ECE 271 Microcomputer Architecture and Applications
Lab 8: Timer Input Capture in C
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Goals

1. Understand the basic concept of input capture function of a timer
2. Handle different events in the interrupt service routine
3. Handle timer counter overflow and underflow
4. Use a timer to measure the timestamp of a signal edge (rising or falling edge) external to the microprocessor

Pre-Lab Assignment

1. Read Chapter 15.4 *Input Capture* of the Textbook.
2. Complete the pre-lab assignment (Part 1 and Part 2).
3. Write your answers to the pre-lab assignment in Readme.md and submit it.

In-Lab Requirement

1. Measure the period of a 1Hz square signal by using TIM4 input capture and calculate the accuracy
2. Measure distance using the ultrasonic sensor and calculate the accuracy
3. Something cool such as printing distance to the LCD display

Post-Lab Assignment

1. Complete the post-lab report
2. Write your report in Readme.md and submit it

Timer Interrupt Status Register

The free-run timer counter (CNT) of timers used in this lab are limited to 16 bits. There are two special events:

- During counting up, CNT restarts from 0 after it reaches 0xFFFF. This event is called ***counter overflow*.**
- During counting down, CNT restarts from 0xFFFF after it reaches 0. This event is called ***counter underflow***.

When an overflow or underflow occurs, the timer can generate a timer interrupt if the Update Interrupt Enable (UIE) bit of the TIM DMA/Interrupt Enable Register (TIM_DIER) is set.

In the interrupt service routine of the corresponding timer, you can check the TIM status register (TIM_SR) to find out what events has generated the timer interrupt.

- If a counter overflow or underflow occurs, the Update Interrupt Flag (UIF) is set in TIM_SR. The UIF flag is set by hardware.

- If a channel is configured as input, a valid transition of an external signal can trigger the timer interrupt. Take channel 1 as an example. If the channel 1 is configured as input capture and the Channel 1 Interrupt Flag (CC1IF) in TIM_SR is set, the capture on Channel 1 has been triggered and the counter value has been copied to CCR1 register. The CC1IF is set by hardware.

The timer interrupt service routine must clear these flags of TIM_SR to prevent it from being called again by the processor. The CC1IF flag is automatically cleared if the TIM_CCR1 register is read. The UIF flag has to be explicitly cleared by software.

Part 1: Measure the period of 1 Hz square signal

Pin	Alternative Functions
PB 6	LPTIM1_ETR/**TIM4_CH1**/TIM8_BKIN2I2C1_SCL/DFSDM_DATIN5/USART1_TX/TSC_G2_IO3/TIM8_BKIN2_COMP2/SAI1_FS_B/TIM16_CH1N/EVENTOUT

Use an external function generator to generate a 1Hz square wave. Use your timer input capture function (specifically, PB 6/Timer 4 Channel 1) to measure the period of the square wave signal.

Make sure the output signal is limited to 3V to prevent damage to your board. It is highly recommended to connect the function generator to your board via a 10 kΩ resistor, limiting currents to a few milliamps.

In this lab, you are required to select High-Speed Internal Clock (HSI, 16MHz) as the processor clock.

Part 2: Interface with Ultrasonic distance sensor

Part 2 involves capturing a square wave generated by an HC-SR04 Ultrasonic distance sensor. We will use PB.10 to trigger the ultrasonic sensor and PB.6 to capture the echo output of the sensor.

	Pin	Alternative Function
Trigger	PE 11	TIM1_CH2
Echo	PB 6	TIM4_CH1

Documentation for this device can be found online, what follows is a brief summary.

- The sensor is powered by 5V. Connect the Vcc line to EXT_5V on the STM32L board, and GND to a ground connection on the board.

- While the board runs at 5V, it can be triggered by a 3.3V pulse. Its output is 5V, but many of the inputs on the STM32L board are five-volt tolerant and can handle a 5V input.
- As described in the documentation, to activate the sensor send a high pulse of at least 10us to the Trig input. An ultrasonic burst of 40kHz will be emitted, and then the device will return a square wave proportional to the distance to the nearest object.
- The return will be on the ECHO pin, a square wave ranging from 150us to 25ms (38ms if nothing is in range). To convert this value to inches, divide the time in us (microseconds) by 148.

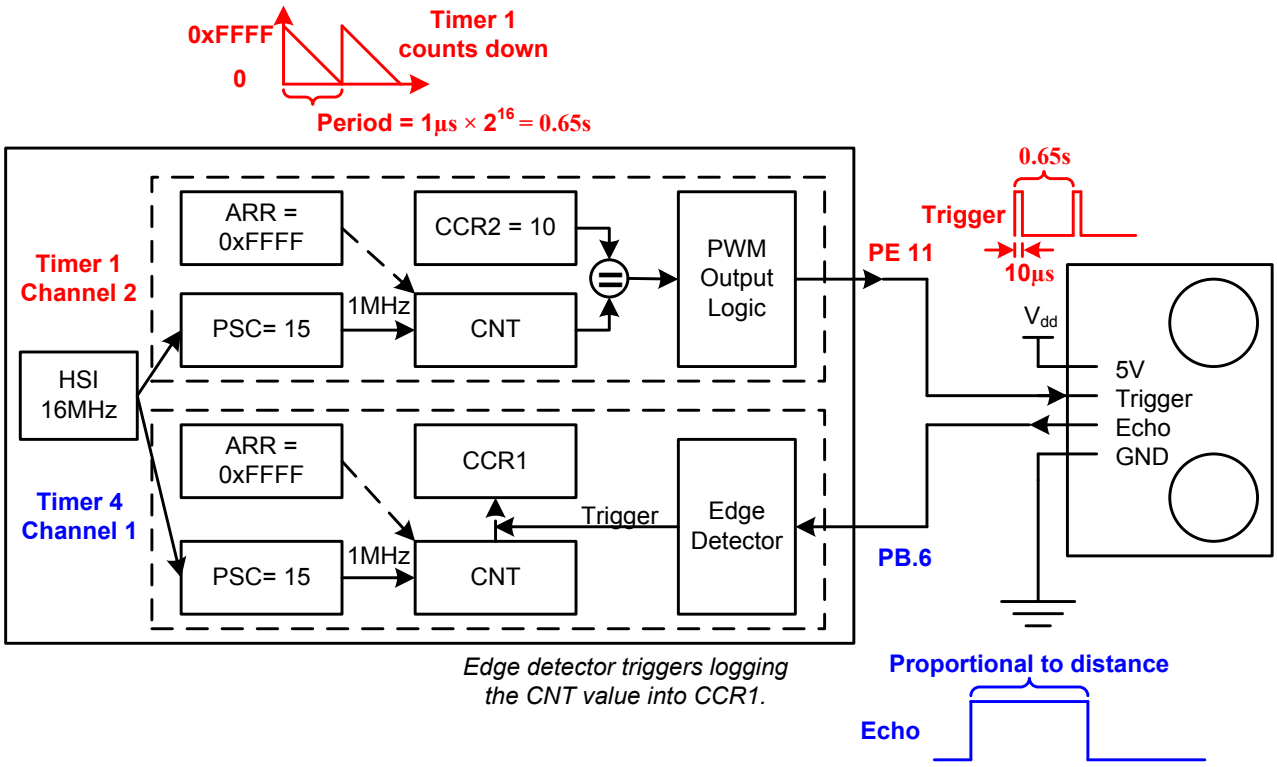

Figure 1. Connection and configuration diagram for interfacing ultrasonic distance sensor

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Lab 8 Timer Input Capture
Pre-Lab Assignment

Part 1: Measure the period of 1 Hz square signal

Pre-Lab Assignment:

$$f_{Timer\ Clock} = \frac{f_{HSI}}{1 + PSC}$$

For Timer 4, the clock pre-scalar register (PSC), the compare/capture register (CCR), and the timer free-run counter has 16 bits. Thus their value is limited to $2^{16} - 1 = 65535$.

Write your answers to Readme.md and submit it to Gitlab server:

Timer Input Clock Frequency: _____16MHz_____

1. **Select your timer prescaler (PSC)**
   PSC = _____

2. **If both rising and fall edges of an external signal are selected as active transition, the time internal between two consecutive timer interrupts is 0.5 second. What should be the difference of CCR values in two consecutive timer interrupts? Show your calculation.**

3. **For the prescaler you have selected, how long (in terms of seconds) after reset a counter overflow or underflow event occurs? Show your calculation.**

4. **If a counter overflow/underflow occurs, the difference of two CCR readings may not correctly measure the time interval. Explain why and how to solve it? (Hints: In the timer interrupt service routine, check the UIF flag)**

Part 2: Interface with Ultrasonic distance sensor

As shown in Figure 1, PSC is selected as 15.

$$f_{Timer\ Clock} = \frac{f_{HSI}}{1 + PSC} = \frac{16MHz}{1 + 15} = 1MHz$$

For Timer 4, the clock pre-scalar register (PSC), the compare/capture register (CCR), and the timer free-run counter has 16 bits. Thus their value is limited to $2^{16} - 1 = 65535$.

Write your answers to Readme.md and submit it to Gitlab server:

Timer Input Clock Frequency: _____16MHz_____

Timer Prescaler: ___15___

1. **What is time resolution (minimum time unit) of the input capture function?**

2. **If the echo signal is high for time duration from 150us to 38ms, what is the min and max value difference of CCR values in two consecutive interrupts?**

3. **For the prescaler you have selected, how long (in terms of seconds) after reset a counter overflow or underflow event occurs? Show your calculation.**

Part 2: Interface with Ultrasonic distance sensor

Configure Timer 4 Channel 1 as input capture

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	**TIMx_CR1**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	UIFREMAP	Res	CKD [1:0]		ARPE	CMS [1:0]		DIR	OPM	URS	UDIS	CEN
	Value																																
0x04	**TIMx_CR2**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	TI1S	MMS[2:0]			CCDS	Res	Res	Res
	Value																																
0x08	**TIMx_SMCR**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	SMS[3]	ETP	ECE	ETPS [1:0]		ETF[3:0]				MSM	TS[2:0]			Res	SMS[2:0]		
	Value																																
0x0C	**TIMx_DIER**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	TDE	COMDE	CC4DE	CC3DE	CC2DE	CC1DE	UDE	Res	TIE	Res	CC4IE	CC3IE	CC2IE	CC1IE	UIE
	Value																																
0x10	**TIMx_SR**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CC4OF	CC3OF	CC2OF	CC1OF	Res	Res	TIF	Res	CC4IF	CC3IF	CC2IF	CC1IF	UIF
	Value																																
0x14	**TIMx_EGR**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	TG	Res	CC4G	CC3G	CC2G	CC1G	UG
	Value																																
0x18	**TIMx_CCMR1** Output Compare mode	Res	Res	Res	Res	Res	Res	Res	OC2M[3]	Res	Res	Res	Res	Res	Res	Res	OC1M[3]	OC2CE	OC2M [2:0]			OC2PE	OC2FE	CC2S [1:0]		OC1CE	OC1M [2:0]			OC1PE	OC1FE	CC1S [1:0]	
	Value																																
	TIMx_CCMR1 Input Capture mode	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	IC2F[3:0]				IC2 PSC [1:0]		CC2S [1:0]		IC1F[3:0]				IC1 PSC [1:0]		CC1S [1:0]	
	Value																																
0x1C	**TIMx_CCMR2** Output Compare mode	Res	Res	Res	Res	Res	Res	Res	OC4M[3]	Res	Res	Res	Res	Res	Res	Res	OC3M[3]	O24CE	OC4M [2:0]			OC4PE	OC4FE	CC4S [1:0]		OC3CE	OC3M [2:0]			OC3PE	OC3FE	CC3S [1:0]	
	Value																																
	TIMx_CCMR2 Input Capture mode	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	IC4F[3:0]				IC4 PSC [1:0]		CC4S [1:0]		IC3F[3:0]				IC3 PSC [1:0]		CC3S [1:0]	
	Value																																
0x20	**TIMx_CCER**	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CC4NP	Res	CC4P	CC4E	CC3NP	Res	CC3P	CC3E	CC2NP	Res	CC2P	CC2E	CC1NP	Res	CC1P	CC1E
	Value																																

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Lab 8: Timer Input Capture
In-Lab Demo

Part 1: Measure the period of 1 Hz square signal

- Basic requirement: In the debug environment, show the period you have measured. Record the accuracy for the post-lab assignment.
- Something cool: for example, show time measurements on LCD.

Part 2: Interface with Ultrasonic distance sensor

- Basic requirement: In the debug environment, show the distance you have measured. . Record the accuracy for the post-lab assignment.
- Something cool: for example, show distance measurements on LCD.

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Lab 8: Timer Input Capture
Post-Lab Assignment

Write your answers to Readme.md and submit it to Gitlab server:

1. Does the timer counter count up or down in your lab? If counting up, how did you handle the counter overflow? (If counting down, how did you handle the counter underflow?)

2. What is the accuracy when measuring the period of 1Hz square wave?

3. What is the accuracy of the distance you have measured?

4. What is the most challenge issue you had in this lab?