



Input Capture with Dedicated Timer

HIGHLIGHTS

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Note: This family reference manual section is meant to serve as a complement to device data sheets.

Please consult the note at the beginning of the “**Input Capture**” chapter in the current device data sheet to check whether this document supports the device you are using.

Device data sheets and family reference manual sections are available for download from the Microchip Worldwide Web site at: <http://www.microchip.com>.

This document supersedes the following PIC24 and dsPIC33 Family Reference Manual sections:

DS Number	Section Number	Title
DS39722A	34	Input Capture with Dedicated Timer

1.0 INTRODUCTION

This section describes the Input Capture module and its associated operational modes. The Input Capture module is used to capture a timer value from an independent timer base upon an event on the input pin. The Input Capture features are useful in applications requiring frequency (time period) and pulse measurement. [Figure 1-1](#) illustrates a simplified block diagram of the Input Capture module.

Note: Refer to the specific device data sheet for further information on the number of channels available in a particular device. All Input Capture channels are functionally identical. In this section, an ‘x’ in the register name is a generic reference to an Input Capture channel number in place of a specific Input Capture channel number.

The Input Capture module has multiple operating modes. These modes are selected through the ICxCON1 register. The operating modes of the Input Capture module include:

- Capture timer value on every falling edge of the input applied at the ICx pin
- Capture timer value on every rising edge of the input applied at the ICx pin
- Capture timer value on every 4th rising edge of the input applied at the ICx pin
- Capture timer value on every 16th rising edge of the input applied at the ICx pin
- Capture timer value on every rising and every falling edge of the input applied at the ICx pin
- Device wake-up from the capture pin during CPU Sleep and Idle modes

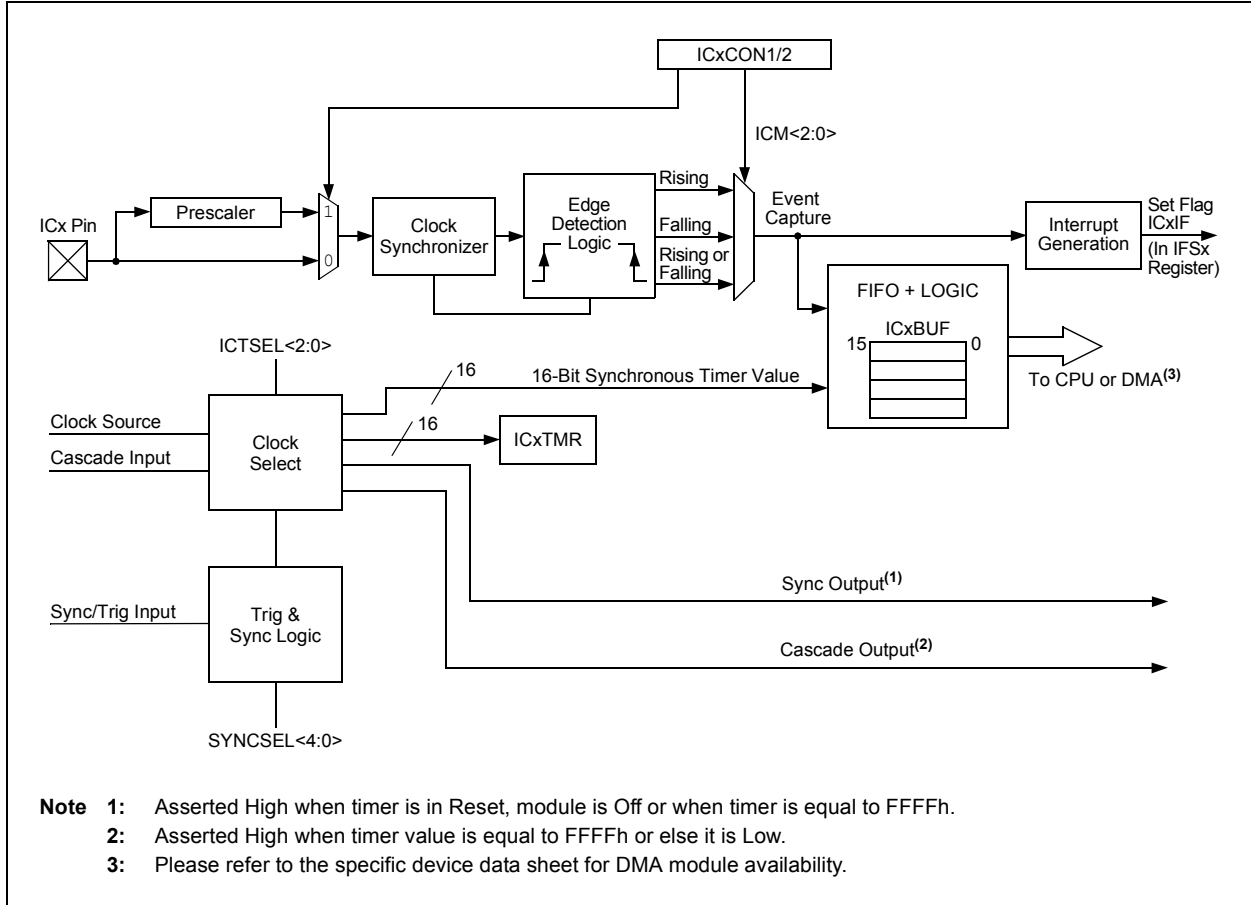
The Input Capture module contains a dedicated 16-bit, synchronous, up-counting timer used for the Input Capture function. It is the value of this timer that is written to the ICxBUF register in the 4-level FIFO buffer when a capture event occurs. In addition, the internal value may be read (with a synchronization delay) using the ICxTMR register. For more information on the ICxTMR register and its memory map details, refer to the specific device data sheet.

In Cascade mode operation, the Input Capture module can be grouped in pairs, for the purpose of cascading them to form 32-bit timers, using the cascade input and cascade output of the module. In Synchronous mode operation, the Input Capture can be synchronized with other modules using the Sync/Trig input source of the module, which is selected using the SYNCSEL<4:0> bits in the ICxCON2 register.

The Input Capture module has a four-level FIFO buffer. The number of capture events required to generate a CPU interrupt can be selected by the user-assigned application via the ICM<2:0> bits in the ICxCON1 register (ICxCON1<2:0>).

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Figure 1-1: Input Capture Block Diagram



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2.0 INPUT CAPTURE REGISTERS

Each capture module has the following registers, where 'x' denotes the number of the capture peripheral:

- ICxCON1: Input Capture x Control Register 1
- ICxCON2: Input Capture x Control Register 2
- ICxBUF: Input Capture x Buffer Register⁽¹⁾
- ICxTMR: Input Capture x Timer Register

Register 2-1: ICxCON1: Input Capture x Control Register 1

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	U-0
—	—	ICSIDL	ICTSEL2	ICTSEL1	ICTSEL0	—	—
bit 15							bit 8

U-0	R/W-0	R/W-0	R/HC/HS-0	R/HC/HS-0	R/W-0	R/W-0	R/W-0
—	ICI1 ⁽¹⁾	ICI0 ⁽¹⁾	ICOV	ICBNE	ICM2	ICM1	ICM0
bit 7							bit 0

Legend:	HC = Hardware Clearable bit	HS = Hardware Settable bit
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 15-14 **Unimplemented:** Read as '0'
- bit 13 **ICSIDL:** Input Capture Stop in Idle Control bit
 1 = Input Capture halts in CPU Idle mode
 0 = Input Capture continues to operate in CPU Idle mode
- bit 12-10 **ICTSEL<12:10>:** Input Capture Timer Select bits
 111 = Peripheral clock (FP) is the clock source for the ICx module
 110 = Reserved
 101 = Reserved
 100 = Timer1 is the clock source for the ICx module
 011 = Timer5 is the clock source for the ICx module
 010 = Timer4 is the clock source for the ICx module
 001 = Timer2 is the clock source for the ICx module
 000 = Timer3 is the clock source for the ICx module
- bit 9-7 **Unimplemented:** Read as '0'
- bit 6-5 **ICI<1:0>:** Number of Captures per Interrupt Select bits⁽¹⁾
 (this field is not used if ICM<2:0> = 001 or 111)
 11 = Interrupt on every fourth capture event
 10 = Interrupt on every third capture event
 01 = Interrupt on every second capture event
 00 = Interrupt on every capture event
- bit 4 **ICOV:** Input Capture Overflow Status Flag bit (read-only)
 1 = Input Capture buffer overflow has occurred
 0 = No Input Capture buffer overflow has occurred
- bit 3 **ICBNE:** Input Capture Buffer Not Empty Status bit (read-only)
 1 = Input Capture buffer is not empty, at least one more capture value can be read
 0 = Input Capture buffer is empty

Note 1: The ICx bits are not applicable in Sleep or Idle modes.

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Register 2-1: ICxCON1: Input Capture x Control Register 1 (Continued)

bit 2-0 **ICM<2:0>**: Input Capture Mode Select bits

111 = Input Capture functions as an interrupt pin only in CPU Sleep and Idle mode (rising edge detect only, all other control bits are not applicable)

110 = Unused (module disabled)

101 = Capture mode, every 16th rising edge (Prescaler Capture mode)

100 = Capture mode, every 4th rising edge (Prescaler Capture mode)

011 = Capture mode, every rising edge (Simple Capture mode)

010 = Capture mode, every falling edge (Simple Capture mode)

001 = Capture mode, every edge, rising and falling (Edge Detect mode (IC1<1:0>), is not used in this mode)

000 = Input Capture module is turned off

Note 1: The IC1x bits are not applicable in Sleep or Idle modes.

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Register 2-2: ICxCON2: Input Capture x Control Register 2

U-0	U-0	U-0	U-0	U-0	U-0	U-0	R/W-0
—	—	—	—	—	—	—	IC32
bit 15							bit 8

R/W-0	R/W/HS-0	U-0	R/W-0	R/W-1	R/W-1	R/W-0	R/W-1
ICTRIG ⁽²⁾	TRIGSTAT ⁽³⁾	—	SYNCSEL4 ⁽⁴⁾	SYNCSEL3 ⁽⁴⁾	SYNCSEL2 ⁽⁴⁾	SYNCSEL1 ⁽⁴⁾	SYNCSEL0 ⁽⁴⁾
bit 7							bit 0

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

- bit 15-9 **Unimplemented:** Read as '0'
- bit 8 **IC32:** Input Capture 32-Bit Timer Mode Select bit (Cascade mode)
 - 1 = ODD IC and EVEN IC form a single 32-bit Input Capture module⁽¹⁾
 - 0 = Cascade module operation is disabled
- bit 7 **ICTRIG:** Input Capture Trigger Operation Select bit⁽²⁾
 - 1 = Input source is used to trigger the Input Capture timer (Trigger mode)
 - 0 = Input source is used to synchronize the Input Capture timer to the timer of another module (Synchronization mode)
- bit 6 **TRIGSTAT:** Timer Trigger Status bit⁽³⁾
 - 1 = ICxTMR has been triggered and is running
 - 0 = ICxTMR has not been triggered and is being held clear
- bit 5 **Unimplemented:** Read as '0'
- bit 4-0 **SYNCSEL<4:0>:** Input Source Select for Synchronization and Trigger Operation bits⁽⁴⁾
See the specific device data sheet for available synchronization inputs.

- Note 1:** The IC32 bit, in both the ODD and EVEN IC, must be set to enable Cascade mode.
- Note 2:** The input source is selected by the SYNCSEL<4:0> bits of the ICxCON2 register.
- Note 3:** This bit is set by the selected input source (selected by the SYNCSEL<4:0> bits). It can be read, set and cleared in software. Refer to [Section 9.2 “Trigger Timer Operation”](#) for more information about this bit.
- Note 4:** Not all Sync options are available for all devices. Some devices might have different Sync options for the same SYNCSEL<4:0> bits. Please see the specific device data sheet for available Sync options.

Note: When Timer1 synchronizes or triggers an ICx module, the Timer1 clock source must be equal to or faster than the ICx clock source for proper ICx module operation.

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Register 2-3: ICxBUF: Input Capture x Buffer Register⁽¹⁾

R	R	R	R	R	R	R	R
ICxBUF<15:8>							
bit 15				bit 8			

R	R	R	R	R	R	R	R
ICxBUF<7:0>							
bit 7				bit 0			

Legend:

R = Readable bit

HS = Set by Hardware

'0' = Bit is cleared

-n = Value at POR

W = Writable bit

U = Unimplemented bit, read as '0'

bit 15-0 **ICxBUF<15:0>**: Input Capture 4-Level FIFO Buffer Register bits

Reading this register will read the first entry in the 4-level Input Capture buffer. If the buffer is empty (ICBNE = 0 in the ICxCON1 register), reading this register will return an unpredictable value.

Note 1: The ICxBUF register is not an actual SFR register, but rather provides memory-mapped reads of the capture buffer FIFO, from either the CPU or DMA interface, if present. Reads from the ICxBUF register always return the first FIFO entry.

3.0 INITIALIZATION

When the Input Capture module is reset or is in the Off mode (ICM<2:0> = 000), the Input Capture logic will:

- Reset the overflow condition flag to a logic '0'
- Reset the receive capture FIFO to the empty state
- Reset the prescale count

4.0 INPUT CAPTURE TIMER CLOCK SOURCE SELECTION

The dsPIC33/PIC24 family devices may have one or more Input Capture modules. Each module can select from one of six clock sources for its time base by using the ICTSEL<2:0> bits. Refer to the device data sheet for the specific timers that can be selected. The clock should be selected before enabling the module and should not be changed during operation.

The timers can be configured to use the internal clock source (FOSC/2) or use an external clock source applied to the TxCK pin with Synchronization mode enabled in the timer.

5.0 INPUT CAPTURE EVENT MODES

The Input Capture module captures the 16-bit value of the Input Capture timer value when an event occurs at the ICx pin. The capture events can be classified into three categories:

1. Simple Capture Event modes:
 - Capture timer value on every falling edge of the input at the ICx pin
 - Capture timer value on every rising edge of the input at the ICx pin
2. Capture timer value on every edge (rising and falling).
3. Prescaler Capture Event modes:
 - Capture timer value on every 4th rising edge of the input at the ICx pin
 - Capture timer value on every 16th rising edge of the input at the ICx pin

These Input Capture modes are configured by setting the appropriate Input Capture Mode Select bits (ICM<2:0>) in the ICxCON1 register (ICxCON1<2:0>).

5.1 Simple Capture Events

The Input Capture module can capture a timer value (dedicated timer) based on its edge selection (rising or falling as defined by the mode) of the input applied to the ICx pin. These modes are configured by setting the ICMx bits (ICM<2:0>) in the ICxCON1 register (ICxCON1<2:0>) to '011' or '010', respectively. In these modes, the prescaler counter is not used. See [Figure 5-1](#) and [Figure 5-2](#) for timing diagrams of a simple capture event.

The Input Capture logic detects and synchronizes the rising or falling edge of the capture pin signal with the internal instruction clock. If the rising or falling edge has occurred, the capture module logic will write the current timer value to the capture buffer and will trigger the interrupt generation logic when the number of elapsed capture events matches the number specified by the ICIX control bits (ICI<1:0>) in the ICxCON1 register (ICxCON1<6:5>). The respective Input Capture x Interrupt Flag, ICxIF, is asserted, two instruction cycles after the capture buffer write event.

If the Input Capture timer increments every instruction cycle, the captured timer value will be the value that was present one or two instruction cycles after the time of the event on the ICx pin. This time delay is a function of the actual ICx edge event related to the instruction clock cycle and delay associated with the Input Capture logic. If the input clock to the capture time base is prescaled, then the delay in the captured value can be eliminated. For more information, see [Figure 5-1](#) and [Figure 5-3](#).

The Input Capture pin has minimum high time and low time specifications. For more information, refer to [Section 13.0 "Design Tips"](#).

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Figure 5-1: Simple Capture Timing Diagram, Time Base Prescaler = 1:1

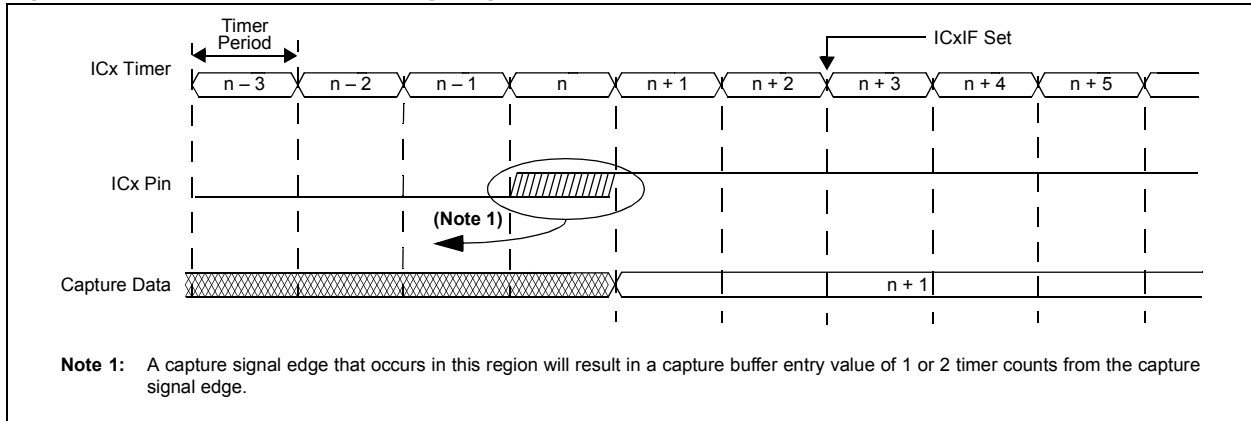
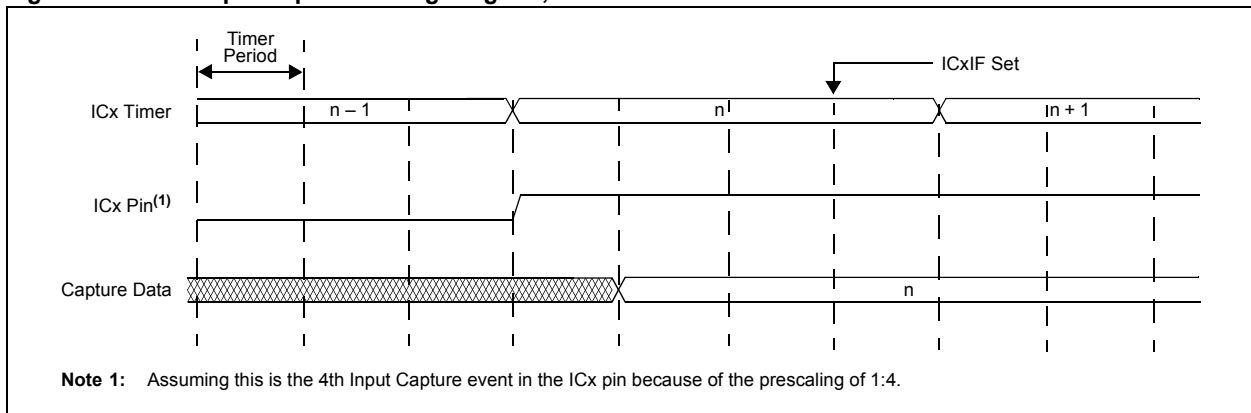


Figure 5-2: Simple Capture Timing Diagram, Time Base Prescaler = 1:4



5.1.1 CHANGING BETWEEN CAPTURE MODES

It is recommended that the user-assigned application turn off the capture module (clear the ICM<2:0> (ICxCON1<2:0>) bits) before switching to a new mode. If the user-assigned application switches to a new Capture mode, the prescaler counter will not be cleared. Therefore, at the time of switching modes, it is possible that the first capture event and its associated interrupt is generated due to a non-zero prescaler counter.

5.2 Prescaler Capture Events

The Input Capture module has two Prescaler Capture modes. The Prescaler Capture modes are selected by setting the ICM<2:0> bits (ICxCON1<2:0>) to '100' or '101', respectively. In these modes, the capture module counts four or sixteen rising edge pin events before a capture event occurs.

The prescaler capture counter is incremented on every valid rising edge applied to the capture pin. The rising edge applied to the pin effectively serves as a clock to a counter. When the prescaler counter equals four or sixteen counts (depending on the mode selected), the counter will output a valid capture event signal, which is then synchronized to the instruction clock cycle.

This synchronized capture event signal triggers a capture buffer write event and signals the interrupt generation logic. The respective Input Capture x Interrupt Flag, ICxIF, is asserted, two instruction cycles after the capture buffer write event.

The Input Capture pin has minimum high time and low time specifications. For more information, refer to the Electrical Characteristics section of the specific device data sheet.

Switching from one prescale setting to another might generate an interrupt and also, the prescaler counter will not be cleared. Therefore, the first capture may be from a non-zero prescaler.

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Example 5-1 provides the recommended method for switching between prescaler capture settings.

The prescaler counter is cleared when:

- The capture channel is turned off (ICM<2:0> = 000)
- Any device Reset

The prescaler counter is not cleared when:

- The user-assigned application switches from one active Capture mode to another

Example 5-1: Prescaler Capture Code Example

```
//The following code example will set the Input Capture1 module for interrupts on every
//second capture event; captured on every fourth rising edge. The clock source for the timer
//would be the system clock. Sync/Trig source is disabled.
//Setup Input Capture1 interrupt for desired priority level (this example assigns level 1
//priority)

IFS0bits.IC1IF = 0;           // Clear the IC1 interrupt status flag
IEC0bits.IC1IE = 1;          // Enable IC1 interrupts
IPC0bits.IC1IP = 1;          // Set module interrupt priority as 1

IC1CON1bits.ICSDL = 0;       // Input capture will continue to operate in CPU idle mode
IC1CON1bits.ICTSEL = 0b111;  // Peripheral (FP) is the clock source for the IC1 module
IC1CON1bits.ICI = 1;         // Interrupt on every capture event
IC1CON1bits.ICBNE = 0;       // Input capture is empty
IC1CON1bits.ICM = 0b100;     // Capture mode; every fourth rising edge (Prescaler Capture mode)

IC1CON2bits.IC32 = 0;        // Cascade module operation is disabled
IC1CON2bits.ICTRIG = 0;      // Input source used to synchronize the input capture timer of
                              // another module (Synchronization mode)
IC1CON2bits.TRIGSTAT = 0;    // IC1TMR has not been triggered and is being held clear
IC1CON2bits.SYNCSEL = 0;     // No Sync or Trigger source for the IC1 module

// The following code shows how to read the capture buffer when
// an interrupt is generated.
// Example code for Input Capture 1 ISR:
unsigned int Capture1, Capture2;
void __attribute__((__interrupt__, no_auto_psv)) _IC1Interrupt(void)
{
    IFS0bits.IC1IF = 0;       // Reset respective interrupt flag
    Capture1 = IC1BUF;        // Read and save off first capture entry
    Capture2 = IC1BUF;        // Read and save off second capture entry
}
```

5.3 Edge Detection Mode

The Input Capture module can capture a time base count value on every rising and falling edge of the input signal applied to the ICx pin. The Edge Detection mode is selected by setting the ICM<2:0> bits (ICxCON1<2:0>) to '001'. In this mode, the prescaler capture counter is not used. For a simplified timing diagram, see [Figure 5-3](#).

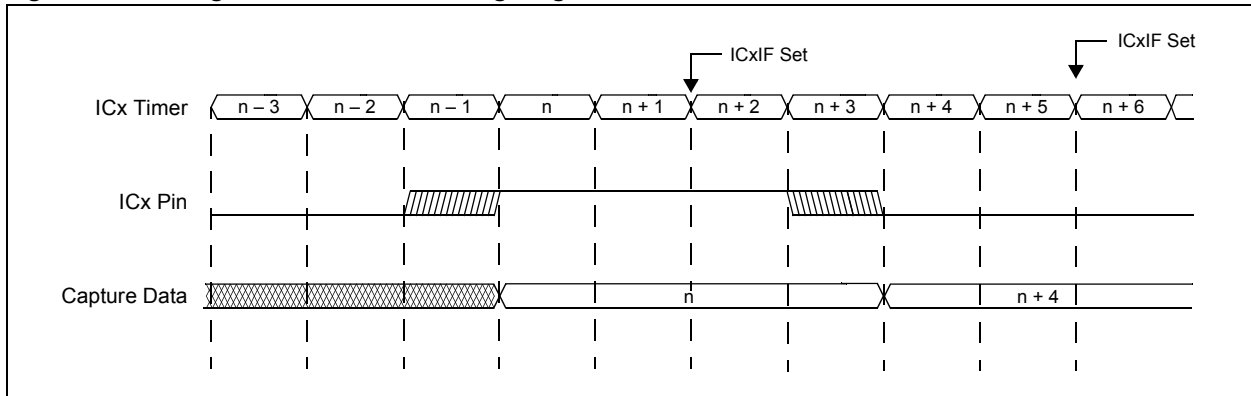
When the Input Capture module is configured for an edge detection (Edge Detection mode), the module performs these tasks:

- Sets the Input Capture x Interrupt Flag (ICxIF) on every edge, rising and falling.
- The Number of Captures per Interrupt Select bits (IC1<1:0>) of the ICxCON1 register (ICxCON1<6:5>) are not used in this mode. Every capture event generates an interrupt.

As with the simple Capture Event mode, the Input Capture logic detects and synchronizes the rising and falling edge of the capture pin signal with the internal phase clocks. If the rising or falling edge has occurred, the capture module logic will write the current timer count on to the capture buffer and signal the interrupt generation logic. The respective Input Capture x Interrupt Flag, ICxIF, is asserted, two instruction cycles after the capture buffer write event.

The captured timer count value will be 1 or 2 timer counts after the occurrence of the edge at the ICx pin (see [Figure 5-3](#)).

Figure 5-3: Edge Detection Mode Timing Diagram



6.0 CAPTURE BUFFER OPERATION

Each capture module has a FIFO buffer associated with it. The ICxBUF register is memory-mapped and provides access to the FIFO. When the Input Capture Mode Select bits (ICxCON1<2:0> = 000) are reset, the Input Capture logic performs these tasks:

- Clears the overflow condition flag (that is, clears ICOV (ICxCON1<4>) to '0')
- Resets the capture buffer to the empty state (clears ICBNE (ICxCON1<3>) to '0')

Reading the FIFO buffer under the following conditions will lead to indeterminate results:

- The Input Capture module is first disabled, and at some later time, re-enabled
- A FIFO read is performed when the buffer is empty
- After a device Reset, before a capture event has occurred

There are two status flags that provide the status on the FIFO buffer:

- ICBNE (ICxCON1<3>): Input Capture Buffer Not Empty
- ICOV (ICxCON1<4>): Input Capture Overflow

6.1 Input Capture Buffer Not Empty (ICBNE)

The ICBNE read-only status bit (ICxCON1<3>) will be set on the first Input Capture event and remains set until all the capture events have been read from the capture buffer. For example, if three capture events have occurred, then three reads of the capture buffer are required before the ICBNE (ICxCON1<3>) bit gets cleared. If four capture events occur, then four reads are required to clear the ICBNE bit. After each read, the remaining words will be allowed to move to the next available top location. Because the ICBNE bit reflects the capture buffer state, the ICBNE status bit will be cleared during a device Reset.

6.2 Input Capture Overflow (ICOV)

The ICOV read-only status bit (ICxCON1<4>) will be set when the capture buffer overflows. In the event that the buffer is full with four capture events, and a fifth capture event occurs prior to reading the buffer, an overrun condition will occur. The ICOV (ICxCON1<4>) bit will be set to logic '1' and the respective capture event interrupt will not be generated. In addition, the fifth capture event is not recorded and subsequent capture events will not alter the current buffer contents.

To clear the overrun condition, the capture buffer must be read four times. Upon the fourth read, the ICOV (ICxCON1<4>) status flag will be cleared and the capture channel will resume normal operation.

Clearing of the overflow condition can be accomplished in the following ways:

- Set the ICM<2:0> bits (ICxCON1<2:0>) = 000
- Read the capture buffer until ICBNE (ICxCON1<3>) = 0
- Any device Reset

A FIFO overflow occurs under the following conditions:

- ICM<2:0> are not equal to '000' (not off)
- ICM<2:0> are not equal to '110' (not disabled)
- ICM<2:0> are not equal to '001' (not in Edge Detect mode)
- Idle_mode = 0 or ICSIDL = 0, or the ICM<2:0> bits are not equal to '111'
- FIFO is full
- Capture event has occurred

Note: When ICI<1:0> = 00 or ICM<2:0> = 001, interrupts occur and the ICOV bit remains clear, even after a buffer overflow has occurred.
--

6.2.1 ICOV AND INTERRUPT ONLY MODE

The Input Capture module can also be configured to function as an external interrupt pin. For this mode, the ICI<1:0> bits (ICxCON1<6:5>) must be cleared to '00'. Interrupts will be generated independent of buffer reads.

7.0 INPUT CAPTURE INTERRUPTS

The Input Capture module can generate interrupts based upon a selected number of capture events. A capture event is defined as a write of a time base value into the capture buffer. This setting is configured by the control bits, ICI<1:0> (ICxCON1<6:5>).

Except for the case when ICI<1:0> = 00 or ICM <2:0> = 001, no interrupts will be generated until a buffer overflow condition is removed (see [Section 6.2 “Input Capture Overflow \(ICOV\)”](#)).

When the capture buffer is emptied, either by a Reset condition or a read operation, the interrupt count is reset. This allows for the resynchronization of the interrupt count to the FIFO entry status.

7.1 Interrupt Control Bits

All Input Capture modules have Input Capture x Interrupt Flag bits (ICxIF), Input Capture x Interrupt Enable bits (ICxIE) and Input Capture x Interrupt Priority bits (ICxIP<2:0>).

8.0 INPUT CAPTURE OPERATION IN POWER-SAVING STATES

8.1 Input Capture Operation in Sleep Mode

When the device enters Sleep mode, the system clock is disabled. In Sleep mode, the Input Capture module can only function as an external interrupt source and the capture result is not valid. This mode is enabled by setting control bits, ICM<2:0> = 111. In this mode, a rising edge on the capture pin will generate a device wake-up from Sleep condition. If the respective module interrupt bit is enabled, and the module priority is of the required priority, an interrupt will be generated; an active timer is not required.

In the event the capture module is configured for a mode other than ICM<2:0> = 111, and the device enters Sleep mode, no external pin stimulus, rising or falling, will generate a wake-up condition from Sleep mode.

8.2 Input Capture Operation in Idle Mode

When the device enters Idle mode, the system clock source remains functional and the CPU stops executing code. The ICSIDL bit (ICxCON1<13>) selection will determine if the module will stop in Idle mode or continue to operate in Idle mode.

If ICSIDL = 0 (ICxCON1<13>), the module will continue operation in Idle mode. Full functionality of the Input Capture module is provided (including the 4:1 and 16:1 prescaler capture settings), as defined by the ICM<2:0> control bits (ICxCON1<2:0>). These modes require that the selected timer is enabled during Idle mode as well.

If the Input Capture mode is configured for ICM<2:0> = 111, the Input Capture pin will serve only as an external interrupt pin when the device is in either CPU Sleep mode or Idle mode. In this mode, a rising edge on the capture pin will generate a device wake-up from Idle mode or Sleep mode. A capture time base does not have to be enabled. If the respective module interrupt enable bit is set, and the user-assigned application priority is greater than the current CPU priority level, an interrupt will be generated.

If ICSIDL = 1 (ICxCON1<13>), the module will stop in Idle mode. The module will perform the same functions when stopped in Idle mode as for Sleep mode (see [Section 8.1 “Input Capture Operation in Sleep Mode”](#)).

8.3 Device Wake-up on Sleep or Idle Mode

An Input Capture event can generate a device wake-up or an interrupt, if enabled, if the device is in Idle or Sleep mode.

Independent of the timer being enabled, the Input Capture module will wake-up from Sleep or Idle mode, when a capture event occurs, if the following are true:

- Input Capture Mode Select bits, ICM<2:0> = 111 (ICxCON1<2:0>)
- The Input Capture x Interrupt Enable bit (ICxIE) is asserted

This same wake-up feature will interrupt the CPU if the respective interrupt is enabled (ICxIE = 1) and is of the required priority.

This wake-up feature is useful for including additional external pin interrupts. The following conditions are true when the Input Capture module is used in this mode:

- The prescaler capture counter is not utilized while in this mode
- The ICI<1:0> bits (ICxCON1<6:5>) are not applicable

8.4 Doze Mode

Input Capture operation in Doze mode is the same as in normal mode. When the device enters Doze mode, the system clock sources remain functional and the CPU may run at a slower clock rate.

8.5 Selective Peripheral Module Control

The Peripheral Module Disable (PMD) registers provide a method to disable the Input Capture module by stopping all clock sources supplied to it. When the module is disabled through the appropriate PMD control bit, it is in a minimum power consumption state. The control and status registers associated with the module will also be disabled, hence any write to these registers will have no effect, and read values will be invalid and return zero.

9.0 INPUT CAPTURE TIMER FUNCTIONALITY

The Input Capture module contains a 16-bit synchronous, up-counting dedicated timer used for the capture function. This timer has the following functionality:

- **Synchronous Operation** – The timer rolls over when it reaches FFFFh or when the Sync/Trig input is enabled.
- **Triggered Operation (hardware and/or software)** – The timer starts operation based on a hardware or software trigger, and can be cleared and stopped by software.
- **Cascaded Operation (32-Bit Timer mode)** – The EVEN timer will increment when the associated ODD timer rolls over and the ODD timer increments every timer clock period when enabled.

9.1 Synchronous Timer Operation

Synchronous operation of the timer is enabled when:

- ICTRIG = 0
- A valid synchronization input is selected using the SYNCSEL<4:0> bits

In synchronous operation, the TRIGSTAT bit has no function. The timer can be synchronized with other modules using the Sync/Trig input source of the module, which is selected using the SYNCSEL<4:0> bits. Input synchronization inputs include module outputs from other Input Capture modules, timers and output compare modules.

[Figure 9-1](#) and [Figure 9-2](#) show the timer operation in conjunction with a Sync/Trig input source. When a valid synchronization input is selected using the Sync/Trig input source bits, the timer increments on every timer clock (selected by the ICTSEL<2:0> bits). When the selected Sync/Trig input source = 1, the timer will be cleared on the next rising edge of the timer clock. As long as the Sync/Trig input source = 1, the timer will remain cleared.

When the Sync/Trig input source is negated, the timer will resume incrementing on the next positive edge of the timer clock. The Sync/Trig input is driven by the synchronization output of another module (typically, an output compare or Input Capture module).

When initializing timers that have synchronous timer operation enabled, the timer being used as the source of synchronization must be enabled last.

- Note 1:** Synchronized timers must select the same clock source to ensure proper function.
- 2:** When initializing timers that have synchronous timer operation enabled, the timer being used as the source of synchronization must be enabled last.
- 3:** The Sync/Trig input must be synchronous to the timer clock to ensure proper operation.

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Figure 9-1: ICx Timer Synchronous Operation Timing (ICTRIG = 0) with External Sync/Trig Input

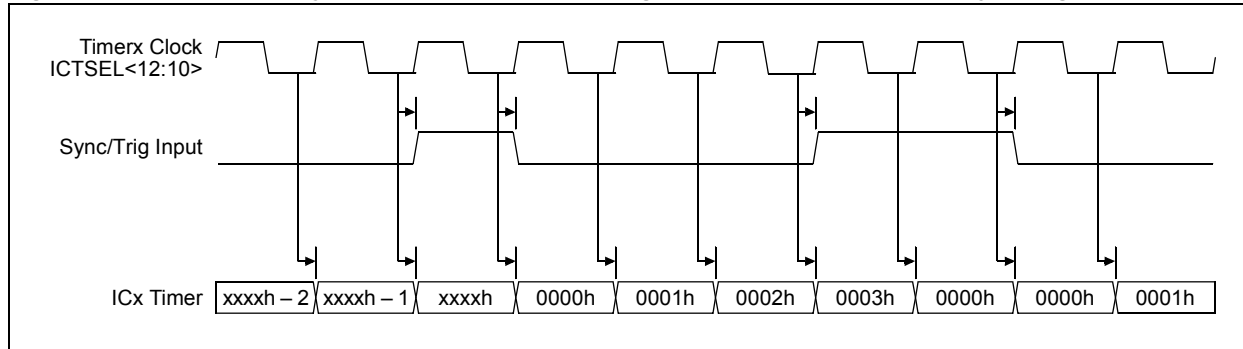
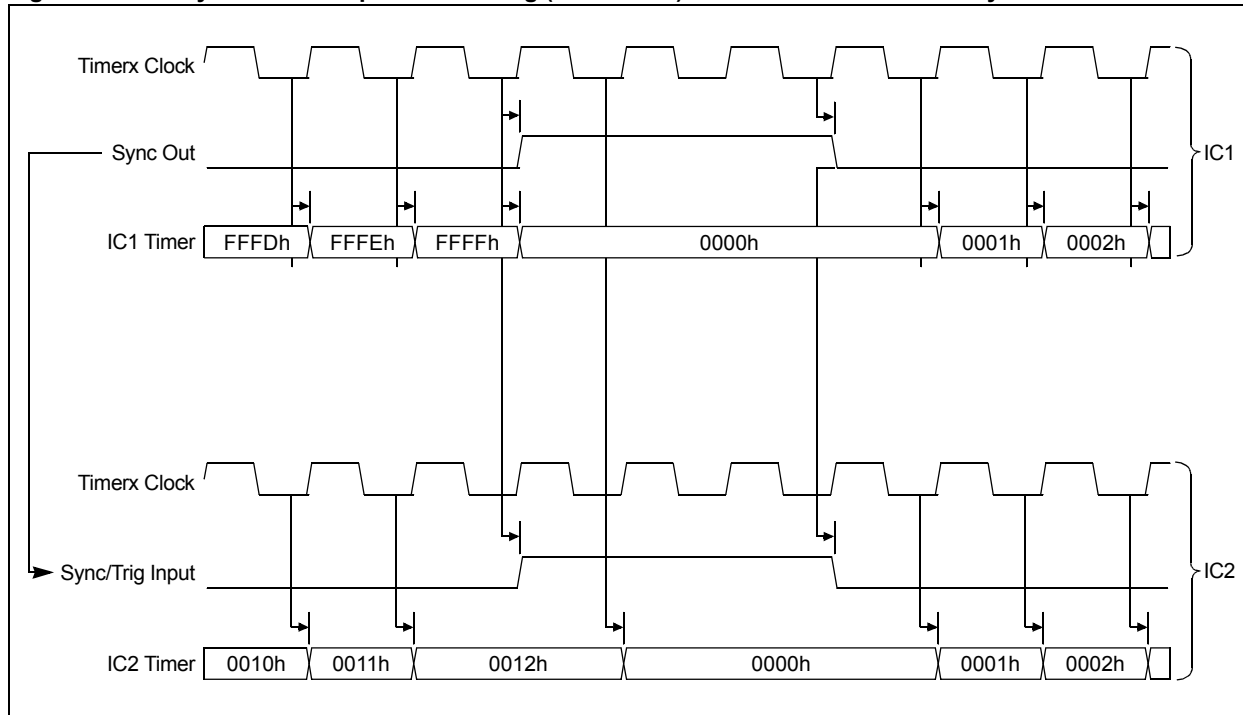


Figure 9-2: Synchronous Operation Timing (ICTRIG = 0): IC1 Base Timer and IC2 Synchronized Timer



9.2 Trigger Timer Operation

Triggered operation of the timer is enabled when $ICTRIG = 1$ and a valid Sync/Trig input source is selected using the $SYNCSEL<4:0>$ bits. During triggered operation, the TRIGSTAT bit is set by hardware or software and can be cleared by software. Input trigger sources include module outputs from other Input Capture modules, timers, output compare modules, comparator modules and ADC modules.

The TRIGSTAT bit has the following functions during trigger operation:

- TRIGSTAT = 0
 - Timer is held in Reset
- TRIGSTAT = 1
 - Timer is released from Reset
 - Timer increments on every positive clock

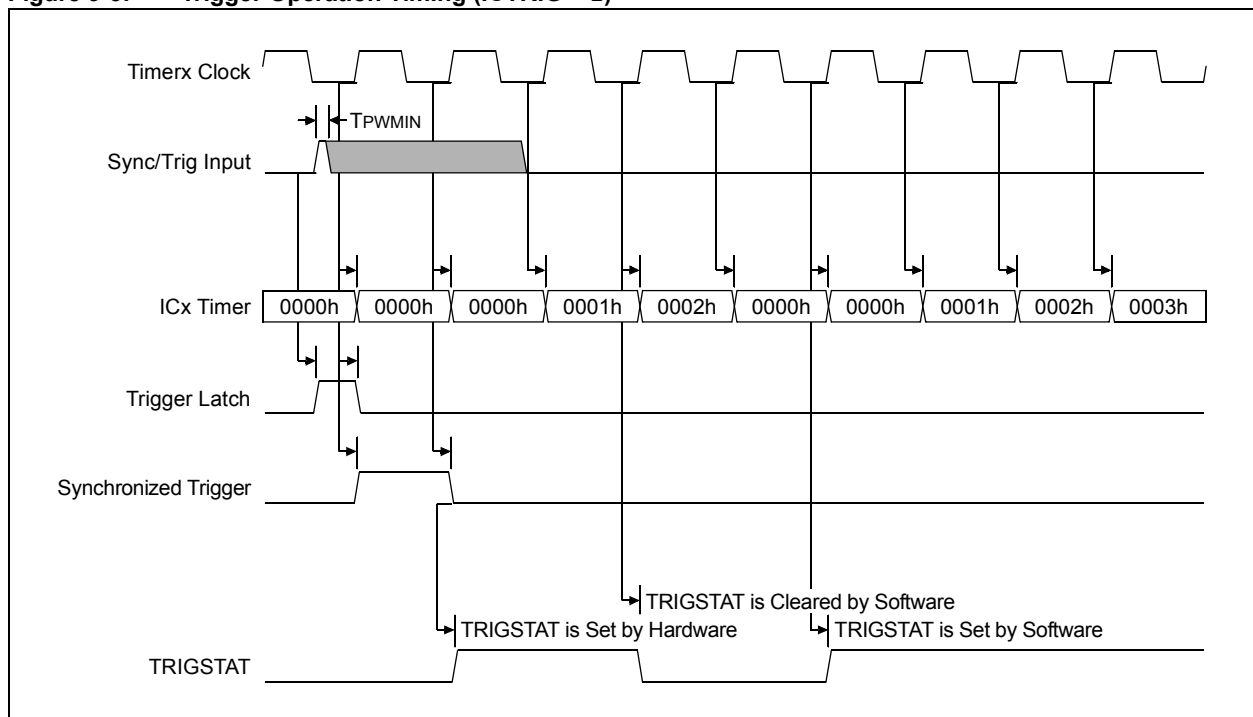
Trigger operation is shown in Figure 9-3. When triggered timer operation is enabled, the timer will be held in a cleared state. It will remain in this cleared state until a trigger occurs on the selected Sync/Trig input source ($SYNCSEL<4:0>$), at which point, the TRIGSTAT bit is set. In addition to being set by hardware, the TRIGSTAT bit may also be set in software. After the TRIGSTAT bit is set, the timer is released from Reset and starts running. When the TRIGSTAT bit is cleared in software, the timer is reset to 0000h and is ready for another Sync/Trig input ($SYNCSEL<4:0>$) assertion.

When TRIGSTAT = 0, the timer is held in Reset (0000h), but the Input Capture functionality is still active. If an Input Capture event occurs during this time, the value of the timer (0000h) will be captured into the FIFO buffer.

When setting up the Input Capture module, make sure to set all other Input Capture configurations and that the TRIGSTAT bit is still zero ('0'), before changing the $ICM<2:0>$ bits from zero ('0'), to enable the Input Capture module. Trigger functionality is based on the rising edge of the Sync/Trig input rather than the level trigger.

Note: The Sync/Trig input must be synchronous to the timer clock and must be a minimum of one timer clock cycle in width to ensure proper operation.

Figure 9-3: Trigger Operation Timing ($ICTRIG = 1$)

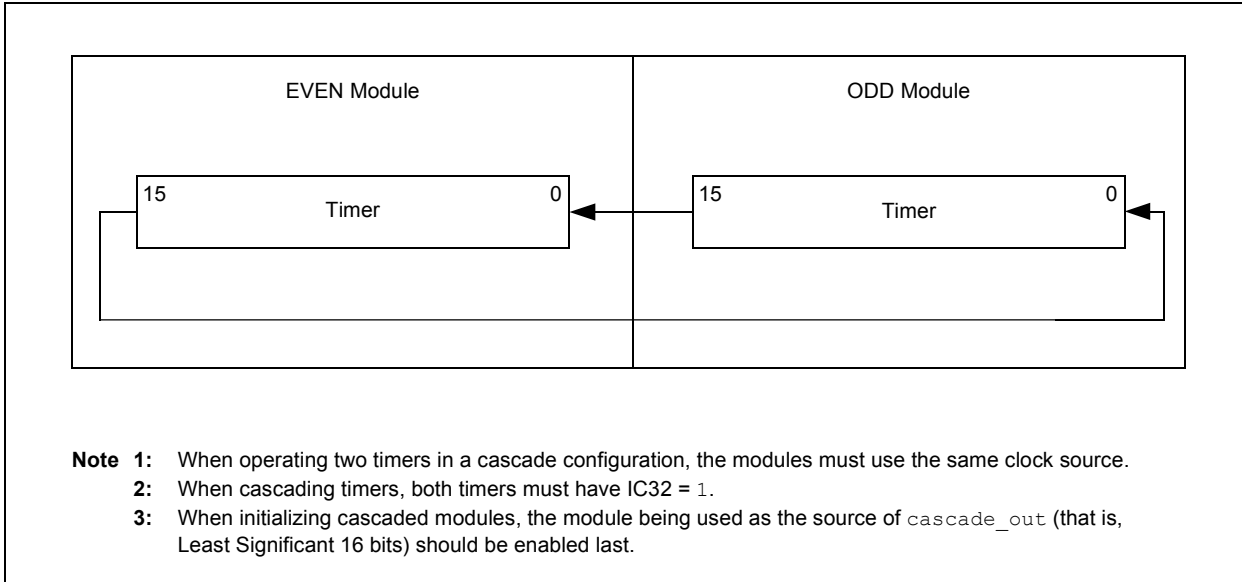


9.3 Cascaded Timer Operation (32-Bit Timer Mode)

Cascaded operation of the timer is enabled when $IC32 = 1$. Timers can be grouped in pairs for the purpose of cascading them to form 32-bit timers using the cascade input and cascade output of the module. They are grouped as ODD and EVEN pairs (1-2, 3-4, 5-6, 7-8 and so on). When cascading, the ODD timer will be the Least Significant 16 bits and the EVEN timer will be the Most Significant 16 bits.

Cascade operation is illustrated in [Figure 9-4](#). As long as the cascade input is low, the timer will not be incremented. When the cascade input is high, the timer will be incremented on the rising edge of the timer clock.

Figure 9-4: Cascaded Timer Operation



While cascading, the `cascade_out` from the ODD Input Capture module will be connected to `cascade_in` of the EVEN Input Capture module. When the ICx timer of the ODD module reaches $FFFFh$, it will assert the `cascade_out`, which will cause the ICx timer of the EVEN module to be incremented in the next clock cycle.

Input Capture with Dedicated Timer

9.3.1 TIMER CONFIGURATION

Based on the timer functionality, as described in [Figure 9-4](#), there are many different configurations that the timer can be operated in:

- **Normal Configuration** – The timer operates as a standard up-counter, rolling over to 0000h only when it reaches FFFFh. This mode is set by: IC32 = 0, ICTRIG = 0 and SYNCSEL<4:0> = 0b00000. In this mode, the TRIGSTAT bit is unused.
- **Synchronous Configuration** – The timer may be synchronized with another timer, such that both timers roll over simultaneously. This mode is set by: IC32 = 0, ICTRIG = 0 and SYNCSEL<4:0> ≠ 0b00000. In this mode, the TRIGSTAT bit is unused.
- **Software Triggered Configuration** – The timer may be triggered by software to start the timer operation. This mode is set by IC32 = 0, ICTRIG = 1 and SYNCSEL<4:0> = 0b00000. In this mode, the TRIGSTAT bit is used.
- **Hardware/Software Triggered Configuration** – The timer may be triggered by a trigger outside the module (for example, the comparator), or by software, to start the timer operation. This mode is set by IC32 = 0, ICTRIG = 1 and SYNCSEL<4:0> ≠ 0b00000. In this mode, the TRIGSTAT bit is used.
- **Normal Cascaded Configuration** – The timer may be cascaded with another timer so that two 16-bit timers can be combined to form a single 32-bit timer. This mode is set by IC32 = 1, ICTRIG = 0 and SYNCSEL<4:0> = 0b00000. In this mode, the TRIGSTAT bit is unused.
- **Synchronous Cascaded Configuration** – The timer may be cascaded with another timer to form a 32-bit timer that is synchronized with another 32-bit timer. This mode is set by IC32 = 1, ICTRIG = 0 and SYNCSEL<4:0> ≠ 0b00000. In this mode, the TRIGSTAT bit is unused.
- **Software Triggered Cascaded Configuration** – The timer may be cascaded with another timer to form a 32-bit timer that may be triggered by software to start the timer operation. This mode is set by IC32 = 1, ICTRIG = 1 and SYNCSEL<4:0> = 0b00000. In this mode, the TRIGSTAT bit is used.
- **Hardware/Software Triggered Cascaded Configuration** – The timer may be cascaded with another timer to form a 32-bit timer that may be triggered from outside the module itself (by the comparator and so on), or by software, to start the timer operation. This mode is set by IC32 = 1, ICTRIG = 1 and SYNCSEL<4:0> ≠ 0b00000. In this mode, the TRIGSTAT bit is used. All other combinations of Configuration bits are undefined and should not be used. [Table 9-1](#) shows a summary of the timer configurations.

Table 9-1: Timer Configuration

Timer Configuration	IC32	ICTRIG	SYNCSEL<4:0>
Normal Configuration	0	0	0b0000 ⁽¹⁾
Synchronous Configuration	0	0	See Register 2-2
Software Triggered Configuration	0	1	0b0000 ⁽¹⁾
Hardware/Software Triggered Configuration	0	1	See Register 2-2
Normal Cascaded Configuration	1	0	0b0000 ⁽¹⁾
Synchronous Cascaded Configuration	1	0	See Register 2-2
Software Triggered Cascaded Configuration	1	1	0b0000 ⁽¹⁾
Hardware/Software Triggered Cascaded Configuration	1	1	See Register 2-2

Note 1: No Sync or Trigger source for the ICx module.

10.0 I/O PIN CONTROL

When the Input Capture module is enabled, the user must ensure that the I/O pin direction is configured for an input by setting the associated TRIS bit. The pin direction is not set when the Input Capture module is enabled. Furthermore, all other peripherals multiplexed with the input pin must be disabled.

11.0 INPUT CAPTURE OPERATION WITH DMA

Some devices include a Direct Memory Access (DMA) module, which allows data to be transferred from the Input Capture module to data memory without CPU intervention. Refer to the specific device data sheet to see if DMA is present on your particular device.

When the Input Capture module and DMA channel are configured, the Input Capture module issues a DMA request for every capture event. The DMA transfers data from the Input Capture x Buffer (ICxBUF) register into RAM and issues a CPU interrupt after a predefined number of transfers.

The DMA channel must be initialized with the following:

- The DMA Request Source Selection (IRQSEL<7:0>) bits in the DMA x Request (DMAxREQ<7:0>) register must select the DMA transfer request from the Input Capture module
- The DMA x Channel Peripheral Address (DMAxPAD) register must be initialized with the address of the Input Capture x Buffer (ICxBUF) register
- The Transfer Direction (DIR) bit in the DMA x Control (DMAxCON<13>) register must be cleared. In this condition, data is read from the peripheral and written to the dual port DMA memory

In addition, the Number of Captures per Interrupt Select bits must be cleared (ICI<1:0> = 00) to generate a DMA request for every capture event.

[Example 11-1](#) provides sample code that transfers the capture values to RAM with DMA.

DMA Channel 0 is set up for the Input Capture module with the following configuration:

- Transfer Data from the Input Capture module to RAM
- One-Shot Operating mode
- Register Indirect with Post-Increment Addressing
- Single Buffer
- 256 Transfers per Buffer
- Transfer Words

Input Capture with Dedicated Timer

Example 11-1: Input Capture with DMA

```
//Define Buffer in DMA RAM as global variable:
__eds__ unsigned int BufferA[256] __attribute__((space(eds)));

//Initialize Input Capture Module:

IC1CON1bits.ICM = 0b000;    // Disable Input Capture 1 module
IC1CON1bits.ICTSEL = 7;    // Select system clock as the IC1 Time base
IC1CON1bits.ICI = 0b00;    // Interrupt on every capture event
IC1CON1bits.ICM = 0b001;   // Generate capture event on every edge
IC1CON2 = 0;               // No sync or trigger source for IC1

//Set up DMA for Input Capture:

DMA0CONbits.AMODE = 0b00;  // Register indirect with post increment
DMA0CONbits.MODE = 0b01;  // One Shot, Ping-Pong mode Disabled
DMA0CONbits.DIR = 0;      // Peripheral to RAM
DMA0PAD = (int)&IC1BUF;    // Address of the capture buffer register
DMA0REQ = 1;              // Select IC module as DMA request source
DMA0CNT = 255;            // Number of words to buffer

DMA0STAH = __builtin_dmapage (&BufferA);
DMA0STAL = __builtin_dmaoffset (&BufferA);

IFS0bits.DMA0IF = 0;      // Clear the DMA interrupt flag bit
IEC0bits.DMA0IE = 1;     // Enable DMA interrupt enable bit
DMA0CONbits.CHEN = 1;

//Set up DMA Interrupt Handler:

void __attribute__((__interrupt__, no_auto_psv)) _DMA0Interrupt(void)
{
    // Process the captured values
    IFS0bits.DMA0IF = 0; // Clear the DMA0 Interrupt Flag
}
```

12.0 REGISTER MAPS

A summary of the registers associated with the Input Capture with Dedicated Timer module is provided in [Table 12-1](#).

Table 12-1: Input Capture with Dedicated Timer Register Map

File Name	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	All Resets
ICxBUF	Input Capture x Buffer Register																xxxx
ICxCON1	—	—	ICSIDL	ICTSEL2	ICTSEL1	ICTSEL0	—	—	—	ICI1	ICI0	ICOV	ICBNE	ICM2	ICM1	ICM0	0000
ICxCON2	—	—	—	—	—	—	—	IC32	ICTRIG	TRIGSTAT	—	SYNCSEL4	SYNCSEL3	SYNCSEL2	SYNCSEL1	SYNCSEL0	000D
ICxTMR	Input Capture x Timer Register																0000

Legend: x = unknown value on Reset; — = unimplemented, read as '0'. Reset values are shown in hexadecimal.

13.0 DESIGN TIPS

Question 1: *Can the Input Capture module be used to wake the device from Sleep mode?*

Answer: Yes. When the Input Capture module is configured to ICM<2:0> = 111, and the respective channel Input Capture x Interrupt Enable bit is asserted (ICxIE = 1), a rising edge on the capture pin will wake the device from Sleep mode (see [Section 8.0 “Input Capture Operation in Power-Saving States”](#)).

14.0 RELATED APPLICATION NOTES

This section lists application notes that are related to this section of the manual. These application notes may not be written specifically for the dsPIC33/PIC24 device families, but the concepts are pertinent and can be used with modification and possible limitations. The current application notes related to the Input Capture with Dedicated Timer are:

Title	Application Note #
No application notes are available.	

Note: Visit the Microchip web site (www.microchip.com) for additional application notes and code examples.

15.0 REVISION HISTORY

Revision A (November 2008)

This is the initial released revision of this document.

Revision B (July 2010)

This revision includes the following updates:

- Updated the Input Capture with Dedicated Timer Block Diagram ([Figure 1-1](#))
- Updated the bit value definitions for the ICTSEL<12:10> bits in the ICxCON1 register ([Register 2-1](#))
- Added Note 5 and updated the bit value definitions for the SYNCSEL<4:0> bits in the ICxCON2 register ([Register 2-2](#))
- Added a shaded note after the ICxCON2 register
- Updated the IC1 Timer values in the Synchronous Operating Timing (ICTRIG = 0) diagram ([Figure 9-2](#))
- Updated the Input Capture with Dedicated Timer with DMA code example ([Example 11-1](#))
- Updated the ICxCON2 All Resets value in the register map ([Table 12-1](#))
- Additional minor formatting updates were incorporated throughout the document

Revision C (August 2013)

This revision includes the following updates:

- Updated to the current Family Reference Manual format
- Updated the Input Capture with Dedicated Timer Block Diagram ([Figure 1-1](#))
- Updated all Register tables to include information for both dsPIC33 and PIC24 devices
- Added Note to [Figure 5-2](#)
- Added [Table 9-1](#)
- Additional formatting changes and text corrections were incorporated throughout the document

Revision D (July 2015)

This revision includes the following updates:

- Changed some instances of Input Capture to Input Capture with Dedicated Timers
- Updated the Family Reference Manual table on [page 2](#).

NOTES:

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