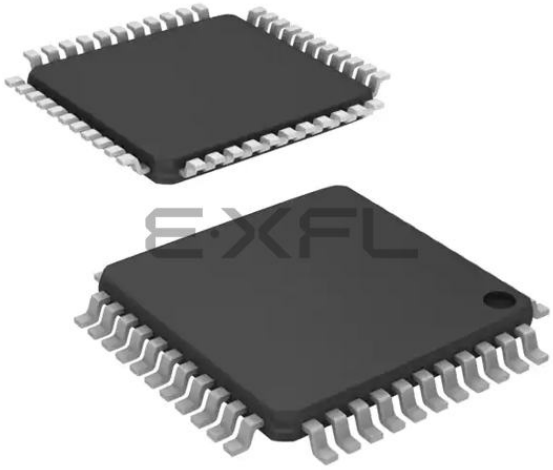

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"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable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

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	PIC
Core Size	8-Bit
Speed	32MHz
Connectivity	I²C, LINbus, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, POR, PWM, WDT
Number of I/O	36
Program Memory Size	14KB (8K x 14)
Program Memory Type	FLASH
EEPROM Size	128 x 8
RAM Size	1K x 8
Voltage - Supply (Vcc/Vdd)	2.3V ~ 5.5V
Data Converters	A/D 28x10b; D/A 4x5b, 4x10b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	44-TQFP
Supplier Device Package	44-TQFP (10x10)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic16f1777t-i-pt

TABLE 1-3: PIC16(L)F1777/9 PINOUT DESCRIPTION

Name	Function	Input Type	Output Type	Description
RA0/AN0/C1IN0-/C2IN0-/ C3IN0-/C4IN0-/C5IN0-/ C6IN0-/C7IN0-/C8IN0-/CLCIN0	RA0	TTL/ST	CMOS	General purpose I/O.
	AN0	AN	—	ADC Channel 0 input.
	C1IN0-	AN	—	Comparator 1 negative input.
	C2IN0-	AN	—	Comparator 2 negative input.
	C3IN0-	AN	—	Comparator 3 negative input.
	C4IN0-	AN	—	Comparator 4 negative input.
	C5IN0-	AN	—	Comparator 5 negative input.
	C6IN0-	AN	—	Comparator 6 negative input.
	C7IN0-	AN	—	Comparator 7 negative input.
	C8IN0-	AN	—	Comparator 8 negative input.
	CLCIN0(1)	TTL/ST	—	CLC input 0.
RA1/AN1/C1IN1-/C2IN1-/ C3IN1-/C4IN1-/PRG1IN0/ PRG2IN1/OPA1OUT/OPA2IN1+/ OPA2IN1-/CLCIN1	RA1	TTL/ST	CMOS	General purpose I/O.
	AN1	AN	—	Channel 1 input.
	C1IN1-	AN	—	Comparator 1 negative input.
	C2IN1-	AN	—	Comparator 2 negative input.
	C3IN1-	AN	—	Comparator 3 negative input.
	C4IN1-	AN	—	Comparator 4 negative input.
	PRG1IN0	AN	—	Ramp generator 1 reference voltage input.
	PRG2IN1	AN	—	Ramp generator 2 reference voltage input.
	OPA1OUT	—	AN	Operational amplifier 1 output.
	OPA2IN1+	AN	—	Operational amplifier 2 non-inverting input.
	OPA2IN1-	AN	—	Operational amplifier 2 inverting input.
	CLCIN1(1)	TTL/ST	—	CLC input 0.

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 I^2C = Schmitt Trigger input with I^2C
HP = High Power XTAL = Crystal levels

Note 1: Default peripheral input. Alternate pins can be selected as the peripheral input with the PPS input selection registers.

2: All pin digital outputs default to PORT latch data. Alternate outputs can be selected as the peripheral digital output with the PPS output selection registers.

3: These peripheral functions are bidirectional. The output pin selections must be the same as the input pin selections.

TABLE 1-3: PIC16(L)F1777/9 PINOUT DESCRIPTION (CONTINUED)

Name	Function	Input Type	Output Type	Description
RB2/AN8/OPA2IN0-/ DAC3OUT1/PRG4F/COG3IN/ MD4MOD	RB2	TTL/ST	CMOS	General purpose I/O.
	AN8	AN	—	ADC Channel 8 input.
	OPA2IN0-	AN	—	Operational amplifier 2 inverting input.
	DAC3OUT1	—	AN	DAC3 voltage output.
	PRG4F(1)	TTL/ST	—	Ramp generator set_falling input.
	COG3IN(1)	TTL/ST	—	Complementary output generator 3 input.
	MD4MOD(1)	TTL/ST	—	Data signal modulator modulation input.
RB3/AN9/C1IN2-/C2IN2-/ C3IN2-/OPA2IN0+/MD3CL	RB3	TTL/ST	CMOS	General purpose I/O.
	AN9	AN	—	ADC Channel 9 input.
	C1IN2-	AN	—	Comparator 1 negative input.
	C2IN2-	AN	—	Comparator 2 negative input.
	C3IN2-	AN	—	Comparator 3 negative input.
	OPA2IN0+	AN		Operational amplifier 2 non-inverting input.
	MD3CL(1)	TTL/ST	—	Data signal modulator 3 low carrier input.
RB4/AN11/C3IN1+/MD3CH	RB4	TTL/ST	CMOS	General purpose I/O.
	AN11	AN	—	ADC Channel 11 input.
	C3IN1+	AN	—	Comparator 3 positive input.
	MD3CH(1)	TTL/ST	—	Data signal modulator 3 high carrier input.
RB5/AN13/DAC5REF1-/ DAC7REF1-/C4IN2-/CCP7/ MD3MOD	RB5	TTL/ST	CMOS	General purpose I/O.
	AN13	AN	—	ADC Channel 11 input.
	DAC5REF1-	AN	—	DAC5 negative reference.
	DAC7REF1-	AN	—	DAC7 negative reference.
	C4IN2-	AN	—	Comparator 4 negative input.
	CCP7(1)	TTL/ST	—	CCP7 capture input.
	MD3MOD(1)	TTL/ST	—	Data signal modulator modulation input.
RB6/DAC5REF1+/DAC7REF1+/ C4IN1+/CLCIN2/ICSPCLK	RB6	TTL/ST	CMOS	General purpose I/O.
	DAC5REF1+	AN	—	DAC5 positive reference.
	DAC7REF1+	AN	—	DAC7 positive reference.
	C4IN1+	AN	—	Comparator 2 positive input.
	CLCIN2(1)	TTL/ST	—	CLC input 2.
	ICSPCLK	ST	—	Serial Programming 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 I^2C = Schmitt Trigger input with I^2C
HP = High Power XTAL = Crystal levels

Note 1: Default peripheral input. Alternate pins can be selected as the peripheral input with the PPS input selection registers.
2: All pin digital outputs default to PORT latch data. Alternate outputs can be selected as the peripheral digital output with the PPS output selection registers.
3: These peripheral functions are bidirectional. The output pin selections must be the same as the input pin selections.

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

Note 1: The method to access Flash memory through the PMCON registers is described in **Section 10.0 "Flash Program Memory Control"**.

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)F1777/8/9 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 Figures 3-1 and 3-2).

3.2 High-Endurance Flash

This device has a 128-byte section of high-endurance program Flash memory (PFM) in lieu of data EEPROM. This area is especially well suited for nonvolatile data storage that is expected to be updated frequently over the life of the end product. See **Section 10.2 "Flash Program Memory Overview"** for more information on writing data to PFM. See **Section 3.2.1.2 "Indirect Read with FSR"** for more information about using the FSR registers to read byte data stored in PFM.

TABLE 3-1: DEVICE SIZES AND ADDRESSES

Device	Program Memory Space (Words)	Last Program Memory Address	High-Endurance Flash Memory Address Range(1)
PIC16(L)F1777	8,192	1FFFh	1F80h-1FFFh
PIC16(L)F1778/9	16,384	3FFFh	3F80h-3FFFh

Note 1: High-endurance Flash applies to the low byte of each address in the range.

7.6 Register Definitions: Interrupt Control

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	IOCIE	TMR0IF	INTF	IOCIF(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	

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 **TMR0IE:** 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 **IOCIE:** Interrupt-on-Change Enable bit
1 = Enables the interrupt-on-change
0 = Disables the interrupt-on-change

bit 2 **TMR0IF:** 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 **IOCIF:** 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 IOCIF Flag bit is read-only and cleared when all the interrupt-on-change flags in the IOCxF registers have been cleared by software.

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.

8.2 Low-Power Sleep Mode

The PIC16F1773/6 devices contain 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 PIC16F1773/6 allow 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 Low-Power Sleep mode is intended for use with the following peripherals only:

- Brown-out Reset (BOR)
- Watchdog Timer (WDT)
- External interrupt pin/interrupt-on-change pins
- Timer1 (with external clock source < 100 kHz)

Note:	The PIC16LF1777/8/9 do not have a configurable Low-Power Sleep mode. PIC16LF1777/8/9 are unregulated devices and are always in the lowest power state when in Sleep, with no wake-up time penalty. These devices have a lower maximum V_{DD} and I/O voltage than the PIC16F1777/8/9. See **Section 36.0 "Electrical Specifications"** for more information.

10.2.2 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

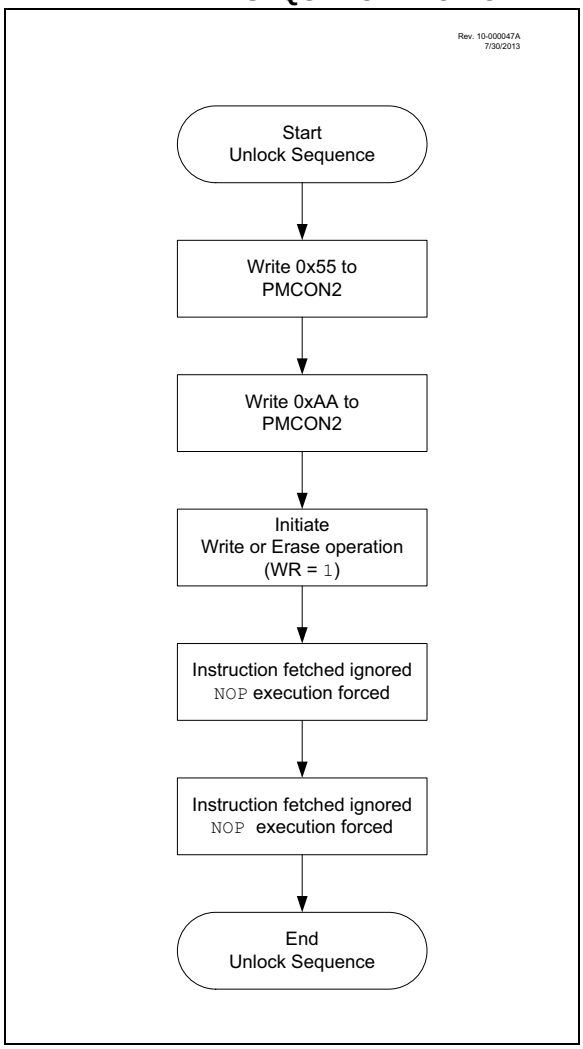
The unlock sequence consists of the following steps:

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 10-3: FLASH PROGRAM MEMORY UNLOCK SEQUENCE FLOWCHART



REGISTER 11-6: ODCONA: PORTA OPEN-DRAIN 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/W-0/0
ODA7	ODA6	ODA5	ODA4	ODA3	ODA2	ODA1	ODA0
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 **ODA<7:0>:** PORTA Open-Drain Enable bits
For RA<7:0> pins
1 = Port pin operates as open-drain drive (sink current only)
0 = Port pin operates as standard push-pull drive (source and sink current)

REGISTER 11-7: SLRCONA: PORTA SLEW RATE CONTROL 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
SLRA7	SLRA6	SLRA5	SLRA4	SLRA3	SLRA2	SLRA1	SLRA0
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 **SLRA<7:0>:** PORTA Slew Rate Enable bits
For RA<7:0> pins
1 = Port pin slew rate is limited
0 = Port pin slews at maximum rate

REGISTER 11-8: INLVLA: PORTA INPUT LEVEL 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/W-0/0
INLVLA7	INLVLA6	INLVLA5	INLVLA4	INLVLA3	INLVLA2	INLVLA1	INLVLA0
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 **INLVLA<7:0>:** PORTA Input Level Select bits
For RA<7:0> pins
1 = Port pin digital input operates with ST thresholds
0 = Port pin digital input operates with TTL thresholds

REGISTER 13-10: IOCEP: INTERRUPT-ON-CHANGE PORTE POSITIVE EDGE REGISTER

U-0	U-0	U-0	U-0	R/W-0/0	U-0	U-0	U-0
—	—	—	—	IOCEP3	—	—	—
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 **IOCEP3:** Interrupt-on-Change PORTE Positive Edge Enable bits
1 = Interrupt-on-Change enabled on the pin for a positive going edge. IOCEFx bit and IOCIF flag will be set upon detecting an edge.
0 = Interrupt-on-Change disabled for the associated pin.

bit 2-0 **Unimplemented:** Read as ‘0’

REGISTER 13-11: IOCEN: INTERRUPT-ON-CHANGE PORTE NEGATIVE EDGE REGISTER

U-0	U-0	U-0	U-0	R/W-0/0	U-0	U-0	U-0
—	—	—	—	IOCEN3	—	—	—
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 **IOCEN3:** Interrupt-on-Change PORTE Negative Edge Enable bits
1 = Interrupt-on-Change enabled on the pin for a negative going edge. IOCEFx bit and IOCIF flag will be set upon detecting an edge.
0 = Interrupt-on-Change disabled for the associated pin.

bit 2-0 **Unimplemented:** Read as ‘0’

20.7 Operation During Sleep

The ZCD current sources and interrupts are unaffected by Sleep.

20.8 Effects of a Reset

The ZCD circuit can be configured to default to the active or inactive state on Power-on-Reset (POR). When the $\overline{ZCD}$ Configuration bit is cleared, the ZCD circuit will be active at POR. When the $\overline{ZCD}$ Configuration bit is set, the ZCDEN bit of the ZCDCON register must be set to enable the ZCD module.

21.1.3 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 eight 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.

21.1.4 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.

21.1.5 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 Table 36-12: Timer0 and Timer1 External Clock Requirements.

21.1.6 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.

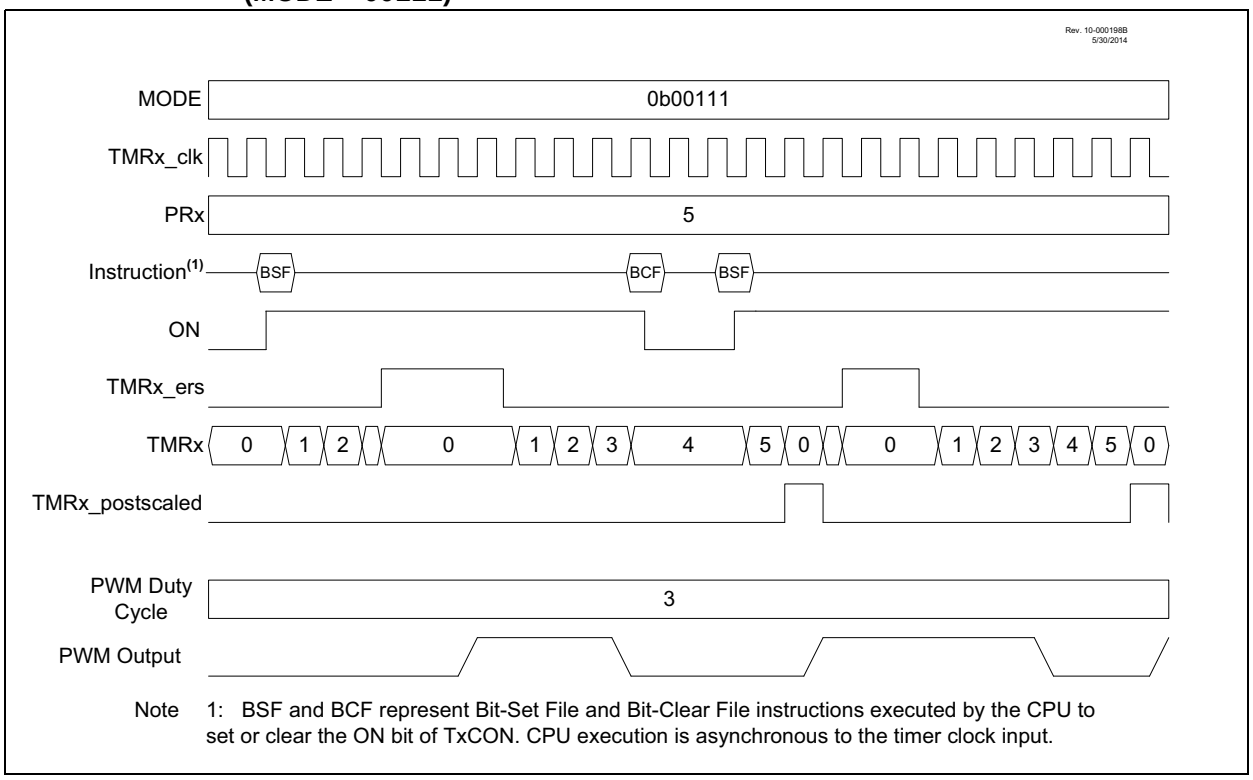
23.6.4 LEVEL-TRIGGERED HARDWARE LIMIT MODE

In the Level-Triggered Hardware Limit Timer modes the counter is reset by high or low levels of the external signal TMRx_ers, as shown in Figure 23-7. Selecting MODE<4:0> = 00110 will cause the timer to reset on a low level external signal. Selecting MODE<4:0> = 00111 will cause the timer to reset on a high level external signal. In the example, the counter is reset while TMRx_ers = 1. ON is controlled by BSF and BCF instructions. When ON = 0 the external signal is ignored.

When the CCP uses the timer as the PWM time base then the PWM output will be set high when the timer starts counting and then set low only when the timer count matches the CCPRx value. The timer is reset when either the timer count matches the PRx value or two clock periods after the external Reset signal goes true and stays true.

The timer starts counting, and the PWM output is set high, on either the clock following the PRx match or two clocks after the external Reset signal relinquishes the Reset. The PWM output will remain high until the timer counts up to match the CCPRx pulse width value. If the external Reset signal goes true while the PWM output is high then the PWM output will remain high until the Reset signal is released allowing the timer to count up to match the CCPRx value.

FIGURE 23-7: LEVEL-TRIGGERED HARDWARE LIMIT MODE TIMING DIAGRAM (MODE = 00111)



Note 1: BSF and BCF represent Bit-Set File and Bit-Clear File instructions executed by the CPU to set or clear the ON bit of TxCON. CPU execution is asynchronous to the timer clock input.

23.9 Register Definitions: Timer2/4/6/8 Control

Long bit name prefixes for the Timer2/4/6/8 peripherals are shown in Table 23-2. Refer to **Section 1.1.2.2 "Long Bit Names"** for more information

TABLE 23-2:

Peripheral	Bit Name Prefix
Timer2	T2
Timer4	T4
Timer6	T6
Timer8	T8

REGISTER 23-1: TxCLKCON: TIMERx CLOCK SELECTION REGISTER

U-0	U-0	U-0	U-0	R/W-0/0	R/W-0/0	R/W-0/0	R/W-0/0
—	—	—	—	CS<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	

bit 7-4 **Unimplemented:** Read as '0'

bit 3-0 **CS<3:0>:** Timerx Clock Selection bits
See Table 23-3.

TABLE 23-3: TIMERx CLOCK SOURCES

CS<3:0>	Timer2	Timer4	Timer6	Timer8
1100-1111	Reserved	Reserved	Reserved	Reserved
1011	LC4_out	LC4_out	LC4_out	LC4_out
1010	LC3_out	LC3_out	LC3_out	LC3_out
1001	LC2_out	LC2_out	LC2_out	LC2_out
1000	LC1_out	LC1_out	LC1_out	LC1_out
0111	ZCD_out	ZCD_out	ZCD_out	ZCD_out
0110	SOSC	SOSC	SOSC	SOSC
0101	MFINTOSC	MFINTOSC	MFINTOSC	MFINTOSC
0100	LFINTOSC	LFINTOSC	LFINTOSC	LFINTOSC
0011	HFINTOSC	HFINTOSC	HFINTOSC	HFINTOSC
0010	Fosc	Fosc	Fosc	Fosc
0001	Fosc/4	Fosc/4	Fosc/4	Fosc/4
0000	Pin selected by T2INPPS	Pin selected by T4INPPS	Pin selected by T6INPPS	Pin selected by T8INPPS

REGISTER 28-9: CLCxGLS2: GATE 3 LOGIC SELECT 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
G3D4T	G3D4N	G3D3T	G3D3N	G3D2T	G3D2N	G3D1T	G3D1N
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 **G3D4T:** Gate 3 Data 4 True (non-inverted) bit
1 = d4T is gated into g3
0 = d4T is not gated into g3

bit 6 **G3D4N:** Gate 3 Data 4 Negated (inverted) bit
1 = d4N is gated into g3
0 = d4N is not gated into g3

bit 5 **G3D3T:** Gate 3 Data 3 True (non-inverted) bit
1 = d3T is gated into g3
0 = d3T is not gated into g3

bit 4 **G3D3N:** Gate 3 Data 3 Negated (inverted) bit
1 = d3N is gated into g3
0 = d3N is not gated into g3

bit 3 **G3D2T:** Gate 3 Data 2 True (non-inverted) bit
1 = d2T is gated into g3
0 = d2T is not gated into g3

bit 2 **G3D2N:** Gate 3 Data 2 Negated (inverted) bit
1 = d2N is gated into g3
0 = d2N is not gated into g3

bit 1 **G3D1T:** Gate 3 Data 1 True (non-inverted) bit
1 = d1T is gated into g3
0 = d1T is not gated into g3

bit 0 **G3D1N:** Gate 3 Data 1 Negated (inverted) bit
1 = d1N is gated into g3
0 = d1N is not gated into g3

29.0 OPERATIONAL AMPLIFIER (OPA) MODULES

The Operational Amplifier (OPA) is a standard three-terminal device requiring external feedback to operate. The OPA module has the following features:

- External connections to I/O ports
- Low leakage inputs
- Factory Calibrated Input Offset Voltage
- Unity gain control
- Programmable positive and negative source selections
- Override controls
  - Forced tri-state output
  - Forced unity gain

TABLE 29-1: AVAILABLE OP AMP MODULES

Device	OPA1	OP2	OPA3	OPA4
PIC16(L)F1778	•	•	•	
PIC16(L)F1777/9	•	•	•	•

FIGURE 29-1: OPAx MODULE BLOCK DIAGRAM

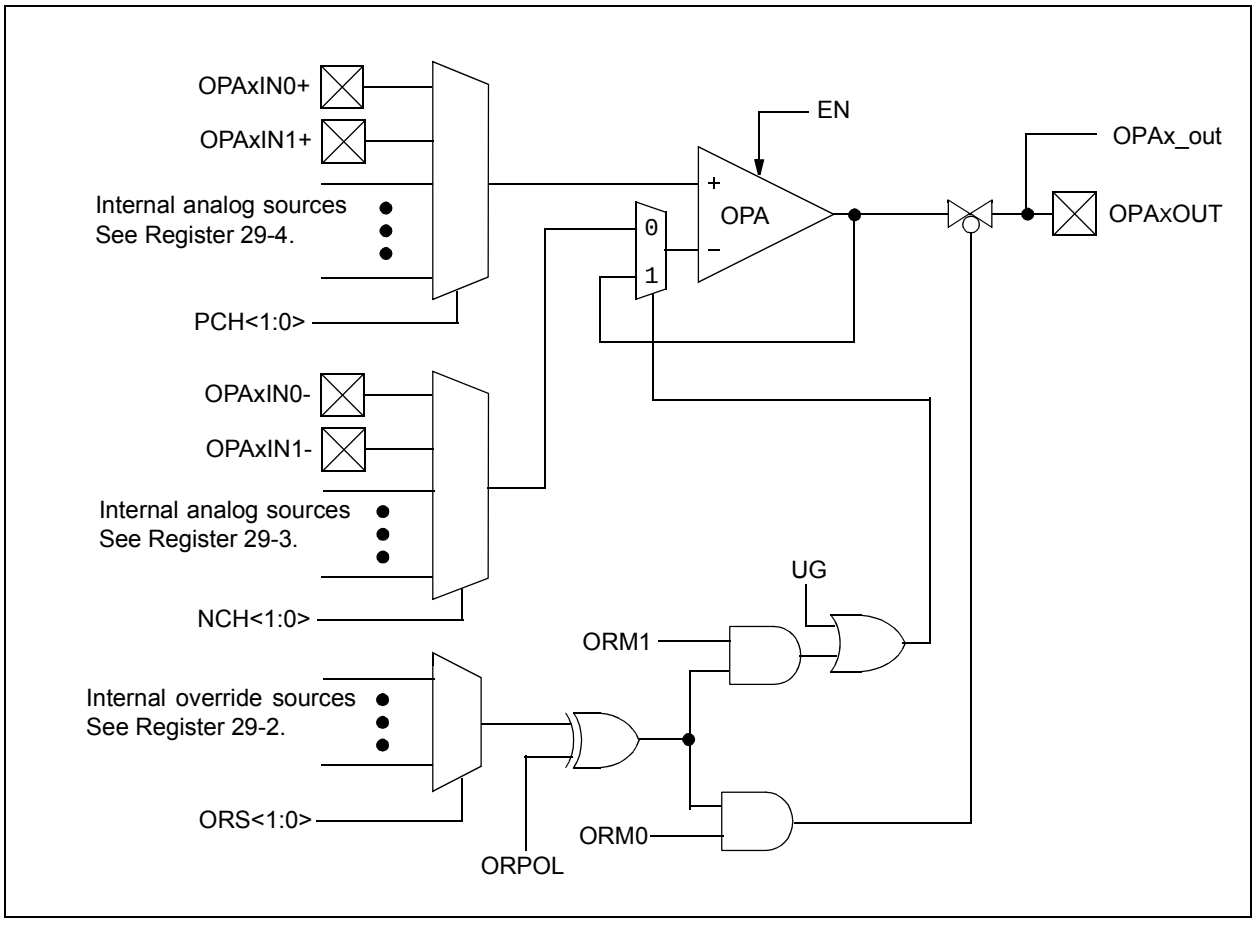


TABLE 30-6: SUMMARY OF REGISTERS ASSOCIATED WITH THE PRG MODULE(1)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Register on Page
PRGxCON0	EN	—	FEDG	REDG	MODE<1:0>		OS	GO	421
PRGxCON1	—	—	—	—	—	RDY	FPOL	RPOL	422
PRGxCON2	—	—	—	ISET<4:0>					423
PRGxINS	—	—	—	—	INS<3:0>				422
PRGxRPPS	—	—	PRGxRPPS<5:0>						424
PRGxFPPS	—	—	PRGxFPPS<5:0>						424
PRGxRTSS	—	—	—	—	RTSS<3:0>				205, 207
PRGxFTSS	—	—	—	—	FTSS<3:0>				205, 207
PORTC	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	186
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	186
ANSELC	ANSC7	ANSC6	ANSC5	ANSC4	ANSC3	ANSC2	—	—	187
WPUC	WPUC7	WPUC6	WPUC5	WPUC4	WPUC3	WPUC2	WPUC1	WPUC0	188

Legend: — = unimplemented, read as '0'. Shaded cells are unused by the PRG module.

Note 1: PRG4 available on PIC16(L)F1777/9 only.

32.5.4 SLAVE MODE 10-BIT ADDRESS RECEPTION

This section describes a standard sequence of events for the MSSP module configured as an I^2C slave in 10-bit Addressing mode.

Figure 32-20 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 I^2C 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 R/$\overline{W}$ 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 SCL.
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 $\overline{ACK}$ 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 $\overline{ACK}$ on the ninth SCL 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 SCL.
18. Steps 13-17 repeat for each received byte.
19. Master sends Stop to end the transmission.

32.5.5 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 SCL line is held low are the same. Figure 32-21 can be used as a reference of a slave in 10-bit addressing with AHEN set.

Figure 32-22 shows a standard waveform for a slave transmitter in 10-bit Addressing mode.

33.4.4 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 33-9 for the timing of the Break character sequence.

33.4.4.1 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 TXIF, the next data byte can be written to TXxREG.

33.4.5 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.

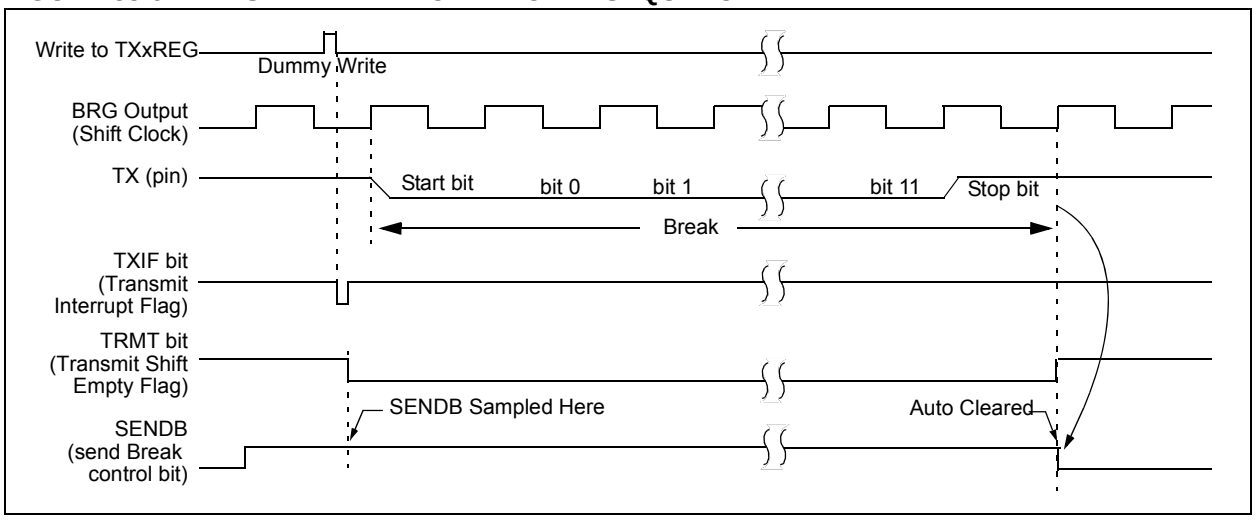
A Break character has been received when:

- RCIF bit is set
- FERR bit is set
- RCxREG = 00h

The second method uses the Auto-Wake-up feature described in **Section 33.4.3 "Auto-Wake-up on Break"**. By enabling this feature, the EUSART will sample the next two transitions on RX/DT, cause an RCIF interrupt, and receive the next data byte followed by another interrupt.

Note that following a Break character, the user will typically want to enable the Auto-Baud Detect feature. For both methods, the user can set the ABDEN bit of the BAUDxCON register before placing the EUSART in Sleep mode.

FIGURE 33-9: SEND BREAK CHARACTER SEQUENCE



35.2 Instruction Descriptions

ADDFSR — Add Literal to FSRn

Syntax:	[*label*] 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.

ADDLW — Add literal and W

Syntax:	[*label*] 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 8-bit literal 'k' and the result is placed in the W register.

ADDWF — Add W and f

Syntax:	[*label*] 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'.

ADDWFC — ADD W and CARRY bit to f

Syntax:	[*label*] 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'.

ANDLW — AND literal with W

Syntax:	[*label*] 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 8-bit literal 'k'. The result is placed in the W register.

ANDWF — AND W with f

Syntax:	[*label*] 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'.

ASRF — Arithmetic Right Shift

Syntax:	[*label*] 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'.

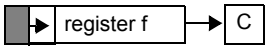


TABLE 36-17: OPERATIONAL AMPLIFIER (OPA)

Operating Conditions (unless otherwise stated) VDD = 3.0V, TA = 25°C, OPAxSP = 1 (High GBWP mode)							
Param No.	**Symbol**	**Parameters**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
OPA01*	GBWP	Gain Bandwidth Product	—	3.5	—	MHz	
OPA02*	TON	Turn-on Time	—	10	—	µs	
OPA03*	PM	Phase Margin	—	40	—	degrees	
OPA04*	SR	Slew Rate	—	3	—	V/µs	
OPA05	OFF	Offset	—	±3	±9	mV	
OPA06	CMRR	Common-Mode Rejection Ratio	52	70	—	dB	
OPA07*	AOL	Open Loop Gain	—	90	—	dB	
OPA08	VICM	Input Common-Mode Voltage	0	—	VDD	V	VDD > 2.5V
OPA09*	PSRR	Power Supply Rejection Ratio	—	80	—	dB	
OPA10*	HZ	High-Impedance On/Off Time	—	50	—	ns	

* These parameters are characterized but not tested.

TABLE 36-18: PROGRAMMABLE RAMP GENERATOR (PRG) SPECIFICATIONS

Operating Conditions (unless otherwise stated) VDD = 3.0V, TA = 25°C (unless otherwise stated)							
Param No.	**Sym.**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Comments**
PRG01	RRR	Rising Ramp Rate(1)	—	1	—	V/µs	PRGxCON2 = 10h
PRG02	FRR	Falling Ramp Rate(1)	—	1	—	V/µs	PRGxCON2 = 10h

* These parameters are characterized but not tested.

Note 1: Response time measured with one comparator input at VDD/2, while the other input transitions from VSS to VDD.

TABLE 36-19: COMPARATOR SPECIFICATIONS

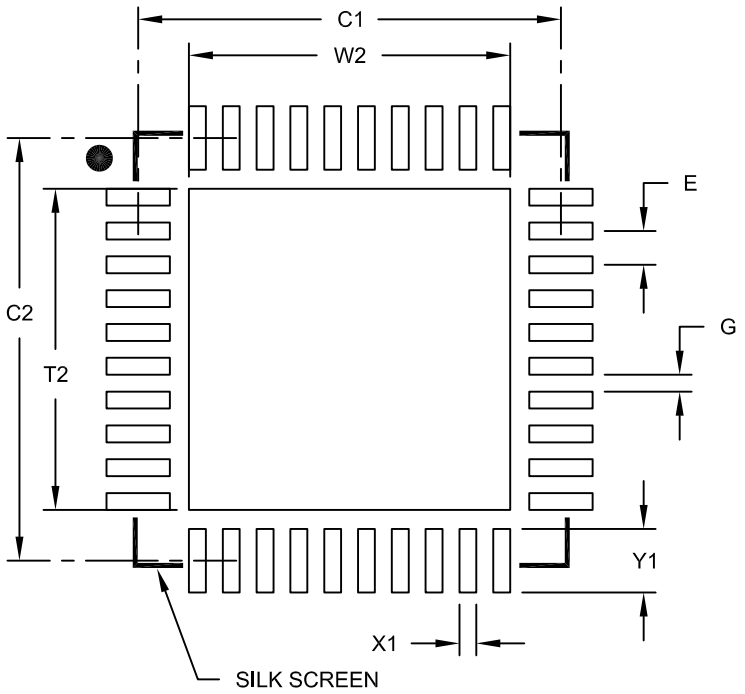
Operating Conditions (unless otherwise stated) VDD = 3.0V, TA = 25°C See **Section 31.0 "DC and AC Characteristics Graphs and Charts"** for operating characterization.							
Param No.	**Sym.**	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Comments**
CM01	VIOFF	Input Offset Voltage	—	±2.5	±5	mV	VICM = VDD/2
CM02	VICM	Input Common-Mode Voltage	0	—	VDD	V	
CM03	CMRR	Common-Mode Rejection Ratio	40	50	—	dB	
CM04A	Tresp(1)	Response Time Rising Edge	—	60	125	ns	CxSP = 1
CM04B		Response Time Falling Edge	—	60	110	ns	CxSP = 1
CM04C		Response Time Rising Edge	—	85	—	ns	CxSP = 0
CM04D		Response Time Falling Edge	—	85	—	ns	CxSP = 0
CM05	TMC2OV	Comparator Mode Change to Output Valid*	—	—	10	µs	
CM06	CHYSTER	Comparator Hysteresis	20	45	75	mV	CxHYS = 1

* These parameters are characterized but not tested.

Note 1: Response time measured with one comparator input at VDD/2, while the other input transitions from VSS to VDD.

40-Lead Plastic Ultra Thin Quad Flat, No Lead Package (MV) - 5x5 mm Body [UQFN]

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		0.40 BSC	
Optional Center Pad Width	W2			3.80
Optional Center Pad Length	T2			3.80
Contact Pad Spacing	C1		5.00	
Contact Pad Spacing	C2		5.00	
Contact Pad Width (X40)	X1			0.20
Contact Pad Length (X40)	Y1			0.75
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. C04-2156B