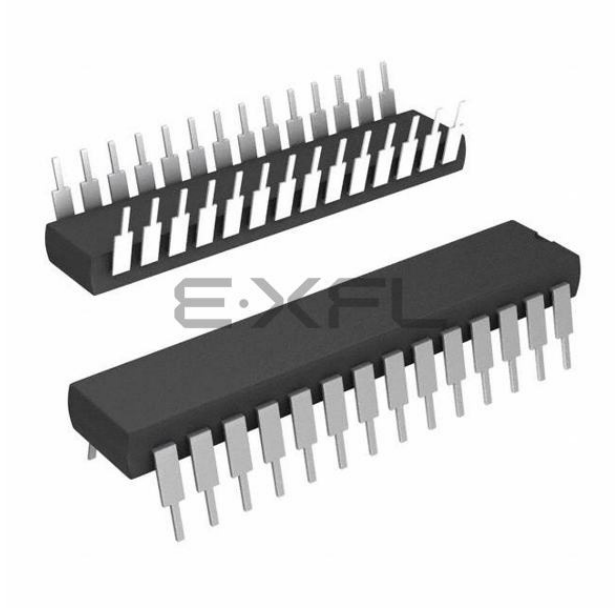

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Details	
Product Status	Active
Core Processor	PIC
Core Size	8-Bit
Speed	48MHz
Connectivity	I²C, SPI, UART/USART, USB
Peripherals	Brown-out Detect/Reset, HLVD, POR, PWM, WDT
Number of I/O	24
Program Memory Size	32KB (16K x 16)
Program Memory Type	FLASH
EEPROM Size	256 x 8
RAM Size	2K x 8
Voltage - Supply (Vcc/Vdd)	2V ~ 5.5V
Data Converters	A/D 10x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Through Hole
Package / Case	28-DIP (0.300", 7.62mm)
Supplier Device Package	28-SPDIP
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic18lf2550-i-sp

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2.3 Oscillator Settings for USB

When these devices are used for USB connectivity, they must have either a 6 MHz or 48 MHz clock for USB operation, depending on whether Low-Speed or Full-Speed mode is being used. This may require some forethought in selecting an oscillator frequency and programming the device.

The full range of possible oscillator configurations compatible with USB operation is shown in Table 2-3.

2.3.1 LOW-SPEED OPERATION

The USB clock for Low-Speed mode is derived from the primary oscillator chain and not directly from the PLL. It is divided by 4 to produce the actual 6 MHz clock. Because of this, the microcontroller can only use a clock frequency of 24 MHz when the USB module is active and the controller clock source is one of the primary oscillator modes (XT, HS or EC, with or without the PLL).

This restriction does not apply if the microcontroller clock source is the secondary oscillator or internal oscillator block.

2.3.2 RUNNING DIFFERENT USB AND MICROCONTROLLER CLOCKS

The USB module, in either mode, can run asynchronously with respect to the microcontroller core and other peripherals. This means that applications can use the primary oscillator for the USB clock while the microcontroller runs from a separate clock source at a lower speed. If it is necessary to run the entire application from only one clock source, full-speed operation provides a greater selection of microcontroller clock frequencies.

TABLE 2-3: OSCILLATOR CONFIGURATION OPTIONS FOR USB OPERATION

Input Oscillator Frequency	PLL Division (PLLDIV2:PLLDIV0)	Clock Mode (FOSC3:FOSC0)	MCU Clock Division (CPUDIV1:CPUDIV0)	Microcontroller Clock Frequency
48 MHz	N/A(1)	EC, ECIO	None (00)	48 MHz
			÷2 (01)	**24 MHz**
			÷3 (10)	16 MHz
			÷4 (11)	12 MHz
48 MHz	÷12 (111)	EC, ECIO	None (00)	48 MHz
			÷2 (01)	**24 MHz**
			÷3 (10)	16 MHz
			÷4 (11)	12 MHz
		ECPLL, ECPIO	÷2 (00)	48 MHz
			÷3 (01)	32 MHz
			÷4 (10)	**24 MHz**
			÷6 (11)	16 MHz
40 MHz	÷10 (110)	EC, ECIO	None (00)	40 MHz
			÷2 (01)	20 MHz
			÷3 (10)	13.33 MHz
			÷4 (11)	10 MHz
		ECPLL, ECPIO	÷2 (00)	48 MHz
			÷3 (01)	32 MHz
			÷4 (10)	**24 MHz**
			÷6 (11)	16 MHz
24 MHz	÷6 (101)	HS, EC, ECIO	None (00)	**24 MHz**
			÷2 (01)	12 MHz
			÷3 (10)	8 MHz
			÷4 (11)	6 MHz
		HSPLL, ECPLL, ECPIO	÷2 (00)	48 MHz
			÷3 (01)	32 MHz
			÷4 (10)	**24 MHz**
			÷6 (11)	16 MHz

Legend: All clock frequencies, except 24 MHz, are exclusively associated with full-speed USB operation (USB clock of 48 MHz). **Bold** is used to highlight clock selections that are compatible with low-speed USB operation (system clock of 24 MHz, USB clock of 6 MHz).

Note 1: Only valid when the USBDIV Configuration bit is cleared.

6.4 Erasing Flash Program Memory

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

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

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

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

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

6.4.1 FLASH PROGRAM MEMORY ERASE SEQUENCE

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

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

EXAMPLE 6-2: ERASING A FLASH PROGRAM MEMORY ROW

```
                MOVLW   CODE_ADDR_UPPER      ; load TBLPTR with the base
                MOVWF   TBLPTRU              ; address of the memory block
                MOVLW   CODE_ADDR_HIGH
                MOVWF   TBLPTRH
                MOVLW   CODE_ADDR_LOW
                MOVWF   TBLPTRL
    ERASE_ROW
                BSF     EECON1, EEPGD        ; point to Flash program memory
                BCF     EECON1, CFGS         ; access Flash program memory
                BSF     EECON1, WREN         ; enable write to memory
                BSF     EECON1, FREE         ; enable Row Erase operation
                BCF     INTCON, GIE          ; disable interrupts
Required        MOVLW   55h
Sequence        MOVWF   EECON2               ; write 55h
                MOVLW   0AAh
                MOVWF   EECON2               ; write 0AAh
                BSF     EECON1, WR           ; start erase (CPU stall)
                BSF     INTCON, GIE          ; re-enable interrupts
```

9.4 PIE Registers

The PIE registers contain the individual enable bits for the peripheral interrupts. Due to the number of peripheral interrupt sources, there are two Peripheral Interrupt Enable registers (PIE1 and PIE2). When IPEN = 0, the PEIE bit must be set to enable any of these peripheral interrupts.

REGISTER 9-6: PIE1: PERIPHERAL INTERRUPT ENABLE REGISTER 1

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
SPPIE(1)	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE
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 **SPPIE:** Streaming Parallel Port Read/Write Interrupt Enable bit(1)
1 = Enables the SPP read/write interrupt
0 = Disables the SPP read/write interrupt

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

bit 5 **RCIE:** EUSART Receive Interrupt Enable bit
1 = Enables the EUSART receive interrupt
0 = Disables the EUSART receive interrupt

bit 4 **TXIE:** EUSART Transmit Interrupt Enable bit
1 = Enables the EUSART transmit interrupt
0 = Disables the EUSART transmit interrupt

bit 3 **SSPIE:** Master Synchronous Serial Port Interrupt Enable bit
1 = Enables the MSSP interrupt
0 = Disables the MSSP interrupt

bit 2 **CCP1IE:** CCP1 Interrupt Enable bit
1 = Enables the CCP1 interrupt
0 = Disables the CCP1 interrupt

bit 1 **TMR2IE:** TMR2 to PR2 Match Interrupt Enable bit
1 = Enables the TMR2 to PR2 match interrupt
0 = Disables the TMR2 to PR2 match interrupt

bit 0 **TMR1IE:** TMR1 Overflow Interrupt Enable bit
1 = Enables the TMR1 overflow interrupt
0 = Disables the TMR1 overflow interrupt

Note 1: This bit is reserved on 28-pin devices; always maintain this bit clear.

10.0 I/O PORTS

Depending on the device selected and features enabled, there are up to five ports available. Some pins of the I/O ports are multiplexed with an alternate function from the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

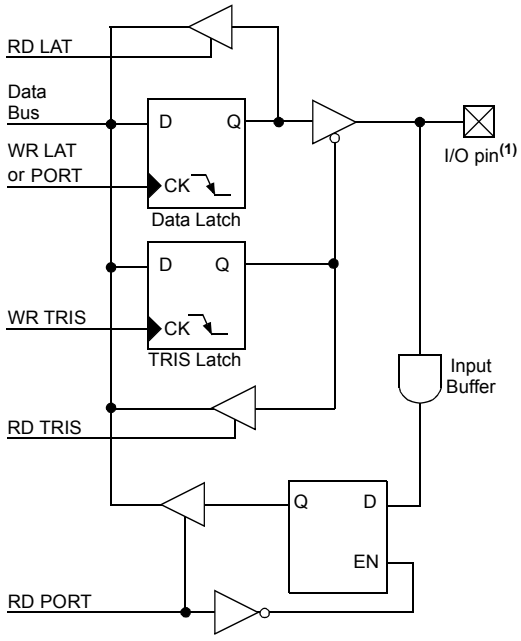
Each port has three registers for its operation. These registers are:

- TRIS register (data direction register)
- PORT register (reads the levels on the pins of the device)
- LAT register (output latch)

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

A simplified model of a generic I/O port, without the interfaces to other peripherals, is shown in Figure 10-1.

FIGURE 10-1: GENERIC I/O PORT OPERATION



Note 1: I/O pins have diode protection to VDD and VSS.

10.1 PORTA, TRISA and LATA Registers

PORTA is an 8-bit wide, bidirectional port. The corresponding Data Direction register is TRISA. Setting a TRISA bit (= 1) will make the corresponding PORTA pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISA bit (= 0) will make the corresponding PORTA pin an output (i.e., put the contents of the output latch on the selected pin).

Reading the PORTA register reads the status of the pins; writing to it will write to the port latch.

The Data Latch register (LATA) is also memory mapped. Read-modify-write operations on the LATA register read and write the latched output value for PORTA.

The RA4 pin is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. The RA6 pin is multiplexed with the main oscillator pin; it is enabled as an oscillator or I/O pin by the selection of the main oscillator in Configuration Register 1H (see **Section 25.1 "Configuration Bits"** for details). When not used as a port pin, RA6 and its associated TRIS and LAT bits are read as '0'.

RA4 is also multiplexed with the USB module; it serves as a receiver input from an external USB transceiver. For details on configuration of the USB module, see **Section 17.2 "USB Status and Control"**.

Several PORTA pins are multiplexed with analog inputs, the analog VREF+ and VREF- inputs and the comparator voltage reference output. The operation of pins RA5 and RA3:RA0 as A/D converter inputs is selected by clearing/setting the control bits in the ADCON1 register (A/D Control Register 1).

Note:	On a Power-on Reset, RA5 and RA3:RA0 are configured as analog inputs and read as '0'. RA4 is configured as a digital input.

All other PORTA pins have TTL input levels and full CMOS output drivers.

The TRISA register controls the direction of the RA pins, even when they are being used as analog inputs. The user must ensure the bits in the TRISA register are maintained set when using them as analog inputs.

EXAMPLE 10-1: INITIALIZING PORTA

```
CLRF    PORTA   ; Initialize PORTA by
                ; clearing output
                ; data latches
CLRF    LATA    ; Alternate method
                ; to clear output
                ; data latches
MOVLW   0Fh     ; Configure A/D
MOVWF   ADCON1  ; for digital inputs
MOVLW   07h     ; Configure comparators
MOVWF   CMCON   ; for digital input
MOVLW   0CFh    ; Value used to
                ; initialize data
                ; direction
MOVWF   TRISA   ; Set RA<3:0> as inputs
                ; RA<5:4> as outputs
```

TABLE 10-8: SUMMARY OF REGISTERS ASSOCIATED WITH PORTD

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Values on page
PORTD(3)	RD7	RD6	RD5	RD4	RD3	RD2	RD1	RD0	56
LATD(3)	LATD7	LATD6	LATD5	LATD4	LATD3	LATD2	LATD1	LATD0	56
TRISD(3)	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0	56
PORTE	RDPU(3)	—	—	—	RE3(1,2)	RE2(3)	RE1(3)	RE0(3)	56
CCP1CON	P1M1(3)	P1M0(3)	DC1B1	DC1B0	CCP1M3	CCP1M2	CCP1M1	CCP1M0	55
SPPCON(3)	—	—	—	—	—	—	SPPOWN	SPPEN	57

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

Note 1: Implemented only when Master Clear functionality is disabled (MCLRE Configuration bit = 0).

2: RE3 is the only PORTE bit implemented on both 28-pin and 40/44-pin devices. All other bits are implemented only when PORTE is implemented (i.e., 40/44-pin devices).

3: These registers and/or bits are unimplemented on 28-pin devices.

11.0 TIMER0 MODULE

The Timer0 module incorporates the following features:

- Software selectable operation as a timer or counter in both 8-bit or 16-bit modes
- Readable and writable registers
- Dedicated 8-bit, software programmable prescaler
- Selectable clock source (internal or external)
- Edge select for external clock
- Interrupt on overflow

The T0CON register (Register 11-1) controls all aspects of the module's operation, including the prescale selection. It is both readable and writable.

A simplified block diagram of the Timer0 module in 8-bit mode is shown in Figure 11-1. Figure 11-2 shows a simplified block diagram of the Timer0 module in 16-bit mode.

REGISTER 11-1: T0CON: TIMER0 CONTROL REGISTER

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
TMR0ON	T08BIT	T0CS	T0SE	PSA	T0PS2	T0PS1	T0PS0
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 **TMR0ON:** Timer0 On/Off Control bit
1 = Enables Timer0
0 = Stops Timer0

bit 6 **T08BIT**: Timer0 8-Bit/16-Bit Control bit
1 = Timer0 is configured as an 8-bit timer/counter
0 = Timer0 is configured as a 16-bit timer/counter

bit 5 **T0CS**: Timer0 Clock Source Select bit
1 = Transition on T0CKI pin
0 = Internal instruction cycle clock (CLKO)

bit 4 **T0SE**: Timer0 Source Edge Select bit
1 = Increment on high-to-low transition on T0CKI pin
0 = Increment on low-to-high transition on T0CKI pin

bit 3 **PSA**: Timer0 Prescaler Assignment bit
1 = TImer0 prescaler is NOT assigned. Timer0 clock input bypasses prescaler.
0 = Timer0 prescaler is assigned. Timer0 clock input comes from prescaler output.

bit 2-0 **T0PS2:T0PS0**: Timer0 Prescaler Select bits
111 = 1:256 Prescale value
110 = 1:128 Prescale value
101 = 1:64 Prescale value
100 = 1:32 Prescale value
011 = 1:16 Prescale value
010 = 1:8 Prescale value
001 = 1:4 Prescale value
000 = 1:2 Prescale value

11.3 Prescaler

An 8-bit counter is available as a prescaler for the Timer0 module. The prescaler is not directly readable or writable; its value is set by the PSA and T0PS2:T0PS0 bits (T0CON<3:0>) which determine the prescaler assignment and prescale ratio.

Clearing the PSA bit assigns the prescaler to the Timer0 module. When it is assigned, prescale values from 1:2 through 1:256, in power-of-2 increments, are selectable.

When assigned to the Timer0 module, all instructions writing to the TMR0 register (e.g., `CLRF TMR0`, `MOVWF TMR0`, `BSF TMR0`, etc.) clear the prescaler count.

Note:	Writing to TMR0 when the prescaler is assigned to Timer0 will clear the prescaler count but will not change the prescaler assignment.

11.3.1 SWITCHING PRESCALER ASSIGNMENT

The prescaler assignment is fully under software control and can be changed “on-the-fly” during program execution.

11.4 Timer0 Interrupt

The TMR0 interrupt is generated when the TMR0 register overflows from FFh to 00h in 8-bit mode, or from FFFFh to 0000h in 16-bit mode. This overflow sets the TMR0IF flag bit. The interrupt can be masked by clearing the TMR0IE bit (INTCON<5>). Before re-enabling the interrupt, the TMR0IF bit must be cleared in software by the Interrupt Service Routine.

Since Timer0 is shut down in Sleep mode, the TMR0 interrupt cannot awaken the processor from Sleep.

TABLE 11-1: REGISTERS ASSOCIATED WITH TIMER0

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Values on page
TMR0L	Timer0 Register Low Byte								54
TMR0H	Timer0 Register High Byte								54
INTCON	GIE/GIEH	PEIE/GIEL	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF	53
INTCON2	$\overline{\text{RBPU}}$	INTEDG0	INTEDG1	INTEDG2	—	TMR0IP	—	RBIP	53
T0CON	TMR0ON	T08BIT	T0CS	T0SE	PSA	T0PS2	T0PS1	T0PS0	54
TRISA	—	TRISA6(1)	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	56

Legend: — = unimplemented locations, read as ‘0’. Shaded cells are not used by Timer0.

Note 1: RA6 is configured as a port pin based on various primary oscillator modes. When the port pin is disabled, all of the associated bits read ‘0’.

REGISTER 17-5: BDnSTAT: BUFFER DESCRIPTOR n STATUS REGISTER (BD0STAT THROUGH BD63STAT), CPU MODE (DATA IS WRITTEN TO THE SIDE)

R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x
UOWN(1)	DTS(2)	KEN	INCDIS	DTSEN	BSTALL	BC9	BC8
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 **UOWN:** USB Own bit(1)
- 0 = The microcontroller core owns the BD and its corresponding buffer

bit 6 **DTS:** Data Toggle Synchronization bit(2)
- 1 = Data 1 packet
- 0 = Data 0 packet

bit 5 **KEN:** BD Keep Enable bit
- 1 = USB will keep the BD indefinitely once UOWN is set (required for SPP endpoint configuration)
- 0 = USB will hand back the BD once a token has been processed

bit 4 **INCDIS:** Address Increment Disable bit
- 1 = Address increment disabled (required for SPP endpoint configuration)
- 0 = Address increment enabled

bit 3 **DTSEN:** Data Toggle Synchronization Enable bit
- 1 = Data toggle synchronization is enabled; data packets with incorrect Sync value will be ignored except for a SETUP transaction, which is accepted even if the data toggle bits do not match
- 0 = No data toggle synchronization is performed

bit 2 **BSTALL:** Buffer Stall Enable bit
- 1 = Buffer stall enabled; STALL handshake issued if a token is received that would use the BD in the given location (UOWN bit remains set, BD value is unchanged)
- 0 = Buffer stall disabled

bit 1-0 **BC9:BC8:** Byte Count 9 and 8 bits

The byte count bits represent the number of bytes that will be transmitted for an IN token or received during an OUT token. Together with BC<7:0>, the valid byte counts are 0-1023.

Note 1: This bit must be initialized by the user to the desired value prior to enabling the USB module.

2: This bit is ignored unless DTSEN = 1.

17.5.2 USB INTERRUPT ENABLE REGISTER (UIE)

The USB Interrupt Enable register (Register 17-8) contains the enable bits for the USB status interrupt sources. Setting any of these bits will enable the respective interrupt source in the UIR register.

The values in this register only affect the propagation of an interrupt condition to the microcontroller's interrupt logic. The flag bits are still set by their interrupt conditions, allowing them to be polled and serviced without actually generating an interrupt.

REGISTER 17-8: UIE: USB INTERRUPT ENABLE REGISTER

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	SOFIE	STALLIE	IDLEIE	TRNIE	ACTVIE	UERRIE	URSTIE
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 **Unimplemented:** Read as '0'

bit 6 **SOFIE:** Start-Of-Frame Token Interrupt Enable bit
1 = Start-Of-Frame token interrupt enabled
0 = Start-Of-Frame token interrupt disabled

bit 5 **STALLIE:** STALL Handshake Interrupt Enable bit
1 = STALL interrupt enabled
0 = STALL interrupt disabled

bit 4 **IDLEIE:** Idle Detect Interrupt Enable bit
1 = Idle detect interrupt enabled
0 = Idle detect interrupt disabled

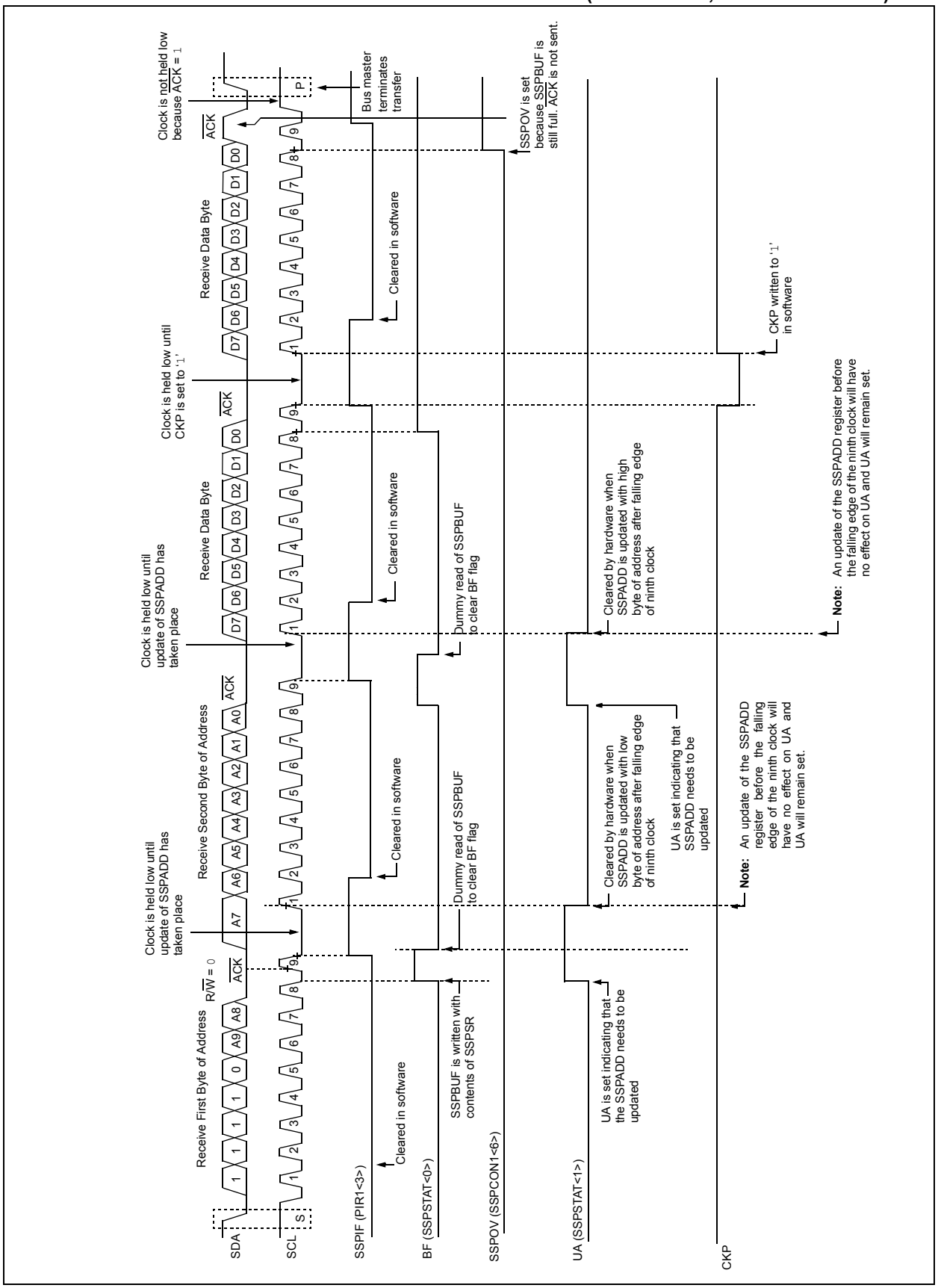
bit 3 **TRNIE:** Transaction Complete Interrupt Enable bit
1 = Transaction interrupt enabled
0 = Transaction interrupt disabled

bit 2 **ACTVIE:** Bus Activity Detect Interrupt Enable bit
1 = Bus activity detect interrupt enabled
0 = Bus activity detect interrupt disabled

bit 1 **UERRIE:** USB Error Interrupt Enable bit
1 = USB error interrupt enabled
0 = USB error interrupt disabled

bit 0 **URSTIE:** USB Reset Interrupt Enable bit
1 = USB Reset interrupt enabled
0 = USB Reset interrupt disabled

FIGURE 19-16: I²C™ SLAVE MODE TIMING WITH SEN = 1 (RECEPTION, 10-BIT ADDRESS)



REGISTER 20-1: TXSTA: 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	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7 **CSRC:** Clock Source Select bit
Asynchronous mode:
Don't care.
Synchronous mode:
1 = Master mode (clock generated internally from BRG)
0 = Slave mode (clock from external source)

bit 6 **TX9:** 9-Bit Transmit Enable bit
1 = Selects 9-bit transmission
0 = Selects 8-bit transmission

bit 5 **TXEN:** Transmit Enable bit(1)
1 = Transmit enabled
0 = Transmit disabled

bit 4 **SYNC:** EUSART Mode Select bit
1 = Synchronous mode
0 = Asynchronous mode

bit 3 **SENDB:** Send Break Character bit
Asynchronous mode:
1 = Send Sync Break on next transmission (cleared by hardware upon completion)
0 = Sync Break transmission completed
Synchronous mode:
Don't care.

bit 2 **BRGH:** High Baud Rate Select bit
Asynchronous mode:
1 = High speed
0 = Low speed
Synchronous mode:
Unused in this mode.

bit 1 **TRMT:** Transmit Shift Register Status bit
1 = TSR empty
0 = TSR full

bit 0 **TX9D:** 9th bit of Transmit Data
Can be address/data bit or a parity bit.

Note 1: SREN/CREN overrides TXEN in Sync mode with the exception that SREN has no effect in Synchronous Slave mode.

20.2 EUSART Asynchronous Mode

The Asynchronous mode of operation is selected by clearing the SYNC bit (TXSTA<4>). In this mode, the EUSART uses standard Non-Return-to-Zero (NRZ) format (one Start bit, eight or nine data bits and one Stop bit). The most common data format is 8 bits. An on-chip dedicated 8-bit/16-bit Baud Rate Generator can be used to derive standard baud rate frequencies from the oscillator.

The EUSART transmits and receives the LSb first. The EUSART's transmitter and receiver are functionally independent but use the same data format and baud rate. The Baud Rate Generator produces a clock, either x16 or x64 of the bit shift rate depending on the BRGH and BRG16 bits (TXSTA<2> and BAUDCON<3>). Parity is not supported by the hardware but can be implemented in software and stored as the 9th data bit.

The TXCKP (BAUDCON<4>) and RXDTP (BAUDCON<5>) bits allow the TX and RX signals to be inverted (polarity reversed). Devices that buffer signals between TTL and RS-232 levels also invert the signal. Setting the TXCKP and RXDTP bits allows for the use of circuits that provide buffering without inverting the signal.

When operating in Asynchronous mode, the EUSART module consists of the following important elements:

- Baud Rate Generator
- Sampling Circuit
- Asynchronous Transmitter
- Asynchronous Receiver
- Auto-Wake-up on Break signal
- 12-Bit Break Character Transmit
- Auto-Baud Rate Detection
- Pin State Polarity

20.2.1 EUSART ASYNCHRONOUS TRANSMITTER

The EUSART transmitter block diagram is shown in Figure 20-3. The heart of the transmitter is the Transmit (Serial) Shift Register (TSR). The Shift register obtains its data from the Read/Write Transmit Buffer register, TXREG. The TXREG register is loaded with data in software. The TSR register is not loaded until the Stop bit has been transmitted from the previous load. As soon as the Stop bit is transmitted, the TSR is loaded with new data from the TXREG register (if available).

Once the TXREG register transfers the data to the TSR register (occurs in one TCY), the TXREG register is empty and the TXIF flag bit (PIR1<4>) is set. This interrupt can be enabled or disabled by setting or clearing the interrupt enable bit, TXIE (PIE1<4>). TXIF will be set regardless of the state of TXIE; it cannot be cleared in software. TXIF is also not cleared immediately upon loading TXREG, but becomes valid in the second instruction cycle following the load instruction. Polling TXIF immediately following a load of TXREG will return invalid results.

While TXIF indicates the status of the TXREG register, another bit, TRMT (TXSTA<1>), shows the status of the TSR register. TRMT is a read-only bit which is set when the TSR register is empty. No interrupt logic is tied to this bit so the user has to poll this bit in order to determine if the TSR register is empty.

The TXCKP bit (BAUDCON<4>) allows the TX signal to be inverted (polarity reversed). Devices that buffer signals from TTL to RS-232 levels also invert the signal (when TTL = 1, RS-232 = negative). Inverting the polarity of the TX pin data by setting the TXCKP bit allows for use of circuits that provide buffering without inverting the signal.

Note 1:	The TSR register is not mapped in data memory so it is not available to the user.
2:	Flag bit, TXIF, is set when enable bit, TXEN, is set.

To set up an Asynchronous Transmission:

1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Enable the asynchronous serial port by clearing bit, SYNC, and setting bit, SPEN.
3. If the signal from the TX pin is to be inverted, set the TXCKP bit.
4. If interrupts are desired, set enable bit, TXIE.
5. If 9-bit transmission is desired, set transmit bit, TX9. Can be used as address/data bit.
6. Enable the transmission by setting bit, TXEN, which will also set bit, TXIF.
7. If 9-bit transmission is selected, the ninth bit should be loaded in bit, TX9D.
8. Load data to the TXREG register (starts transmission).
9. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

20.2.2 EUSART ASYNCHRONOUS RECEIVER

The receiver block diagram is shown in Figure 20-6. The data is received on the RX pin and drives the data recovery block. The data recovery block is actually a high-speed shifter operating at x16 times the baud rate, whereas the main receive serial shifter operates at the bit rate or at FOSC. This mode would typically be used in RS-232 systems.

The RXDTP bit (BAUDCON<5>) allows the RX signal to be inverted (polarity reversed). Devices that buffer signals from RS-232 to TTL levels also perform an inversion of the signal (when RS-232 = positive, TTL = 0). Inverting the polarity of the RX pin data by setting the RXDTP bit allows for the use of circuits that provide buffering without inverting the signal.

To set up an Asynchronous Reception:

1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Enable the asynchronous serial port by clearing bit, SYNC, and setting bit, SPEN.
3. If the signal at the RX pin is to be inverted, set the RXDTP bit.
4. If interrupts are desired, set enable bit, RCIE.
5. If 9-bit reception is desired, set bit, RX9.
6. Enable the reception by setting bit, CREN.
7. Flag bit, RCIF, will be set when reception is complete and an interrupt will be generated if enable bit, RCIE, was set.
8. Read the RCSTA register to get the 9th bit (if enabled) and determine if any error occurred during reception.
9. Read the 8-bit received data by reading the RCREG register.
10. If any error occurred, clear the error by clearing enable bit, CREN.
11. If using interrupts, ensure that the GIE and PEIE bits in the INTCON register (INTCON<7:6>) are set.

20.2.3 SETTING UP 9-BIT MODE WITH ADDRESS DETECT

This mode would typically be used in RS-485 systems. To set up an Asynchronous Reception with Address Detect Enable:

1. Initialize the SPBRGH:SPBRG registers for the appropriate baud rate. Set or clear the BRGH and BRG16 bits, as required, to achieve the desired baud rate.
2. Enable the asynchronous serial port by clearing the SYNC bit and setting the SPEN bit.
3. If the signal at the RX pin is to be inverted, set the RXDTP bit. If the signal from the TX pin is to be inverted, set the TXCKP bit.
4. If interrupts are required, set the RCEN bit and select the desired priority level with the RCIP bit.
5. Set the RX9 bit to enable 9-bit reception.
6. Set the ADDEN bit to enable address detect.
7. Enable reception by setting the CREN bit.
8. The RCIF bit will be set when reception is complete. The interrupt will be Acknowledged if the RCIE and GIE bits are set.
9. Read the RCSTA register to determine if any error occurred during reception, as well as read bit 9 of data (if applicable).
10. Read RCREG to determine if the device is being addressed.
11. If any error occurred, clear the CREN bit.
12. If the device has been addressed, clear the ADDEN bit to allow all received data into the receive buffer and interrupt the CPU.

RETURN **Return from Subroutine**

Syntax: RETURN {s}

Operands: s ∈ [0,1]

Operation: (TOS) → PC;
if s = 1,
(WS) → W,
(STATUSS) → STATUS,
(BSRS) → BSR,
PCLATU, PCLATH are unchanged

Status Affected: None

Encoding:

0000	0000	0001	001s

Description: Return from subroutine. The stack is popped and the top of the stack (TOS) is loaded into the program counter. If 's'= 1, the contents of the shadow registers WS, STATUSS and BSRS are loaded into their corresponding registers, W, STATUS and BSR. If 's' = 0, no update of these registers occurs (default).

Words: 1

Cycles: 2

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	No operation	Process Data	Pop PC from stack
No operation	No operation	No operation	No operation

Example: RETURN

After Instruction:
PC = TOS

RLCF **Rotate Left f through Carry**

Syntax: RLCF f {,d {,a}}

Operands: 0 ≤ f ≤ 255
d ∈ [0,1]
a ∈ [0,1]

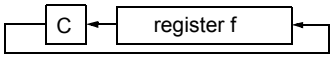
Operation: (f<n>) → dest<n + 1>,
(f<7>) → C,
(C) → dest<0>

Status Affected: C, N, Z

Encoding:

0011	01da	ffff	ffff

Description: The contents of register 'f' are rotated one bit to the left through the Carry flag. If 'd' is '0', the result is placed in W. If 'd' is '1', the result is stored back in register 'f' (default).
If 'a' is '0', the Access Bank is selected. If 'a' is '1', the BSR is used to select the GPR bank (default).
If 'a' is '0' and the extended instruction set is enabled, this instruction operates in Indexed Literal Offset Addressing mode whenever f ≤ 95 (5Fh). See **Section 26.2.3 "Byte-Oriented and Bit-Oriented Instructions in Indexed Literal Offset Mode"** for details.



Words: 1

Cycles: 1

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read register 'f'	Process Data	Write to destination

Example: RLCF REG, 0, 0

Before Instruction
REG = 1110 0110
C = 0
After Instruction
REG = 1110 0110
W = 1100 1100
C = 1

CALLW **Subroutine Call Using WREG**

Syntax: CALLW

Operands: None

Operation: (PC + 2) → TOS,
(W) → PCL,
(PCLATH) → PCH,
(PCLATU) → PCU

Status Affected: None

Encoding:

0000	0000	0001	0100

Description: First, the return address (PC + 2) is pushed onto the return stack. Next, the contents of W are written to PCL; the existing value is discarded. Then the contents of PCLATH and PCLATU are latched into PCH and PCU, respectively. The second cycle is executed as a NOP instruction while the new next instruction is fetched. Unlike CALL, there is no option to update W, STATUS or BSR.

Words: 1

Cycles: 2

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Read WREG	Push PC to stack	No operation
No operation	No operation	No operation	No operation

Example: HERE CALLW

Before Instruction
PC = address (HERE)
PCLATH = 10h
PCLATU = 00h
W = 06h
After Instruction
PC = 001006h
TOS = address (HERE + 2)
PCLATH = 10h
PCLATU = 00h
W = 06h

MOVSF **Move Indexed to f**

Syntax: MOVSF [z_s], f_d

Operands: $0 \le z_s \le 127$
$0 \le f_d \le 4095$

Operation: ((FSR2) + z_s) → f_d

Status Affected: None

Encoding:

1st word (source)	1110	1011	0zzz	$zzzz_s$
2nd word (destin.)	1111	ffff	ffff	$ffff_d$

Description: The contents of the source register are moved to destination register 'f_d'. The actual address of the source register is determined by adding the 7-bit literal offset 'z_s' in the first word to the value of FSR2. The address of the destination register is specified by the 12-bit literal 'f_d' in the second word. Both addresses can be anywhere in the 4096-byte data space (000h to FFFh).
The MOVSF instruction cannot use the PCL, TOSU, TOSH or TOSL as the destination register.
If the resultant source address points to an indirect addressing register, the value returned will be 00h.

Words: 2

Cycles: 2

Q Cycle Activity:

Q1	Q2	Q3	Q4
Decode	Determine source addr	Determine source addr	Read source reg
Decode	No operation No dummy read	No operation	Write register 'f' (dest)

Example: MOVSF [05h], REG2

Before Instruction
FSR2 = 80h
Contents of 85h = 33h
REG2 = 11h
After Instruction
FSR2 = 80h
Contents of 85h = 33h
REG2 = 33h

26.2.3 BYTE-ORIENTED AND BIT-ORIENTED INSTRUCTIONS IN INDEXED LITERAL OFFSET MODE

Note:	Enabling the PIC18 instruction set extension may cause legacy applications to behave erratically or fail entirely.

In addition to eight new commands in the extended set, enabling the extended instruction set also enables Indexed Literal Offset Addressing mode (**Section 5.6.1 "Indexed Addressing with Literal Offset"**). This has a significant impact on the way that many commands of the standard PIC18 instruction set are interpreted.

When the extended set is disabled, addresses embedded in opcodes are treated as literal memory locations: either as a location in the Access Bank ('a' = 0) or in a GPR bank designated by the BSR ('a' = 1). When the extended instruction set is enabled and 'a' = 0, however, a file register argument of 5Fh or less is interpreted as an offset from the pointer value in FSR2 and not as a literal address. For practical purposes, this means that all instructions that use the Access RAM bit as an argument – that is, all byte-oriented and bit-oriented instructions, or almost half of the core PIC18 instructions – may behave differently when the extended instruction set is enabled.

When the content of FSR2 is 00h, the boundaries of the Access RAM are essentially remapped to their original values. This may be useful in creating backward compatible code. If this technique is used, it may be necessary to save the value of FSR2 and restore it when moving back and forth between C and assembly routines in order to preserve the Stack Pointer. Users must also keep in mind the syntax requirements of the extended instruction set (see **Section 26.2.3.1 "Extended Instruction Syntax with Standard PIC18 Commands"**).

Although the Indexed Literal Offset Addressing mode can be very useful for dynamic stack and pointer manipulation, it can also be very annoying if a simple arithmetic operation is carried out on the wrong register. Users who are accustomed to the PIC18 programming must keep in mind that, when the extended instruction set is enabled, register addresses of 5Fh or less are used for Indexed Literal Offset Addressing.

Representative examples of typical byte-oriented and bit-oriented instructions in the Indexed Literal Offset Addressing mode are provided on the following page to show how execution is affected. The operand conditions shown in the examples are applicable to all instructions of these types.

26.2.3.1 Extended Instruction Syntax with Standard PIC18 Commands

When the extended instruction set is enabled, the file register argument, 'f', in the standard byte-oriented and bit-oriented commands is replaced with the literal offset value, 'k'. As already noted, this occurs only when 'f' is less than or equal to 5Fh. When an offset value is used, it must be indicated by square brackets ("[ ]"). As with the extended instructions, the use of brackets indicates to the compiler that the value is to be interpreted as an index or an offset. Omitting the brackets, or using a value greater than 5Fh within brackets, will generate an error in the MPASM Assembler.

If the index argument is properly bracketed for Indexed Literal Offset Addressing mode, the Access RAM argument is never specified; it will automatically be assumed to be '0'. This is in contrast to standard operation (extended instruction set disabled) when 'a' is set on the basis of the target address. Declaring the Access RAM bit in this mode will also generate an error in the MPASM Assembler.

The destination argument, 'd', functions as before.

In the latest versions of the MPASM assembler, language support for the extended instruction set must be explicitly invoked. This is done with either the command line option, /y, or the PE directive in the source listing.

26.2.4 CONSIDERATIONS WHEN ENABLING THE EXTENDED INSTRUCTION SET

It is important to note that the extensions to the instruction set may not be beneficial to all users. In particular, users who are not writing code that uses a software stack may not benefit from using the extensions to the instruction set.

Additionally, the Indexed Literal Offset Addressing mode may create issues with legacy applications written to the PIC18 assembler. This is because instructions in the legacy code may attempt to address registers in the Access Bank below 5Fh. Since these addresses are interpreted as literal offsets to FSR2 when the instruction set extension is enabled, the application may read or write to the wrong data addresses.

When porting an application to the PIC18F2455/2550/4455/4550, it is very important to consider the type of code. A large, re-entrant application that is written in 'C' and would benefit from efficient compilation will do well when using the instruction set extensions. Legacy applications that heavily use the Access Bank will most likely not benefit from using the extended instruction set.

26.2.5 SPECIAL CONSIDERATIONS WITH MICROCHIP MPLAB® IDE TOOLS

The latest versions of Microchip's software tools have been designed to fully support the extended instruction set of the PIC18F2455/2550/4455/4550 family of devices. This includes the MPLAB C18 C compiler, MPASM Assembly language and MPLAB Integrated Development Environment (IDE).

When selecting a target device for software development, MPLAB IDE will automatically set default Configuration bits for that device. The default setting for the XINST Configuration bit is '0', disabling the extended instruction set and Indexed Literal Offset Addressing mode. For proper execution of applications developed to take advantage of the extended instruction set, XINST must be set during programming.

To develop software for the extended instruction set, the user must enable support for the instructions and the Indexed Addressing mode in their language tool(s). Depending on the environment being used, this may be done in several ways:

- A menu option, or dialog box within the environment, that allows the user to configure the language tool and its settings for the project
- A command line option
- A directive in the source code

These options vary between different compilers, assemblers and development environments. Users are encouraged to review the documentation accompanying their development systems for the appropriate information.

28.2 DC Characteristics: Power-Down and Supply Current PIC18F2455/2550/4455/4550 (Industrial) PIC18LF2455/2550/4455/4550 (Industrial) (Continued)

PIC18LF2455/2550/4455/4550 (Industrial)	Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial
PIC18F2455/2550/4455/4550 (Industrial)	**Standard Operating Conditions (unless otherwise stated)** Operating temperature -40°C ≤ TA ≤ +85°C for industrial

Param No.	Symbol	Device	Typ	Max	Units	Conditions		
		Supply Current (IDD)(2)						
		PIC18LFX455/X550	250	500	µA	-40°C	VDD = 2.0V	FOSC = 1 MHz (**PRI_RUN**, EC oscillator)
			250	500	µA	+25°C		
			250	500	µA	+85°C		
		PIC18LFX455/X550	550	650	µA	-40°C	VDD = 3.0V	
			480	650	µA	+25°C		
			460	650	µA	+85°C		
		All devices	1.2	1.6	mA	-40°C	VDD = 5.0V	
			1.1	1.5	mA	+25°C		
			1.0	1.4	mA	+85°C		
		PIC18LFX455/X550	0.74	2.0	mA	-40°C	VDD = 2.0V	FOSC = 4 MHz (**PRI_RUN**, EC oscillator)
			0.74	2.0	mA	+25°C		
			0.74	2.0	mA	+85°C		
		PIC18LFX455/X550	1.3	3.0	mA	-40°C	VDD = 3.0V	
			1.3	3.0	mA	+25°C		
			1.3	3.0	mA	+85°C		
		All devices	2.7	6.0	mA	-40°C	VDD = 5.0V	
			2.6	6.0	mA	+25°C		
			2.5	6.0	mA	+85°C		
		All devices	15	35	mA	-40°C	VDD = 4.2V	FOSC = 40 MHz (**PRI_RUN**, EC oscillator)
			16	35	mA	+25°C		
			16	35	mA	+85°C		
		All devices	21	40	mA	-40°C	VDD = 5.0V	
			21	40	mA	+25°C		
			21	40	mA	+85°C		
		All devices	20	40	mA	-40°C	VDD = 4.2V	FOSC = 48 MHz (**PRI_RUN**, EC oscillator)
			20	40	mA	+25°C		
			20	40	mA	+85°C		
		All devices	25	50	mA	-40°C	VDD = 5.0V	
			25	50	mA	+25°C		
			25	50	mA	+85°C		

Legend: Shading of rows is to assist in readability of the table.

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

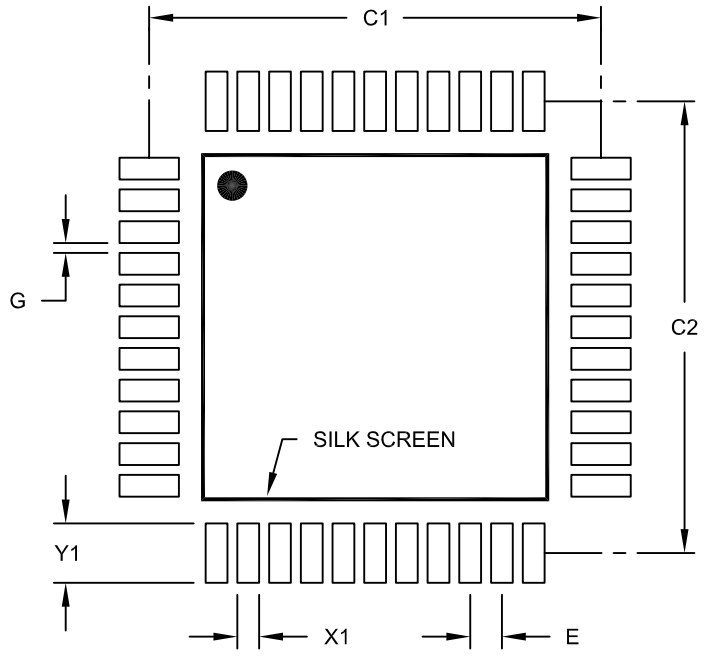
2: The supply current is mainly a function of operating voltage, frequency and mode. Other factors, such as I/O pin loading and switching rate, oscillator type and circuit, internal code execution pattern and temperature, also have an impact on the current consumption.
The test conditions for all IDD measurements in active operation mode are:
OSC1 = external square wave, from rail-to-rail; all I/O pins tri-stated, pulled to VDD or VSS;
$\overline{MCLR}$ = VDD; WDT enabled/disabled as specified.

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

4: BOR and HLVD enable internal band gap reference. With both modules enabled, current consumption will be less than the sum of both specifications.

44-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		0.80 BSC	
Contact Pad Spacing	C1		11.40	
Contact Pad Spacing	C2		11.40	
Contact Pad Width (X44)	X1			0.55
Contact Pad Length (X44)	Y1			1.50
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. C04-2076A