0>				197
CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>				197
CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>				197
CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>				197
CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>				197
CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>				197
CCPR1L	Capture/Compare/PWM Register 1 Low Byte (LSB)								184*
CCPR2L	Capture/Compare/PWM Register 2 Low Byte (LSB)								184*
CCPR3L	Capture/Compare/PWM Register 3 Low Byte (LSB)								184*
CCPR4L	Capture/Compare/PWM Register 4 Low Byte (LSB)								184*
CCPR5L	Capture/Compare/PWM Register 5 Low Byte (LSB)								184*
CCPR6L	Capture/Compare/PWM Register 6 Low Byte (LSB)								184*
CCPR7L	Capture/Compare/PWM Register 7 Low Byte (LSB)								184*
CCPR8L	Capture/Compare/PWM Register 8 Low Byte (LSB)								184*
CCPR9L	Capture/Compare/PWM Register 9 Low Byte (LSB)								184*
CCPR10L	Capture/Compare/PWM Register 10 Low Byte (LSB)								184*
CCPR1H	Capture/Compare/PWM Register 1 High Byte (MSB)								184*
CCPR2H	Capture/Compare/PWM Register 2 High Byte (MSB)								184*
CCPR3H	Capture/Compare/PWM Register 3 High Byte (MSB)								184*
CCPR4H	Capture/Compare/PWM Register 4 High Byte (MSB)								184*
CCPR5H	Capture/Compare/PWM Register 5 High Byte (MSB)								184*
CCPR6H	Capture/Compare/PWM Register 6 High Byte (MSB)								184*
CCPR7H	Capture/Compare/PWM Register 7 High Byte (MSB)								184*
CCPR8H	Capture/Compare/PWM Register 8 High Byte (MSB)								184*
CCPR9H	Capture/Compare/PWM Register 9 High Byte (MSB)								184*
CCPR10H	Capture/Compare/PWM Register 10 High Byte (MSB)								184*
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88
T1CON	TMR1CS<1:0>		T1CKPS<1:0>		SOSCEN	T1SYNC	—	TMR1ON	176
T3CON	TMR3CS<1:0>		T3CKPS<1:0>		SOSCEN	T3SYNC	—	TMR3ON	176
T5CON	TMR5CS<1:0>		T5CKPS<1:0>		SOSCEN	T5SYNC	—	TMR5ON	176
T1GCON	TMR1GE	T1GPOL	T1GTM	T1GSPM	T1GGO/DONE	T1GVAL	T1GSS<1:0>		177
T3GCON	TMR3GE	T3GPOL	T3GTM	T3GSPM	T3GGO/DONE	T3GVAL	T3GSS<1:0>		177

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by Capture mode.
 * Page provides register information.

TABLE 20-2: SUMMARY OF REGISTERS ASSOCIATED WITH CAPTURE (CONTINUED)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
T5GCON	TMR5GE	T5GPOL	T5GTM	T5GSPM	T5GGO/DONE	T5GVAL	T5GSS<1:0>		177
TMR1L	Holding Register for the Least Significant Byte of the 16-bit TMR1 Register								172*
TMR3L	Holding Register for the Least Significant Byte of the 16-bit TMR3 Register								172*
TMR6L	Holding Register for the Least Significant Byte of the 16-bit TMR6 Register								172*
TMR1H	Holding Register for the Most Significant Byte of the 16-bit TMR1 Register								172*
TMR3H	Holding Register for the Most Significant Byte of the 16-bit TMR3 Register								172*
TMR6H	Holding Register for the Most Significant Byte of the 16-bit TMR6 Register								172*
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by Capture mode.

* Page provides register information.

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20.2 Compare Mode

The Compare mode function described in this section is available and identical for CCP modules.

Compare mode makes use of the 16-bit Timer1/3/5 resource. The 16-bit value of the CCPRxH:CCPRxL register pair is constantly compared against the 16-bit value of the TMRxH:TMRxL register pair. When a match occurs, one of the following events can occur:

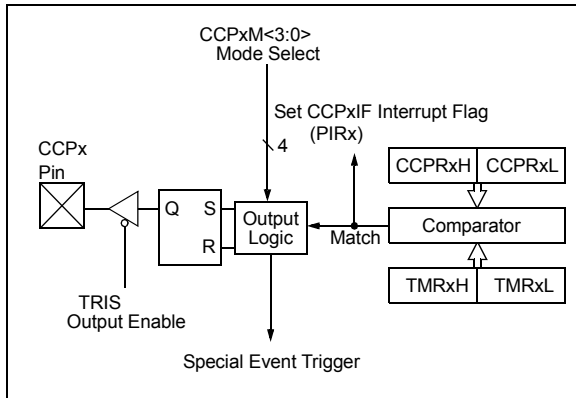
- Toggle the CCPx output
- Set the CCPx output
- Clear the CCPx output
- Generate a Special Event Trigger
- Generate a Software Interrupt

The action on the pin is based on the value of the CCPxM<3:0> control bits of the CCPxCON register. At the same time, the interrupt flag CCPxIF bit is set.

All Compare modes can generate an interrupt.

Figure 20-2 shows a simplified diagram of the Compare operation.

FIGURE 20-2: COMPARE MODE OPERATION BLOCK DIAGRAM



20.2.1 CCP PIN CONFIGURATION

The user must configure the CCPx pin as an output by clearing the associated TRIS bit.

Also, the CCPx pin function can be moved to alternative pins using the APFCON register. Refer to [Section 12.1 “Alternate Pin Function”](#) for more details.

Note: Clearing the CCPxCON register will force the CCPx compare output latch to the default low level. This is not the PORT I/O data latch.

20.2.2 TIMER1/3/5 MODE RESOURCE

In Compare mode, Timer1/3/5 must be running in either Timer mode or Synchronized Counter mode. The compare operation may not work in Asynchronous Counter mode.

TABLE 20-3: CCPx COMPARE TIMER1/3/5 RESOURCES

CCP	TMR1	TMR3	TMR5
CCP1	•	•	
CCP2	•	•	
CCP3	•	•	
CCP4	•	•	
CCP5	•	•	
CCP6	•		•
CCP7	•		•
CCP8	•		•
CCP9	•		•
CCP10	•		•

See [Section 18.0 “Timer1/3/5 Module with Gate Control”](#) for more information on configuring Timer1/3/5.

Note: Clocking Timer1/3/5 from the system clock (FOSC) should not be used in Compare mode. In order for Compare mode to recognize the trigger event on the CCPx pin, Timer1/3/5 must be clocked from the instruction clock (FOSC/4) or from an external clock source.

20.2.3 SOFTWARE INTERRUPT MODE

When Generate Software Interrupt mode is chosen (CCPxM<3:0> = 1010), the CCPx module does not assert control of the CCPx pin (see the CCPxCON register).

20.2.4 SPECIAL EVENT TRIGGER

When Special Event Trigger mode is chosen (CCPxM<3:0> = 1011), the CCPx module does the following:

- Resets Timer1/3/5
- Starts an ADC conversion if ADC is enabled

The CCPx module does not assert control of the CCPx pin in this mode.

The Special Event Trigger output of the CCP occurs immediately upon a match between the TMRxH, TMRxL register pair and the CCPRxH, CCPRxL register pair. The TMRxH, TMRxL register pair is not reset until the next rising edge of the Timer1/3/5 clock. The Special Event Trigger output starts an A/D conversion (if the A/D module is enabled). This allows the CCPRxH, CCPRxL register pair to effectively provide a 16-bit programmable period register for Timer1/3/5.

TABLE 20-4: SPECIAL EVENT TRIGGER

Device	CCPx
PIC16(L)F1526/27	CCP10

Refer to [Section 16.2.5 “Special Event Trigger”](#) for more information.

Note 1: The Special Event Trigger from the CCP module does not set interrupt flag bit TMRxIF of the PIRx register.

2: Removing the match condition by changing the contents of the CCPRxH and CCPRxL register pair, between the clock edge that generates the Special Event Trigger and the clock edge that generates the Timer1/3/5 Reset, will preclude the Reset from occurring.

20.2.5 COMPARE DURING SLEEP

The Compare mode is dependent upon the system clock (Fosc) for proper operation. Since Fosc is shut down during Sleep mode, the Compare mode will not function properly during Sleep.

20.2.6 ALTERNATE PIN LOCATIONS

This module incorporates I/O pins that can be moved to other locations with the use of the alternate pin function register, APFCON. To determine which pins can be moved and what their default locations are upon a Reset, see [Section 12.1 “Alternate Pin Function”](#) for more information.

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TABLE 20-5: SUMMARY OF REGISTERS ASSOCIATED WITH COMPARE

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	118
CCP1CON	—	—	DC1B<1:0>		CCP1M<3:0>				197
CCP2CON	—	—	DC2B<1:0>		CCP2M<3:0>				197
CCP3CON	—	—	DC3B<1:0>		CCP3M<3:0>				197
CCP4CON	—	—	DC4B<1:0>		CCP4M<3:0>				197
CCP5CON	—	—	DC5B<1:0>		CCP5M<3:0>				197
CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>				197
CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>				197
CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>				197
CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>				197
CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>				197
CCPR1L	Capture/Compare/PWM Register 1 Low Byte (LSB)								184*
CCPR2L	Capture/Compare/PWM Register 2 Low Byte (LSB)								184*
CCPR3L	Capture/Compare/PWM Register 3 Low Byte (LSB)								184*
CCPR4L	Capture/Compare/PWM Register 4 Low Byte (LSB)								184*
CCPR5L	Capture/Compare/PWM Register 5 Low Byte (LSB)								184*
CCPR6L	Capture/Compare/PWM Register 6 Low Byte (LSB)								184*
CCPR7L	Capture/Compare/PWM Register 7 Low Byte (LSB)								184*
CCPR8L	Capture/Compare/PWM Register 8 Low Byte (LSB)								184*
CCPR9L	Capture/Compare/PWM Register 9 Low Byte (LSB)								184*
CCPR10L	Capture/Compare/PWM Register 10 Low Byte (LSB)								184*
CCPR1H	Capture/Compare/PWM Register 1 High Byte (MSB)								184*
CCPR2H	Capture/Compare/PWM Register 2 High Byte (MSB)								184*
CCPR3H	Capture/Compare/PWM Register 3 High Byte (MSB)								184*
CCPR4H	Capture/Compare/PWM Register 4 High Byte (MSB)								184*
CCPR5H	Capture/Compare/PWM Register 5 High Byte (MSB)								184*
CCPR6H	Capture/Compare/PWM Register 6 High Byte (MSB)								184*
CCPR7H	Capture/Compare/PWM Register 7 High Byte (MSB)								184*
CCPR8H	Capture/Compare/PWM Register 8 High Byte (MSB)								184*
CCPR9H	Capture/Compare/PWM Register 9 High Byte (MSB)								184*
CCPR10H	Capture/Compare/PWM Register 10 High Byte (MSB)								184*
INTCON	GIE	PEIE	TMR0IE	INTE	IOCF	TMR0IF	INTF	IOCF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88
T1CON	TMR1CS<1:0>		T1CKPS<1:0>		SOSCEN	T1SYNC	—	TMR1ON	176
T3CON	TMR3CS<1:0>		T3CKPS<1:0>		SOSCEN	T3SYNC	—	TMR3ON	176
T5CON	TMR5CS<1:0>		T5CKPS<1:0>		SOSCEN	T5SYNC	—	TMR5ON	176
T1GCON	TMR1GE	T1GPOL	T1GTM	T1GSPM	T1GGO/DONE	T1GVAL	T1GSS<1:0>		177
T3GCON	TMR3GE	T3GPOL	T3GTM	T3GSPM	T3GGO/DONE	T3GVAL	T3GSS<1:0>		177

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by Compare mode.
* Page provides register information.

TABLE 20-5: SUMMARY OF REGISTERS ASSOCIATED WITH COMPARE (CONTINUED)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
T5GCON	TMR5GE	T5GPOL	T5GTM	T5GSPM	T5GGO/DONE	T5GVAL	T5GSS<1:0>		177
TMR1L	Holding Register for the Least Significant Byte of the 16-bit TMR1 Register								172*
TMR3L	Holding Register for the Least Significant Byte of the 16-bit TMR3 Register								172*
TMR6L	Holding Register for the Least Significant Byte of the 16-bit TMR6 Register								172*
TMR1H	Holding Register for the Most Significant Byte of the 16-bit TMR1 Register								172*
TMR3H	Holding Register for the Most Significant Byte of the 16-bit TMR3 Register								172*
TMR6H	Holding Register for the Most Significant Byte of the 16-bit TMR6 Register								172*
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by Compare mode.

* Page provides register information.

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20.3 PWM Overview

Pulse-Width Modulation (PWM) is a scheme that provides power to a load by switching quickly between fully on and fully off states. The PWM signal resembles a square wave where the high portion of the signal is considered the on state and the low portion of the signal is considered the off state. The high portion, also known as the pulse width, can vary in time and is defined in steps. A larger number of steps applied, which lengthens the pulse width, also supplies more power to the load. Lowering the number of steps applied, which shortens the pulse width, supplies less power. The PWM period is defined as the duration of one complete cycle or the total amount of on and off time combined.

PWM resolution defines the maximum number of steps that can be present in a single PWM period. A higher resolution allows for more precise control of the pulse width time and in turn the power that is applied to the load.

The term duty cycle describes the proportion of the on time to the off time and is expressed in percentages, where 0% is fully off and 100% is fully on. A lower duty cycle corresponds to less power applied and a higher duty cycle corresponds to more power applied.

Figure 20-3 shows a typical waveform of the PWM signal.

20.3.1 STANDARD PWM OPERATION

The standard PWM function described in this section is available and identical for CCP modules.

The standard PWM mode generates a Pulse-Width modulation (PWM) signal on the CCPx pin with up to 10 bits of resolution. The period, duty cycle, and resolution are controlled by the following registers:

- PRx registers
- TxCON registers
- CCPxL registers
- CCPxCON registers

Figure 20-4 shows a simplified block diagram of PWM operation.

Note 1: The corresponding TRIS bit must be cleared to enable the PWM output on the CCPx pin.

2: Clearing the CCPxCON register will relinquish control of the CCPx pin.

FIGURE 20-3: CCP PWM OUTPUT SIGNAL

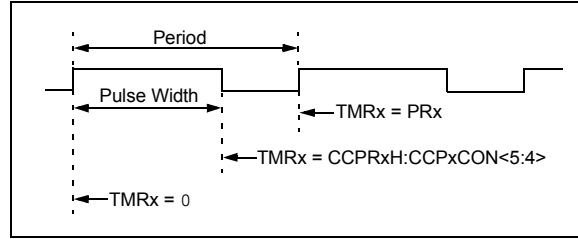


FIGURE 20-4: SIMPLIFIED PWM BLOCK DIAGRAM

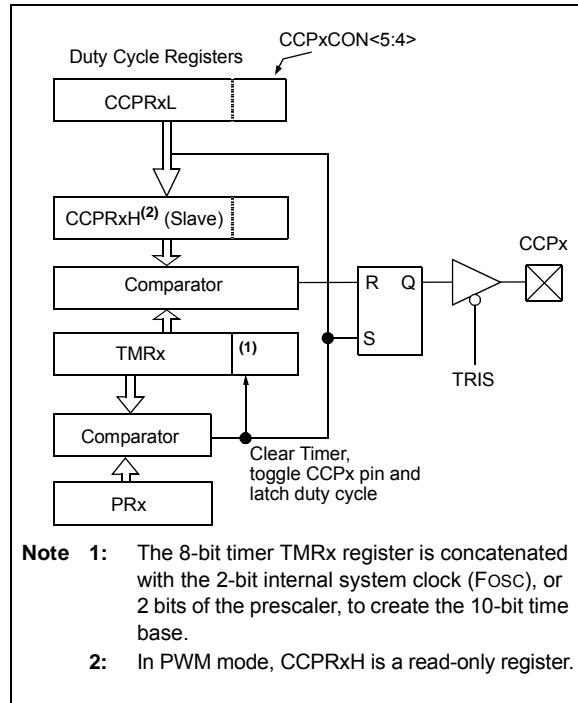


TABLE 20-6: CCPx PWM TIMER2/4/6/8/10 RESOURCES

CCP	TMR2	TMR4	TMR6	TMR8	TMR10
CCP1	•	•	•		
CCP2	•	•	•		
CCP3	•	•	•		
CCP4	•	•	•		
CCP5	•		•	•	
CCP6	•		•	•	
CCP7	•		•	•	
CCP8	•			•	•
CCP9	•			•	•
CCP10	•			•	•

20.3.2 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 PRx 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 Timer2/4/6/8/10:
 - Select the Timer2/4/6/8/10 resource to be used for PWM generation by setting the CxTSEL<1:0> bits in the CCPTMRSx register.
 - Clear the TMRxIF interrupt flag bit of the PIRx register. See Note below.
 - Configure the TxCKPS bits of the TxCON register with the Timer prescale value.
 - Enable the Timer by setting the TMRxON bit of the TxCON register.
6. Enable PWM output pin:
 - Wait until the Timer overflows and the TMRxIF bit of the PIRx 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.

20.3.3 TIMER2/4/6/8/10 TIMER RESOURCE

The PWM standard mode makes use of one of the 8-bit Timer2/4/6/8/10 timer resources to specify the PWM period.

Configuring the CxTSEL<1:0> bits in the CCPTMRSx register selects which Timer2/4/6/8/10 timer is used.

See [Table 20-6](#) for CCPx PWM Timer2/4/6/8/10 resources.

20.3.4 PWM PERIOD

The PWM period is specified by the PRx register of Timer2/4/6/8/10. The PWM period can be calculated using the formula of [Equation 20-1](#).

EQUATION 20-1: PWM PERIOD

$$PWM\ Period = [(PRx) + 1] \cdot 4 \cdot TOSC \cdot (TMRx\ Prescale\ Value)$$

Note 1: TOSC = 1/FOSC

When TMRx is equal to PRx, the following three events occur on the next increment cycle:

- TMRx 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 "Timer2/4/6/8/10 Operation"](#)) is not used in the determination of the PWM frequency.

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20.3.5 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 PRx and TMRx registers occurs). While using the PWM, the CCPRxH register is read-only.

Equation 20-2 is used to calculate the PWM pulse width.

Equation 20-3 is used to calculate the PWM duty cycle ratio.

EQUATION 20-2: PULSE WIDTH

$$\text{Pulse Width} = (\text{CCPRxL:CCPxCON}<5:4>) \cdot T_{\text{OSC}} \cdot (\text{TMRx Prescale Value})$$

EQUATION 20-3: DUTY CYCLE RATIO

$$\text{Duty Cycle Ratio} = \frac{(\text{CCPRxL:CCPxCON}<5:4>)}{4(\text{PRx} + 1)}$$

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 TMRx register is concatenated with either the 2-bit internal system clock (Fosc), or 2 bits of the prescaler, to create the 10-bit time base. The system clock is used if the Timer2/4/6/8/10 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 20-4).

20.3.6 PWM RESOLUTION

The resolution determines the number of available duty cycles for a given period. For example, a 10-bit resolution will result in 1024 discrete duty cycles, whereas an 8-bit resolution will result in 256 discrete duty cycles.

The maximum PWM resolution is 10 bits when PRx is 255. The resolution is a function of the PRx register value as shown by Equation 20-4.

EQUATION 20-4: PWM RESOLUTION

$$\text{Resolution} = \frac{\log[4(\text{PRx} + 1)]}{\log(2)} \text{ bits}$$

Note: If the pulse width value is greater than the period the assigned PWM pin(s) will remain unchanged.

TABLE 20-7: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (Fosc = 20 MHz)

PWM Frequency	1.22 kHz	4.88 kHz	19.53 kHz	78.12 kHz	156.3 kHz	208.3 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PRx Value	0xFF	0xFF	0xFF	0x3F	0x1F	0x17
Maximum Resolution (bits)	10	10	10	8	7	6.6

TABLE 20-8: EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (Fosc = 8 MHz)

PWM Frequency	1.22 kHz	4.90 kHz	19.61 kHz	76.92 kHz	153.85 kHz	200.0 kHz
Timer Prescale (1, 4, 16)	16	4	1	1	1	1
PRx Value	0x65	0x65	0x65	0x19	0x0C	0x09
Maximum Resolution (bits)	8	8	8	6	5	5

20.3.7 OPERATION IN SLEEP MODE

In Sleep mode, the TMRx register will not increment and the state of the module will not change. If the CCPx pin is driving a value, it will continue to drive that value. When the device wakes up, TMRx will continue from its previous state.

20.3.8 CHANGES IN SYSTEM CLOCK FREQUENCY

The PWM frequency is derived from the system clock frequency. Any changes in the system clock frequency will result in changes to the PWM frequency. See [Section 5.0 “Oscillator Module \(With Fail-Safe Clock Monitor\)”](#) for additional details.

20.3.9 EFFECTS OF RESET

Any Reset will force all ports to Input mode and the CCP registers to their Reset states.

20.3.10 ALTERNATE PIN LOCATIONS

This module incorporates I/O pins that can be moved to other locations with the use of the alternate pin function register, APFCON. To determine which pins can be moved and what their default locations are upon a Reset, see [Section 12.1 “Alternate Pin Function”](#) for more information.

TABLE 20-9: SUMMARY OF REGISTERS ASSOCIATED WITH STANDARD PWM

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
APFCON	—	—	—	—	—	—	T3CKISEL	CCP2SEL	118
CCP1CON	—	—	DC1B<1:0>		CCP1M<3:0>				197
CCP2CON	—	—	DC2B<1:0>		CCP2M<3:0>				197
CCP3CON	—	—	DC3B<1:0>		CCP3M<3:0>				197
CCP4CON	—	—	DC4B<1:0>		CCP4M<3:0>				197
CCP5CON	—	—	DC5B<1:0>		CCP5M<3:0>				197
CCP6CON	—	—	DC6B<1:0>		CCP6M<3:0>				197
CCP7CON	—	—	DC7B<1:0>		CCP7M<3:0>				197
CCP8CON	—	—	DC8B<1:0>		CCP8M<3:0>				197
CCP9CON	—	—	DC9B<1:0>		CCP9M<3:0>				197
CCP10CON	—	—	DC10B<1:0>		CCP10M<3:0>				197
INTCON	GIE	PEIE	TMR0IE	INTE	IOCFIE	TMR0IF	INTF	IOCFIF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	82
PIE3	CCP6IE	CCP5IE	CCP4IE	CCP3IE	TMR6IE	TMR5IE	TMR4IE	TMR3IE	83
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR3	CCP6IF	CCP5IF	CCP4IF	CCP3IF	TMR6IF	TMR5IF	TMR4IF	TMR3IF	87
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88
PR2	Timer2 Period Register								179*
PR4	Timer4 Period Register								179*
PR6	Timer6 Period Register								179*
PR8	Timer8 Period Register								179*
PR10	Timer10 Period Register								179*
T2CON	—	T2OUTPS<3:0>			TMR2ON	T2CKPS<:0>1			176
T4CON	—	T4OUTPS<3:0>			TMR4ON	T4CKPS<:0>1			176
T6CON	—	T6OUTPS<3:0>			TMR6ON	T6CKPS<:0>1			176

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by the PWM.

* Page provides register information.

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TABLE 20-10: SUMMARY OF REGISTERS ASSOCIATED WITH STANDARD PWM (CONTINUED)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
T8CON	—	T8OUTPS<3:0>				TMR8ON	T8CKPS<:0>1		176
T10CON	—	T10OUTPS<3:0>				TMR10ON	T10CKPS<:0>1		176
TMR2	Timer2 Module Register								179*
TMR4	Timer4 Module Register								179*
TMR6	Timer6 Module Register								179*
TMR8	Timer8 Module Register								179*
TMR10	Timer10 Module Register								179*
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	120

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by the PWM.

* Page provides register information.

20.4 CCP Control Registers

REGISTER 20-1: CCPxCON: CCPx CONTROL REGISTER

U-0	U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
—	—	DCxB<1:0>		CCPxM<3:0>			
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 Reset

'1' = Bit is set

'0' = Bit is cleared

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

bit 5-4 **DCxB<1:0>:** PWM Duty Cycle Least Significant bits

Capture mode:

Unused

Compare mode:

Unused

PWM mode:

These bits are the two LSBs of the PWM duty cycle. The eight MSBs are found in CCPRxL.

bit 3-0 **CCPxM<3:0>:** CCPx Mode Select bits

0000 = Capture/Compare/PWM off (resets CCPx 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: set output on compare match (set CCPxIF)

1001 = Compare mode: clear output on compare match (set CCPxIF)

1010 = Compare mode: generate software interrupt only

1011 = Compare mode: Special Event Trigger (sets CCP10IF bit (CCP10), starts A/D conversion if A/D module is enabled)⁽¹⁾

11xx = PWM mode

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REGISTER 20-2: CCPTMRS0: CCP TIMER SELECTION CONTROL REGISTER 0

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
C4TSEL<1:0>		C3TSEL<1:0>		C2TSEL<1:0>		C1TSEL<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 **C4TSEL<1:0>**: CCP4 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP4 is based off Timer1 in Capture/Compare mode
 x1 = CCP4 is based off Timer3 in Capture/Compare mode
When in PWM mode:
 00 = CCP4 is based off Timer2 in PWM mode
 01 = CCP4 is based off Timer4 in PWM mode
 10 = CCP4 is based off Timer6 in PWM mode
 11 = Reserved
- bit 5-4 **C3TSEL<1:0>**: CCP3 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP3 is based off Timer1 in Capture/Compare mode
 x1 = CCP3 is based off Timer3 in Capture/Compare mode
When in PWM mode:
 00 = CCP3 is based off Timer2 in PWM mode
 01 = CCP3 is based off Timer4 in PWM mode
 10 = CCP3 is based off Timer6 in PWM mode
 11 = Reserved
- bit 3-2 **C2TSEL<1:0>**: CCP2 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP2 is based off Timer1 in Capture/Compare mode
 x1 = CCP2 is based off Timer3 in Capture/Compare mode
When in PWM mode:
 00 = CCP2 is based off Timer2 in PWM mode
 01 = CCP2 is based off Timer4 in PWM mode
 10 = CCP2 is based off Timer6 in PWM mode
 11 = Reserved
- bit 1-0 **C1TSEL<1:0>**: CCP1 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP1 is based off Timer1 in Capture/Compare mode
 x1 = CCP1 is based off Timer3 in Capture/Compare mode
When in PWM mode:
 00 = CCP1 is based off Timer2 in PWM mode
 01 = CCP1 is based off Timer4 in PWM mode
 10 = CCP1 is based off Timer6 in PWM mode
 11 = Reserved

REGISTER 20-3: CCPTMRS1: CCP TIMER SELECTION CONTROL REGISTER 1

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
C8TSEL<1:0>		C7TSEL<1:0>		C6TSEL<1:0>		C5TSEL<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 **C8TSEL<1:0>**: CCP8 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP8 is based off Timer1 in Capture/Compare mode
 x1 = CCP8 is based off Timer5 in Capture/Compare mode
When in PWM mode:
 00 = CCP8 is based off Timer2 in PWM mode
 01 = CCP8 is based off Timer8 in PWM mode
 10 = CCP8 is based off Timer10 in PWM mode
 11 = Reserved
- bit 5-4 **C7TSEL<1:0>**: CCP7 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP7 is based off Timer1 in Capture/Compare mode
 x1 = CCP7 is based off Timer5 in Capture/Compare mode
When in PWM mode:
 00 = CCP7 is based off Timer2 in PWM mode
 01 = CCP7 is based off Timer6 in PWM mode
 10 = CCP7 is based off Timer8 in PWM mode
 11 = Reserved
- bit 3-2 **C6TSEL<1:0>**: CCP6 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP6 is based off Timer1 in Capture/Compare mode
 x1 = CCP6 is based off Timer5 in Capture/Compare mode
When in PWM mode:
 00 = CCP6 is based off Timer2 in PWM mode
 01 = CCP6 is based off Timer6 in PWM mode
 10 = CCP6 is based off Timer8 in PWM mode
 11 = Reserved
- bit 1-0 **C5TSEL<1:0>**: CCP5 Timer Selection bits
When in Capture/Compare mode:
 x0 = CCP5 is based off Timer1 in Capture/Compare mode
 x1 = CCP5 is based off Timer5 in Capture/Compare mode
When in PWM mode:
 00 = CCP5 is based off Timer2 in PWM mode
 01 = CCP5 is based off Timer6 in PWM mode
 10 = CCP5 is based off Timer8 in PWM mode
 11 = Reserved

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REGISTER 20-4: CCPTMRS2: CCP TIMER SELECTION CONTROL REGISTER 2

U-0	U-0	U-0	U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
—	—	—	—	C10TSEL<1:0>		C9TSEL<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 7-4 **Unimplemented:** Read as '0'

bit 3-2 **C10TSEL<1:0>:** CCP10 Timer Selection bits

When in Capture/Compare mode:

x0 = CCP10 is based off Timer1 in Capture/Compare mode

x1 = CCP10 is based off Timer5 in Capture/Compare mode

When in PWM mode:

00 = CCP10 is based off Timer2 in PWM mode

01 = CCP10 is based off Timer8 in PWM mode

10 = CCP10 is based off Timer10 in PWM mode

11 = Reserved

bit 1-0 **C9TSEL<1:0>:** CCP9 Timer Selection bits

When in Capture/Compare mode:

x0 = CCP9 is based off Timer1 in Capture/Compare mode

x1 = CCP9 is based off Timer5 in Capture/Compare mode

When in PWM mode:

00 = CCP9 is based off Timer2 in PWM mode

01 = CCP9 is based off Timer8 in PWM mode

10 = CCP9 is based off Timer10 in PWM mode

11 = Reserved

21.0 MASTER SYNCHRONOUS SERIAL PORT (MSSP1 AND MSSP2) MODULE

21.1 Master SSPx (MSSPx) Module Overview

The Master Synchronous Serial Port (MSSPx) 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 MSSPx module can operate in one of two modes:

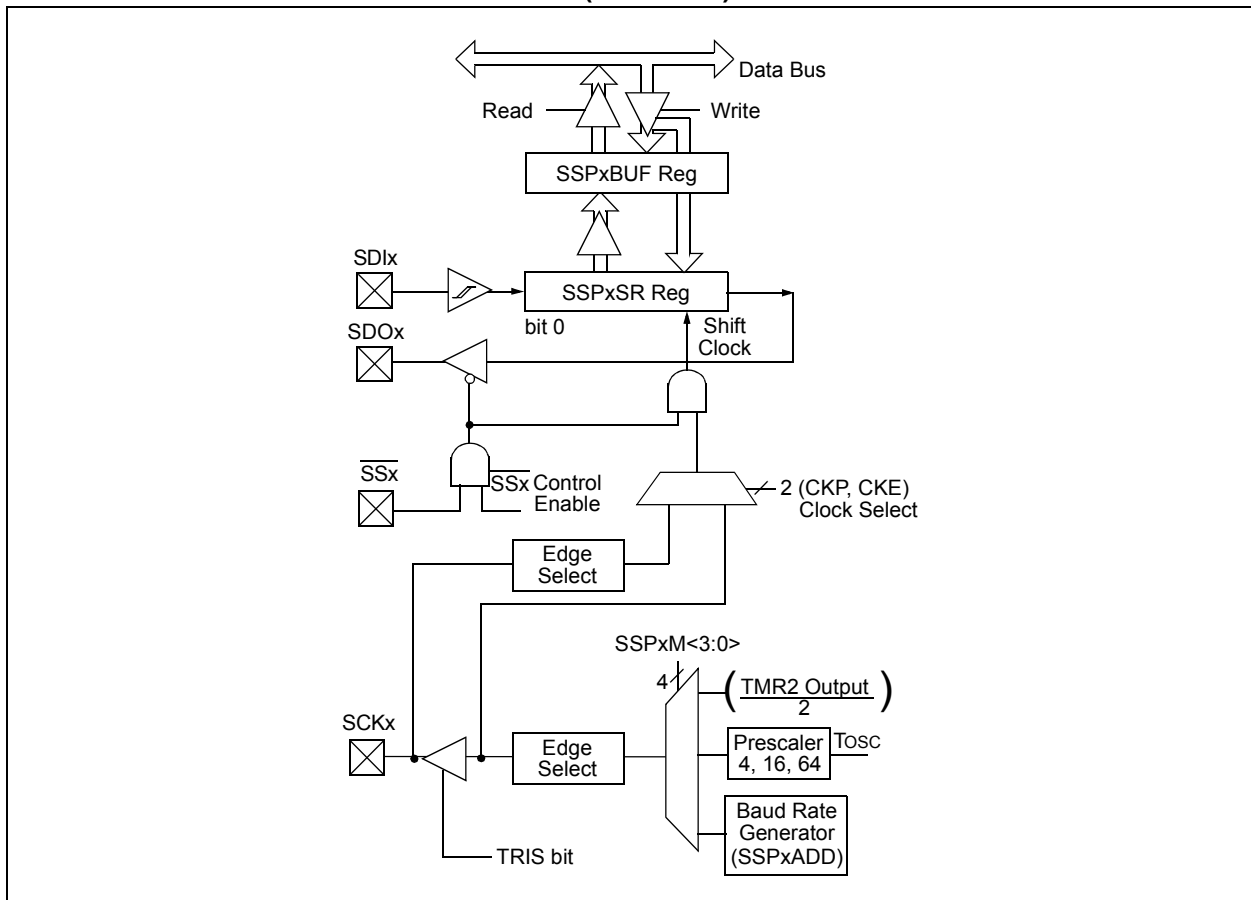
- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit (I²C™)

The SPI interface supports the following modes and features:

- Master mode
- Slave mode
- Clock Parity
- Slave Select Synchronization (Slave mode only)
- Daisy-chain connection of slave devices

Figure 21-1 is a block diagram of the SPI interface module.

FIGURE 21-1: MSSPX BLOCK DIAGRAM (SPI MODE)



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The I²C interface supports the following modes and features:

- Master mode
- Slave mode
- Byte NACKing (Slave mode)
- Limited Multi-master support
- 7-bit and 10-bit addressing
- Start and Stop interrupts
- Interrupt masking
- Clock stretching
- Bus collision detection
- General call address matching
- Address masking
- Address Hold and Data Hold modes
- Selectable SDAx hold times

Figure 21-2 is a block diagram of the I²C Interface module in Master mode. Figure 21-3 is a diagram of the I²C interface module in Slave mode.

The PIC16F1527 has two MSSP modules, MSSP1 and MSSP2, each module operating independently from the other.

Note 1: In devices with more than one MSSP module, it is very important to pay close attention to SSPxCONx register names. SSP1CON1 and SSP1CON2 registers control different operational aspects of the same module, while SSP1CON1 and SSP2CON1 control the same features for two different modules.

2: Throughout this section, generic references to an MSSP module in any of its operating modes may be interpreted as being equally applicable to MSSP1 or MSSP2. Register names, module I/O signals, and bit names may use the generic designator 'x' to indicate the use of a numeral to distinguish a particular module when required.

FIGURE 21-2: MSSPX BLOCK DIAGRAM (I²C™ MASTER MODE)

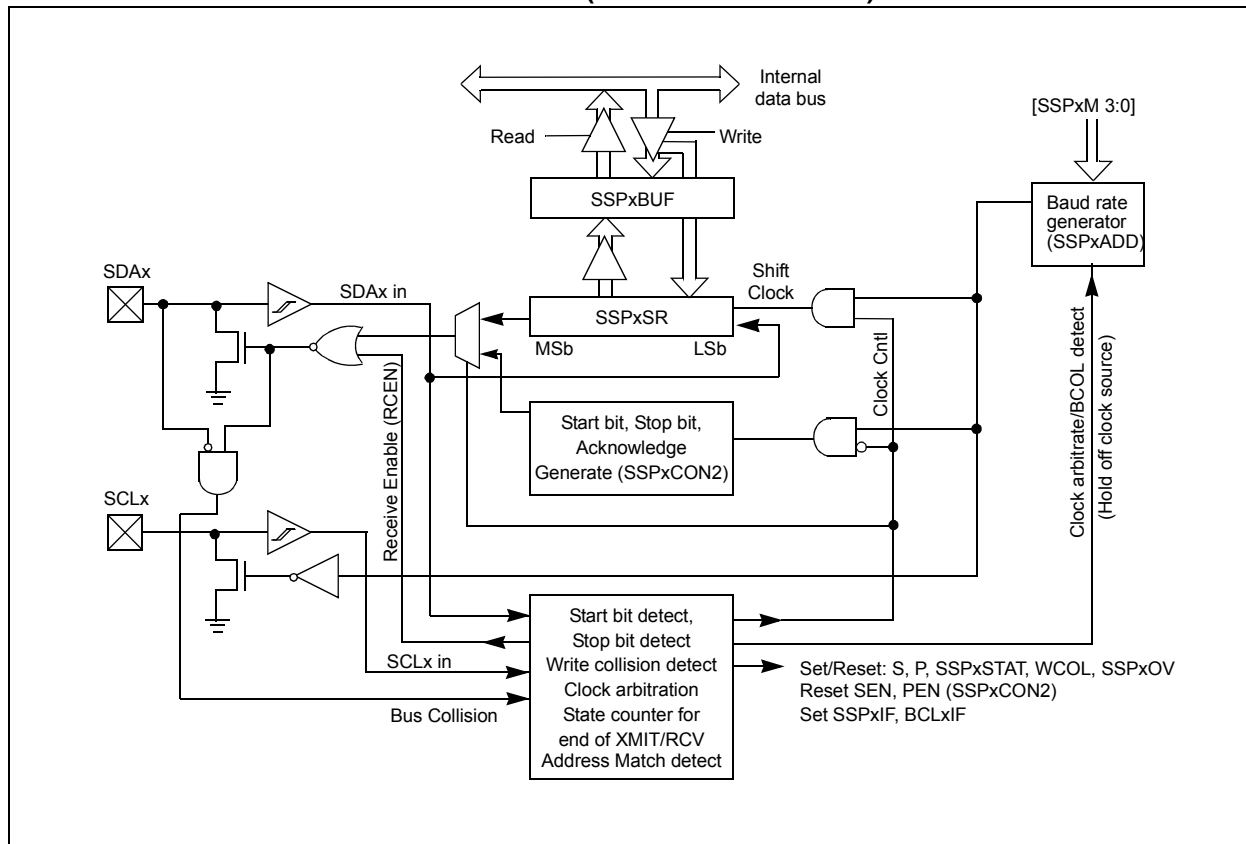
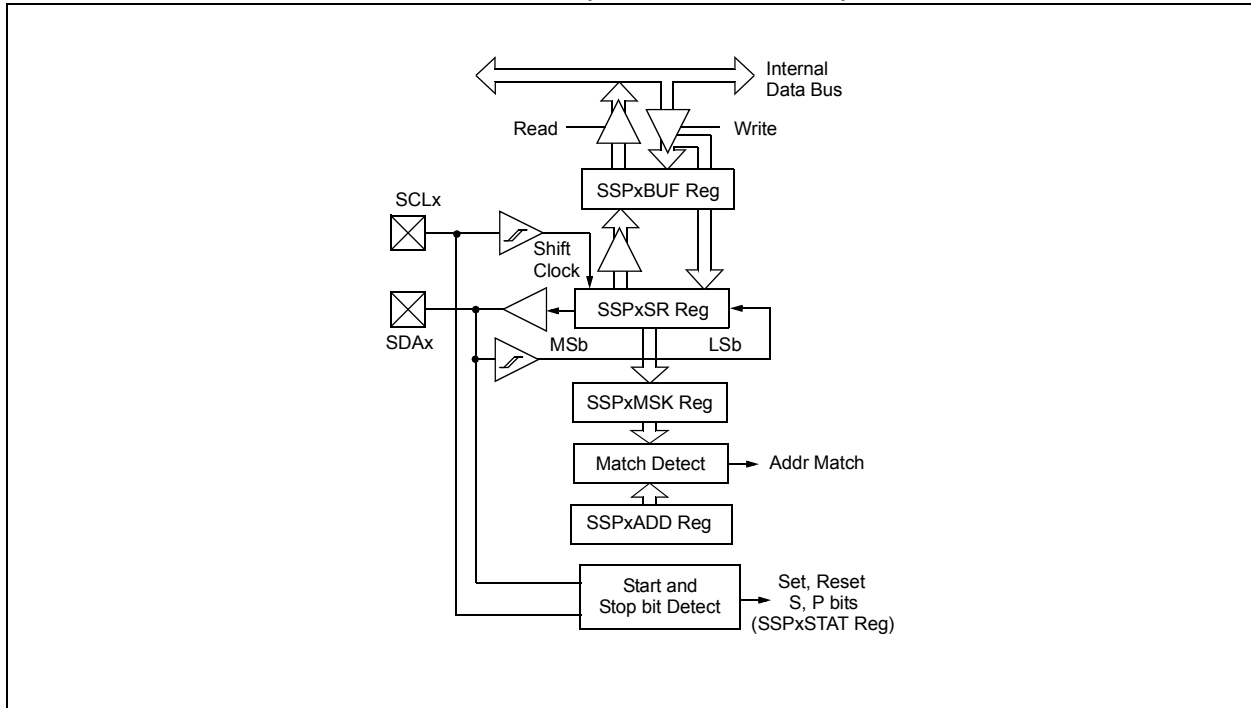


FIGURE 21-3: MSSPX BLOCK DIAGRAM (I²C™ SLAVE MODE)



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21.2 SPI Mode Overview

The Serial Peripheral Interface (SPI) bus is a synchronous serial data communication bus that operates in Full-Duplex mode. Devices communicate in a master/slave environment where the master device initiates the communication. A slave device is controlled through a Chip Select known as Slave Select.

The SPI bus specifies four signal connections:

- Serial Clock (SCKx)
- Serial Data Out (SDOx)
- Serial Data In (SDIx)
- Slave Select (\overline{SSx})

Figure 21-1 shows the block diagram of the MSSPx module when operating in SPI mode.

The SPI bus operates with a single master device and one or more slave devices. When multiple slave devices are used, an independent Slave Select connection is required from the master device to each slave device.

Figure 21-4 shows a typical connection between a master device and multiple slave devices.

The master selects only one slave at a time. Most slave devices have tri-state outputs so their output signal appears disconnected from the bus when they are not selected.

Transmissions involve two shift registers, eight bits in size, one in the master and one in the slave. With either the master or the slave device, data is always shifted out one bit at a time, with the Most Significant bit (MSb) shifted out first. At the same time, a new Least Significant bit (LSb) is shifted into the same register.

Figure 21-5 shows a typical connection between two processors configured as master and slave devices.

Data is shifted out of both shift registers on the programmed clock edge and latched on the opposite edge of the clock.

The master device transmits information out on its SDOx output pin which is connected to, and received by, the slave's SDIx input pin. The slave device transmits information out on its SDOx output pin, which is connected to, and received by, the master's SDIx input pin.

To begin communication, the master device first sends out the clock signal. Both the master and the slave devices should be configured for the same clock polarity.

The master device starts a transmission by sending out the MSb from its shift register. The slave device reads this bit from that same line and saves it into the LSb position of its shift register.

During each SPI clock cycle, a full-duplex data transmission occurs. This means that while the master device is sending out the MSb from its shift register (on its SDOx pin) and the slave device is reading this bit and saving it as the LSb of its shift register, that the slave device is also sending out the MSb from its shift register (on its SDOx pin) and the master device is reading this bit and saving it as the LSb of its shift register.

After 8 bits have been shifted out, the master and slave have exchanged register values.

If there is more data to exchange, the shift registers are loaded with new data and the process repeats itself.

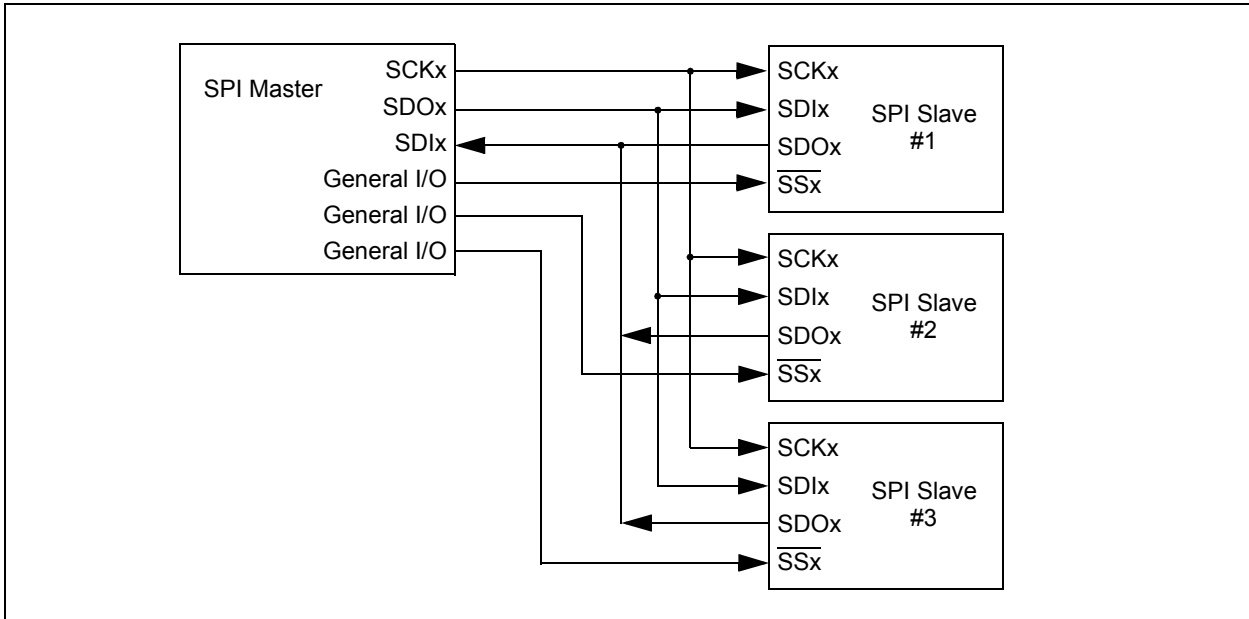
Whether the data is meaningful or not (dummy data), depends on the application software. This leads to three scenarios for data transmission:

- Master sends useful data and slave sends dummy data.
- Master sends useful data and slave sends useful data.
- Master sends dummy data and slave sends useful data.

Transmissions may involve any number of clock cycles. When there is no more data to be transmitted, the master stops sending the clock signal and it deselects the slave.

Every slave device connected to the bus that has not been selected through its slave select line must disregard the clock and transmission signals and must not transmit out any data of its own.

FIGURE 21-4: SPI MASTER AND MULTIPLE SLAVE CONNECTION



21.2.1 SPI MODE REGISTERS

The MSSPx module has five registers for SPI mode operation. These are:

- MSSPx STATUS register (SSPxSTAT)
- MSSPx Control Register 1 (SSPxCON1)
- MSSPx Control Register 3 (SSPxCON3)
- MSSPx Data Buffer register (SSPxBUF)
- MSSPx Address register (SSPxADD)
- MSSPx Shift register (SSPxSR)
(Not directly accessible)

SSPxCON1 and SSPxSTAT are the control and STATUS registers in SPI mode operation. The SSPxCON1 register is readable and writable. The lower 6 bits of the SSPxSTAT are read-only. The upper two bits of the SSPxSTAT are read/write.

In one SPI Master mode, SSPxADD can be loaded with a value used in the Baud Rate Generator. More information on the Baud Rate Generator is available in [Section 21.7 “Baud Rate Generator”](#).

SSPxSR is the shift register used for shifting data in and out. SSPxBUF provides indirect access to the SSPxSR register. SSPxBUF is the buffer register to which data bytes are written, and from which data bytes are read.

In receive operations, SSPxSR and SSPxBUF together create a buffered receiver. When SSPxSR receives a complete byte, it is transferred to SSPxBUF and the SSPxIF interrupt is set.

During transmission, the SSPxBUF is not buffered. A write to SSPxBUF will write to both SSPxBUF and SSPxSR.

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21.2.2 SPI MODE OPERATION

When initializing the SPI, several options need to be specified. This is done by programming the appropriate control bits (SSPxCON1<5:0> and SSPxSTAT<7:6>). These control bits allow the following to be specified:

- Master mode (SCKx is the clock output)
- Slave mode (SCKx is the clock input)
- Clock Polarity (Idle state of SCKx)
- Data Input Sample Phase (middle or end of data output time)
- Clock Edge (output data on rising/falling edge of SCKx)
- Clock Rate (Master mode only)
- Slave Select mode (Slave mode only)

To enable the serial port, SSPx Enable bit, SSPxEN of the SSPxCON1 register, must be set. To reset or reconfigure SPI mode, clear the SSPxEN bit, re-initialize the SSPxCONx registers and then set the SSPxEN bit. This configures the SDIx, SDOx, SCKx and \overline{SSx} 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:

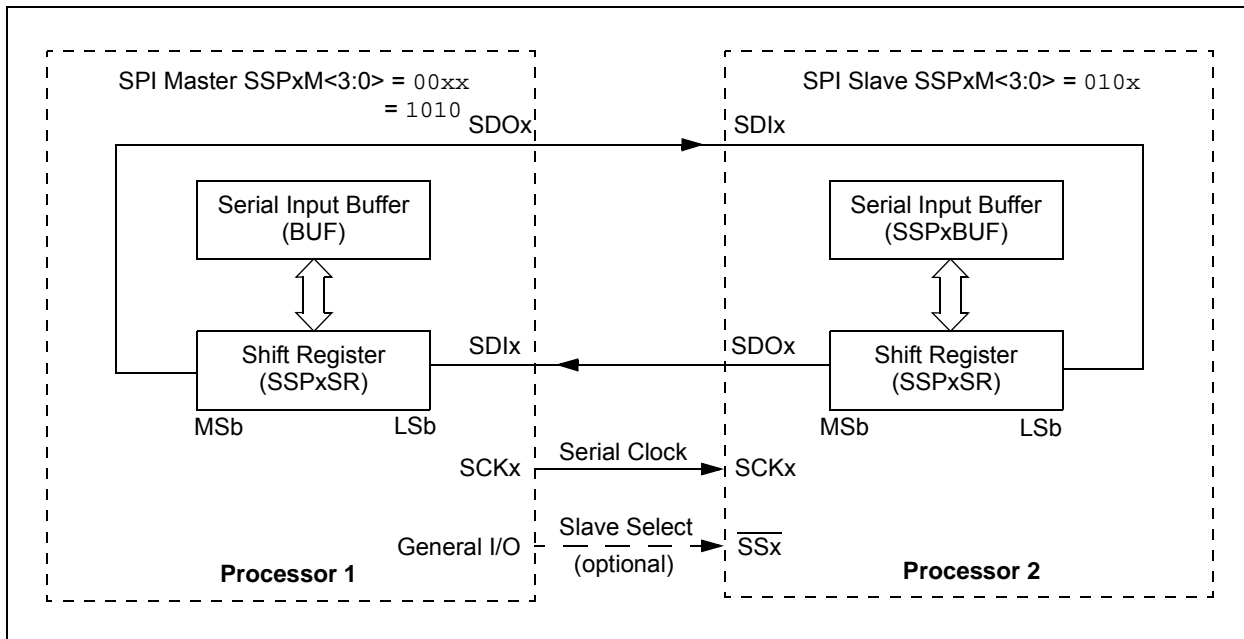
- SDIx must have corresponding TRIS bit set
- SDOx must have corresponding TRIS bit cleared
- SCKx (Master mode) must have corresponding TRIS bit cleared
- SCKx (Slave mode) must have corresponding TRIS bit set
- \overline{SSx} must have corresponding TRIS bit set

Any serial port function that is not desired may be overridden by programming the corresponding data direction (TRIS) register to the opposite value.

The MSSPx consists of a transmit/receive shift register (SSPxSR) and a buffer register (SSPxBUF). The SSPxSR shifts the data in and out of the device, MSb first. The SSPxBUF holds the data that was written to the SSPxSR until the received data is ready. Once the 8 bits of data have been received, that byte is moved to the SSPxBUF register. Then, the Buffer Full Detect bit, BF of the SSPxSTAT register, and the interrupt flag bit, SSPxIF, are set. This double-buffering of the received data (SSPxBUF) allows the next byte to start reception before reading the data that was just received. Any write to the SSPxBUF register during transmission/reception of data will be ignored and the write collision detect bit WCOL of the SSPxCON1 register, will be set. User software must clear the WCOL bit to allow the following write(s) to the SSPxBUF register to complete successfully.

When the application software is expecting to receive valid data, the SSPxBUF should be read before the next byte of data to transfer is written to the SSPxBUF. The Buffer Full bit, BF of the SSPxSTAT register, indicates when SSPxBUF has been loaded with the received data (transmission is complete). When the SSPxBUF is read, the BF bit is cleared. This data may be irrelevant if the SPI is only a transmitter. Generally, the MSSPx interrupt is used to determine when the transmission/reception has completed. 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.

FIGURE 21-5: SPI MASTER/SLAVE CONNECTION



21.2.3 SPI MASTER MODE

The master can initiate the data transfer at any time because it controls the SCKx line. The master determines when the slave (Processor 2, [Figure 21-5](#)) is to broadcast data by the software protocol.

In Master mode, the data is transmitted/received as soon as the SSPxBUF register is written to. If the SPI is only going to receive, the SDOx output could be disabled (programmed as an input). The SSPxSR register will continue to shift in the signal present on the SDIx pin at the programmed clock rate. As each byte is received, it will be loaded into the SSPxBUF register as if a normal received byte (interrupts and Status bits appropriately set).

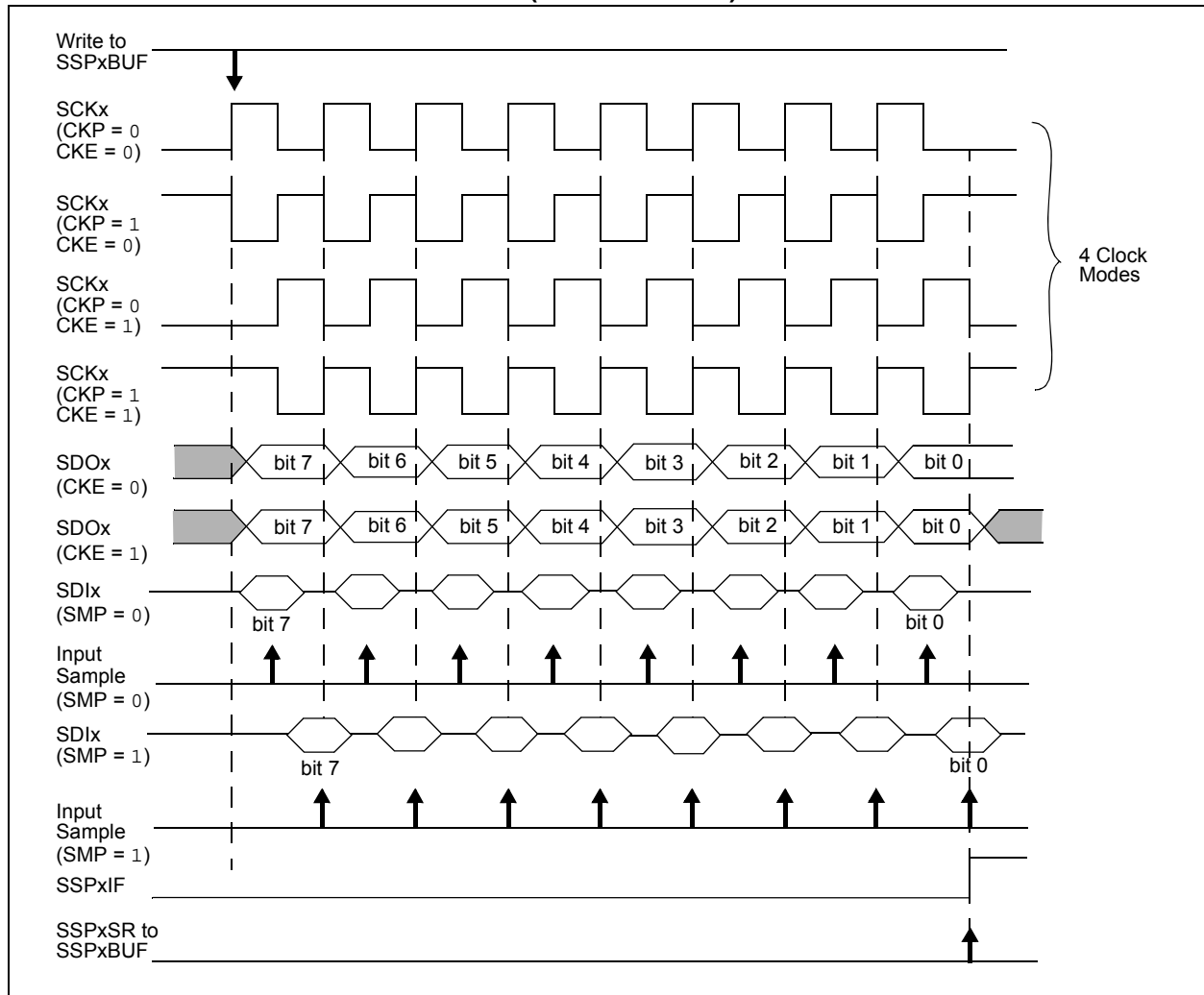
The clock polarity is selected by appropriately programming the CKP bit of the SSPxCON1 register and the CKE bit of the SSPxSTAT register. This then, would give waveforms for SPI communication as shown in [Figure 21-6](#), [Figure 21-8](#) and [Figure 21-9](#), where the MSB is transmitted first. In Master mode, the SPI clock rate (bit rate) is user programmable to be one of the following:

- $F_{osc}/4$ (or T_{CY})
- $F_{osc}/16$ (or $4 * T_{CY}$)
- $F_{osc}/64$ (or $16 * T_{CY}$)
- Timer2 output/2
- $F_{osc}/(4 * (SSPxADD + 1))$

[Figure 21-6](#) shows the waveforms for Master mode.

When the CKE bit is set, the SDOx data is valid before there is a clock edge on SCKx. The change of the input sample is shown based on the state of the SMP bit. The time when the SSPxBUF is loaded with the received data is shown.

FIGURE 21-6: SPI MODE WAVEFORM (MASTER MODE)



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21.2.4 SPI SLAVE MODE

In Slave mode, the data is transmitted and received as external clock pulses appear on SCKx. When the last bit is latched, the SSPxIF 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 SCKx pin. The Idle state is determined by the CKP bit of the SSPxCON1 register.

While in Slave mode, the external clock is supplied by the external clock source on the SCKx 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. The shift register is clocked from the SCKx pin input and when a byte is received, the device will generate an interrupt. If enabled, the device will wake-up from Sleep.

21.2.4.1 Daisy-Chain Configuration

The SPI bus can sometimes be connected in a daisy-chain configuration. The first slave output is connected to the second slave input, the second slave output is connected to the third slave input, and so on. The final slave output is connected to the master input. Each slave sends out, during a second group of clock pulses, an exact copy of what was received during the first group of clock pulses. The whole chain acts as one large communication shift register. The daisy-chain feature only requires a single Slave Select line from the master device.

Figure 21-7 shows the block diagram of a typical daisy-chain connection when operating in SPI mode.

In a daisy-chain configuration, only the most recent byte on the bus is required by the slave. Setting the BOEN bit of the SSPxCON3 register will enable writes to the SSPxBUF register, even if the previous byte has not been read. This allows the software to ignore data that may not apply to it.

21.2.5 SLAVE SELECT SYNCHRONIZATION

The Slave Select can also be used to synchronize communication. The Slave Select line is held high until the master device is ready to communicate. When the Slave Select line is pulled low, the slave knows that a new transmission is starting.

If the slave fails to receive the communication properly, it will be reset at the end of the transmission, when the Slave Select line returns to a high state. The slave is then ready to receive a new transmission when the Slave Select line is pulled low again. If the Slave Select line is not used, there is a risk that the slave will eventually become out of sync with the master. If the slave misses a bit, it will always be one bit off in future transmissions. Use of the Slave Select line allows the slave and master to align themselves at the beginning of each transmission.

The \overline{SSx} pin allows a Synchronous Slave mode. The SPI must be in Slave mode with \overline{SSx} pin control enabled (SSPxCON1<3:0> = 0100).

When the \overline{SSx} pin is low, transmission and reception are enabled and the SDOx pin is driven.

When the \overline{SSx} pin goes high, the SDOx 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.

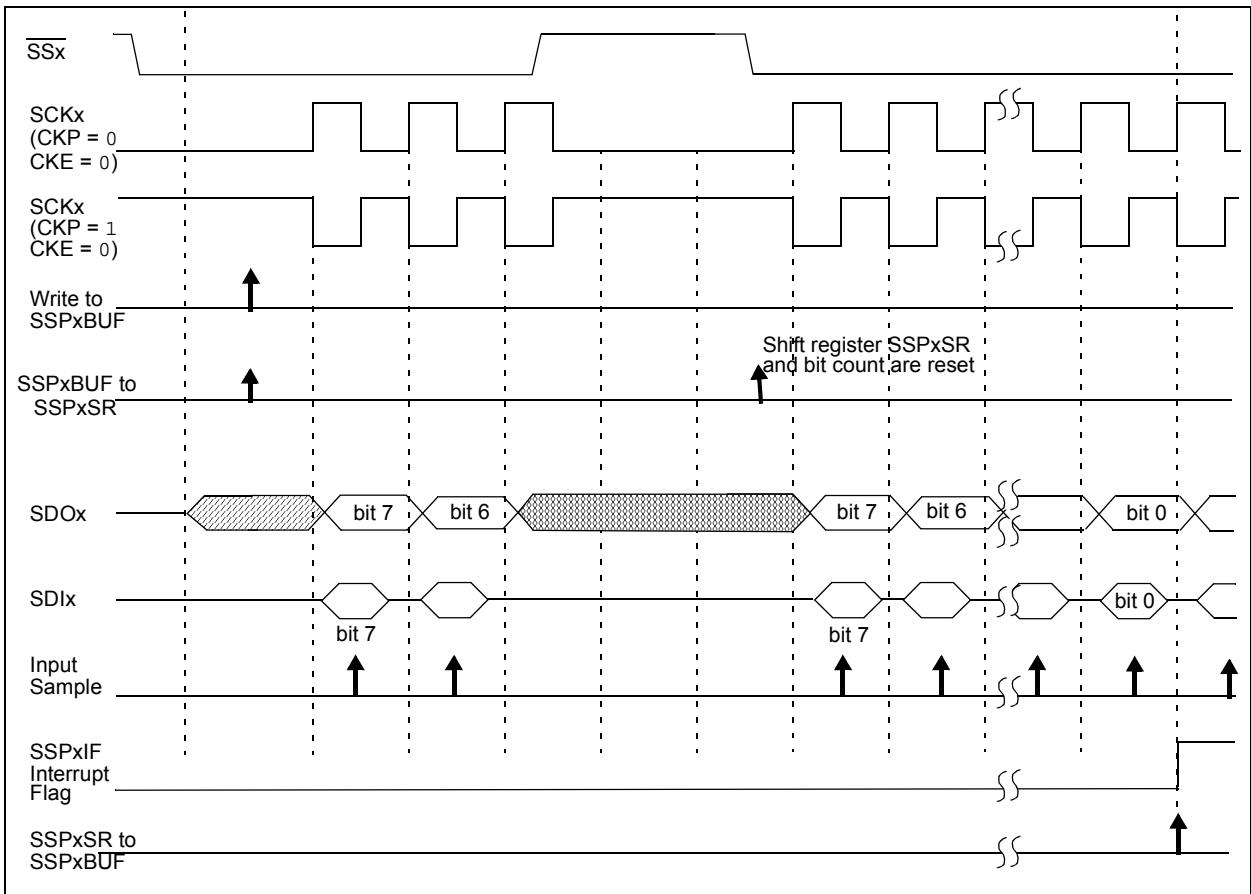
- | |
|--|
| <p>Note 1: When the SPI is in Slave mode with \overline{SSx} pin control enabled (SSPxCON1<3:0> = 0100), the SPI module will reset if the \overline{SSx} pin is set to VDD.</p> <p>2: When the SPI is used in Slave mode with CKE set; the user must enable \overline{SSx} pin control.</p> <p>3: While operated in SPI Slave mode the SMP bit of the SSPxSTAT register must remain clear.</p> |
|--|

When the SPI module resets, the bit counter is forced to '0'. This can be done by either forcing the \overline{SSx} pin to a high level or clearing the SSPxEN bit.

FIGURE 21-7: SPI DAISY-CHAIN CONNECTION



FIGURE 21-8: SLAVE SELECT SYNCHRONOUS WAVEFORM



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FIGURE 21-9: SPI MODE WAVEFORM (SLAVE MODE WITH CKE = 0)

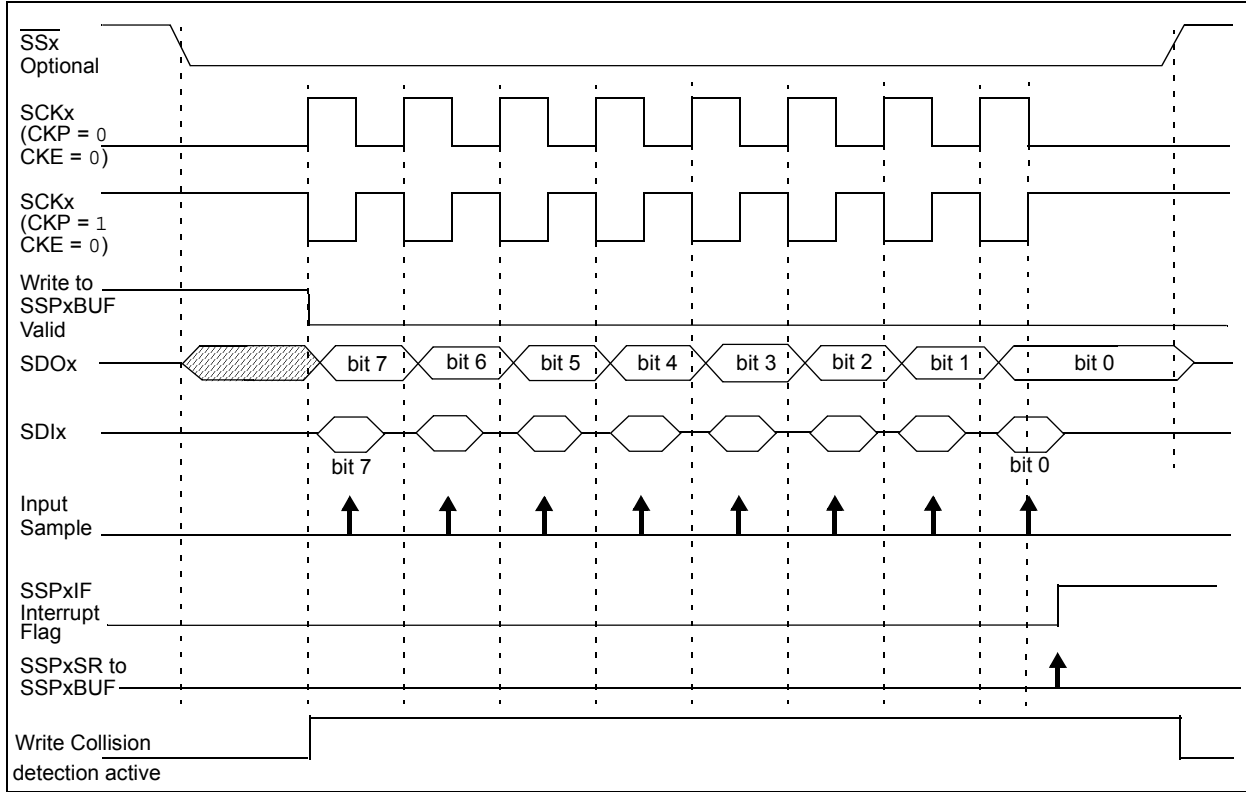
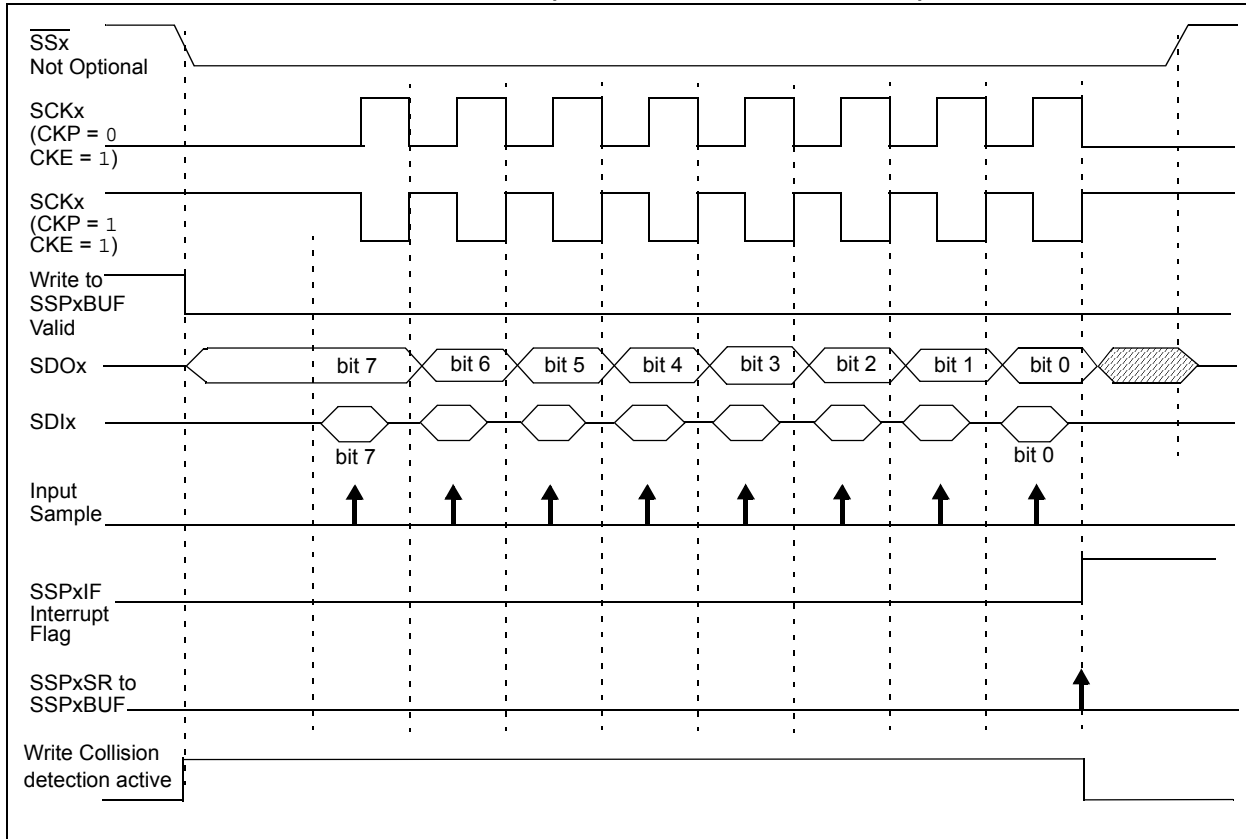


FIGURE 21-10: SPI MODE WAVEFORM (SLAVE MODE WITH CKE = 1)



21.2.6 SPI OPERATION IN SLEEP MODE

In SPI Master mode, module clocks may be operating at a different speed than when in Full-Power mode; in the case of the Sleep mode, all clocks are halted.

Special care must be taken by the user when the MSSPx clock is much faster than the system clock.

In Slave mode, when MSSPx interrupts are enabled, after the master completes sending data, an MSSPx interrupt will wake the controller from Sleep.

If an exit from Sleep mode is not desired, MSSPx interrupts should be disabled.

In SPI Master mode, when 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 Sleep mode and data to be shifted into the SPI Transmit/Receive Shift register. When all 8 bits have been received, the MSSPx interrupt flag bit will be set and if enabled, will wake the device.

TABLE 21-1: SUMMARY OF REGISTERS ASSOCIATED WITH SPI OPERATION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
ANSELF	ANSF7	ANSF6	ANSF5	ANSF4	ANSF3	ANSF2	ANSF1	ANSF0	136
INTCON	GIE	PEIE	TMR0IE	INTE	IOCFIE	TMR0IF	INTF	IOCF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88
SSP1BUF	MSSPx Receive Buffer/Transmit Register								205*
SSP2BUF	MSSPx Receive Buffer/Transmit Register								205*
SSP1CON1	WCOL	SSPOV	SSPEN	CKP	SSPM<3:0>				251
SSP2CON1	WCOL	SSPOV	SSPEN	CKP	SSPM<3:0>				251
SSP1CON3	ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN	253
SSP2CON3	ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN	253
SSP1STAT	SMP	CKE	D/Ā	P	S	R/Ī	UA	BF	249
SSP2STAT	SMP	CKE	D/Ā	P	S	R/Ī	UA	BF	249
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	126
TRISD	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0	129
TRISF	TRISF7	TRISF6	TRISF5	TRISF4	TRISF3	TRISF2	TRISF1	TRISF0	135

Legend: — = Unimplemented location, read as '0'. Shaded cells are not used by the MSSPx in SPI mode.

* Page provides register information.

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21.3 I²C MODE OVERVIEW

The Inter-Integrated Circuit Bus (I²C) is a multi-master serial data communication bus. Devices communicate in a master/slave environment where the master devices initiate the communication. A slave device is controlled through addressing.

The I²C bus specifies two signal connections:

- Serial Clock (SCLx)
- Serial Data (SDAx)

Figure 21-11 shows the block diagram of the MSSPx module when operating in I²C mode.

Both the SCLx and SDAx connections are bidirectional open-drain lines, each requiring pull-up resistors for the supply voltage. Pulling the line to ground is considered a logical zero and letting the line float is considered a logical one.

Figure 21-11 shows a typical connection between two processors configured as master and slave devices.

The I²C bus can operate with one or more master devices and one or more slave devices.

There are four potential modes of operation for a given device:

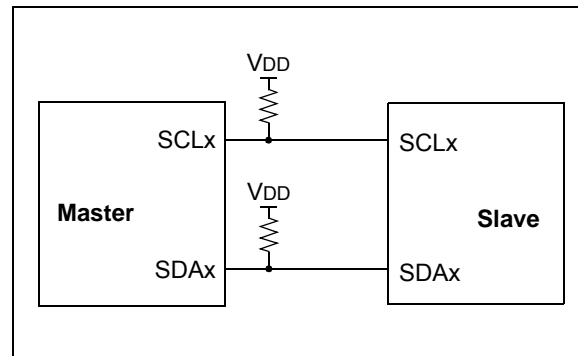
- Master Transmit mode
(master is transmitting data to a slave)
- Master Receive mode
(master is receiving data from a slave)
- Slave Transmit mode
(slave is transmitting data to a master)
- Slave Receive mode
(slave is receiving data from the master)

To begin communication, a master device starts out in Master Transmit mode. The master device sends out a Start bit followed by the address byte of the slave it intends to communicate with. This is followed by a single Read/Write bit, which determines whether the master intends to transmit to or receive data from the slave device.

If the requested slave exists on the bus, it will respond with an Acknowledge bit, otherwise known as an ACK. The master then continues in either Transmit mode or Receive mode and the slave continues in the complement, either in Receive mode or Transmit mode, respectively.

A Start bit is indicated by a high-to-low transition of the SDAx line while the SCLx line is held high. Address and data bytes are sent out, Most Significant bit (MSb) first. The Read/Write bit is sent out as a logical one when the master intends to read data from the slave, and is sent out as a logical zero when it intends to write data to the slave.

FIGURE 21-11: I²C MASTER/SLAVE CONNECTION



The Acknowledge bit ($\overline{\text{ACK}}$) is an active-low signal, which holds the SDAx line low to indicate to the transmitter that the slave device has received the transmitted data and is ready to receive more.

The transition of a data bit is always performed while the SCLx line is held low. Transitions that occur while the SCLx line is held high are used to indicate Start and Stop bits.

If the master intends to write to the slave, then it repeatedly sends out a byte of data, with the slave responding after each byte with an $\overline{\text{ACK}}$ bit. In this example, the master device is in Master Transmit mode and the slave is in Slave Receive mode.

If the master intends to read from the slave, then it repeatedly receives a byte of data from the slave, and responds after each byte with an $\overline{\text{ACK}}$ bit. In this example, the master device is in Master Receive mode and the slave is Slave Transmit mode.

On the last byte of data communicated, the master device may end the transmission by sending a Stop bit. If the master device is in Receive mode, it sends the Stop bit in place of the last ACK bit. A Stop bit is indicated by a low-to-high transition of the SDAx line while the SCLx line is held high.

In some cases, the master may want to maintain control of the bus and re-initiate another transmission. If so, the master device may send another Start bit in place of the Stop bit or last ACK bit when it is in Receive mode.

The I²C bus specifies three message protocols;

- Single message where a master writes data to a slave.
- Single message where a master reads data from a slave.
- Combined message where a master initiates a minimum of two writes, or two reads, or a combination of writes and reads, to one or more slaves.

When one device is transmitting a logical one, or letting the line float, and a second device is transmitting a logical zero, or holding the line low, the first device can detect that the line is not a logical one. This detection, when used on the SCLx line, is called clock stretching. Clock stretching gives slave devices a mechanism to control the flow of data. When this detection is used on the SDAx line, it is called arbitration. Arbitration ensures that there is only one master device communicating at any single time.

21.3.1 CLOCK STRETCHING

When a slave device has not completed processing data, it can delay the transfer of more data through the process of clock stretching. An addressed slave device may hold the SCLx clock line low after receiving or sending a bit, indicating that it is not yet ready to continue. The master that is communicating with the slave will attempt to raise the SCLx line in order to transfer the next bit, but will detect that the clock line has not yet been released. Because the SCLx connection is open-drain, the slave has the ability to hold that line low until it is ready to continue communicating.

Clock stretching allows receivers that cannot keep up with a transmitter to control the flow of incoming data.

21.3.2 ARBITRATION

Each master device must monitor the bus for Start and Stop bits. If the device detects that the bus is busy, it cannot begin a new message until the bus returns to an Idle state.

However, two master devices may try to initiate a transmission on or about the same time. When this occurs, the process of arbitration begins. Each transmitter checks the level of the SDAx data line and compares it to the level that it expects to find. The first transmitter to observe that the two levels do not match, loses arbitration, and must stop transmitting on the SDAx line.

For example, if one transmitter holds the SDAx line to a logical one (lets it float) and a second transmitter holds it to a logical zero (pulls it low), the result is that the SDAx line will be low. The first transmitter then observes that the level of the line is different than expected and concludes that another transmitter is communicating.

The first transmitter to notice this difference is the one that loses arbitration and must stop driving the SDAx line. If this transmitter is also a master device, it also must stop driving the SCLx line. It then can monitor the lines for a Stop condition before trying to reissue its transmission. In the meantime, the other device that has not noticed any difference between the expected and actual levels on the SDAx line continues with its original transmission. It can do so without any complications, because so far, the transmission appears exactly as expected with no other transmitter disturbing the message.

Slave Transmit mode can also be arbitrated, when a master addresses multiple slaves, but this is less common.

If two master devices are sending a message to two different slave devices at the address stage, the master sending the lower slave address always wins arbitration. When two master devices send messages to the same slave address, and addresses can sometimes refer to multiple slaves, the arbitration process must continue into the data stage.

Arbitration usually occurs very rarely, but it is a necessary process for proper multi-master support.

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21.4 I²C MODE OPERATION

All MSSPx I²C communication is byte oriented and shifted out MSb first. Six SFR registers and 2 interrupt flags interface the module with the PIC[®] microcontroller and user software. Two pins, SDAx and SCLx, are exercised by the module to communicate with other external I²C devices.

21.4.1 BYTE FORMAT

All communication in I²C is done in 9-bit segments. A byte is sent from a master to a slave or vice-versa, followed by an Acknowledge bit sent back. After the 8th falling edge of the SCLx line, the device outputting data on the SDAx changes that pin to an input and reads in an acknowledge value on the next clock pulse.

The clock signal, SCLx, is provided by the master. Data is valid to change while the SCLx signal is low, and sampled on the rising edge of the clock. Changes on the SDAx line while the SCLx line is high define special conditions on the bus, explained below.

21.4.2 DEFINITION OF I²C TERMINOLOGY

There is language and terminology in the description of I²C communication that have definitions specific to I²C. That word usage is defined below and may be used in the rest of this document without explanation. This table was adapted from the Philips I²C specification.

21.4.3 SDAX AND SCLX PINS

Selection of any I²C mode with the SSPxEN bit set, forces the SCLx and SDAx pins to be open-drain. These pins should be set by the user to inputs by setting the appropriate TRIS bits.

Note: Data is tied to output zero when an I²C mode is enabled.

21.4.4 SDAX HOLD TIME

The hold time of the SDAx pin is selected by the SDAHT bit of the SSPxCON3 register. Hold time is the time SDAx is held valid after the falling edge of SCLx. Setting the SDAHT bit selects a longer 300 ns minimum hold time and may help on buses with large capacitance.

TABLE 21-2: I²C BUS TERMS

TERM	Description
Transmitter	The device which shifts data out onto the bus.
Receiver	The device which shifts data in from the bus.
Master	The device that initiates a transfer, generates clock signals and terminates a transfer.
Slave	The device addressed by the master.
Multi-master	A bus with more than one device that can initiate data transfers.
Arbitration	Procedure to ensure that only one master at a time controls the bus. Winning arbitration ensures that the message is not corrupted.
Synchronization	Procedure to synchronize the clocks of two or more devices on the bus.
Idle	No master is controlling the bus, and both SDAx and SCLx lines are high.
Active	Any time one or more master devices are controlling the bus.
Addressed Slave	Slave device that has received a matching address and is actively being clocked by a master.
Matching Address	Address byte that is clocked into a slave that matches the value stored in SSPxADD.
Write Request	Slave receives a matching address with R/W bit clear, and is ready to clock in data.
Read Request	Master sends an address byte with the R/W bit set, indicating that it wishes to clock data out of the Slave. This data is the next and all following bytes until a Restart or Stop.
Clock Stretching	When a device on the bus hold SCLx low to stall communication.
Bus Collision	Any time the SDAx line is sampled low by the module while it is outputting and expected high state.

21.4.5 START CONDITION

The I²C specification defines a Start condition as a transition of SDAx from a high to a low state while SCLx line is high. A Start condition is always generated by the master and signifies the transition of the bus from an Idle to an Active state. Figure 21-10 shows wave forms for Start and Stop conditions.

A bus collision can occur on a Start condition if the module samples the SDAx line low before asserting it low. This does not conform to the I²C Specification that states no bus collision can occur on a Start.

21.4.6 STOP CONDITION

A Stop condition is a transition of the SDAx line from low-to-high state while the SCLx line is high.

Note: At least one SCLx low time must appear before a Stop is valid, therefore, if the SDAx line goes low then high again while the SCLx line stays high, only the Start condition is detected.

21.4.7 RESTART CONDITION

A Restart is valid any time that a Stop would be valid. A master can issue a Restart if it wishes to hold the bus after terminating the current transfer. A Restart has the same effect on the slave that a Start would, resetting all slave logic and preparing it to clock in an address. The master may want to address the same or another slave.

In 10-bit Addressing Slave mode a Restart is required for the master to clock data out of the addressed slave. Once a slave has been fully addressed, matching both high and low address bytes, the master can issue a Restart and the high address byte with the R/W bit set. The slave logic will then hold the clock and prepare to clock out data.

After a full match with R/W clear in 10-bit mode, a prior match flag is set and maintained. Until a Stop condition, a high address with R/W clear, or high address match fails.

21.4.8 START/STOP CONDITION INTERRUPT MASKING

The SCIE and PCIE bits of the SSPxCON3 register can enable the generation of an interrupt in Slave modes that do not typically support this function. Slave modes where interrupt on Start and Stop detect are already enabled, these bits will have no effect.

FIGURE 21-12: I²C START AND STOP CONDITIONS

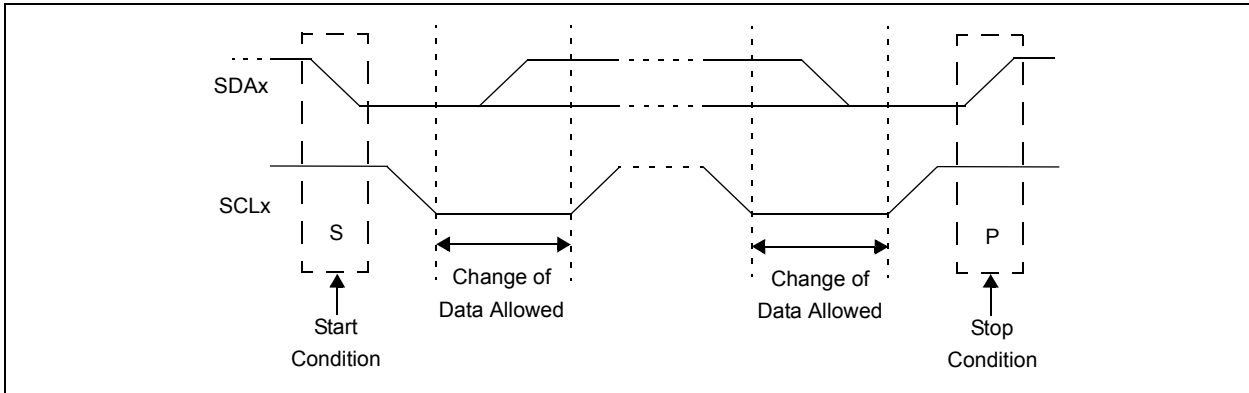
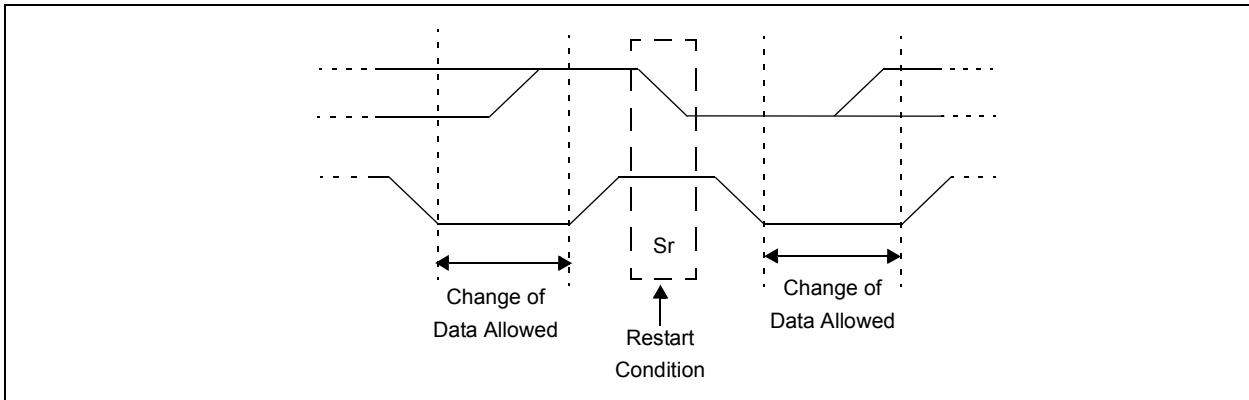


FIGURE 21-13: I²C RESTART CONDITION



21.4.9 ACKNOWLEDGE SEQUENCE

The 9th SCLx pulse for any transferred byte in I²C is dedicated as an Acknowledge. It allows receiving devices to respond back to the transmitter by pulling the SDAx line low. The transmitter must release control of the line during this time to shift in the response. The Acknowledge (ACK) is an active-low signal, pulling the SDAx line low indicated to the transmitter that the device has received the transmitted data and is ready to receive more.

The result of an $\overline{\text{ACK}}$ is placed in the ACKSTAT bit of the SSPxCON2 register.

Slave software, when the AHEN and DHEN bits are set, allow the user to set the $\overline{\text{ACK}}$ value sent back to the transmitter. The ACKDT bit of the SSPxCON2 register is set/cleared to determine the response.

Slave hardware will generate an $\overline{\text{ACK}}$ response if the AHEN and DHEN bits of the SSPxCON3 register are clear.

There are certain conditions where an $\overline{\text{ACK}}$ will not be sent by the slave. If the BF bit of the SSPxSTAT register or the SSPxOV bit of the SSPxCON1 register are set when a byte is received.

When the module is addressed, after the 8th falling edge of SCLx on the bus, the ACKTIM bit of the SSPxCON3 register is set. The ACKTIM bit indicates the acknowledge time of the active bus. The ACKTIM Status bit is only active when the AHEN bit or DHEN bit is enabled.

21.5 I²C SLAVE MODE OPERATION

The MSSPx Slave mode operates in one of four modes selected in the SSPxM bits of SSPxCON1 register. The modes can be divided into 7-bit and 10-bit Addressing mode. 10-bit Addressing modes operate the same as 7-bit with some additional overhead for handling the larger addresses.

Modes with Start and Stop bit interrupts operated the same as the other modes with SSPxIF additionally getting set upon detection of a Start, Restart, or Stop condition.

21.5.1 SLAVE MODE ADDRESSES

The SSPxADD register ([Register 21-6](#)) contains the Slave mode address. The first byte received after a Start or Restart condition is compared against the value stored in this register. If the byte matches, the value is loaded into the SSPxBUF register and an interrupt is generated. If the value does not match, the module goes Idle and no indication is given to the software that anything happened.

The SSPx Mask register ([Register 21-5](#)) affects the address matching process. See [Section 21.5.9 “SSPx Mask Register”](#) for more information.

21.5.1.1 I²C Slave 7-bit Addressing Mode

In 7-bit Addressing mode, the LSb of the received data byte is ignored when determining if there is an address match.

21.5.1.2 I²C Slave 10-bit Addressing Mode

In 10-bit Addressing mode, the first received byte is compared to the binary value of ‘1 1 1 0 A9 A8 0’. A9 and A8 are the two MSb of the 10-bit address and stored in bits 2 and 1 of the SSPxADD register.

After the acknowledge of the high byte the UA bit is set and SCLx is held low until the user updates SSPxADD with the low address. The low address byte is clocked in and all 8 bits are compared to the low address value in SSPxADD. Even if there is not an address match; SSPxIF and UA are set, and SCLx is held low until SSPxADD is updated to receive a high byte again. When SSPxADD is updated the UA bit is cleared. This ensures the module is ready to receive the high address byte on the next communication.

A high and low address match as a write request is required at the start of all 10-bit addressing communication. A transmission can be initiated by issuing a Restart once the slave is addressed, and clocking in the high address with the R/W bit set. The slave hardware will then acknowledge the read request and prepare to clock out data. This is only valid for a slave after it has received a complete high and low address byte match.

21.5.2 SLAVE RECEPTION

When the $\overline{R/W}$ bit of a matching received address byte is clear, the $\overline{R/W}$ bit of the SSPxSTAT register is cleared. The received address is loaded into the SSPxBUF register and acknowledged.

When the overflow condition exists for a received address, then not Acknowledge is given. An overflow condition is defined as either bit BF of the SSPxSTAT register is set, or bit SSPxOV of the SSPxCON1 register is set. The BOEN bit of the SSPxCON3 register modifies this operation. For more information see [Register 21-4](#).

An MSSPx interrupt is generated for each transferred data byte. Flag bit, SSPxIF, must be cleared by software.

When the SEN bit of the SSPxCON2 register is set, SCLx will be held low (clock stretch) following each received byte. The clock must be released by setting the CKP bit of the SSPxCON1 register, except sometimes in 10-bit mode. See [Section 21.2.3 “SPI Master Mode”](#) for more detail.

21.5.2.1 7-bit Addressing Reception

This section describes a standard sequence of events for the MSSPx module configured as an I²C slave in 7-bit Addressing mode. All decisions made by hardware or software and their effect on reception. [Figure 21-13](#) and [Figure 21-14](#) is used as a visual reference for this description.

This is a step by step process of what typically must be done to accomplish I²C communication.

1. Start bit detected.
2. S bit of SSPxSTAT is set; SSPxIF is set if interrupt on Start detect is enabled.
3. Matching address with $\overline{R/W}$ bit clear is received.
4. The slave pulls SDAx low sending an \overline{ACK} to the master, and sets SSPxIF bit.
5. Software clears the SSPxIF bit.
6. Software reads received address from SSPxBUF clearing the BF flag.
7. If SEN = 1; Slave software sets CKP bit to release the SCLx line.
8. The master clocks out a data byte.
9. Slave drives SDAx low sending an \overline{ACK} to the master, and sets SSPxIF bit.
10. Software clears SSPxIF.
11. Software reads the received byte from SSPxBUF clearing BF.
12. Steps 8-12 are repeated for all received bytes from the master.
13. Master sends Stop condition, setting P bit of SSPxSTAT, and the bus goes Idle.

21.5.2.2 7-bit Reception with AHEN and DHEN

Slave device reception with AHEN and DHEN set operate the same as without these options with extra interrupts and clock stretching added after the 8th falling edge of SCLx. These additional interrupts allow the slave software to decide whether it wants to ACK the receive address or data byte, rather than the hardware. This functionality adds support for PMBus™ that was not present on previous versions of this module.

This list describes the steps that need to be taken by slave software to use these options for I²C communication. [Figure 21-15](#) displays a module using both address and data holding. [Figure 21-16](#) includes the operation with the SEN bit of the SSPxCON2 register set.

1. S bit of SSPxSTAT is set; SSPxIF is set if interrupt on Start detect is enabled.
2. Matching address with $\overline{R/W}$ bit clear is clocked in. SSPxIF is set and CKP cleared after the 8th falling edge of SCLx.
3. Slave clears the SSPxIF.
4. Slave can look at the ACKTIM bit of the SSPxCON3 register to determine if the SSPxIF was after or before the \overline{ACK} .
5. Slave reads the address value from SSPxBUF, clearing the BF flag.
6. Slave sets \overline{ACK} value clocked out to the master by setting ACKDT.
7. Slave releases the clock by setting CKP.
8. SSPxIF is set after an \overline{ACK} , not after a NACK.
9. If SEN = 1 the slave hardware will stretch the clock after the \overline{ACK} .
10. Slave clears SSPxIF.

Note: SSPxIF is still set after the 9th falling edge of SCLx even if there is no clock stretching and BF has been cleared. Only if NACK is sent to master is SSPxIF not set

11. SSPxIF set and CKP cleared after 8th falling edge of SCLx for a received data byte.
12. Slave looks at ACKTIM bit of SSPxCON3 to determine the source of the interrupt.
13. Slave reads the received data from SSPxBUF clearing BF.
14. Steps 7-14 are the same for each received data byte.
15. Communication is ended by either the slave sending an $\overline{ACK} = 1$, or the master sending a Stop condition. If a Stop is sent and Interrupt on Stop Detect is disabled, the slave will only know by polling the P bit of the SSTSTAT register.

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FIGURE 21-14: I²C SLAVE, 7-BIT ADDRESS, RECEPTION (SEN = 0, AHEN = 0, DHEN = 0)

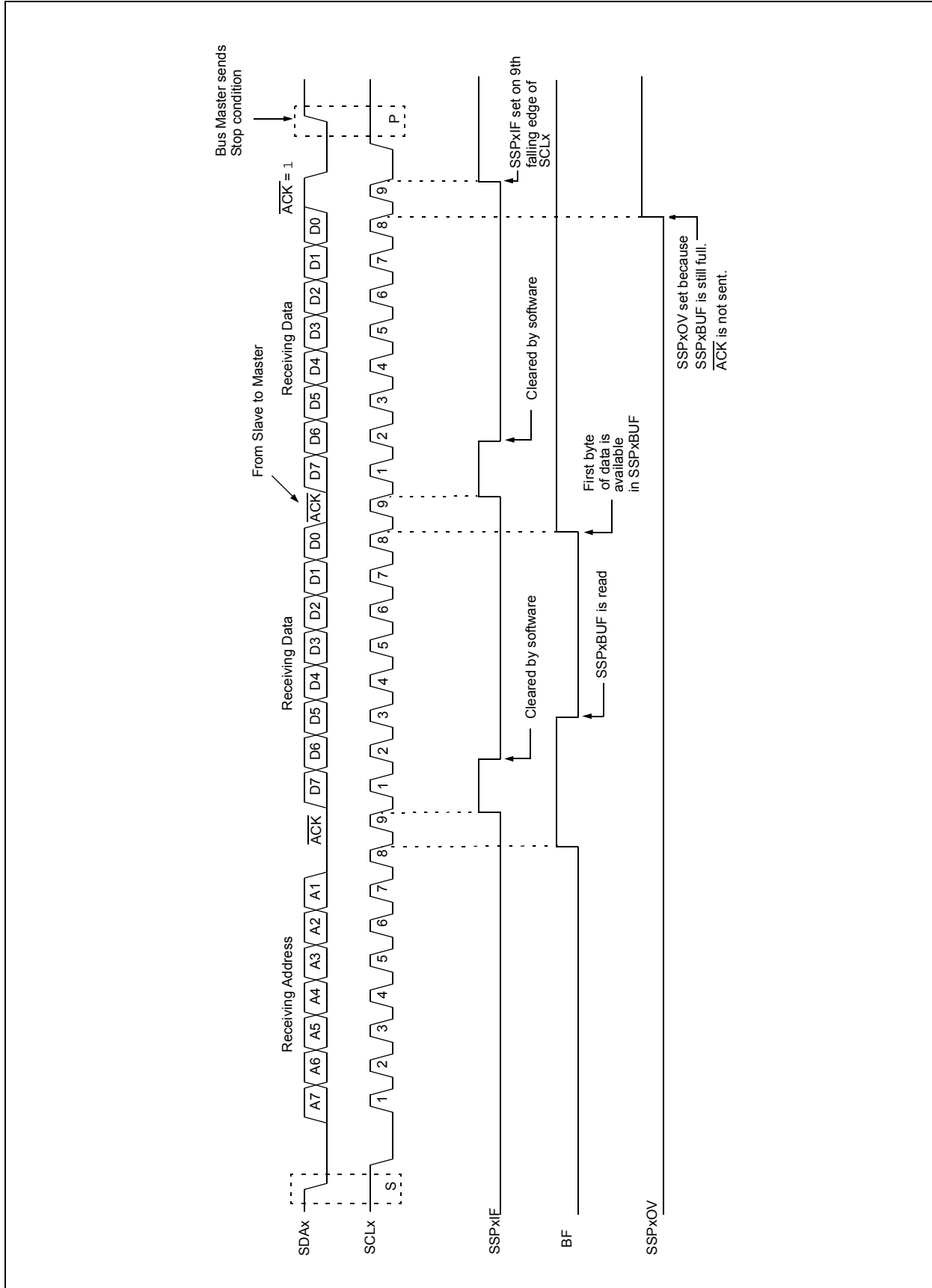
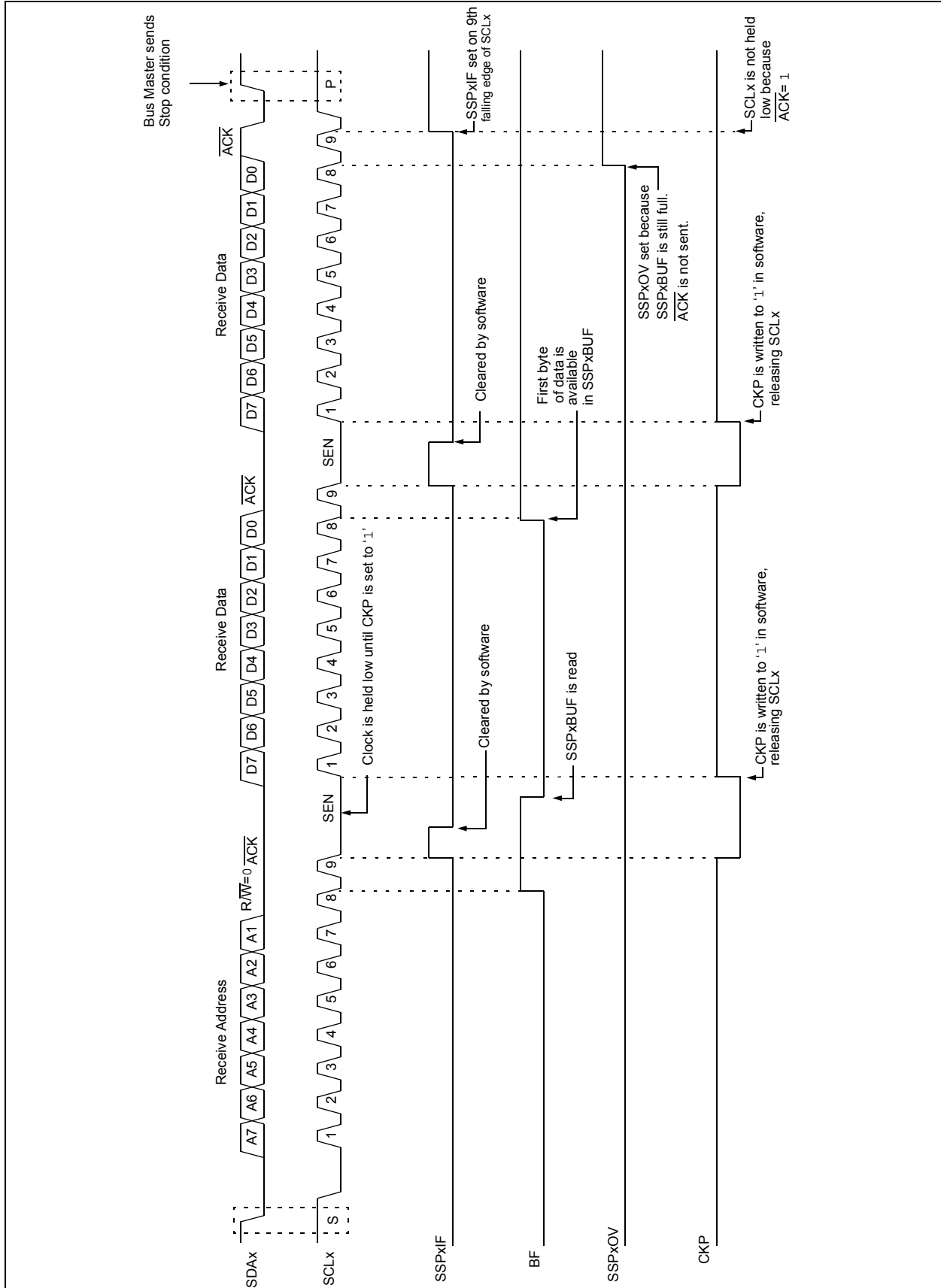


FIGURE 21-15: I²C SLAVE, 7-BIT ADDRESS, RECEPTION (SEN = 1, AHEN = 0, DHEN = 0)



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FIGURE 21-16: I²C SLAVE, 7-BIT ADDRESS, RECEPTION (SEN = 0, AHEN = 1, DHEN = 1)

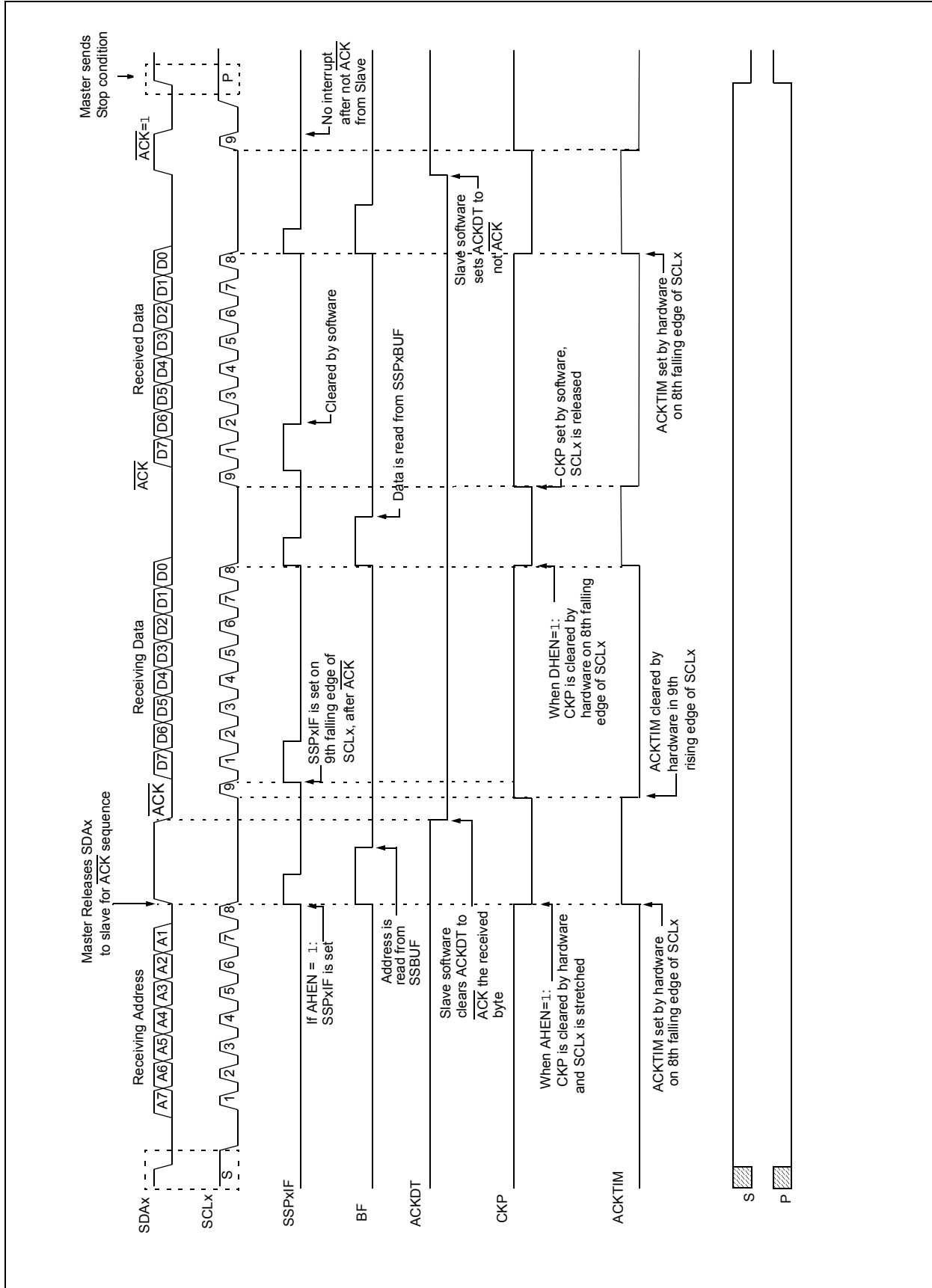
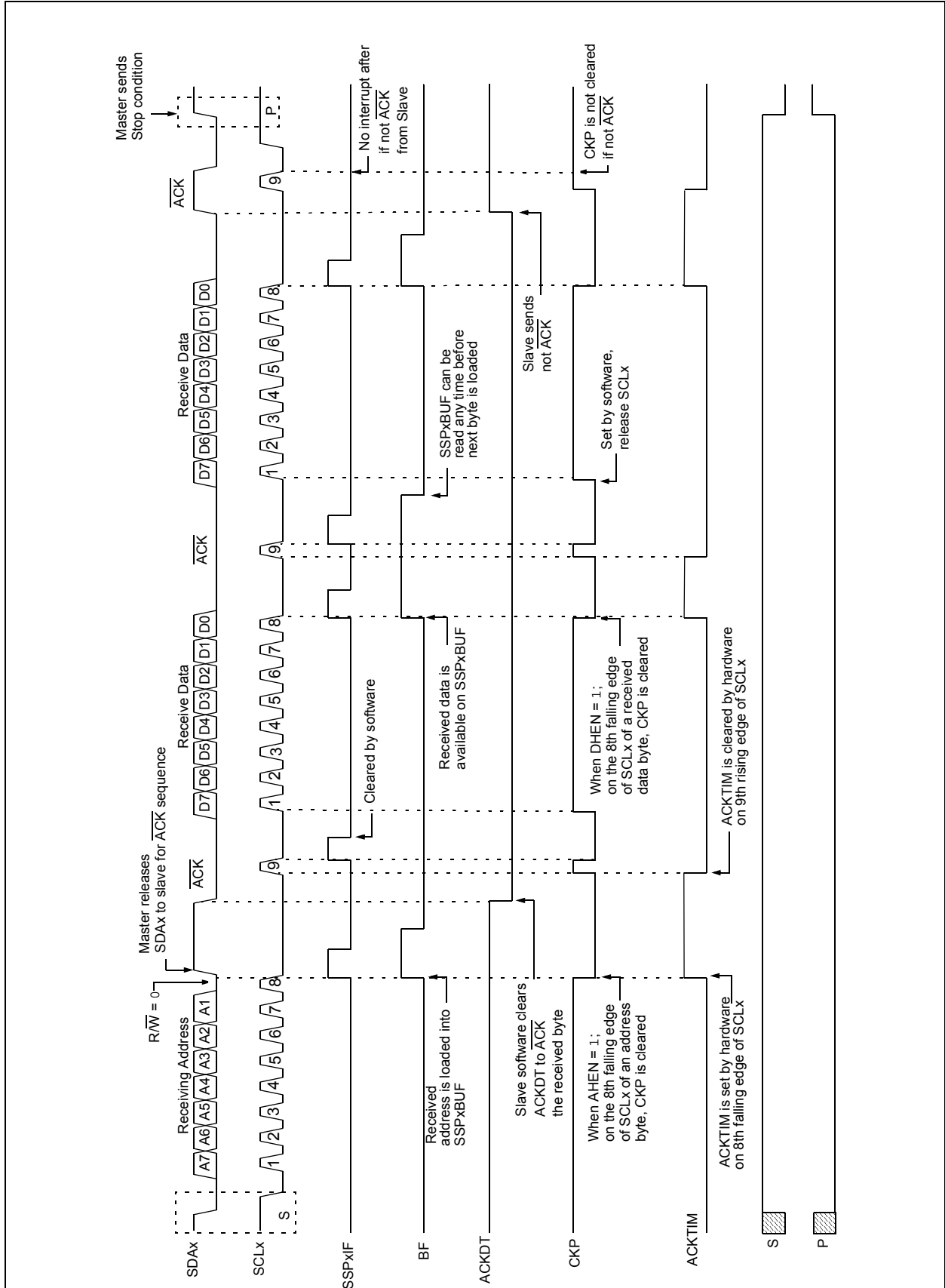


FIGURE 21-17: I²C SLAVE, 7-BIT ADDRESS, RECEPTION (SEN = 1, AHEN = 1, DHEN = 1)



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21.5.3 SLAVE TRANSMISSION

When the $\overline{R/W}$ bit of the incoming address byte is set and an address match occurs, the $\overline{R/W}$ bit of the SSPxSTAT register is set. The received address is loaded into the SSPxBUF register, and an \overline{ACK} pulse is sent by the slave on the ninth bit.

Following the \overline{ACK} , slave hardware clears the CKP bit and the SCLx pin is held low (see [Section 21.5.6 “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 SSPxBUF register which also loads the SSPxSR register. Then the SCLx pin should be released by setting the CKP bit of the SSPxCON1 register. The eight data bits are shifted out on the falling edge of the SCLx input. This ensures that the SDAx signal is valid during the SCLx high time.

The \overline{ACK} pulse from the master-receiver is latched on the rising edge of the ninth SCLx input pulse. This \overline{ACK} value is copied to the ACKSTAT bit of the SSPxCON2 register. If ACKSTAT is set (not \overline{ACK}), then the data transfer is complete. In this case, when the not \overline{ACK} is latched by the slave, the slave goes Idle and waits for another occurrence of the Start bit. If the SDAx line was low (\overline{ACK}), the next transmit data must be loaded into the SSPxBUF register. Again, the SCLx pin must be released by setting bit CKP.

An MSSPx interrupt is generated for each data transfer byte. The SSPxIF bit must be cleared by software and the SSPxSTAT register is used to determine the status of the byte. The SSPxIF bit is set on the falling edge of the ninth clock pulse.

21.5.3.1 Slave Mode Bus Collision

A slave receives a Read request and begins shifting data out on the SDAx line. If a bus collision is detected and the SBCDE bit of the SSPxCON3 register is set, the BCLxIF bit of the PIRx register is set. Once a bus collision is detected, the slave goes Idle and waits to be addressed again. User software can use the BCLxIF bit to handle a slave bus collision.

21.5.3.2 7-bit Transmission

A master device can transmit a read request to a slave, and then clock data out of the slave. The list below outlines what software for a slave will need to do to accomplish a standard transmission. [Figure 21-17](#) can be used as a reference to this list.

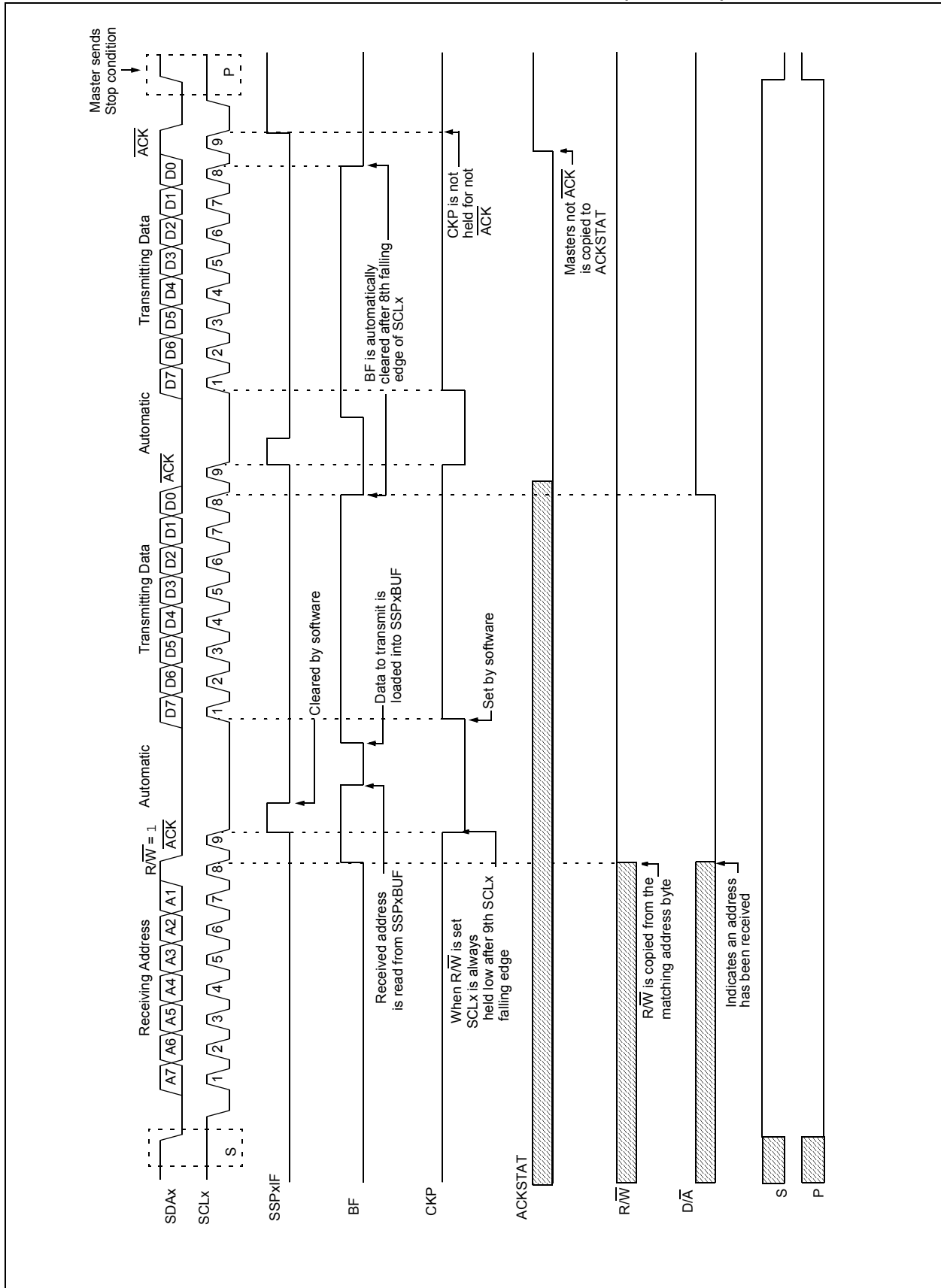
1. Master sends a Start condition on SDAx and SCLx.
2. S bit of SSPxSTAT is set; SSPxIF is set if interrupt on Start detect is enabled.
3. Matching address with $\overline{R/W}$ bit set is received by the slave setting SSPxIF bit.
4. Slave hardware generates an \overline{ACK} and sets SSPxIF.
5. SSPxIF bit is cleared by user.
6. Software reads the received address from SSPxBUF, clearing BF.
7. $\overline{R/W}$ is set so CKP was automatically cleared after the \overline{ACK} .
8. The slave software loads the transmit data into SSPxBUF.
9. CKP bit is set releasing SCLx, allowing the master to clock the data out of the slave.
10. SSPxIF is set after the \overline{ACK} response from the master is loaded into the ACKSTAT register.
11. SSPxIF bit is cleared.
12. The slave software checks the ACKSTAT bit to see if the master wants to clock out more data.

Note 1: If the master \overline{ACK} s the clock will be stretched.

2: ACKSTAT is the only bit updated on the rising edge of SCLx (9th) rather than the falling.

13. Steps 9-13 are repeated for each transmitted byte.
14. If the master sends a not \overline{ACK} ; the clock is not held, but SSPxIF is still set.
15. The master sends a Restart condition or a Stop.
16. The slave is no longer addressed.

FIGURE 21-18: I²C SLAVE, 7-BIT ADDRESS, TRANSMISSION (AHEN = 0)



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21.5.3.3 7-bit Transmission with Address Hold Enabled

Setting the AHEN bit of the SSPxCON3 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 SSPxIF interrupt is set.

Figure 21-18 displays a standard waveform of a 7-bit Address Slave Transmission with AHEN enabled.

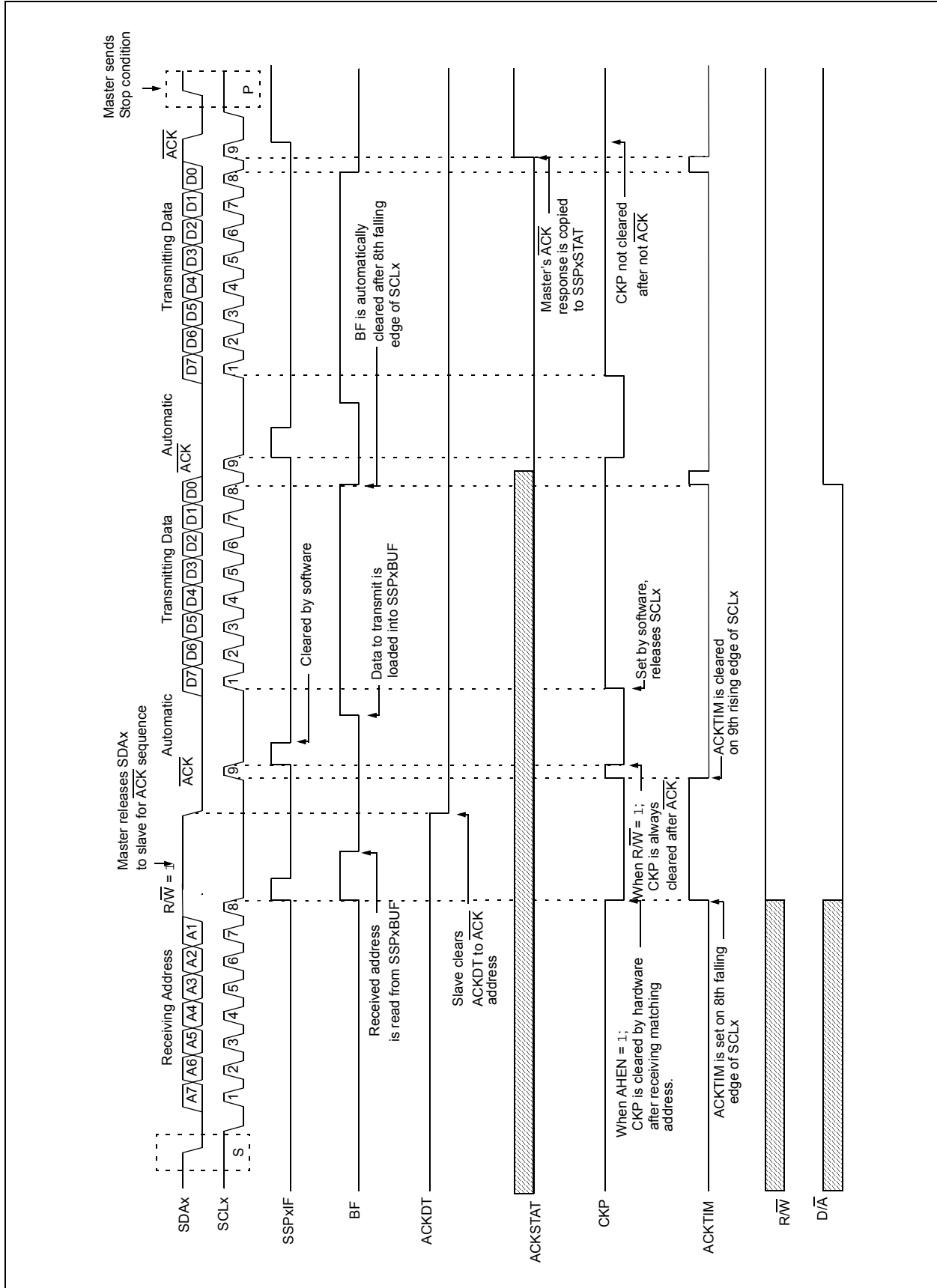
1. Bus starts Idle.
2. Master sends Start condition; the S bit of SSPxSTAT is set; SSPxIF is set if interrupt on Start detect is enabled.
3. Master sends matching address with $\overline{R/W}$ bit set. After the 8th falling edge of the SCLx line the CKP bit is cleared and SSPxIF interrupt is generated.
4. Slave software clears SSPxIF.
5. Slave software reads ACKTIM bit of SSPxCON3 register, and $\overline{R/W}$ and D/A of the SSPxSTAT register to determine the source of the interrupt.
6. Slave reads the address value from the SSPxBUF register clearing the BF bit.
7. Slave software decides from this information if it wishes to ACK or not ACK and sets ACKDT bit of the SSPxCON2 register accordingly.
8. Slave sets the CKP bit releasing SCLx.
9. Master clocks in the \overline{ACK} value from the slave.
10. Slave hardware automatically clears the CKP bit and sets SSPxIF after the \overline{ACK} if the $\overline{R/W}$ bit is set.
11. Slave software clears SSPxIF.
12. Slave loads value to transmit to the master into SSPxBUF setting the BF bit.

Note: SSPxBUF 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 SCLx pulse.
15. Slave hardware copies the \overline{ACK} value into the ACKSTAT bit of the SSPxCON2 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 SCLx line to receive a Stop.

FIGURE 21-19: I²C SLAVE, 7-BIT ADDRESS, TRANSMISSION (AHEN = 1)



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21.5.4 SLAVE MODE 10-BIT ADDRESS RECEPTION

This section describes a standard sequence of events for the MSSPx module configured as an I²C slave in 10-bit Addressing mode.

Figure 21-19 is used as a visual reference for this description.

This is a step by step process of what must be done by slave software to accomplish I²C communication.

1. Bus starts Idle.
2. Master sends Start condition; S bit of SSPxSTAT is set; SSPxIF is set if interrupt on Start detect is enabled.
3. Master sends matching high address with $\overline{R/W}$ bit clear; UA bit of the SSPxSTAT register is set.
4. Slave sends \overline{ACK} and SSPxIF is set.
5. Software clears the SSPxIF bit.
6. Software reads received address from SSPxBUF clearing the BF flag.
7. Slave loads low address into SSPxADD, releasing SCLx.
8. Master sends matching low address byte to the slave; UA bit is set.

Note: Updates to the SSPxADD register are not allowed until after the ACK sequence.

9. Slave sends \overline{ACK} and SSPxIF is set.

Note: If the low address does not match, SSPxIF and UA are still set so that the slave software can set SSPxADD back to the high address. BF is not set because there is no match. CKP is unaffected.

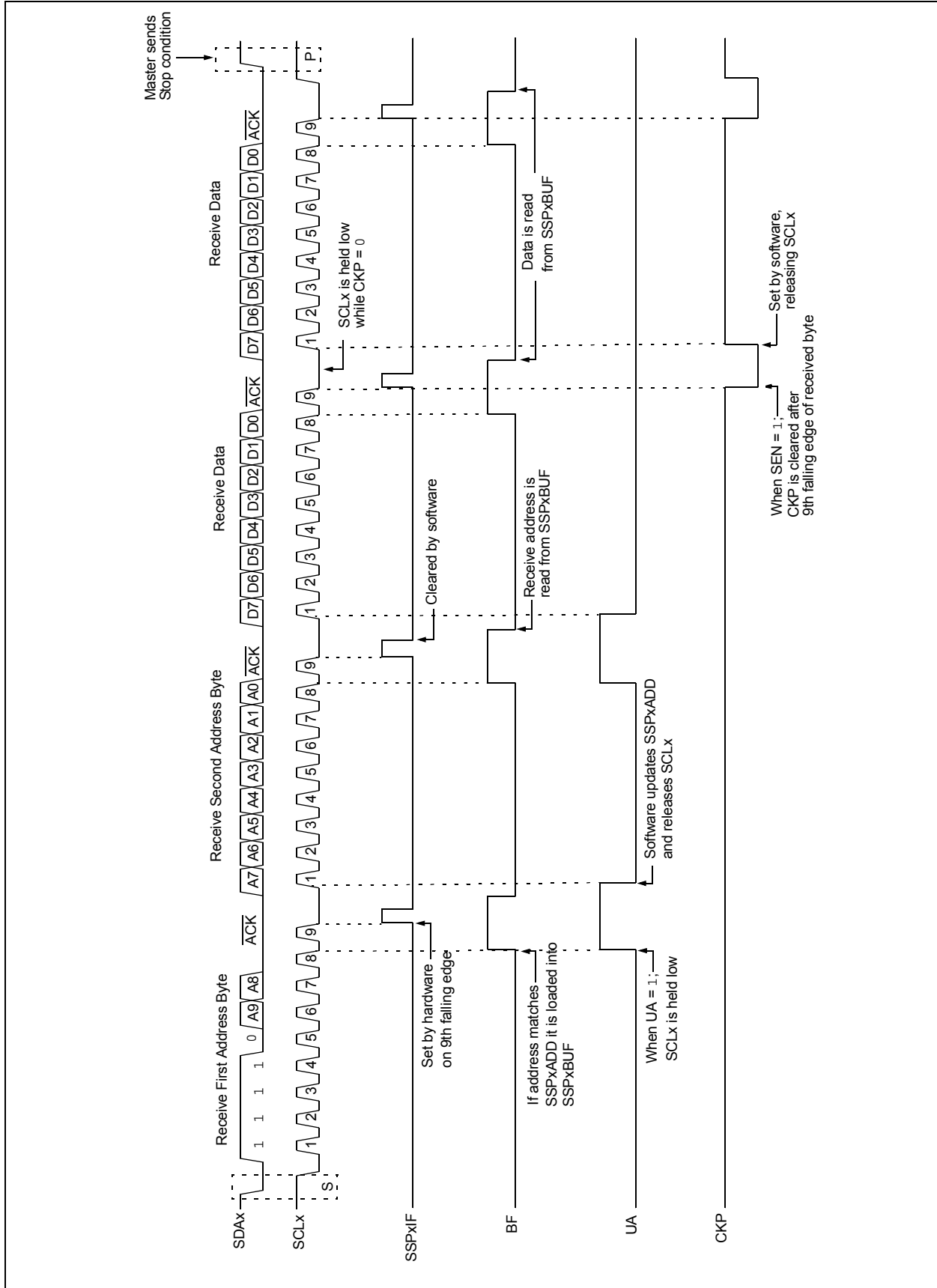
10. Slave clears SSPxIF.
11. Slave reads the received matching address from SSPxBUF clearing BF.
12. Slave loads high address into SSPxADD.
13. Master clocks a data byte to the slave and clocks out the slaves ACK on the 9th SCLx pulse; SSPxIF is set.
14. If SEN bit of SSPxCON2 is set, CKP is cleared by hardware and the clock is stretched.
15. Slave clears SSPxIF.
16. Slave reads the received byte from SSPxBUF clearing BF.
17. If SEN is set the slave sets CKP to release the SCLx.
18. Steps 13-17 repeat for each received byte.
19. Master sends Stop to end the transmission.

21.5.5 10-BIT ADDRESSING WITH ADDRESS OR DATA HOLD

Reception using 10-bit addressing with AHEN or DHEN set is the same as with 7-bit modes. The only difference is the need to update the SSPxADD register using the UA bit. All functionality, specifically when the CKP bit is cleared and SCLx line is held low are the same. Figure 21-20 can be used as a reference of a slave in 10-bit addressing with AHEN set.

Figure 21-21 shows a standard waveform for a slave transmitter in 10-bit Addressing mode.

FIGURE 21-20: I²C SLAVE, 10-BIT ADDRESS, RECEPTION (SEN = 1, AHEN = 0, DHEN = 0)

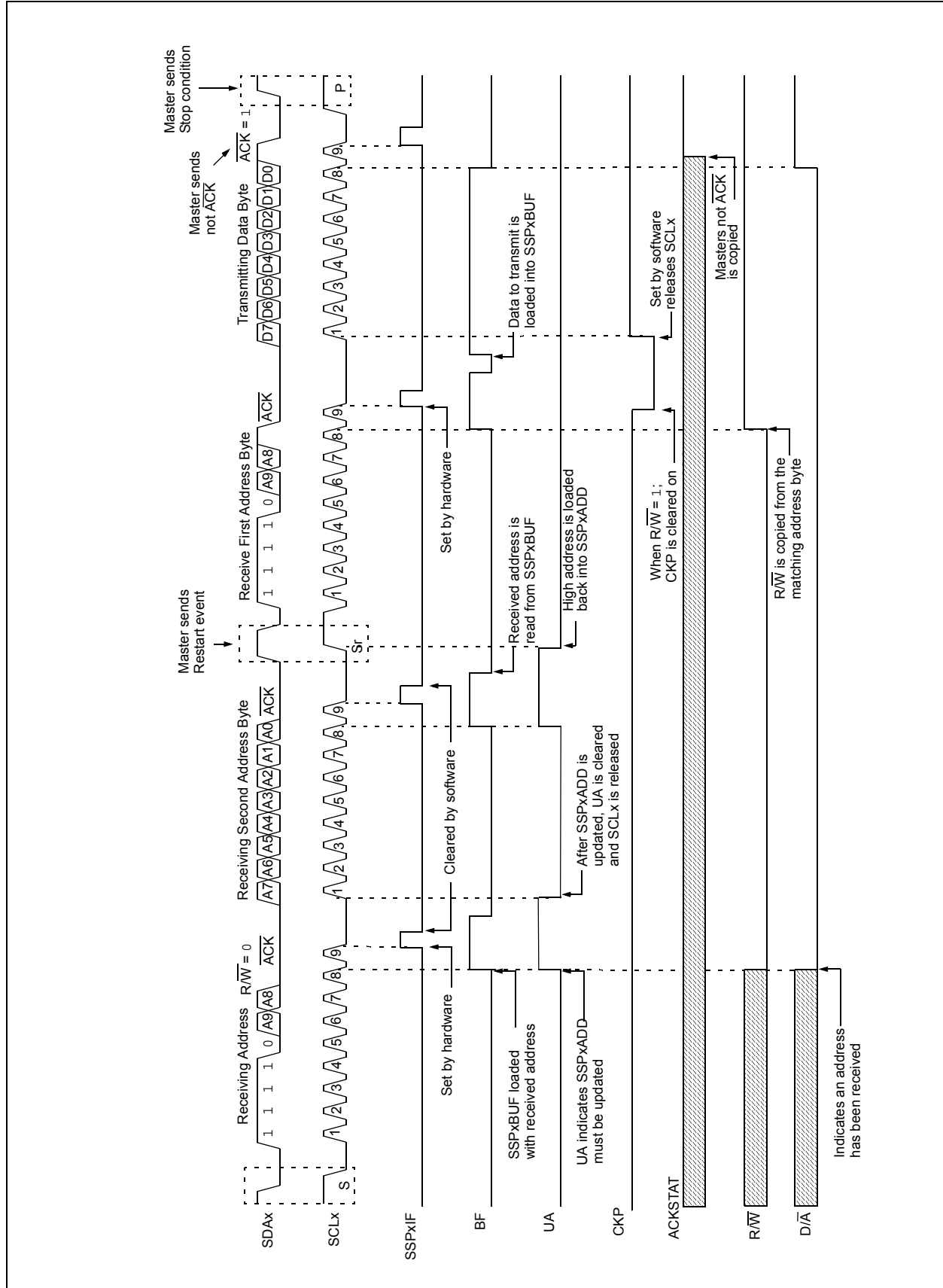


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FIGURE 21-21: I²C SLAVE, 10-BIT ADDRESS, RECEPTION (SEN = 0, AHEN = 1, DHEN = 0)



FIGURE 21-22: I²C SLAVE, 10-BIT ADDRESS, TRANSMISSION (SEN = 0, AHEN = 0, DHEN = 0)



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21.5.6 CLOCK STRETCHING

Clock stretching occurs when a device on the bus holds the SCLx line low effectively pausing communication. The slave may stretch the clock to allow more time to handle data or prepare a response for the master device. A master device is not concerned with stretching as anytime it is active on the bus and not transferring data it is stretching. Any stretching done by a slave is invisible to the master software and handled by the hardware that generates SCLx.

The CKP bit of the SSPxCON1 register is used to control stretching in software. Any time the CKP bit is cleared, the module will wait for the SCLx line to go low and then hold it. Setting CKP will release SCLx and allow more communication.

21.5.6.1 Normal Clock Stretching

Following an $\overline{\text{ACK}}$ if the $\overline{\text{R/W}}$ bit of SSPxSTAT is set, a read request, the slave hardware will clear CKP. This allows the slave time to update SSPxBUF with data to transfer to the master. If the SEN bit of SSPxCON2 is set, the slave hardware will always stretch the clock after the $\overline{\text{ACK}}$ sequence. Once the slave is ready; CKP is set by software and communication resumes.

Note 1: The BF bit has no effect on if the clock will be stretched or not. This is different than previous versions of the module that would not stretch the clock, clear CKP, if SSPxBUF was read before the 9th falling edge of SCLx.

2: Previous versions of the module did not stretch the clock for a transmission if SSPxBUF was loaded before the 9th falling edge of SCLx. It is now always cleared for read requests.

21.5.6.2 10-bit Addressing Mode

In 10-bit Addressing mode, when the UA bit is set, the clock is always stretched. This is the only time the SCLx is stretched without CKP being cleared. SCLx is released immediately after a write to SSPxADD.

Note: Previous versions of the module did not stretch the clock if the second address byte did not match.

21.5.6.3 Byte NACKing

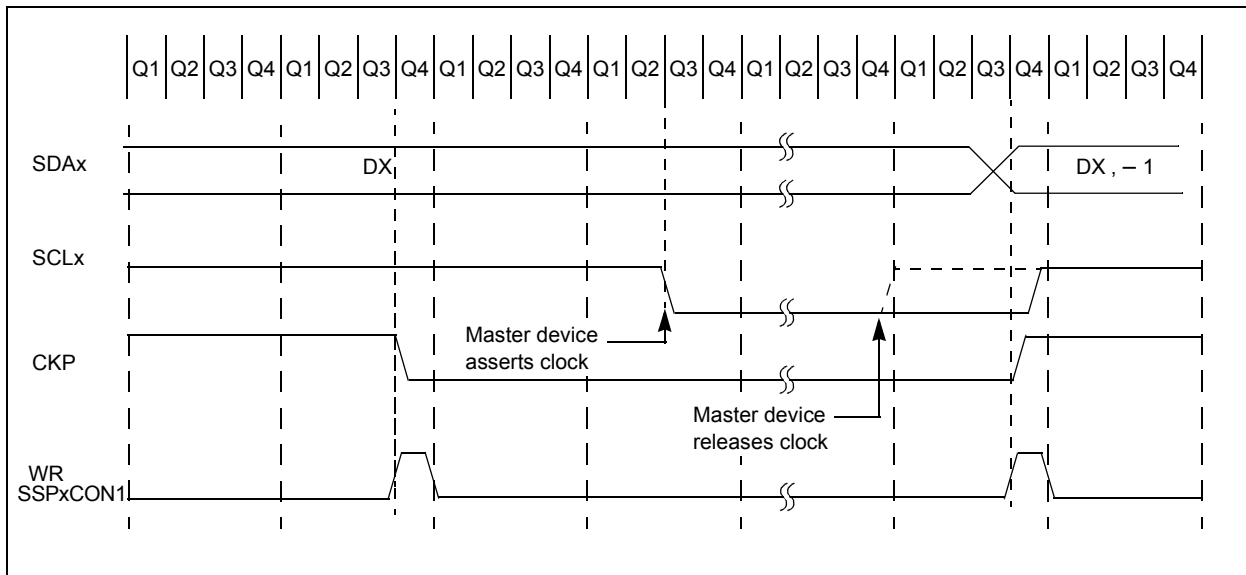
When AHEN bit of SSPxCON3 is set; CKP is cleared by hardware after the 8th falling edge of SCLx for a received matching address byte. When DHEN bit of SSPxCON3 is set; CKP is cleared after the 8th falling edge of SCLx for received data.

Stretching after the 8th falling edge of SCLx allows the slave to look at the received address or data and decide if it wants to ACK the received data.

21.5.7 CLOCK SYNCHRONIZATION AND THE CKP BIT

Any time the CKP bit is cleared, the module will wait for the SCLx line to go low and then hold it. However, clearing the CKP bit will not assert the SCLx output low until the SCLx output is already sampled low. Therefore, the CKP bit will not assert the SCLx line until an external I²C master device has already asserted the SCLx line. The SCLx output will remain low until the CKP bit is set and all other devices on the I²C bus have released SCLx. This ensures that a write to the CKP bit will not violate the minimum high time requirement for SCLx (see [Figure 21-22](#)).

FIGURE 21-23: CLOCK SYNCHRONIZATION TIMING



21.5.8 GENERAL CALL ADDRESS SUPPORT

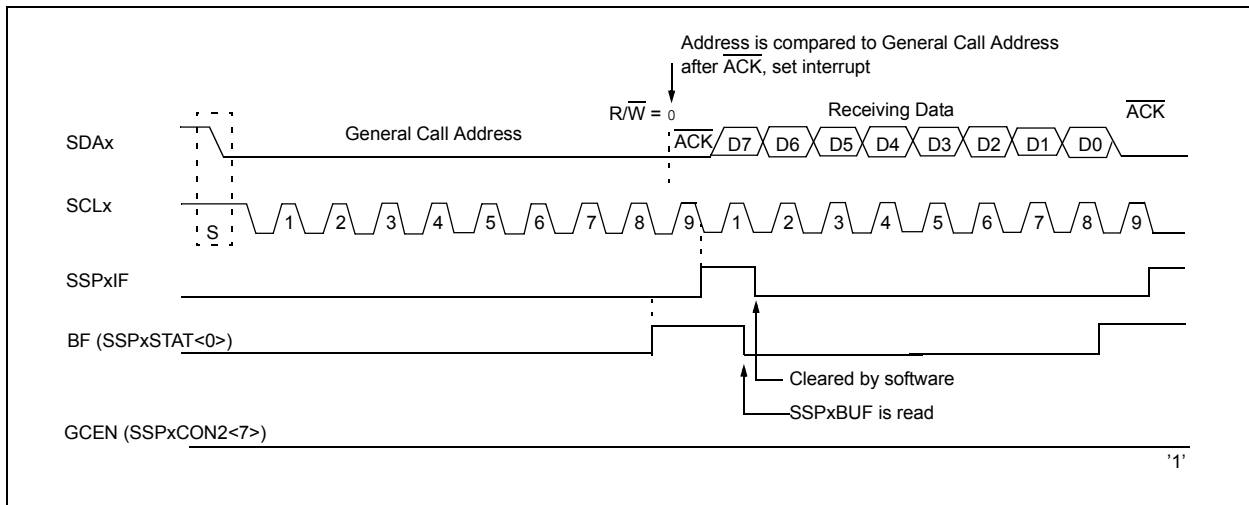
The addressing procedure for the I²C bus is such that the first byte after the Start condition usually determines which device will be the slave addressed by the master device. The exception is the general call address which can address all devices. When this address is used, all devices should, in theory, respond with an Acknowledge.

The general call address is a reserved address in the I²C protocol, defined as address 0x00. When the GCEN bit of the SSPxCON2 register is set, the slave module will automatically ACK the reception of this address regardless of the value stored in SSPxADD. After the slave clocks in an address of all zeros with the R/W bit clear, an interrupt is generated and slave software can read SSPxBUF and respond. Figure 21-23 shows a general call reception sequence.

In 10-bit Address mode, the UA bit will not be set on the reception of the general call address. The slave will prepare to receive the second byte as data, just as it would in 7-bit mode.

If the AHEN bit of the SSPxCON3 register is set, just as with any other address reception, the slave hardware will stretch the clock after the 8th falling edge of SCLx. The slave must then set its ACKDT value and release the clock with communication progressing as it would normally.

FIGURE 21-24: SLAVE MODE GENERAL CALL ADDRESS SEQUENCE



21.5.9 SSPX MASK REGISTER

An SSPx Mask (SSPxMSK) register (Register 21-5) is available in I²C Slave mode as a mask for the value held in the SSPxSR register during an address comparison operation. A zero ('0') bit in the SSPxMSK register has the effect of making the corresponding bit of the received address a "don't care".

This register is reset to all '1's upon any Reset condition and, therefore, has no effect on standard SSPx operation until written with a mask value.

The SSPx Mask register is active during:

- 7-bit Address mode: address compare of A<7:1>.
- 10-bit Address mode: address compare of A<7:0> only. The SSPx mask has no effect during the reception of the first (high) byte of the address.

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21.6 I²C MASTER MODE

Master mode is enabled by setting and clearing the appropriate SSPxM bits in the SSPxCON1 register and by setting the SSPxEN bit. In Master mode, the SDA and SCK pins must be configured as inputs. The MSSP peripheral hardware will override the output driver TRIS controls when necessary to drive the pins low.

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 MSSPx module is disabled. Control of the I²C bus may be taken when the P bit is set, or the bus is Idle.

In Firmware Controlled Master mode, user code conducts all I²C bus operations based on Start and Stop bit condition detection. Start and Stop condition detection is the only active circuitry in this mode. All other communication is done by the user software directly manipulating the SDAx and SCLx lines.

The following events will cause the SSPx Interrupt flag bit, SSPxIF, to be set (SSPx interrupt, if enabled):

- Start condition detected
- Stop condition detected
- Data transfer byte transmitted/received
- Acknowledge transmitted/received
- Repeated Start generated

Note 1: The MSSPx module, when configured in I²C Master mode, does not allow queuing of events. For instance, the user is not allowed to initiate a Start condition and immediately write the SSPxBUF register to initiate transmission before the Start condition is complete. In this case, the SSPxBUF will not be written to and the WCOL bit will be set, indicating that a write to the SSPxBUF did not occur

2: When in Master mode, Start/Stop detection is masked and an interrupt is generated when the SEN/PEN bit is cleared and the generation is complete.

21.6.1 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 SDAx, while SCLx 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.

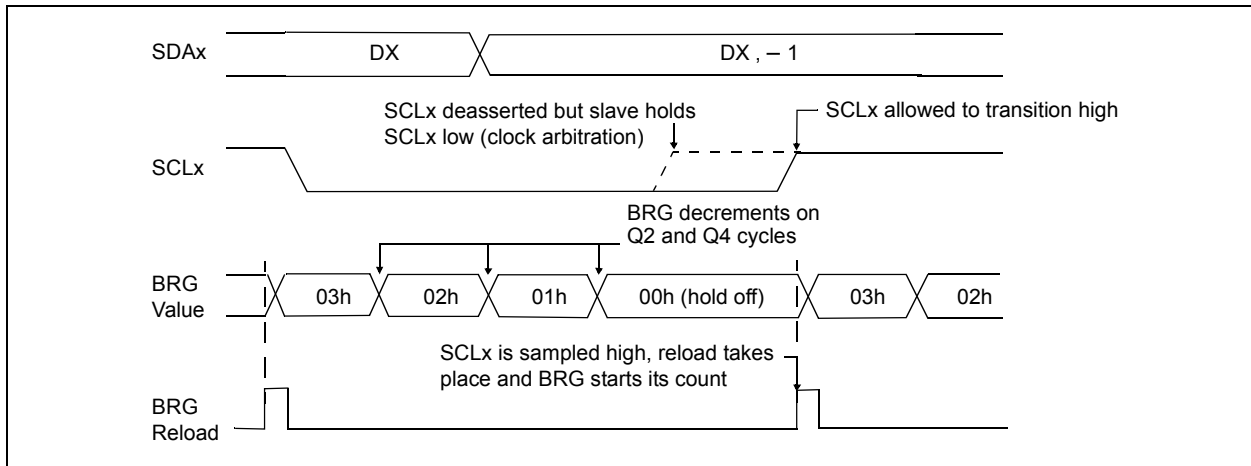
In Master Receive mode, the first byte transmitted contains the slave address of the transmitting device (7 bits) and the R/W bit. In this case, the R/W bit will be logic '1'. Thus, the first byte transmitted is a 7-bit slave address followed by a '1' to indicate the receive bit. Serial data is received via SDAx, while SCLx 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.

A Baud Rate Generator is used to set the clock frequency output on SCLx. See [Section 21.7 "Baud Rate Generator"](#) for more detail.

21.6.2 CLOCK ARBITRATION

Clock arbitration occurs when the master, during any receive, transmit or Repeated Start/Stop condition, releases the SCLx pin (SCLx allowed to float high). When the SCLx pin is allowed to float high, the Baud Rate Generator (BRG) is suspended from counting until the SCLx pin is actually sampled high. When the SCLx pin is sampled high, the Baud Rate Generator is reloaded with the contents of SSPxADD<7:0> and begins counting. This ensures that the SCLx 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 21-25).

FIGURE 21-25: BAUD RATE GENERATOR TIMING WITH CLOCK ARBITRATION



21.6.3 WCOL STATUS FLAG

If the user writes the SSPxBUF when a Start, Restart, Stop, Receive or Transmit sequence is in progress, the WCOL is set and the contents of the buffer are unchanged (the write does not occur). Any time the WCOL bit is set it indicates that an action on SSPxBUF was attempted while the module was not Idle.

Note: Because queueing of events is not allowed, writing to the lower 5 bits of SSPxCON2 is disabled until the Start condition is complete.

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21.6.4 I²C MASTER MODE START CONDITION TIMING

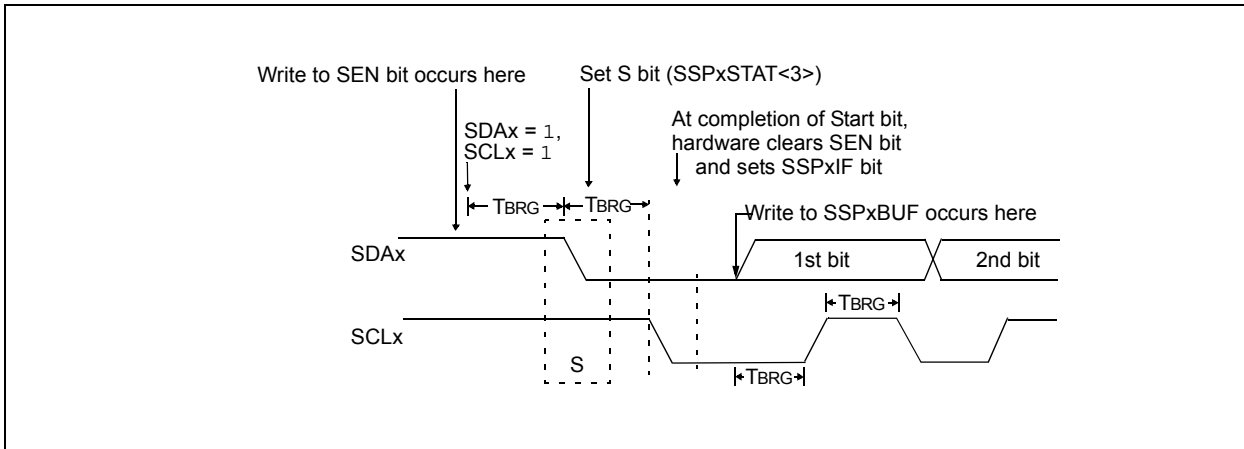
To initiate a Start condition, the user sets the Start Enable bit, SEN bit of the SSPxCON2 register. If the SDAx and SCLx pins are sampled high, the Baud Rate Generator is reloaded with the contents of SSPxADD<7:0> and starts its count. If SCLx and SDAx are both sampled high when the Baud Rate Generator times out (TBRG), the SDAx pin is driven low. The action of the SDAx being driven low while SCLx is high is the Start condition and causes the S bit of the SSPxSTAT1 register to be set. Following this, the Baud Rate Generator is reloaded with the contents of SSPxADD<7:0> and resumes its count. When the Baud Rate Generator times out (TBRG), the SEN bit of the SSPxCON2 register will be automatically cleared

by hardware; the Baud Rate Generator is suspended, leaving the SDAx line held low and the Start condition is complete.

Note 1: If at the beginning of the Start condition, the SDAx and SCLx pins are already sampled low, or if during the Start condition, the SCLx line is sampled low before the SDAx line is driven low, a bus collision occurs, the Bus Collision Interrupt Flag, BCLxIF, is set, the Start condition is aborted and the I²C module is reset into its Idle state.

2: The Philips I²C Specification states that a bus collision cannot occur on a Start.

FIGURE 21-26: FIRST START BIT TIMING



21.6.5 I²C MASTER MODE REPEATED START CONDITION TIMING

A Repeated Start condition occurs when the RSEN bit of the SSPxCON2 register is programmed high and the master state machine is no longer active. When the RSEN bit is set, the SCLx pin is asserted low. When the SCLx pin is sampled low, the Baud Rate Generator is loaded and begins counting. The SDAx pin is released (brought high) for one Baud Rate Generator count (TBRG). When the Baud Rate Generator times out, if SDAx is sampled high, the SCLx pin will be deasserted (brought high). When SCLx is sampled high, the Baud Rate Generator is reloaded and begins counting. SDAx and SCLx must be sampled high for one TBRG. This action is then followed by assertion of the SDAx pin (SDAx = 0) for one TBRG while SCLx is high. SCLx is asserted low. Following this, the RSEN bit of the

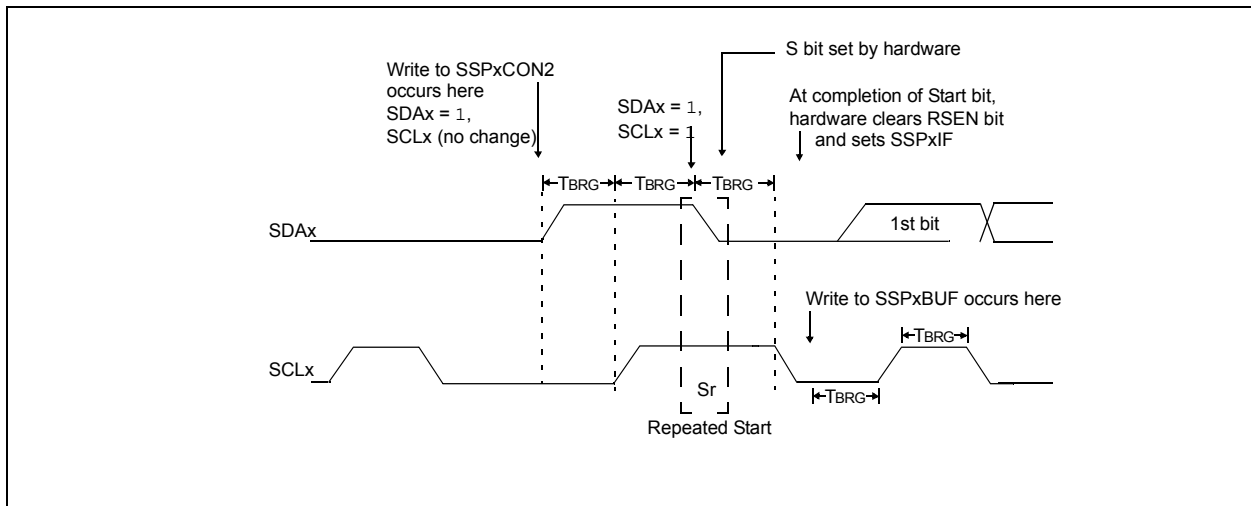
SSPxCON2 register will be automatically cleared and the Baud Rate Generator will not be reloaded, leaving the SDAx pin held low. As soon as a Start condition is detected on the SDAx and SCLx pins, the S bit of the SSPxSTAT register will be set. The SSPxIF bit will not be set until the Baud Rate Generator 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:

- SDAx is sampled low when SCLx goes from low-to-high.
- SCLx goes low before SDAx is asserted low. This may indicate that another master is attempting to transmit a data '1'.

FIGURE 21-27: REPEAT START CONDITION WAVEFORM



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21.6.6 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 SSPxBUF 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 SDAx pin after the falling edge of SCLx is asserted. SCLx is held low for one Baud Rate Generator rollover count (TBRG). Data should be valid before SCLx is released high. When the SCLx pin is released high, it is held that way for TBRG. The data on the SDAx pin must remain stable for that duration and some hold time after the next falling edge of SCLx. After the eighth bit is shifted out (the falling edge of the eighth clock), the BF flag is cleared and the master releases SDAx. 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 $\overline{\text{ACK}}$ is written into the ACKSTAT bit on the rising 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 SSPxIF bit is set and the master clock (Baud Rate Generator) is suspended until the next data byte is loaded into the SSPxBUF, leaving SCLx low and SDAx unchanged (Figure 21-27).

After the write to the SSPxBUF, each bit of the address will be shifted out on the falling edge of SCLx until all seven address bits and the R/W bit are completed. On the falling edge of the eighth clock, the master will release the SDAx pin, allowing the slave to respond with an Acknowledge. On the falling edge of the ninth clock, the master will sample the SDAx pin to see if the address was recognized by a slave. The status of the $\overline{\text{ACK}}$ bit is loaded into the ACKSTAT Status bit of the SSPxCON2 register. Following the falling edge of the ninth clock transmission of the address, the SSPxIF is set, the BF flag is cleared and the Baud Rate Generator is turned off until another write to the SSPxBUF takes place, holding SCLx low and allowing SDAx to float.

21.6.6.1 BF Status Flag

In Transmit mode, the BF bit of the SSPxSTAT register is set when the CPU writes to SSPxBUF and is cleared when all 8 bits are shifted out.

21.6.6.2 WCOL Status Flag

If the user writes the SSPxBUF when a transmit is already in progress (i.e., SSPxSR is still shifting out a data byte), the WCOL is set and the contents of the buffer are unchanged (the write does not occur).

WCOL must be cleared by software before the next transmission.

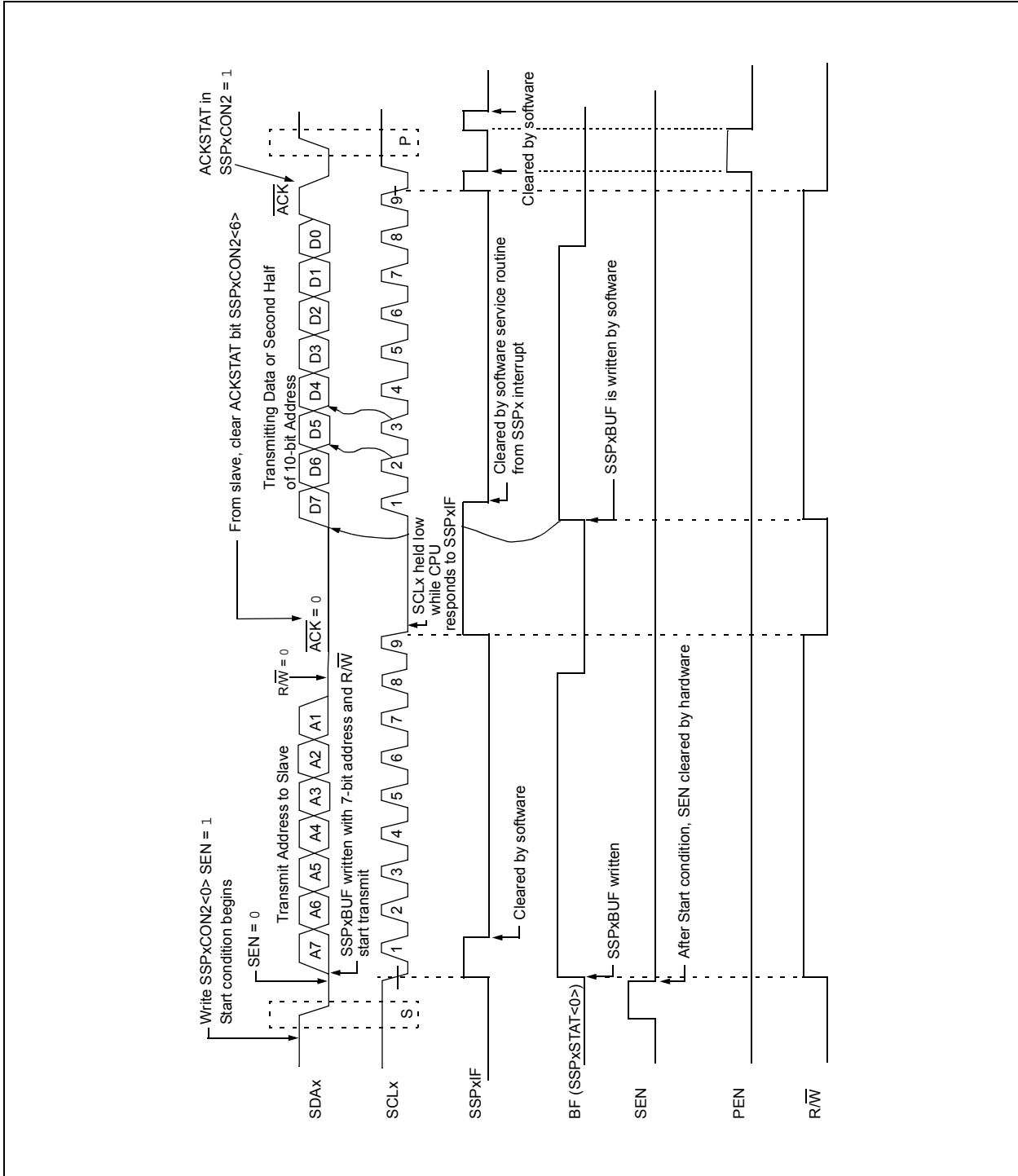
21.6.6.3 ACKSTAT Status Flag

In Transmit mode, the ACKSTAT bit of the SSPxCON2 register is cleared when the slave has sent an Acknowledge ($\text{ACK} = 0$) and is set when the slave does not Acknowledge ($\text{ACK} = 1$). A slave sends an Acknowledge when it has recognized its address (including a general call), or when the slave has properly received its data.

21.6.6.4 Typical transmit sequence:

1. The user generates a Start condition by setting the SEN bit of the SSPxCON2 register.
2. SSPxIF is set by hardware on completion of the Start.
3. SSPxIF is cleared by software.
4. The MSSPx module will wait the required start time before any other operation takes place.
5. The user loads the SSPxBUF with the slave address to transmit.
6. Address is shifted out the SDAx pin until all 8 bits are transmitted. Transmission begins as soon as SSPxBUF is written to.
7. The MSSPx module shifts in the $\overline{\text{ACK}}$ bit from the slave device and writes its value into the ACKSTAT bit of the SSPxCON2 register.
8. The MSSPx module generates an interrupt at the end of the ninth clock cycle by setting the SSPxIF bit.
9. The user loads the SSPxBUF with eight bits of data.
10. Data is shifted out the SDAx pin until all 8 bits are transmitted.
11. The MSSPx module shifts in the $\overline{\text{ACK}}$ bit from the slave device and writes its value into the ACKSTAT bit of the SSPxCON2 register.
12. Steps 8-11 are repeated for all transmitted data bytes.
13. The user generates a Stop or Restart condition by setting the PEN or RSEN bits of the SSPxCON2 register. Interrupt is generated once the Stop/Restart condition is complete.

FIGURE 21-28: I²C MASTER MODE WAVEFORM (TRANSMISSION, 7 OR 10-BIT ADDRESS)



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21.6.7 I²C MASTER MODE RECEPTION

Master mode reception is enabled by programming the Receive Enable bit, RCEN bit of the SSPxCON2 register.

Note: The MSSPx module must be in an Idle state before the RCEN bit is set or the RCEN bit will be disregarded.

The Baud Rate Generator begins counting and on each rollover, the state of the SCLx pin changes (high-to-low/low-to-high) and data is shifted into the SSPxSR. After the falling edge of the eighth clock, the receive enable flag is automatically cleared, the contents of the SSPxSR are loaded into the SSPxBUF, the BF flag bit is set, the SSPxIF flag bit is set and the Baud Rate Generator is suspended from counting, holding SCLx low. The MSSPx 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, ACKEN bit of the SSPxCON2 register.

21.6.7.1 BF Status Flag

In receive operation, the BF bit is set when an address or data byte is loaded into SSPxBUF from SSPxSR. It is cleared when the SSPxBUF register is read.

21.6.7.2 SSPxOV Status Flag

In receive operation, the SSPxOV bit is set when 8 bits are received into the SSPxSR and the BF flag bit is already set from a previous reception.

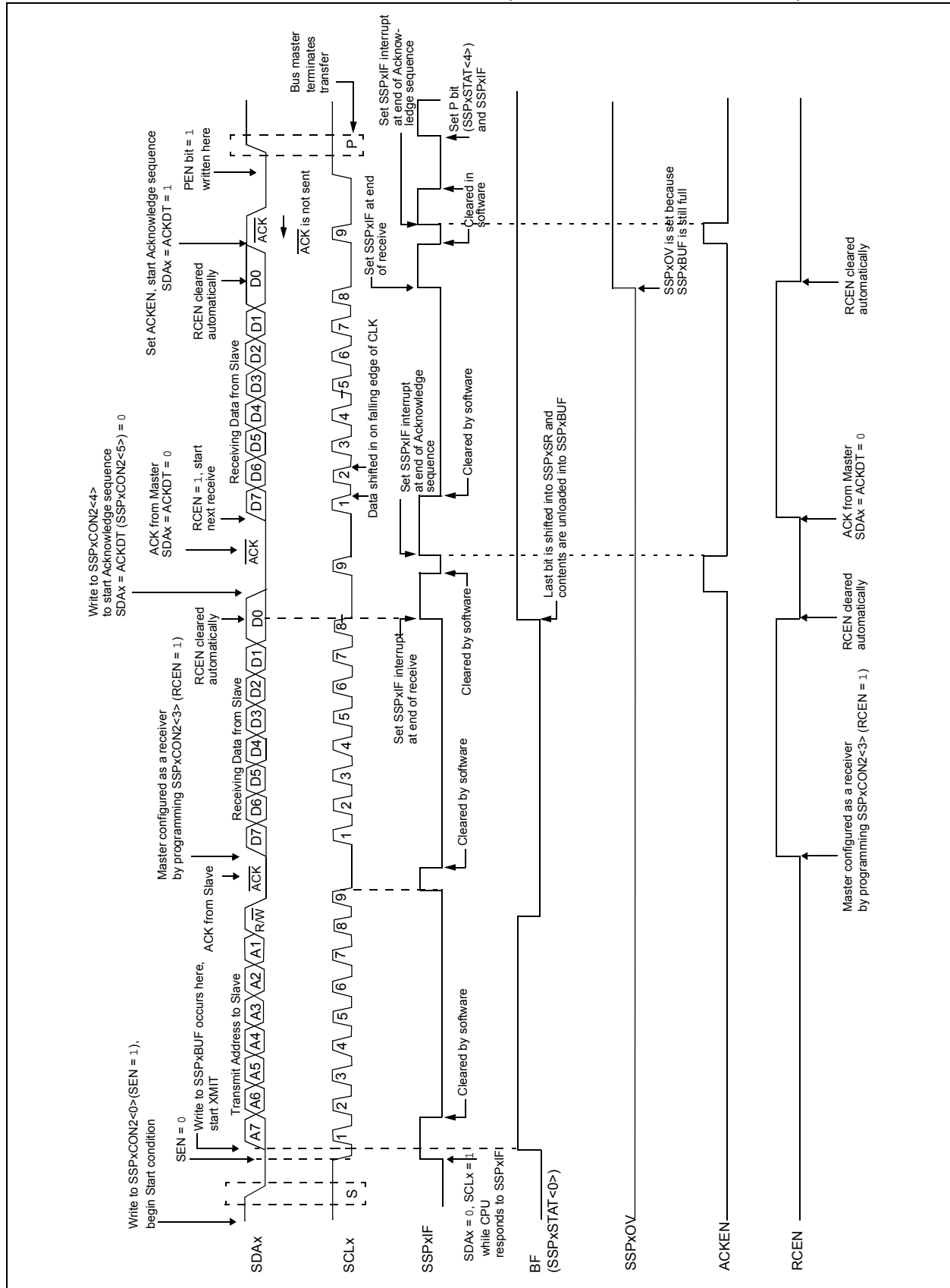
21.6.7.3 WCOL Status Flag

If the user writes the SSPxBUF when a receive is already in progress (i.e., SSPxSR is still shifting in a data byte), the WCOL bit is set and the contents of the buffer are unchanged (the write does not occur).

21.6.7.4 Typical Receive Sequence:

1. The user generates a Start condition by setting the SEN bit of the SSPxCON2 register.
2. SSPxIF is set by hardware on completion of the Start.
3. SSPxIF is cleared by software.
4. User writes SSPxBUF with the slave address to transmit and the R/W bit set.
5. Address is shifted out the SDAx pin until all 8 bits are transmitted. Transmission begins as soon as SSPxBUF is written to.
6. The MSSPx module shifts in the $\overline{\text{ACK}}$ bit from the slave device and writes its value into the ACKSTAT bit of the SSPxCON2 register.
7. The MSSPx module generates an interrupt at the end of the ninth clock cycle by setting the SSPxIF bit.
8. User sets the RCEN bit of the SSPxCON2 register and the master clocks in a byte from the slave.
9. After the 8th falling edge of SCLx, SSPxIF and BF are set.
10. Master clears SSPxIF and reads the received byte from SSPxUF, clears BF.
11. Master sets $\overline{\text{ACK}}$ value sent to slave in ACKDT bit of the SSPxCON2 register and initiates the $\overline{\text{ACK}}$ by setting the ACKEN bit.
12. Masters $\overline{\text{ACK}}$ is clocked out to the slave and SSPxIF is set.
13. User clears SSPxIF.
14. Steps 8-13 are repeated for each received byte from the slave.
15. Master sends a not $\overline{\text{ACK}}$ or Stop to end communication.

FIGURE 21-29: I²C MASTER MODE WAVEFORM (RECEPTION, 7-BIT ADDRESS)



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21.6.8 ACKNOWLEDGE SEQUENCE TIMING

An Acknowledge sequence is enabled by setting the Acknowledge Sequence Enable bit, ACKEN bit of the SSPxCON2 register. When this bit is set, the SCLx pin is pulled low and the contents of the Acknowledge data bit are presented on the SDAx 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 SCLx pin is deasserted (pulled high). When the SCLx pin is sampled high (clock arbitration), the Baud Rate Generator counts for TBRG. The SCLx pin is then pulled low. Following this, the ACKEN bit is automatically cleared, the Baud Rate Generator is turned off and the MSSPx module then goes into Idle mode (Figure 21-29).

21.6.8.1 WCOL Status Flag

If the user writes the SSPxBUF when an Acknowledge sequence is in progress, then WCOL is set and the contents of the buffer are unchanged (the write does not occur).

21.6.9 STOP CONDITION TIMING

A Stop bit is asserted on the SDAx pin at the end of a receive/transmit by setting the Stop Sequence Enable bit, PEN bit of the SSPxCON2 register. At the end of a receive/transmit, the SCLx line is held low after the falling edge of the ninth clock. When the PEN bit is set, the master will assert the SDAx line low. When the SDAx line is sampled low, the Baud Rate Generator is reloaded and counts down to '0'. When the Baud Rate Generator times out, the SCLx pin will be brought high and one TBRG (Baud Rate Generator rollover count) later, the SDAx pin will be deasserted. When the SDAx pin is sampled high while SCLx is high, the P bit of the SSPxSTAT register is set. A TBRG later, the PEN bit is cleared and the SSPxIF bit is set (Figure 21-30).

21.6.9.1 WCOL Status Flag

If the user writes the SSPxBUF 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 21-30: ACKNOWLEDGE SEQUENCE WAVEFORM

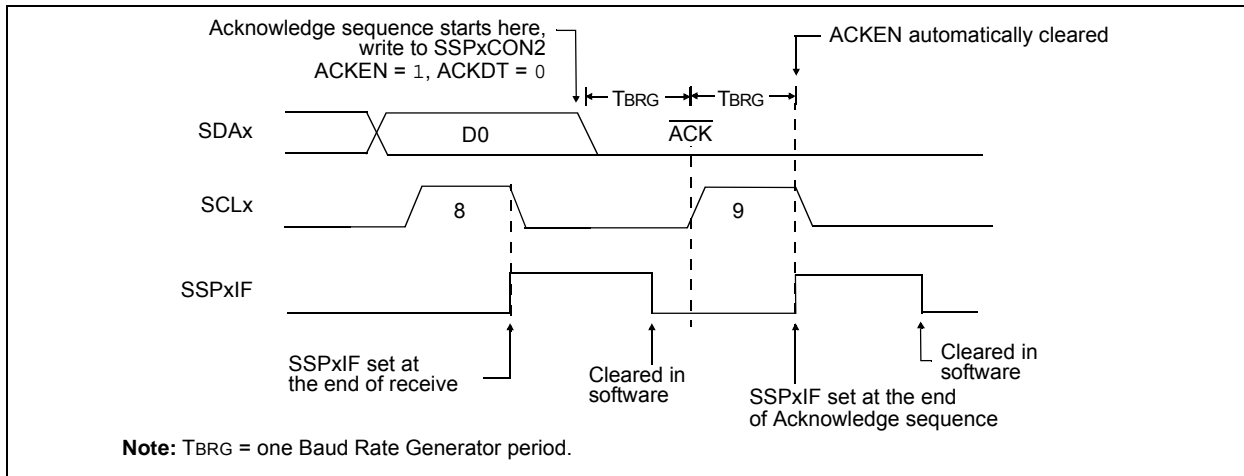
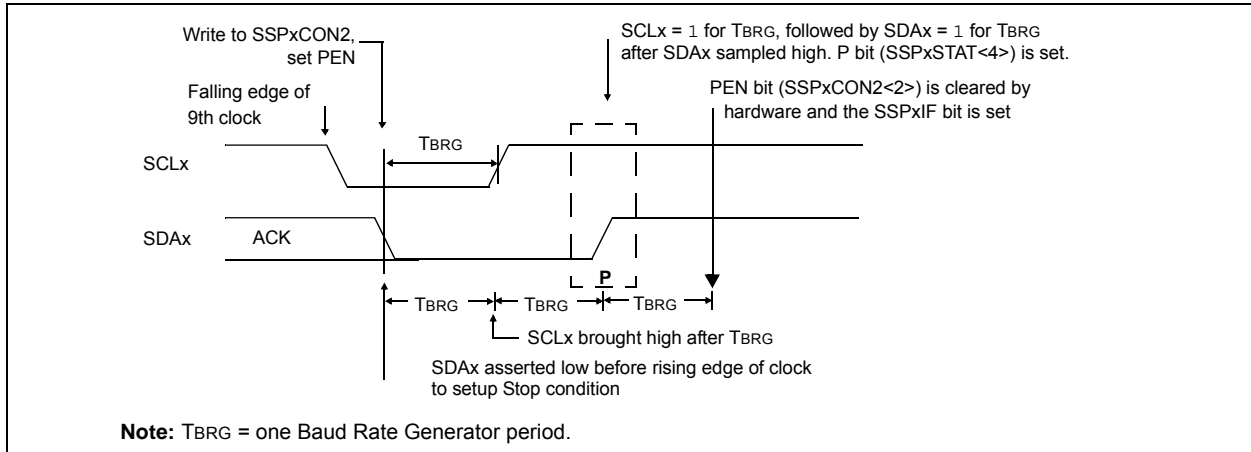


FIGURE 21-31: STOP CONDITION RECEIVE OR TRANSMIT MODE



21.6.10 SLEEP OPERATION

While in Sleep mode, the I²C slave module can receive addresses or data and when an address match or complete byte transfer occurs, wake the processor from Sleep (if the MSSPx interrupt is enabled).

21.6.11 EFFECTS OF A RESET

A Reset disables the MSSPx module and terminates the current transfer.

21.6.12 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 MSSPx module is disabled. Control of the I²C bus may be taken when the P bit of the SSPxSTAT register is set, or the bus is Idle, with both the S and P bits clear. When the bus is busy, enabling the SSPx interrupt will generate the interrupt when the Stop condition occurs.

In multi-master operation, the SDAx line must be monitored for arbitration to see if the signal level is the expected output level. This check is performed by hardware with the result placed in the BCLxIF bit.

The states where arbitration can be lost are:

- Address Transfer
- Data Transfer
- A Start Condition
- A Repeated Start Condition
- An Acknowledge Condition

21.6.13 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 SDAx pin, arbitration takes place when the master outputs a '1' on SDAx, by letting SDAx float high and another master asserts a '0'. When the SCLx pin floats high, data should be stable. If the expected data on SDAx is a '1' and the data sampled on the SDAx pin is '0', then a bus collision has taken place. The master will set the Bus Collision Interrupt Flag, BCLxIF and reset the I²C port to its Idle state (Figure 21-31).

If a transmit was in progress when the bus collision occurred, the transmission is halted, the BF flag is cleared, the SDAx and SCLx lines are deasserted and the SSPxBUF can be written to. When the user services the bus collision Interrupt Service Routine and if the I²C 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 SDAx and SCLx lines are deasserted and the respective control bits in the SSPxCON2 register are cleared. When the user services the bus collision Interrupt Service Routine and if the I²C bus is free, the user can resume communication by asserting a Start condition.

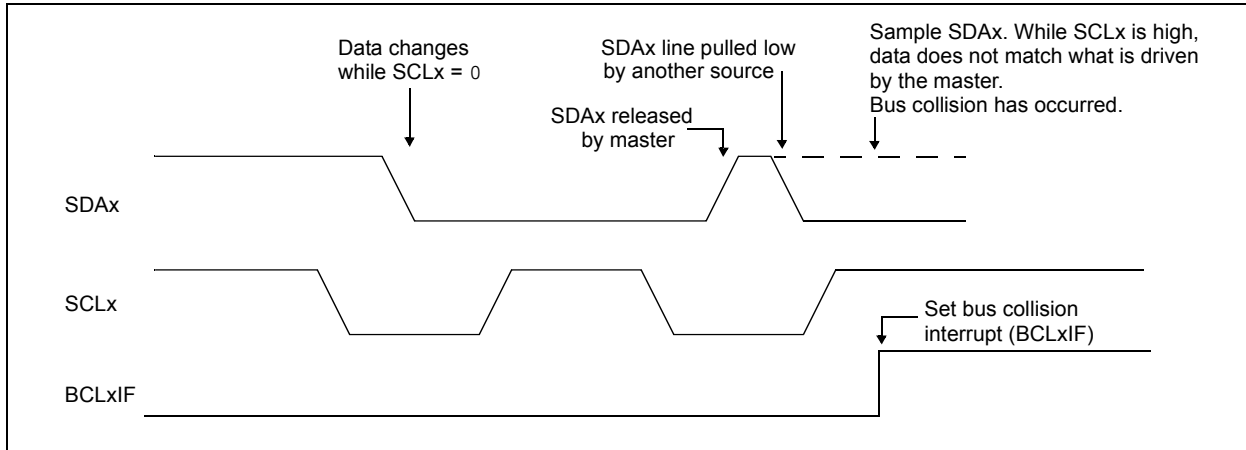
The master will continue to monitor the SDAx and SCLx pins. If a Stop condition occurs, the SSPxIF bit will be set.

A write to the SSPxBUF 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 I²C bus can be taken when the P bit is set in the SSPxSTAT register, or the bus is Idle and the S and P bits are cleared.

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FIGURE 21-32: BUS COLLISION TIMING FOR TRANSMIT AND ACKNOWLEDGE



21.6.13.1 Bus Collision During a Start Condition

During a Start condition, a bus collision occurs if:

- SDAx or SCLx are sampled low at the beginning of the Start condition (Figure 21-32).
- SCLx is sampled low before SDAx is asserted low (Figure 21-33).

During a Start condition, both the SDAx and the SCLx pins are monitored.

If the SDAx pin is already low, or the SCLx pin is already low, then all of the following occur:

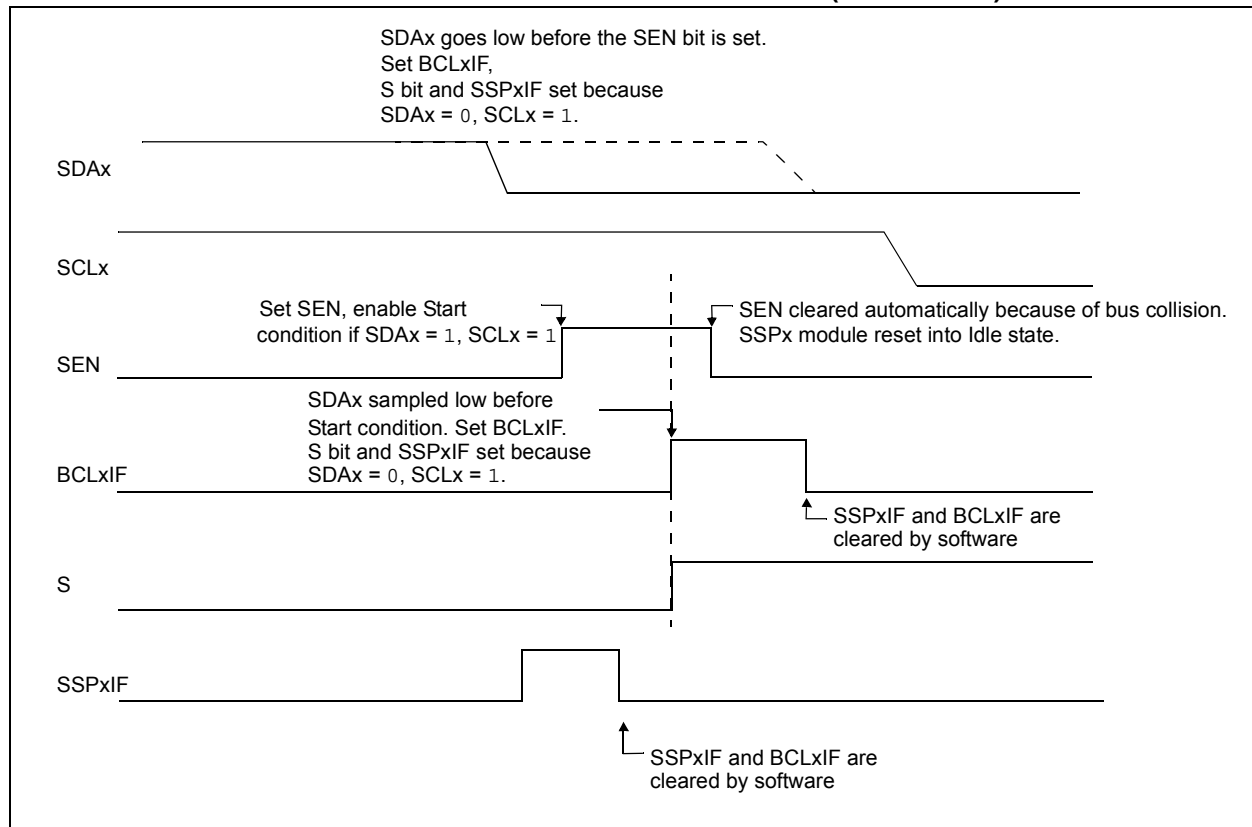
- the Start condition is aborted,
- the BCLxIF flag is set and
- the MSSPx module is reset to its Idle state (Figure 21-32).

The Start condition begins with the SDAx and SCLx pins deasserted. When the SDAx pin is sampled high, the Baud Rate Generator is loaded and counts down. If the SCLx pin is sampled low while SDAx 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 SDAx pin is sampled low during this count, the BRG is reset and the SDAx line is asserted early (Figure 21-34). If, however, a '1' is sampled on the SDAx pin, the SDAx pin is asserted low at the end of the BRG count. The Baud Rate Generator is then reloaded and counts down to zero; if the SCLx pin is sampled as '0' during this time, a bus collision does not occur. At the end of the BRG count, the SCLx 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 SDAx 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 21-33: BUS COLLISION DURING START CONDITION (SDAx ONLY)



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FIGURE 21-34: BUS COLLISION DURING START CONDITION (SCLX = 0)

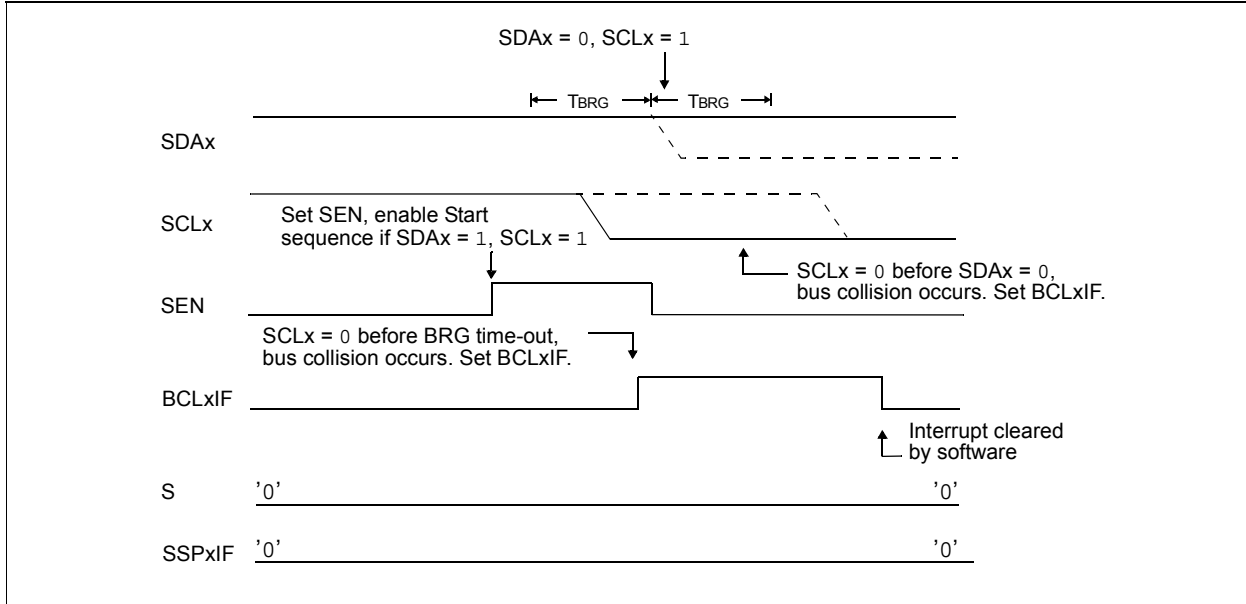
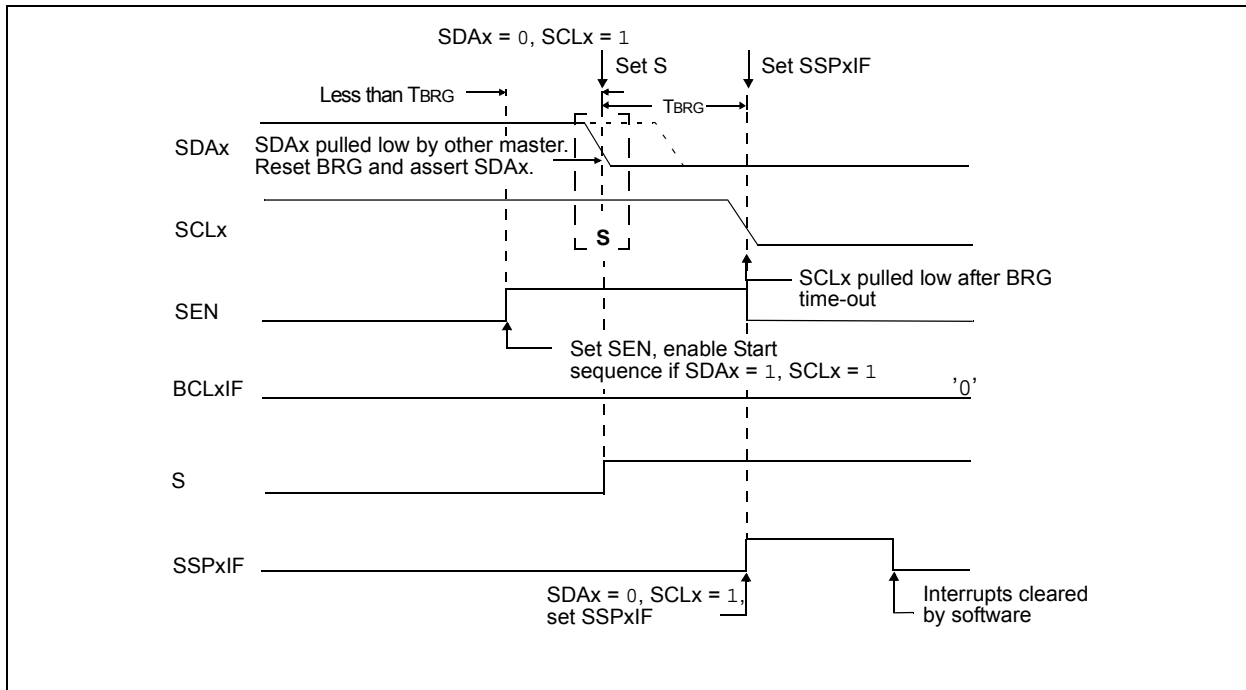


FIGURE 21-35: BRG RESET DUE TO SDA ARBITRATION DURING START CONDITION



21.6.13.2 Bus Collision During a Repeated Start Condition

During a Repeated Start condition, a bus collision occurs if:

- A low level is sampled on SDAx when SCLx goes from low level to high level.
- SCLx goes low before SDAx is asserted low, indicating that another master is attempting to transmit a data '1'.

When the user releases SDAx and the pin is allowed to float high, the BRG is loaded with SSPxADD and counts down to zero. The SCLx pin is then deasserted and when sampled high, the SDAx pin is sampled.

If SDAx is low, a bus collision has occurred (i.e., another master is attempting to transmit a data '0', [Figure 21-35](#)). If SDAx is sampled high, the BRG is reloaded and begins counting. If SDAx goes from high-to-low before the BRG times out, no bus collision occurs because no two masters can assert SDAx at exactly the same time.

If SCLx goes from high-to-low before the BRG times out and SDAx 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 21-36](#).

If, at the end of the BRG time-out, both SCLx and SDAx are still high, the SDAx pin is driven low and the BRG is reloaded and begins counting. At the end of the count, regardless of the status of the SCLx pin, the SCLx pin is driven low and the Repeated Start condition is complete.

FIGURE 21-36: BUS COLLISION DURING A REPEATED START CONDITION (CASE 1)

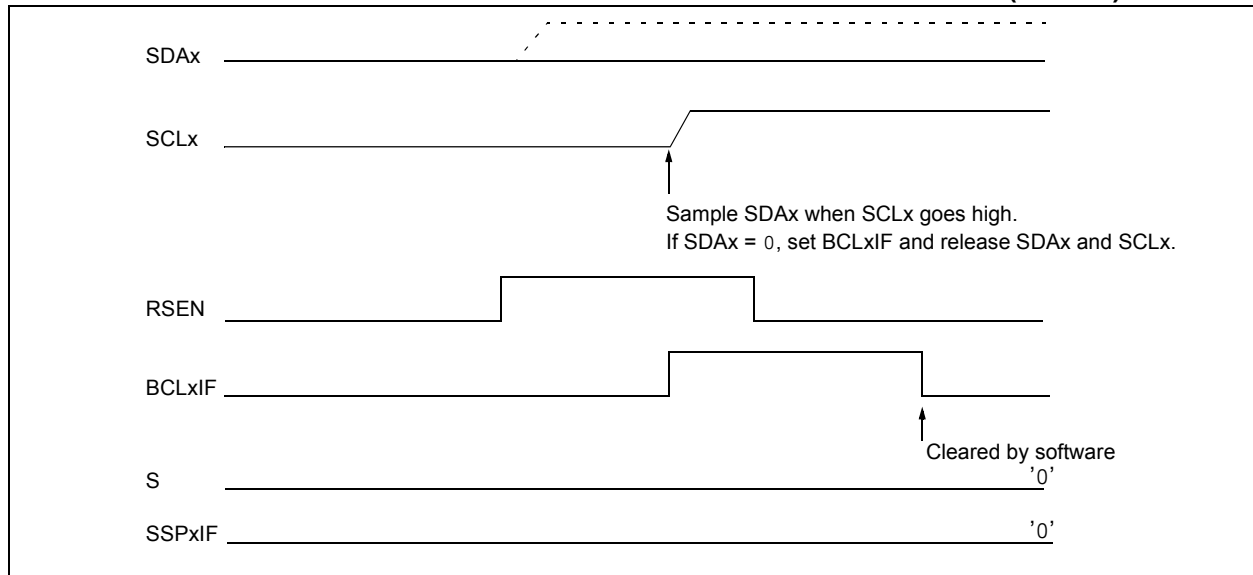
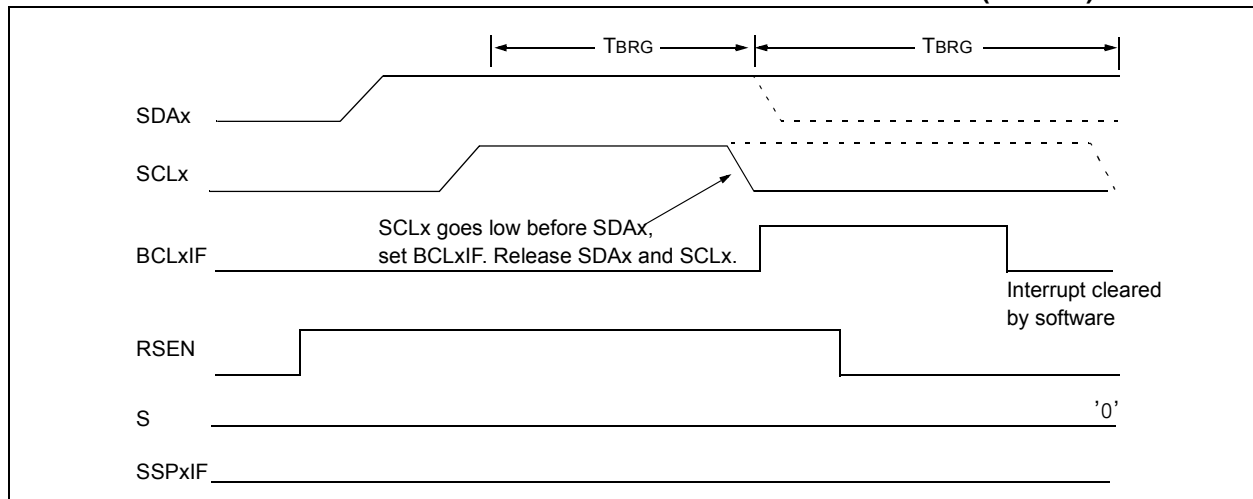


FIGURE 21-37: BUS COLLISION DURING REPEATED START CONDITION (CASE 2)



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21.6.13.3 Bus Collision During a Stop Condition

Bus collision occurs during a Stop condition if:

- a) After the SDAx pin has been deasserted and allowed to float high, SDAx is sampled low after the BRG has timed out.
- b) After the SCLx pin is deasserted, SCLx is sampled low before SDAx goes high.

The Stop condition begins with SDAx asserted low. When SDAx is sampled low, the SCLx pin is allowed to float. When the pin is sampled high (clock arbitration), the Baud Rate Generator is loaded with SSPxADD and counts down to 0. After the BRG times out, SDAx is sampled. If SDAx is sampled low, a bus collision has occurred. This is due to another master attempting to drive a data '0' (Figure 21-37). If the SCLx pin is sampled low before SDAx is allowed to float high, a bus collision occurs. This is another case of another master attempting to drive a data '0' (Figure 21-38).

FIGURE 21-38: BUS COLLISION DURING A STOP CONDITION (CASE 1)

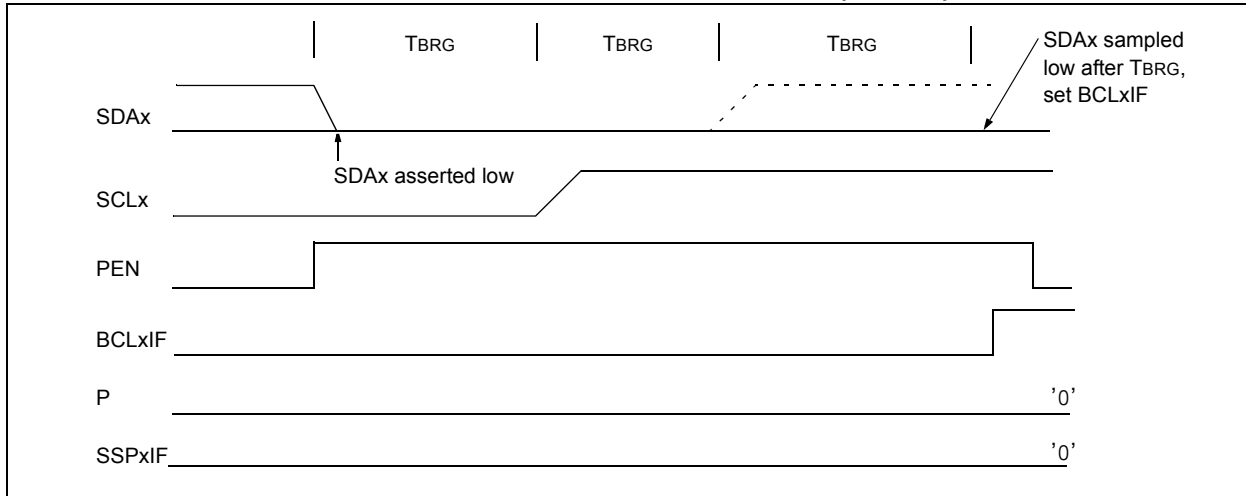


FIGURE 21-39: BUS COLLISION DURING A STOP CONDITION (CASE 2)

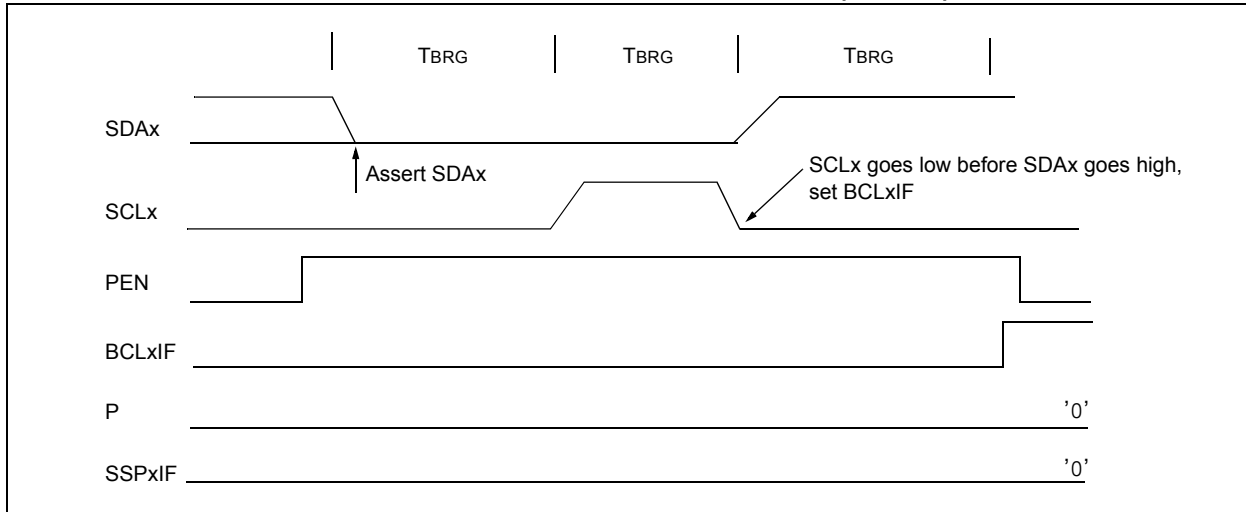


TABLE 21-3: SUMMARY OF REGISTERS ASSOCIATED WITH I²C™ OPERATION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Values on Page:
INTCON	GIE	PEIE	TMR0IE	INTE	IOCFIE	TMR0IF	INTF	IOCFIF	80
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	81
PIE2	OSFIE	TMR5GIE	TMR3GIE	—	BCL1IE	TMR10IE	TMR8IE	CCP2IE	82
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	84
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	85
PIR2	OSFIF	TMR5GIF	TMR3GIF	—	BCL1IF	TMR10IF	TMR8IF	CCP2IF	86
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	88
SSP1ADD	ADD<7:0>								254
SSP2ADD	ADD<7:0>								254
SSP1BUF	MSSPx Receive Buffer/Transmit Register								205*
SSP2BUF	MSSPx Receive Buffer/Transmit Register								205*
SSP1CON1	WCOL	SSPOV	SSPEN	CKP	SSPM<3:0>				251
SSP2CON1	WCOL	SSPOV	SSPEN	CKP	SSPM<3:0>				251
SSP1CON2	GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN	252
SSP2CON2	GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN	252
SSP1CON3	ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN	253
SSP2CON3	ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN	253
SSP1MSK	MSK<7:0>								254
SSP2MSK	MSK<7:0>								254
SSP1STAT	SMP	CKE	D \bar{A}	P	S	R \bar{W}	UA	BF	249
SSP2STAT	SMP	CKE	D \bar{A}	P	S	R \bar{W}	UA	BF	249
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	126
TRISD	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0	129

Legend: — = unimplemented location, read as '0'. Shaded cells are not used by the MSSP module in I²C™ mode.

* Page provides register information.

Note 1: PIC16(L)F1527 only.

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21.7 BAUD RATE GENERATOR

The MSSPx module has a Baud Rate Generator available for clock generation in both I²C and SPI Master modes. The Baud Rate Generator (BRG) reload value is placed in the SSPxADD register (Register 21-6). When a write occurs to SSPxBUF, the Baud Rate Generator will automatically begin counting down.

Once the given operation is complete, the internal clock will automatically stop counting and the clock pin will remain in its last state.

An internal signal “Reload” in Figure 21-39 triggers the value from SSPxADD to be loaded into the BRG counter. This occurs twice for each oscillation of the

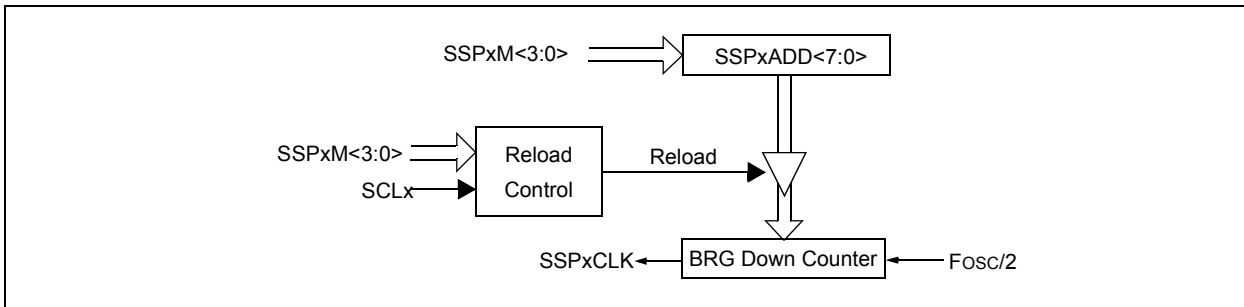
module clock line. The logic dictating when the reload signal is asserted depends on the mode the MSSPx is being operated in.

Table 21-4 demonstrates clock rates based on instruction cycles and the BRG value loaded into SSPxADD.

EQUATION 21-1:

$$F_{CLOCK} = \frac{F_{OSC}}{(SSPxADD + 1)(4)}$$

FIGURE 21-40: BAUD RATE GENERATOR BLOCK DIAGRAM



Note: Values of 0x00, 0x01 and 0x02 are not valid for SSPxADD when used as a Baud Rate Generator for I²C. This is an implementation limitation.

TABLE 21-4: MSSPX CLOCK RATE W/BRG

Fosc	Fcy	BRG Value	FCLOCK (2 Rollovers of BRG)
16 MHz	4 MHz	09h	400 kHz ⁽¹⁾
16 MHz	4 MHz	0Ch	308 kHz
16 MHz	4 MHz	27h	100 kHz
4 MHz	1 MHz	09h	100 kHz

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.

21.8 MSSP Control Registers

REGISTER 21-1: SSPxSTAT: SSPx STATUS REGISTER

R/W-0/0	R/W-0/0	R-0/0	R-0/0	R-0/0	R-0/0	R-0/0	R-0/0
SMP	CKE	D \bar{A}	P	S	R \bar{W}	UA	BF
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	<p>SMP: SPI Data Input Sample bit</p> <p><u>SPI Master mode:</u> 1 = Input data sampled at end of data output time 0 = Input data sampled at middle of data output time</p> <p><u>SPI Slave mode:</u> SMP must be cleared when SPI is used in Slave mode</p> <p><u>In I²C Master or Slave mode:</u> 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)</p>
bit 6	<p>CKE: SPI Clock Edge Select bit (SPI mode only)</p> <p><u>In SPI Master or Slave mode:</u> 1 = Transmit occurs on transition from active to Idle clock state 0 = Transmit occurs on transition from Idle to active clock state</p> <p><u>In I²C™ mode only:</u> 1 = Enable input logic so that thresholds are compliant with SMBus specification 0 = Disable SMBus specific inputs</p>
bit 5	<p>D\bar{A}: Data/Address bit (I²C mode only)</p> <p>1 = Indicates that the last byte received or transmitted was data 0 = Indicates that the last byte received or transmitted was address</p>
bit 4	<p>P: Stop bit</p> <p>(I²C mode only. This bit is cleared when the MSSPx module is disabled, SSPxEN is cleared.) 1 = Indicates that a Stop bit has been detected last (this bit is '0' on Reset) 0 = Stop bit was not detected last</p>
bit 3	<p>S: Start bit</p> <p>(I²C mode only. This bit is cleared when the MSSPx module is disabled, SSPxEN is cleared.) 1 = Indicates that a Start bit has been detected last (this bit is '0' on Reset) 0 = Start bit was not detected last</p>
bit 2	<p>R\bar{W}: Read/Write bit information (I²C mode only)</p> <p>This bit holds the R\bar{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.</p> <p><u>In I²C Slave mode:</u> 1 = Read 0 = Write</p> <p><u>In I²C Master mode:</u> 1 = Transmit is in progress 0 = Transmit is not in progress</p> <p>OR-ing this bit with SEN, RSEN, PEN, RCEN or ACKEN will indicate if the MSSPx is in Idle mode.</p>
bit 1	<p>UA: Update Address bit (10-bit I²C mode only)</p> <p>1 = Indicates that the user needs to update the address in the SSPxADD register 0 = Address does not need to be updated</p>

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REGISTER 21-1: SSPxSTAT: SSPx STATUS REGISTER (CONTINUED)

bit 0

BF: Buffer Full Status bit

Receive (SPI and I²C modes):

1 = Receive complete, SSPxBUF is full

0 = Receive not complete, SSPxBUF is empty

Transmit (I²C mode only):

1 = Data transmit in progress (does not include the $\overline{\text{ACK}}$ and Stop bits), SSPxBUF is full

0 = Data transmit complete (does not include the $\overline{\text{ACK}}$ and Stop bits), SSPxBUF is empty

REGISTER 21-2: SSPxCON1: SSPx CONTROL REGISTER 1

R/C/HS-0/0	R/C/HS-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
WCOL	SSPxOV	SSPxEN	CKP	SSPxM<3:0>			
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	HS = Bit is set by hardware C = User cleared

bit 7	<p>WCOL: Write Collision Detect bit</p> <p><u>Master mode:</u></p> <p>1 = A write to the SSPxBUF register was attempted while the I²C conditions were not valid for a transmission to be started</p> <p>0 = No collision</p> <p><u>Slave mode:</u></p> <p>1 = The SSPxBUF register is written while it is still transmitting the previous word (must be cleared in software)</p> <p>0 = No collision</p>
bit 6	<p>SSPxOV: Receive Overflow Indicator bit⁽¹⁾</p> <p><u>In SPI mode:</u></p> <p>1 = A new byte is received while the SSPxBUF register is still holding the previous data. In case of overflow, the data in SSPxSR is lost. Overflow can only occur in Slave mode. In Slave mode, the user must read the SSPxBUF, even if only transmitting data, to avoid setting overflow. In Master mode, the overflow bit is not set since each new reception (and transmission) is initiated by writing to the SSPxBUF register (must be cleared in software).</p> <p>0 = No overflow</p> <p><u>In I²C mode:</u></p> <p>1 = A byte is received while the SSPxBUF register is still holding the previous byte. SSPxOV is a "don't care" in Transmit mode (must be cleared in software).</p> <p>0 = No overflow</p>
bit 5	<p>SSPxEN: Synchronous Serial Port Enable bit</p> <p>In both modes, when enabled, these pins must be properly configured as input or output</p> <p><u>In SPI mode:</u></p> <p>1 = Enables serial port and configures SCKx, SDOx, SDIx and SSx as the source of the serial port pins⁽²⁾</p> <p>0 = Disables serial port and configures these pins as I/O port pins</p> <p><u>In I²C mode:</u></p> <p>1 = Enables the serial port and configures the SDAx and SCLx pins as the source of the serial port pins⁽³⁾</p> <p>0 = Disables serial port and configures these pins as I/O port pins</p>
bit 4	<p>CKP: Clock Polarity Select bit</p> <p><u>In SPI mode:</u></p> <p>1 = Idle state for clock is a high level</p> <p>0 = Idle state for clock is a low level</p> <p><u>In I²C Slave mode:</u></p> <p>SCLx release control</p> <p>1 = Enable clock</p> <p>0 = Holds clock low (clock stretch). (Used to ensure data setup time.)</p> <p><u>In I²C Master mode:</u></p> <p>Unused in this mode</p>
bit 3-0	<p>SSPxM<3:0>: Synchronous Serial Port Mode Select bits</p> <p>0000 = SPI Master mode, clock = Fosc/4</p> <p>0001 = SPI Master mode, clock = Fosc/16</p> <p>0010 = SPI Master mode, clock = Fosc/64</p> <p>0011 = SPI Master mode, clock = TMR2 output/2</p> <p>0100 = SPI Slave mode, clock = SCKx pin, SSx pin control enabled</p> <p>0101 = SPI Slave mode, clock = SCKx pin, SSx pin control disabled, SSx can be used as I/O pin</p> <p>0110 = I²C Slave mode, 7-bit address</p> <p>0111 = I²C Slave mode, 10-bit address</p> <p>1000 = I²C Master mode, clock = Fosc/(4 * (SSPxADD+1))⁽⁴⁾</p> <p>1001 = Reserved</p> <p>1010 = SPI Master mode, clock = Fosc/(4 * (SSPxADD+1))⁽⁵⁾</p> <p>1011 = I²C firmware controlled Master mode (Slave idle)</p> <p>1100 = Reserved</p> <p>1101 = Reserved</p> <p>1110 = I²C Slave mode, 7-bit address with Start and Stop bit interrupts enabled</p> <p>1111 = I²C Slave mode, 10-bit address with Start and Stop bit interrupts enabled</p>

- Note**
- 1: In Master mode, the overflow bit is not set since each new reception (and transmission) is initiated by writing to the SSPxBUF register.
 - 2: When enabled, these pins must be properly configured as input or output.
 - 3: When enabled, the SDAx and SCLx pins must be configured as inputs.
 - 4: SSPxADD values of 0, 1 or 2 are not supported for I²C mode.
 - 5: SSPxADD value of '0' is not supported. Use SSPxM = 0000 instead.

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REGISTER 21-3: SSPxCON2: SSPx CONTROL REGISTER 2

R/W-0/0	R-0/0	R/W-0/0	R/S/HS-0/0	R/S/HS-0/0	R/S/HS-0/0	R/S/HS-0/0	R/W/HS-0/0
GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN
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	HC = Cleared by hardware S = User set

- bit 7 **GCEN:** General Call Enable bit (in I²C Slave mode only)
 1 = Enable interrupt when a general call address (0x00 or 00h) is received in the SSPxSR
 0 = General call address disabled
- bit 6 **ACKSTAT:** Acknowledge Status bit (in I²C mode only)
 1 = Acknowledge was not received
 0 = Acknowledge was received
- bit 5 **ACKDT:** Acknowledge Data bit (in I²C mode only)
In Receive mode:
 Value transmitted when the user initiates an Acknowledge sequence at the end of a receive
 1 = Not Acknowledge
 0 = Acknowledge
- bit 4 **ACKEN:** Acknowledge Sequence Enable bit (in I²C Master mode only)
In Master Receive mode:
 1 = Initiate Acknowledge sequence on SDAx and SCLx pins, and transmit ACKDT data bit.
 Automatically cleared by hardware.
 0 = Acknowledge sequence Idle
- bit 3 **RCEN:** Receive Enable bit (in I²C Master mode only)
 1 = Enables Receive mode for I²C
 0 = Receive Idle
- bit 2 **PEN:** Stop Condition Enable bit (in I²C Master mode only)
SCKx Release Control:
 1 = Initiate Stop condition on SDAx and SCLx pins. Automatically cleared by hardware.
 0 = Stop condition Idle
- bit 1 **RSEN:** Repeated Start Condition Enabled bit (in I²C Master mode only)
 1 = Initiate Repeated Start condition on SDAx and SCLx pins. Automatically cleared by hardware.
 0 = Repeated Start condition Idle
- bit 0 **SEN:** Start Condition Enabled bit (in I²C Master mode only)
In Master mode:
 1 = Initiate Start condition on SDAx and SCLx pins. Automatically cleared by hardware.
 0 = Start condition Idle
In Slave mode:
 1 = Clock stretching is enabled for both slave transmit and slave receive (stretch enabled)
 0 = Clock stretching is disabled

Note 1: For bits ACKEN, RCEN, PEN, RSEN, SEN: If the I²C module is not in the Idle mode, this bit may not be set (no spooling) and the SSPxBUF may not be written (or writes to the SSPxBUF are disabled).

REGISTER 21-4: SSPxCON3: SSPx CONTROL REGISTER 3

R-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
ACKTIM	PCIE	SCIE	BOEN	SDAHT	SBCDE	AHEN	DHEN
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 **ACKTIM:** Acknowledge Time Status bit (I²C mode only)⁽³⁾
 1 = Indicates the I²C bus is in an Acknowledge sequence, set on 8TH falling edge of SCLx clock
 0 = Not an Acknowledge sequence, cleared on 9TH rising edge of SCLx clock
- bit 6 **PCIE:** Stop Condition Interrupt Enable bit (I²C mode only)
 1 = Enable interrupt on detection of Stop condition
 0 = Stop detection interrupts are disabled⁽²⁾
- bit 5 **SCIE:** Start Condition Interrupt Enable bit (I²C mode only)
 1 = Enable interrupt on detection of Start or Restart conditions
 0 = Start detection interrupts are disabled⁽²⁾
- bit 4 **BOEN:** Buffer Overwrite Enable bit
In SPI Slave mode:⁽¹⁾
 1 = SSPxBUF updates every time that a new data byte is shifted in ignoring the BF bit
 0 = If new byte is received with BF bit of the SSPxSTAT register already set, SSPxOV bit of the SSPxCON1 register is set, and the buffer is not updated
In I²C Master mode and SPI Master mode:
 This bit is ignored.
In I²C Slave mode:
 1 = SSPxBUF is updated and $\overline{\text{ACK}}$ is generated for a received address/data byte, ignoring the state of the SSPxOV bit only if the BF bit = 0.
 0 = SSPxBUF is only updated when SSPxOV is clear
- bit 3 **SDAHT:** SDAx Hold Time Selection bit (I²C mode only)
 1 = Minimum of 300 ns hold time on SDAx after the falling edge of SCLx
 0 = Minimum of 100 ns hold time on SDAx after the falling edge of SCLx
- bit 2 **SBCDE:** Slave Mode Bus Collision Detect Enable bit (I²C Slave mode only)
 If on the rising edge of SCLx, SDAx is sampled low when the module is outputting a high state, the BCLxIF bit of the PIR2 register is set, and bus goes Idle
 1 = Enable slave bus collision interrupts
 0 = Slave bus collision interrupts are disabled
- bit 1 **AHEN:** Address Hold Enable bit (I²C Slave mode only)
 1 = Following the 8th falling edge of SCLx for a matching received address byte; CKP bit of the SSPxCON1 register will be cleared and the SCLx will be held low.
 0 = Address holding is disabled
- bit 0 **DHEN:** Data Hold Enable bit (I²C Slave mode only)
 1 = Following the 8th falling edge of SCLx for a received data byte; slave hardware clears the CKP bit of the SSPxCON1 register and SCLx is held low.
 0 = Data holding is disabled

- Note 1:** For daisy-chained SPI operation; allows the user to ignore all but the last received byte. SSPxOV is still set when a new byte is received and BF = 1, but hardware continues to write the most recent byte to SSPxBUF.
- 2:** This bit has no effect in Slave modes that Start and Stop condition detection is explicitly listed as enabled.
- 3:** The ACKTIM Status bit is only active when the AHEN bit or DHEN bit is set.

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REGISTER 21-5: SSPxMSK: SSPx MASK 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
MSK<7:0>							
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 7-1 **MSK<7:1>**: Mask bits

- 1 = The received address bit n is compared to SSPxADD<n> to detect I²C address match
- 0 = The received address bit n is not used to detect I²C address match

bit 0 **MSK<0>**: Mask bit for I²C Slave mode, 10-bit Address

I²C Slave mode, 10-bit address (SSPxM<3:0> = 0111 or 1111):

- 1 = The received address bit 0 is compared to SSPxADD<0> to detect I²C address match
- 0 = The received address bit 0 is not used to detect I²C address match

I²C Slave mode, 7-bit address, the bit is ignored

REGISTER 21-6: SSPxADD: MSSPx ADDRESS AND BAUD RATE REGISTER (I²C MODE)

R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
ADD<7:0>							
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	

Master mode:

bit 7-0 **ADD<7:0>**: Baud Rate Clock Divider bits
 $SCLx \text{ pin clock period} = ((ADD<7:0> + 1) * 4) / F_{osc}$

10-Bit Slave mode — Most Significant Address byte:

bit 7-3 **Not used**: Unused for Most Significant Address byte. Bit state of this register is a “don't care”. Bit pattern sent by master is fixed by I²C specification and must be equal to '11110'. However, those bits are compared by hardware and are not affected by the value in this register.

bit 2-1 **ADD<2:1>**: Two Most Significant bits of 10-bit address

bit 0 **Not used**: Unused in this mode. Bit state is a “don't care”.

10-Bit Slave mode — Least Significant Address byte:

bit 7-0 **ADD<7:0>**: Eight Least Significant bits of 10-bit address

7-Bit Slave mode:

bit 7-1 **ADD<7:1>**: 7-bit address

bit 0 **Not used**: Unused in this mode. Bit state is a “don't care”.

22.0 ENHANCED UNIVERSAL SYNCHRONOUS ASYNCHRONOUS RECEIVER TRANSMITTER (EUSART)

Note: The PIC16(L)F1526/27 devices have two EUSARTs. Therefore, all information in this section refers to both EUSART 1 and EUSART 2.

The Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) module is a serial I/O communications peripheral. It contains all the clock generators, shift registers and data buffers necessary to perform an input or output serial data transfer independent of device program execution. The EUSART, also known as a Serial Communications Interface (SCI), can be configured as a full-duplex asynchronous system or half-duplex synchronous system. Full-Duplex mode is useful for communications with peripheral systems, such as CRT terminals and personal computers. Half-Duplex Synchronous mode is intended for communications with peripheral devices, such as A/D or D/A integrated circuits, serial EEPROMs or other microcontrollers.

These devices typically do not have internal clocks for baud rate generation and require the external clock signal provided by a master synchronous device.

The EUSART module includes the following capabilities:

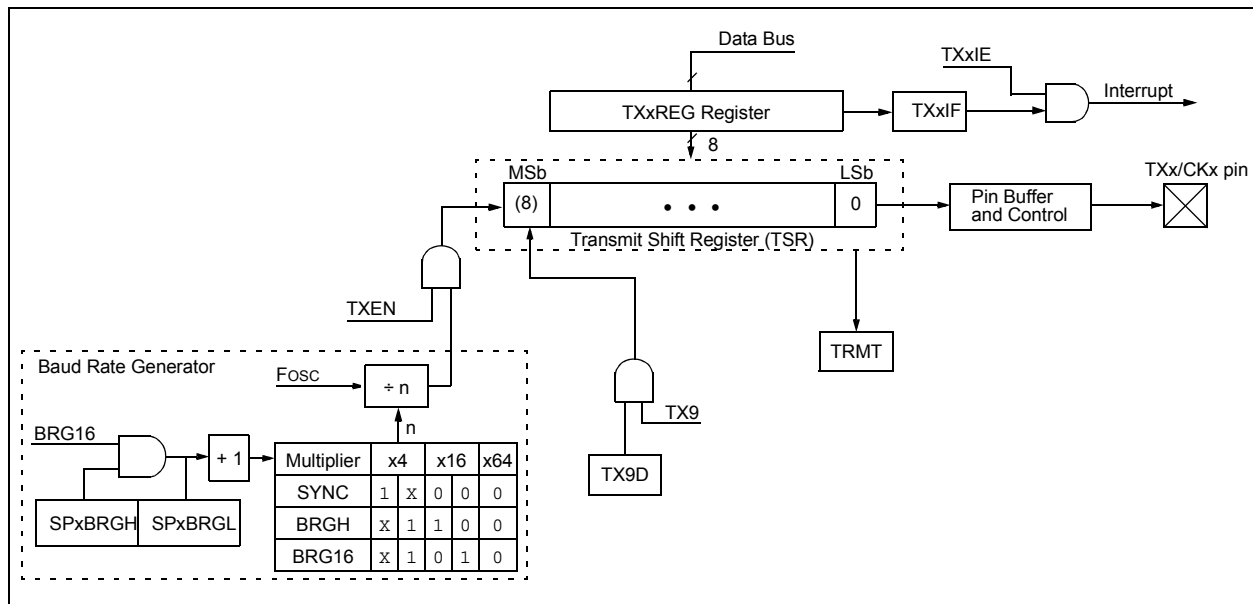
- Full-duplex asynchronous transmit and receive
- Two-character input buffer
- One-character output buffer
- Programmable 8-bit or 9-bit character length
- Address detection in 9-bit mode
- Input buffer overrun error detection
- Received character framing error detection
- Half-duplex synchronous master
- Half-duplex synchronous slave
- Programmable clock and data polarity

The EUSART module implements the following additional features, making it ideally suited for use in Local Interconnect Network (LIN) bus systems:

- Automatic detection and calibration of the baud rate
- Wake-up on Break reception
- 13-bit Break character transmit

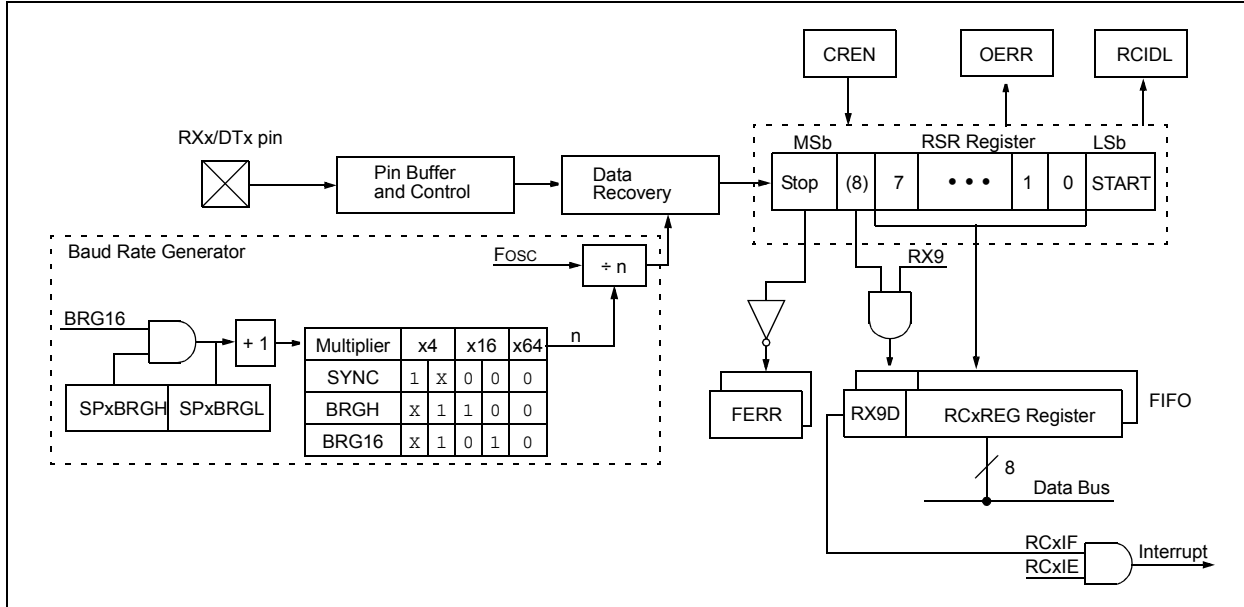
Block diagrams of the EUSART transmitter and receiver are shown in [Figure 22-1](#) and [Figure 22-2](#).

FIGURE 22-1: EUSART TRANSMIT BLOCK DIAGRAM



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FIGURE 22-2: EUSART RECEIVE BLOCK DIAGRAM



The operation of the EUSART module is controlled through three registers:

- Transmit Status and Control (TXxSTA)
- Receive Status and Control (RCxSTA)
- Baud Rate Control (BAUDxCON)

These registers are detailed in [Register 22-1](#), [Register 22-2](#) and [Register 22-3](#), respectively.

For all modes of EUSART operation, the TRIS control bits corresponding to the RXx/DTx and TXx/CKx pins should be set to '1'. The EUSART control will automatically reconfigure the pin from input to output, as needed.

When the receiver or transmitter section is not enabled then the corresponding RXx/DTx or TXx/CKx pin may be used for general purpose input and output.

22.1 EUSART Asynchronous Mode

The EUSART transmits and receives data using the standard non-return-to-zero (NRZ) format. NRZ is implemented with two levels: a V_{OH} mark state which represents a '1' data bit, and a V_{OL} space state which represents a '0' data bit. NRZ refers to the fact that consecutively transmitted data bits of the same value stay at the output level of that bit without returning to a neutral level between each bit transmission. An NRZ transmission port idles in the mark state. Each character transmission consists of one Start bit followed by eight or nine data bits and is always terminated by one or more Stop bits. The Start bit is always a space and the Stop bits are always marks. The most common data format is 8 bits. Each transmitted bit persists for a period of 1/(Baud Rate). An on-chip dedicated 8-bit/16-bit Baud Rate Generator is used to derive standard baud rate frequencies from the system oscillator. See [Table 22-5](#) for examples of baud rate configurations.

The EUSART transmits and receives the LSb first. The EUSART's transmitter and receiver are functionally independent, but share the same data format and baud rate. Parity is not supported by the hardware, but can be implemented in software and stored as the ninth data bit.

22.1.1 EUSART ASYNCHRONOUS TRANSMITTER

The EUSART transmitter block diagram is shown in [Figure 22-1](#). The heart of the transmitter is the serial Transmit Shift Register (TSR), which is not directly accessible by software. The TSR obtains its data from the transmit buffer, which is the TXxREG register.

22.1.1.1 Enabling the Transmitter

The EUSART transmitter is enabled for asynchronous operations by configuring the following three control bits:

- TXEN = 1
- SYNC = 0
- SPEN = 1

All other EUSART control bits are assumed to be in their default state.

Setting the TXEN bit of the TXxSTA register enables the transmitter circuitry of the EUSART. Clearing the SYNC bit of the TXxSTA register configures the EUSART for asynchronous operation. Setting the SPEN bit of the RCxSTA register enables the EUSART. The programmer must set the corresponding TRIS bit to configure the TXx/CKx I/O pin as an output. If the TXx/CKx pin is shared with an analog peripheral, the analog I/O function must be disabled by clearing the corresponding ANSEL bit.

Note: The TXxIF transmitter interrupt flag is set when the TXEN enable bit is set.

22.1.1.2 Transmitting Data

A transmission is initiated by writing a character to the TXxREG register. If this is the first character, or the previous character has been completely flushed from the TSR, the data in the TXxREG is immediately transferred to the TSR register. If the TSR still contains all or part of a previous character, the new character data is held in the TXxREG until the Stop bit of the previous character has been transmitted. The pending character in the TXxREG is then transferred to the TSR in one T_{cy} immediately following the Stop bit transmission. The transmission of the Start bit, data bits and Stop bit sequence commences immediately following the transfer of the data to the TSR from the TXxREG.

22.1.1.3 Transmit Data Polarity

The polarity of the transmit data can be controlled with the CKTXP bit of the BAUDxCON register. The default state of this bit is '0' which selects high true transmit idle and data bits. Setting the CKTXP bit to '1' will invert the transmit data resulting in low true idle and data bits. The CKTXP bit controls transmit data polarity only in Asynchronous mode. In Synchronous mode the CKTXP bit has a different function.

22.1.1.4 Transmit Interrupt Flag

The TXxIF interrupt flag bit of the PIR1/PIR4 register is set whenever the EUSART transmitter is enabled and no character is being held for transmission in the TXxREG. In other words, the TXxIF bit is only clear when the TSR is busy with a character and a new character has been queued for transmission in the TXxREG. The TXxIF flag bit is not cleared immediately upon writing TXxREG. TXxIF becomes valid in the second instruction cycle following the write execution. Polling TXxIF immediately following the TXxREG write will return invalid results. The TXxIF bit is read-only, it cannot be set or cleared by software.

The TXxIF interrupt can be enabled by setting the TXxIE interrupt enable bit of the PIE1/PIE4 register. However, the TXxIF flag bit will be set whenever the TXxREG is empty, regardless of the state of TXxIE enable bit.

To use interrupts when transmitting data, set the TXxIE bit only when there is more data to send. Clear the TXxIE interrupt enable bit upon writing the last character of the transmission to the TXxREG.

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22.1.1.5 TSR Status

The TRMT bit of the TXxSTA register indicates the status of the TSR register. This is a read-only bit. The TRMT bit is set when the TSR register is empty and is cleared when a character is transferred to the TSR register from the TXxREG. The TRMT bit remains clear until all bits have been shifted out of the TSR register. No interrupt logic is tied to this bit, so the user needs to poll this bit to determine the TSR status.

Note: The TSR register is not mapped in data memory, so it is not available to the user.

22.1.1.6 Transmitting 9-Bit Characters

The EUSART supports 9-bit character transmissions. When the TX9 bit of the TXxSTA register is set the EUSART will shift 9 bits out for each character transmitted. The TX9D bit of the TXxSTA register is the ninth, and Most Significant, data bit. When transmitting 9-bit data, the TX9D data bit must be written before writing the 8 Least Significant bits into the TXxREG. All nine bits of data will be transferred to the TSR shift register immediately after the TXxREG is written.

A special 9-bit Address mode is available for use with multiple receivers. See [Section 22.1.2.8 “Address Detection”](#) for more information on the Address mode.

22.1.1.7 Asynchronous Transmission Set-up:

1. Initialize the SPxBRGH:SPxBRGL register pair and the BRGH and BRG16 bits to achieve the desired baud rate (see [Section 22.4 “EUSART Baud Rate Generator \(BRG\)”](#)).
2. Set the RXx/DTx and TXx/CKx TRIS controls to ‘1’.
3. Enable the asynchronous serial port by clearing the SYNC bit and setting the SPEN bit.
4. If 9-bit transmission is desired, set the TX9 control bit. A set ninth data bit will indicate that the 8 Least Significant data bits are an address when the receiver is set for address detection.
5. Set the CKTXP control bit if inverted transmit data polarity is desired.
6. Enable the transmission by setting the TXEN control bit. This will cause the TXxIF interrupt bit to be set.
7. If interrupts are desired, set the TXxIE interrupt enable bit. An interrupt will occur immediately provided that the GIE and PEIE bits of the INTCON register are also set.
8. If 9-bit transmission is selected, the ninth bit should be loaded into the TX9D data bit.
9. Load 8-bit data into the TXxREG register. This will start the transmission.

FIGURE 22-3: ASYNCHRONOUS TRANSMISSION

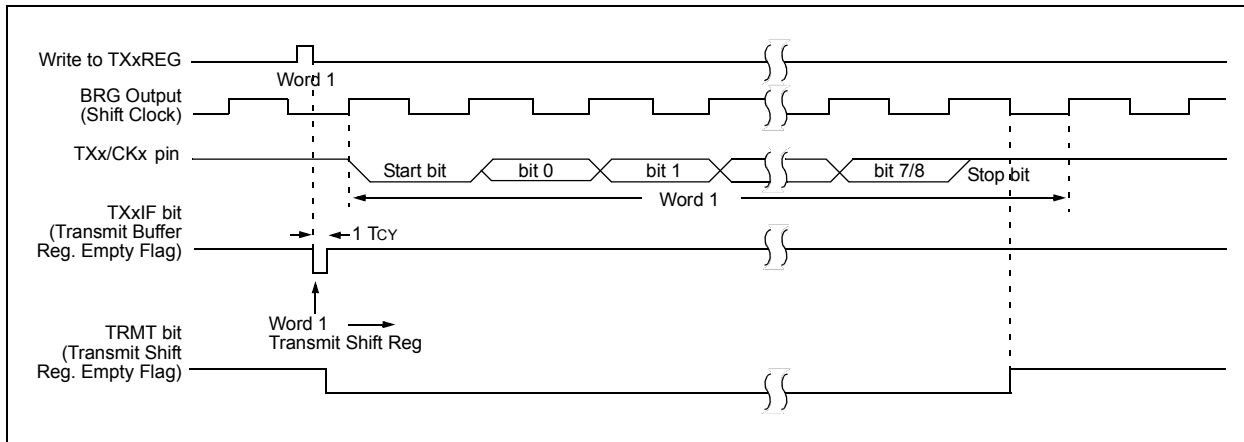


FIGURE 22-4: ASYNCHRONOUS TRANSMISSION (BACK-TO-BACK)

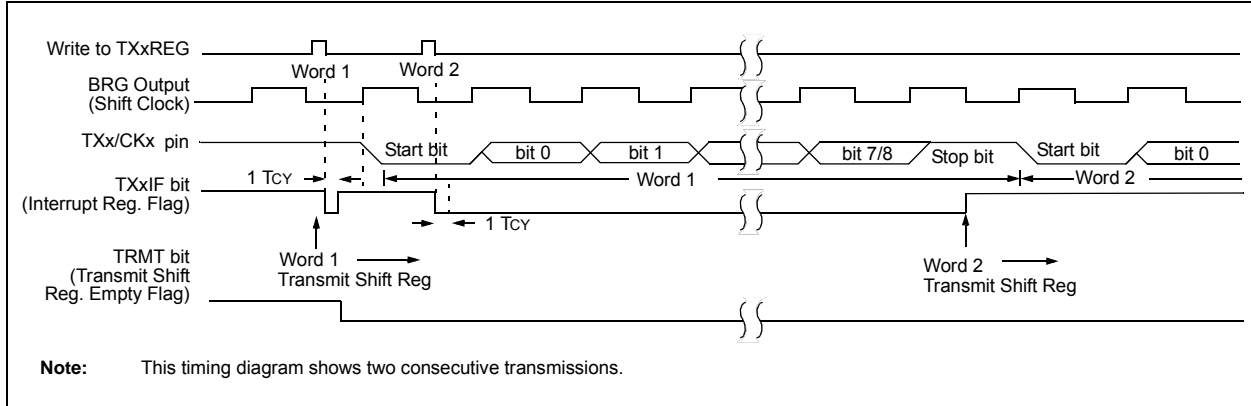


TABLE 22-1: REGISTERS ASSOCIATED WITH ASYNCHRONOUS TRANSMISSION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	93
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	94
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	97
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	98
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	97
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TX1REG	EUSART1 Transmit Register								257*
TX1STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264
TX2REG	EUSART2 Transmit Register								257*
TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264

Legend: — = unimplemented locations, read as '0'. Shaded bits are not used for asynchronous transmission.

* Page provides register information.

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22.1.2 EUSART ASYNCHRONOUS RECEIVER

The Asynchronous mode would typically be used in RS-232 systems. The receiver block diagram is shown in [Figure 22-2](#). The data is received on the RXx/DTx pin and drives the data recovery block. The data recovery block is actually a high-speed shifter operating at 16 times the baud rate, whereas the serial Receive Shift Register (RSR) operates at the bit rate. When all 8 or 9 bits of the character have been shifted in, they are immediately transferred to a two character First-In-First-Out (FIFO) memory. The FIFO buffering allows reception of two complete characters and the start of a third character before software must start servicing the EUSART receiver. The FIFO and RSR registers are not directly accessible by software. Access to the received data is via the RCxREG register.

22.1.2.1 Enabling the Receiver

The EUSART receiver is enabled for asynchronous operation by configuring the following three control bits:

- CREN = 1
- SYNC = 0
- SPEN = 1

All other EUSART control bits are assumed to be in their default state.

Setting the CREN bit of the RCxSTA register enables the receiver circuitry of the EUSART. Clearing the SYNC bit of the TXxSTA register configures the EUSART for asynchronous operation. Setting the SPEN bit of the RCxSTA register enables the EUSART. The programmer must set the corresponding TRIS bit to configure the RXx/DTx I/O pin as an input.

Note 1: If the RX/DT function is on an analog pin, the corresponding ANSEL bit must be cleared for the receiver to function.

If the RXx/DTx pin is shared with an analog peripheral the analog I/O function must be disabled by clearing the corresponding ANSEL bit.

22.1.2.2 Receiving Data

The receiver data recovery circuit initiates character reception on the falling edge of the first bit. The first bit, also known as the Start bit, is always a zero. The data recovery circuit counts one-half bit time to the center of the Start bit and verifies that the bit is still a zero. If it is not a zero then the data recovery circuit aborts character reception, without generating an error, and resumes looking for the falling edge of the Start bit. If the Start bit zero verification succeeds then the data recovery circuit counts a full bit time to the center of the next bit. The bit is then sampled by a majority detect circuit and the resulting '0' or '1' is shifted into the RSR. This repeats until all data bits have been sampled and shifted into the RSR. One final bit time is measured and the level sampled. This is the Stop bit, which is always a '1'. If the data recovery circuit samples a '0' in the Stop bit position then a framing error is set for this character, otherwise the framing error is cleared for this character. See [Section 22.1.2.5 "Receive Framing Error"](#) for more information on framing errors.

Immediately after all data bits and the Stop bit have been received, the character in the RSR is transferred to the EUSART receive FIFO and the RCxIF interrupt flag bit of the PIR1/PIR4 register is set. The top character in the FIFO is transferred out of the FIFO by reading the RCxREG register.

Note: If the receive FIFO is overrun, no additional characters will be received until the overrun condition is cleared. See [Section 22.1.2.6 "Receive Overrun Error"](#) for more information on overrun errors.

22.1.2.3 Receive Data Polarity

The polarity of the receive data can be controlled with the DTRXP bit of the BAUDxCON register. The default state of this bit is '0' which selects high true receive idle and data bits. Setting the DTRXP bit to '1' will invert the receive data resulting in low true idle and data bits. The DTRXP bit controls receive data polarity only in Asynchronous mode. In Synchronous mode the DTRXP bit has a different function.

22.1.2.4 Receive Interrupts

The RCxIF interrupt flag bit of the PIR1/PIR4 register is set whenever the EUSART receiver is enabled and there is an unread character in the receive FIFO. The RCxIF interrupt flag bit is read-only, it cannot be set or cleared by software.

RCxIF interrupts are enabled by setting the following bits:

- RCxIE interrupt enable bit of the PIE1/PIE4 register
- PEIE peripheral interrupt enable bit of the INTCON register
- GIE global interrupt enable bit of the INTCON register

The RCxIF interrupt flag bit will be set when there is an unread character in the FIFO, regardless of the state of interrupt enable bits.

22.1.2.5 Receive Framing Error

Each character in the receive FIFO buffer has a corresponding framing error Status bit. A framing error indicates that a Stop bit was not seen at the expected time. The framing error status is accessed via the FERR bit of the RCxSTA register. The FERR bit represents the status of the top unread character in the receive FIFO. Therefore, the FERR bit must be read before reading the RCxREG.

The FERR bit is read-only and only applies to the top unread character in the receive FIFO. A framing error (FERR = 1) does not preclude reception of additional characters. It is not necessary to clear the FERR bit. Reading the next character from the FIFO buffer will advance the FIFO to the next character and the next corresponding framing error.

The FERR bit can be forced clear by clearing the SPEN bit of the RCxSTA register which resets the EUSART. Clearing the CREN bit of the RCxSTA register does not affect the FERR bit. A framing error by itself does not generate an interrupt.

Note: If all receive characters in the receive FIFO have framing errors, repeated reads of the RCxREG will not clear the FERR bit.

22.1.2.6 Receive Overrun Error

The receive FIFO buffer can hold two characters. An overrun error will be generated if a third character, in its entirety, is received before the FIFO is accessed. When this happens the OERR bit of the RCxSTA register is set. The characters already in the FIFO buffer can be read but no additional characters will be received until the error is cleared. The error must be cleared by either clearing the CREN bit of the RCxSTA register or by resetting the EUSART by clearing the SPEN bit of the RCxSTA register.

22.1.2.7 Receiving 9-bit Characters

The EUSART supports 9-bit character reception. When the RX9 bit of the RCxSTA register is set, the EUSART will shift 9 bits into the RSR for each character received. The RX9D bit of the RCxSTA register is the ninth and Most Significant data bit of the top unread character in the receive FIFO. When reading 9-bit data from the receive FIFO buffer, the RX9D data bit must be read before reading the 8 Least Significant bits from the RCxREG.

22.1.2.8 Address Detection

A special Address Detection mode is available for use when multiple receivers share the same transmission line, such as in RS-485 systems. Address detection is enabled by setting the ADDEN bit of the RCxSTA register.

Address detection requires 9-bit character reception. When address detection is enabled, only characters with the ninth data bit set will be transferred to the receive FIFO buffer, thereby setting the RCxIF interrupt bit. All other characters will be ignored.

Upon receiving an address character, user software determines if the address matches its own. Upon address match, user software must disable address detection by clearing the ADDEN bit before the next Stop bit occurs. When user software detects the end of the message, determined by the message protocol used, software places the receiver back into the Address Detection mode by setting the ADDEN bit.

22.1.2.9 Asynchronous Reception Set-up:

1. Initialize the SPxBRGH:SPxBRGL register pair and the BRGH and BRG16 bits to achieve the desired baud rate (see [Section 22.4 “EUSART Baud Rate Generator \(BRG\)”](#)).
2. Set the RXx/DTx and TXx/CKx TRIS controls to ‘1’.
3. Enable the serial port by setting the SPEN bit and the RXx/DTx pin TRIS bit. The SYNC bit must be clear for asynchronous operation.
4. If interrupts are desired, set the RCxIE interrupt enable bit and set the GIE and PEIE bits of the INTCON register.
5. If 9-bit reception is desired, set the RX9 bit.
6. Set the DTRXP if inverted receive polarity is desired.
7. Enable reception by setting the CREN bit.
8. The RCxIF interrupt flag bit will be set when a character is transferred from the RSR to the receive buffer. An interrupt will be generated if the RCxIE interrupt enable bit was also set.
9. Read the RCxSTA register to get the error flags and, if 9-bit data reception is enabled, the ninth data bit.
10. Get the received 8 Least Significant data bits from the receive buffer by reading the RCxREG register.
11. If an overrun occurred, clear the OERR flag by clearing the CREN receiver enable bit.

22.1.2.10 9-bit Address Detection Mode Set-up

This mode would typically be used in RS-485 systems. To set up an Asynchronous Reception with Address Detect Enable:

1. Initialize the SPxBRGH, SPxBRGL register pair and the BRGH and BRG16 bits to achieve the desired baud rate (see [Section 22.4 “EUSART Baud Rate Generator \(BRG\)”](#)).
2. Set the RXx/DTx and TXx/CKx TRIS controls to ‘1’.
3. Enable the serial port by setting the SPEN bit. The SYNC bit must be clear for asynchronous operation.
4. If interrupts are desired, set the RCxIE interrupt enable bit and set the GIE and PEIE bits of the INTCON register.
5. Enable 9-bit reception by setting the RX9 bit.
6. Enable address detection by setting the ADDEN bit.
7. Set the DTRXP if inverted receive polarity is desired.
8. Enable reception by setting the CREN bit.
9. The RCxIF interrupt flag bit will be set when a character with the ninth bit set is transferred from the RSR to the receive buffer. An interrupt will be generated if the RCxIE interrupt enable bit was also set.
10. Read the RCxSTA register to get the error flags. The ninth data bit will always be set.
11. Get the received 8 Least Significant data bits from the receive buffer by reading the RCxREG register. Software determines if this is the device’s address.
12. If an overrun occurred, clear the OERR flag by clearing the CREN receiver enable bit.
13. If the device has been addressed, clear the ADDEN bit to allow all received data into the receive buffer and generate interrupts.

FIGURE 22-5: ASYNCHRONOUS RECEPTION

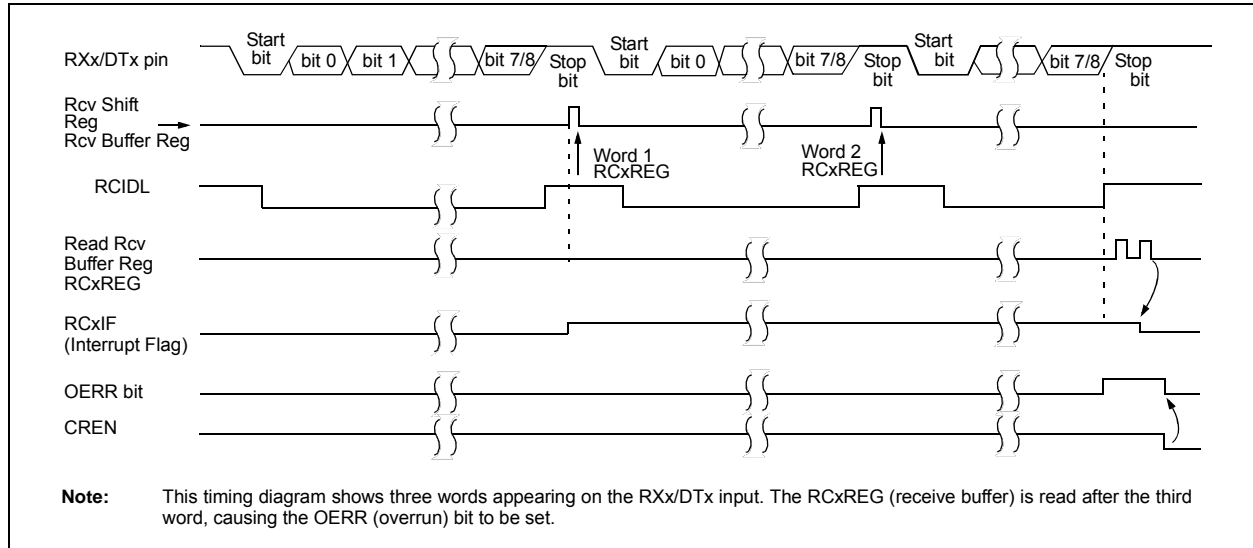


TABLE 22-2: REGISTERS ASSOCIATED WITH ASYNCHRONOUS RECEPTION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	93
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	94
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	97
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	98
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	97
RC1REG	EUSART1 Receive Register								260*
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2REG	EUSART2 Receive Register								260*
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	134
TX1STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264
TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264

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

* Page provides register information.

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22.2 Clock Accuracy with Asynchronous Operation

The factory calibrates the internal oscillator block output (HFINTOSC). However, the HFINTOSC frequency may drift as VDD or temperature changes, and this directly affects the asynchronous baud rate. Two methods may be used to adjust the baud rate clock, but both require a reference clock source of some kind.

The first (preferred) method uses the OSCTUNE register to adjust the HFINTOSC output. Adjusting the value in the OSCTUNE register allows for fine resolution changes to the system clock source. See [Section 5.2 “Clock Source Types”](#) for more information.

The other method adjusts the value in the Baud Rate Generator. This can be done automatically with the Auto-Baud Detect feature (see [Section 22.4.1 “Auto-Baud Detect”](#)). There may not be fine enough resolution when adjusting the Baud Rate Generator to compensate for a gradual change in the peripheral clock frequency.

22.3 USART Control Registers

REGISTER 22-1: TXxSTA: TRANSMIT STATUS AND CONTROL REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-1	R/W-0
CSRC	TX9	TXEN ⁽¹⁾	SYNC	SENDB	BRGH	TRMT	TX9D
bit 7							bit 0

Legend:

R = Readable bit
-n = Value at POR

W = Writable bit
'1' = Bit is set

U = Unimplemented bit, read as '0'
'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:** Ninth bit of Transmit Data
Can be address/data bit or a parity bit.

Note 1: SREN/CREN overrides TXEN in Sync mode.

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

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-0	R-0	R-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'
-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 RXx/DTx and TXx/CKx 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 RCxREG 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.

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REGISTER 22-3: BAUDxCON: BAUD RATE CONTROL REGISTER

R-0/0	R-1/1	U-0	R/W-0/0	R/W-0/0	U-0	R/W-0/0	R/W-0/0
ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN
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 **ABDOVF:** Auto-Baud Detect Overflow bit
Asynchronous mode:
 1 = Auto-baud timer overflowed
 0 = Auto-baud timer did not overflow
Synchronous mode:
 Don't care
- bit 6 **RCIDL:** Receive Idle Flag bit
Asynchronous mode:
 1 = Receiver is Idle
 0 = Start bit has been received and the receiver is receiving
Synchronous mode:
 Don't care
- bit 5 **Unimplemented:** Read as '0'
- bit 4 **SCKP:** Synchronous Clock Polarity Select bit
Asynchronous mode:
 1 = Transmit inverted data to the TXx/CKx pin
 0 = Transmit non-inverted data to the TXx/CKx pin
Synchronous mode:
 1 = Data is clocked on rising edge of the clock
 0 = Data is clocked on falling edge of the clock
- bit 3 **BRG16:** 16-bit Baud Rate Generator bit
 1 = 16-bit Baud Rate Generator is used
 0 = 8-bit Baud Rate Generator is used
- bit 2 **Unimplemented:** Read as '0'
- bit 1 **WUE:** Wake-up Enable bit
Asynchronous mode:
 1 = Receiver is waiting for a falling edge. No character will be received, byte RCIF will be set. WUE will automatically clear after RCIF is set.
 0 = Receiver is operating normally
Synchronous mode:
 Don't care
- bit 0 **ABDEN:** Auto-Baud Detect Enable bit
Asynchronous mode:
 1 = Auto-Baud Detect mode is enabled (clears when auto-baud is complete)
 0 = Auto-Baud Detect mode is disabled
Synchronous mode:
 Don't care

22.4 EUSART Baud Rate Generator (BRG)

The Baud Rate Generator (BRG) is an 8-bit or 16-bit timer that is dedicated to the support of both the asynchronous and synchronous EUSART operation. By default, the BRG operates in 8-bit mode. Setting the BRG16 bit of the BAUDxCON register selects 16-bit mode.

The SPxBRGH:SPxBRGL register pair determines the period of the free running baud rate timer. In Asynchronous mode the multiplier of the baud rate period is determined by both the BRGH bit of the TXxSTA register and the BRG16 bit of the BAUDxCON register. In Synchronous mode, the BRGH bit is ignored.

[Example 22-1](#) provides a sample calculation for determining the desired baud rate, actual baud rate, and baud rate % error.

Typical baud rates and error values for various Asynchronous modes have been computed for your convenience and are shown in [Table 22-5](#). It may be advantageous to use the high baud rate (BRGH = 1), or the 16-bit BRG (BRG16 = 1) to reduce the baud rate error. The 16-bit BRG mode is used to achieve slow baud rates for fast oscillator frequencies.

Writing a new value to the SPxBRGH, SPxBRGL register pair 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.

If the system clock is changed during an active receive operation, a receive error or data loss may result. To avoid this problem, check the status of the RCIDL bit to make sure that the receive operation is Idle before changing the system clock.

EXAMPLE 22-1: CALCULATING BAUD RATE ERROR

For a device with Fosc of 16 MHz, desired baud rate of 9600, Asynchronous mode, 8-bit BRG:

$$\text{Desired Baud Rate} = \frac{F_{OSC}}{64([SPxBRGH:SPxBRG] + 1)}$$

Solving for SPxBRGH:SPxBRGL:

$$SPxBRGH:SPxBRGL = \frac{F_{OSC}}{\text{Desired Baud Rate}} - 1$$

$$= \frac{16000000}{9600} - 1$$

$$= [25.042] = 25$$

$$\text{ActualBaudRate} = \frac{16000000}{64(25 + 1)}$$

$$= 9615$$

$$\text{Baud Rate \% Error} = \frac{\text{Calc. Baud Rate} - \text{Desired Baud Rate}}{\text{Desired Baud Rate}}$$

$$= \frac{(9615 - 9600)}{9600} = 0.16\%$$

TABLE 22-3: BAUD RATE FORMULAS

Configuration Bits			BRG/EUSART Mode	Baud Rate Formula
SYNC	BRG16	BRGH		
0	0	0	8-bit/Asynchronous	Fosc/[64 (n+1)]
0	0	1	8-bit/Asynchronous	Fosc/[16 (n+1)]
0	1	0	16-bit/Asynchronous	
0	1	1	16-bit/Asynchronous	Fosc/[4 (n+1)]
1	0	x	8-bit/Synchronous	
1	1	x	16-bit/Synchronous	

Legend: x = Don't care, n = value of SPxBRGH, SPxBRGL register pair

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TABLE 22-4: REGISTERS ASSOCIATED WITH BAUD RATE GENERATOR

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Values on page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TX1STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264
TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264

Legend: — = unimplemented, read as '0'. Shaded bits are not used by the BRG.

* Page provides register information.

TABLE 22-5: BAUD RATES FOR ASYNCHRONOUS MODES

BAUD RATE	SYNC = 0, BRGH = 0, BRG16 = 0											
	Fosc = 20.000 MHz			Fosc = 18.432 MHz			Fosc = 16.000 MHz			Fosc = 11.0592 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	—	—	—	—	—	—	—	—	—	—	—	—
1200	1221	1.73	255	1200	0.00	239	1202	0.16	207	1200	0.00	143
2400	2404	0.16	129	2400	0.00	119	2404	0.16	103	2400	0.00	71
9600	9470	-1.36	32	9600	0.00	29	9615	0.16	25	9600	0.00	17
10417	10417	0.00	29	10286	-1.26	27	10417	0.00	23	10165	-2.42	16
19.2k	19.53k	1.73	15	19.20k	0.00	14	19.23k	0.16	12	19.20k	0.00	8
57.6k	—	—	—	57.60k	0.00	7	—	—	—	57.60k	0.00	2
115.2k	—	—	—	—	—	—	—	—	—	—	—	—

BAUD RATE	SYNC = 0, BRGH = 0, BRG16 = 0											
	Fosc = 8.000 MHz			Fosc = 4.000 MHz			Fosc = 3.6864 MHz			Fosc = 1.000 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	—	—	—	300	0.16	207	300	0.00	191	300	0.16	51
1200	1202	0.16	103	1202	0.16	51	1200	0.00	47	1202	0.16	12
2400	2404	0.16	51	2404	0.16	25	2400	0.00	23	—	—	—
9600	9615	0.16	12	—	—	—	9600	0.00	5	—	—	—
10417	10417	0.00	11	10417	0.00	5	—	—	—	—	—	—
19.2k	—	—	—	—	—	—	19.20k	0.00	2	—	—	—
57.6k	—	—	—	—	—	—	57.60k	0.00	0	—	—	—
115.2k	—	—	—	—	—	—	—	—	—	—	—	—

BAUD RATE	SYNC = 0, BRGH = 1, BRG16 = 0											
	Fosc = 20.000 MHz			Fosc = 18.432 MHz			Fosc = 16.000 MHz			Fosc = 11.0592 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	—	—	—	—	—	—	—	—	—	—	—	—
1200	—	—	—	—	—	—	—	—	—	—	—	—
2400	—	—	—	—	—	—	—	—	—	—	—	—
9600	9615	0.16	129	9600	0.00	119	9615	0.16	103	9600	0.00	71
10417	10417	0.00	119	10378	-0.37	110	10417	0.00	95	10473	0.53	65
19.2k	19.23k	0.16	64	19.20k	0.00	59	19.23k	0.16	51	19.20k	0.00	35
57.6k	56.82k	-1.36	21	57.60k	0.00	19	58.82k	2.12	16	57.60k	0.00	11
115.2k	113.64k	-1.36	10	115.2k	0.00	9	111.1k	-3.55	8	115.2k	0.00	5

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TABLE 22-5: BAUD RATES FOR ASYNCHRONOUS MODES (CONTINUED)

BAUD RATE	SYNC = 0, BRGH = 1, BRG16 = 0											
	Fosc = 8.000 MHz			Fosc = 4.000 MHz			Fosc = 3.6864 MHz			Fosc = 1.000 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	—	—	—	—	—	—	—	—	—	300	0.16	207
1200	—	—	—	1202	0.16	207	1200	0.00	191	1202	0.16	51
2400	2404	0.16	207	2404	0.16	103	2400	0.00	95	2404	0.16	25
9600	9615	0.16	51	9615	0.16	25	9600	0.00	23	—	—	—
10417	10417	0.00	47	10417	0.00	23	10473	0.53	21	10417	0.00	5
19.2k	19231	0.16	25	19.23k	0.16	12	19.2k	0.00	11	—	—	—
57.6k	55556	-3.55	8	—	—	—	57.60k	0.00	3	—	—	—
115.2k	—	—	—	—	—	—	115.2k	0.00	1	—	—	—

BAUD RATE	SYNC = 0, BRGH = 0, BRG16 = 1											
	Fosc = 20.000 MHz			Fosc = 18.432 MHz			Fosc = 16.000 MHz			Fosc = 11.0592 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	300.0	-0.01	4166	300.0	0.00	3839	300.03	0.01	3332	300.0	0.00	2303
1200	1200	-0.03	1041	1200	0.00	959	1200.5	0.04	832	1200	0.00	575
2400	2399	-0.03	520	2400	0.00	479	2398	-0.08	416	2400	0.00	287
9600	9615	0.16	129	9600	0.00	119	9615	0.16	103	9600	0.00	71
10417	10417	0.00	119	10378	-0.37	110	10417	0.00	95	10473	0.53	65
19.2k	19.23k	0.16	64	19.20k	0.00	59	19.23k	0.16	51	19.20k	0.00	35
57.6k	56.818	-1.36	21	57.60k	0.00	19	58.82k	2.12	16	57.60k	0.00	11
115.2k	113.636	-1.36	10	115.2k	0.00	9	111.11k	-3.55	8	115.2k	0.00	5

BAUD RATE	SYNC = 0, BRGH = 0, BRG16 = 1											
	Fosc = 8.000 MHz			Fosc = 4.000 MHz			Fosc = 3.6864 MHz			Fosc = 1.000 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	299.9	-0.02	1666	300.1	0.04	832	300.0	0.00	767	300.5	0.16	207
1200	1199	-0.08	416	1202	0.16	207	1200	0.00	191	1202	0.16	51
2400	2404	0.16	207	2404	0.16	103	2400	0.00	95	2404	0.16	25
9600	9615	0.16	51	9615	0.16	25	9600	0.00	23	—	—	—
10417	10417	0.00	47	10417	0.00	23	10473	0.53	21	10417	0.00	5
19.2k	19.23k	0.16	25	19.23k	0.16	12	19.20k	0.00	11	—	—	—
57.6k	55556	-3.55	8	—	—	—	57.60k	0.00	3	—	—	—
115.2k	—	—	—	—	—	—	115.2k	0.00	1	—	—	—

TABLE 22-5: BAUD RATES FOR ASYNCHRONOUS MODES (CONTINUED)

BAUD RATE	SYNC = 0, BRGH = 1, BRG16 = 1 or SYNC = 1, BRG16 = 1											
	Fosc = 20.000 MHz			Fosc = 18.432 MHz			Fosc = 16.000 MHz			Fosc = 11.0592 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	300.0	0.00	16665	300.0	0.00	15359	300.0	0.00	13332	300.0	0.00	9215
1200	1200	-0.01	4166	1200	0.00	3839	1200.1	0.01	3332	1200	0.00	2303
2400	2400	0.02	2082	2400	0.00	1919	2399.5	-0.02	1666	2400	0.00	1151
9600	9597	-0.03	520	9600	0.00	479	9592	-0.08	416	9600	0.00	287
10417	10417	0.00	479	10425	0.08	441	10417	0.00	383	10433	0.16	264
19.2k	19.23k	0.16	259	19.20k	0.00	239	19.23k	0.16	207	19.20k	0.00	143
57.6k	57.47k	-0.22	86	57.60k	0.00	79	57.97k	0.64	68	57.60k	0.00	47
115.2k	116.3k	0.94	42	115.2k	0.00	39	114.29k	-0.79	34	115.2k	0.00	23

BAUD RATE	SYNC = 0, BRGH = 1, BRG16 = 1 or SYNC = 1, BRG16 = 1											
	Fosc = 8.000 MHz			Fosc = 4.000 MHz			Fosc = 3.6864 MHz			Fosc = 1.000 MHz		
	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)	Actual Rate	% Error	SPBRG value (decimal)
300	300.0	0.00	6666	300.0	0.01	3332	300.0	0.00	3071	300.1	0.04	832
1200	1200	-0.02	1666	1200	0.04	832	1200	0.00	767	1202	0.16	207
2400	2401	0.04	832	2398	0.08	416	2400	0.00	383	2404	0.16	103
9600	9615	0.16	207	9615	0.16	103	9600	0.00	95	9615	0.16	25
10417	10417	0	191	10417	0.00	95	10473	0.53	87	10417	0.00	23
19.2k	19.23k	0.16	103	19.23k	0.16	51	19.20k	0.00	47	19.23k	0.16	12
57.6k	57.14k	-0.79	34	58.82k	2.12	16	57.60k	0.00	15	—	—	—
115.2k	117.6k	2.12	16	111.1k	-3.55	8	115.2k	0.00	7	—	—	—

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22.4.1 AUTO-BAUD DETECT

The EUSART module supports automatic detection and calibration of the baud rate.

In the Auto-Baud Detect (ABD) mode, the clock to the BRG is reversed. Rather than the BRG clocking the incoming RXx signal, the RXx signal is timing the BRG. The Baud Rate Generator is used to time the period of a received 55h (ASCII “U”) which is the Sync character for the LIN bus. The unique feature of this character is that it has five rising edges including the Stop bit edge.

Setting the ABDEN bit of the BAUDxCON register starts the auto-baud calibration sequence (Figure 22.4.2). While the ABD sequence takes place, the EUSART state machine is held in Idle. On the first rising edge of the receive line, after the Start bit, the SPxBRGL begins counting up using the BRG counter clock as shown in Table 22-6. The fifth rising edge will occur on the RXx/DTx pin at the end of the eighth bit period. At that time, an accumulated value totaling the proper BRG period is left in the SPxBRGH:SPxBRGL register pair, the ABDEN bit is automatically cleared, and the RCxIF interrupt flag is set. A read operation on the RCxREG needs to be performed to clear the RCxIF interrupt. RCxREG content should be discarded. When calibrating for modes that do not use the SPxBRGH register the user can verify that the SPxBRGL register did not overflow by checking for 00h in the SPxBRGH register.

The BRG auto-baud clock is determined by the BRG16 and BRGH bits as shown in Table 22-6. During ABD, both the SPxBRGH and SPxBRGL registers are used as a 16-bit counter, independent of the BRG16 bit setting. While calibrating the baud rate period, the SPxBRGH and SPxBRGL registers are clocked at

1/8th the BRG base clock rate. The resulting byte measurement is the average bit time when clocked at full speed.

Note 1: If the WUE bit is set with the ABDEN bit, auto-baud detection will occur on the byte following the Break character (see Section 22.4.3 “Auto-Wake-up on Break”).

2: It is up to the user to determine that the incoming character baud rate is within the range of the selected BRG clock source. Some combinations of oscillator frequency and EUSART baud rates are not possible.

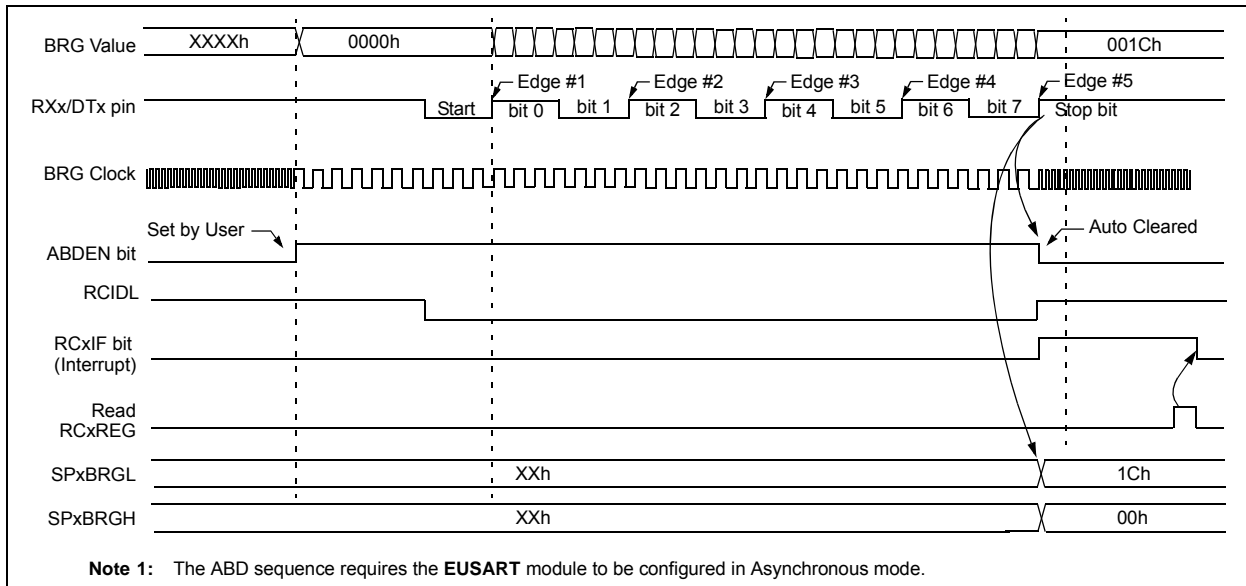
3: During the auto-baud process, the auto-baud counter starts counting at 1. Upon completion of the auto-baud sequence, to achieve maximum accuracy, subtract 1 from the SPxBRGH:SPxBRGL register pair.

TABLE 22-6: BRG COUNTER CLOCK RATES

BRG16	BRGH	BRG Base Clock	BRG ABD Clock
0	0	Fosc/64	Fosc/512
0	1	Fosc/16	Fosc/128
1	0	Fosc/16	Fosc/128
1	1	Fosc/4	Fosc/32

Note: During the ABD sequence, SPxBRGL and SPxBRGH registers are both used as a 16-bit counter, independent of BRG16 setting.

FIGURE 22-6: AUTOMATIC BAUD RATE CALIBRATION



22.4.2 AUTO-BAUD OVERFLOW

During the course of automatic baud detection, the ABDOVF bit of the BAUDxCON register will be set if the baud rate counter overflows before the fifth rising edge is detected on the RX pin. The ABDOVF bit indicates that the counter has exceeded the maximum count that can fit in the 16 bits of the SPxBRGH:SPxBRGL register pair. After the ABDOVF has been set, the counter continues to count until the fifth rising edge is detected on the RXx/DTx pin. Upon detecting the fifth RXx/DTx edge, the hardware will set the RCxIF interrupt flag and clear the ABDEN bit of the BAUDxCON register. The RCxIF flag can be subsequently cleared by reading the RCxREG. The ABDOVF flag can be cleared by software directly.

To terminate the auto-baud process before the RCxIF flag is set, clear the ABDEN bit then clear the ABDOVF bit. The ABDOVF bit will remain set if the ABDEN bit is not cleared first.

22.4.3 AUTO-WAKE-UP ON BREAK

During Sleep mode, all clocks to the EUSART are suspended. Because of this, the Baud Rate Generator is inactive and a proper character reception cannot be performed. The Auto-Wake-up feature allows the controller to wake-up due to activity on the RXx/DTx line. This feature is available only in Asynchronous mode.

The Auto-Wake-up feature is enabled by setting the WUE bit of the BAUDxCON register. Once set, the normal receive sequence on RXx/DTx 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 RXx/DTx line. (This coincides with the start of a Sync Break or a wake-up signal character for the LIN protocol.)

The EUSART module generates an RCxIF interrupt coincident with the wake-up event. The interrupt is generated synchronously to the Q clocks in normal CPU operating modes (Figure 22-7), and asynchronously if the device is in Sleep mode (Figure 22-8). The interrupt condition is cleared by reading the RCxREG register.

The WUE bit is automatically cleared by the low-to-high transition on the RXx line at the end of the Break. This signals to the user that the Break event is over. At this point, the EUSART module is in Idle mode waiting to receive the next character.

22.4.3.1 Special Considerations

Break Character

To avoid character errors or character fragments during a wake-up event, the wake-up character must be all zeros.

When the wake-up is enabled the function works independent of the low time on the data stream. If the WUE bit is set and a valid non-zero character is received, the low time from the Start bit to the first rising edge will be interpreted as the wake-up event. The remaining bits in the character will be received as a fragmented character and subsequent characters can result in framing or overrun errors.

Therefore, the initial character in the transmission must be all '0's. This must be 10 or more bit times, 13-bit times recommended for LIN bus, or any number of bit times for standard RS-232 devices.

Oscillator Startup Time

Oscillator start-up time must be considered, especially in applications using oscillators with longer start-up intervals (i.e., LP, 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.

WUE Bit

The wake-up event causes a receive interrupt by setting the RCxIF bit. The WUE bit is cleared by hardware by a rising edge on RXx/DTx. The interrupt condition is then cleared by software by reading the RCxREG register and discarding its contents.

To ensure that no actual data is lost, check the RCIDL bit to verify that a receive operation is not in process before setting the WUE bit. If a receive operation is not occurring, the WUE bit may then be set just prior to entering the Sleep mode.

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FIGURE 22-7: AUTO-WAKE-UP BIT (WUE) TIMING DURING NORMAL OPERATION

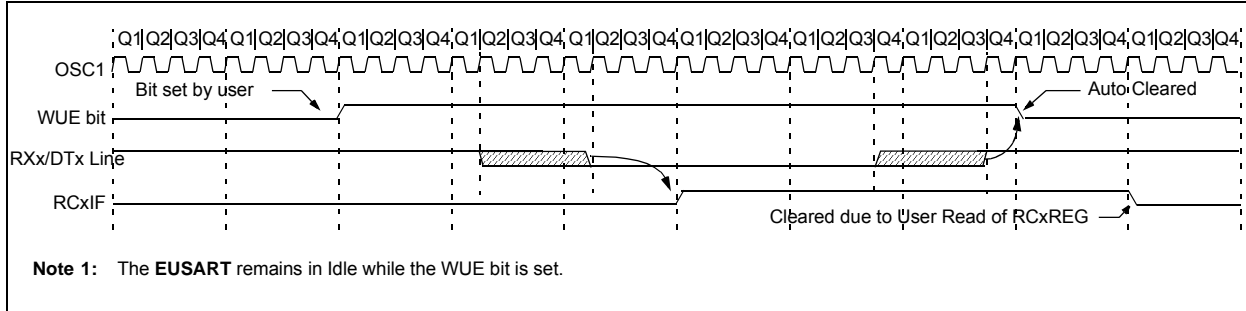
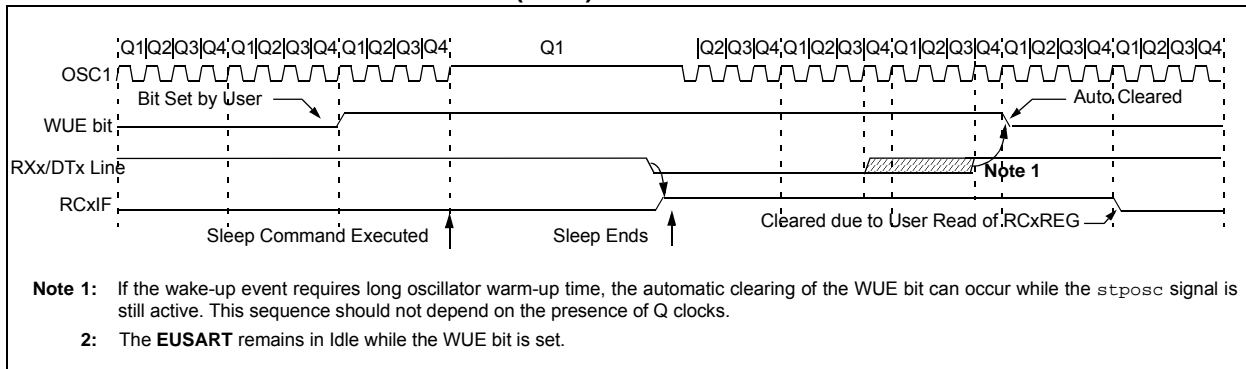


FIGURE 22-8: AUTO-WAKE-UP BIT (WUE) TIMINGS DURING SLEEP



22.4.4 BREAK CHARACTER SEQUENCE

The EUSART module has the capability of sending the special Break character sequences that are required by the LIN bus standard. A Break character consists of a Start bit, followed by 12 '0' bits and a Stop bit.

To send a Break character, set the SENDB and TXEN bits of the TXxSTA register. The Break character transmission is then initiated by a write to the TXxREG. The value of data written to TXxREG 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).

The TRMT bit of the TXxSTA register indicates when the transmit operation is active or Idle, just as it does during normal transmission. See Figure 22-9 for the timing of the Break character sequence.

22.4.4.1 Break and Sync Transmit Sequence

The following sequence will start 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 enable the Break sequence.
3. Load the TXxREG with a dummy character to initiate transmission (the value is ignored).
4. Write '55h' to TXxREG to load the Sync character into the transmit FIFO buffer.
5. After the Break has been sent, the SENDB bit is reset by hardware and the Sync character is then transmitted.

When the TXxREG becomes empty, as indicated by the TXxIF, the next data byte can be written to TXxREG.

22.4.5 RECEIVING A BREAK CHARACTER

The Enhanced EUSART module can receive a Break character in two ways.

The first method to detect a Break character uses the FERR bit of the RCxSTA register and the Received data as indicated by RCxREG. The Baud Rate Generator is assumed to have been initialized to the expected baud rate.

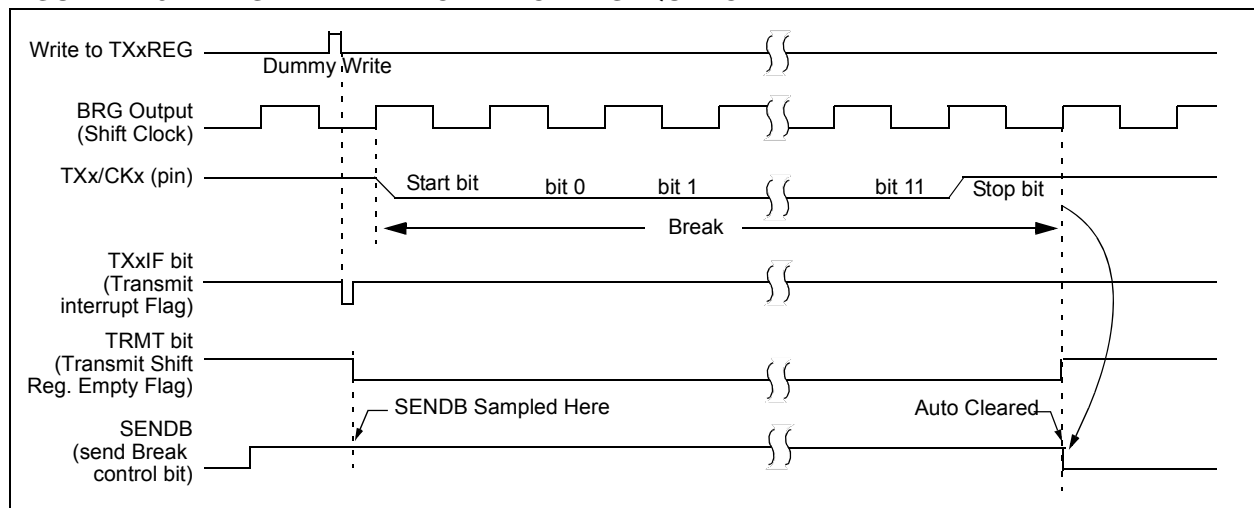
A Break character has been received when;

- RCxIF bit is set
- FERR bit is set
- RCxREG = 00h

The second method uses the Auto-Wake-up feature described in Section 22.4.3 "Auto-Wake-up on Break". By enabling this feature, the EUSART will sample the next two transitions on RXx/DTx, cause an RCxIF 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 Detect feature. For both methods, the user can set the ABDEN bit of the BAUDxCON register before placing the EUSART in Sleep mode.

FIGURE 22-9: SEND BREAK CHARACTER SEQUENCE



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22.5 EUSART Synchronous Mode

Synchronous serial communications are typically used in systems with a single master and one or more slaves. The master device contains the necessary circuitry for baud rate generation and supplies the clock for all devices in the system. Slave devices can take advantage of the master clock by eliminating the internal clock generation circuitry.

There are two signal lines in Synchronous mode: a bidirectional data line and a clock line. Slaves use the external clock supplied by the master to shift the serial data into and out of their respective receive and transmit shift registers. Since the data line is bidirectional, synchronous operation is half-duplex only. Half-duplex refers to the fact that master and slave devices can receive and transmit data but not both simultaneously. The EUSART can operate as either a master or slave device.

Start and Stop bits are not used in synchronous transmissions.

22.5.1 SYNCHRONOUS MASTER MODE

The following bits are used to configure the EUSART for Synchronous Master operation:

- SYNC = 1
- CSRC = 1
- SREN = 0 (for transmit); SREN = 1 (for receive)
- CREN = 0 (for transmit); CREN = 1 (for receive)
- SPEN = 1

Setting the SYNC bit of the TXxSTA register configures the device for synchronous operation. Setting the CSRC bit of the TXxSTA register configures the device as a master. Clearing the SREN and CREN bits of the RCxSTA register ensures that the device is in the Transmit mode, otherwise the device will be configured to receive. Setting the SPEN bit of the RCxSTA register enables the EUSART. If the RXx/DTx or TXx/CKx pins are shared with an analog peripheral the analog I/O functions must be disabled by clearing the corresponding ANSEL bits.

The TRIS bits corresponding to the RXx/DTx and TXx/CKx pins should be set.

22.5.1.1 Master Clock

Synchronous data transfers use a separate clock line, which is synchronous with the data. A device configured as a master transmits the clock on the TXx/CKx line. The TXx/CKx pin output driver is automatically enabled when the EUSART is configured for synchronous transmit or receive operation. Serial data bits change on the leading edge to ensure they are valid at the trailing edge of each clock. One clock cycle is generated for each data bit. Only as many clock cycles are generated as there are data bits.

22.5.1.2 Clock Polarity

A clock polarity option is provided for Microwire compatibility. Clock polarity is selected with the CKTXP bit of the BAUDxCON register. Setting the CKTXP bit sets the clock Idle state as high. When the CKTXP bit is set, the data changes on the falling edge of each clock and is sampled on the rising edge of each clock. Clearing the CKTXP bit sets the Idle state as low. When the CKTXP bit is cleared, the data changes on the rising edge of each clock and is sampled on the falling edge of each clock.

22.5.1.3 Synchronous Master Transmission

Data is transferred out of the device on the RXx/DTx pin. The RXx/DTx and TXx/CKx pin output drivers are automatically enabled when the EUSART is configured for synchronous master transmit operation.

A transmission is initiated by writing a character to the TXxREG register. If the TSR still contains all or part of a previous character the new character data is held in the TXxREG until the last bit of the previous character has been transmitted. If this is the first character, or the previous character has been completely flushed from the TSR, the data in the TXxREG is immediately transferred to the TSR. The transmission of the character commences immediately following the transfer of the data to the TSR from the TXxREG.

Each data bit changes on the leading edge of the master clock and remains valid until the subsequent leading clock edge.

Note: The TSR register is not mapped in data memory, so it is not available to the user.

22.5.1.4 Data Polarity

The polarity of the transmit and receive data can be controlled with the DTRXP bit of the BAUDxCON register. The default state of this bit is '0' which selects high true transmit and receive data. Setting the DTRXP bit to '1' will invert the data resulting in low true transmit and receive data.

22.5.1.5 Synchronous Master Transmission Set-up:

1. Initialize the SPxBRGH, SPxBRGL register pair and the BRGH and BRG16 bits to achieve the desired baud rate (see [Section 22.4 “EUSART Baud Rate Generator \(BRG\)”](#)).
2. Set the RXx/DTx and TXx/CKx TRIS controls to '1'.
3. Enable the synchronous master serial port by setting bits SYNC, SPEN and CSRC. Set the TRIS bits corresponding to the RXx/DTx and TXx/CKx I/O pins.
4. Disable Receive mode by clearing bits SREN and CREN.
5. Enable Transmit mode by setting the TXEN bit.
6. If 9-bit transmission is desired, set the TX9 bit.
7. If interrupts are desired, set the TXxIE, GIE and PEIE interrupt enable bits.
8. If 9-bit transmission is selected, the ninth bit should be loaded in the TX9D bit.
9. Start transmission by loading data to the TXxREG register.

FIGURE 22-10: SYNCHRONOUS TRANSMISSION

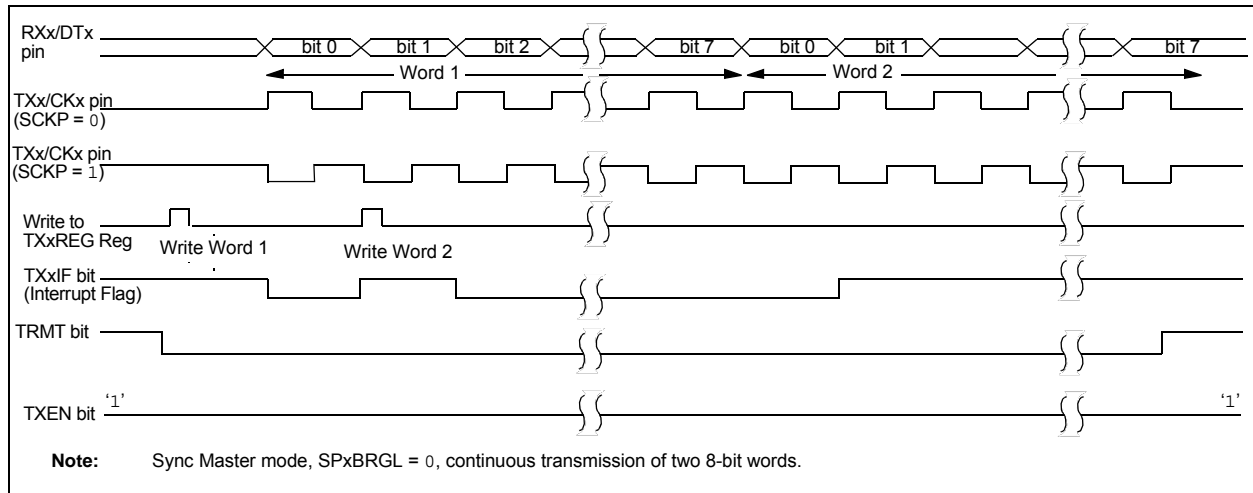
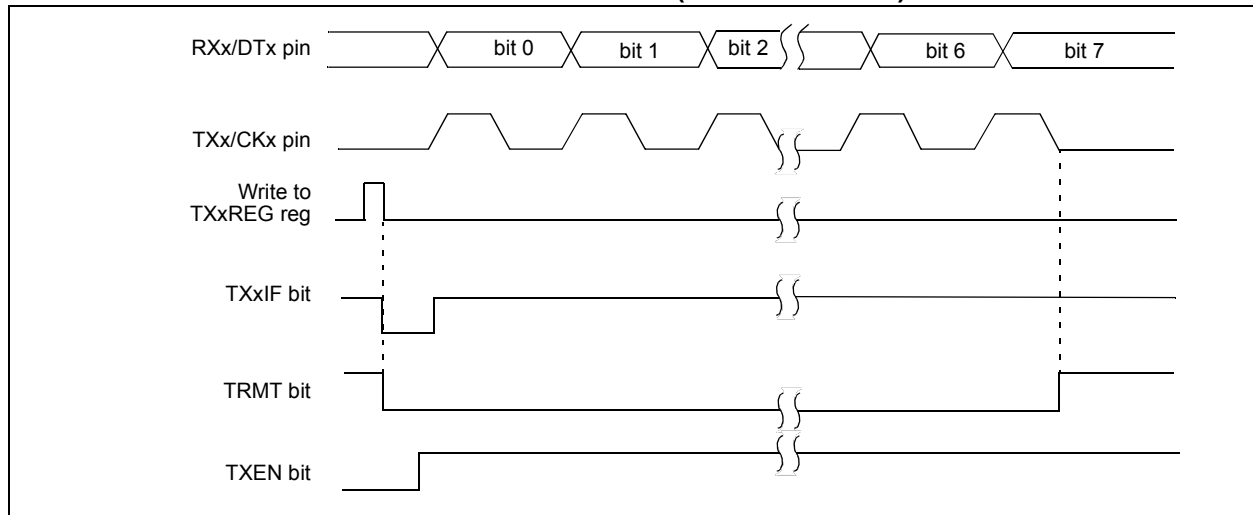


FIGURE 22-11: SYNCHRONOUS TRANSMISSION (THROUGH TXEN)



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TABLE 22-7: REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER TRANSMISSION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
INTCON	GIE	PEIE	TMR0IE	INTE	IOCF	TMR0IF	INTF	IOCF	93
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	94
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	97
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	98
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	97
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	134
TRISG	—	—	—	TRISG4	TRISG3	TRISG2	TRISG1	TRISG0	134
TX1REG	EUSART1 Transmit Register								257*
TX1STA	CSRC	TX9	TXEN	SYNC	SEnDB	BRGH	TRMT	TX9D	264
TX2REG	EUSART2 Transmit Register								257*
TX2STA	CSRC	TX9	TXEN	SYNC	SEnDB	BRGH	TRMT	TX9D	264

Legend: — = unimplemented locations, read as '0'. Shaded bits are not used for synchronous master transmission.

* Page provides register information.

22.5.1.6 Synchronous Master Reception

Data is received at the RXx/DTx pin. The RXx/DTx pin output driver must be disabled by setting the corresponding TRIS bits when the EUSART is configured for synchronous master receive operation.

In Synchronous mode, reception is enabled by setting either the Single Receive Enable bit (SREN of the RCxSTA register) or the Continuous Receive Enable bit (CREN of the RCxSTA register).

When SREN is set and CREN is clear, only as many clock cycles are generated as there are data bits in a single character. The SREN bit is automatically cleared at the completion of one character. When CREN is set, clocks are continuously generated until CREN is cleared. If CREN is cleared in the middle of a character the CK clock stops immediately and the partial character is discarded. If SREN and CREN are both set, then SREN is cleared at the completion of the first character and CREN takes precedence.

To initiate reception, set either SREN or CREN. Data is sampled at the RXx/DTx pin on the trailing edge of the TXx/CKx clock pin and is shifted into the Receive Shift Register (RSR). When a complete character is received into the RSR, the RCxIF bit is set and the character is automatically transferred to the two character receive FIFO. The Least Significant eight bits of the top character in the receive FIFO are available in RCxREG. The RCxIF bit remains set as long as there are un-read characters in the receive FIFO.

22.5.1.7 Slave Clock

Synchronous data transfers use a separate clock line, which is synchronous with the data. A device configured as a slave receives the clock on the TXx/CKx line. The TXx/CKx pin output driver must be disabled by setting the associated TRIS bit when the device is configured for synchronous slave transmit or receive operation. Serial data bits change on the leading edge to ensure they are valid at the trailing edge of each clock. One data bit is transferred for each clock cycle. Only as many clock cycles should be received as there are data bits.

22.5.1.8 Receive Overrun Error

The receive FIFO buffer can hold two characters. An overrun error will be generated if a third character, in its entirety, is received before RCxREG is read to access the FIFO. When this happens the OERR bit of the RCxSTA register is set. Previous data in the FIFO will not be overwritten. The two characters in the FIFO buffer can be read, however, no additional characters will be received until the error is cleared. The OERR bit can only be cleared by clearing the overrun condition. If the overrun error occurred when the SREN bit is set and CREN is clear then the error is cleared by reading RCxREG.

If the overrun occurred when the CREN bit is set then the error condition is cleared by either clearing the CREN bit of the RCxSTA register or by clearing the SPEN bit which resets the EUSART.

22.5.1.9 Receiving 9-bit Characters

The EUSART supports 9-bit character reception. When the RX9 bit of the RCxSTA register is set the EUSART will shift 9-bits into the RSR for each character received. The RX9D bit of the RCxSTA register is the ninth, and Most Significant, data bit of the top unread character in the receive FIFO. When reading 9-bit data from the receive FIFO buffer, the RX9D data bit must be read before reading the 8 Least Significant bits from the RCxREG.

22.5.1.10 Synchronous Master Reception Set-up:

1. Initialize the SPxBRGH, SPxBRGL register pair for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Set the RXx/DTx and TXx/CKx TRIS controls to '1'.
3. Enable the synchronous master serial port by setting bits SYNC, SPEN and CSRC. Disable RXx/DTx and TXx/CKx output drivers by setting the corresponding TRIS bits.
4. Ensure bits CREN and SREN are clear.
5. If using interrupts, set the GIE and PEIE bits of the INTCON register and set RCxIE.
6. If 9-bit reception is desired, set bit RX9.
7. Start reception by setting the SREN bit or for continuous reception, set the CREN bit.
8. Interrupt flag bit RCxIF will be set when reception of a character is complete. An interrupt will be generated if the enable bit RCxIE was set.
9. Read the RCxSTA register to get the ninth bit (if enabled) and determine if any error occurred during reception.
10. Read the 8-bit received data by reading the RCxREG register.
11. If an overrun error occurs, clear the error by either clearing the CREN bit of the RCxSTA register or by clearing the SPEN bit which resets the EUSART.

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

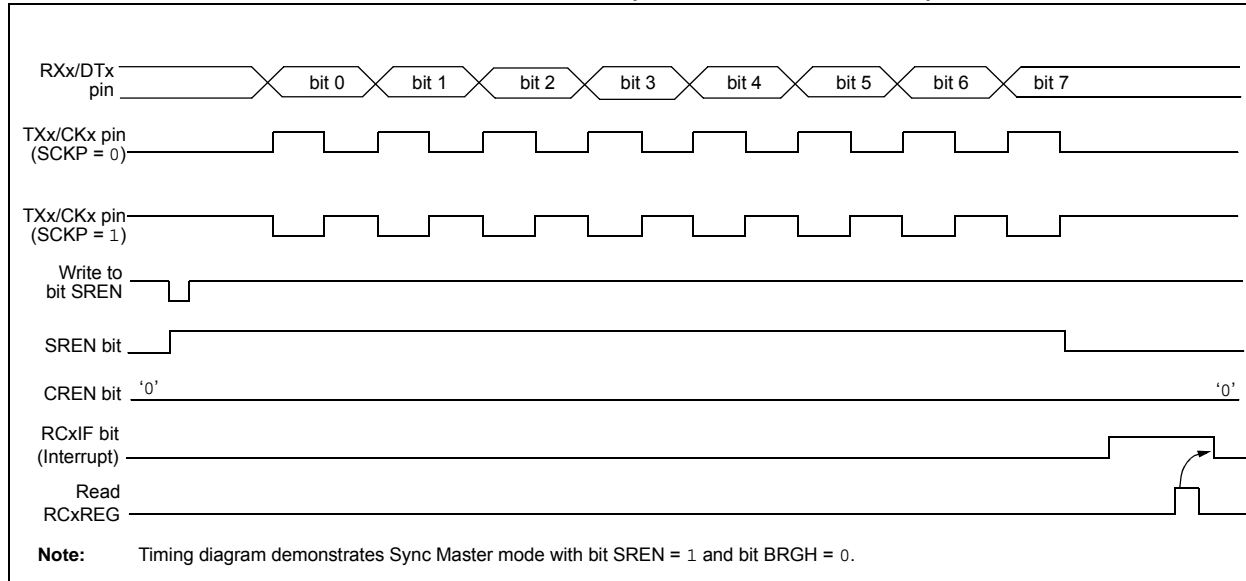


TABLE 22-8: REGISTERS ASSOCIATED WITH SYNCHRONOUS MASTER RECEPTION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
INTCON	GIE	PEIE	TMR0IE	INTE	IOCFE	TMR0IF	INTF	IOCFIF	93
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	94
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	97
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	98
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	97
RC1REG	EUSART1 Receive Register								260*
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2REG	EUSART2 Receive Register								260*
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TX1STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264
TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264

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

* Page provides register information.

22.5.2 SYNCHRONOUS SLAVE MODE

The following bits are used to configure the EUSART for Synchronous slave operation:

- SYNC = 1
- CSRC = 0
- SREN = 0 (for transmit); SREN = 1 (for receive)
- CREN = 0 (for transmit); CREN = 1 (for receive)
- SPEN = 1

Setting the SYNC bit of the TXxSTA register configures the device for synchronous operation. Clearing the CSRC bit of the TXxSTA register configures the device as a slave. Clearing the SREN and CREN bits of the RCxSTA register ensures that the device is in the Transmit mode, otherwise the device will be configured to receive. Setting the SPEN bit of the RCxSTA register enables the EUSART. If the RXx/DTx or TXx/CKx pins are shared with an analog peripheral the analog I/O functions must be disabled by clearing the corresponding ANSEL bits.

RXx/DTx and TXx/CKx pin output drivers must be disabled by setting the corresponding TRIS bits.

22.5.2.1 EUSART Synchronous Slave Transmit

The operation of the Synchronous Master and Slave modes are identical (see [Section 22.5.1.3 “Synchronous Master Transmission”](#)), except in the case of the Sleep mode.

If two words are written to the TXxREG and then the SLEEP instruction is executed, the following will occur:

1. The first character will immediately transfer to the TSR register and transmit.
2. The second word will remain in TXxREG register.
3. The TXxIF bit will not be set.
4. After the first character has been shifted out of TSR, the TXxREG register will transfer the second character to the TSR and the TXxIF bit will now be set.
5. If the PEIE and TXxIE bits are set, the interrupt will wake the device from Sleep and execute the next instruction. If the GIE bit is also set, the program will call the Interrupt Service Routine.

22.5.2.2 Synchronous Slave Transmission Set-up:

1. Set the SYNC and SPEN bits and clear the CSRC bit.
2. Set the RXx/DTx and TXx/CKx TRIS controls to '1'.
3. Clear the CREN and SREN bits.
4. If using interrupts, ensure that the GIE and PEIE bits of the INTCON register are set and set the TXxIE bit.
5. If 9-bit transmission is desired, set the TX9 bit.
6. Enable transmission by setting the TXEN bit.
7. If 9-bit transmission is selected, insert the Most Significant bit into the TX9D bit.
8. Start transmission by writing the Least Significant 8 bits to the TXxREG register.

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TABLE 22-9: REGISTERS ASSOCIATED WITH SYNCHRONOUS SLAVE TRANSMISSION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
INTCON	GIE	PEIE	TMR0IE	INTE	IOCFIE	TMR0IF	INTF	IOCFIF	93
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	94
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	97
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	98
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	97
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	134
TX1REG	EUSART1 Transmit Register								257*
TX1STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264
TX2REG	EUSART2 Transmit Register								257*
TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264

Legend: — = unimplemented locations, read as '0'. Shaded bits are not used for synchronous slave transmission.

* Page provides register information.

22.5.2.3 EUSART Synchronous Slave Reception

The operation of the Synchronous Master and Slave modes is identical ([Section 22.5.1.6 “Synchronous Master Reception”](#)), with the following exceptions:

- Sleep
- CREN bit is always set, therefore the receiver is never Idle
- SREN bit, which is a “don’t care” in Slave mode

A character may be received while in Sleep mode by setting the CREN bit prior to entering Sleep. Once the word is received, the RSR register will transfer the data to the RCxREG register. If the RCxIE enable bit is set, the interrupt generated will wake the device from Sleep and execute the next instruction. If the GIE bit is also set, the program will branch to the interrupt vector.

22.5.2.4 Synchronous Slave Reception Set-up:

1. Set the SYNC and SPEN bits and clear the CSRC bit.
2. Set the RXx/DTx and TXx/CKx TRIS controls to ‘1’.
3. If using interrupts, ensure that the GIE and PEIE bits of the INTCON register are set and set the RCxIE bit.
4. If 9-bit reception is desired, set the RX9 bit.
5. Set the CREN bit to enable reception.
6. The RCxIF bit will be set when reception is complete. An interrupt will be generated if the RCxIE bit was set.
7. If 9-bit mode is enabled, retrieve the Most Significant bit from the RX9D bit of the RCxSTA register.
8. Retrieve the 8 Least Significant bits from the receive FIFO by reading the RCxREG register.
9. If an overrun error occurs, clear the error by either clearing the CREN bit of the RCxSTA register or by clearing the SPEN bit which resets the EUSART.

TABLE 22-10: REGISTERS ASSOCIATED WITH SYNCHRONOUS SLAVE RECEPTION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
BAUD1CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
BAUD2CON	ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN	266
INTCON	GIE	PEIE	TMR0IE	INTE	IOCIE	TMR0IF	INTF	IOCIF	93
PIE1	TMR1GIE	ADIE	RC1IE	TX1IE	SSP1IE	CCP1IE	TMR2IE	TMR1IE	94
PIE4	CCP10IE	CCP9IE	RC2IE	TX2IE	CCP8IE	CCP7IE	BCL2IE	SSP2IE	97
PIR1	TMR1GIF	ADIF	RC1IF	TX1IF	SSP1IF	CCP1IF	TMR2IF	TMR1IF	98
PIR4	CCP10IF	CCP9IF	RC2IF	TX2IF	CCP8IF	CCP7IF	BCL2IF	SSP2IF	97
RC1REG	EUSART1 Receive Register								260*
RC1STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
RC2REG	EUSART2 Receive Register								260*
RC2STA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	265
SP1BRGL	EUSART1 Baud Rate Generator, Low Byte								267*
SP1BRGH	EUSART1 Baud Rate Generator, High Byte								267*
SP2BRGL	EUSART2 Baud Rate Generator, Low Byte								267*
SP2BRGH	EUSART2 Baud Rate Generator, High Byte								267*
TX1STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264
TX2STA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D	264

Legend: — = unimplemented locations, read as ‘0’. Shaded bits are not used for synchronous slave reception.

* Page provides register information.

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NOTES:

23.0 IN-CIRCUIT SERIAL PROGRAMMING™ (ICSP™)

ICSP™ programming allows customers to manufacture circuit boards with unprogrammed devices. Programming can be done after the assembly process allowing the device to be programmed with the most recent firmware or a custom firmware. Five pins are needed for ICSP™ programming:

- ICSPCLK
- ICSPDAT
- MCLR/VPP
- VDD
- VSS

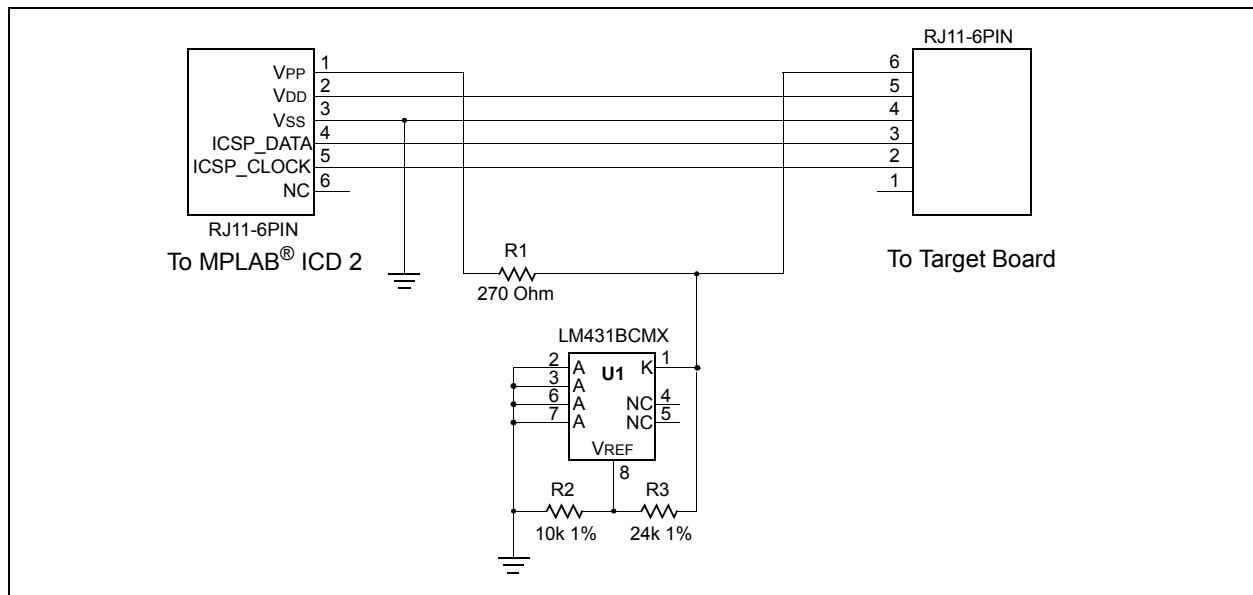
In Program/Verify mode the program memory, user IDs and the Configuration Words are programmed through serial communications. The ICSPDAT pin is a bidirectional I/O used for transferring the serial data and the ICSPCLK pin is the clock input. For more information on ICSP™ refer to the “PIC16F/LF151X/152X Memory Programming Specification” (DS41422).

23.1 High-Voltage Programming Entry Mode

The device is placed into High-Voltage Programming Entry mode by holding the ICSPCLK and ICSPDAT pins low then raising the voltage on MCLR/VPP to V_{IH} .

Some programmers produce V_{PP} greater than V_{IH} (9.0V), an external circuit is required to limit the V_{PP} voltage. See Figure 23-1 for example circuit.

FIGURE 23-1: VPP LIMITER EXAMPLE CIRCUIT



Note: The MPLAB® ICD 2 produces a V_{PP} voltage greater than the maximum V_{PP} specification of the PIC16(L)F1526/27.

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23.2 Low-Voltage Programming Entry Mode

The Low-Voltage Programming Entry mode allows the PIC16(L)F1526/27 devices to be programmed using VDD only, without high voltage. When the LVP bit of Configuration Word 2 is set to '1', the low-voltage ICSP programming entry is enabled. To disable the Low-Voltage ICSP mode, the LVP bit must be programmed to '0'.

Entry into the Low-Voltage Programming Entry mode requires the following steps:

1. $\overline{\text{MCLR}}$ is brought to VIL.
2. A 32-bit key sequence is presented on ICSPDAT, while clocking ICSPCLK.

Once the key sequence is complete, $\overline{\text{MCLR}}$ must be held at VIL for as long as Program/Verify mode is to be maintained.

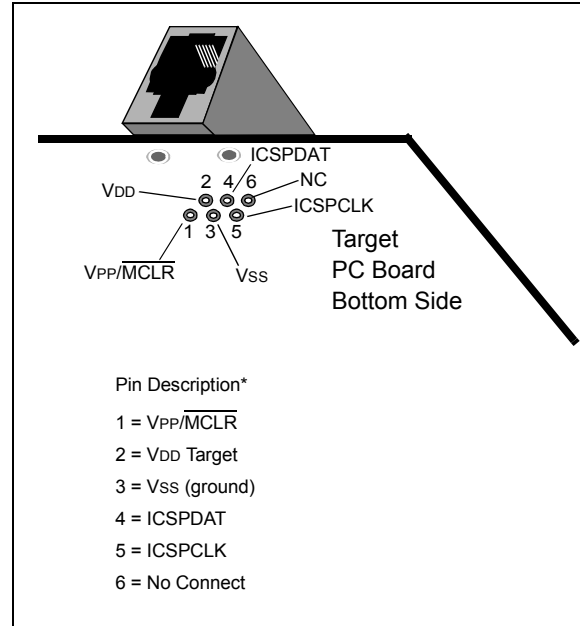
If low-voltage programming is enabled (LVP = 1), the $\overline{\text{MCLR}}$ Reset function is automatically enabled and cannot be disabled. See [Section 6.3 "Low-Power Brown-out Reset \(LPBOR\)"](#) for more information.

The LVP bit can only be reprogrammed to '0' by using the High-Voltage Programming mode.

23.3 Common Programming Interfaces

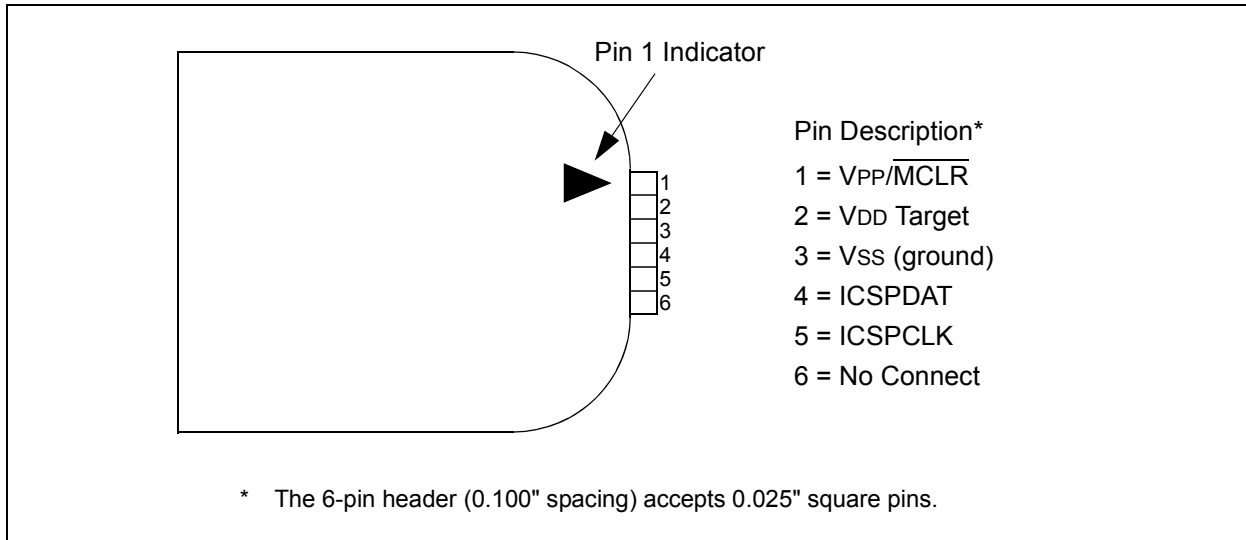
Connection to a target device is typically done through an ICSP™ header. A commonly found connector on development tools is the RJ-11 in the 6P6C (6 pin, 6 connector) configuration. See [Figure 23-2](#).

FIGURE 23-2: ICD RJ-11 STYLE CONNECTOR INTERFACE



Another connector often found in use with the PICKIT™ programmers is a standard 6-pin header with 0.1 inch spacing. Refer to [Figure 23-3](#).

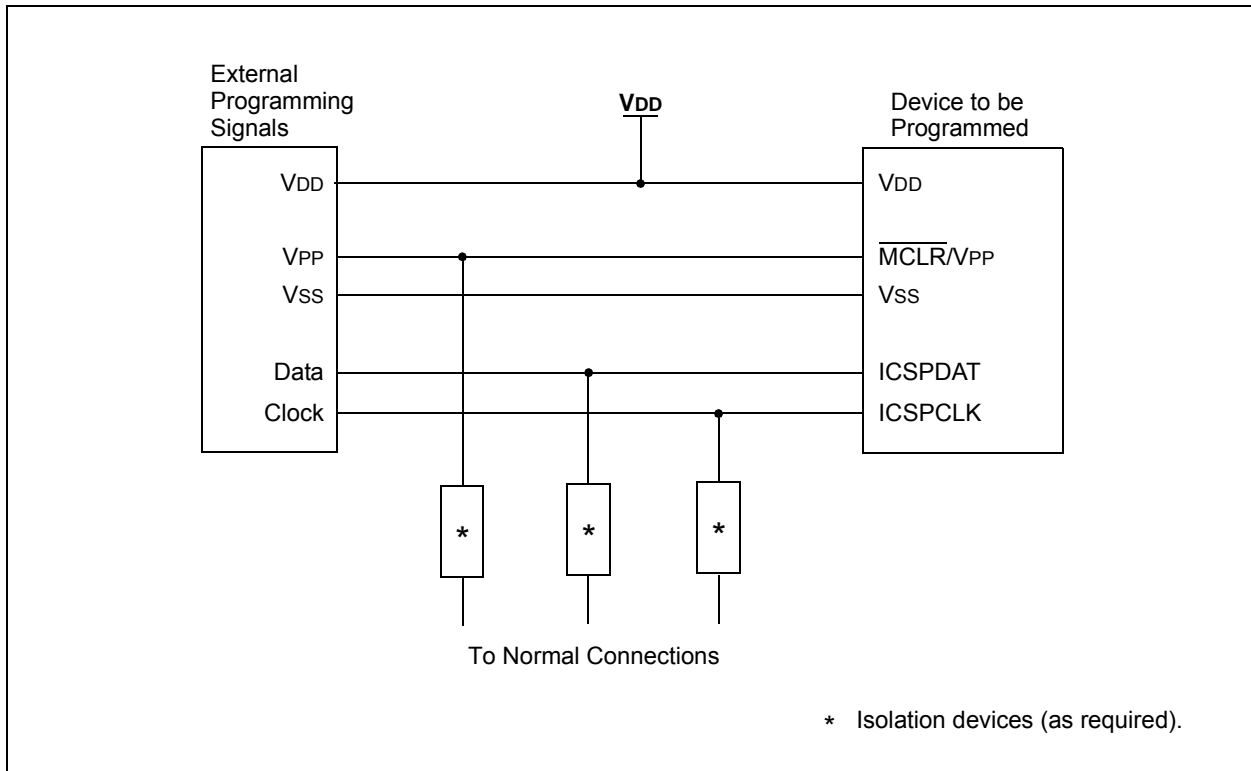
FIGURE 23-3: PICKIT™ STYLE CONNECTOR INTERFACE



For additional interface recommendations, refer to your specific device programmer manual prior to PCB design.

It is recommended that isolation devices be used to separate the programming pins from other circuitry. The type of isolation is highly dependent on the specific application and may include devices such as resistors, diodes, or even jumpers. See [Figure 23-4](#) for more information.

FIGURE 23-4: TYPICAL CONNECTION FOR ICSP™ PROGRAMMING



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NOTES:

24.0 INSTRUCTION SET SUMMARY

Each PIC16 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 24-3 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 4 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

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FIGURE 24-1: GENERAL FORMAT FOR INSTRUCTIONS

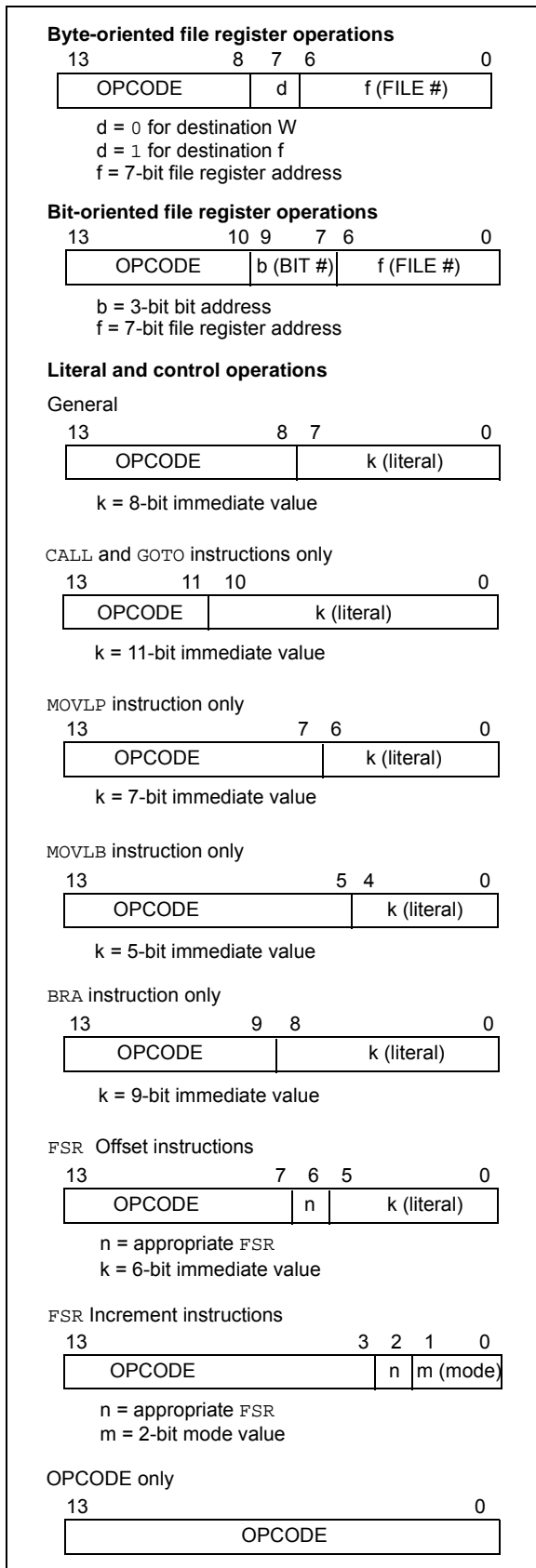


TABLE 24-3: INSTRUCTION SET

Mnemonic, Operands	Description	Cycles	14-Bit Opcode				Status Affected	Notes	
			MSb	LSb					
BYTE-ORIENTED FILE REGISTER OPERATIONS									
ADDWF	f, d	Add W and f	1	00	0111	dfff	ffff	C, DC, Z	2
ADDWFC	f, d	Add with Carry W and f	1	11	1101	dfff	ffff	C, DC, Z	2
ANDWF	f, d	AND W with f	1	00	0101	dfff	ffff	Z	2
ASRF	f, d	Arithmetic Right Shift	1	11	0111	dfff	ffff	C, Z	2
LSLF	f, d	Logical Left Shift	1	11	0101	dfff	ffff	C, Z	2
LSRF	f, d	Logical Right Shift	1	11	0110	dfff	ffff	C, Z	2
CLRF	f	Clear f	1	00	0001	1fff	ffff	Z	2
CLRWF	–	Clear W	1	00	0001	0000	00xx	Z	2
COMF	f, d	Complement f	1	00	1001	dfff	ffff	Z	2
DECF	f, d	Decrement f	1	00	0011	dfff	ffff	Z	2
INCF	f, d	Increment f	1	00	1010	dfff	ffff	Z	2
IORWF	f, d	Inclusive OR W with f	1	00	0100	dfff	ffff	Z	2
MOVF	f, d	Move f	1	00	1000	dfff	ffff	Z	2
MOVWF	f	Move W to f	1	00	0000	1fff	ffff	Z	2
RLF	f, d	Rotate Left f through Carry	1	00	1101	dfff	ffff	C	2
RRF	f, d	Rotate Right f through Carry	1	00	1100	dfff	ffff	C	2
SUBWF	f, d	Subtract W from f	1	00	0010	dfff	ffff	C, DC, Z	2
SUBWFB	f, d	Subtract with Borrow W from f	1	11	1011	dfff	ffff	C, DC, Z	2
SWAPF	f, d	Swap nibbles in f	1	00	1110	dfff	ffff	Z	2
XORWF	f, d	Exclusive OR W with f	1	00	0110	dfff	ffff	Z	2
BYTE ORIENTED SKIP OPERATIONS									
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00	1011	dfff	ffff		1, 2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00	1111	dfff	ffff		1, 2
BIT-ORIENTED FILE REGISTER OPERATIONS									
BCF	f, b	Bit Clear f	1	01	00bb	bfff	ffff		2
BSF	f, b	Bit Set f	1	01	01bb	bfff	ffff		2
BIT-ORIENTED SKIP OPERATIONS									
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01	10bb	bfff	ffff		1, 2
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01	11bb	bfff	ffff		1, 2
LITERAL OPERATIONS									
ADDLW	k	Add literal and W	1	11	1110	kkkk	kkkk	C, DC, Z	
ANDLW	k	AND literal with W	1	11	1001	kkkk	kkkk	Z	
IORLW	k	Inclusive OR literal with W	1	11	1000	kkkk	kkkk	Z	
MOVLB	k	Move literal to BSR	1	00	0000	001k	kkkk		
MOVLP	k	Move literal to PCLATH	1	11	0001	1kkk	kkkk		
MOVLW	k	Move literal to W	1	11	0000	kkkk	kkkk		
SUBLW	k	Subtract W from literal	1	11	1100	kkkk	kkkk	C, DC, Z	
XORLW	k	Exclusive OR literal with W	1	11	1010	kkkk	kkkk	Z	

Note 1: If the Program Counter (PC) is modified, or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

2: If this instruction addresses an INDF register and the MSb of the corresponding FSR is set, this instruction will require one additional instruction cycle.

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TABLE 24-3: INSTRUCTION SET (CONTINUED)

Mnemonic, Operands	Description	Cycles	14-Bit Opcode			Status Affected	Notes		
			MSb	LSb					
CONTROL OPERATIONS									
BRA	k	Relative Branch	2	11	001k	kkkk	kkkk		
BRW	–	Relative Branch with W	2	00	0000	0000	1011		
CALL	k	Call Subroutine	2	10	0kkk	kkkk	kkkk		
CALLW	–	Call Subroutine with W	2	00	0000	0000	1010		
GOTO	k	Go to address	2	10	1kkk	kkkk	kkkk		
RETFIE	k	Return from interrupt	2	00	0000	0000	1001		
RETLW	k	Return with literal in W	2	11	0100	kkkk	kkkk		
RETURN	–	Return from Subroutine	2	00	0000	0000	1000		
INHERENT OPERATIONS									
CLRWDT	–	Clear Watchdog Timer	1	00	0000	0110	0100	\overline{TO} , \overline{PD}	
NOP	–	No Operation	1	00	0000	0000	0000		
OPTION	–	Load OPTION_REG register with W	1	00	0000	0110	0010		
RESET	–	Software device Reset	1	00	0000	0000	0001		
SLEEP	–	Go into Standby mode	1	00	0000	0110	0011	\overline{TO} , \overline{PD}	
TRIS	f	Load TRIS register with W	1	00	0000	0110	0fff		
C-COMPILER OPTIMIZED									
ADDFSR	n, k	Add Literal k to FSRn	1	11	0001	0nkk	kkkk		
MOVIW	n mm	Move Indirect FSRn to W with pre/post inc/dec modifier, mm	1	00	0000	0001	0nmm	Z	2, 3
	k[n]	Move INDFn to W, Indexed Indirect.	1	11	1111	0nkk	kkkk	Z	2
MOVWI	n mm	Move W to Indirect FSRn with pre/post inc/dec modifier, mm	1	00	0000	0001	1nmm		2, 3
	k[n]	Move W to INDFn, Indexed Indirect.	1	11	1111	1nkk	kkkk		2

Note 1: If the Program Counter (PC) is modified, or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

- 2:** If this instruction addresses an INDF register and the MSb of the corresponding FSR is set, this instruction will require one additional instruction cycle.
- 3:** See Table in the MOVIW and MOVWI instruction descriptions.

24.2 Instruction Descriptions

ADDFSR	Add Literal to FSRn
Syntax:	[<i>label</i>] ADDFSR FSRn, k
Operands:	-32 ≤ k ≤ 31 n ∈ [0, 1]
Operation:	FSR(n) + k → FSR(n)
Status Affected:	None
Description:	The signed 6-bit literal 'k' is added to the contents of the FSRnH:FSRnL register pair.
	FSRn is limited to the range 0000h - FFFFh. Moving beyond these bounds will cause the FSR to wrap-around.

ANDLW	AND literal with W
Syntax:	[<i>label</i>] ANDLW k
Operands:	0 ≤ k ≤ 255
Operation:	(W) .AND. (k) → (W)
Status Affected:	Z
Description:	The contents of W register are AND'ed with the eight-bit literal 'k'. The result is placed in the W register.

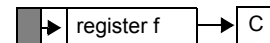
ADDLW	Add literal and W
Syntax:	[<i>label</i>] ADDLW k
Operands:	0 ≤ k ≤ 255
Operation:	(W) + k → (W)
Status Affected:	C, DC, Z
Description:	The contents of the W register are added to the eight-bit literal 'k' and the result is placed in the W register.

ANDWF	AND W with f
Syntax:	[<i>label</i>] ANDWF f,d
Operands:	0 ≤ f ≤ 127 d ∈ [0,1]
Operation:	(W) .AND. (f) → (destination)
Status Affected:	Z
Description:	AND the W register with register 'f'. If 'd' is '0', the result is stored in the W register. If 'd' is '1', the result is stored back in register 'f'.

ADDWF	Add W and f
Syntax:	[<i>label</i>] ADDWF f,d
Operands:	0 ≤ f ≤ 127 d ∈ [0,1]
Operation:	(W) + (f) → (destination)
Status Affected:	C, DC, Z
Description:	Add the contents of the W register with register 'f'. If 'd' is '0', the result is stored in the W register. If 'd' is '1', the result is stored back in register 'f'.

ASRF	Arithmetic Right Shift
Syntax:	[<i>label</i>] ASRF f {,d}
Operands:	0 ≤ f ≤ 127 d ∈ [0,1]
Operation:	(f<7>) → dest<7> (f<7:1>) → dest<6:0>, (f<0>) → C,
Status Affected:	C, Z
Description:	The contents of register 'f' are shifted one bit to the right through the Carry flag. The MSb remains unchanged. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is stored back in register 'f'.

ADDWFC	ADD W and CARRY bit to f
Syntax:	[<i>label</i>] ADDWFC f {,d}
Operands:	0 ≤ f ≤ 127 d ∈ [0,1]
Operation:	(W) + (f) + (C) → dest
Status Affected:	C, DC, Z
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'.



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BCF **Bit Clear f**

Syntax: [*label*] BCF f,b
Operands: $0 \leq f \leq 127$
 $0 \leq b \leq 7$
Operation: $0 \rightarrow (f)$
Status Affected: None
Description: Bit 'b' in register 'f' is cleared.

BTFSC **Bit Test f, Skip if Clear**

Syntax: [*label*] BTFSC f,b
Operands: $0 \leq f \leq 127$
 $0 \leq b \leq 7$
Operation: skip if (f) = 0
Status Affected: None
Description: If bit 'b' in register 'f' is '1', the next instruction is executed.
 If bit 'b', in register 'f', is '0', the next instruction is discarded, and a NOP is executed instead, making this a 2-cycle instruction.

BRA **Relative Branch**

Syntax: [*label*] BRA label
 [*label*] BRA \$+k
Operands: $-256 \leq \text{label} - \text{PC} + 1 \leq 255$
 $-256 \leq k \leq 255$
Operation: $(\text{PC}) + 1 + k \rightarrow \text{PC}$
Status Affected: None
Description: Add the signed 9-bit literal 'k' to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 1 + k. This instruction is a two-cycle instruction. This branch has a limited range.

BTFSS **Bit Test f, Skip if Set**

Syntax: [*label*] BTFSS f,b
Operands: $0 \leq f \leq 127$
 $0 \leq b < 7$
Operation: skip if (f) = 1
Status Affected: None
Description: If bit 'b' in register 'f' is '0', the next instruction is executed.
 If bit 'b' is '1', then the next instruction is discarded and a NOP is executed instead, making this a 2-cycle instruction.

BRW **Relative Branch with W**

Syntax: [*label*] BRW
Operands: None
Operation: $(\text{PC}) + (W) \rightarrow \text{PC}$
Status Affected: None
Description: Add the contents of W (unsigned) to the PC. Since the PC will have incremented to fetch the next instruction, the new address will be PC + 1 + (W). This instruction is a two-cycle instruction.

BSF **Bit Set f**

Syntax: [*label*] BSF f,b
Operands: $0 \leq f \leq 127$
 $0 \leq b \leq 7$
Operation: $1 \rightarrow (f)$
Status Affected: None
Description: Bit 'b' in register 'f' is set.

CALL Call Subroutine

Syntax: [*label*] CALL *k*

Operands: $0 \leq k \leq 2047$

Operation: (PC)+ 1 → TOS,
 $k \rightarrow PC<10:0>$,
(PCLATH<6:3>) → PC<14:11>

Status Affected: None

Description: Call Subroutine. First, return address (PC + 1) is pushed onto the stack. The eleven-bit immediate address is loaded into PC bits <10:0>. The upper bits of the PC are loaded from PCLATH. CALL is a two-cycle instruction.

CLRWDT Clear Watchdog Timer

Syntax: [*label*] CLRWDT

Operands: None

Operation: 00h → WDT
0 → WDT prescaler,
1 → \overline{TO}
1 → \overline{PD}

Status Affected: \overline{TO} , \overline{PD}

Description: CLRWDT instruction resets the Watchdog Timer. It also resets the prescaler of the WDT. Status bits \overline{TO} and \overline{PD} are set.

CALLW Subroutine Call With W

Syntax: [*label*] CALLW

Operands: None

Operation: (PC) + 1 → TOS,
(W) → PC<7:0>,
(PCLATH<6:0>) → PC<14:8>

Status Affected: None

Description: Subroutine call with W. First, the return address (PC + 1) is pushed onto the return stack. Then, the contents of W is loaded into PC<7:0>, and the contents of PCLATH into PC<14:8>. CALLW is a two-cycle instruction.

COMF Complement f

Syntax: [*label*] COMF *f,d*

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: (\bar{f}) → (destination)

Status Affected: Z

Description: The contents of register 'f' are complemented. If 'd' is '0', the result is stored in W. If 'd' is '1', the result is stored back in register 'f'.

CLRF Clear f

Syntax: [*label*] CLRF *f*

Operands: $0 \leq f \leq 127$

Operation: 00h → (f)
1 → Z

Status Affected: Z

Description: The contents of register 'f' are cleared and the Z bit is set.

DECF Decrement f

Syntax: [*label*] DECF *f,d*

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: (f) - 1 → (destination)

Status Affected: Z

Description: Decrement register 'f'. If 'd' is '0', the result is stored in the W register. If 'd' is '1', the result is stored back in register 'f'.

CLRW Clear W

Syntax: [*label*] CLRW

Operands: None

Operation: 00h → (W)
1 → Z

Status Affected: Z

Description: W register is cleared. Zero bit (Z) is set.

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DECFSZ **Decrement f, Skip if 0**

Syntax: [*label*] DECFSZ f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f) - 1 \rightarrow (\text{destination});$
 skip if result = 0

Status Affected: None

Description: The contents of register 'f' are decremented. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed back in register 'f'. If the result is '1', the next instruction is executed. If the result is '0', then a NOP is executed instead, making it a 2-cycle instruction.

INCFSZ **Increment f, Skip if 0**

Syntax: [*label*] INCFSZ f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f) + 1 \rightarrow (\text{destination});$
 skip if result = 0

Status Affected: None

Description: The contents of register 'f' are incremented. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed back in register 'f'. If the result is '1', the next instruction is executed. If the result is '0', a NOP is executed instead, making it a 2-cycle instruction.

GOTO **Unconditional Branch**

Syntax: [*label*] GOTO k

Operands: $0 \leq k \leq 2047$

Operation: $k \rightarrow PC<10:0>$
 $PCLATH<6:3> \rightarrow PC<14:11>$

Status Affected: None

Description: GOTO is an unconditional branch. The eleven-bit immediate value is loaded into PC bits <10:0>. The upper bits of PC are loaded from PCLATH<4:3>. GOTO is a two-cycle instruction.

IORLW **Inclusive OR literal with W**

Syntax: [*label*] IORLW k

Operands: $0 \leq k \leq 255$

Operation: $(W) .OR. k \rightarrow (W)$

Status Affected: Z

Description: The contents of the W register are OR'ed with the eight-bit literal 'k'. The result is placed in the W register.

INCF **Increment f**

Syntax: [*label*] INCF f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f) + 1 \rightarrow (\text{destination})$

Status Affected: Z

Description: The contents of register 'f' are incremented. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed back in register 'f'.

IORWF **Inclusive OR W with f**

Syntax: [*label*] IORWF f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(W) .OR. (f) \rightarrow (\text{destination})$

Status Affected: Z

Description: Inclusive OR the W register with register 'f'. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed back in register 'f'.

LSLF **Logical Left Shift**

Syntax: `[label] LSLF f {,d}`

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f<7>) \rightarrow C$
 $(f<6:0>) \rightarrow \text{dest}<7:1>$
 $0 \rightarrow \text{dest}<0>$

Status Affected: C, Z

Description: The contents of register 'f' are shifted one bit to the left through the Carry flag. A '0' is shifted into the LSb. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is stored back in register 'f'.



LSRF **Logical Right Shift**

Syntax: `[label] LSLF f {,d}`

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $0 \rightarrow \text{dest}<7>$
 $(f<7:1>) \rightarrow \text{dest}<6:0>$,
 $(f<0>) \rightarrow C$,

Status Affected: C, Z

Description: The contents of register 'f' are shifted one bit to the right through the Carry flag. A '0' is shifted into the MSb. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is stored back in register 'f'.



MOVf **Move f**

Syntax: `[label] MOVf f,d`

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f) \rightarrow (\text{dest})$

Status Affected: Z

Description: The contents of register f is moved to a destination dependent upon the status of d. If d = 0, destination is W register. If d = 1, the destination is file register f itself. d = 1 is useful to test a file register since status flag Z is affected.

Words: 1

Cycles: 1

Example: `MOVf FSR, 0`

After Instruction

`W = value in FSR register`

`Z = 1`

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MOVIW Move INDFn to W

Syntax: [*label*] MOVIW ++FSRn
 [*label*] MOVIW --FSRn
 [*label*] MOVIW FSRn++
 [*label*] MOVIW FSRn--
 [*label*] MOVIW k[FSRn]

Operands: $n \in [0,1]$
 $mm \in [00,01, 10, 11]$
 $-32 \leq k \leq 31$

Operation: INDFn \rightarrow W
 Effective address is determined by

- FSR + 1 (preincrement)
- FSR - 1 (predecrement)
- FSR + k (relative offset)

After the Move, the FSR value will be either:

- FSR + 1 (all increments)
- FSR - 1 (all decrements)
- Unchanged

Status Affected: Z

Mode	Syntax	mm
Preincrement	++FSRn	00
Predecrement	--FSRn	01
Postincrement	FSRn++	10
Postdecrement	FSRn--	11

Description: This instruction is used to move data between W and one of the indirect registers (INDFn). Before/after this move, the pointer (FSRn) is updated by pre/post incrementing/decrementing it.

Note: The INDFn registers are not physical registers. Any instruction that accesses an INDFn register actually accesses the register at the address specified by the FSRn.

FSRn is limited to the range 0000h - FFFFh. Incrementing/decrementing it beyond these bounds will cause it to wrap-around.

MOVLB Move literal to BSR

Syntax: [*label*] MOVLB k

Operands: $0 \leq k \leq 15$

Operation: $k \rightarrow$ BSR

Status Affected: None

Description: The five-bit literal 'k' is loaded into the Bank Select Register (BSR).

MOVLP Move literal to PCLATH

Syntax: [*label*] MOVLP k

Operands: $0 \leq k \leq 127$

Operation: $k \rightarrow$ PCLATH

Status Affected: None

Description: The seven-bit literal 'k' is loaded into the PCLATH register.

MOVLW Move literal to W

Syntax: [*label*] MOVLW k

Operands: $0 \leq k \leq 255$

Operation: $k \rightarrow$ (W)

Status Affected: None

Description: The eight-bit literal 'k' is loaded into W register. The "don't cares" will assemble as '0's.

Words: 1

Cycles: 1

Example: MOVLW 0x5A
 After Instruction
 W = 0x5A

MOVWF Move W to f

Syntax: [*label*] MOVWF f

Operands: $0 \leq f \leq 127$

Operation: (W) \rightarrow (f)

Status Affected: None

Description: Move data from W register to register 'f'.

Words: 1

Cycles: 1

Example: MOVWF OPTION_REG
 Before Instruction
 OPTION_REG = 0xFF
 W = 0x4F
 After Instruction
 OPTION_REG = 0x4F
 W = 0x4F

MOVWI Move W to INDFn

Syntax: [*label*] MOVWI ++FSRn
 [*label*] MOVWI --FSRn
 [*label*] MOVWI FSRn++
 [*label*] MOVWI FSRn--
 [*label*] MOVWI k[FSRn]

Operands: $n \in [0,1]$
 $mm \in [00,01, 10, 11]$
 $-32 \leq k \leq 31$

Operation: $W \rightarrow \text{INDFn}$
 Effective address is determined by

- FSR + 1 (preincrement)
- FSR - 1 (predecrement)
- FSR + k (relative offset)

After the Move, the FSR value will be either:

- FSR + 1 (all increments)
- FSR - 1 (all decrements)

Unchanged

Status Affected: None

Mode	Syntax	mm
Preincrement	++FSRn	00
Predecrement	--FSRn	01
Postincrement	FSRn++	10
Postdecrement	FSRn--	11

Description: This instruction is used to move data between W and one of the indirect registers (INDFn). Before/after this move, the pointer (FSRn) is updated by pre/post incrementing/decrementing it.

Note: The INDFn registers are not physical registers. Any instruction that accesses an INDFn register actually accesses the register at the address specified by the FSRn.

FSRn is limited to the range 0000h - FFFFh. Incrementing/decrementing it beyond these bounds will cause it to wrap-around.

The increment/decrement operation on FSRn WILL NOT affect any Status bits.

NOP No Operation

Syntax: [*label*] NOP

Operands: None

Operation: No operation

Status Affected: None

Description: No operation.

Words: 1

Cycles: 1

Example: NOP

OPTION Load OPTION_REG Register with W

Syntax: [*label*] OPTION

Operands: None

Operation: $(W) \rightarrow \text{OPTION_REG}$

Status Affected: None

Description: Move data from W register to OPTION_REG register.

Words: 1

Cycles: 1

Example: OPTION

Before Instruction
 OPTION_REG = 0xFF
 W = 0x4F

After Instruction
 OPTION_REG = 0x4F
 W = 0x4F

RESET Software Reset

Syntax: [*label*] RESET

Operands: None

Operation: Execute a device Reset. Resets the nRI flag of the PCON register.

Status Affected: None

Description: This instruction provides a way to execute a hardware Reset by software.

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RETFIE Return from Interrupt

Syntax: [*label*] RETFIE

Operands: None

Operation: TOS → PC,
1 → GIE

Status Affected: None

Description: Return from Interrupt. Stack is POPed and Top-of-Stack (TOS) is loaded in the PC. Interrupts are enabled by setting Global Interrupt Enable bit, GIE (INTCON<7>). This is a two-cycle instruction.

Words: 1

Cycles: 2

Example:

```

RETFIE
After Interrupt
PC = TOS
GIE = 1

```

RETLW Return with literal in W

Syntax: [*label*] RETLW *k*

Operands: $0 \leq k \leq 255$

Operation: *k* → (W);
TOS → PC

Status Affected: None

Description: The W register is loaded with the eight bit literal '*k*'. The program counter is loaded from the top of the stack (the return address). This is a two-cycle instruction.

Words: 1

Cycles: 2

Example:

```

CALL TABLE;W contains table
;offset value
• ;W now has table value
•
•
ADDWF PC ;W = offset
RETLW k1 ;Begin table
RETLW k2 ;
•
•
•
RETLW kn ; End of table

```

Before Instruction
W = 0x07

After Instruction
W = value of k8

RETURN Return from Subroutine

Syntax: [*label*] RETURN

Operands: None

Operation: TOS → PC

Status Affected: None

Description: Return from subroutine. The stack is POPed and the top of the stack (TOS) is loaded into the program counter. This is a two-cycle instruction.

RLF Rotate Left f through Carry

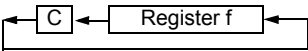
Syntax: [*label*] RLF *f*,*d*

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: See description below

Status Affected: C

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 the W register. If '*d*' is '1', the result is stored back in register '*f*'.



Words: 1

Cycles: 1

Example:

```

RLF    REG1,0

```

Before Instruction

```

REG1   = 1110 0110
C      = 0

```

After Instruction

```

REG1   = 1110 0110
W      = 1100 1100
C      = 1

```

RRF Rotate Right f through Carry

Syntax: [*label*] RRF f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: See description below

Status Affected: C

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 the W register. If 'd' is '1', the result is placed back in register 'f'.



SLEEP Enter Sleep mode

Syntax: [*label*] SLEEP

Operands: None

Operation: 00h → WDT,
 0 → WDT prescaler,
 1 → \overline{TO} ,
 0 → \overline{PD}

Status Affected: \overline{TO} , \overline{PD}

Description: The power-down Status bit, \overline{PD} is cleared. Time-out Status bit, \overline{TO} is set. Watchdog Timer and its prescaler are cleared.
 The processor is put into Sleep mode with the oscillator stopped.

SUBLW Subtract W from literal

Syntax: [*label*] SUBLW k

Operands: $0 \leq k \leq 255$

Operation: $k - (W) \rightarrow (W)$

Status Affected: C, DC, Z

Description: The W register is subtracted (2's complement method) from the eight-bit literal 'k'. The result is placed in the W register.

C = 0	$W > k$
C = 1	$W \leq k$
DC = 0	$W<3:0> > k<3:0>$
DC = 1	$W<3:0> \leq k<3:0>$

SUBWF Subtract W from f

Syntax: [*label*] SUBWF f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f) - (W) \rightarrow (\text{destination})$

Status Affected: C, DC, Z

Description: Subtract (2's complement method) W register from register 'f'. If 'd' is '0', the result is stored in the W register. If 'd' is '1', the result is stored back in register 'f'.

C = 0	$W > f$
C = 1	$W \leq f$
DC = 0	$W<3:0> > f<3:0>$
DC = 1	$W<3:0> \leq f<3:0>$

SUBWFB Subtract W from f with Borrow

Syntax: SUBWFB f {,d}

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: $(f) - (W) - (\overline{B}) \rightarrow \text{dest}$

Status Affected: C, DC, Z

Description: Subtract W and the BORROW flag (CARRY) 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'.

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SWAPF **Swap Nibbles in f**

Syntax: [*label*] SWAPF f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: ($f<3:0>$) \rightarrow (destination<7:4>),
 ($f<7:4>$) \rightarrow (destination<3:0>)

Status Affected: None

Description: The upper and lower nibbles of register 'f' are exchanged. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed in register 'f'.

XORLW **Exclusive OR literal with W**

Syntax: [*label*] XORLW k

Operands: $0 \leq k \leq 255$

Operation: (W) .XOR. k \rightarrow (W)

Status Affected: Z

Description: The contents of the W register are XOR'ed with the eight-bit literal 'k'. The result is placed in the W register.

TRIS **Load TRIS Register with W**

Syntax: [*label*] TRIS f

Operands: $5 \leq f \leq 7$

Operation: (W) \rightarrow TRIS register 'f'

Status Affected: None

Description: Move data from W register to TRIS register.
 When 'f' = 5, TRISA is loaded.
 When 'f' = 6, TRISB is loaded.
 When 'f' = 7, TRISC is loaded.

XORWF **Exclusive OR W with f**

Syntax: [*label*] XORWF f,d

Operands: $0 \leq f \leq 127$
 $d \in [0,1]$

Operation: (W) .XOR. (f) \rightarrow (destination)

Status Affected: Z

Description: Exclusive OR the contents of the W register with register 'f'. If 'd' is '0', the result is stored in the W register. If 'd' is '1', the result is stored back in register 'f'.

25.0 ELECTRICAL SPECIFICATIONS

Absolute Maximum Ratings^(†)

Ambient temperature under bias	-40°C to +125°C
Storage temperature	-65°C to +150°C
Voltage on VDD with respect to Vss, PIC16F1526/7	-0.3V to +6.5V
Voltage on VDD with respect to Vss, PIC16LF1526/7	-0.3V to +4.0V
Voltage on MCLR with respect to Vss	-0.3V to +9.0V
Voltage on all other pins with respect to Vss	-0.3V to (VDD + 0.3V)
Total power dissipation ⁽¹⁾	800 mW
Maximum current out of Vss pin, -40°C ≤ TA ≤ +85°C for industrial	425 mA
Maximum current out of Vss pin, -40°C ≤ TA ≤ +125°C for extended	175 mA
Maximum current into VDD pin, -40°C ≤ TA ≤ +85°C for industrial	425 mA
Maximum current into VDD pin, -40°C ≤ TA ≤ +125°C for extended	175 mA
Clamp current, IK (VPIN < 0 or VPIN > 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

Note 1: Power dissipation is calculated as follows: $P_{DIS} = V_{DD} \times \{I_{DD} - \sum I_{OH}\} + \sum \{(V_{DD} - V_{OH}) \times I_{OH}\} + \sum (V_{OL} \times I_{OL})$.

† 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 above maximum rating conditions for extended periods may affect device reliability.

PIC16(L)F1526/27

FIGURE 25-1: PIC16F1526/7 VOLTAGE FREQUENCY GRAPH, $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$

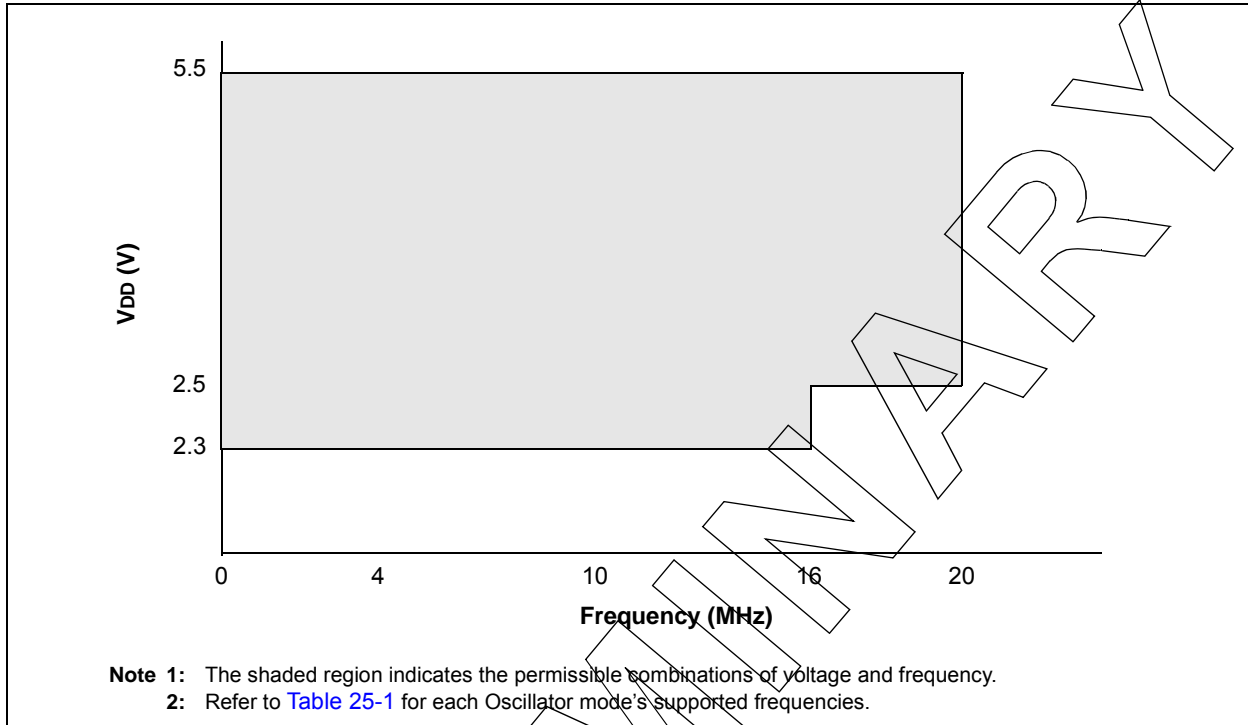
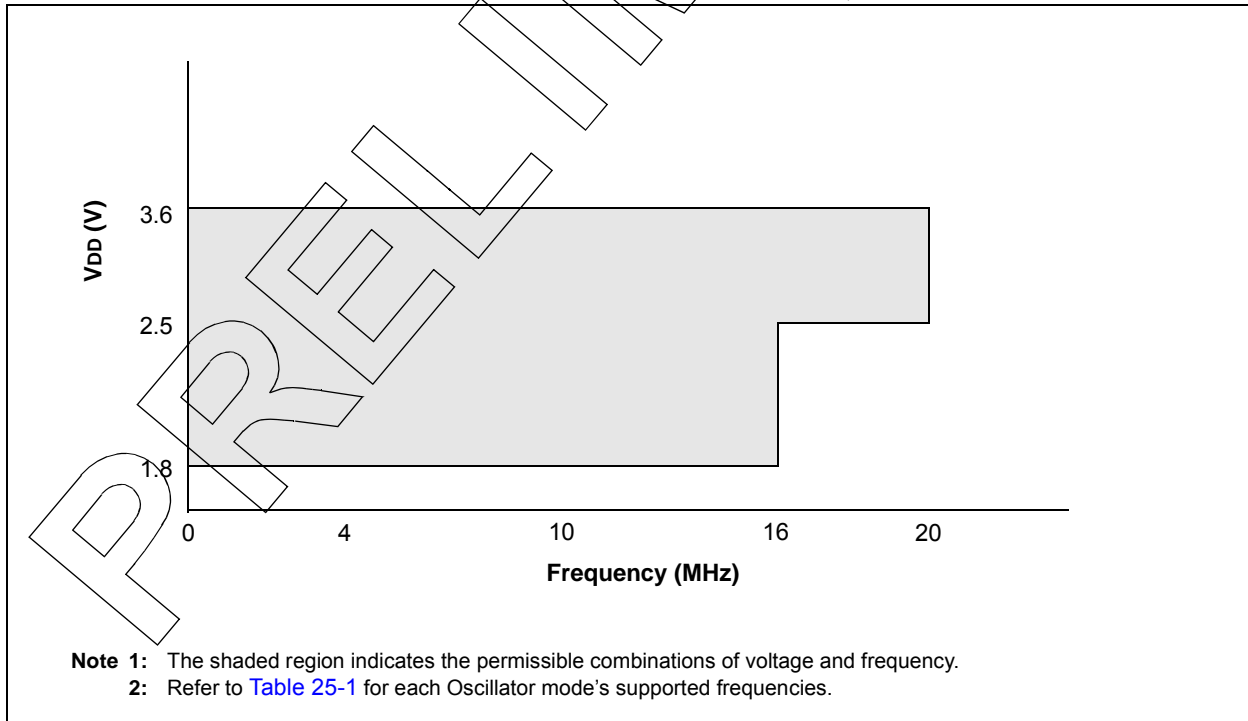


FIGURE 25-2: PIC16LF1526/7 VOLTAGE FREQUENCY GRAPH, $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$



25.1 DC Characteristics: PIC16(L)F1526/27-I/E (Industrial, Extended)

PIC16LF1526/7		Standard Operating Conditions (unless otherwise stated)					
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended					
PIC16F1526/7		Standard Operating Conditions (unless otherwise stated)					
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended					
Param. No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
D001	VDD	Supply Voltage					
		PIC16LF1526/7	1.8 2.5	—	3.6 3.6	V	Fosc ≤ 16 MHz: Fosc ≤ 20 MHz
D001		PIC16F1526/7	2.3	—	5.5	V	Fosc ≤ 16 MHz:
			2.5	—	5.5	V	Fosc ≤ 20 MHz
D002*	VDR	RAM Data Retention Voltage⁽¹⁾					
		PIC16LF1526/7	1.5	—	—	V	Device in Sleep mode
D002*		PIC16F1526/7	1.7	—	—	V	Device in Sleep mode
	VPOR*	Power-on Reset Release Voltage	—	1.6	—	V	
	VPORR*	Power-on Reset Rearm Voltage					
		PIC16LF1526/7	—	0.8	—	V	Device in Sleep mode
		PIC16F1526/7	—	1.7	—	V	Device in Sleep mode
D003	VADFVR	Fixed Voltage Reference Voltage for ADC, Initial Accuracy	-7		6	%	1.024V, VDD ≥ 2.5V, 85°C (NOTE 2)
			-8		6		1.024V, VDD ≥ 2.5V, 125°C (NOTE 2)
			-7		6		2.048V, VDD ≥ 2.5V, 85°C
			-8		6		2.048V, VDD ≥ 2.5V, 125°C
			-7		6		4.096V, VDD ≥ 4.75V, 85°C
			-8		6		4.096V, VDD ≥ 4.75V, 125°C
D003A	VCDAFVR	Fixed Voltage Reference Voltage for Comparator and DAC, Initial Accuracy	-11		7	%	1.024V, VDD ≥ 2.5V, 85°C
			-11		7		1.024V, VDD ≥ 2.5V, 125°C
			-11		7		2.048V, VDD ≥ 2.5V, 85°C
			-11		7		2.048V, VDD ≥ 2.5V, 125°C
			-11		7		4.096V, VDD ≥ 4.75V, 85°C
			-11		7		4.096V, VDD ≥ 4.75V, 125°C
D004*	SVDD	VDD Rise Rate to ensure internal Power-on Reset signal	0.05	—	—	V/ms	See Section 6.1 "Power-on Reset (POR)" for details.

* These parameters are characterized but not tested.

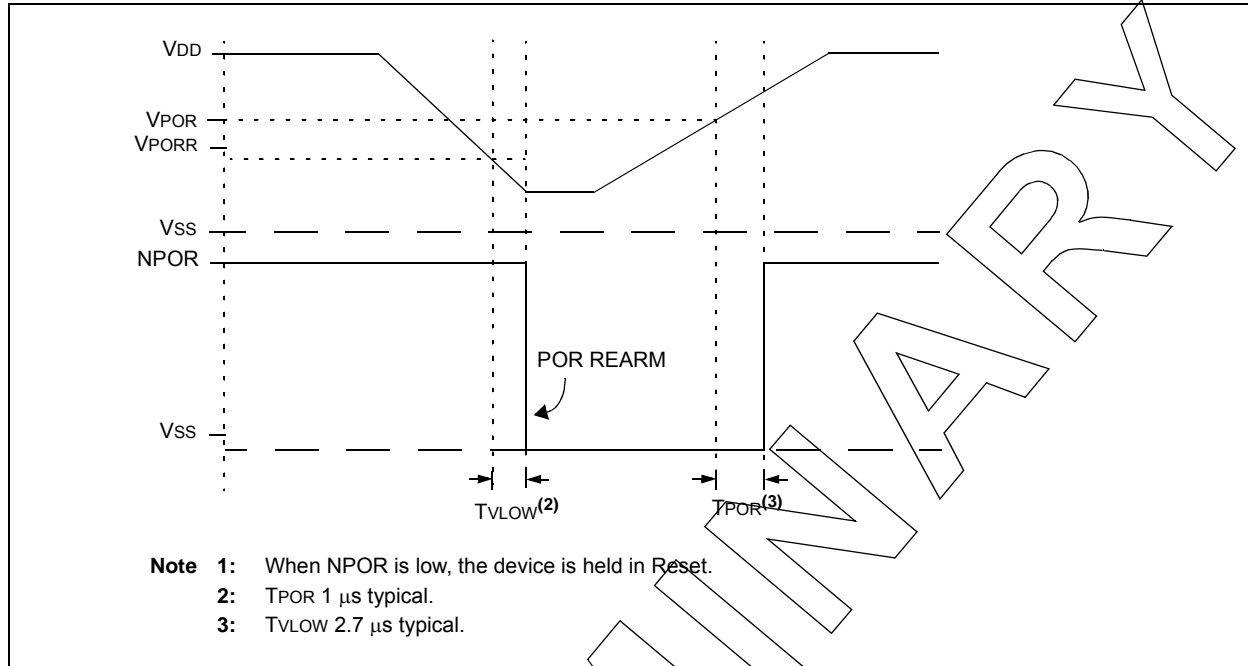
† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note 1: This is the limit to which VDD can be lowered in Sleep mode without losing RAM data.

Note 2: For proper operation, the minimum value of the ADC positive voltage reference must be 1.8V or greater. When selecting the FVR or the VREF+ pin as the source of the ADC positive voltage reference, be aware that the voltage must be 1.8V or greater.

PIC16(L)F1526/27

FIGURE 25-3: POR AND POR REARM WITH SLOW RISING V_{DD}



25.2 DC Characteristics: PIC16(L)F1526/27-I/E (Industrial, Extended)

PIC16LF1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended						
PIC16F1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended						
Param No.	Device Characteristics	Min.	Typ†	Max.	Units	Conditions		
						VDD	Note	
Supply Current (IDD)^(1, 2)								
D010		—	8.0	—	μA	1.8	Fosc = 32 kHz LP Oscillator mode	
		—	12.0	—	μA	3.0		
D010		—	11	—	μA	2.3	Fosc = 32 kHz LP Oscillator mode	
		—	13	—	μA	3.0		
		—	14	—	μA	5.0		
D011		—	60	—	μA	1.8	Fosc = 1 MHz XT Oscillator mode	
		—	110	—	μA	3.0		
D011		—	92	—	μA	2.3	Fosc = 1 MHz XT Oscillator mode	
		—	135	—	μA	3.0		
		—	170	—	μA	5.0		
D012		—	145	—	μA	1.8	Fosc = 4 MHz XT Oscillator mode	
		—	260	—	μA	3.0		
D012		—	190	—	μA	2.3	Fosc = 4 MHz XT Oscillator mode	
		—	305	—	μA	3.0		
		—	365	—	μA	5.0		
D014		—	118	—	μA	1.8	Fosc = 4 MHz EC Oscillator mode, Medium-power mode	
		—	210	—	μA	3.0		
D014		—	156	—	μA	2.3	Fosc = 4 MHz EC Oscillator mode Medium-power mode	
		—	260	—	μA	3.0		
		—	330	—	μA	5.0		
D015		—	2.0	—	μA	1.8	Fosc = 31 kHz LFINTOSC mode	
		—	4.0	—	μA	3.0		
D015		—	18	—	μA	2.3	Fosc = 31 kHz LFINTOSC mode	
		—	24	—	μA	3.0		
		—	25	—	μA	5.0		

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note**
- 1: 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 disabled.
 - 2: The supply current is mainly a function of the operating voltage and frequency. Other factors, such as I/O pin loading and switching rate, oscillator type, internal code execution pattern and temperature, also have an impact on the current consumption.
 - 3: For RC oscillator configurations, current through REXT is not included. The current through the resistor can be extended by the formula $I_R = V_{DD}/2R_{EXT}$ (mA) with REXT in kΩ.

PIC16(L)F1526/27

25.2 DC Characteristics: PIC16(L)F1526/27-I/E (Industrial, Extended) (Continued)

PIC16LF1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature					-40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended	
PIC16F1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature					-40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended	
Param No.	Device Characteristics	Min.	Typ†	Max.	Units	Conditions		
						VDD	Note	
Supply Current (IDD)^(1, 2)								
D016		—	110	—	μA	1.8	Fosc = 500 kHz	
		—	150	—	μA	3.0	HFINTOSC mode	
D016		—	150	—	μA	2.3	Fosc = 500 kHz	
		—	210	—	μA	3.0	HFINTOSC mode	
		—	335	—	μA	5.0		
D017*		—	0.25	—	mA	1.8	Fosc = 8 MHz	
		—	0.45	—	mA	3.0	HFINTOSC mode	
D017*		—	0.35	—	mA	2.3	Fosc = 8 MHz	
		—	0.69	—	mA	3.0	HFINTOSC mode	
		—	0.75	—	mA	5.0		
D018		—	0.47	—	mA	1.8	Fosc = 16 MHz	
		—	0.84	—	mA	3.0	HFINTOSC mode	
D018		—	0.70	—	mA	2.3	Fosc = 16 MHz	
		—	1.00	—	mA	3.0	HFINTOSC mode	
		—	1.17	—	mA	5.0		
D019A		—	1.15	—	mA	3.0	Fosc = 20 MHz ECH mode	
D019A		—	1.15	—	mA	3.0	Fosc = 20 MHz	
		—	1.3	—	mA	5.0	ECH mode	
D019B		—	8	—	μA	1.8	Fosc = 32 kHz	
		—	10	—	μA	3.0	ECL mode	
D019B		—	10	—	μA	3.0	Fosc = 32 kHz	
		—	11	—	μA	5.0	ECL mode	
D019C		—	25	—	μA	1.8	Fosc = 500 kHz	
		—	35	—	μA	3.0	ECL mode	
D019C		—	35	—	μA	3.0	Fosc = 500 kHz	
		—	40	—	μA	5.0	ECL mode	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note**
- 1: 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 disabled.
 - 2: The supply current is mainly a function of the operating voltage and frequency. Other factors, such as I/O pin loading and switching rate, oscillator type, internal code execution pattern and temperature, also have an impact on the current consumption.
 - 3: For RC oscillator configurations, current through REXT is not included. The current through the resistor can be extended by the formula $I_R = V_{DD}/2R_{EXT}$ (mA) with REXT in kΩ.

25.2 DC Characteristics: PIC16(L)F1526/27-I/E (Industrial, Extended) (Continued)

PIC16LF1526/7		Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended					
PIC16F1526/7		Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended					
Param No.	Device Characteristics	Min.	Typ†	Max.	Units	Conditions	
						VDD	Note
Supply Current (IDD)^(1, 2)							
D020		—	1.0	—	mA	3.0	Fosc = 20 MHz HS Oscillator mode
		—	1.2	—	mA	3.6	
D020		—	1.4	—	mA	3.0	Fosc = 20 MHz HS Oscillator mode
		—	1.7	—	mA	5.0	
D021		—	300	—	μA	1.8	Fosc = 4 MHz EXTRC mode (Note 3)
		—	500	—	μA	3.0	
D021		—	165	—	μA	2.3	Fosc = 4 MHz EXTRC mode (Note 3)
		—	280	—	μA	3.0	
		—	350	—	μA	5.0	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note 1:** 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 disabled.
- Note 2:** The supply current is mainly a function of the operating voltage and frequency. Other factors, such as I/O pin loading and switching rate, oscillator type, internal code execution pattern and temperature, also have an impact on the current consumption.
- Note 3:** For RC oscillator configurations, current through REXT is not included. The current through the resistor can be extended by the formula $I_R = V_{DD}/2R_{EXT}$ (mA) with REXT in kΩ.

PIC16(L)F1526/27

25.3 DC Characteristics: PIC16(L)F1526/27-I/E (Power-Down)

PIC16LF1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended						
PIC16F1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended						
Param No.	Device Characteristics	Min.	Typ†	Max. +85°C	Max. +125°C	Units	Conditions	
							VDD	Note
Power-down Base Current (IPD)⁽²⁾								
D022		—	20	—	—	nA	1.8	WDT, BOR, FVR, and SOSC disabled, all peripherals inactive
		—	30	—	—	nA	3.0	
D022		—	300	—	—	nA	3.0	WDT, BOR, FVR, and SOSC disabled, all peripherals inactive, low-power regulator active
		—	470	—	—	nA	5.0	
D023		—	300	—	—	nA	1.8	LPWDT Current (Note 1)
		—	750	—	—	nA	3.0	
D023		—	500	—	—	nA	2.3	LPWDT Current (Note 1)
		—	770	—	—	nA	3.0	
		—	850	—	—	nA	5.0	
D023A		—	8.5	—	—	μA	1.8	FVR current (Note 1)
		—	8.5	—	—	μA	3.0	
D023A		—	18	—	—	μA	2.3	FVR current (Note 1)
		—	18.5	—	—	μA	3.0	
		—	19	—	—	μA	5.0	
D024		—	8.0	—	—	μA	3.0	BOR Current (Note 1)
D024		—	7	—	—	μA	3.0	BOR Current (Note 1)
		—	9	—	—	μA	5.0	
D024A		—	300	—	—	nA	3.0	LPBOR Current
D024A		—	300	—	—	nA	3.0	LPBOR Current
		—	450	—	—	nA	5.0	
D025		—	0.6	—	—	μA	1.8	SOSC Current (Note 1)
		—	1.8	—	—	μA	3.0	
D025		—	0.7	—	—	μA	2.3	SOSC Current (Note 1)
		—	3	—	—	μA	3.0	
		—	6	—	—	μA	5.0	
D026		—	0.1	—	—	μA	1.8	A/D Current (Note 1, Note 3), no conversion in progress
		—	0.1	—	—	μA	3.0	
D026		—	160	—	—	nA	2.3	A/D Current (Note 1, Note 3), no conversion in progress
		—	400	—	—	nA	3.0	
		—	500	—	—	nA	5.0	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note 1:** The peripheral current is the sum of the base IDD or IPD and the additional current consumed when this peripheral is enabled. The peripheral Δ current can be determined by subtracting the base IDD or IPD current from this limit. Max values should be used when calculating total current consumption.
- Note 2:** 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.
- Note 3:** A/D oscillator source is FRC.

25.3 DC Characteristics: PIC16(L)F1526/27-I/E (Power-Down) (Continued)

PIC16LF1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended						
PIC16F1526/7		Standard Operating Conditions (unless otherwise stated)						
		Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended						
Param No.	Device Characteristics	Min.	Typ†	Max. +85°C	Max. +125°C	Units	Conditions	
							VDD	Note
Power-down Base Current (IPD)⁽²⁾								
D026A*		—	250	—	—	μA	1.8	A/D Current (Note 1, Note 3), conversion in progress
		—	250	—	—	μA	3.0	
D026A*		—	280	—	—	μA	2.3	A/D Current (Note 1, Note 3), conversion in progress
		—	280	—	—	μA	3.0	
		—	280	—	—	μA	5.0	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note 1:** The peripheral current is the sum of the base IDD or IPD and the additional current consumed when this peripheral is enabled. The peripheral Δ current can be determined by subtracting the base IDD or IPD current from this limit. Max values should be used when calculating total current consumption.
- Note 2:** 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.
- Note 3:** A/D oscillator source is FRC.

PIC16(L)F1526/27

25.4 DC Characteristics: PIC16(L)F1526/27-I/E

DC CHARACTERISTICS			Standard Operating Conditions (unless otherwise stated) Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for extended				
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
D030 D030A D031 D032 D033	V _{IL}	Input Low Voltage					
		I/O PORT:					
		with TTL buffer	—	—	0.8	V	$4.5\text{V} \leq V_{DD} \leq 5.5\text{V}$
		with Schmitt Trigger buffer	—	—	$0.15 V_{DD}$	V	$1.8\text{V} \leq V_{DD} \leq 4.5\text{V}$
		with I ² C™ levels	—	—	$0.2 V_{DD}$	V	$2.0\text{V} \leq V_{DD} \leq 5.5\text{V}$
		with SMBus levels	—	—	$0.3 V_{DD}$	V	$2.7\text{V} \leq V_{DD} \leq 5.5\text{V}$
D032		MCLR, OSC1 (RC mode) ⁽¹⁾	—	—	$0.2 V_{DD}$	V	
D033		OSC1 (HS mode)	—	—	$0.3 V_{DD}$	V	
D040 D040A D041 D042 D043A D043B	V _{IH}	Input High Voltage					
		I/O ports:					
		with TTL buffer	2.0	—	—	V	$4.5\text{V} \leq V_{DD} \leq 5.5\text{V}$
			$0.25 V_{DD} + 0.8$	—	—	V	$1.8\text{V} \leq V_{DD} \leq 4.5\text{V}$
		with Schmitt Trigger buffer	$0.8 V_{DD}$	—	—	V	$2.0\text{V} \leq V_{DD} \leq 5.5\text{V}$
		with I ² C™ levels	$0.7 V_{DD}$	—	—	V	
		with SMBus levels	2.1	—	—	V	$2.7\text{V} \leq V_{DD} \leq 5.5\text{V}$
		D042		MCLR	$0.8 V_{DD}$	—	—
D043A		OSC1 (HS mode)	$0.7 V_{DD}$	—	—	V	
D043B		OSC1 (RC mode)	$0.9 V_{DD}$	—	—	V	(Note 1)
D060 D061	I _{IL}	Input Leakage Current⁽²⁾					
		I/O ports	—	± 5	± 125	nA	$V_{SS} \leq V_{PIN} \leq V_{DD}$, Pin at high-impedance at 85°C
D061		MCLR ⁽³⁾	—	± 5	± 1000	nA	125°C
D061			—	± 50	± 200	nA	$V_{SS} \leq V_{PIN} \leq V_{DD}$ at 85°C
D070*	I _{PUR}	Weak Pull-up Current					
			25 25	100 140	200 300	μA	$V_{DD} = 3.3\text{V}$, $V_{PIN} = V_{SS}$ $V_{DD} = 5.0\text{V}$, $V_{PIN} = V_{SS}$
D080	V _{OL}	Output Low Voltage⁽⁴⁾					
		I/O ports	—	—	0.6	V	I _{OL} = 8mA, V _{DD} = 5V I _{OL} = 6mA, V _{DD} = 3.3V I _{OL} = 1.8mA, V _{DD} = 1.8V
D090	V _{OH}	Output High Voltage⁽⁴⁾					
		I/O ports	$V_{DD} - 0.7$	—	—	V	I _{OH} = 3.5mA, V _{DD} = 5V I _{OH} = 3mA, V _{DD} = 3.3V I _{OH} = 1mA, V _{DD} = 1.8V
D101* D101A*	C _{OSC2} C _{IO}	Capacitive Loading Specs on Output Pins					
		OSC2 pin	—	—	15	pF	In XT, HS and LP modes when external clock is used to drive OSC1
D101A*	C _{IO}	All I/O pins	—	—	50	pF	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note 1: In RC oscillator configuration, the OSC1/CLKIN pin is a Schmitt Trigger input. It is not recommended to use an external clock in RC mode.

2: Negative current is defined as current sourced by the pin.

3: 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.

4: Including OSC2 in CLKOUT mode.

25.5 Memory Programming Requirements

DC CHARACTERISTICS			Standard Operating Conditions (unless otherwise stated) Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$				
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
Program Memory Programming Specifications							
D110	VIHH	Voltage on $\overline{\text{MCLR}}/\text{VPP}$ pin	8.0	—	9.0	V	(Note 2, Note 3)
D111	IDDP	Supply Current during Programming	—	—	10	mA	
D112		VDD for Bulk Erase	2.7	—	VDD max.	V	
D113	VPEW	VDD for Write or Row Erase	VDD min.	—	VDD max.	V	
D114	IPPPGM	Current on $\overline{\text{MCLR}}/\text{VPP}$ during Erase/Write	—	—	1.0	mA	
D115	IDDPGM	Current on VDD during Erase/Write	—	—	5.0	mA	
Program Flash Memory							
D121	EP	Cell Endurance	10K	—	—	E/W	-40°C to $+85^{\circ}\text{C}$ (Note 1)
D122	VPR	VDD for Read	VDD min.	—	VDD max.	V	
D123	TIW	Self-timed Write Cycle Time	—	2	2.5	ms	Provided no other specifications are violated
D124	TRETD	Characteristic Retention	40	—	—	Year	

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note 1: Self-write and Block Erase.

Note 2: Required only if single-supply programming is disabled.

Note 3: The MPLAB ICD 2 does not support variable VPP output. Circuitry to limit the ICD 2 VPP voltage must be placed between the ICD 2 and target system when programming or debugging with the ICD 2.

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25.6 Thermal Considerations

Standard Operating Conditions (unless otherwise stated)					
Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$					
Param No.	Sym.	Characteristic	Typ.	Units	Conditions
TH01	θ_{JA}	Thermal Resistance Junction to Ambient	TBD	$^{\circ}\text{C}/\text{W}$	64-pin TQFP package
			TBD	$^{\circ}\text{C}/\text{W}$	64-pin QFN package
TH02	θ_{JC}	Thermal Resistance Junction to Case	TBD	$^{\circ}\text{C}/\text{W}$	64-pin TQFP package
			TBD	$^{\circ}\text{C}/\text{W}$	64-pin QFN package
TH03	T_{JMAX}	Maximum Junction Temperature	150	$^{\circ}\text{C}$	
TH04	PD	Power Dissipation	—	W	$PD = P_{INTERNAL} + P_{I/O}$
TH05	$P_{INTERNAL}$	Internal Power Dissipation	—	W	$P_{INTERNAL} = I_{DD} \times V_{DD}^{(1)}$
TH06	$P_{I/O}$	I/O Power Dissipation	—	W	$P_{I/O} = \sum (I_{OL} \times V_{OL}) + \sum (I_{OH} \times (V_{DD} - V_{OH}))$
TH07	P_{DER}	Derated Power	—	W	$P_{DER} = P_{D_{MAX}} (T_J - T_A) / \theta_{JA}^{(2)}$

Legend: TBD = To Be Determined

Note 1: I_{DD} is current to run the chip alone without driving any load on the output pins.

2: T_A = Ambient Temperature.

3: T_J = Junction Temperature.

PRELIMINARY

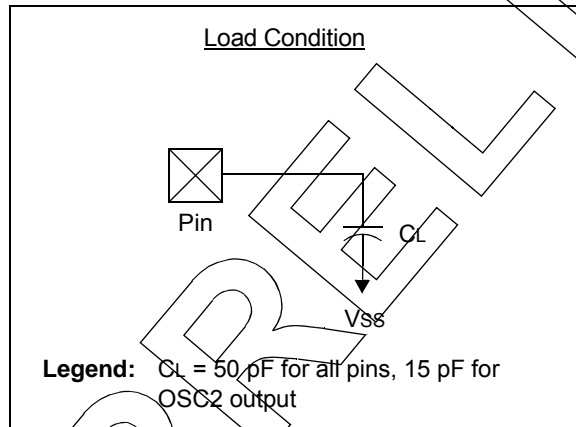
25.7 Timing Parameter Symbology

The timing parameter symbols have been created with one of the following formats:

1. TppS2ppS
2. TppS

T		T	
F	Frequency	T	Time
Lowercase letters (pp) and their meanings:			
pp		pp	
cc	CCP1	osc	OSC1
ck	CLKOUT	rd	\overline{RD}
cs	\overline{CS}	rw	\overline{RD} or \overline{WR}
di	SDIx	sc	SCKx
do	SDO	ss	\overline{SS}
dt	Data in	t0	T0CKI
io	I/O PORT	t1	T1CKI
mc	MCLR	wr	\overline{WR}
Uppercase letters and their meanings:			
S		S	
F	Fall	P	Period
H	High	R	Rise
I	Invalid (High-impedance)	V	Valid
L	Low	Z	High-impedance

FIGURE 25-4: LOAD CONDITIONS



PIC16(L)F1526/27

25.8 AC Characteristics: PIC16(L)F1526/27-I/E

FIGURE 25-5: CLOCK TIMING

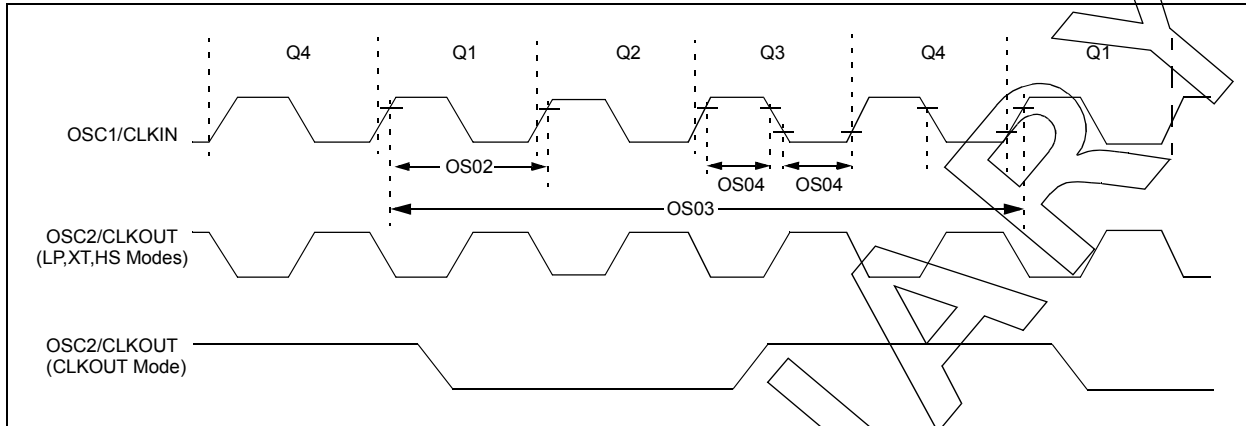


TABLE 25-1: CLOCK OSCILLATOR TIMING REQUIREMENTS

Standard Operating Conditions (unless otherwise stated)							
Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$							
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
OS01	Fosc	External CLKIN Frequency ⁽¹⁾	DC	—	0.5	MHz	EC Oscillator mode (low)
			DC	—	4	MHz	EC Oscillator mode (medium)
			DC	—	20	MHz	EC Oscillator mode (high)
	Oscillator Frequency ⁽¹⁾	—	32,768	—	kHz	LP Oscillator mode	
		0.1	—	4	MHz	XT Oscillator mode	
1		—	4	MHz	HS Oscillator mode, $V_{DD} \leq 2.7\text{V}$		
1		—	20	MHz	HS Oscillator mode, $V_{DD} > 2.7\text{V}$		
OS02	Tosc	External CLKIN Period ⁽¹⁾	27	—	∞	μs	LP Oscillator mode
			250	—	∞	ns	XT Oscillator mode
			50	—	∞	ns	HS Oscillator mode
			50	—	∞	ns	EC Oscillator mode
	Oscillator Period ⁽¹⁾	—	30.5	—	μs	LP Oscillator mode	
		250	—	10,000	ns	XT Oscillator mode	
		50	—	1,000	ns	HS Oscillator mode	
OS03	Tcy	Instruction Cycle Time ⁽¹⁾	125	—	DC	ns	$T_{CY} = F_{OSC}/4$
			250	—	—	ns	RC Oscillator mode
OS04*	TosH, TosL	External CLKIN High, External CLKIN Low	2	—	—	μs	LP oscillator
			100	—	—	ns	XT oscillator
			20	—	—	ns	HS oscillator
OS05*	TosR, TosF	External CLKIN Rise, External CLKIN Fall	0	—	∞	ns	LP oscillator
			0	—	∞	ns	XT oscillator
			0	—	∞	ns	HS oscillator

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note 1: Instruction cycle period (T_{CY}) equals four times the input oscillator time base period. All specified values are based on characterization data for that particular oscillator type under standard operating conditions with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at "min" values with an external clock applied to OSC1 pin. When an external clock input is used, the "max" cycle time limit is "DC" (no clock) for all devices.

TABLE 25-2: OSCILLATOR PARAMETERS

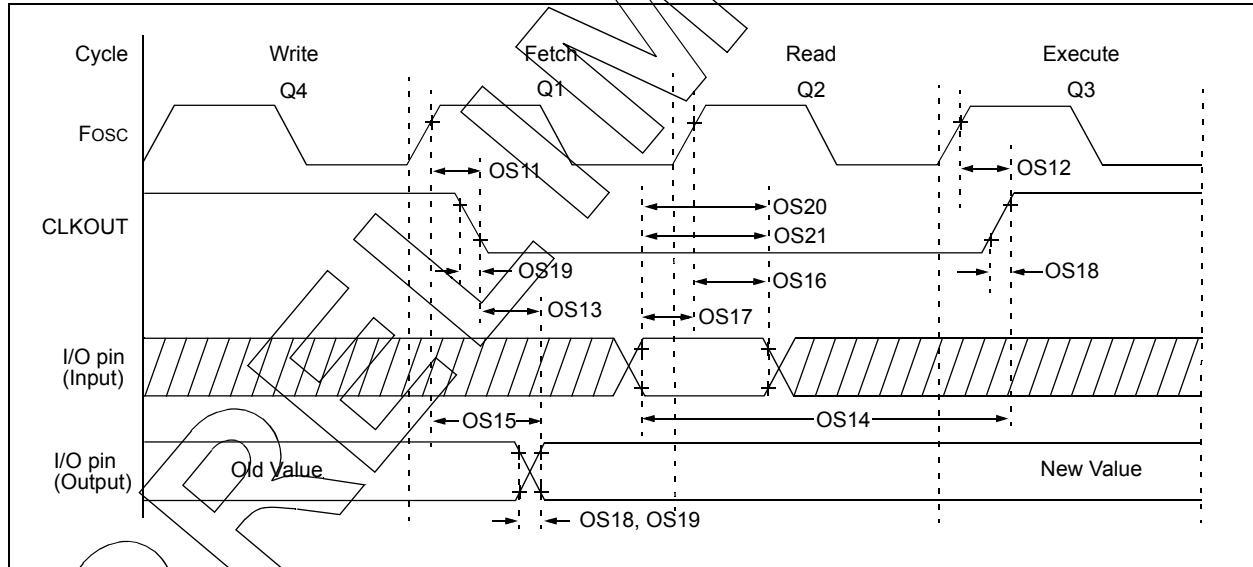
Standard Operating Conditions (unless otherwise stated)								
Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$								
Param No.	Sym.	Characteristic	Freq. Tolerance	Min.	Typ†	Max.	Units	Conditions
OS08	HFosc	Internal Calibrated HFINTOSC Frequency ⁽²⁾	$\pm 10\%$	—	16.0	—	MHz	$0^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$
OS09	LFosc	Internal LFINTOSC Frequency	—	—	31	—	kHz	
OS10*	Tiosc ST	HFINTOSC Wake-up from Sleep Start-up Time	—	—	5	8	μs	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note 1:** Instruction cycle period (T_{cy}) equals four times the input oscillator time base period. All specified values are based on characterization data for that particular oscillator type under standard operating conditions with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at "min" values with an external clock applied to the OSC1 pin. When an external clock input is used, the "max" cycle time limit is "DC" (no clock) for all devices.
- 2:** To ensure these oscillator frequency tolerances, V_{DD} and V_{SS} must be capacitively decoupled as close to the device as possible. 0.1 μF and 0.01 μF values in parallel are recommended.
- 3:** By design.

FIGURE 25-6: CLKOUT AND I/O TIMING



PIC16(L)F1526/27

TABLE 25-3: CLKOUT AND I/O TIMING PARAMETERS

Standard Operating Conditions (unless otherwise stated) Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$							
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
OS11	TosH2ckL	Fosc↑ to CLKOUT↓ ⁽¹⁾	—	—	70	ns	VDD = 3.3-5.0V
OS12	TosH2ckH	Fosc↑ to CLKOUT↑ ⁽¹⁾	—	—	72	ns	VDD = 3.3-5.0V
OS13	TckL2ioV	CLKOUT↓ to Port out valid ⁽¹⁾	—	—	20	ns	
OS14	TioV2ckH	Port input valid before CLKOUT↑ ⁽¹⁾	Tosc + 200 ns	—	—	ns	
OS15	TosH2ioV	Fosc↑ (Q1 cycle) to Port out valid	—	50	70*	ns	VDD = 3.3-5.0V
OS16	TosH2ioI	Fosc↑ (Q2 cycle) to Port input invalid (I/O in hold time)	50	—	—	ns	VDD = 3.3-5.0V
OS17	TioV2osH	Port input valid to Fosc↑ (Q2 cycle) (I/O in setup time)	20	—	—	ns	
OS18	TioR	Port output rise time ⁽²⁾	—	40	72	ns	VDD = 1.8V VDD = 3.3-5.0V
OS19	TioF	Port output fall time ⁽²⁾	—	28	55	ns	VDD = 1.8V VDD = 3.3-5.0V
OS20*	Tinp	INT pin input high or low time	25	—	—	ns	
OS21*	Tioc	Interrupt-on-change new input level time	25	—	—	ns	

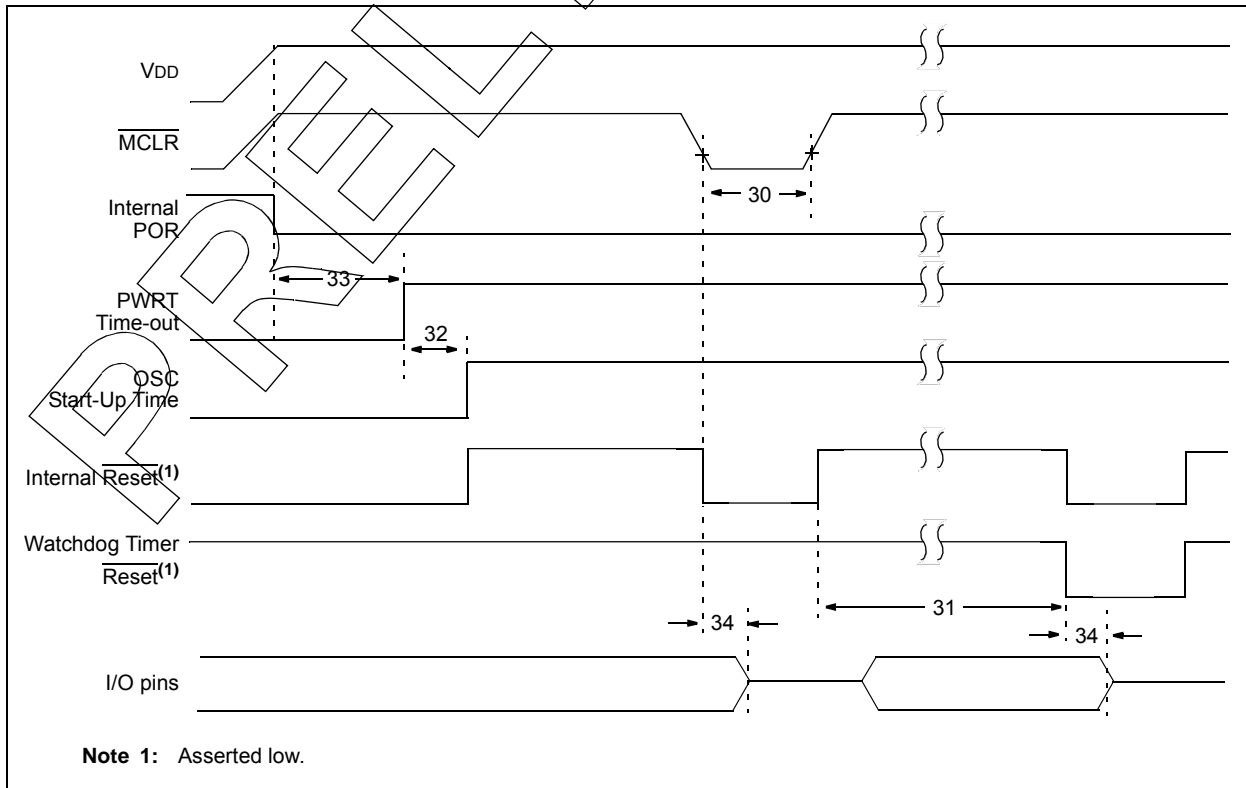
* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated.

Note 1: Measurements are taken in RC mode where CLKOUT output is 4 x Tosc.

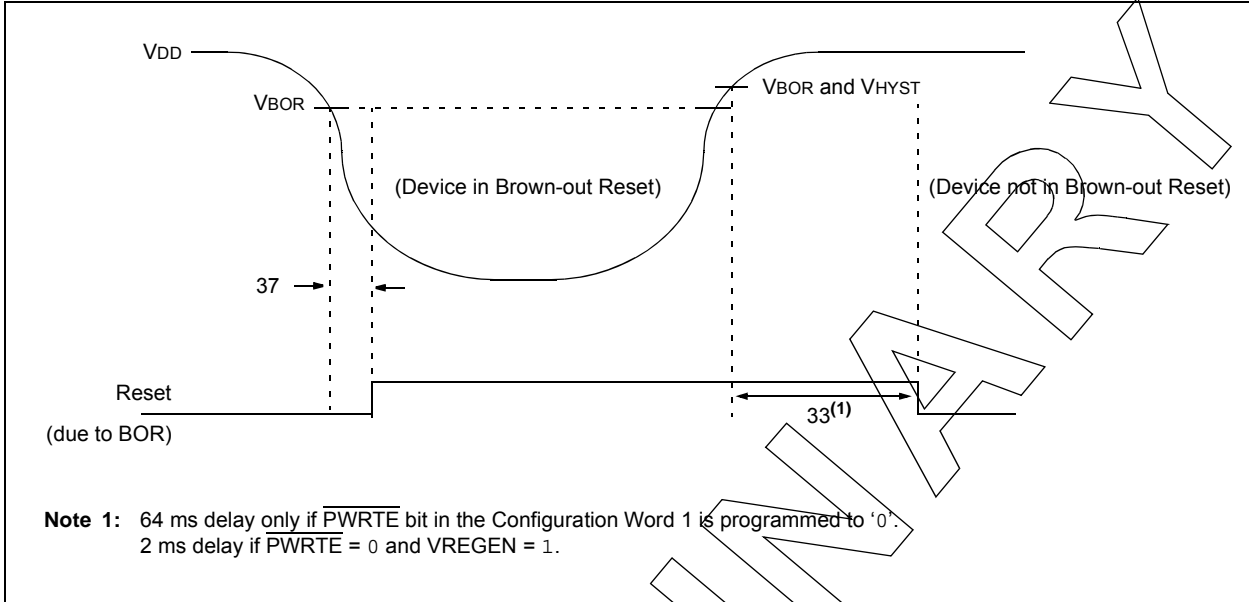
2: Includes OSC2 in CLKOUT mode.

FIGURE 25-7: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER TIMING



Note 1: Asserted low.

FIGURE 25-8: BROWN-OUT RESET TIMING AND CHARACTERISTICS



PIC16(L)F1526/27

TABLE 25-4: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER, POWER-UP TIMER AND BROWN-OUT RESET PARAMETERS

Standard Operating Conditions (unless otherwise stated)							
Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$							
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
30	TMCL	MCLR Pulse Width (low)	2	—	—	μs	$V_{DD} = 3.3\text{-}5\text{V}$, -40°C to $+85^{\circ}\text{C}$ $V_{DD} = 3.3\text{-}5\text{V}$
			5	—	—	μs	
31	TWDTLP	Low-Power Watchdog Timer Time-out Period	10	16	27	ms	$V_{DD} = 3.3\text{V}\text{-}5\text{V}$, 1:16 Prescaler used
32	TOST	Oscillator Start-up Timer Period ^{(1), (2)}	—	1024	—	T_{OSC}	(Note 3)
33*	TPWRT	Power-up Timer Period, $PWRTE = 0$	40	65	140	ms	
34*	TIOZ	I/O high-impedance from MCLR Low or Watchdog Timer Reset	—	—	2.0	μs	
35	VBOR	Brown-out Reset Voltage	2.38	2.5	2.65	V	BORV=2.5V BORV=1.9V
			1.80	1.9	2.05		
36*	VHYST	Brown-out Reset Hysteresis	0	25	50	mV	-40°C to $+85^{\circ}\text{C}$
37*	TBORDC	Brown-out Reset DC Response Time	1	3	5	μs	$V_{DD} \leq V_{BOR}$
38	VLPBOR	Low-Power Brown-out Reset Voltage	TBD	TBD	TBD	V	LPBOR = 1

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note 1: Instruction cycle period (T_{CY}) equals four times the input oscillator time base period. All specified values are based on characterization data for that particular oscillator type under standard operating conditions with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at "min" values with an external clock applied to the OSC1 pin. When an external clock input is used, the "max" cycle time limit is "DC" (no clock) for all devices.

2: By design.

3: Period of the slower clock.

4: To ensure these voltage tolerances, V_{DD} and V_{SS} must be capacitively decoupled as close to the device as possible. 0.1 μF and 0.01 μF values in parallel are recommended.

FIGURE 25-9: TIMER0 AND TIMER1 EXTERNAL CLOCK TIMINGS

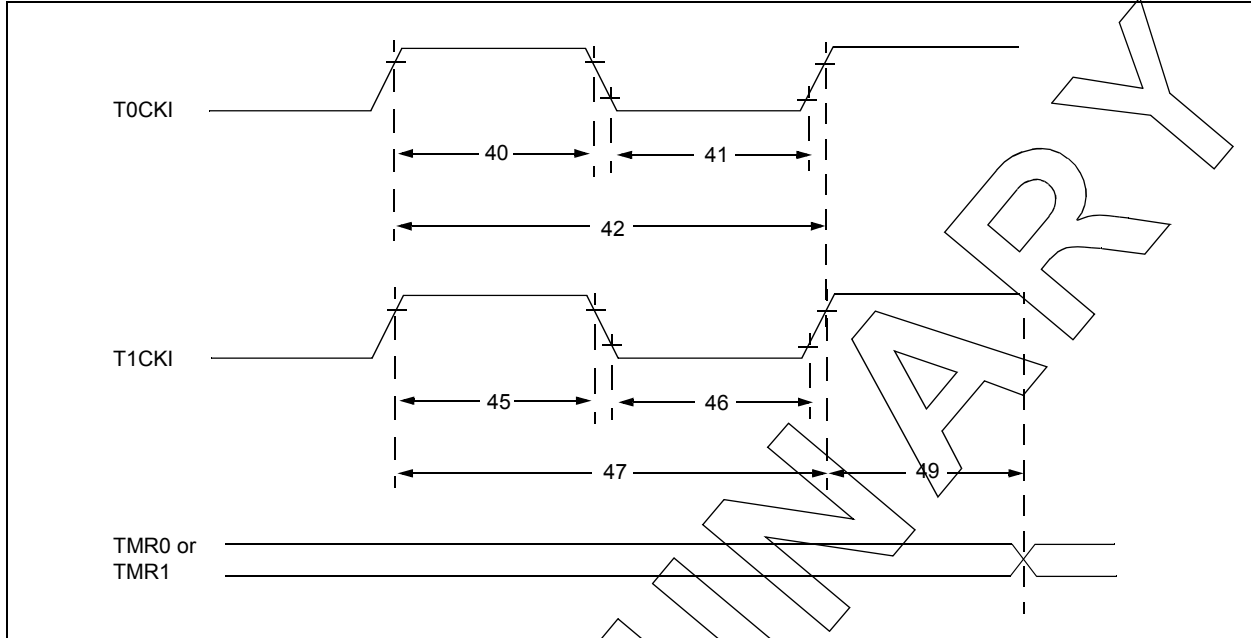


TABLE 25-5: TIMER0 AND TIMER1 EXTERNAL CLOCK REQUIREMENTS

Standard Operating Conditions (unless otherwise stated) Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$								
Param No.	Sym.	Characteristic		Min.	Typ†	Max.	Units	Conditions
40*	Tt0H	T0CKI High Pulse Width	No Prescaler	$0.5 T_{CY} + 20$	—	—	ns	
			With Prescaler	10	—	—	ns	
41*	Tt0L	T0CKI Low Pulse Width	No Prescaler	$0.5 T_{CY} + 20$	—	—	ns	
			With Prescaler	10	—	—	ns	
42*	Tt0P	T0CKI Period		Greater of: 20 or $\frac{T_{CY} + 40}{N}$	—	—	ns	N = prescale value (2, 4, ..., 256)
45*	Tt1H	T1CKI High Time	Synchronous, No Prescaler	$0.5 T_{CY} + 20$	—	—	ns	
			Synchronous, with Prescaler	15	—	—	ns	
			Asynchronous	30	—	—	ns	
46*	Tt1L	T1CKI Low Time	Synchronous, No Prescaler	$0.5 T_{CY} + 20$	—	—	ns	
			Synchronous, with Prescaler	15	—	—	ns	
			Asynchronous	30	—	—	ns	
47*	Tt1P	T1CKI Input Period	Synchronous	Greater of: 30 or $\frac{T_{CY} + 40}{N}$	—	—	ns	N = prescale value (1, 2, 4, 8)
			Asynchronous	60	—	—	ns	
48	Ft1	Secondary Oscillator Input Frequency Range (oscillator enabled by setting bit SOSSEN)		32.4	32.768	33.1	kHz	
49*	TCKEZTMR1	Delay from External Clock Edge to Timer Increment		$2 T_{OSC}$	—	$7 T_{OSC}$	—	Timers in Sync mode

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

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FIGURE 25-10: CAPTURE/COMPARE/PWM TIMINGS (CCP)

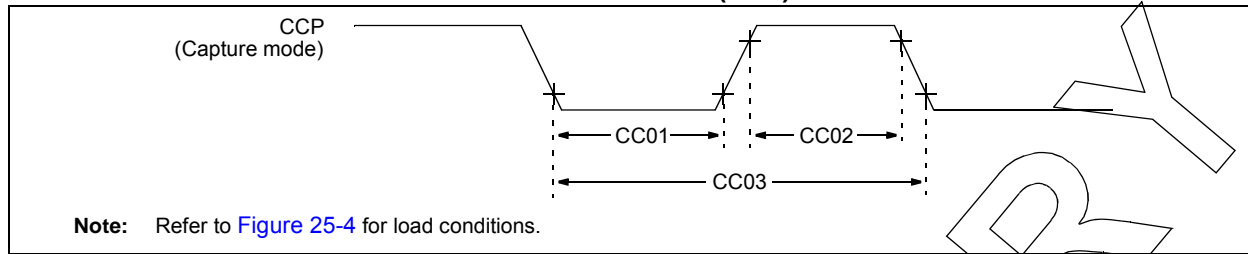


TABLE 25-6: CAPTURE/COMPARE/PWM REQUIREMENTS (CCP)

Standard Operating Conditions (unless otherwise stated)								
Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$								
Param No.	Sym.	Characteristic		Min.	Typ†	Max.	Units	Conditions
CC01*	TccL	CCP Input Low Time	No Prescaler	$0.5T_{CY} + 20$	—	—	ns	
			With Prescaler	20	—	—	ns	
CC02*	TccH	CCP Input High Time	No Prescaler	$0.5T_{CY} + 20$	—	—	ns	
			With Prescaler	20	—	—	ns	
CC03*	TccP	CCP Input Period		$\frac{3T_{CY} + 40}{N}$	—	—	ns	N = prescale value (1, 4 or 16)

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

TABLE 25-7: PIC16(L)F1526/27 A/D CONVERTER (ADC) CHARACTERISTICS:

Standard Operating Conditions (unless otherwise stated)							
Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$							
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
AD01	NR	Resolution	—	—	10	bit	
AD02	EIL	Integral Error	—	—	± 1.7	LSb	$V_{REF} = 3.0\text{V}$
AD03	EDL	Differential Error	—	—	± 1	LSb	No missing codes $V_{REF} = 3.0\text{V}$
AD04	E _{OFF}	Offset Error	—	—	± 2	LSb	$V_{REF} = 3.0\text{V}$
AD05	E _{GN}	Gain Error	—	—	± 1.5	LSb	$V_{REF} = 3.0\text{V}$
AD06	V _{REF}	Reference Voltage ⁽³⁾	1.8	—	V _{DD}	V	$V_{REF} = (V_{REF+} \text{ minus } V_{REF-})$ (NOTE 5)
AD07	V _{AIN}	Full-Scale Range	V _{SS}	—	V _{REF}	V	
AD08	Z _{AIN}	Recommended Impedance of Analog Voltage Source	—	—	10	kΩ	Can go higher if external 0.01μF capacitor is present on input pin.

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

- Note 1:** Total Absolute Error includes integral, differential, offset and gain errors.
2: The A/D conversion result never decreases with an increase in the input voltage and has no missing codes.
3: ADC V_{REF} is from external V_{REF}, V_{DD} pin or FV_{REF}, whichever is selected as reference input.
4: When ADC is off, it will not consume any current other than leakage current. The power-down current specification includes any such leakage from the ADC module.
5: FVR voltage selected must be 2.048V or 4.096V.

TABLE 25-8: PIC16(L)F1526/27 A/D CONVERSION REQUIREMENTS

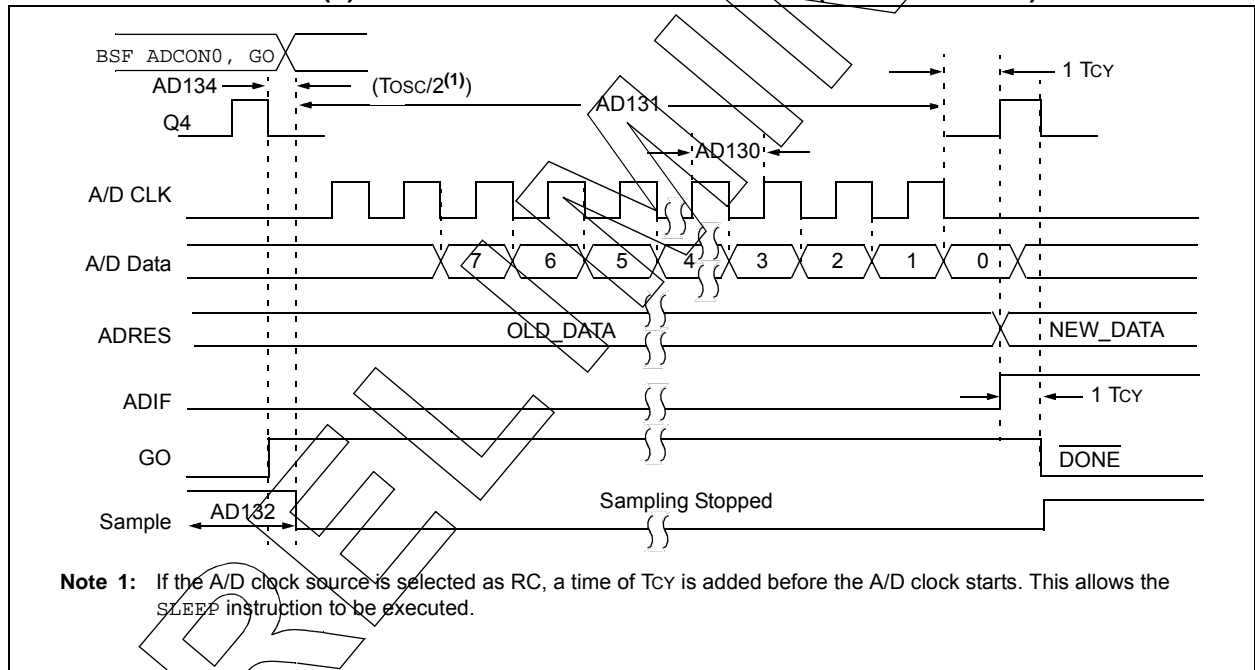
Standard Operating Conditions (unless otherwise stated)							
Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$							
Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
AD130*	TAD	A/D Clock Period	1.0	—	9.0	μs	TOSC-based
		A/D Internal RC Oscillator Period	1.0	1.6	6.0	μs	ADCS<1:0> = 11 (ADRC mode)
AD131	TCNV	Conversion Time (not including Acquisition Time) ⁽¹⁾	—	11	—	TAD	Set GO/DONE bit to conversion complete
AD132*	TACQ	Acquisition Time	—	5.0	—	μs	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

Note 1: The ADRES register may be read on the following T_{cy} cycle.

FIGURE 25-11: PIC16(L)F1526/27 A/D CONVERSION TIMING (NORMAL MODE)



PIC16(L)F1526/27

FIGURE 25-12: PIC16(L)F1526/27 A/D CONVERSION TIMING (SLEEP MODE)

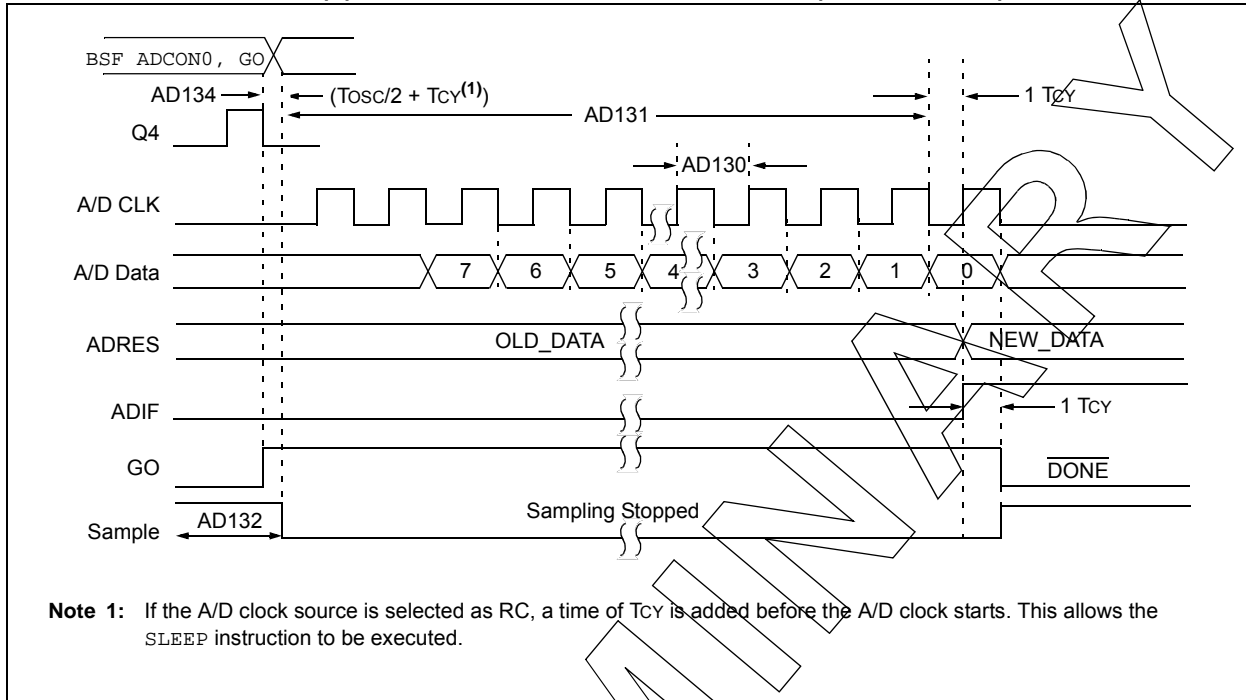


TABLE 25-9: PIC16(L)F1526/27 LOW DROPOUT (LDO) REGULATOR CHARACTERISTICS:

Standard Operating Conditions (unless otherwise stated)
 Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$

Param No.	Sym.	Characteristic	Min.	Typ†	Max.	Units	Conditions
LD001		LDO Regulation Voltage	—	3.2	—	V	
LD002		LDO External Capacitor	0.1	—	1	μF	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

FIGURE 25-13: USART SYNCHRONOUS TRANSMISSION (MASTER/SLAVE) TIMING

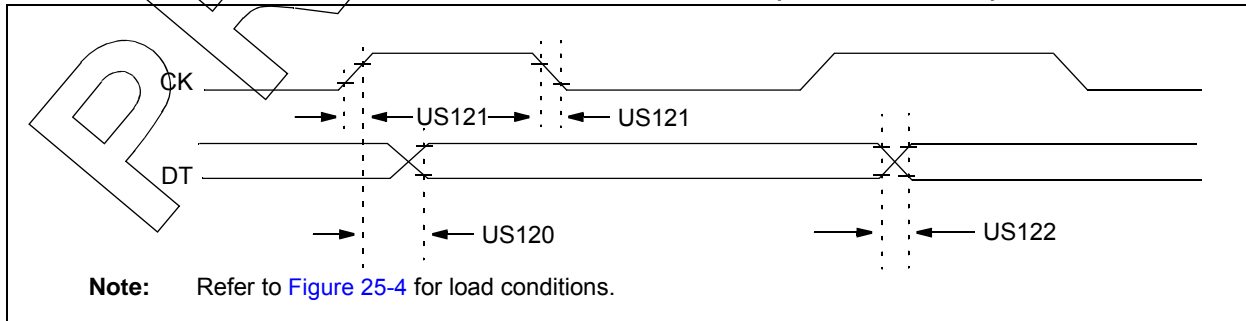


TABLE 25-10: USART SYNCHRONOUS TRANSMISSION REQUIREMENTS

Standard Operating Conditions (unless otherwise stated)						
Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$						
Param. No.	Symbol	Characteristic	Min.	Max.	Units	Conditions
US120	TckH2DTV	SYNC XMIT (Master and Slave)	3.0-5.5V	—	80	ns
		Clock high to data-out valid	1.8-5.5V	—	100	ns
US121	TCKRF	Clock out rise time and fall time (Master mode)	3.0-5.5V	—	45	ns
			1.8-5.5V	—	50	ns
US122	TDTRF	Data-out rise time and fall time	3.0-5.5V	—	45	ns
			1.8-5.5V	—	50	ns

FIGURE 25-14: USART SYNCHRONOUS RECEIVE (MASTER/SLAVE) TIMING

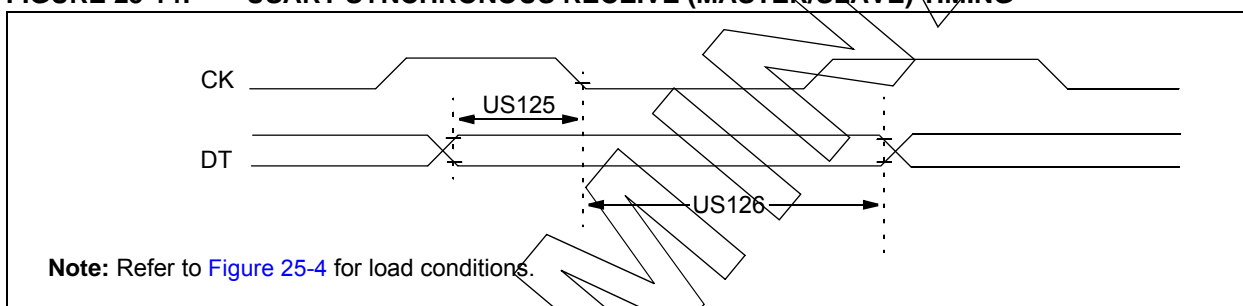


TABLE 25-11: USART SYNCHRONOUS RECEIVE REQUIREMENTS

Standard Operating Conditions (unless otherwise stated)						
Operating Temperature $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$						
Param. No.	Symbol	Characteristic	Min.	Max.	Units	Conditions
US125	TdtV2ckL	SYNC RCV (Master and Slave) Data hold before CK \downarrow (DT hold time)	10	—	ns	
US126	TckL2DTL	Data hold after CK \downarrow (DT hold time)	15	—	ns	

PIC16(L)F1526/27

FIGURE 25-15: SPI MASTER MODE TIMING (CKE = 0, SMP = 0)

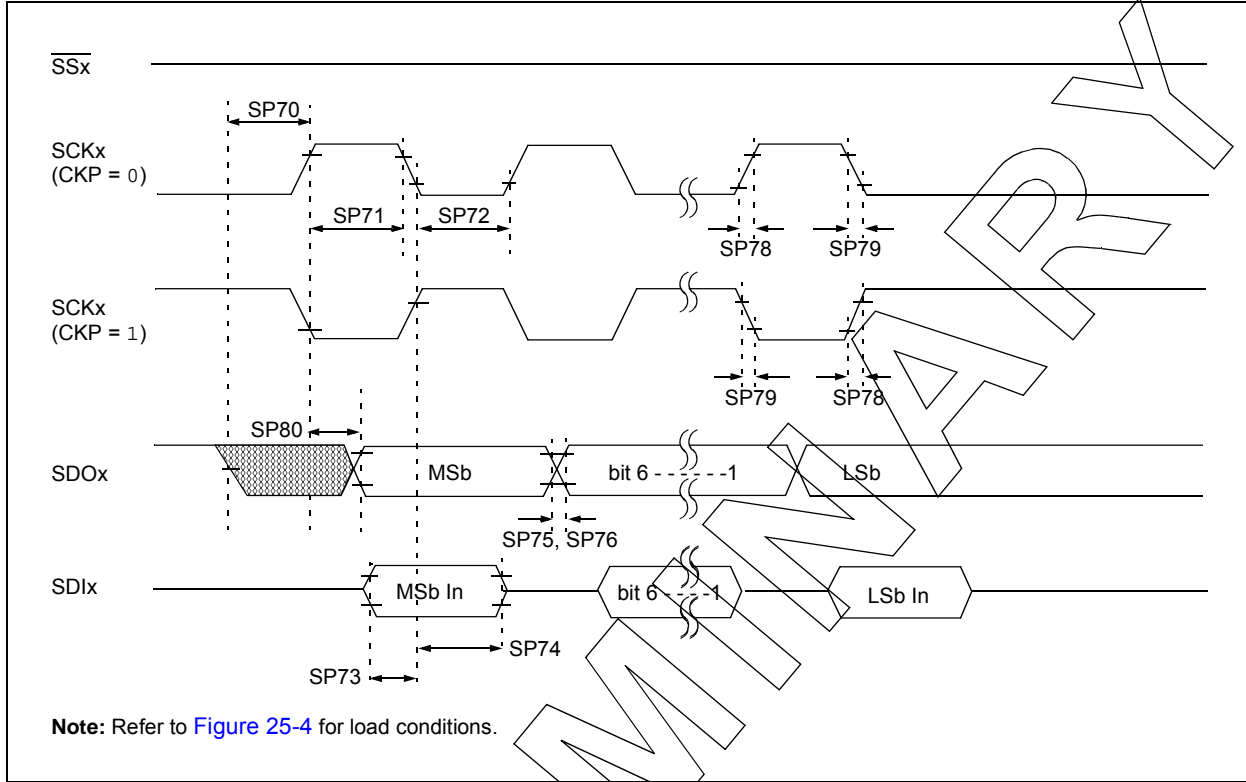


FIGURE 25-16: SPI MASTER MODE TIMING (CKE = 1, SMP = 1)

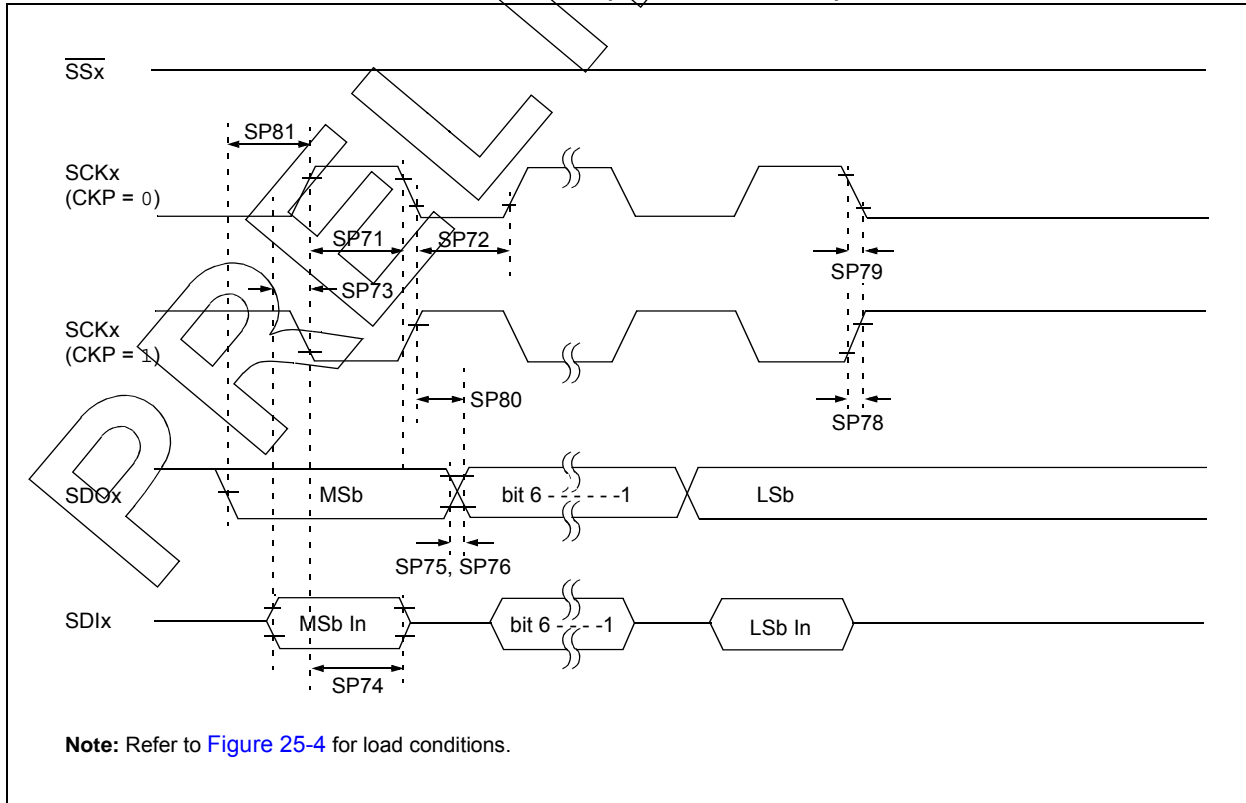


FIGURE 25-17: SPI SLAVE MODE TIMING (CKE = 0)

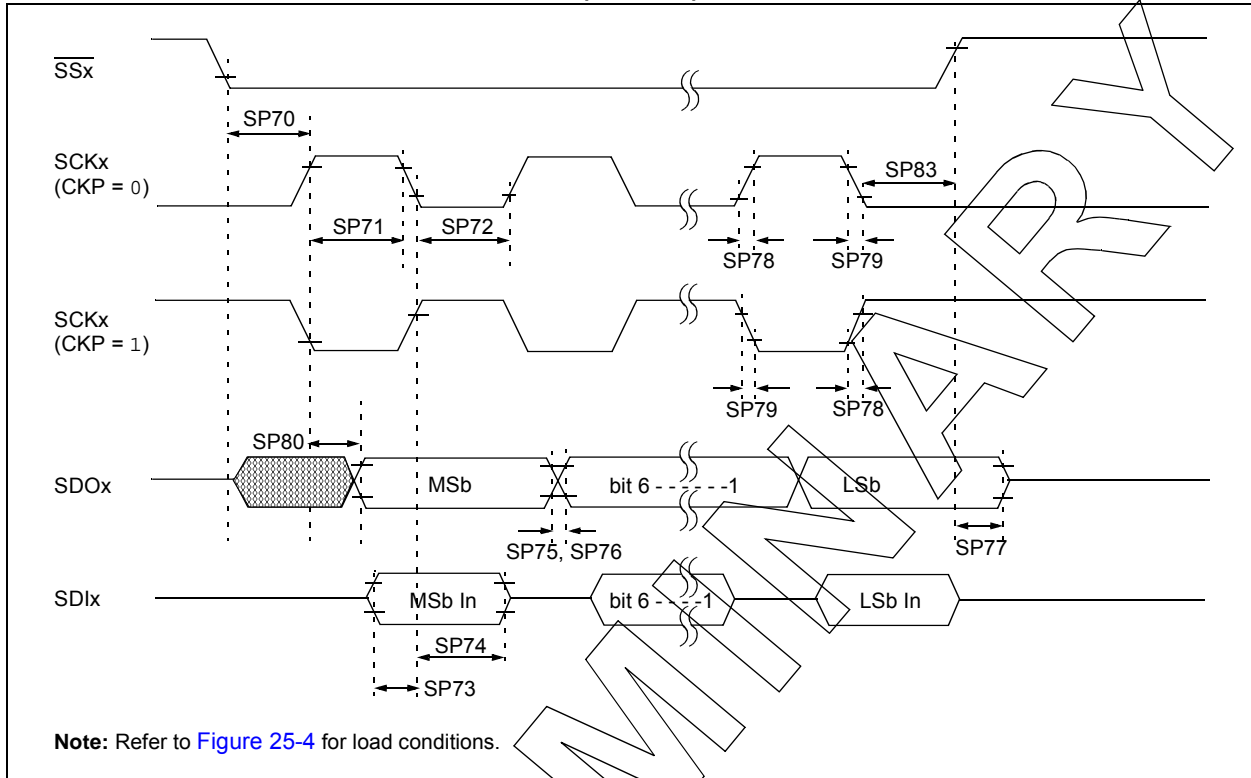
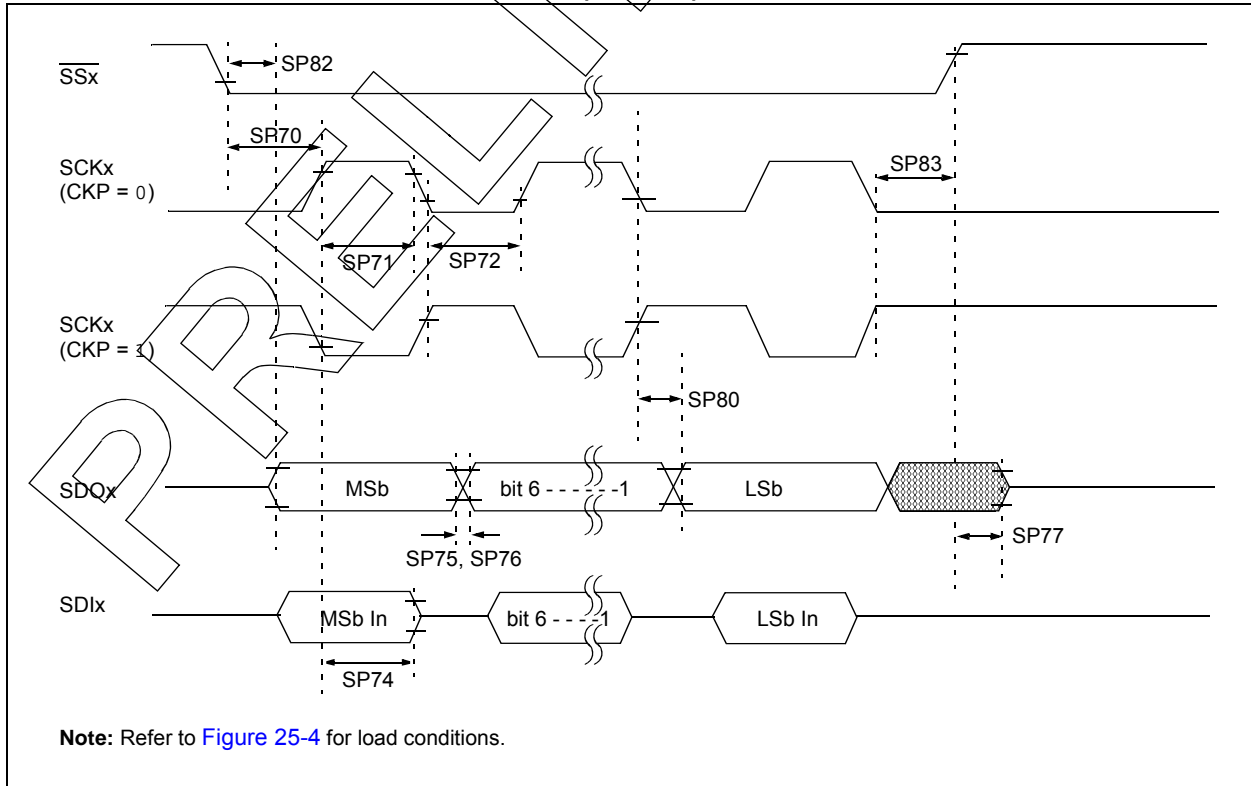


FIGURE 25-18: SPI SLAVE MODE TIMING (CKE = 1)



PIC16(L)F1526/27

TABLE 25-12: SPI MODE REQUIREMENTS

Param No.	Symbol	Characteristic	Min.	Typ†	Max.	Units	Conditions
SP70*	TssL2sch, TssL2scL	\overline{SSx} ↓ to SCKx↓ or SCKx↑ input	Tcy	—	—	ns	
SP71*	Tsch	SCKx input high time (Slave mode)	Tcy + 20	—	—	ns	
SP72*	TscL	SCKx input low time (Slave mode)	Tcy + 20	—	—	ns	
SP73*	TdIV2sch, TdIV2scL	Setup time of SDIx data input to SCKx edge	100	—	—	ns	
SP74*	Tsch2dIL, TscL2dIL	Hold time of SDIx data input to SCKx edge	100	—	—	ns	
SP75*	TdoR	SDO data output rise time	3.0-5.5V	—	10	25	ns
			1.8-5.5V	—	25	50	ns
SP76*	TdoF	SDOx data output fall time	—	10	25	ns	
SP77*	TssH2doZ	\overline{SSx} ↑ to SDOx output high-impedance	10	—	50	ns	
SP78*	TscR	SCKx output rise time (Master mode)	3.0-5.5V	—	10	25	ns
			1.8-5.5V	—	25	50	ns
SP79*	TscF	SCKx output fall time (Master mode)	—	10	25	ns	
SP80*	Tsch2doV, TscL2doV	SDOx data output valid after SCKx edge	3.0-5.5V	—	—	50	ns
			1.8-5.5V	—	—	145	ns
SP81*	TdoV2sch, TdoV2scL	SDOx data output setup to SCKx edge	Tcy	—	—	ns	
SP82*	TssL2doV	SDOx data output valid after \overline{SSx} ↓ edge	—	—	50	ns	
SP83*	Tsch2ssH, TscL2ssH	\overline{SSx} ↑ after SCKx edge	1.5Tcy + 40	—	—	ns	

* These parameters are characterized but not tested.

† Data in "Typ" column is at 3.0V, 25°C unless otherwise stated. These parameters are for design guidance only and are not tested.

FIGURE 25-19: I²C™ BUS START/STOP BITS TIMING

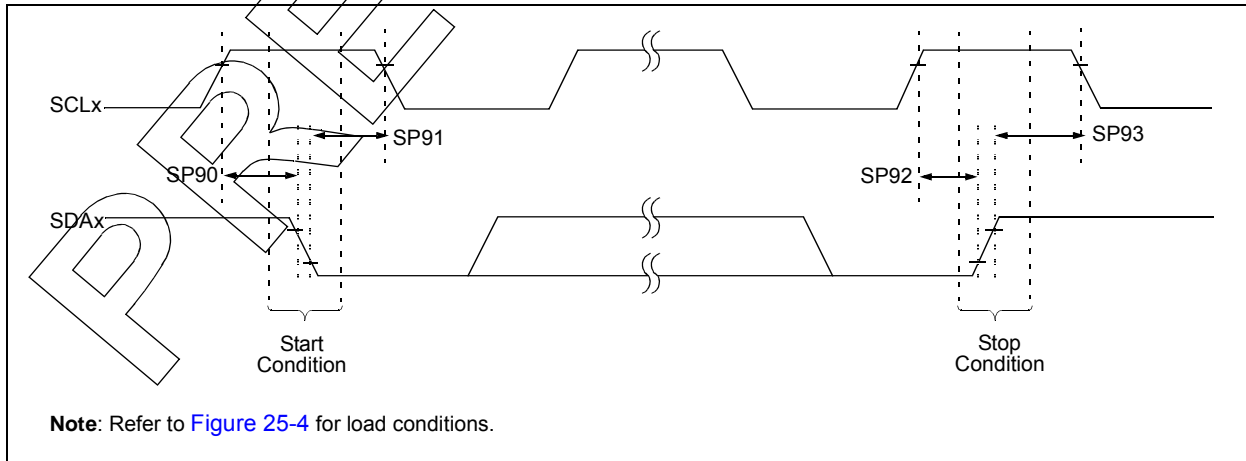
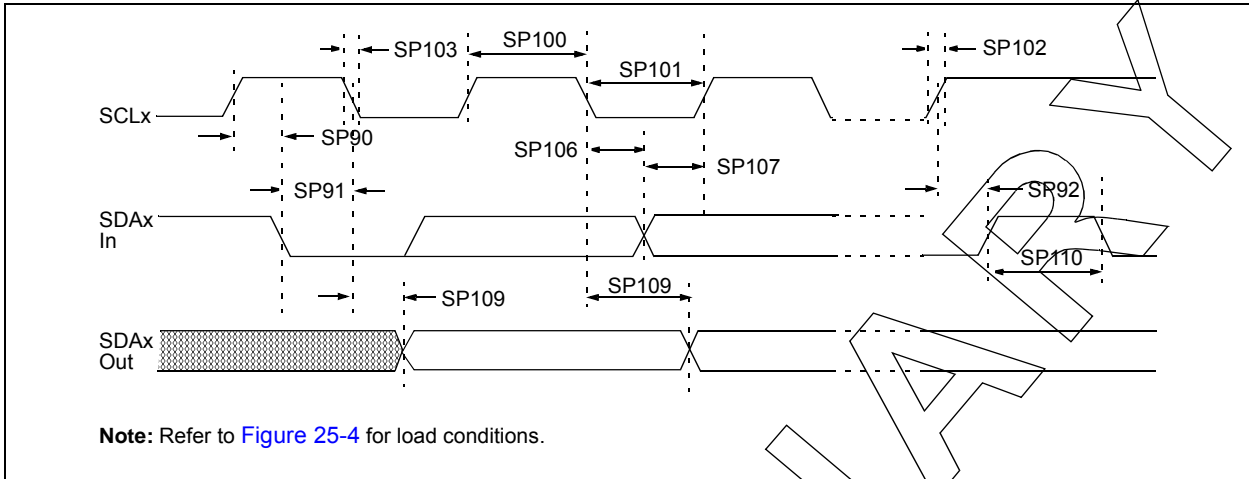


FIGURE 25-20: I²C™ BUS DATA TIMING



PRELIMINARY

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TABLE 25-13: I²C™ BUS DATA REQUIREMENTS

Param. No.	Symbol	Characteristic		Min.	Max.	Units	Conditions
SP100*	THIGH	Clock high time	100 kHz mode	4.0	—	μs	Device must operate at a minimum of 1.5 MHz
			400 kHz mode	0.6	—	μs	Device must operate at a minimum of 10 MHz
			SSP module	1.5T _{CY}	—	—	
SP101*	TLOW	Clock low time	100 kHz mode	4.7	—	μs	Device must operate at a minimum of 1.5 MHz
			400 kHz mode	1.3	—	μs	Device must operate at a minimum of 10 MHz
			SSP module	1.5T _{CY}	—	—	
SP102*	TR	SDA _x and SCL _x rise time	100 kHz mode	—	1000	ns	CB is specified to be from 10-400 pF
			400 kHz mode	20 + 0.1CB	300	ns	
SP103*	TF	SDA _x and SCL _x fall time	100 kHz mode	—	250	ns	CB is specified to be from 10-400 pF
			400 kHz mode	20 + 0.1CB	250	ns	
SP106*	THD:DAT	Data input hold time	100 kHz mode	0	—	ns	
			400 kHz mode	0	0.9	μs	
SP107*	TSU:DAT	Data input setup time	100 kHz mode	250	—	ns	(Note 2)
			400 kHz mode	100	—	ns	
SP109*	TAA	Output valid from clock	100 kHz mode	—	3500	ns	(Note 1)
			400 kHz mode	—	—	ns	
SP110*	TBUF	Bus free time	100 kHz mode	4.7	—	μs	Time the bus must be free before a new transmission can start
			400 kHz mode	1.3	—	μs	
SP111	CB	Bus capacitive loading		—	400	pF	

* These parameters are characterized but not tested.

- 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_x to avoid unintended generation of Start or Stop conditions.
- 2:** A Fast mode (400 kHz) I²C™ bus device can be used in a Standard mode (100 kHz) I²C bus system, but the requirement TSU:DAT ≥ 250 ns must then be met. This will automatically be the case if the device does not stretch the low period of the SCL_x signal. If such a device does stretch the low period of the SCL_x signal, it must output the next data bit to the SDA_x line TR max. + TSU:DAT = 1000 + 250 = 1250 ns (according to the Standard mode I²C bus specification), before the SCL_x line is released.

26.0 DC AND AC CHARACTERISTICS GRAPHS AND CHARTS

Graphs and charts are not available at this time.

PIC16(L)F1526/27

NOTES:

27.0 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

27.1 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.

27.2 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.

27.3 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, pre-processor, and one-step driver, and can run on multiple platforms.

27.4 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

27.5 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

27.6 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

27.7 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.

27.8 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.

27.9 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.

27.10 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.

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27.11 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.

27.12 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.

27.13 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.

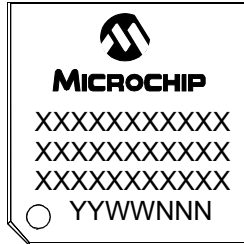
Also available are starter kits that contain everything needed to experience the specified device. This usually includes a single application and debug capability, all on one board.

Check the Microchip web page (www.microchip.com) for the complete list of demonstration, development and evaluation kits.

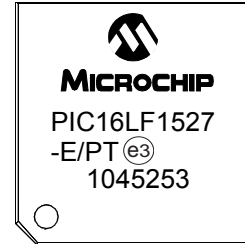
28.0 PACKAGING INFORMATION

28.1 Package Marking Information

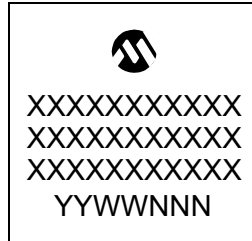
64-Lead TQFP (10x10x1mm)



Example



64-Lead QFN (9X9X0.9mm)



Example



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(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.

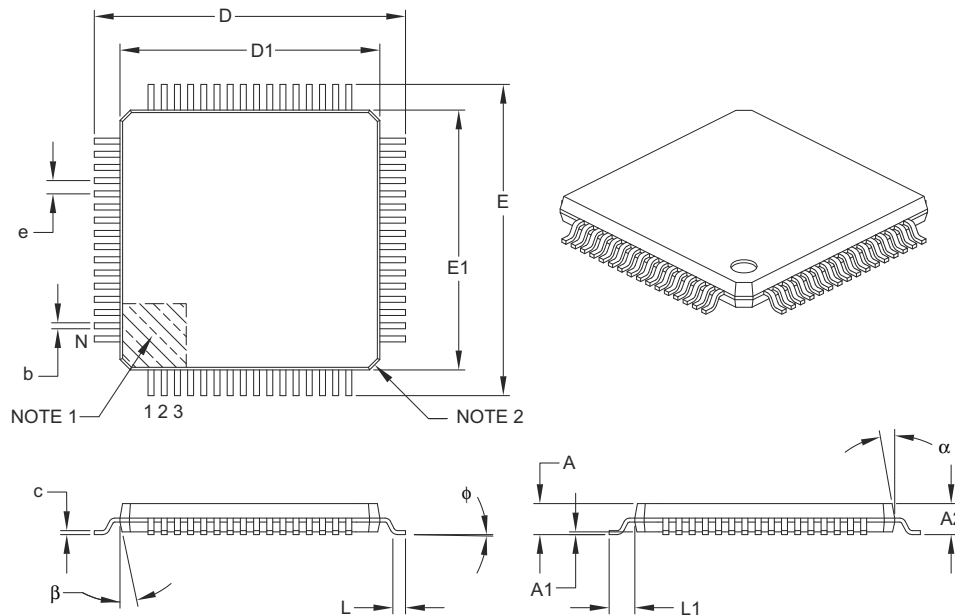
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28.2 Package Details

The following sections give the technical details of the packages.

64-Lead Plastic Thin Quad Flatpack (PT) – 10x10x1 mm Body, 2.00 mm [TQFP]

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



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Leads	N	64		
Lead Pitch	e	0.50 BSC		
Overall Height	A	–	–	1.20
Molded Package Thickness	A2	0.95	1.00	1.05
Standoff	A1	0.05	–	0.15
Foot Length	L	0.45	0.60	0.75
Footprint	L1	1.00 REF		
Foot Angle	ϕ	0°	3.5°	7°
Overall Width	E	12.00 BSC		
Overall Length	D	12.00 BSC		
Molded Package Width	E1	10.00 BSC		
Molded Package Length	D1	10.00 BSC		
Lead Thickness	c	0.09	–	0.20
Lead Width	b	0.17	0.22	0.27
Mold Draft Angle Top	α	11°	12°	13°
Mold Draft Angle Bottom	β	11°	12°	13°

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Chamfers at corners are optional; size may vary.
- Dimensions D1 and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

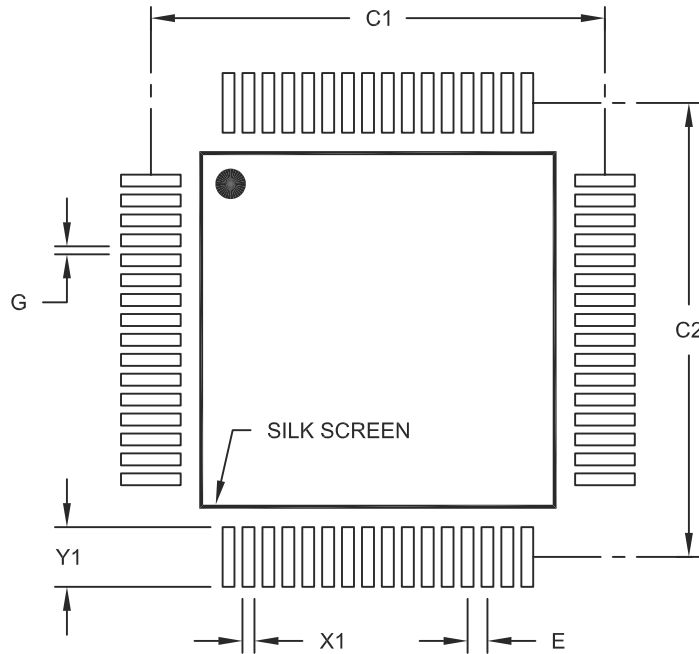
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-085B

64-Lead Plastic Thin Quad Flatpack (PT) – 10x10x1 mm Body, 2.00 mm [TQFP]

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



RECOMMENDED LAND PATTERN

		Units	MILLIMETERS		
		Dimension Limits	MIN	NOM	MAX
Contact Pitch	E		0.50 BSC		
Contact Pad Spacing	C1			11.40	
Contact Pad Spacing	C2			11.40	
Contact Pad Width (X64)	X1				0.30
Contact Pad Length (X64)	Y1				1.50
Distance Between Pads	G	0.20			

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

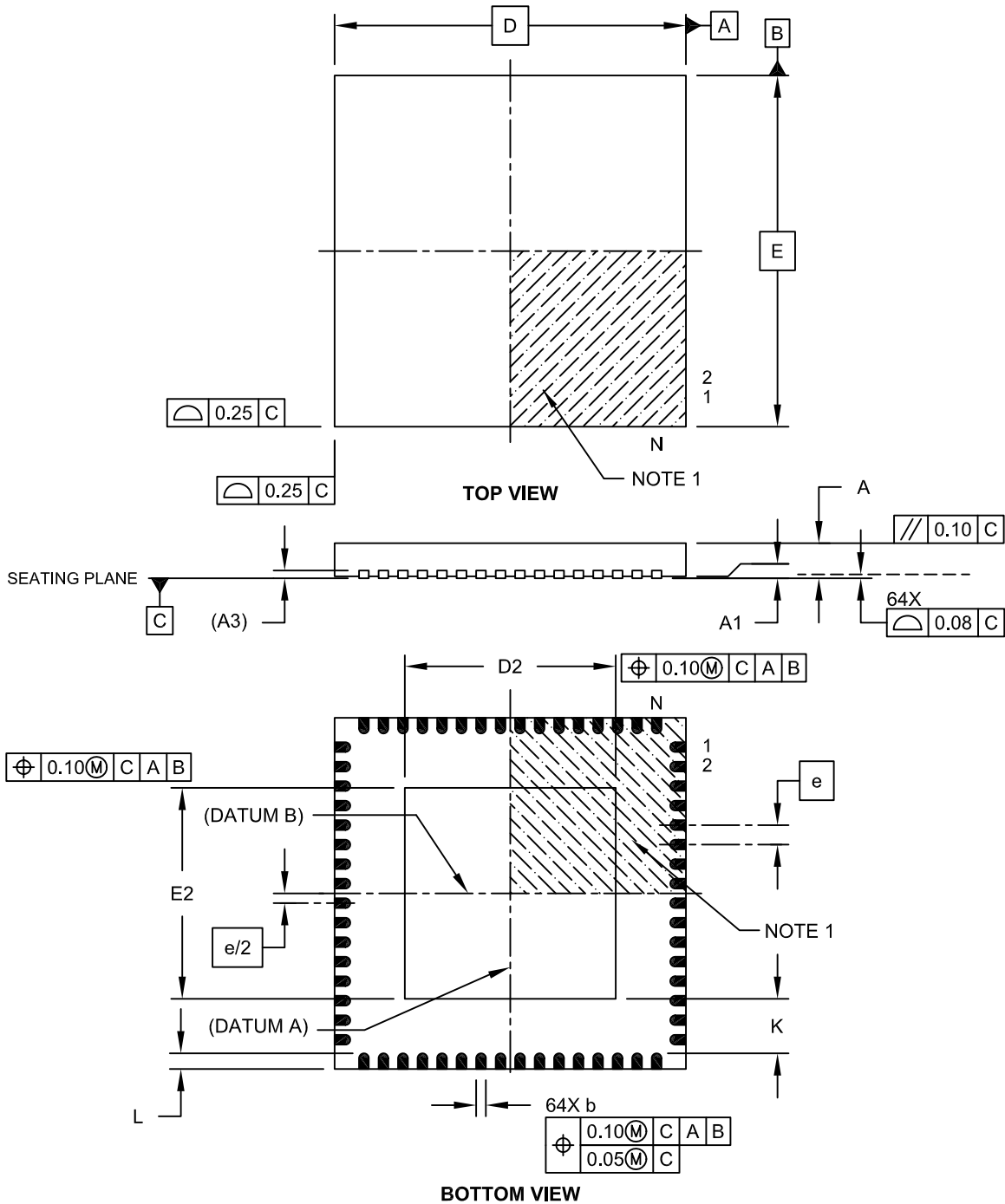
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2085A

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64-Lead Plastic Quad Flat, No Lead Package (MR) – 9x9x0.9 mm Body with 5.40 x 5.40 Exposed Pad [QFN]

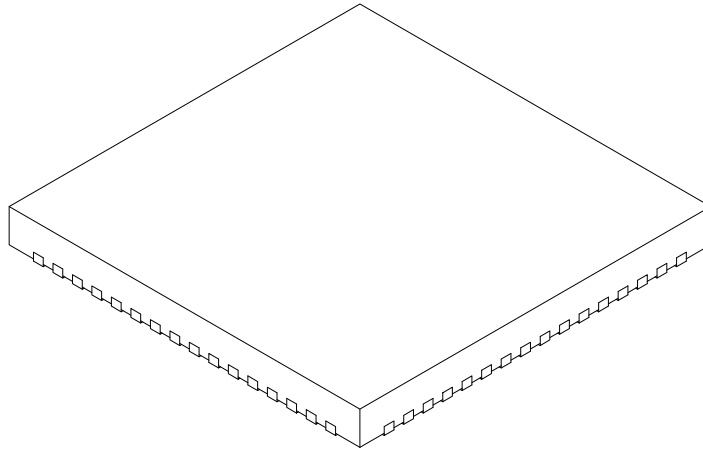
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-154A Sheet 1 of

64-Lead Plastic Quad Flat, No Lead Package (MR) – 9x9x0.9 mm Body with 5.40 x 5.40 Exposed Pad [QFN]

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



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	64		
Pitch	e	0.50 BSC		
Overall Height	A	0.80	0.90	1.00
Standoff	A1	0.00	0.02	0.05
Contact Thickness	A3	0.20 REF		
Overall Width	E	9.00 BSC		
Exposed Pad Width	E2	5.30	5.40	5.50
Overall Length	D	9.00 BSC		
Exposed Pad Length	D2	5.30	5.40	5.50
Contact Width	b	0.20	0.25	0.30
Contact Length	L	0.30	0.40	0.50
Contact-to-Exposed Pad	K	0.20	-	-

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated.
- 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 C04-154A Sheet 2 of 2

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NOTES:

APPENDIX A: DATA SHEET REVISION HISTORY

Revision A

Original release (01/2011)

Revision B

Electrical Spec updates (05/2011)

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