

Embedded System Laboratory Course

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Protected: Lab 5 – Output Compare Match (PWM)

In this lab, we are going to blink LEDs and control the brightness of LEDs in three different Output Compare Match Modes, namely the normal mode, the CTC mode and the PWM mode.

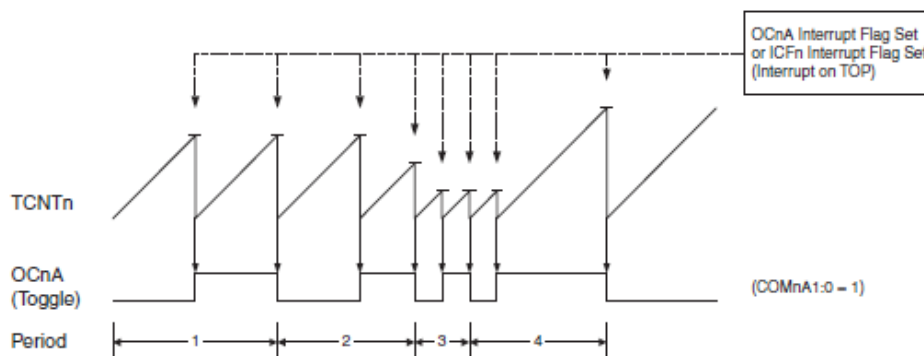
Part 1 (CTC Mode)

Introduction:

Output Compare Unit belongs to the Timer Module. The unit uses a 16-bits comparator continuously compare the Timer1 register TCTN1 with a pre-stored value in the Output Compare Register (**OCR1A**). When the counter TCTN1 matches (is equal to) OCR1A, the comparator signals a **Compare Match**. An Output Compare Interrupt (**TIMER1_COMPA_vect**) will be triggered. Please check the Timer Interrupt Mask Register (**TIMSK1**) to enable this interrupt.

There are different operation Mode. In Clear Time on Compare match (CTC) mode, the Counter (TCTN1) is increased by one in each clock cycle and will be automatically clear to zero when it matches OCR1A ($TCTN1 = OCR1A$). Please have a look at table 16-4 to check how to set to CTC mode. You need to set bits in the register TCCR1A and TCCR1B.

Figure 16-6. CTC Mode, Timing Diagram



Inside the Output Compare Interrupt Service Routine, you can write program to set the pins of PORTD to be on (logic high) or off (logic low). By setting the proper value in OCR1A, you can make LED blinking.

There is also a special output pin associated to the output compare unit, called **OC1A(PORTB1, please chek the Pin Layout diagram)**. This pin will auto-

matically toggle each time when the Compare Match happens (TCNT1=OCR1A) if you set the corresponding bit in TCCR1A, please check table 16-1.

Apart from generating equal on-off-time waveforms by fixed OCR1A, one can dynamically change the value in OCR1A to control the ratio of the on-time of the output waveform. When you have an LED blinking with a very high frequency (prescale = 1), human can hardly perceive its off-time. But the brightness of the LED is determined by the average of the on-time current, i.e., the logic high period of the waveform. By adjusting the on-time ratio, one can control the brightness of the LED. This type of digital-to-analog converting (convert a digital 16-bits value to an analog on-time ratio) is called **Pulse Width Modulation (PWM)**.

PreLab Tasks:

1. Read the the corresponding content in the datasheet and study the functions of necessary registers in order to enable the Output Compare Interrupt.
2. Calculate a proper combination of the value in OCR1A and counting frequency to have an Output Compare Match every 1 second.
3. Design a program that you can generate PWM signal on the pins of PORTD and on the pin OC1A.

Lab Assignments:

1. Write a proper program to blink the LED by output compare interrupt.
2. Try to have PWM waveform on PORTD.
3. Modify your counting frequency higher and higher such that you can not perceive the LED off. Try to have different brightness of your LED.

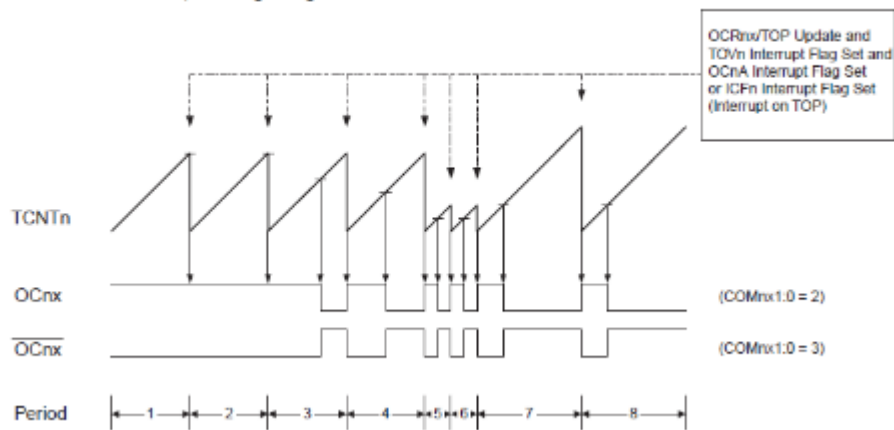
Lab Report: The requirements are the same as the previous lab.

Part 2 (Fast PWM Mode and the OC1A pin)

Introduction:

In Fast PWM mode, the Counter TCNT1 counts from BOTTOM (TCNT1=0) to TOP (TCNT1=TOP) and restarts from BOTTOM. Please look at Figure 16-7 below, the Compare Match happens when TCNT1 = OCR1A. **The pin OC1A can be cleared to be 0 on Compare Match and is set to be 1 when TCNT1=0 (at BOTTOM).** In the Table 16-2 in the datasheet, you can set the corresponding bits in TCCR1A register to allow the pin OC1A to behave in the above mentioned manner.

Figure 16-7. Fast PWM Mode, Timing Diagram



Then you can set the TOP value to be fixed and change the value of OCR1A to change the on-time, off-time duration of the pin OC1A. In order to set it to Fast PWM mode and set the TOP value, you need to set the register **TCCR1A** and **TCCR1B** (check table 16-4). Don't forget to set the prescale to be 1. A similar function is also applied to output pin **OC0A(PORTD6), OC0B(PORTD5), OC1B(PORTB2), OC2A(PORTB3), OC2B(PORTD3)**.

PreLab Tasks:

Find out how to generate a fast PWM signal on OC1A pin by setting proper registers.

Lab Assignments:

1. Check the Arduino Pin Layout and find out which pin is Output Compare pin OC1A. Connect one of your LED to this pin.
2. Control the brightness of the LEDs on pin OC1A by fast PWM Mode.
3. Make the LED starting from dark to bright automatically by using PWM Mode.