An LED and Spectroscopy System for Detecting Aflatoxin in Corn

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ECE 445 Presentation -- Spring 2018

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Objective

- Aflatoxins: toxic carcinogens produced by fungi, majorly Aspergillus flavus and Aspergillus parasiticus
- It grows in agricultural crops such as corn, peanuts, and tree nuts [1].
- Exposure to Aflatoxins can cause fatal damages to organs, especially for children. This may leads to stunted growth, liver damage, and liver cancer [2].
- We decide to create a low-cost Light Emitting Diodes (LEDs) spectroscopy system to let researchers from other places participate in this aflatoxin research.
- A group of researchers have built a device in the laboratory of Professor Matt Stasiewicz. We worked with John M. Hart to build and improve the reflectance spectroscopy system based on these principles for detecting the presence of aflatoxins, which can be reproduced and distributed.

Background

- Near infrared reflectance spectroscopy with a range of 550nm to 1700nm was used to evaluate the quality of grains and nuts [3]
- According to Ali Güneş's research, spectral data collected from NIR spectroscopy on a specimen, can be used to determine the presence of the toxins [4].
- Under ultraviolet light, the toxins exhibits Bright Greenish Yellow Fluorescence (BGYF) in visible light spectrum.
- The B-group Aflatoxins exhibit blue fluorescence (wavelength: 450 nm)
- The G-group exhibits yellow-green fluorescence (wavelength: 550 nm) under ultraviolet light [5].

Block Diagram

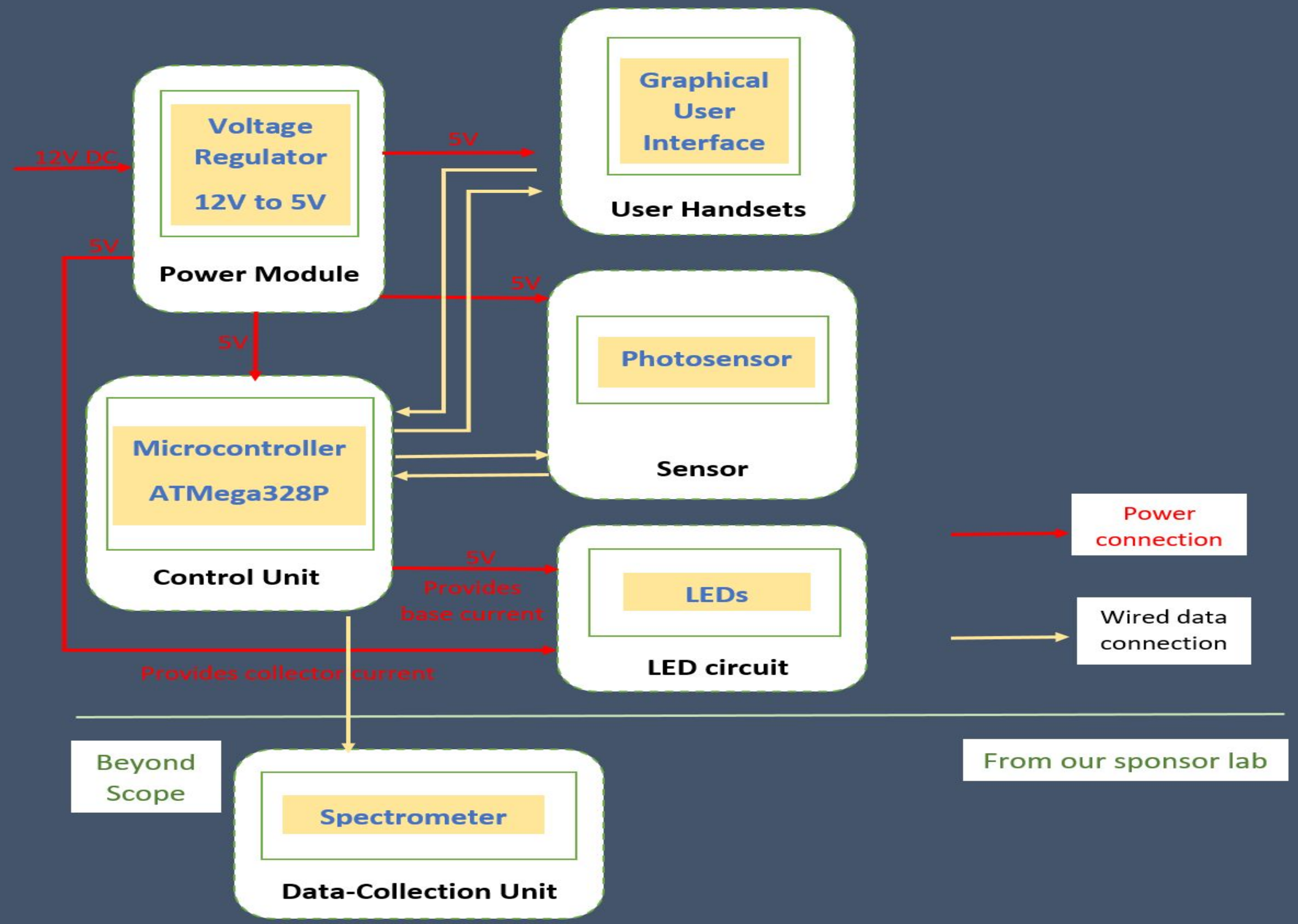


Figure 1: Block diagram

High Level Requirement

- Control the brightness of each individual groups of LED
- Voltage regulator can output 5V and provide sufficient current to the circuit
- Spectrum can be collected and displayed on computer/laptop

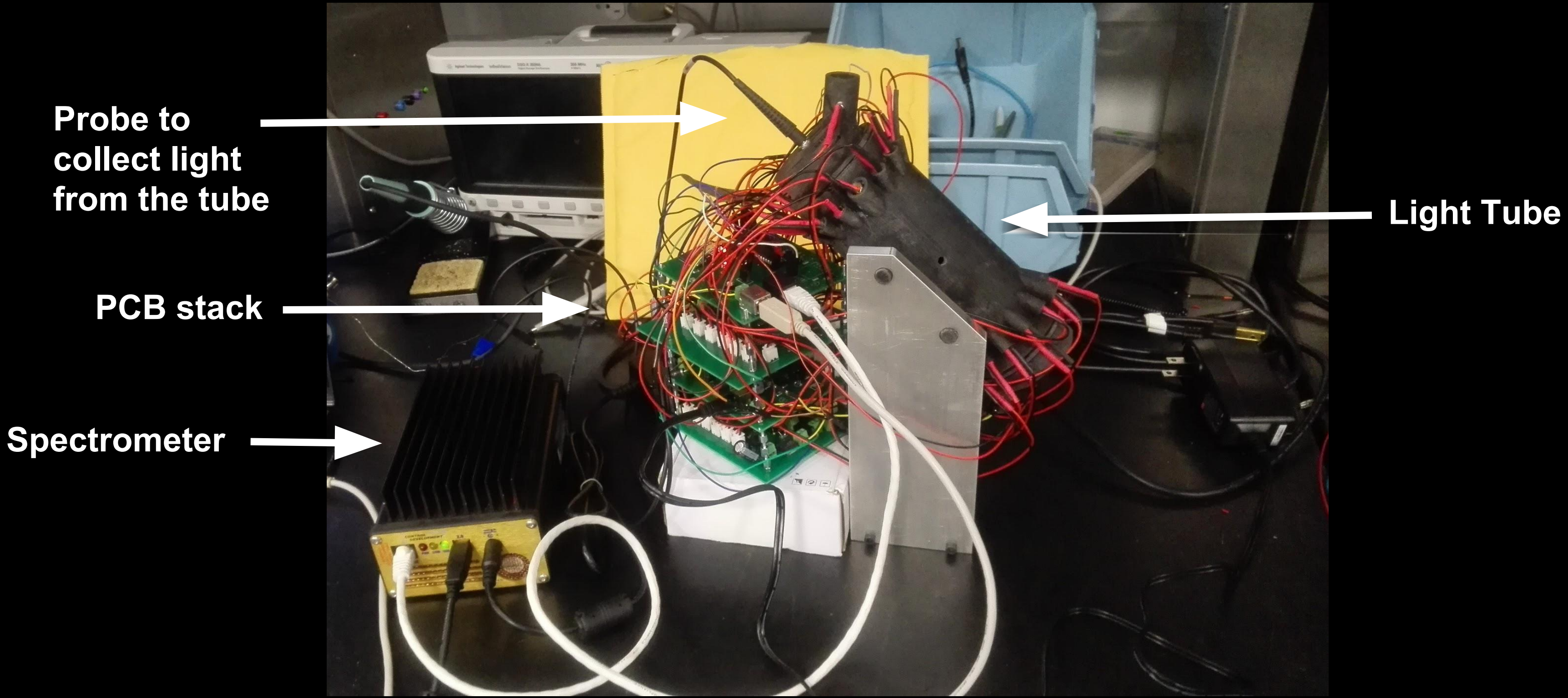


Figure 2: Set-up of the project

LED integration into tube assembly

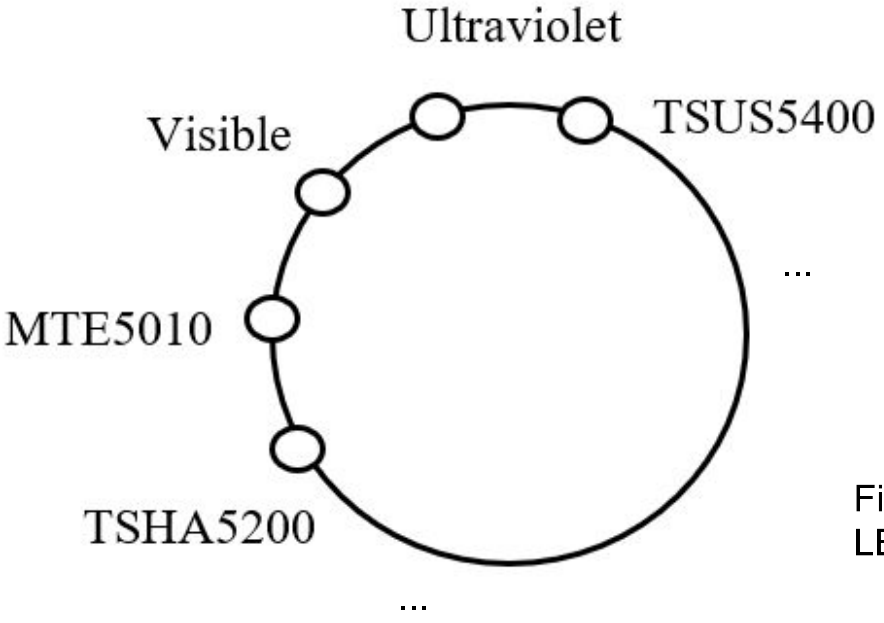
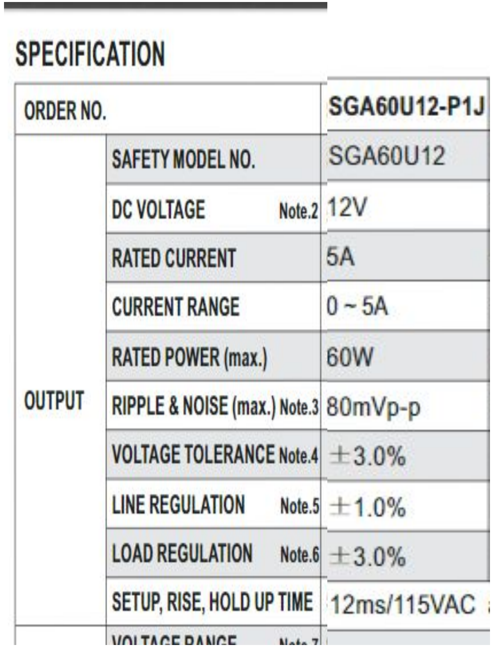


Figure 3: Arrangement of LEDs around the light tube

Power Supply (12V, 5A)

Figure 4: Power plugged into socket on lab bench



SPECIFICATION

ORDER NO.		SGA60U12-P1J
OUTPUT	SAFETY MODEL NO.	SGA60U12
	DC VOLTAGE Note.2	12V
	RATED CURRENT	5A
	CURRENT RANGE	0 ~ 5A
	RATED POWER (max.)	60W
	RIPPLE & NOISE (max.) Note.3	80mVp-p
	VOLTAGE TOLERANCE Note.4	±3.0%
	LINE REGULATION Note.5	±1.0%
	LOAD REGULATION Note.6	±3.0%
	SETUP, RISE, HOLD UP TIME	12ms/115VAC
	VOLTAGE RANGE Note.7	

Figure 5: Specification from the power adapter datasheet

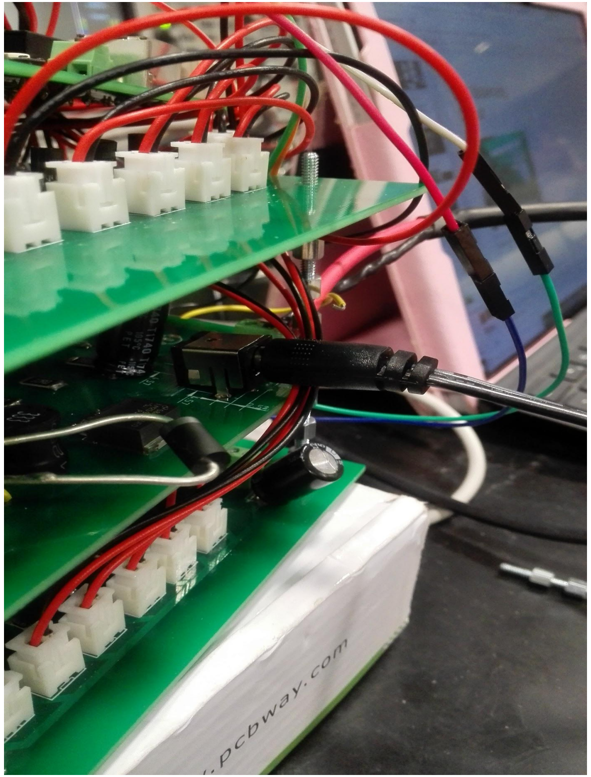


Figure 6: Power adapter connected to circuit board with a barrel connector

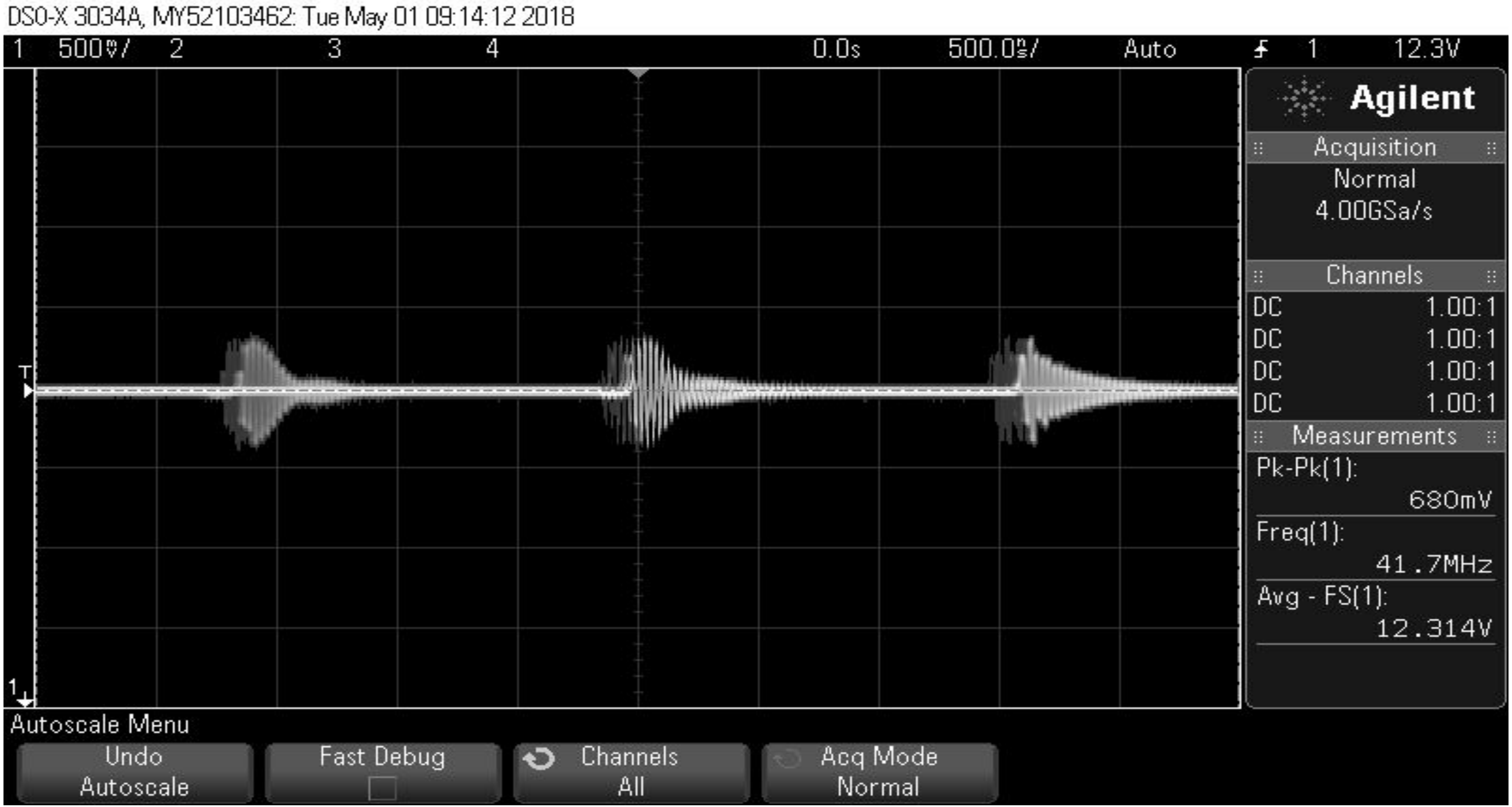


Figure 6: Screenshot captured from oscilloscope

Voltage regulator (LM2596-5.0)

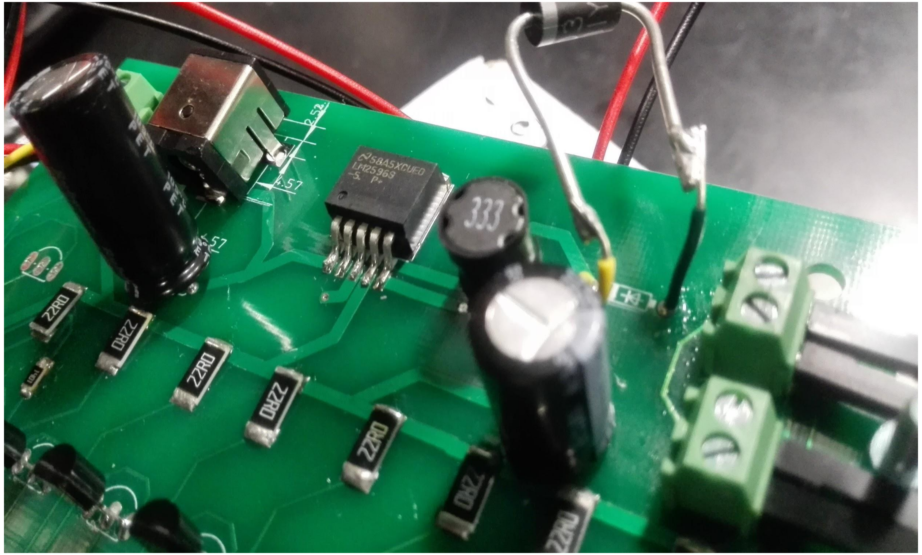


Figure 7: Voltage Regulator PCB

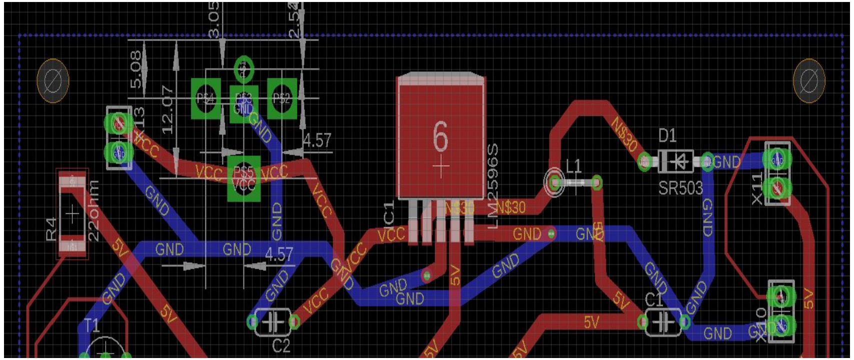


Figure 8: Voltage Regulator PCB Design

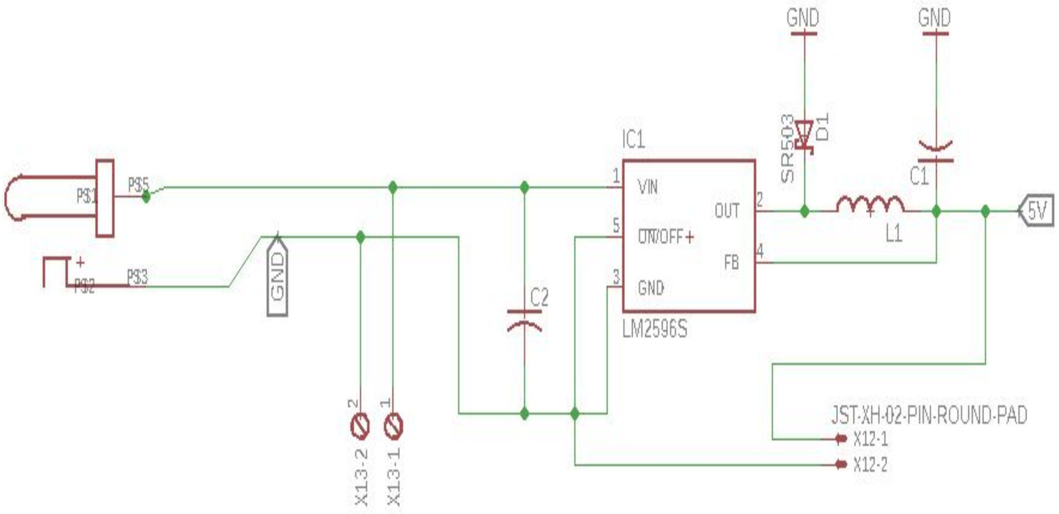


Figure 9: Voltage Regulator Schematic

- Input and output capacitor: Reduce noise

(For an aluminum electrolytic, the capacitor voltage rating must be approximately 1.5 times the maximum input voltage)[6]

- Inductor: Store energy and ensure the regulator to function well in continuous mode

- Schottky diode: prevent backflow of current

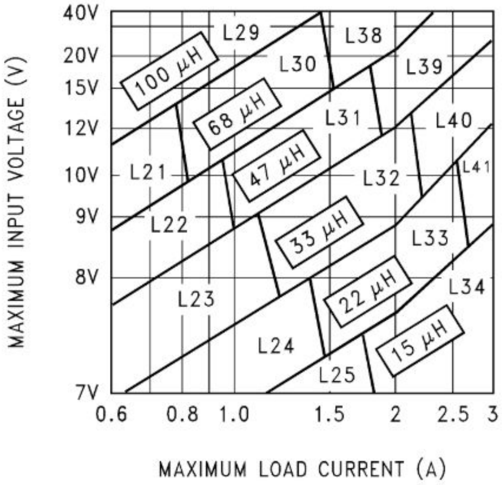


Figure 28. LM2596-5.0

Voltage Regulator Datasheet [6]

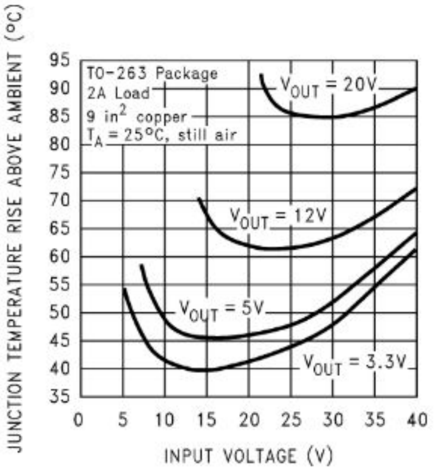
9.2.1.2.3 Catch Diode Selection (D1)

1. The catch diode current rating must be at least 1.3 times greater than the maximum load current. Also, if the power supply design must withstand a continuous output short, the diode must have a current rating equal to the maximum current limit of the LM2596. The most stressful condition for this diode is an overload or shorted output condition. See Table 4. In this example, a 5-A, 20-V, 1N5823 Schottky diode will provide the best performance, and will not be overstressed even for a shorted output.

Table 4. Diode Selection Table

VR	3-A DIODES				4-A TO 6-A DIODES			
	SURFACE-MOUNT		THROUGH-HOLE		SURFACE-MOUNT		THROUGH-HOLE	
	SCHOTTKY	ULTRA FAST RECOVERY	SCHOTTKY	ULTRA FAST RECOVERY	SCHOTTKY	ULTRA FAST RECOVERY	SCHOTTKY	ULTRA FAST RECOVERY
		All of these diodes are rated to at least 50V.	1N5820	All of these diodes are rated to at least 50V.		All of these diodes are rated to at least 50V.	SR502	All of these diodes are rated to at least 50V.
20 V	SK32		SR302				1N5823	
			MBR320				SB520	
	30WQ03		1N5821					
30 V	SK33		MBR330		50WQ03		SR503	
			31DQ03				1N5824	
			1N5822				SB530	
40 V	SK34		SR304		50WQ04		SR504	
	MBRS340		MBR340				1N5825	
	30WQ04	MURS320	31DQ04	MUR320		MURS620	SB540	MUR620
50 V	SK35	30WF10	SR305			50WF10		HER601
or	MBRS360		MBR350		50WQ05		SB550	
More	30WQ05		31DQ05				50SQ080	

Voltage Regulator Datasheet [6]



CIRCUIT DATA FOR TEMPERATURE RISE CURVE TO-263 PACKAGE (S)

Capacitors	Surface-mount tantalum, molded *D* size
Inductor	Surface-mount, Pulse Engineering, 68 µH
Diode	Surface-mount, 5-A 40-V, Schottky
PCB	9-square inch, single-sided, 2-oz. copper (0.0028″)

Figure 41. Junction Temperature Rise, TO-263

Requirement and Verification (Voltage Regulator 1)

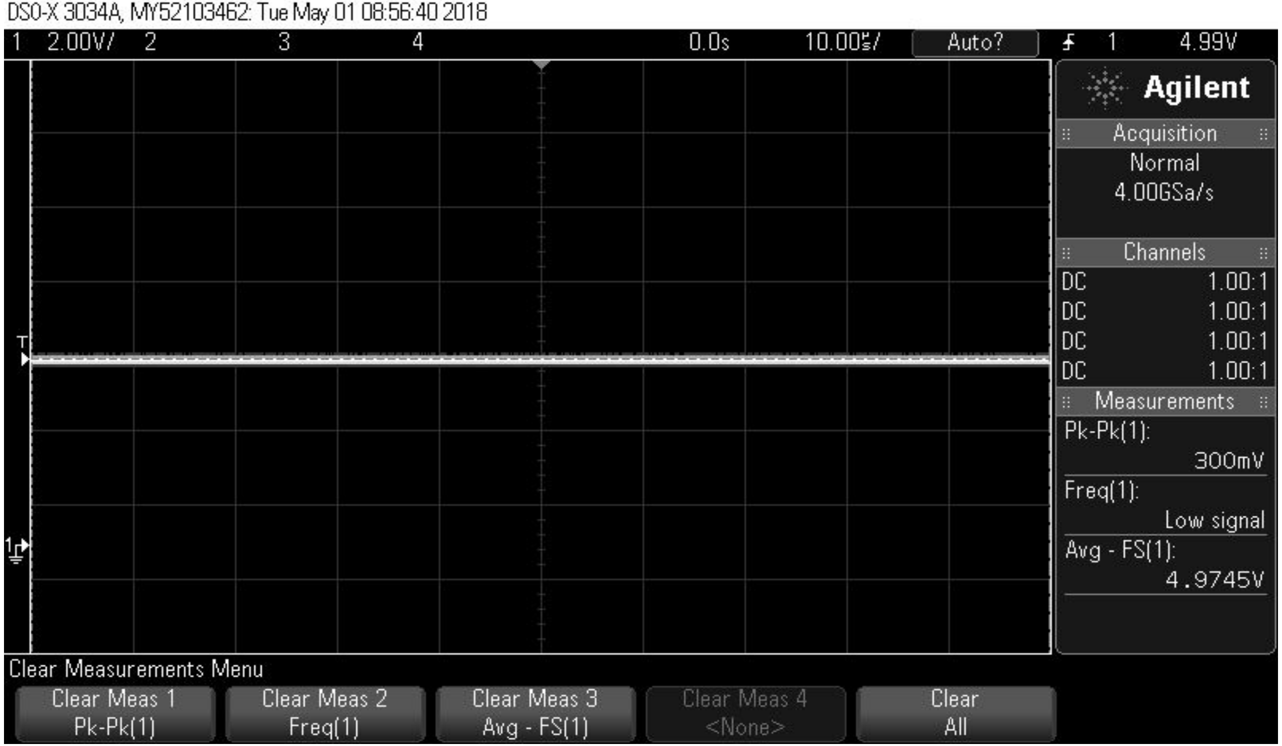


Figure 10: Voltage Regulator 1 Output

Requirement and Verification (Voltage Regulator 2)

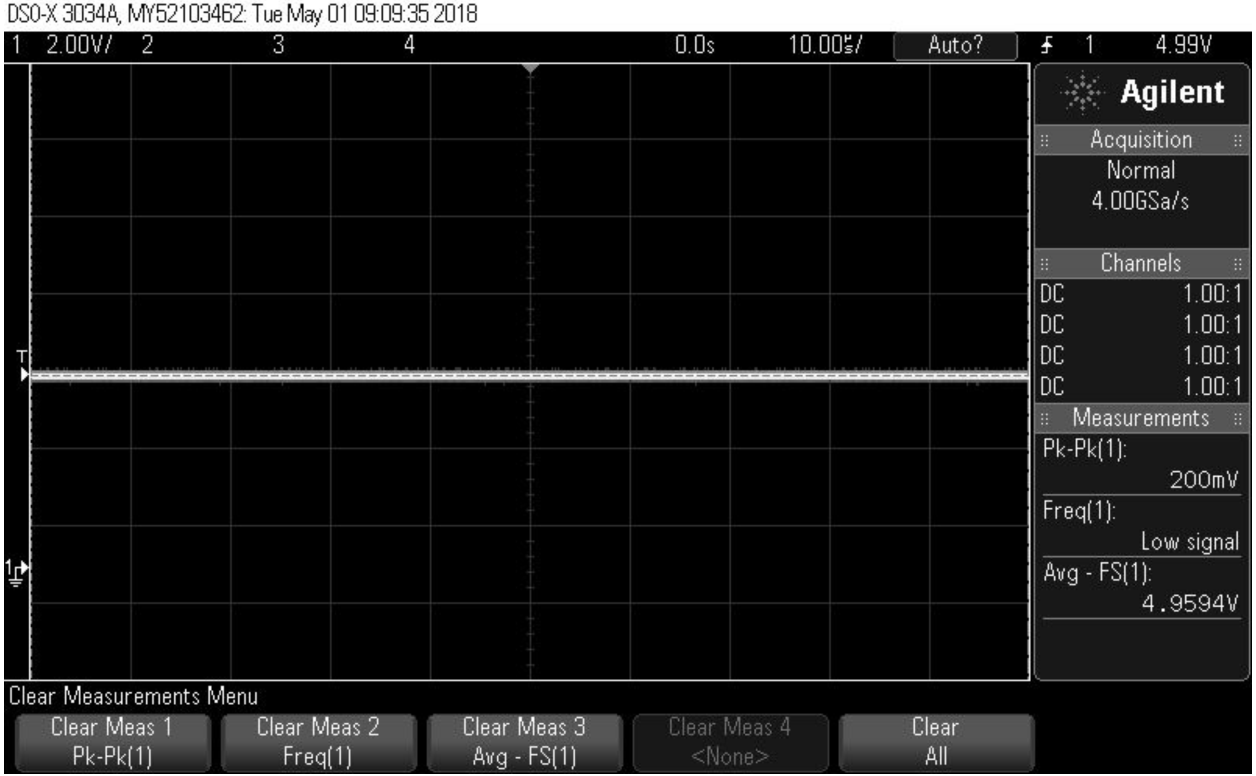


Figure 11: Voltage Regulator 2 Output

LED Selection

TSUS5400 950nm

TSHA5200 870nm

MTE5010 1050nm

MTE3650 365nm

C513A 450nm, 600nm

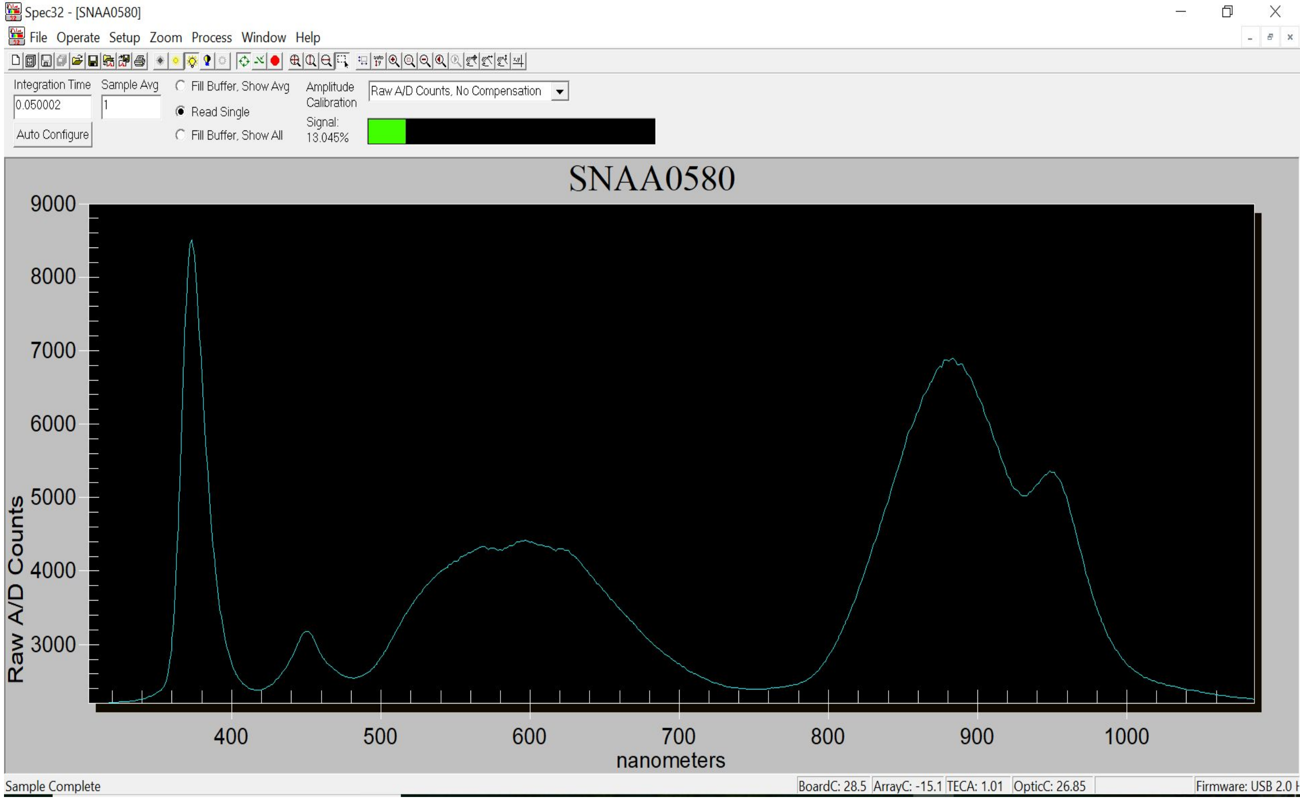


Figure 12: Spectrum of LEDs used in experiment

LED Balancing Circuit

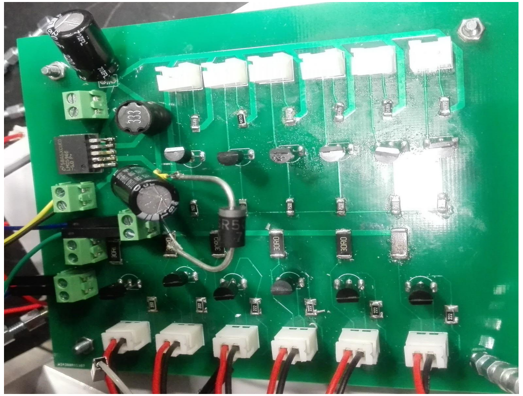


Figure 13: LED PCB

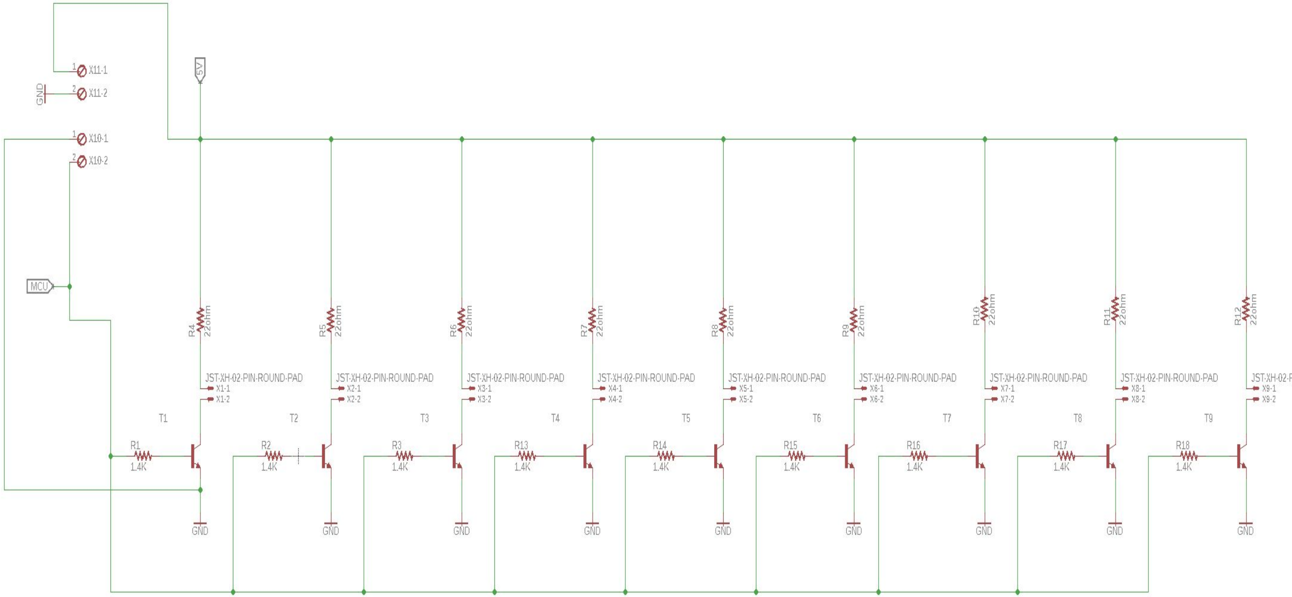


Figure 14: LED schematic

$$R_c = \frac{V_{cc} - V_{led} - V_{CE}}{I_c}$$

$$I_B = \frac{I_c}{h_{FE}}$$

$$R_B = \frac{V_{pin} - V_{BE}}{I_B}$$

V_{CE} = 0.3V
V_{BE} = 0.6V-1.0V
h_{FE} = 35-50
I_B <= 40mA

Maximum Brightness

LED part number	Forward Voltage from Datasheet (V)	Actual voltage across the LED (V)
TSUS5400	1.3	1.385, 1.365, 1.394, 1.428, 1.358, 1.585
TSHA5200	1.5	1.401, 1.411, 1.387, 1.386, 1.398, 1.385
MTE5010	1.2	1.236, 1.230, 1.237, 1.228, 1.229, 1.226
MTE3650	3.5	3.352, 3.389, 3.360, 3.389, 3.344, 3.348
C513A	3.2	3.124, 3.092, 4.85, 3.036, 3.080, 3.082

LED and Sensor

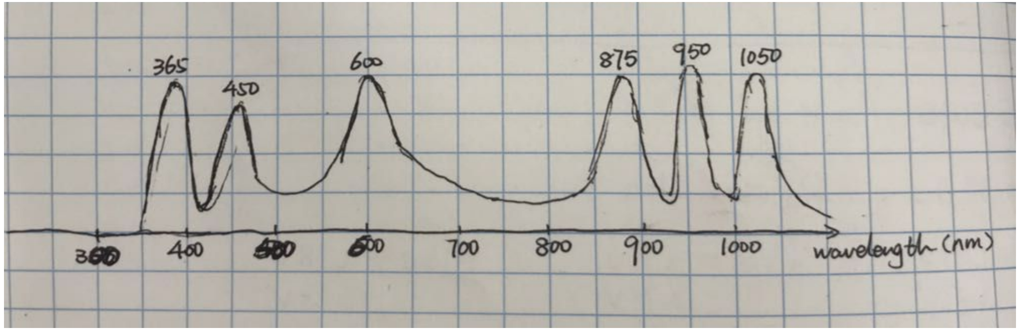


Figure 15: Wavelength of LEDs used in experiment

MTE1077N1-R:

770nm visible light LED

SD5600 honeywell sensor:

(peak wavelength: 850, relative sensitivity at 770 nm: 0.9)

Light is detected: ~1

Light is blocked: ~1000

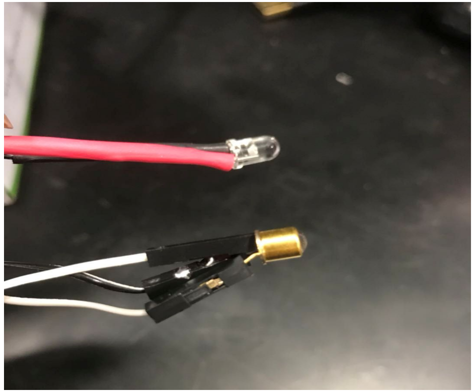


Figure 16: 770 nm LED and SD5600 sensor

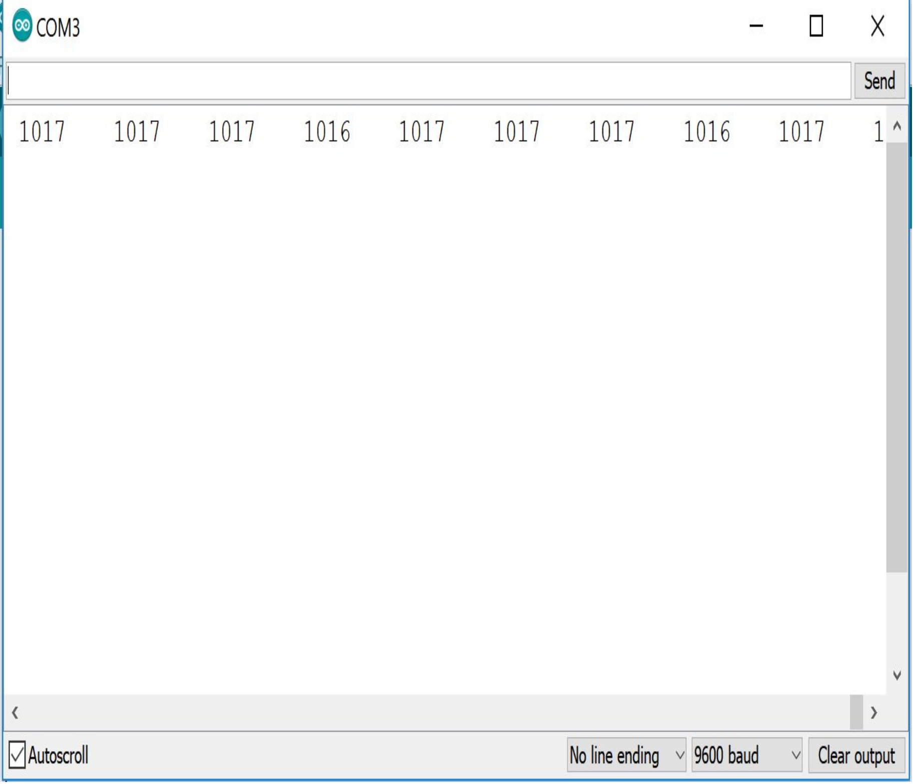


Figure 17: sensor reading: When light is blocked

Figure 18: sensor reading: when light is detected

Voltage across 770 nm LEDs: 1.666V, 1.680V (forward voltage is 1.55V).

Controller (FT232RL-Atmega328P)

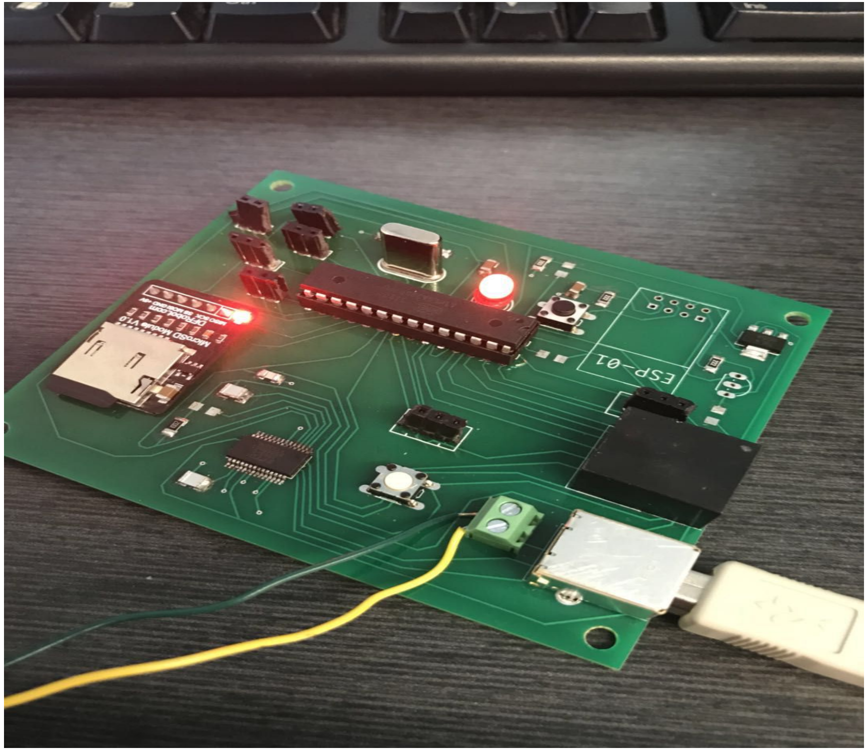


Figure 19: Controller PCB

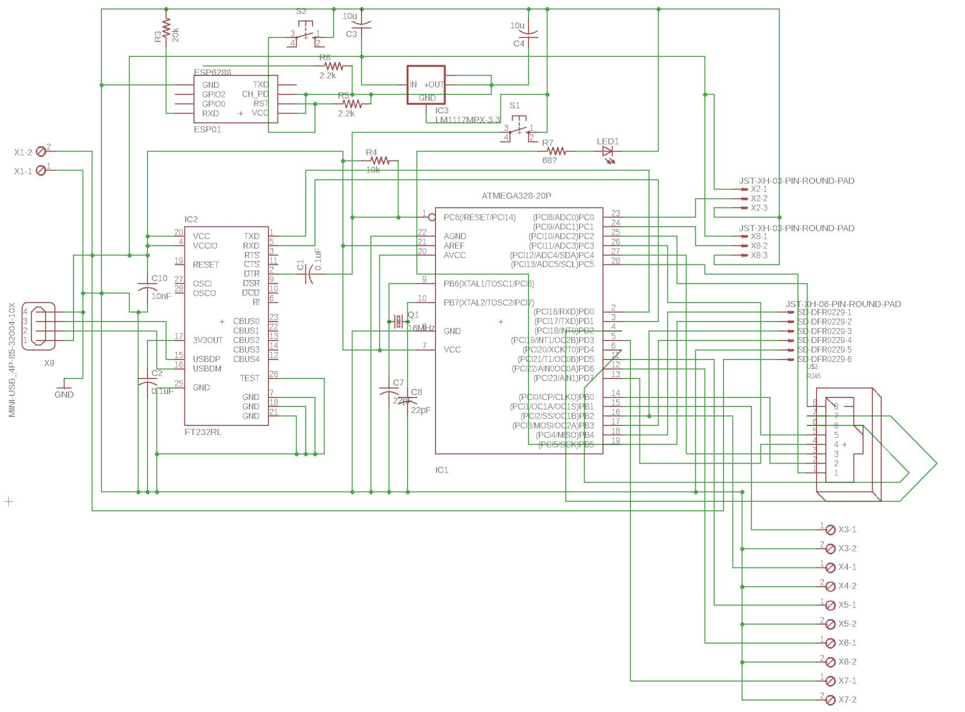


Figure 20: Controller schematic

Flow Chart for programming

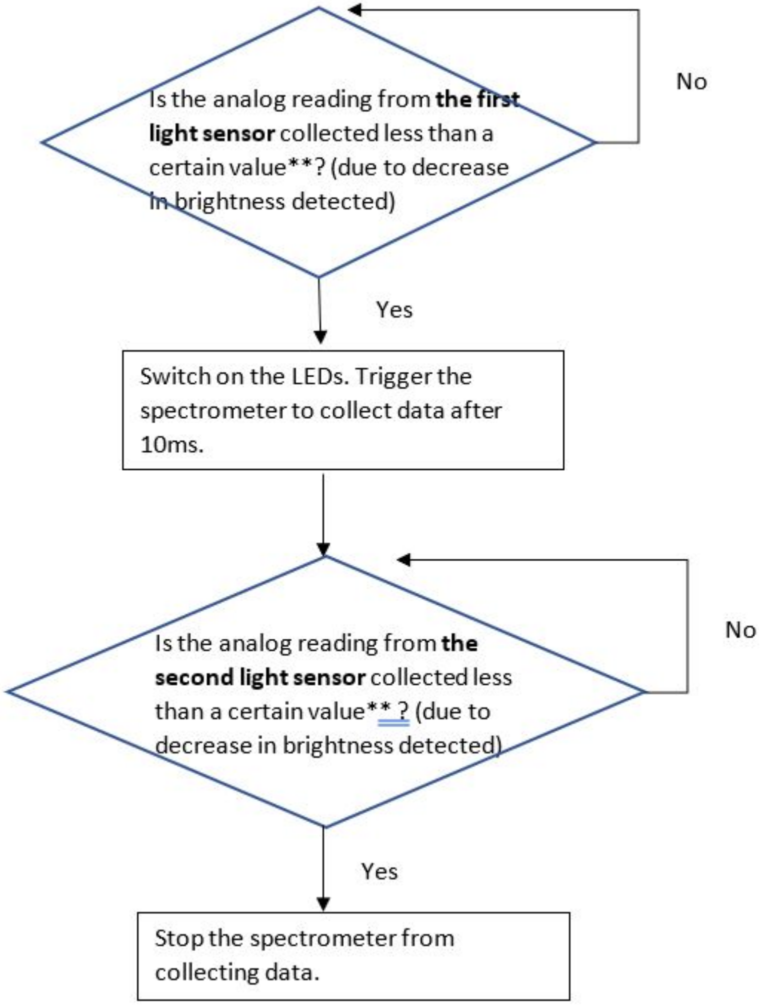
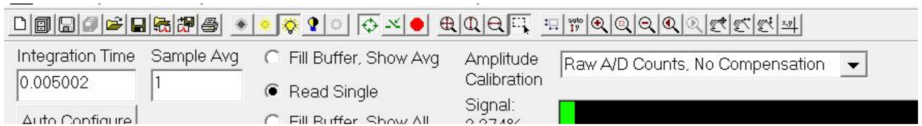


Figure 21: Flowchart to program light sensor, LEDs and spectrometer

Steps to configure the spectrometer:

1. Adjust the integration time to 0.005s
2. Change the amplitude calibration to “Raw A/D Counts, no compensation”
3. Click on ‘Setup’ and choose ‘Trigger Mode’, choose “Fast Asynchronous Clocking” and “External” (TTL input signal) for trigger control



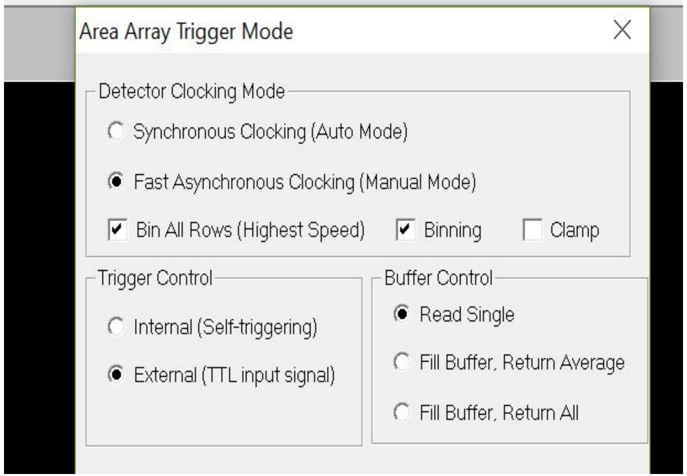
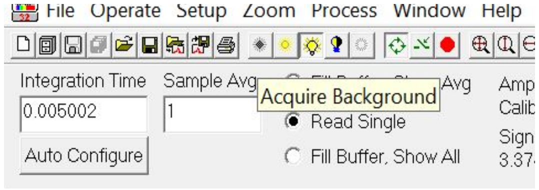


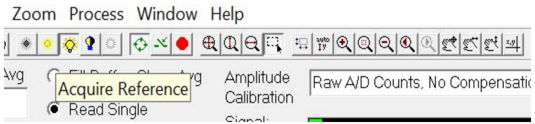
Figure 22: Spectrometer software

Steps to configure the spectrometer:

4. Collect the background brightness (with lights off)



5. Collect the reference brightness (with lights on)



6. Setup the trigger mode back to synchronous clocking and internal (self-triggering) for trigger control

7. Click on “Scan Continuous”

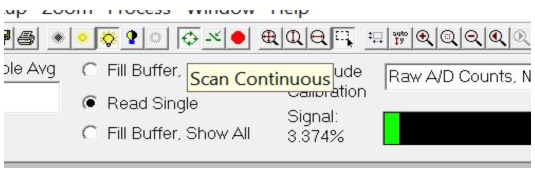


Figure 23: Spectrometer software

PWM (pin 5, 11, 12, 15, 16, 17)

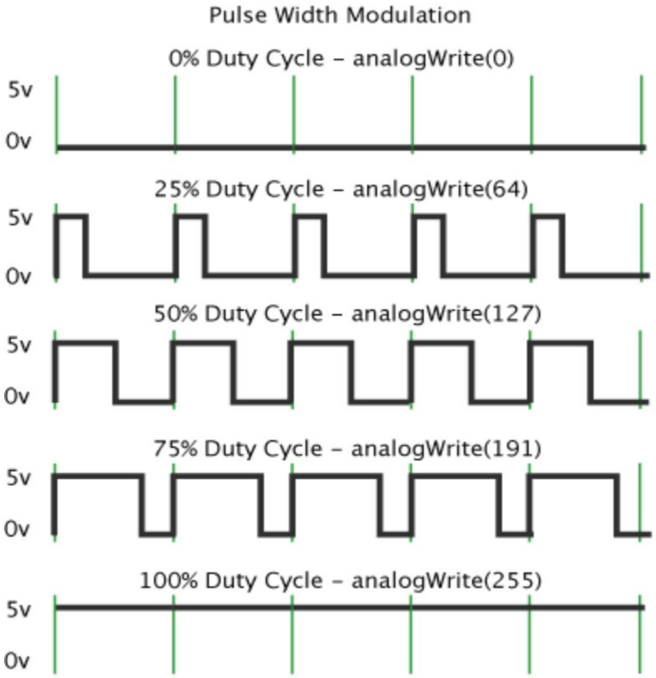


Figure 24: Pulse Width Modulation

```
analogWrite(led1, bri1);
analogWrite(led2, bri2);
analogWrite(led3, bri3);
analogWrite(led4, bri4);
analogWrite(led5, bri5);
digitalWrite(pin3, HIGH);
delay(10);
digitalWrite(pin3, LOW);
```

Duty Cycle: 100%, analogWrite(255)

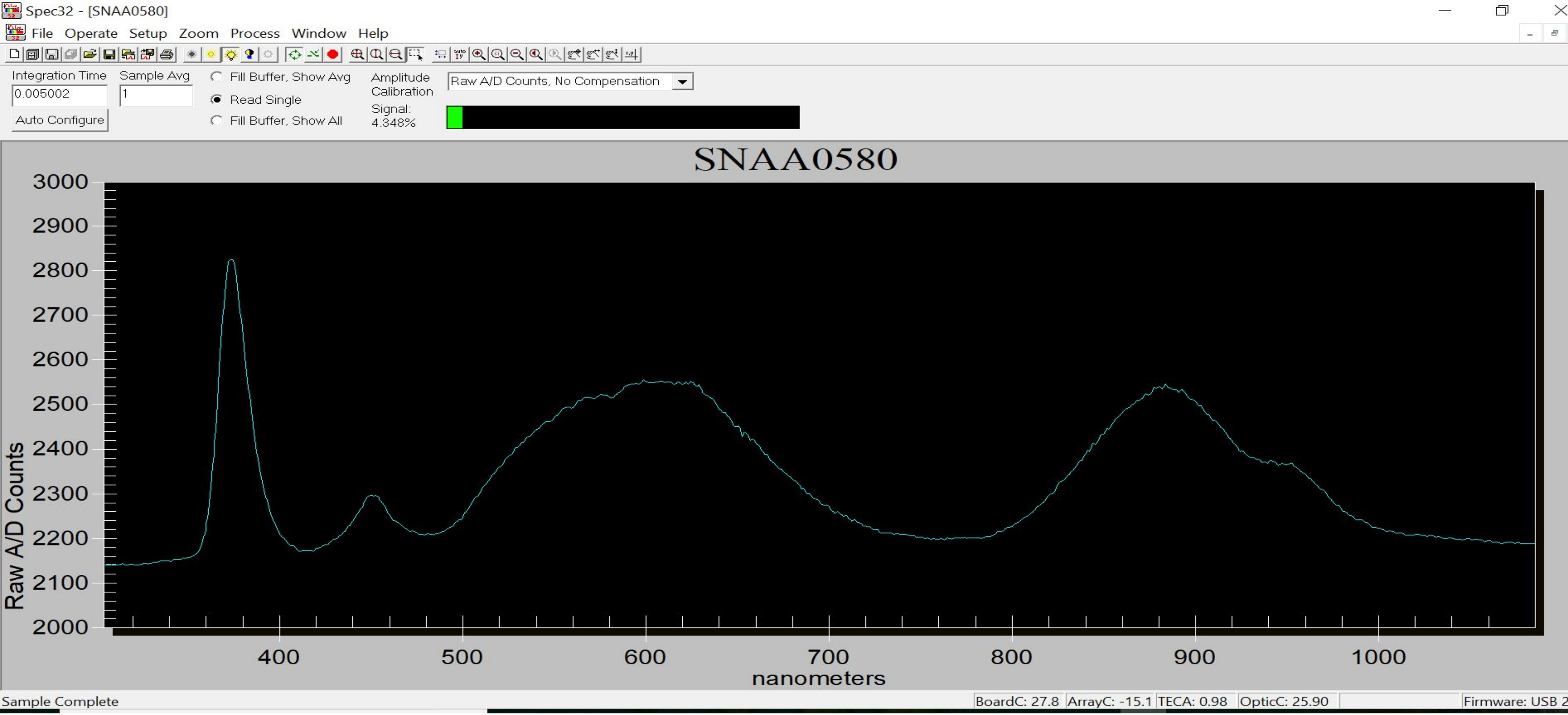


Figure 25: Spectrum at 100% duty cycle

Duty Cycle: 75%, analogWrite(191)

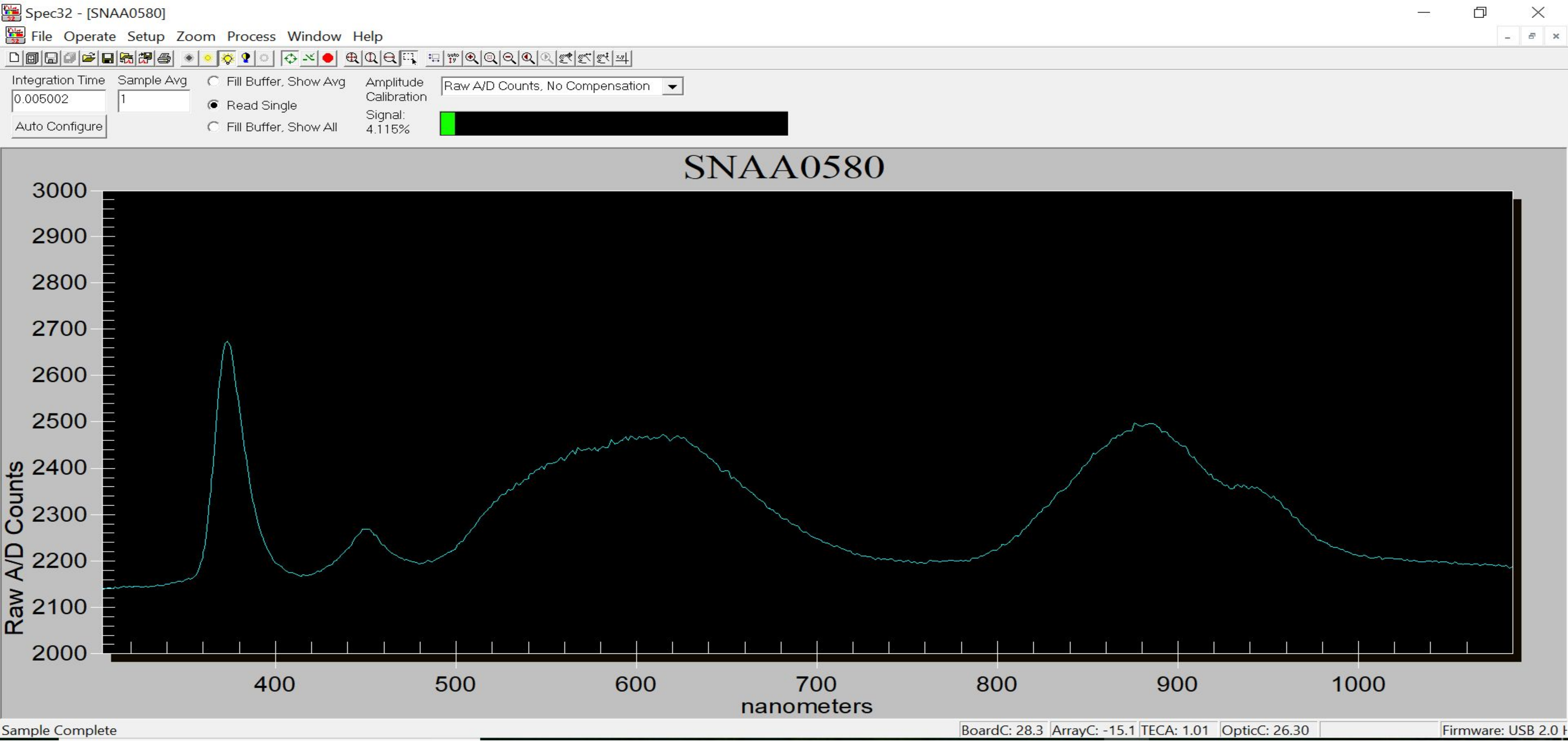


Figure 26: Spectrum at 75% duty cycle

Duty Cycle: 50%, analogWrite(127)

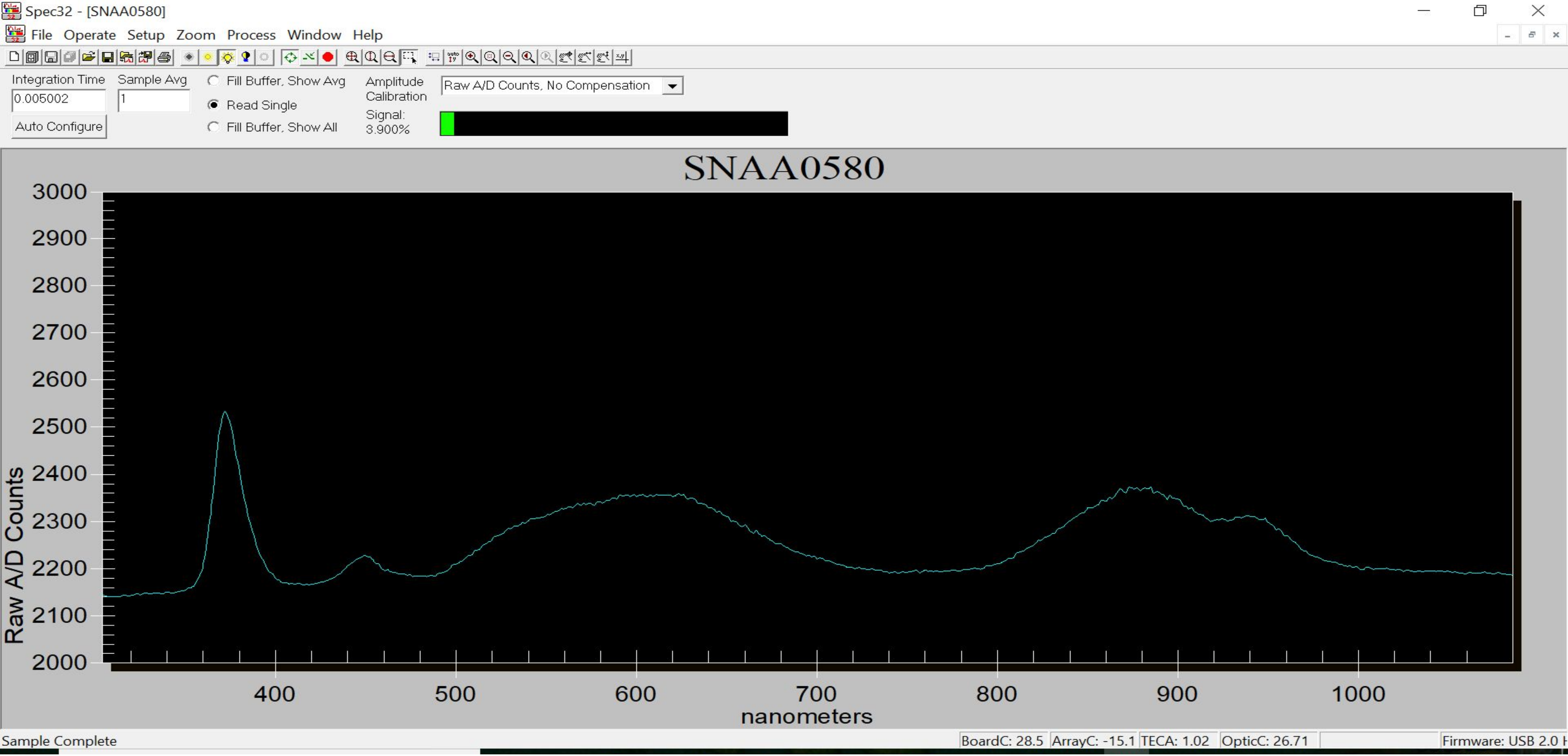


Figure 27: Spectrum at 50% duty cycle

Duty Cycle: 25%, analogWrite(64)

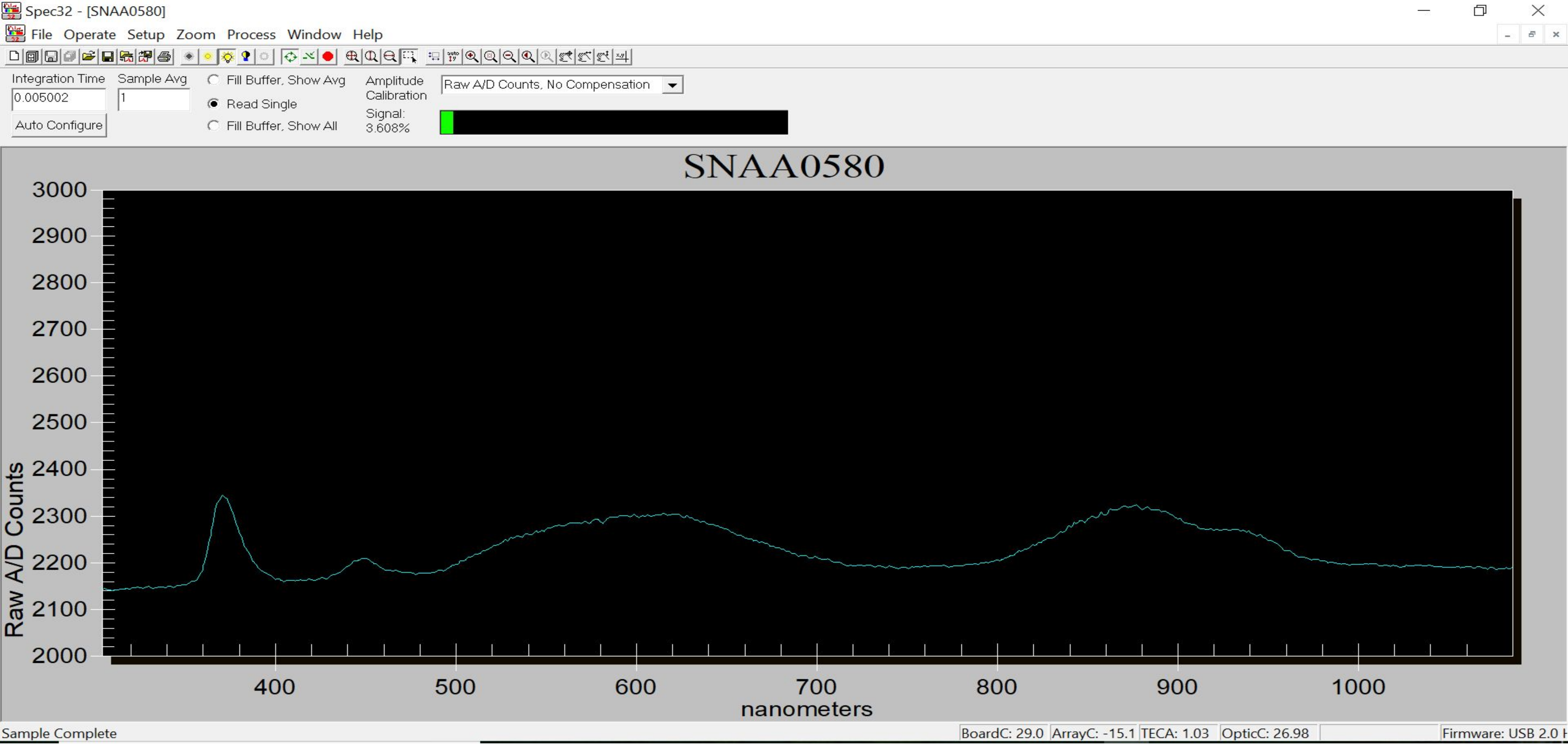


Figure 28: Spectrum at 25% duty cycle

Duty Cycle: 0%, analogWrite(0)

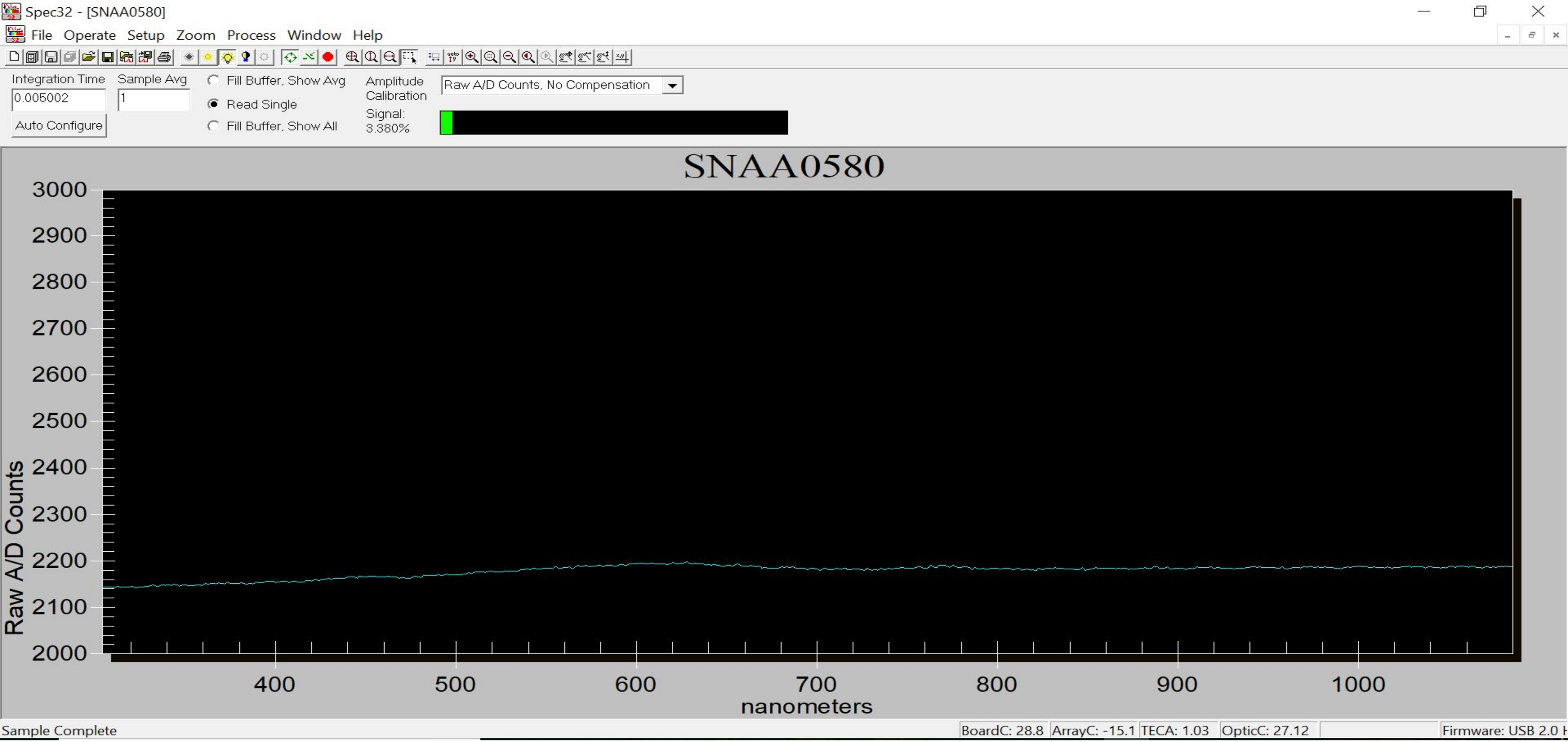
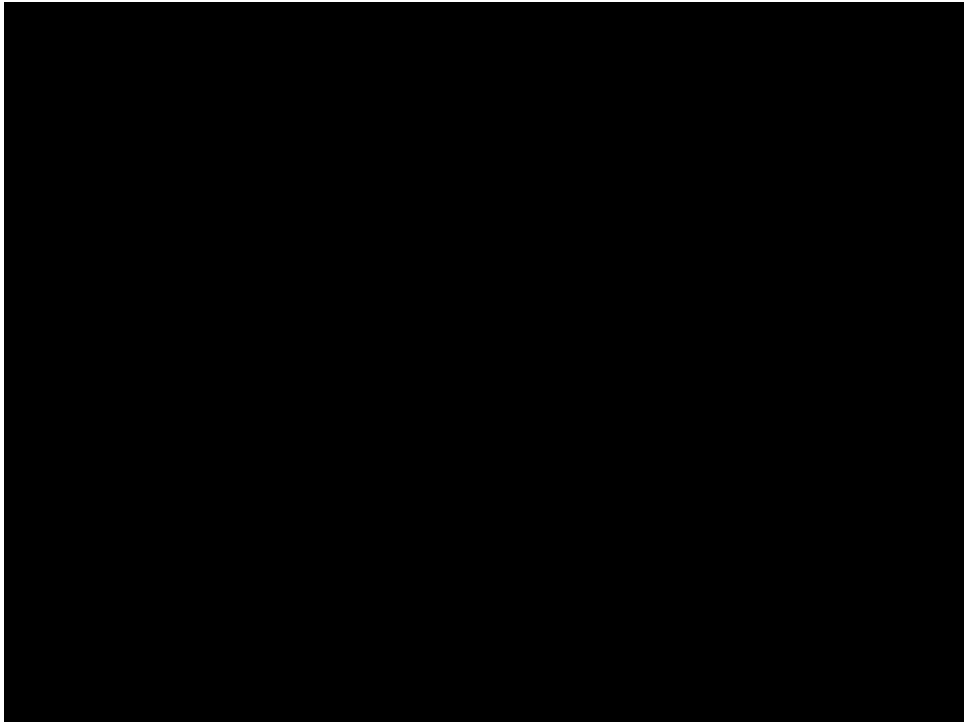
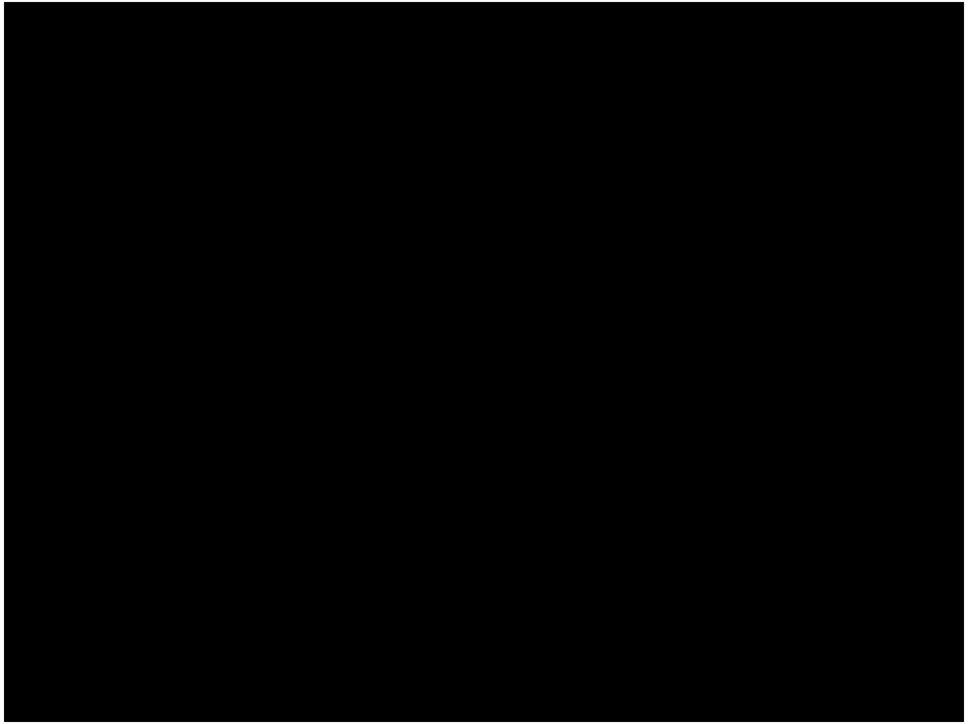


Figure 29: Spectrum at 0% duty cycle

Demonstration of putting the kernel into the light tube



Response on the spectrum as the kernel slides through the light tube



Conclusion and Future Work

Improvement on Hardware

- Circuit design to lessen heat dissipation
- Make the board thicker so that the trace can be wider (suitable for the amount of current)

Conclusion and Future Work

Improvement of Software

- Save data from spectrometer
- Improve on programming method (using Matlab GUI or Simulink in Matlab)

Credits

- John Hart
- Professor Stasiewicz and Eric Cheng
- TA Channing Philbrick
- And other TAs for this class

Reference

[1] National Cancer Institute. (2018). Aflatoxins. [online] Available at: https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/aflatoxins [Accessed 19 Mar. 2018].

[2] "Aflatoxin Effect On Health", Fao.org, 2018. [Online]. Available: http://www.fao.org/fileadmin/user_upload/wa_workshop/ECAfrica-caadp/4._Aflatoxin_USAID.p df [Accessed: 05- Feb- 2018].

[3] T. C. Pearson, D. T. Wicklow, E. B. Maghirang, F. Xie and F. E. Dowell, "DETECTING AFLATOXIN IN SINGLE CORN KERNELS BY TRANSMITTANCE AND REFLECTANCE SPECTROSCOPY", Transactions of the ASAE , vol. 44, no. 5, 2001.

[4] "Detection of Aflatoxin Contaminated Figs Using Near-Infrared (NIR) Reflectance Spectroscopy", Research Gate, 2018. [Online]. Available: https://www.researchgate.net/publication/262684486_Detection_of_Aflatoxin_Contaminated_Fig s_Using_Near-Infrared_NIR_Reflectance_Spectroscopy [Accessed: 05- Feb- 2018].

[5] A. Wacoo, D. Wendiro, P. Vuzi and J. Hawumba, "Methods for Detection of Aflatoxins in Agricultural Food Crops", Hindawi, 2018. [Online]. Available: https://www.hindawi.com/journals/jac/2014/706291/ [Accessed: 03- Feb- 2018].

[6] Ti.com. (2018). LM2596 SIMPLE SWITCHER® Power Converter 150-kHz 3-A Step-Down Voltage Regulator. [online] Available at: http://www.ti.com/lit/ds/symlink/lm2596.pdf [Accessed 19 Feb. 2018].