MEAM 5100: Design of Mechatronic Systems Fall 2024

Lab 1 Solutions

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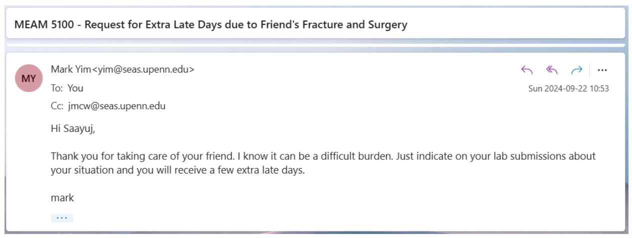
I had requested for extension/extra late days from Prof Yim due to some unforeseen circumstances. He told me to just mention in the lab report so I am attaching the proof here. Thank you for the consideration.



MEAM 5100 - Request for Extra Late Days due to Friend's Fracture and Surgery

MY Mark Yim<yim@seas.upenn.edu>
To: You
Cc: jmcw@seas.upenn.edu
Sun 2024-09-22 10:53

Hi Saayuj,

Thank you for taking care of your friend. I know it can be a difficult burden. Just indicate on your lab submissions about your situation and you will receive a few extra late days.

mark

Figure 1: Proof of extra late days awarded

1 LED

1. 1. • The LED I chose was 160-1709-ND LED 3MM YELLOW TRANSPARENT, LTL-1CHYE. For this LED, the relevant datasheet from the Digikey website is:

Electrical Optical Characteristics at T_A=25℃

Parameter	Symbol	Min.	Typ.	Max.	Unit	Test Condition
Luminous Intensity	I_V	12.6	40		mcd	I_F = 10mA Note 1,4
Viewing Angle	$2\theta_{1/2}$		45		deg	Note 2 (Fig.6)
Peak Emission Wavelength	λ_P		585		nm	Measurement @Peak (Fig.1)
Dominant Wavelength	λ_d		588		nm	Note 3
Spectral Line Half-Width	$\Delta\lambda$		35		nm	
Forward Voltage	V_F		2.1	2.6	V	I_F = 20mA
Reverse Current	I_R			100	μA	V_R = 5V
Capacitance	C		15		pF	V_F = 0 , f = 1MHz

Figure 2: LTL-1CHYE Electrical Optical Characteristics

• From these specifications, we can see that the typical forward voltage $V_f = 2.1$V and forward current $I_f = 20$mA. For a source voltage of $V_s = 5$V, resistance

$R = \frac{V_s - V_f}{I_f} = 145\Omega$. We can also verify the minimum resistance using the absolute maximum ratings, though this is not recommended because even a bit of perturbation from the absolute values can cause damage to the circuit. But just as a second measure let us use that too. From the absolute maximum ratings datasheet, the maximum power dissipation P is 60mW and thus the minimum resistance is $P \leq \frac{(V_s - V_f)^2}{R} \implies R \geq \frac{(V_s - V_f)^2}{P} = 140.17\Omega$. Thus, it is safe to say that the resistance $R \geq 145\Omega$ is a good estimate. Thus, I chose the 150Ω resistor, which was the closest larger value to 145Ω.

2.
- I chose a 150Ω resistor, which was the closest larger value to 145Ω. For 150Ω, the LED glows very brightly. For 1kΩ, 3.3kΩ, 10kΩ, 13.3kΩ, the LED continues to glow but its brightness reduces significantly. Finally, for a resistance value of 16.2kΩ, the LED becomes very very dim. So **16.2kΩ** would be the answer.
- For this resistor value, the current on the voltage supply shows 0.000A, which makes sense because the current is so low that the voltage supply cannot sense it due to its least count of 0.001A. Let us calculate the current I for this case:

$$I = \frac{V_s - V_f}{R} = \frac{5 - 2.1}{16200} = 0.000179A$$

3.
- I chose the green water clear 5mm LED (LTL-4238) and the InGaN blue water clear 5mm LED (LTL2T3TBK5).
- The typical forward voltage for the green LED is 2.1V and for the blue LED it is 3.5V. So from specifications, only the green LED should glow or at least glow brighter because it has a lower forward voltage. This is what we observe while performing the experiment as well, as seen in 3. In this case, since the forward voltage for the blue LED is much larger than that of the green LED, only the green LED glows. But if they were comparable, green would glow brighter but the blue one would also glow dimly.
- Voltage at point A is 2.06V, which is very close to the forward voltage of the green LED, which is 2.1V. This is correct because current only flows through the green LED since it has a lower forward voltage, hence the voltage only drops across the green LED, causing the current to be $\frac{5-2.1}{330}A$. Thus the voltage at A is simply $5 - \frac{5-2.1}{330} * 330 = 2.1V$. Thus, the experimental value more or less matches with the theoretical value, and the forward voltage of the two LEDs is the specification which determines the voltage at point A.

4.
- I increased the power supply to 6V to get both the LEDs to glow. This is expected too because the forward voltages of the two LEDs are 3.5V and 2.1V, so the power supply should be greater than equal to 5.6V to get both the LEDs to be forward biased. The green LED was placed closer to the resistor and power supply, while the blue LED was connected to ground.
- The following table explains the theoretical and experimental voltage readings at the following junctions with respect to ground:

Measurement Location	Theoretical Voltage	Experimental Voltage
Resistor-Green LED interface	4.825V	5.6V
Green LED-Blue LED interface	2.87V	3.5V

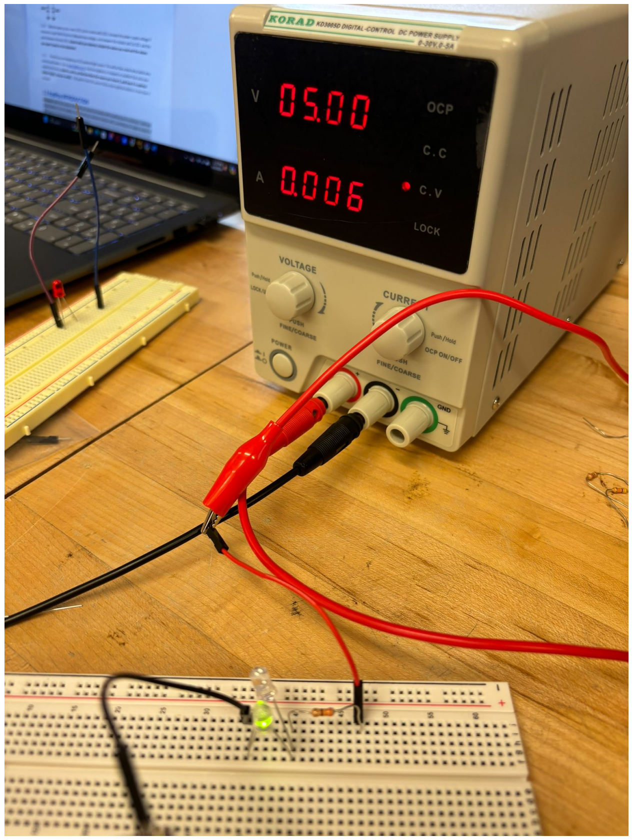


Figure 3: Parallel connection of the two LEDs

- This experimental result is very far off from our theoretical result, which is mostly due to the fact that very close to the cutoff voltages, the diodes do not behave ideally and the forward voltage is not really a step function but an increasing curve with a finite slope. Hence, the measured voltages come out to be less than the theoretical values. As we go on increasing the supply voltage from 6V to 12V, the experimental voltages at the junctions move closer to the theoretical voltages, because the supply voltage is enough to forward bias the diodes enough to bring it closer to the 'idealized' step function forward voltages or maximum forward voltages.

5. I chose JB3030AWT-P-U30EA0000-N0000001 - LED J WARM WHT 3000K SMD for the purpose of a desk lamp, as seen in 4. I chose this LED because it is only for $0.10/unit, has an ambient and warm white color which is good for working on the desk, has a broad viewing angle of 120°, can be surface mounted and is very small (3mm x 3mm) so can be fitted anywhere.

2 ItsyBitsy Introduction

2. 1. I chose pin PB6 on the ItsyBitsy board, thus I changed the registers DDRB and PORTB. This is because for our application we need to define PB6 as output and then

Figure 4: Chosen LED from Digikey

turn it on (or set it to 1). Thus, I set DDRB = PORTB = 0x40 to set B6 as output and turn it on. Then PORTB = 0x00 will switch off PB6. This is useful for getting the LED to blink.

2. - 5 shows the circuit I made. I connected the LED LTL-1CHYE in series with 150Ω resistor. The positive end of the LED is connected to pin B6 and the negative end to the ground G on the board.
   - I chose the same LED that I took in Q1. For this LED, the minimum resistance value is 145Ω, so I chose the closest larger resistance value available in the ministore, which was 150Ω. The explanation and working to derive the minimum resistance value is there in 1.1. I added the resistance in series to protect the LED and ItsyBitsy from any damage due to excess current flowing through the LED terminals.
3. The commented code is submitted separately on Gradescope.
4. - The commented code is submitted separately on Gradescope.
   - The off time for a constant on time has been derived in the following way:

$$DutyCycle = \frac{OnTime}{OnTime + OffTime} \implies OffTime = OnTime*(\frac{1}{DutyCycle} - 1)$$

I have fixed the on time as 50 ms.

3 Timers

3. 1. - I used Timer 3 with prescaler = /64 (CS31 = CS30 = 1, CS32 = 0) for this question. For a desired frequency of 20 Hz, the LED should be on for 1/40 seconds and off for the same time. Thus, we get our counter cutoff to be:

$$TCNT3_{threshold} = \frac{16MHz}{64 * 40} = 6250$$

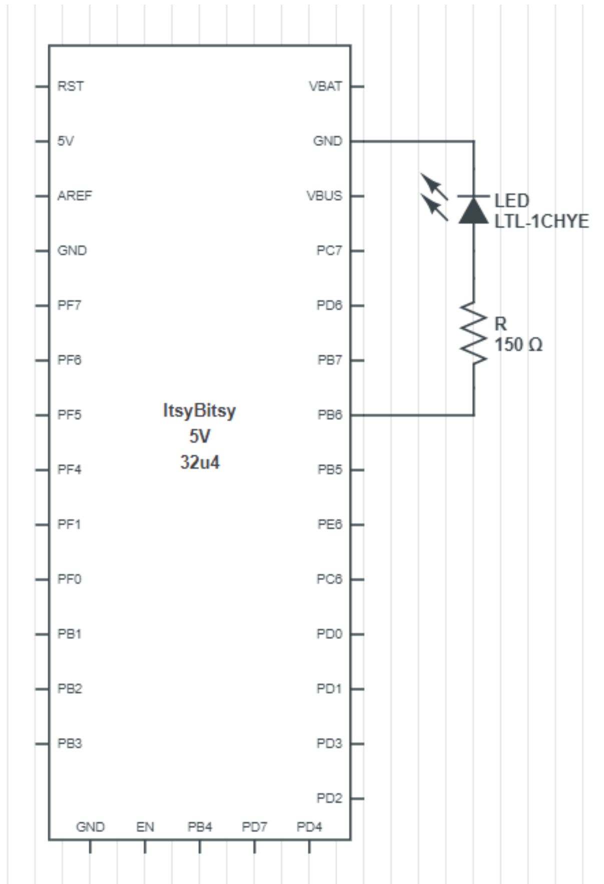


Figure 5: Circuit diagram of LED, ItsyBitsy and Resistor R

Thus, the LED will be on for 6250 counts, off for the next 6250 counts and so on. That is what has been implemented in the code.

- 6 shows the oscilloscope screen showing the 20 Hz signal.
- The commented code is submitted separately on Gradescope.

2. - The system clock frequency is 16 MHz.
   - If we adjust the system clock pre-scaler without changing the timer counter threshold (6250 for my case), as we decrease the prescaler, our frequency decreases. For a counter threshold of 6250, and a prescaler of /1, I got a frequency of 1.28 kHz, for a prescaler of /8, frequency was 160.45 Hz, and for a prescaler of /256, frequency was $<$ 10 Hz. But if we calculate the corresponding counter threshold for the prescaler then we can maintain our 20 Hz frequency. For example, for a prescaler of /256

$$TCNT3_{threshold} = \frac{16MHz}{256 * 40} = 1562.5$$

This counter value when used as the cutoff/compare value gave a frequency of 20 Hz. This is according to expected behaviour only, because the prescaler affects our counter compare value and thus we need to change it to make sense of the frequency output.

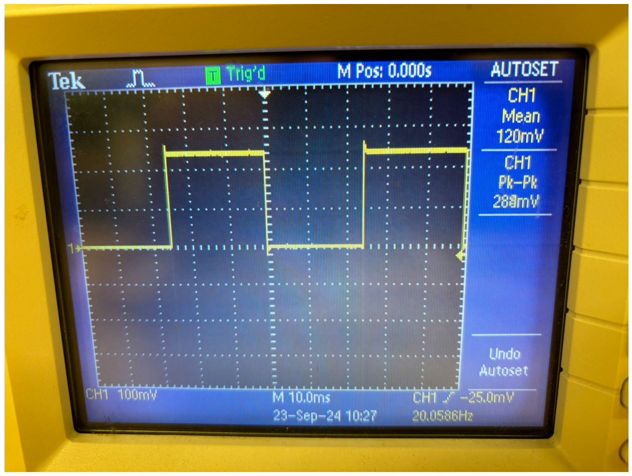


Figure 6: Oscilloscope screen showing 20 Hz signal

3. - For this question, I had to switch from pin B6 to pin C6 because OC3A is multiplexed onto C6, and I was already using Timer 3 so I continued with that. I made DDRC = PORTC = 0x40 to enable PC6 as output and turn it on. I used the following timer options for generating the PWM:-
     - WGM33 = WGM32 = WGM32 = 1, WGM30 = 0 $\implies$ Timer UP to ICR3, PWM mode
     - COM3A1 = 1, COM3A0 = 0 $\implies$ clear at OCR3A, set at rollover
     - CS31 = CS30 = 1, CS32 = 0 $\implies$ Prescaler = /64
     - ICR3 = 4999 $\implies$

$$Frequency = \frac{F_{CPU}}{Prescaler * (ICR3 + 1)} = \frac{16MHz}{64 * 5000} = 50Hz$$

     - $\because$ Duty cycle is the ratio of OCR3A to ICR3 register values:

$$OCR3A = \frac{DutyCycle(in\%) * ICR3}{100.0}$$

   - Link to video of generating PWM with different duty cycles: Link
   - In the video, you can clearly see that the code can generate 0% and 100% duty cycles. When duty cycle = 0%, OCR3A = 0, and when duty cycle = 100%, OCR3A = ICR3 = 4999.
   - The commented code is submitted separately on Gradescope.

4 Practice with Loops

4\. 1. - Link to video of repeating asymmetric pulses (0.3 seconds to full intensity and 0.6 seconds to 0 intensity): Link
   - 7 is the circuit diagram for this question. Pin C6 is used because Timer 3 of the ItsyBitsy is multiplexed onto C6. A resistor is connected in series with the LED

to protect it from overheating and damage due to excess current flowing through its terminals. The negative end of the LED is connected to the ground G on the ItsyBitsy.

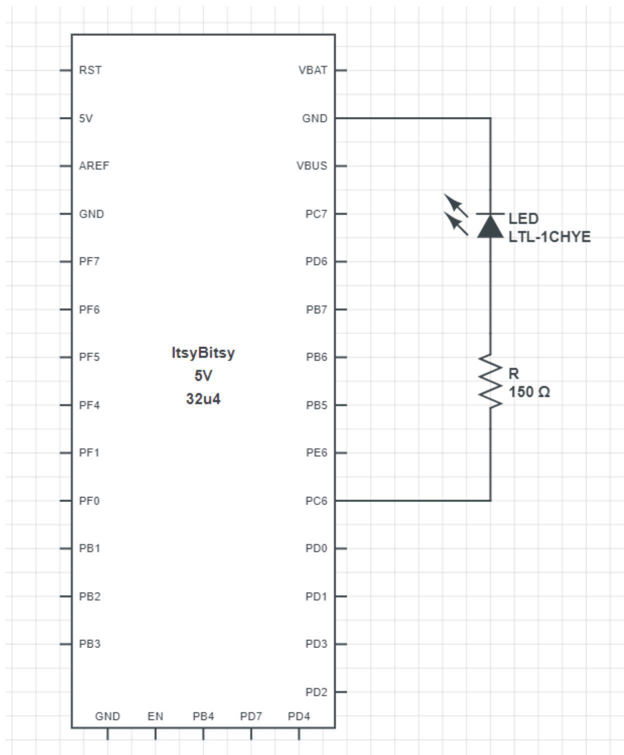


Figure 7: Circuit diagram consisting of ItsyBitsy, LED, Resistor R

- The commented code is submitted separately on Gradescope.

2. - Link to video of LED blinking like a heartbeat: Link
   - The commented code is submitted separately on Gradescope.
3. - Link to video of LED blinking like a weakening heartbeat: Link
   - The commented code is submitted separately on Gradescope.
   - Checked off by TA Haorui Li.

5 Retrospective

5. 0. Time taken for each section:
   - 1 LED - 3-4 hours
   - 2 ItsyBitsy Introduction - 6-7 hours
   - 3 Timers - 8-9 hours
   - 4 Practice with Loops - 6-7 hours

6 References

1. Latex template from the course CIS 5190 taught this fall.
2. MEAM 5100 Fall 2024 Lecture Slides.
3. Digikey for LED specifications and datasheets.
4. Stack Overflow for writing in C.
5. ItsyBitsy from CircuitLab
6. I performed some of the experiments in the lab with other people but have written my own report.