AMERICAN INTERNATIONAL UNIVERSITY-BANGLADESH (AIUB)
Faculty of Engineering
Department of Electrical and Electronic Engineering

Course/Lab Name: EEE4103 Microprocessor and Embedded Systems

Semester: Spring 2024-25 **Term**: Final **Quiz**: 02F **Total Marks**: 30 **Time**: 30 Minutes

Question Mapping with Course Outcomes:

Item	COs	POIs	K	P	A	Marks	Obtained Marks
Q1-3	CO1	P.a.4.C.3	K4			10 + 10 + 10	
					Total:	30	

Student Information:

Student Name:	Solve Sheet		**Section:**	P
Student ID #:	Solve Sheet	**Date:** 28.05.2025	**Department:**	

1. **Identify** the operation mode and the Timer of the Arduino Uno Microcontroller. **Compute** the duty cycle and PWM frequency of the identified mode based on the following program segment. **Sketch** the PWM waveform obtained at port D of Arduino Uno. The system clock frequency is 16 MHz. [**10**]

```
DDRD |= (1<<PD6);
OCR0A= 195;
TCCR0A |= (1 << COM0B1) | (1 << COM0B0) | (1<<WGM01) | (1<<WGM00);
TCCR0B |= (1<<WGM02) | (1<<CS02) | (1<<CS00);
```

Answer:
Here, Timer0 is used whose register setups are as follows for the Timer0:
TCCR0A = 0b00110011 and TCCR0B = 0b00001101
Since WGM02:0 bits are set to 111, it will operate in the **Fast PWM mode 7**. Since COM0B1:0 bits are set to 11, it produces an **inverting PWM signal** at port B (OC0B, PD5) by setting a HIGH to the OC0B pin while up-counting by the Timer0's counter register, TCNT0, and a LOW value to the OC0B pin when TCNT0 count value goes down to zero (BOTTOM). Since CS02:0 bits are 100, the pre-scaler value is, N = 1024.
The PWM frequency of the **Output B** for the Fast PWM Mode 3 is:

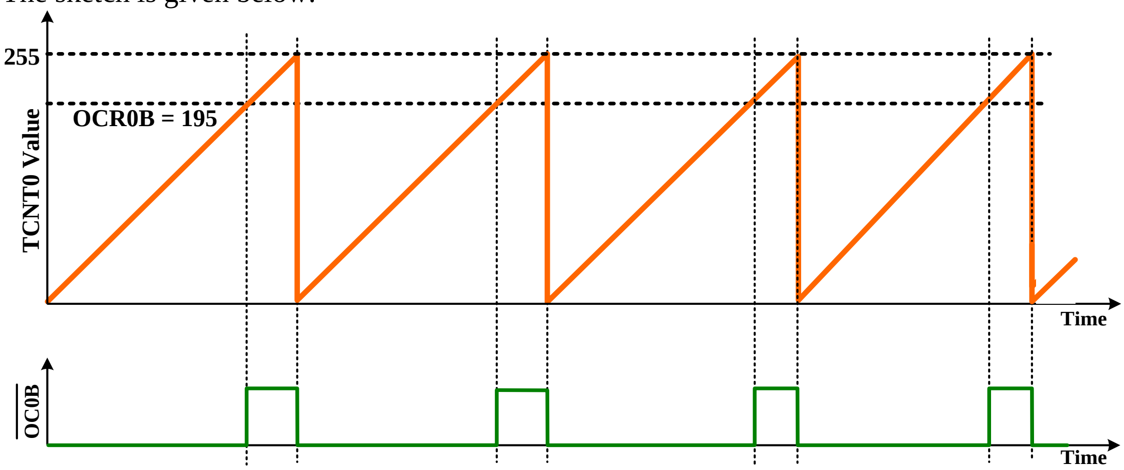
$$f_{OC0BFPWM} = \frac{f_{clk\_IO}}{N \times 256} = \frac{16 \times 10^6}{1024 \times 256} = 61.035 \text{ Hz}$$

The duty cycle of the **inverting mode Fast PWM** is calculated using the formula-

$$OCR0B = 255 - \frac{256D}{100} \Rightarrow \frac{256D}{100} = 255 - OCR0B$$

$$\therefore D = \frac{255 - OCR0B}{256} \times 100 = \frac{255 - 195}{256} \times 100 \cong 23.44\%$$

The sketch is given below:

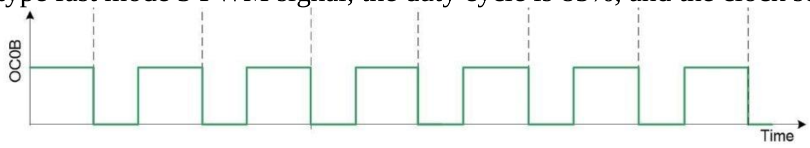


Bit	7	6	5	4	3	2	1	0	
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00	TCCR0A
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Bit	7	6	5	4	3	2	1	0	
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00	TCCR0B
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

CS02	CS01	CS00	Description
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	$clk_{I/O}$/(No prescaling)
0	1	0	$clk_{I/O}$/8 (From prescaler)
0	1	1	$clk_{I/O}$/64 (From prescaler)
1	0	0	$clk_{I/O}$/256 (From prescaler)
1	0	1	$clk_{I/O}$/1024 (From prescaler)
1	1	0	External clock source on T0 pin. Clock on falling edge.
1	1	1	External clock source on T0 pin. Clock on rising edge.

2. **Compute** the ON time and OFF time of the following PWM wave if the CPU's oscillator frequency, f_{OSC} = 16 MHz. **Compute** the value of the OCR0B register for the corresponding duty cycle. Assume a non-inverting type fast mode 3 PWM signal, the duty cycle is 85%, and the clock select bits are 011. [**10**]



Answer:

Assuming a non-inverting type PWM signal, we compute the OCR0B register value for 85% duty cycles,

$$OCR0B = \frac{256D}{100} - 1 = \frac{256 \times 85}{100} - 1 = 218 - 1 = 217$$

Therefore, the PWM frequency for the given waveform, using the Fast mode-3 PWM signal with N = 64 (since the clock select bits are 011),

$$f_{OC0A} = \frac{f_{clk\_IO}}{N \times 256} = \frac{16 \times 10^6}{64 \times 256} = 976.5625 \text{ Hz}$$

So, time period of this signal is

$$T = \frac{1}{f_{OC0A}} = \frac{1}{976.5625} = 1024\ \mu s$$

So, ON time, $T_{ON} = 1024 \times 0.85 = 870.4\ \mu s$ and OFF time, $T_{OFF} = 1024 \times 0.15 = 153.6\ \mu s$

3. **Compute** the OCR0B value, **identify** the values of TCCR0A and TCCR0B registers, and operation modes, and **compute** the PWM frequency of the defined mode based on the following parameters: [**10**]
   i. Fast inverting PWM mode 3 (011);
   ii. The TOP value = 210;
   iii. Pre-scalar value 64 (011);
   iv. Duty cycle to 70%;
   v. The system clock frequency is 16 MHz.

Fill up the blank spaces of the following code segment:

```
DDRD |= (1<<_____);
OCR0A = ____________;
OCR0B = ____________;
TCCR0A |= (1 << _________) | (1 << _________) | (1<<______________)| (1<<______________);
TCCR0B |= (1<<____________) | (1<<__________)
```

Sketch the waveform obtained at port D of the Arduino.

Answer:

Here, Timer0 is used whose register setups are, TCCR0A = 0b00110011 and TCCR0B = 0b00000011. Since it will operate in the Fast PWM mode 3, the WGM02:0 bits are set to 011. Since it will produce an inverting PWM signal at port B (the program has both OCR0A and OC0B), port OC0B, that is, port PD5, will produce the output. As such, COM0B1:0 bits are set to 11. That is, the output toggles the PWM signal at port B (OC0B, PD5) upon the comparison match with the OCR0B register's contents with that of the TCNT0 register. OCR0A value is the TOP value as given as 210. Since the pre-scaler value is, N = 64, CS02:0 bits are set to 011.

The PWM frequency of **Output B** for the **Fast PWM Mode 3** is:

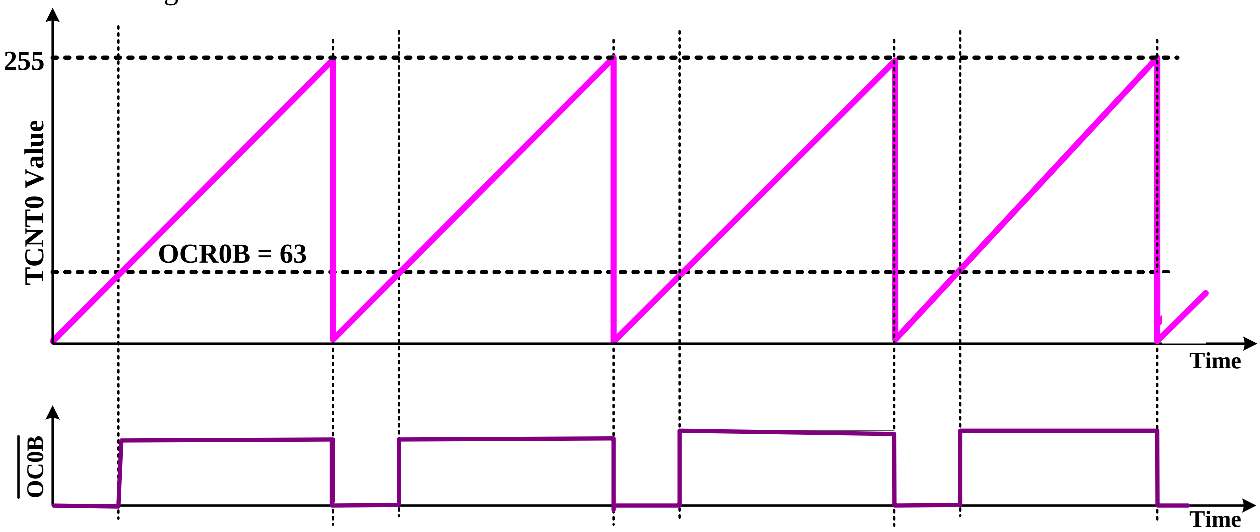
$$f_{OC0BFPWM} = \frac{f_{clk\_IO}}{N \times (1 + OCR0A)} = \frac{16 \times 10^6}{64 \times (1 + 210)} = 1184.84 \text{ Hz}$$

The value of the output compare register, OCR0B for the **inverting Fast PWM Mode 3** is given by (TOP = OCR0A = 210):

$$OCR0B = OCR0A - \frac{(1 + OCR0A)D}{100}$$

$$\therefore OCR0B = 210 - \frac{(1 + 210) \times 70}{100} = 63$$

The sketch is given below:



The blank spaces of the codes are corrected as follows:

```
DDRD |= (1<<_PD5_);
OCR0A = _210_;
OCR0B = __63__;
TCCR0A |= (1 << _COM0B1__) |(1 << _COM0B0__) | (1<<__WGM01_) | (1<<__WGM00_);
TCCR0B |= (1<<_CS01_)| (1<<_CS00_);
```