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Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	PIC
Core Size	8-Bit
Speed	48MHz
Connectivity	I²C, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	16
Program Memory Size	16KB (8K x 16)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	3.8K x 8
Voltage - Supply (Vcc/Vdd)	2.15V ~ 3.6V
Data Converters	A/D 10x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	28-SSOP (0.209", 5.30mm Width)
Supplier Device Package	28-SSOP
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic18f24j11t-i-ss

TABLE 1-1: DEVICE FEATURES FOR THE PIC18F2XJ11 (28-PIN DEVICES)

Features	PIC18F24J11	PIC18F25J11	PIC18F26J11
Operating Frequency	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz
Program Memory (Bytes)	16K	32K	64K
Program Memory (Instructions)	8,192	16,384	32,768
Data Memory (Bytes)	3.8K	3.8K	3.8K
Interrupt Sources	30		
I/O Ports	Ports A, B, C		
Timers	5		
Enhanced Capture/Compare/PWM Modules	2		
Serial Communications	MSSP (2), Enhanced USART (2)		
Parallel Communications (PMP/PSP)	No		
10-Bit Analog-to-Digital Module	10 Input Channels		
Resets (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow, $\overline{\text{MCLR}}$, WDT (PWRT, OST)		
Instruction Set	75 Instructions, 83 with Extended Instruction Set Enabled		
Packages	28-Pin QFN, SOIC, SSOP and SPDIP (300 mil)		

TABLE 1-2: DEVICE FEATURES FOR THE PIC18F4XJ11 (44-PIN DEVICES)

Features	PIC18F44J11	PIC18F45J11	PIC18F46J11
Operating Frequency	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz
Program Memory (Bytes)	16K	32K	64K
Program Memory (Instructions)	8,192	16,384	32,768
Data Memory (Bytes)	3.8K	3.8K	3.8K
Interrupt Sources	30		
I/O Ports	Ports A, B, C, D, E		
Timers	5		
Enhanced Capture/Compare/PWM Modules	2		
Serial Communications	MSSP (2), Enhanced USART (2)		
Parallel Communications (PMP/PSP)	Yes		
10-Bit Analog-to-Digital Module	13 Input Channels		
Resets (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow, $\overline{\text{MCLR}}$, WDT (PWRT, OST)		
Instruction Set	75 Instructions, 83 with Extended Instruction Set Enabled		
Packages	44-Pin QFN and TQFP		

TABLE 1-4: PIC18F4XJ11 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number		Pin Type	Buffer Type	Description
	44-QFN	44-TQFP			
					PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/AN12/INT0/RP3	9	8			
RB0			I/O	DIG	Digital I/O.
AN12			I	Analog	Analog input 12.
INT0			I	ST	External interrupt 0.
RP3			I/O	DIG	Remappable peripheral pin 3.
RB1/AN10/PMBE/RTCC/RP4	10	9			
RB1			I/O	DIG	Digital I/O.
AN10			I	Analog	Analog input 10.
PMBE			O	DIG	Parallel Master Port byte enable.
RTCC			O	DIG	Real Time Clock Calendar output.
RP4			I/O	DIG	Remappable peripheral pin 4.
RB2/AN8/CTED1/PMA3/REFO/RP5	11	10			
RB2			I/O	DIG	Digital I/O.
AN8			I	Analog	Analog input 8.
CTED1			I	ST	CTMU edge 1 input.
PMA3			O	DIG	Parallel Master Port address.
REFO			O	DIG	Reference output clock.
RP5			I/O	DIG	Remappable peripheral pin 5.
RB3/AN9/CTED2/PMA2/RP6	12	11			
RB3			I/O	DIG	Digital I/O.
AN9			I	Analog	Analog input 9.
CTED2			I	ST	CTMU edge 2 input.
PMA2			O	DIG	Parallel Master Port address.
RP6			I/O	DIG	Remappable peripheral pin 6.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; Analog = Analog input; I = Input; O = Output; P = Power; OD = Open-Drain (no P diode to V_{DD}); DIG = Digital output

Note 1: RA7 and RA6 will be disabled if OSC1 and OSC2 are used for the clock function.

3.2.5.1 OSCTUNE Register

The internal oscillator's output has been calibrated at the factory but can be adjusted in the user's application. This is done by writing to the OSCTUNE register (Register 3-1).

When the OSCTUNE register is modified, the INTOSC frequency will begin shifting to the new frequency. Code execution continues during this shift. There is no indication that the shift has completed.

The OSCTUNE register also contains the INTSRC bit. The INTSRC bit allows users to select which internal oscillator provides the clock source when the 31 kHz frequency option is selected. This is covered in more detail in **Section 3.3.1 "Oscillator Control Register"**.

The 4x Phase Locked Loop (PLL) can be used with the internal oscillator block to produce faster device clock speeds than are normally possible with the internal oscillator sources. When enabled, the PLL produces a clock speed up to 32 MHz.

PLL operation is controlled through software. The control bit, PLLEN (OSCTUNE<6>), is used to enable or disable its operation. The PLL is available only to INTOSC when the device is configured to use one of the INTPLL modes as the primary clock source, SCS<1:0> = 00 (FOSC<2:0> = 011 or 010). Additionally, the PLL will only function when the selected output frequency is either 4 MHz or 8 MHz (OSCCON<6:4> = 111 or 110).

When configured for one of the PLL enabled modes, setting the PLLEN bit does not immediately switch the device clock to the PLL output. The PLL requires up to two milliseconds to start-up and lock, during which time, the device continues to be clocked. Once the PLL output is ready, the microcontroller core will automatically switch to the PLL derived frequency.

3.2.5.2 Internal Oscillator Output Frequency and Drift

The internal oscillator block is calibrated at the factory to produce an INTOSC output frequency of 8.0 MHz. However, this frequency may drift as V_{DD} or temperature changes, which can affect the controller operation in a variety of ways.

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

3.2.5.3 Compensating for INTOSC Drift

It is possible to adjust the INTOSC frequency by modifying the value in the OSCTUNE register. This has no effect on the INTRC clock source frequency.

Tuning the INTOSC source requires knowing when to make the adjustment, in which direction it should be made, and in some cases, how large a change is needed. When using the EUSART, for example, an adjustment may be required when it begins to generate framing errors or receives data with errors while in Asynchronous mode. Framing errors indicate that the device clock frequency is too high; to adjust for this, decrement the value in OSCTUNE to reduce the clock frequency. On the other hand, errors in data may suggest that the clock speed is too low; to compensate, increment OSCTUNE to increase the clock frequency.

It is also possible to verify device clock speed against a reference clock. Two timers may be used: one timer is clocked by the peripheral clock, while the other is clocked by a fixed reference source, such as the Timer1 oscillator. Both timers are cleared, but the timer clocked by the reference generates interrupts. When an interrupt occurs, the internally clocked timer is read and both timers are cleared. If the internally clocked timer value is greater than expected, then the internal oscillator block is running too fast. To adjust for this, decrement the OSCTUNE register.

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

If the measured time is greater than the calculated time, the internal oscillator block is running too fast; to compensate, decrement the OSCTUNE register. If the measured time is less than the calculated time, the internal oscillator block is running too slow; to compensate, increment the OSCTUNE register.

REGISTER 10-24: RPOR3: PERIPHERAL PIN SELECT OUTPUT REGISTER 3 (BANKED EC9h)

U-0	U-0	U-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0
—	—	—	RP3R4	RP3R3	RP3R2	RP3R1	RP3R0
bit 7							bit 0

Legend:	R/$\overline{W}$ = Readable, Writable if IOLOCK = 0		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

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

bit 4-0 **RP3R<4:0>:** Peripheral Output Function is Assigned to RP3 Output Pin bits
(see Table 10-14 for peripheral function numbers)

REGISTER 10-25: RPOR4: PERIPHERAL PIN SELECT OUTPUT REGISTER 4 (BANKED ECAh)

U-0	U-0	U-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0
—	—	—	RP4R4	RP4R3	RP4R2	RP4R1	RP4R0
bit 7							bit 0

Legend:	R/$\overline{W}$ = Readable, Writable if IOLOCK = 0		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

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

bit 4-0 **RP4R<4:0>:** Peripheral Output Function is Assigned to RP4 Output Pin bits
(see Table 10-14 for peripheral function numbers)

REGISTER 10-26: RPOR5: PERIPHERAL PIN SELECT OUTPUT REGISTER 5 (BANKED ECBh)

U-0	U-0	U-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0	R/$\overline{W}$-0
—	—	—	RP5R4	RP5R3	RP5R2	RP5R1	RP5R0
bit 7							bit 0

Legend:	R/$\overline{W}$ = Readable, Writable if IOLOCK = 0		
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

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

bit 4-0 **RP5R<4:0>:** Peripheral Output Function is Assigned to RP5 Output Pin bits
(see Table 10-14 for peripheral function numbers)

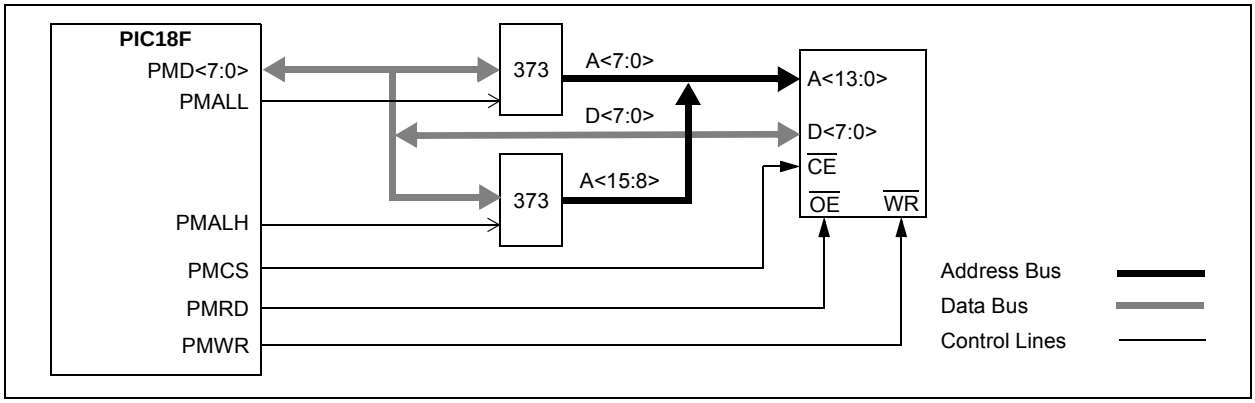
11.4 Application Examples

This section introduces some potential applications for the PMP module.

11.4.1 MULTIPLEXED MEMORY OR PERIPHERAL

Figure 11-27 demonstrates the hookup of a memory or another addressable peripheral in Full Multiplex mode. Consequently, this mode achieves the best pin saving from the microcontroller perspective. However, for this configuration, there needs to be some external latches to maintain the address.

FIGURE 11-27: EXAMPLE – MULTIPLEXED ADDRESSING APPLICATION



11.4.2 PARTIALLY MULTIPLEXED MEMORY OR PERIPHERAL

Partial multiplexing implies using more pins; however, for a few extra pins, some extra performance can be achieved. Figure 11-28 provides an example of a memory or peripheral that is partially multiplexed with an external latch. If the peripheral has internal latches, as displayed in Figure 11-29, then no extra circuitry is required except for the peripheral itself.

FIGURE 11-28: EXAMPLE OF A PARTIALLY MULTIPLEXED ADDRESSING APPLICATION

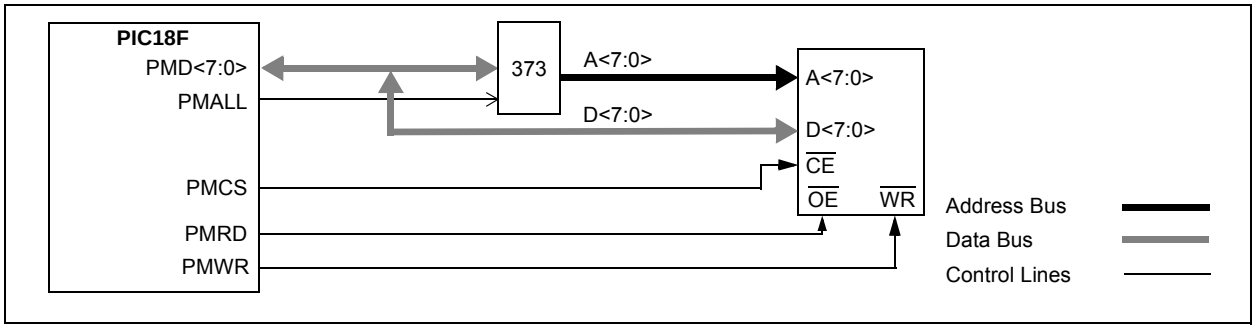
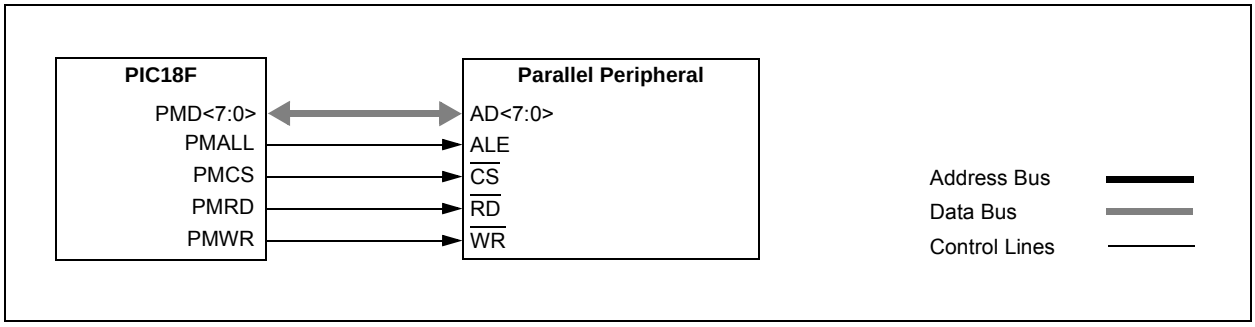


FIGURE 11-29: EXAMPLE OF AN 8-BIT MULTIPLEXED ADDRESS AND DATA APPLICATION



REGISTER 15-3: TCLKCON: TIMER CLOCK CONTROL REGISTER (BANKED F52h)

U-0	U-0	U-0	R-0	U-0	U-0	R/W-0	R/W-0
—	—	—	T1RUN	—	—	T3CCP2	T3CCP1
bit 7							bit 0

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

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

bit 4 **T1RUN:** Timer1 Run Status bit

1 = Device is currently clocked by T1OSC/T1CKI
0 = System clock comes from an oscillator other than T1OSC/T1CKI

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

bit 1-0 **T3CCP<2:1>:** ECCP Timer Assignment bits

10 = ECCP1 and ECCP2 both use Timer3 (capture/compare) and Timer4 (PWM)
01 = ECCP1 uses Timer1 (compare/capture) and Timer2 (PWM); ECCP2 uses Timer3 (capture/compare) and Timer4 (PWM)
00 = ECCP1 and ECCP2 both use Timer1 (capture/compare) and Timer2 (PWM)

15.6 Timer3 Interrupt

The TMR3 register pair (TMR3H:TMR3L) increments from 0000h to FFFFh and overflows to 0000h. The Timer3 interrupt, if enabled, is generated on overflow and is latched in interrupt flag bit, TMR3IF (PIR2<1>). This interrupt can be enabled or disabled by setting or clearing the Timer3 Interrupt Enable bit, TMR3IE (PIE2<1>).

15.7 Resetting Timer3 Using the ECCP Special Event Trigger

If ECCP1 or ECCP2 is configured to use Timer3 and to generate a Special Event Trigger in Compare mode (CCPxM<3:0> = 1011), this signal will reset Timer3. The trigger from ECCP2 will also start an A/D conversion if the A/D module is enabled (see **Section 18.3.4 "Special Event Trigger"** for more information).

The module must be configured as either a timer or synchronous counter to take advantage of this feature. When used this way, the CCPRxH:CCPRxL register pair effectively becomes a Period register for Timer3.

If Timer3 is running in Asynchronous Counter mode, the Reset operation may not work.

In the event that a write to Timer3 coincides with a Special Event Trigger from an ECCP module, the write will take precedence.

Note:	The Special Event Triggers from the ECCPx module will not set the TMR3IF interrupt flag bit (PIR1<0>).

TABLE 15-3: REGISTERS ASSOCIATED WITH TIMER3 AS A TIMER/COUNTER

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Values on Page:
INTCON	GIE/GIEH	PEIE/GIEL	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF	90
PIR2	OSCFIF	CM2IF	CM1IF	—	BCL1IF	LVDIF	TMR3IF	CCP2IF	92
PIE2	OSCFIE	CM2IE	CM1IE	—	BCL1IE	LVDIE	TMR3IE	CCP2IE	92
IPR2	OSCFIP	CM2IP	CM1IP	—	BCL1IP	LVDIP	TMR3IP	CCP2IP	92
TMR3L	Timer3 Register Low Byte								93
TMR3H	Timer3 Register High Byte								93
T1CON	TMR1CS1	TMR1CS0	T1CKPS1	T1CKPS0	T1OSCEN	$\overline{\text{T1SYNC}}$	RD16	TMR1ON	91
T3CON	TMR3CS1	TMR3CS0	T3CKPS1	T3CKPS0	—	$\overline{\text{T3SYNC}}$	RD16	TMR3ON	93
T3GCON	TMR3GE	T3GPOL	T3GTM	T3GSPM	T3GGO/$\overline{\text{T3DONE}}$	T3GVAL	T3GSS1	T3GSS0	92
TCLKCON	—	—	—	T1RUN	—	—	T3CCP2	T3CCP1	94
PIR3	SSP2IF	BCL2IF	RC2IF	TX2IF	TMR4IF	CTMUIF	TMR3GIF	RTCCIF	92
PIE3	SSP2IE	BCL2IE	RC2IE	TX2IE	TMR4IE	CTMUIE	TMR3GIE	RTCCIE	92
IPR3	SSP2IP	BCL2IP	RC2IP	TX2IP	TMR4IP	CTMUIP	TMR3GIP	RTCCIP	92

Legend: — = unimplemented, read as '0'. Shaded cells are not used by the Timer3 module.

REGISTER 19-3: DMACON1: DMA CONTROL REGISTER 1 (ACCESS F88h)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
SSCON1	SSCON0	TXINC	RXINC	DUPLEX1	DUPLEX0	DLYINTEN	DMAEN
bit 7							bit 0

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

bit 7-6 **SSCON<1:0>:** $\overline{\text{SSDMA}}$ Output Control bits (Master modes only)
11 = $\overline{\text{SSDMA}}$ is asserted for the duration of 4 bytes; DLYINTEN is always reset low
01 = $\overline{\text{SSDMA}}$ is asserted for the duration of 2 bytes; DLYINTEN is always reset low
10 = $\overline{\text{SSDMA}}$ is asserted for the duration of 1 byte; DLYINTEN is always reset low
00 = $\overline{\text{SSDMA}}$ is not controlled by the DMA module; DLYINTEN bit is software programmable

bit 5 **TXINC:** Transmit Address Increment Enable bit
Allows the transmit address to increment as the transfer progresses.
1 = The transmit address is to be incremented from the initial value of TXADDR<11:0>
0 = The transmit address is always set to the initial value of TXADDR<11:0>

bit 4 **RXINC:** Receive Address Increment Enable bit
Allows the receive address to increment as the transfer progresses.
1 = The received address is to be incremented from the initial value of RXADDR<11:0>
0 = The received address is always set to the initial value of RXADDR<11:0>

bit 3-2 **DUPLEX<1:0>:** Transmit/Receive Operating Mode Select bits
10 = SPI DMA operates in Full-Duplex mode, data is simultaneously transmitted and received
01 = DMA operates in Half-Duplex mode, data is transmitted only
00 = DMA operates in Half-Duplex mode, data is received only

bit 1 **DLYINTEN:** Delay Interrupt Enable bit
Enables the interrupt to be invoked after the number of SCK cycles specified in DLYCYC<2:0> has elapsed from the latest completed transfer.
1 = The interrupt is enabled, SSCON<1:0> must be set to '00'
0 = The interrupt is disabled

bit 0 **DMAEN:** DMA Operation Start/Stop bit
This bit is set by the users' software to start the DMA operation. It is reset back to zero by the DMA engine when the DMA operation is completed or aborted.
1 = DMA is in session
0 = DMA is not in session

19.5.2 OPERATION

The MSSP module functions are enabled by setting the MSSP Enable bit, SSPEN (SSPxCON1<5>).

The SSPxCON1 register allows control of the I^2C operation. Four mode selection bits (SSPxCON1<3:0>) allow one of the following I^2C modes to be selected:

- I^2C Master mode, clock
- I^2C Slave mode (7-bit address)
- I^2C Slave mode (10-bit address)
- I^2C Slave mode (7-bit address) with Start and Stop bit interrupts enabled
- I^2C Slave mode (10-bit address) with Start and Stop bit interrupts enabled
- I^2C Firmware Controlled Master mode, slave is Idle

Selection of any I^2C mode with the SSPEN bit set forces the SCLx and SDAx pins to be open-drain, provided these pins are programmed as inputs by setting the appropriate TRISB or TRISD bits. To ensure proper operation of the module, pull-up resistors must be provided externally to the SCLx and SDAx pins.

19.5.3 SLAVE MODE

In Slave mode, the SCLx and SDAx pins must be configured as inputs (TRISB<5:4> set). The MSSP module will override the input state with the output data when required (slave-transmitter).

The I^2C Slave mode hardware will always generate an interrupt on an address match. Address masking will allow the hardware to generate an interrupt for more than one address (up to 31 in 7-bit addressing and up to 63 in 10-bit addressing). Through the mode select bits, the user can also choose to interrupt on Start and Stop bits.

When an address is matched, or the data transfer after an address match is received, the hardware automatically will generate the Acknowledge ($\overline{ACK}$) pulse and load the SSPxBUF register with the received value currently in the SSPxSR register.

Any combination of the following conditions will cause the MSSP module not to give this $\overline{ACK}$ pulse:

- The Buffer Full bit, BF (SSPxSTAT<0>), was set before the transfer was received.
- The overflow bit, SSPOV (SSPxCON1<6>), was set before the transfer was received.

In this case, the SSPxSR register value is not loaded into the SSPxBUF, but bit, SSPxIF, is set. The BF bit is cleared by reading the SSPxBUF register, while bit, SSPOV, is cleared through software.

The SCLx clock input must have a minimum high and low for proper operation. The high and low times of the I^2C specification, as well as the requirement of the MSSP module, are shown in timing parameter 100 and parameter 101.

19.5.3.1 Addressing

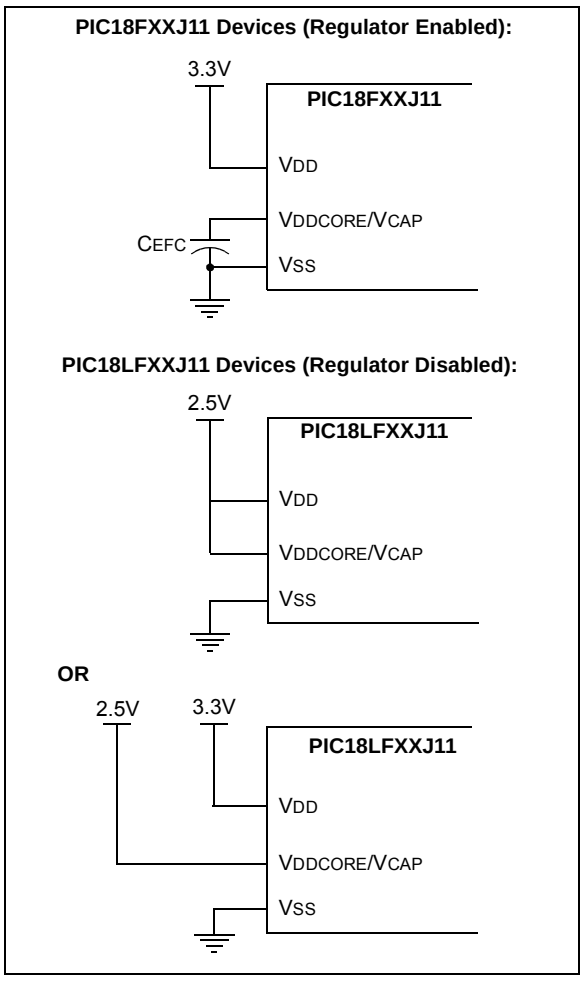
Once the MSSP module has been enabled, it waits for a Start condition to occur. Following the Start condition, the 8 bits are shifted into the SSPxSR register. All incoming bits are sampled with the rising edge of the clock (SCLx) line. The value of register, SSPxSR<7:1>, is compared to the value of the SSPxADD register. The address is compared on the falling edge of the eighth clock (SCLx) pulse. If the addresses match and the BF and SSPOV bits are clear, the following events occur:

1. The SSPxSR register value is loaded into the SSPxBUF register.
2. The Buffer Full bit, BF, is set.
3. An $\overline{ACK}$ pulse is generated.
4. The MSSPx Interrupt Flag bit, SSPxIF, is set (and interrupt is generated, if enabled) on the falling edge of the ninth SCLx pulse.

In 10-Bit Addressing mode, two address bytes need to be received by the slave. The five Most Significant bits (MSbs) of the first address byte specify if this is a 10-bit address. Bit R/$\overline{W}$ (SSPxSTAT<2>) must specify a write so the slave device will receive the second address byte. For a 10-bit address, the first byte would equal '11110 A9 A8 0', where 'A9' and 'A8' are the two MSbs of the address. The sequence of events for 10-bit addressing is as follows, with steps 7 through 9 for the slave-transmitter:

1. Receive first (high) byte of address (bits, SSPxIF, BF and UA, are set on address match).
2. Update the SSPxADD register with second (low) byte of address (clears bit, UA, and releases the SCLx line).
3. Read the SSPxBUF register (clears bit, BF) and clear flag bit, SSPxIF.
4. Receive second (low) byte of address (bits, SSPxIF, BF and UA, are set).
5. Update the SSPxADD register with the first (high) byte of address. If match releases SCLx line, this will clear bit, UA.
6. Read the SSPxBUF register (clears bit, BF) and clear flag bit, SSPxIF.
7. Receive Repeated Start condition.
8. Receive first (high) byte of address (bits, SSPxIF and BF, are set).
9. Read the SSPxBUF register (clears bit, BF) and clear flag bit, SSPxIF.

FIGURE 26-2: CONNECTIONS FOR THE ON-CHIP REGULATOR



26.3.2 ON-CHIP REGULATOR AND BOR

When the on-chip regulator is enabled, PIC18F46J11 family devices also have a simple brown-out capability. If the voltage supplied to the regulator is inadequate to maintain a minimum output level; the regulator Reset circuitry will generate a Brown-out Reset (BOR). This event is captured by the $\overline{\text{BOR}}$ flag bit (RCON<0>).

The operation of the BOR is described in more detail in **Section 5.4 "Brown-out Reset (BOR)"** and **Section 5.4.1 "Detecting BOR"**. The brown-out voltage levels are specific in **Section 29.1 "DC Characteristics: Supply Voltage PIC18F46J11 Family (Industrial)"**.

26.3.3 POWER-UP REQUIREMENTS

The on-chip regulator is designed to meet the power-up requirements for the device. If the application does not use the regulator, then strict power-up conditions must be adhered to. While powering up, V_{DDCORE} should not exceed V_{DD} by 0.3 volts.

26.3.4 OPERATION IN SLEEP MODE

When enabled, the on-chip regulator always consumes a small incremental amount of current over I_{DD}. This includes when the device is in Sleep mode, even though the core digital logic does not require much power. To provide additional savings in applications where power resources are critical, the regulator can be configured to automatically enter a lower quiescent draw standby mode whenever the device goes into Sleep mode. This feature is controlled by the REGSLP bit (WDTCON<7>, Register 26-11). If this bit is set upon entry into Sleep mode, the regulator will transition into a lower power state. In this state, the regulator still provides a regulated output voltage necessary to maintain SRAM state information, but consumes less quiescent current.

Substantial Sleep mode power savings can be obtained by setting the REGSLP bit, but device wake-up time will increase in order to insure the regulator has enough time to stabilize.

27.0 INSTRUCTION SET SUMMARY

The PIC18F46J11 family of devices incorporates the standard set of 75 PIC18 core instructions, and an extended set of eight new instructions for the optimization of code that is recursive or that utilizes a software stack. The extended set is discussed later in this section.

27.1 Standard Instruction Set

The standard PIC18 instruction set adds many enhancements to the previous PIC® MCU instruction sets, while maintaining an easy migration from these PIC MCU instruction sets. Most instructions are a single program memory word (16 bits), but there are four instructions that require two program memory locations.

Each single-word instruction is a 16-bit word divided into an opcode, which specifies the instruction type and one or more operands, which further specify the operation of the instruction.

The instruction set is highly orthogonal and is grouped into four basic categories:

- **Byte-oriented** operations
- **Bit-oriented** operations
- **Literal** operations
- **Control** operations

The PIC18 instruction set summary in Table 27-2 lists the **byte-oriented**, **bit-oriented**, **literal** and **control** operations.

Table 27-1 provides the opcode field descriptions.

Most **Byte-oriented** instructions have three operands:

1. The file register (specified by ‘f’)
2. The destination of the result (specified by ‘d’)
3. The accessed memory (specified by ‘a’)

The file register designator, ‘f’, specifies which file register is to be used by the instruction. The destination designator, ‘d’, specifies where the result of the operation is to be placed. If ‘d’ is ‘0’, the result is placed in the WREG register. If ‘d’ is ‘1’, the result is placed in the file register specified in the instruction.

All **Bit-oriented** instructions have three operands:

1. The file register (specified by ‘f’)
2. The bit in the file register (specified by ‘b’)
3. The accessed memory (specified by ‘a’)

The bit field designator ‘b’ selects the number of the bit affected by the operation, while the file register designator, ‘f’, represents the number of the file in which the bit is located.

The **Literal** instructions may use some of the following operands:

- A literal value to be loaded into a file register (specified by ‘k’)
- The desired FSR register to load the literal value into (specified by ‘f’)
- No operand required (specified by ‘—’)

The **Control** instructions may use some of the following operands:

- A program memory address (specified by ‘n’)
- The mode of the CALL or RETURN instructions (specified by ‘s’)
- The mode of the table read and table write instructions (specified by ‘m’)
- No operand required (specified by ‘—’)

All instructions are a single word, except for four double-word instructions. These instructions were made double-word to contain the required information in 32 bits. In the second word, the 4 MSbs are ‘1’s. If this second word is executed as an instruction (by itself), it will execute as a NOP.

All single-word instructions are executed in a single instruction cycle, unless a conditional test is true or the Program Counter (PC) is changed as a result of the instruction. In these cases, the execution takes two instruction cycles with the additional instruction cycle(s) executed as a NOP.

The double-word instructions execute in two instruction cycles.

One instruction cycle consists of four oscillator periods. Thus, for an oscillator frequency of 4 MHz, the normal instruction execution time is 1 μs. If a conditional test is true, or the program counter is changed as a result of an instruction, the instruction execution time is 2 μs. Two-word branch instructions (if true) would take 3 μs.

Figure 27-1 provides the general formats that the instructions can have. All examples use the convention ‘nnh’ to represent a hexadecimal number.

The instruction set summary, provided in Table 27-2, lists the standard instructions recognized by the Microchip MPASM™ Assembler.

Section 27.1.1 “Standard Instruction Set” provides a description of each instruction.

BTFSC **Bit Test File, Skip if Clear**

Syntax: BTFSC f, b {,a}

Operands: $0 \le f \le 255$
$0 \le b \le 7$
$a \in [0,1]$

Operation: skip if (f<b>) = 0

Status Affected: None

Encoding:

1011	bbba	ffff	ffff

Description: If bit 'b' in register 'f' is '0', then the next instruction is skipped. If bit 'b' is '0', then the next instruction fetched during the current instruction execution is discarded and a NOP is executed instead, making this a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever $f \le 95$ (5Fh). See **Section 27.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode"** for details.

Words: 1

Cycles: 1(2)
Note: 3 cycles if skip and followed by a 2-word instruction.

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read register 'f'	Process Data	No operation

If skip:

Q1	Q2	Q3	Q4
No operation	No operation	No operation	No operation

If skip and followed by 2-word instruction:

Q1	Q2	Q3	Q4
No operation	No operation	No operation	No operation
No operation	No operation	No operation	No operation

Example:
```
HERE    BTFSC   FLAG, 1, 0
FALSE   :
TRUE    :
```

Before Instruction
PC = address (HERE)
After Instruction
If FLAG<1> = 0;
PC = address (TRUE)
If FLAG<1> = 1;
PC = address (FALSE)

BTFSS **Bit Test File, Skip if Set**

Syntax: BTFSS f, b {,a}

Operands: $0 \le f \le 255$
$0 \le b < 7$
$a \in [0,1]$

Operation: skip if (f<b>) = 1

Status Affected: None

Encoding:

1010	bbba	ffff	ffff

Description: If bit 'b' in register 'f' is '1', then the next instruction is skipped. If bit 'b' is '1', then the next instruction fetched during the current instruction execution is discarded and a NOP is executed instead, making this a two-cycle instruction.

If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).

If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever $f \le 95$ (5Fh). See **Section 27.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode"** for details.

Words: 1

Cycles: 1(2)
Note: 3 cycles if skip and followed by a 2-word instruction.

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read register 'f'	Process Data	No operation

If skip:

Q1	Q2	Q3	Q4
No operation	No operation	No operation	No operation

If skip and followed by 2-word instruction:

Q1	Q2	Q3	Q4
No operation	No operation	No operation	No operation
No operation	No operation	No operation	No operation

Example:
```
HERE    BTFSS   FLAG, 1, 0
FALSE   :
TRUE    :
```

Before Instruction
PC = address (HERE)
After Instruction
If FLAG<1> = 0;
PC = address (FALSE)
If FLAG<1> = 1;
PC = address (TRUE)

27.2.2 EXTENDED INSTRUCTION SET

ADDFSR **Add Literal to FSR**

Syntax: ADDFSR f, k

Operands: $0 \le k \le 63$
$f \in [0, 1, 2]$

Operation: FSR(f) + k → FSR(f)

Status Affected: None

Encoding:

1110	1000	ffkk	kkkk

Description: The 6-bit literal 'k' is added to the contents of the FSR specified by 'f'.

Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read literal 'k'	Process Data	Write to FSR

Example: `ADDFSR 2, 0x23`

Before Instruction
FSR2 = 03FFh
After Instruction
FSR2 = 0422h

ADDULNK **Add Literal to FSR2 and Return**

Syntax: ADDULNK k

Operands: $0 \le k \le 63$

Operation: FSR2 + k → FSR2,
(TOS) → PC

Status Affected: None

Encoding:

1110	1000	11kk	kkkk

Description: The 6-bit literal 'k' is added to the contents of FSR2. A RETURN is then executed by loading the PC with the TOS.

The instruction takes two cycles to execute; a NOP is performed during the second cycle.

This may be thought of as a special case of the ADDFSR instruction, where f = 3 (binary '11'); it operates only on FSR2.

Words: 1

Cycles: 2

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read literal 'k'	Process Data	Write to FSR
No Operation	No Operation	No Operation	No Operation

Example: `ADDULNK 0x23`

Before Instruction
FSR2 = 03FFh
PC = 0100h
After Instruction
FSR2 = 0422h
PC = (TOS)

Note: All PIC18 instructions may take an optional label argument preceding the instruction mnemonic for use in symbolic addressing. If a label is used, the instruction format then becomes: {label} instruction argument(s).

29.2 DC Characteristics: Power-Down and Supply Current PIC18F46J11 Family (Industrial) (Continued)

PIC18LFXXJ11 Family		Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial					
PIC18FXXJ11 Family		**Standard Operating Conditions (unless otherwise stated)** Operating temperature -40°C ≤ TA ≤ +85°C for industrial					
Param No.	**Device**	**Typ**	**Max**	**Units**	**Conditions**		
	Supply Current (IDD)(2)						
	PIC18LFXXJ11	1.9	3.6	mA	-40°C	VDD = 2.0V, VDDCORE = 2.0V	FOSC = 8 MHz, **RC_RUN** mode, Internal RC Oscillator
		2.0	3.8	mA	+25°C		
		2.0	3.8	mA	+85°C		
	PIC18LFXXJ11	2.8	4.8	mA	-40°C	VDD = 2.5V, VDDCORE = 2.5V	
		2.8	4.8	mA	+25°C		
		2.8	4.9	mA	+85°C		
	PIC18FXXJ11	2.3	4.2	mA	-40°C	VDD = 2.15V, VDDCORE = 10 µF Capacitor	
		2.3	4.2	mA	+25°C		
		2.4	4.5	mA	+85°C		
	PIC18FXXJ11	2.8	5.1	mA	-40°C	VDD = 3.3V, VDDCORE = 10 µF Capacitor	
		2.8	5.1	mA	+25°C		
		2.8	5.4	mA	+85°C		
	PIC18LFXXJ11	1.9	9.4	µA	-40°C	VDD = 2.0V, VDDCORE = 2.0V	FOSC = 31 kHz, **RC_IDLE** mode, Internal RC Oscillator, INTSRC = 0
		2.3	9.4	µA	+25°C		
		4.5	17.2	µA	+85°C		
	PIC18LFXXJ11	2.4	10.5	µA	-40°C	VDD = 2.5V, VDDCORE = 2.5V	
		2.8	10.5	µA	+25°C		
		5.4	19.5	µA	+85°C		
	PIC18FXXJ11	33.3	75	µA	-40°C	VDD = 2.15V, VDDCORE = 10 µF Capacitor	
		43.8	75	µA	+25°C		
		55.3	92	µA	+85°C		
	PIC18FXXJ11	36.1	82	µA	-40°C	VDD = 3.3V, VDDCORE = 10 µF Capacitor	
		44.5	82	µA	+25°C		
		56.3	105	µA	+85°C		

Note 1: The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 oscillator, BOR, etc.).

2: The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption. All features that add delta current are disabled (WDT, etc.). 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/VSS;
$\overline{MCLR}$ = VDD; WDT disabled unless otherwise specified.

3: Low-Power Timer1 with standard, low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.

29.2 DC Characteristics: Power-Down and Supply Current PIC18F46J11 Family (Industrial) (Continued)

PIC18LFXXJ11 Family		Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial					
PIC18FXXJ11 Family		**Standard Operating Conditions (unless otherwise stated)** Operating temperature -40°C ≤ TA ≤ +85°C for industrial					
Param No.	**Device**	**Typ**	**Max**	**Units**	**Conditions**		
	Supply Current (IDD)(2)						
	PIC18LFXXJ11	0.285	0.700	mA	-40°C	VDD = 2.0V, VDDCORE = 2.0V	FOSC = 4 MHz, **PRI_IDLE** mode, EC Oscillator
		0.300	0.700	mA	+25°C		
		0.336	0.750	mA	+85°C		
	PIC18LFXXJ11	0.372	1.00	mA	-40°C	VDD = 2.5V, VDDCORE = 2.5V	
		0.397	1.00	mA	+25°C		
		0.495	1.10	mA	+85°C		
	PIC18FXXJ11	0.357	0.850	mA	-40°C	VDD = 2.15V, VDDCORE = 10 µF Capacitor	
		0.383	0.850	mA	+25°C		
		0.407	0.900	mA	+85°C		
	PIC18FXXJ11	0.449	1.30	mA	-40°C	VDD = 3.3V, VDDCORE = 10 µF Capacitor	
		0.488	1.20	mA	+25°C		
		0.554	1.20	mA	+85°C		
	PIC18LFXXJ11	4.5	6.5	mA	-40°C	VDD = 2.5V, VDDCORE = 2.5V	FOSC = 48 MHz **PRI_IDLE** mode, EC oscillator
		4.5	6.5	mA	+25°C		
		4.6	6.5	mA	+85°C		
	PIC18FXXJ11	4.9	12.4	mA	-40°C	VDD = 3.3V, VDDCORE = 10 µF Capacitor	
		5.0	11.5	mA	+25°C		
		5.1	11.5	mA	+85°C		

Note 1: The power-down current in Sleep mode does not depend on the oscillator type. Power-down current is measured with the part in Sleep mode, with all I/O pins in high-impedance state and tied to VDD or VSS and all features that add delta current disabled (such as WDT, Timer1 oscillator, BOR, etc.).

2: The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption. All features that add delta current are disabled (WDT, etc.). 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/VSS;
$\overline{MCLR}$ = VDD; WDT disabled unless otherwise specified.

3: Low-Power Timer1 with standard, low-cost 32 kHz crystals have an operating temperature range of -10°C to +70°C. Extended temperature crystals are available at a much higher cost.

FIGURE 29-3: HIGH/LOW-VOLTAGE DETECT CHARACTERISTICS

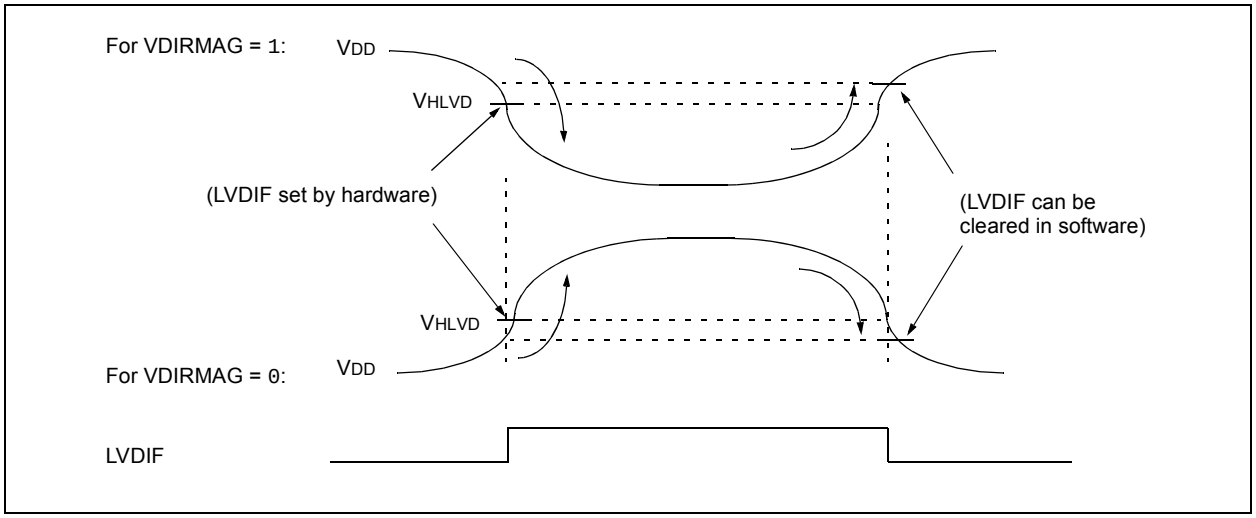
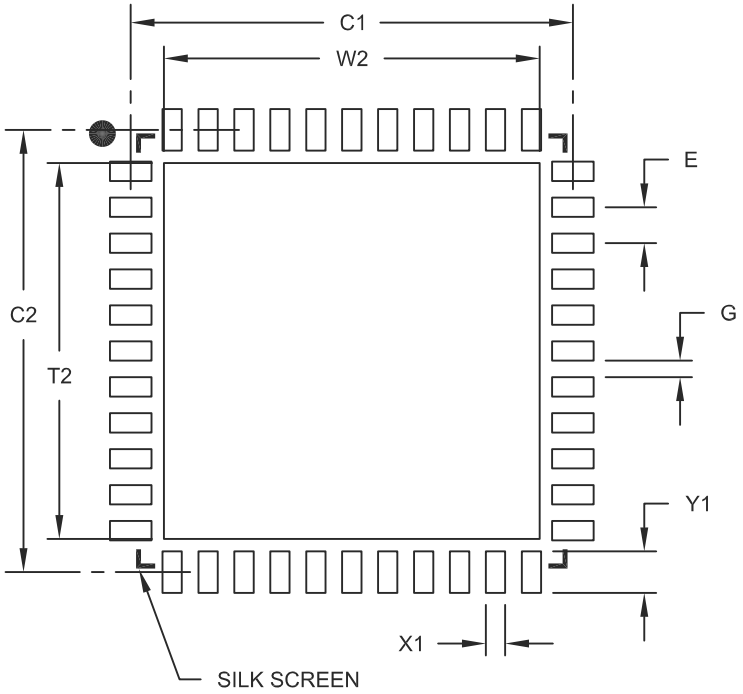


TABLE 29-7: HIGH/LOW-VOLTAGE DETECT CHARACTERISTICS

Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial								
Param No.	**Symbol**	**Characteristic**		**Min**	**Typ**	**Max**	**Units**	**Conditions**
D420		HLVD Voltage on VDD Transition High-to-Low	HLVDL<3:0> = 1000	2.33	2.45	2.57	V	
			HLVDL<3:0> = 1001	2.47	2.60	2.73	V	
			HLVDL<3:0> = 1010	2.66	2.80	2.94	V	
			HLVDL<3:0> = 1011	2.76	2.90	3.05	V	
			HLVDL<3:0> = 1100	2.85	3.00	3.15	V	
			HLVDL<3:0> = 1101	2.97	3.13	3.29	V	
			HLVDL<3:0> = 1110	3.23	3.40	3.57	V	
D421	TIRVST	Time for Internal Reference Voltage to become Stable		—	20	—	μs	
D422	TLVD	High/Low-Voltage Detect Pulse Width		200	—	—	μs	

44-Lead Plastic Quad Flat, No Lead Package (ML) – 8x8 mm Body [QFN]

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.65 BSC	
Optional Center Pad Width	W2			6.80
Optional Center Pad Length	T2			6.80
Contact Pad Spacing	C1		8.00	
Contact Pad Spacing	C2		8.00	
Contact Pad Width (X44)	X1			0.35
Contact Pad Length (X44)	Y1			0.80
Distance Between Pads	G	0.25		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

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

Microchip Technology Drawing No. C04-2103A

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