UNIVERSITY OF CENTRAL FLORIDA

Absorption Dependent Intensity Detector for Chlorophyll

Group 7 - Final Demonstration
James Aurilio (PSE), James Brutus (PSE), Logan Farley (EEL)

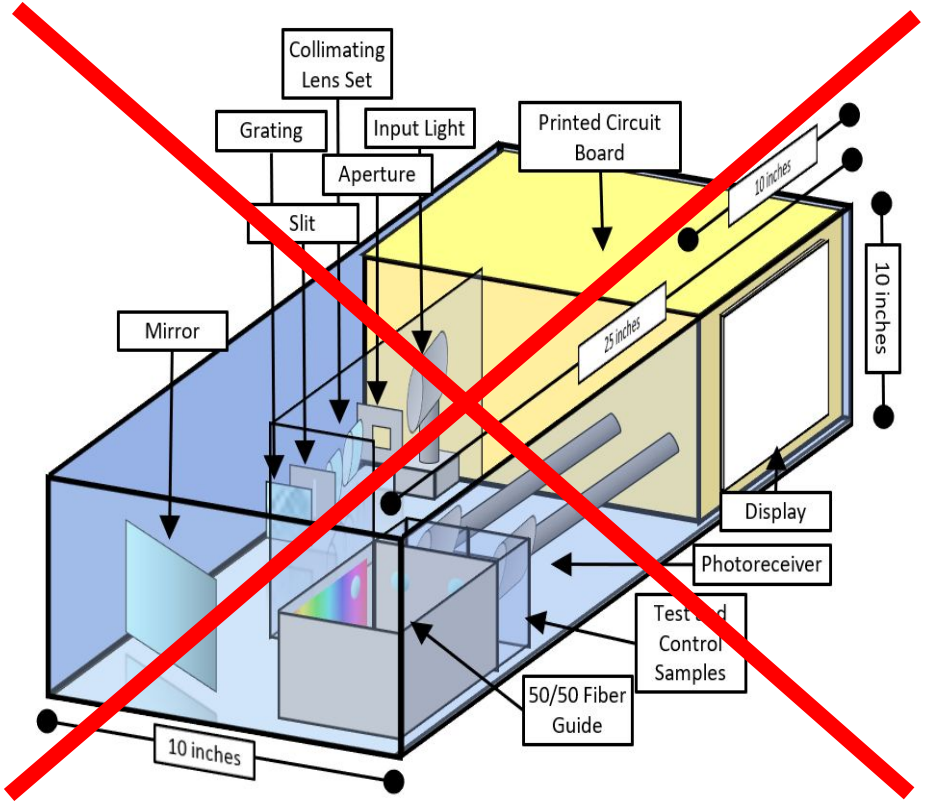
Presentation Overview

- Design Overview
- Electrical Design
- Optical Design 1
- Optical Design 2
- Problems Encountered

Initial Design Overview

Design Goals and Specifications

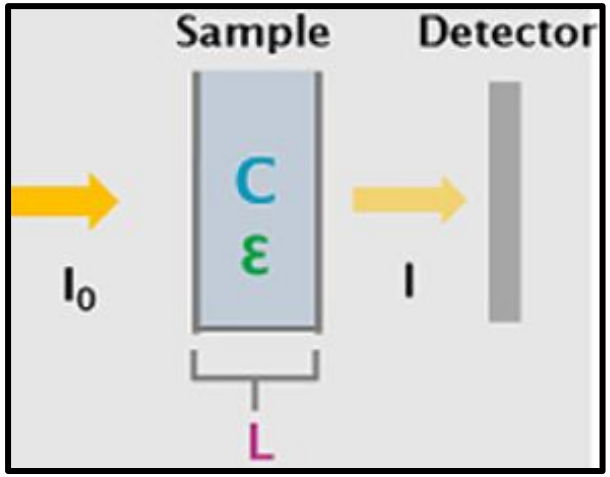
Specification	Description
Power	Powered by a standard USB connection and Rechargeable
Battery Life	1 Hour (1 Hour, 15 min Charge-Time)
Accuracy	90%+ of trace elements discovered
Mean Test Sample Response Time	30 seconds
Cost	< $1000
PCB	Should be less 10in x 10in x 10in
Concentration Detection Precision	Detects chlorophyll in concentrations as low as 100mg/g



Technical Background

Spectrophotometry

- VIS Spectrophotometry (400-700nm)
- Limited Inorganic Ion Detection
- Wavelength Selection
- **Lambert-Beer Law**
- Molecule Standard Wavelength Absorption Profiles



Lambert-Beer Law

Equations:

- $T = I/I_0$ — T: Transmission, I: Output Intensity, I_0: Input Intensity
- $A = \log(1/T)$ — A: Absorption
- $A = CL\varepsilon$ — C: Concentration, L: Impurity Length, ε: Extinction Coefficient

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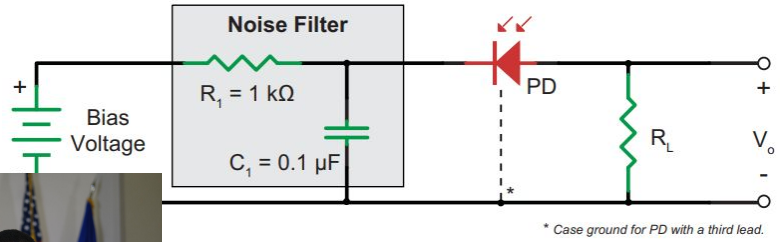
Technical Background

Wavelength LEDs

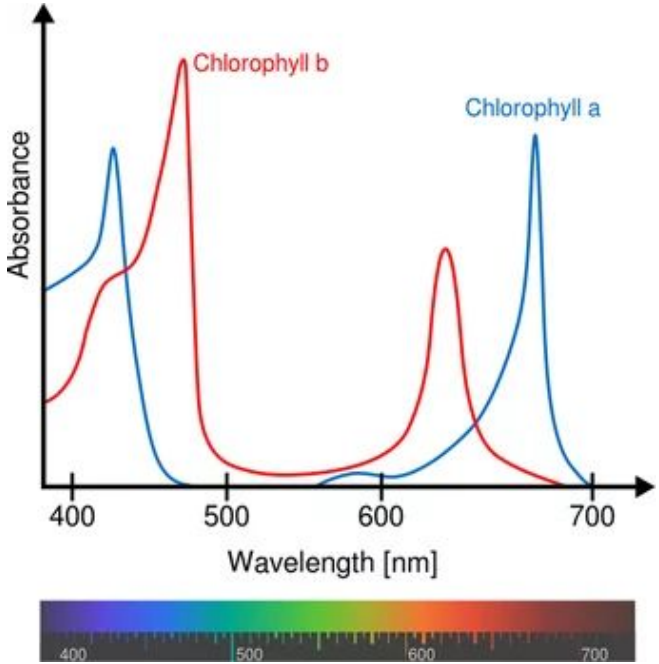
- LED430L (430nm)
- LED505L (505nm)
- LED660L (660nm)

Photodiode

- BPW77NA
  - 400-1000nm Response Range



Chlorophyll Absorbance Spectra



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Phototransistor

- **BPW77NA**
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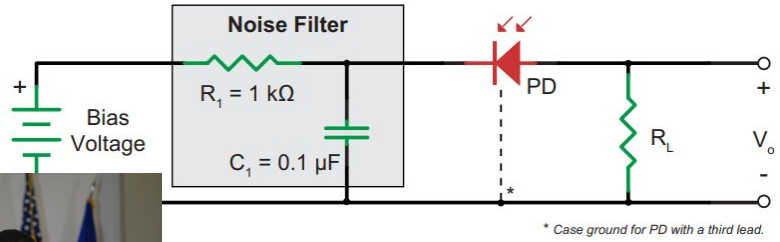
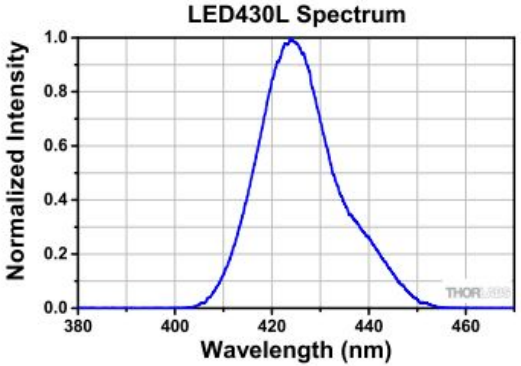
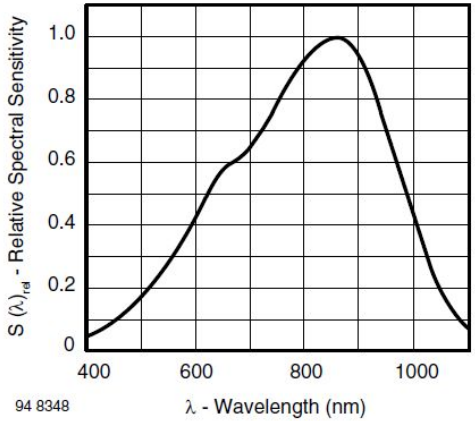
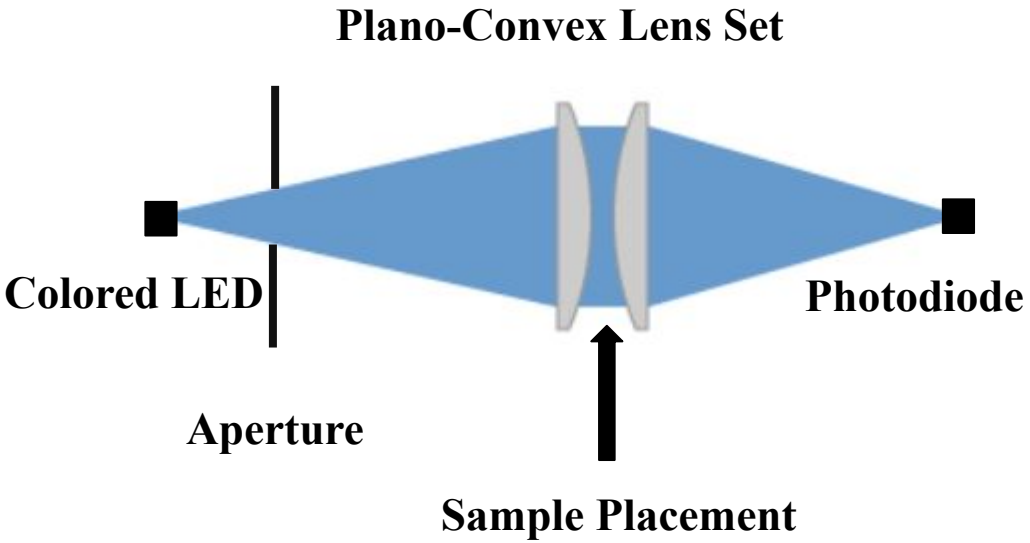






Technical Background



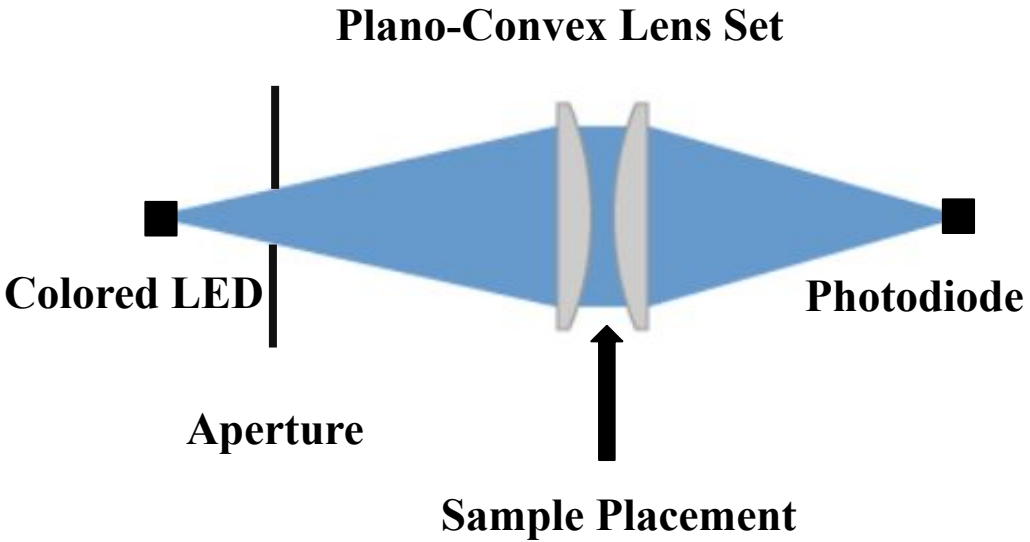
Technical Background

Colored LEDs

- LED430L (430nm)
  - Viewing Half Angle: 18°
- LED505L (505nm)
  - Viewing Half Angle: 20°
- LED660L (660nm)
  - Viewing Half Angle: 22°

Photodiode

- BPW77NA
  - Active Area Diameter: Ø0.25 mm



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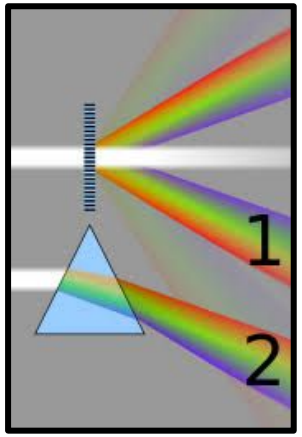
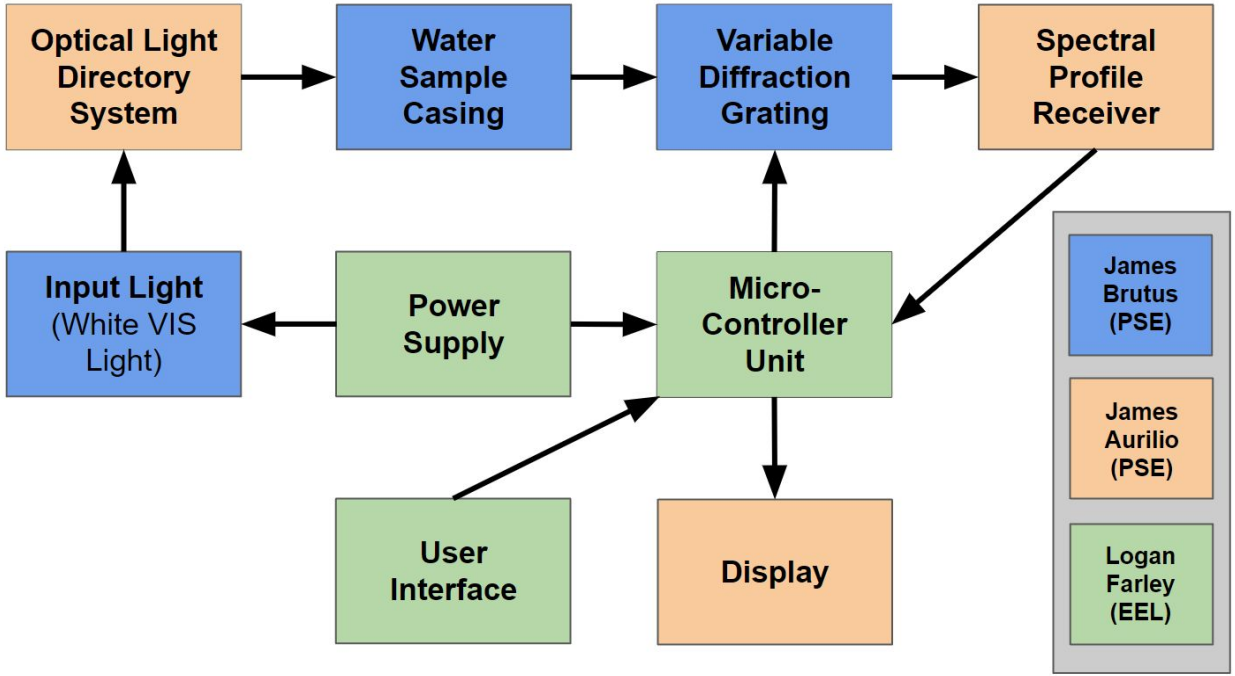


Wavelength Selection

- Wavelength Separation of White Light
  - Diffraction/Refraction
- Varying Set Wavelength LEDs

1. Diffraction Grating
2. Prism
3. ~~Acousto-Optic Modulator~~
4. ~~Electro-Optic Modulator~~

Initial Block Diagram



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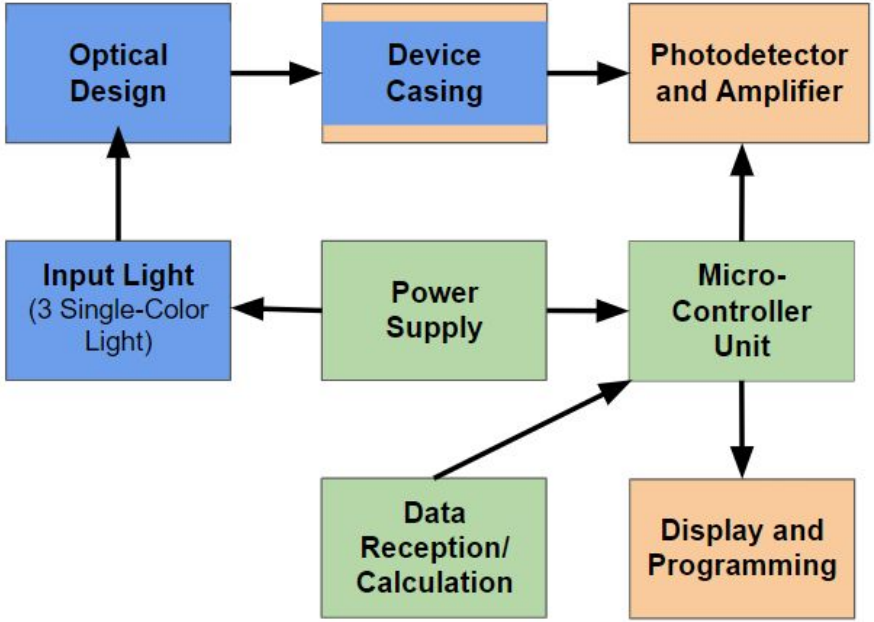
Current Block Diagram



James Brutus (PSE)

James Aurilio (PSE)

Logan Farley (EEL)

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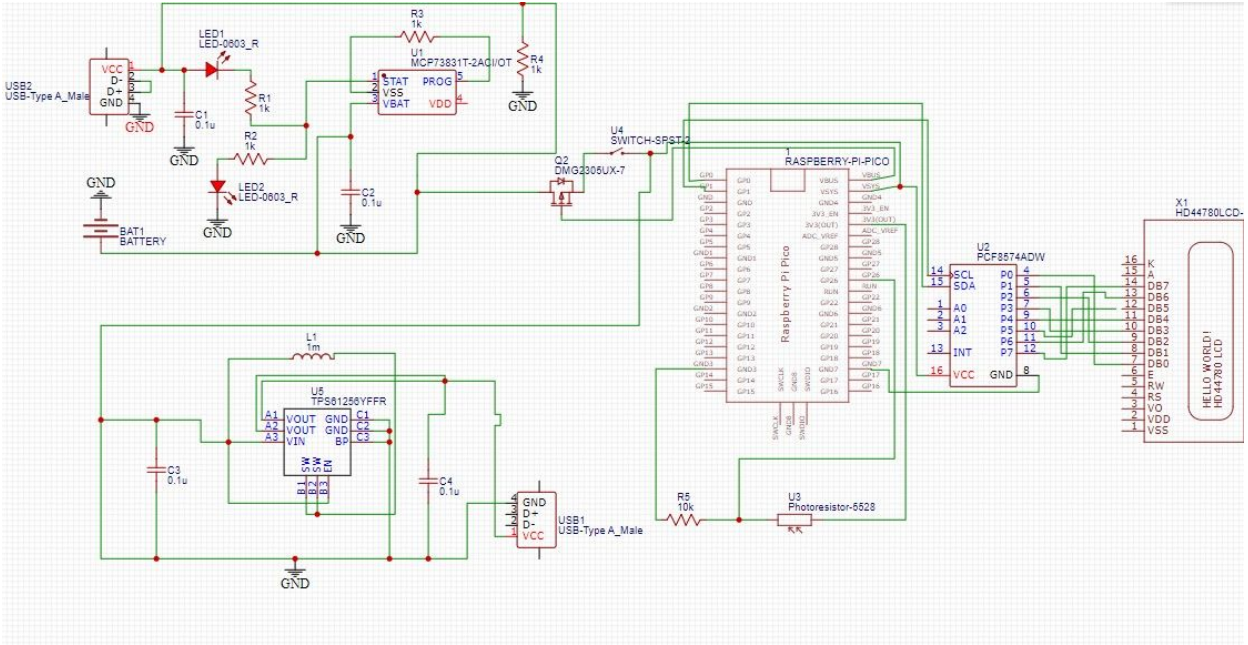
Schematic Design



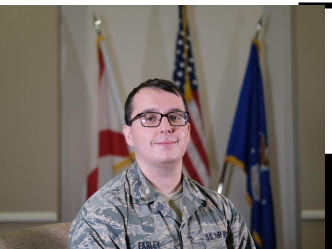
Power Supply

USB Powered 5V
    Charges the battery

Rechargeable with Lithium Ion Battery
    3.7V - 4.2V

Battery Goal of 1 hour of continuous use

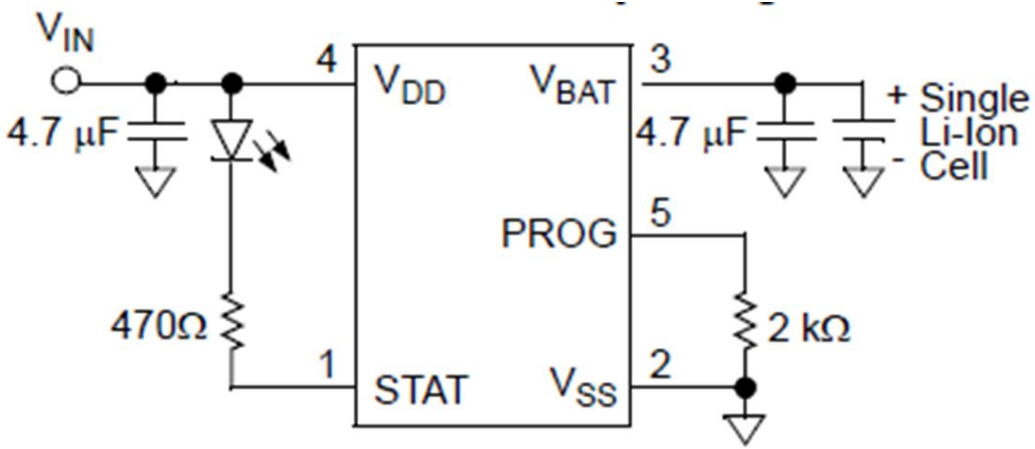
15 min charge time

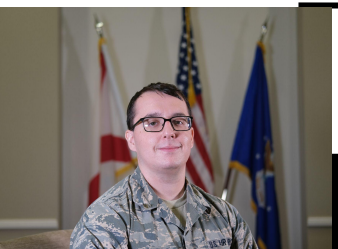


Battery Charging

MCP73831 by MicroChip
Example Circuit

93% Efficiency WEBENCH
Power Rating





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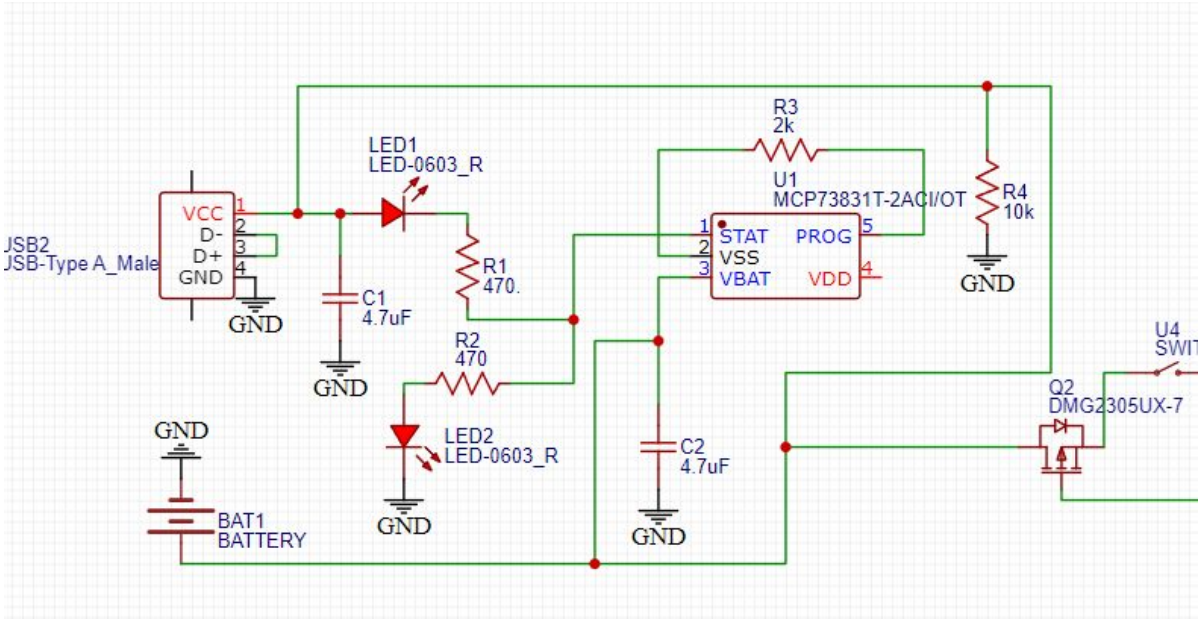
Power Supply Schematic



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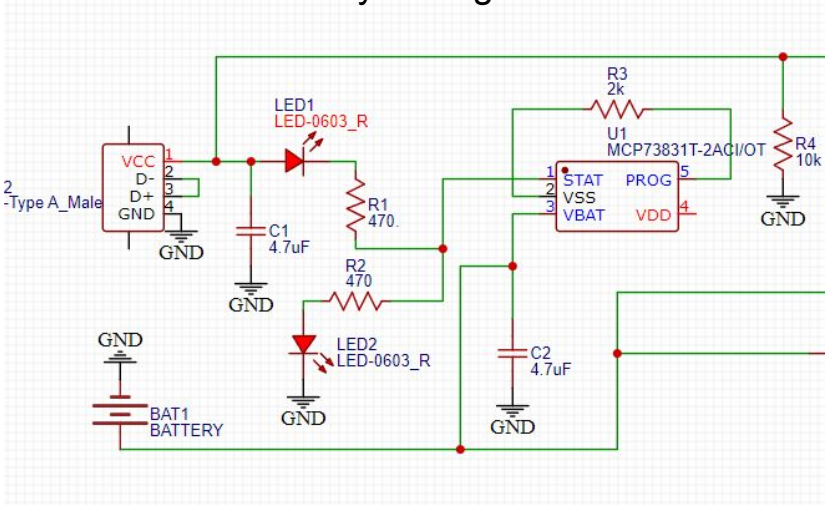
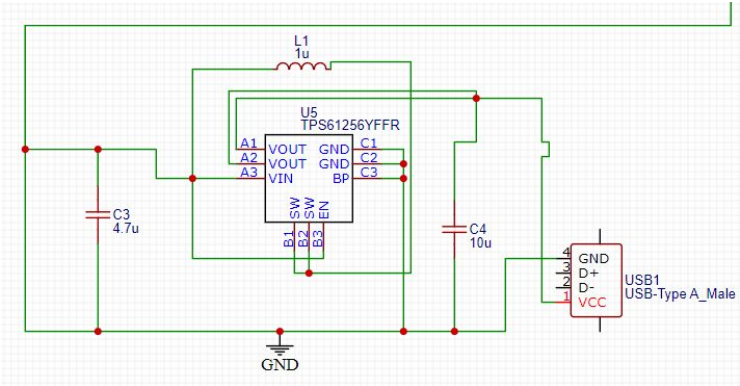
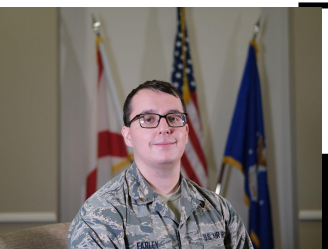
Schematic Design

5v to 3.7v convertor
94.2% Efficiency Rating WEBENCH



3.7v to 5v convertor
91.4% Efficiency Rating WEBENCH





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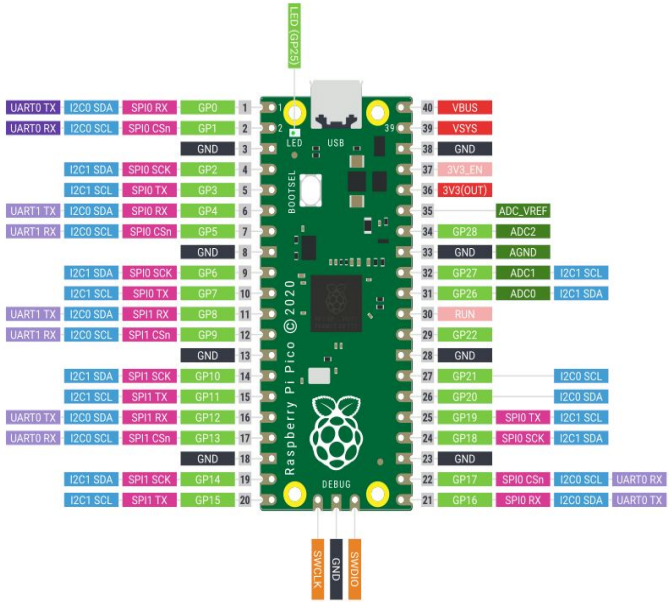
MCU

Raspberry Pi Pico
Based on RP2040 MCU
~$4

Brain of the operation
Handle all calculations and computations

Can Output 3.3V

MCU


LED (GP25)
UART0 TX I2C0 SDA SPI0 RX GP0 1
UART0 RX I2C0 SCL SPI0 CSn GP1 2
GND 3
I2C1 SDA SPI0 SCK GP2 4
I2C1 SCL SPI0 TX GP3 5
UART1 TX I2C0 SDA SPI0 RX GP4 6
UART1 RX I2C0 SCL SPI0 CSn GP5 7
GND 8
I2C1 SDA SPI0 SCK GP6 9
I2C1 SCL SPI0 TX GP7 10
UART1 TX I2C0 SDA SPI1 RX GP8 11
UART1 RX I2C0 SCL SPI1 CSn GP9 12
GND 13
I2C1 SDA SPI1 SCK GP10 14
I2C1 SCL SPI1 TX GP11 15
UART0 TX I2C0 SDA SPI1 RX GP12 16
UART0 RX I2C0 SCL SPI1 CSn GP13 17
GND 18
I2C1 SDA SPI1 SCK GP14 19
I2C1 SCL SPI1 TX GP15 20
40 VBUS
39 VSYS
38 GND
37 3V3_EN
36 3V3(OUT)
35 ADC_VREF
34 GP28 ADC2
33 GND AGND
32 GP27 ADC1 I2C1 SCL
31 GP26 ADC0 I2C1 SDA
30 RUN
29 GP22
28 GND
27 GP21 I2C0 SCL
26 GP20 I2C0 SDA
25 GP19 SPI0 TX I2C1 SCL
24 GP18 SPI0 SCK I2C1 SDA
23 GND
22 GP17 SPI0 CSn I2C0 SCL UART0 RX
21 GP16 SPI0 RX I2C0 SDA UART0 TX
LED
USB
BOOTSEL
Raspberry Pi Pico © 2020
DEBUG
SWCLK
GND
SWDIO
Power
Ground
UART / UART (default)
GPIO, PIO, and PWM
ADC
SPI
I2C
System Control
Debugging

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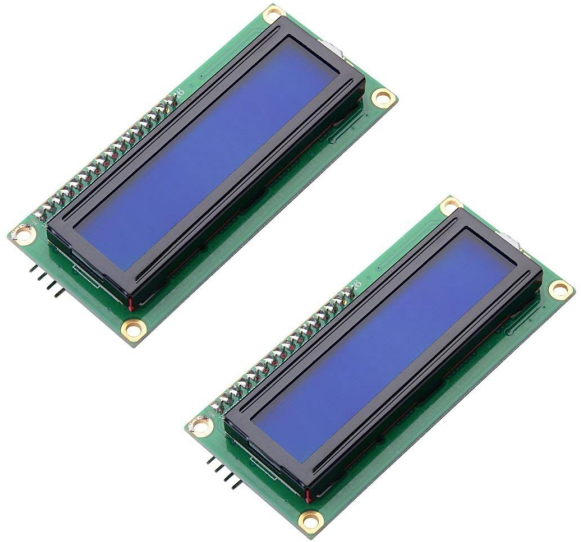
Display

HD44780 IIC I2C1602 LCD Display

~$11 for 2

SPI interface

3.3V - 5V



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Choosing Between Options

Rotation-stage diffraction element • Too many moving parts in Optical Design	Electro-optic modulator • Too selective, does not allow for broad selection of wavelengths	3-color LED options • Input
Raman spectroscopy (UV) • Highly costly for source/detector, difficult to get enough power to be captured	Absorption (VIS) • Cheaper option, reliable power throughput	

Optoelectronics

Photodetector Selection

Sensitive to light across the visible spectrum

a. Amplified photocurrent production compared to photodetector
b. Resilient to aberrations in voltage and current
c. Cheap and amplifiable

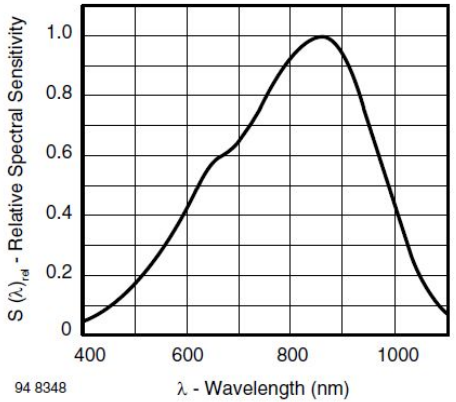
BPW77NA Phototransistor without glass dome casing

Item #	Wavelength Range	Optical Power	Viewing Half Angle	Collector Emitter Max Voltage	Cost
BPW77NA	400-1000 nm	7.5 to 15 mA	10°	70 V	$3.24

Optoelectronics

Photodetector Selection

Consideration is given to the difference in relative response based on wavelength



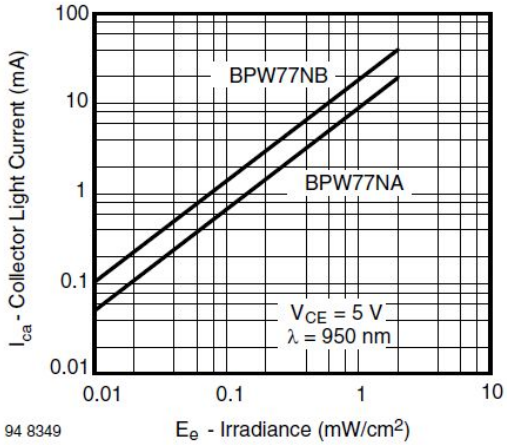
BPW77NA Phototransistor spectral responsivity

Item #	Wavelength Range	Optical Power	Viewing Half Angle	Collector Emitter Max Voltage	Cost
BPW77NA	400-1000 nm	7.5 to 15 mA	10°	70 V	$3.24

Optoelectronics

Photodetector Selection

Consideration is also given to the logarithmic response to irradiance in expecting a response



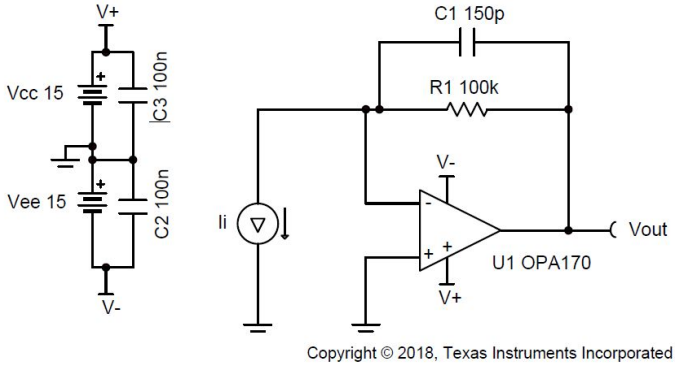
BPW77NA Phototransistor photocurrent response at 950 nm

Item #	Wavelength Range	Optical Power	Viewing Half Angle	Collector Emitter Max Voltage	Cost
BPW77NA	400-1000 nm	7.5 to 15 mA	10°	70 V	$3.24

Optoelectronics

Amplifying Circuit Decisions

- Current from phototransistor would be too low
- Amplifier circuit “captures” current and reads it as a voltage
- Voltage is then amplified to a readable degree



Circuit design for a transimpedance amplifier circuit

Financing

- Estimated Project Funding
  - ~$530
- Price may change with implementation of optical equipment
- Availability of part selections

Item	Cost	Quantity	Total Cost
MCU	$30	1	$30
Display	$50	1	$50
PCB	$50	1	$50
Breadboard	$20	1	$20
Optical Array	$20	1	$20
Photodiode and Mount	$36	1	$36
Lens	$40	2	$80
Diffraction Grating	$20	1	$20
Mirror	$30	1	$60
Fiber Optic Light Guide	$80	1	$80
Power Supply PCB	$25	1	$25
Glass Vials	$10	1	$10
MicroUSB connectors	$2	2	$4
Misc Electronic Parts	<$50	TBD	<$50
TOTAL COST			<$530

Group Responsibilities

Components:	Farley	Aurilio	Brutus
Optical Design		“Casing”	Complete
Input light source		Helped	Complete
Photodetection		Complete	
Aqueous contaminant research			Complete
Schematic Design	Complete		
PCB Design	Complete		
Electronic Components	Complete		
Coding	Helped	Complete	

Specification 1 Demo

Specification 1 - Mean Absorption for Each LED					
Blue LED (430 nm)		Green LED (505 nm)		Red LED (660 nm)	
Chloropyll Concentration	Measured Voltage	Chloropyll Concentration	Measured Voltage	Chloropyll Concentration	Measured Voltage
0mg	2.2	0mg	1.9	0mg	2.3
10mg	0.7	10mg	0.8	10mg	0.8
10mg	0.6	10mg	0.5	10mg	1
10mg	0.6	10mg	0.7	10mg	0.8
10mg	0.8	10mg	0.7	10mg	1
10mg	0.6	10mg	0.6	10mg	0.9
10mg	0.6	10mg	0.6	10mg	0.9
10mg	0.8	10mg	0.8	10mg	0.9
10mg	0.7	10mg	0.7	10mg	0.8
10mg	0.5	10mg	0.6	10mg	0.9
10mg	0.6	10mg	0.5	10mg	1
Mean Voltage Drop at 100mg of Chlorophyll Concentration	1.55	Mean Voltage Drop at 100mg of Chlorophyll Concentration	1.25	Mean Voltage Drop at 100mg of Chlorophyll Concentration	1.4

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Specification 2 Demo

Specification 2 - Concentration Limits		
Red LED (660 nm)		
Chlorophyll Concentration	Measured Voltage	Approximate Voltage Change
0mg	2.3	0
3.3mg	2	0.3
6.6mg	2.1	0.2
10mg	1.3	1
13.3mg	1.5	0.8
16.6mg	1.2	1.1
20mg	1	1.3
23.3mg	1.1	1.2
26.6mg	0.9	1.4
30mg	1	1.3
33.3mg	0.8	1.5
36.6mg	0.7	1.6
40mg	0.7	1.6
43.3mg	0.6	1.7

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Specifications 3 Demo

Test #	Voltage Reading Sample Count	Response Time to Produce Mean Voltage (s)
Test 1	156	31
Test 2	156	30
Test 3	156	29
Test 4	156	30
Test 5	156	30
Test 6	156	28
Test 7	156	28
Test 8	156	30
Test 9	156	29
Test 10	156	29
Average	156	29.4

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Questions?