E80 AUV Project

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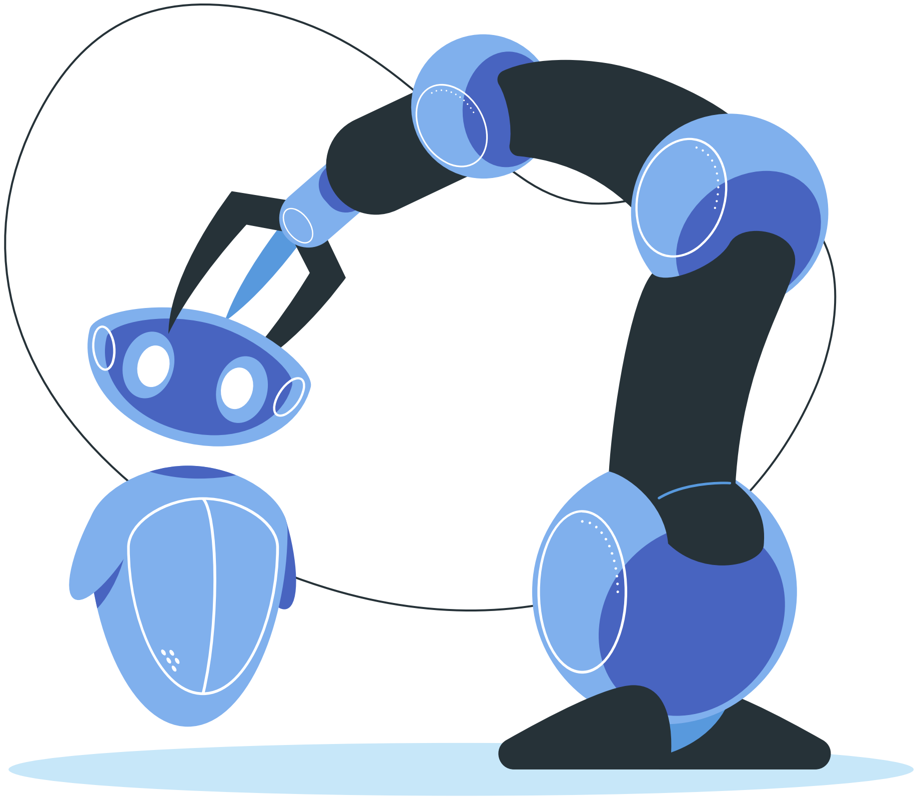

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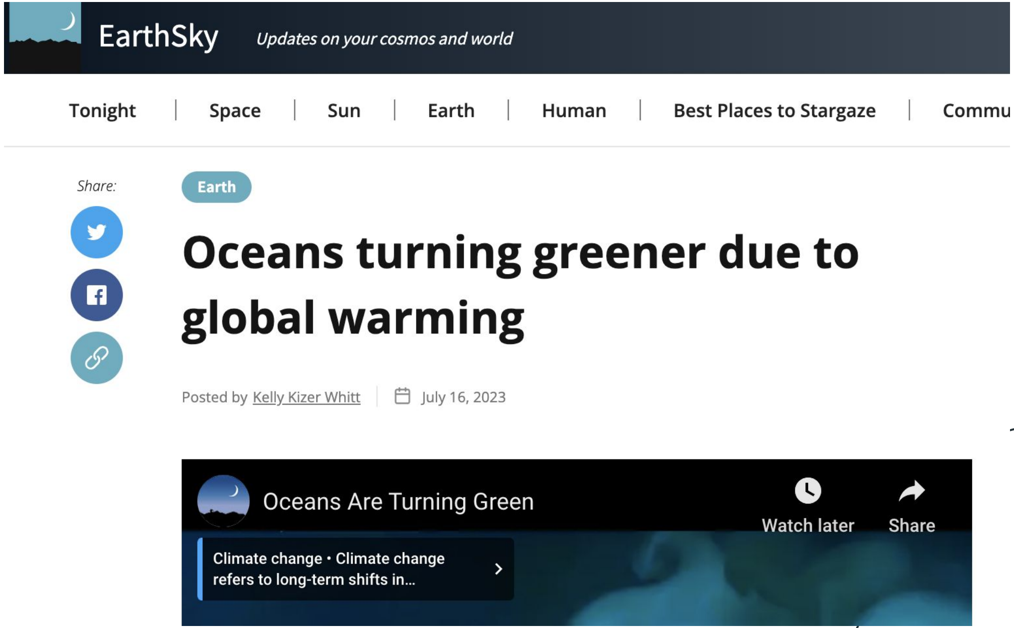
Motivation

- Global warming changing the color of the ocean
- Potential link to increase in phytoplankton
- Big impact on marine life and the marine ecosystem



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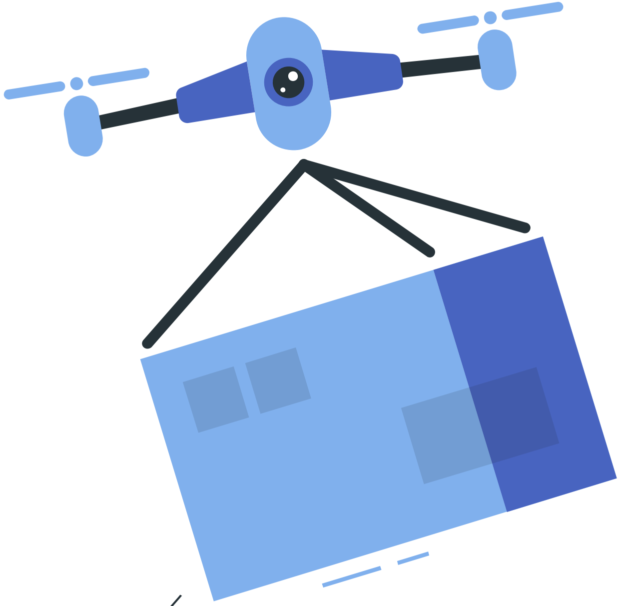
Engineering Goal

- Relationship between algae concentration vs depth and temperature



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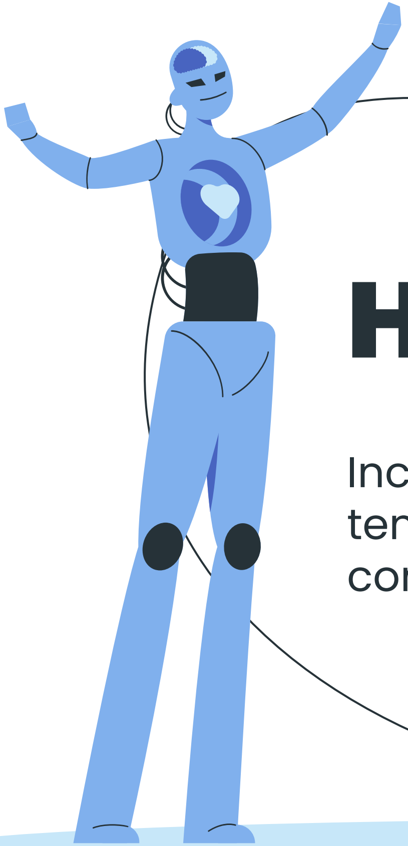
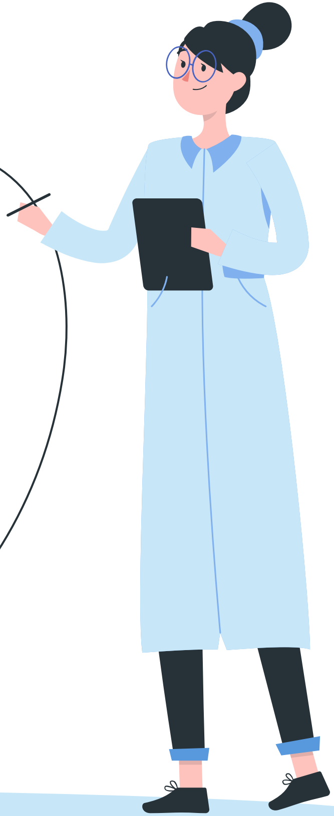


Hypothesis

Increase in depth and decrease in temperature → decrease in algae concentration



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Engineering Design

1

Pressure

MPX5700 Pressure Sensor Circuit

2

Temperature

Murata NXFT15WB473FA2B150 Thermistor Interface Circuit

3

Turbidity

555 timer circuit with green LED received by two transimpedance amplifier circuits each with BPW46 photodiodes

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Sensor Considerations

Murata NXFT15WB473FA2B150 thermistor:

- Simple to implement
- Quick response time

MPX5700 Pressure Sensor

- Output range 0.2V to 4.7V

Turbidity

- Green LED
- Two BPW46 Photodiodes

Sensor Placement:

- Turbidity casing placed at equal height with pressure sensor tube

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Sensor Design: Pressure

- Independent variable to Temperature and Turbidity
- Allows the AUV to navigate to desired depths of the ocean

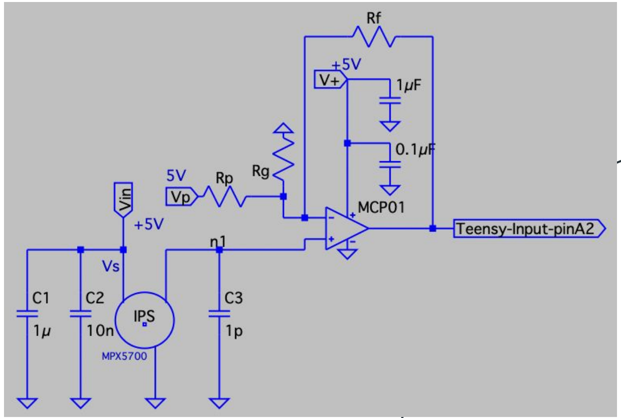
- Expected ocean depth range: 0m - 4m
  - Corresponding pressure 101.325 kpa - 150.525 kPa

$$V_{out} = V_S(0.00128858P + 0.04)$$

- Output voltage range before op amp mapping: 0.853 V - 1.170 V

$$V_{out} = (\frac{Rf}{Rg} + \frac{Rf}{Rp} + 1)V_{n1} - V_p(\frac{Rf}{Rp})$$

- Expected output voltage range into the Teensy: 0.579 V - 2.984 V



$R_f = 33k\Omega$
$R_g = 6.1k\Omega$
$R_p = 28k\Omega$

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Sensor Design: Temperature

Expected temperature range: 10°C - 20°C

- Thermistor resistance equation

$$R = R_0 exp(B(\frac{1}{T} - \frac{1}{T_0}))$$

Expected resistance range (approx.): 60kΩ - 100 kΩ
Choose R_1 to be approx. middle of this range: 82kΩ

- Voltage divider input

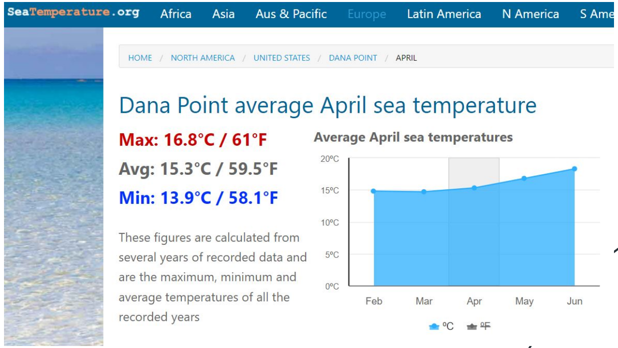
$$V_{out,\, thermistor\ circuit} = \frac{R_1}{R_1 + R_{thermistor}} \cdot V_{in}$$

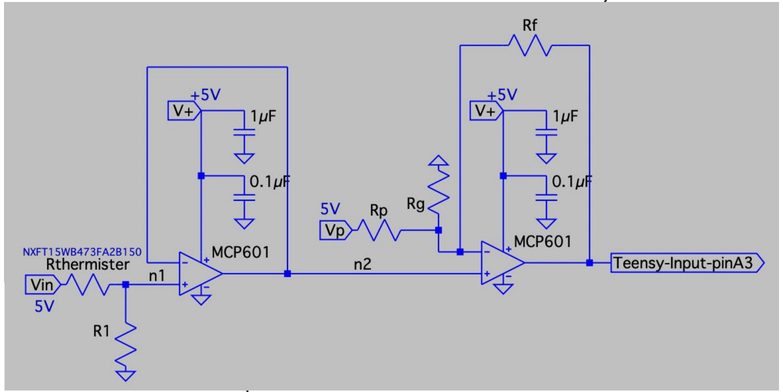
Expected voltage output range: 2.25V - 2.88V

- Inverting offset amplifier

$$V_{out} = (\frac{R_1}{R_1 + R_{therm}})(\frac{R_f}{R_g} + \frac{R_f}{R_p} + 1) \cdot V_{in} - (\frac{R_f}{R_p}) \cdot V_p$$

Expected final voltage output range: 0.42V - 2.88V





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Sensor Design: Turbidity

- Measures 90° and transmitted light through a solution
  - The ratio indicates amount of dispelled particles

- 555 Timer – Periodic signal
  - Accounts for ambient light
  - Drives green LED
- Transimpedance Amplifier – Converts optical sensor's output current to voltage
  - BPW46
- Min/max detector – Avoids aliasing
- Turbidity Meter Casing – Mitigates ambient light

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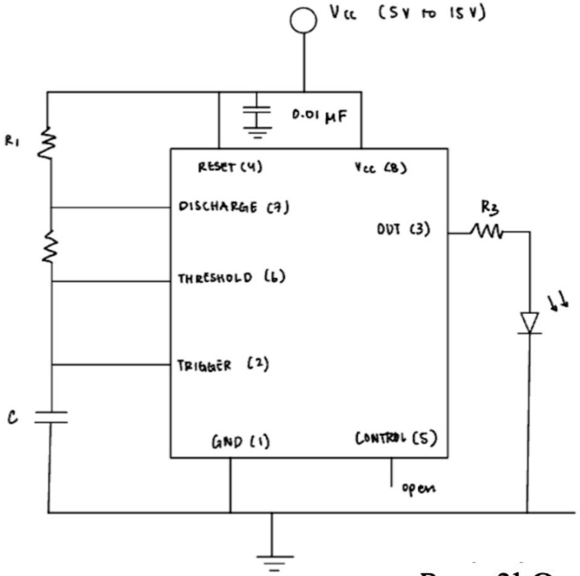
555 timer

- Periodic signal allows ambient light to be taken into account.

$$f \approx \frac{1.44}{C(R_1+2R_2)} \qquad Duty\ Cycle\ =\ 1-\frac{R_1}{R_1-2R_2}$$

$$f = 1\text{kHz} \qquad Duty\ Cycle\ = 60\%$$

- R_3 chosen to limit the voltage across the LED to the forward voltage (2.2V)



$R_1 = 3\text{k}\Omega$

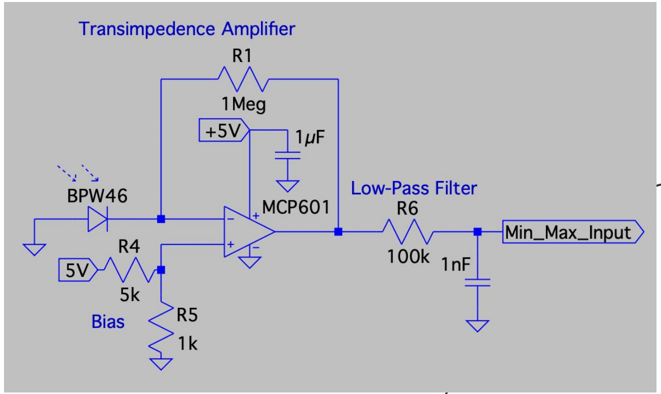
$R_2 = 6\text{k}\Omega$

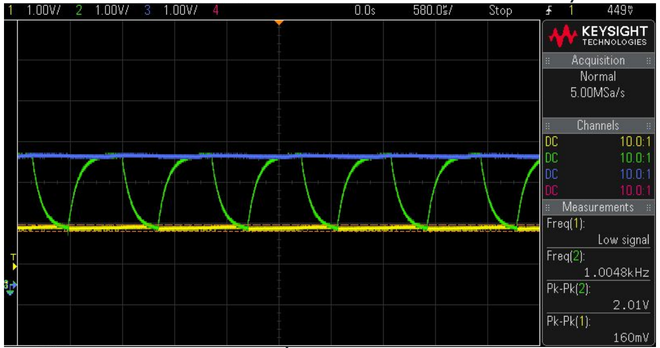
$R_3 = 200\Omega$

$C = 0.1\mu\text{F}$

Transimpedance Amplifier

- Converts the output current of BPW46 photodiode to a voltage
- R_1 = 1MΩ chosen to convert the output current to a large enough voltage.
- Low-pass Filter implemented to smooth out high frequency ringing in output signal.



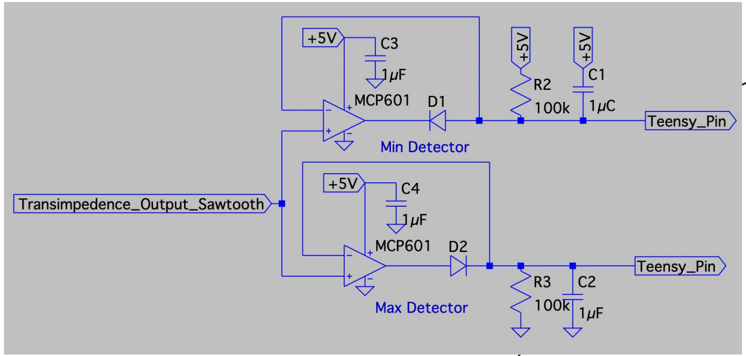


Min/Max Detector

- Mitigates Aliasing by converting minimum and maximum values to a pair of DC signals

$$f_{sample} \geq 2f_{max}$$

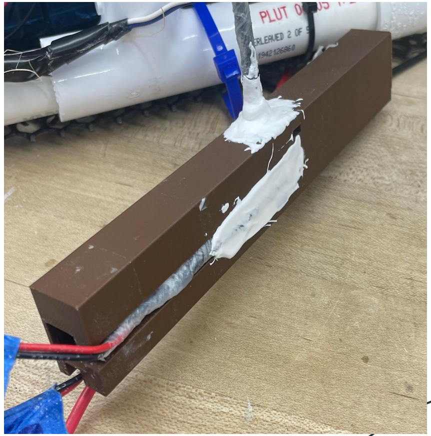
$$f_{sample} = 10\ \mathrm{Hz}$$
$$f_{max} = 1\mathrm{kHz}$$



- Modified Low Pass filter
  - R_6 = 100kΩ C = 1nF
  - τ = 5/π Hz

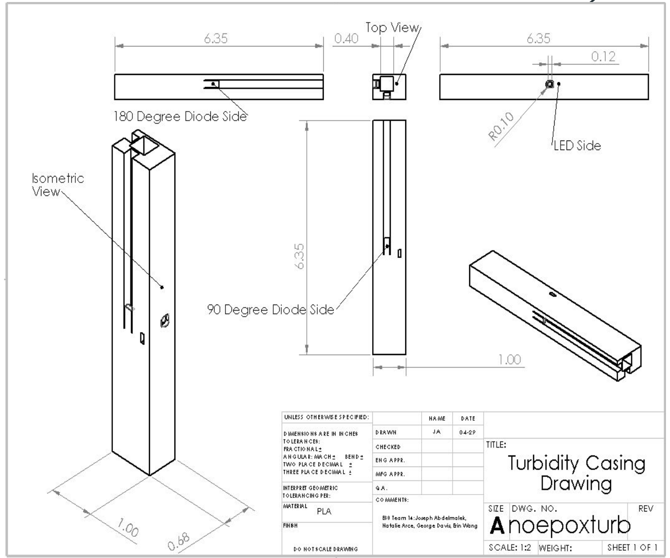
$$\tau = \frac{1}{2\pi RC}$$

Turbidity Meter

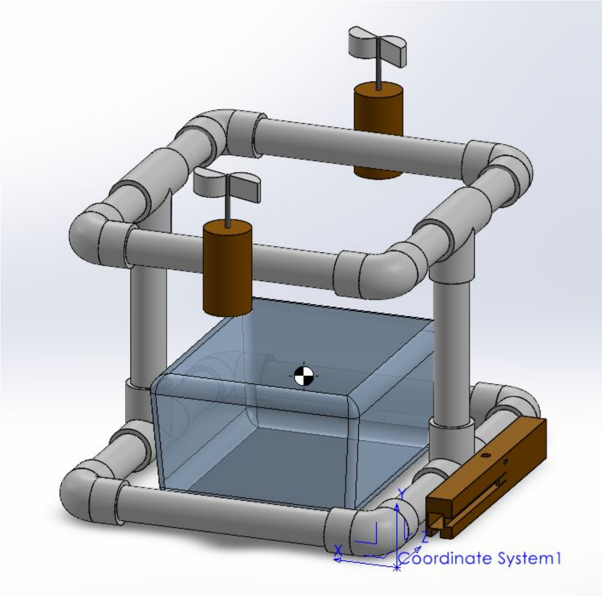


- Oriented the pair of the BPW46 photodiodes orthogonal to each other.
- The LED across from one diode and orthogonal to the other.

- Manufactured to limit ambient light
  - Dark 3D print material
  - Long chamber

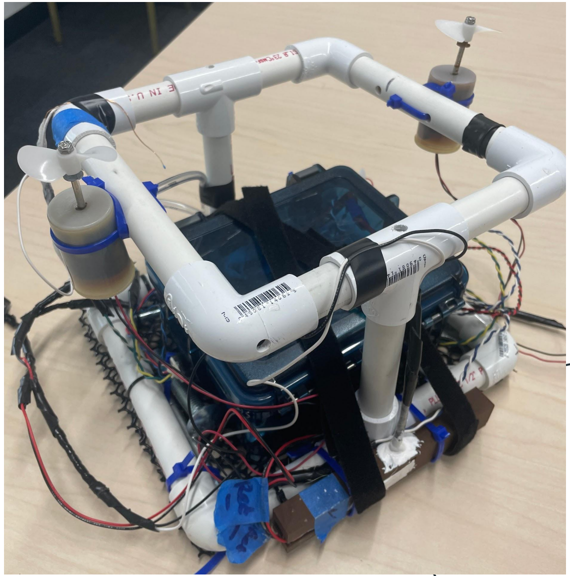


Mechanical Design



Center of Mass/Buoyancy centered using ballast weights on the outer frame.

Final Weight: 3.201 kg



Design Modifications:
- Smaller/Symmetrical Frame
- Dual motors

Safety Considerations

Waterproofing

Avoid electrical wires from being conductive

Launching

At least 5 ft away from other testing groups

Robot Retrieval

Attach cord to pull robot back up if necessary

Security of Parts

Avoid wires getting caught in motor and kelp

Deployment

1. pHake Lake
   a. Waterproofing
   b. Temperature vs Depth

2. Dana Point
   a. Dock Launch Point
   b. Final Data!

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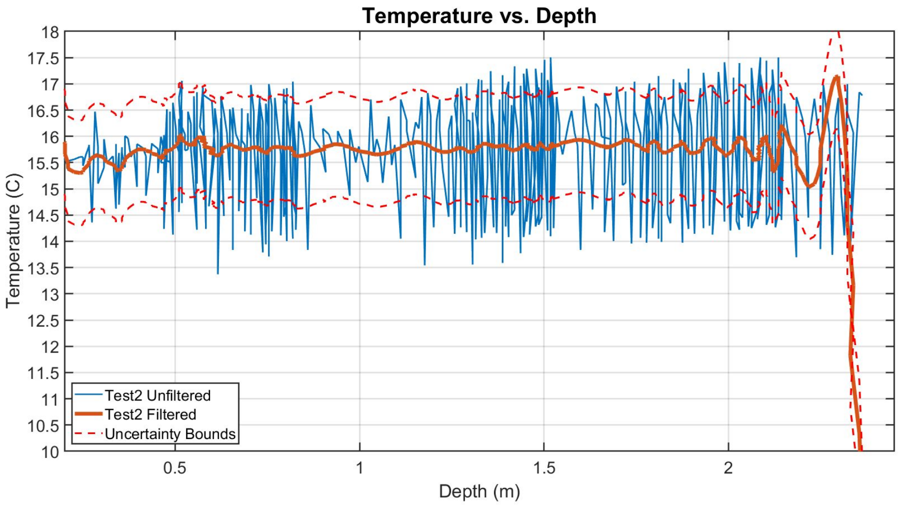
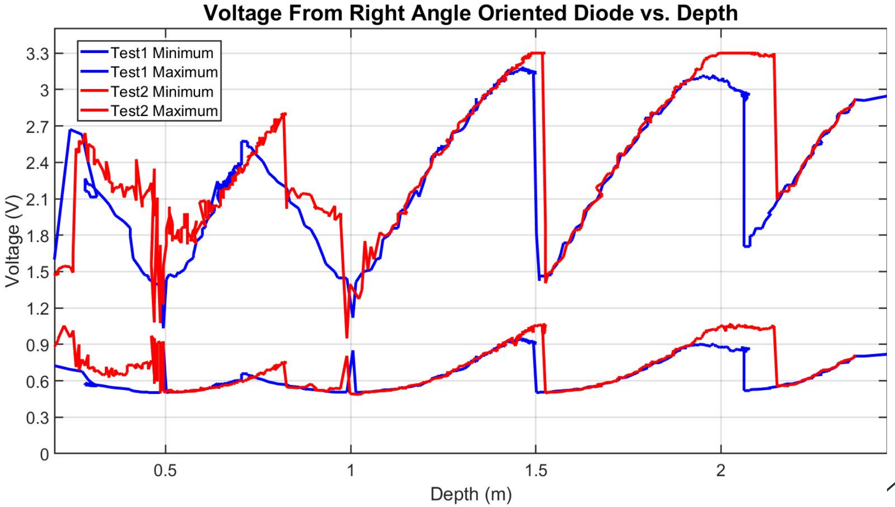
Data Analysis





- Constant temperature at varying depths
  - Average Temperature after filtering using fourier transforms: 15.75°C
- Temperature well within error margin

- Increasing max voltage until rail-out voltage
- Lower max voltages when in motion
- 4.152979*depth-4.783872

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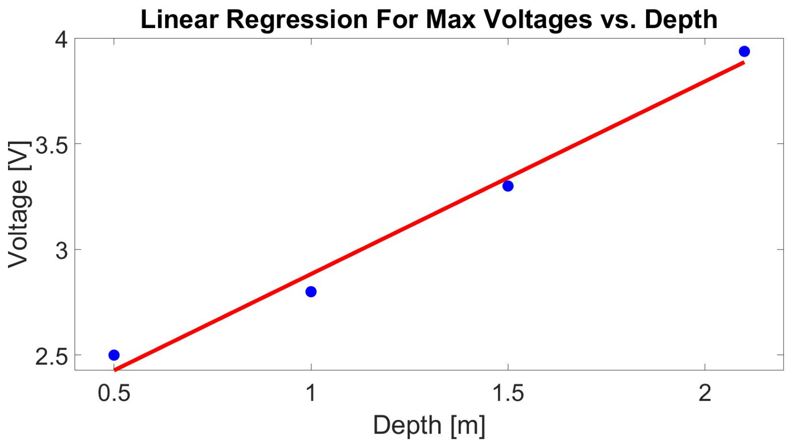
Results

- Temperature and Depth graph indicates little to no change in temperature with depth at this range.

- Using linear regression and estimation, a fit of the data indicates a positive correlation between depth and green matter.



volts=0.912*depth+1.972

Conclusion

Algae concentration increases as depth increases for a short range of depth away from the surface.

- Static temperature indicates no correlation can be made between algae and temperature
- Our hypothesis was disproved; Between about 0 - 2 meters, algae concentration increased with depth.
- Further investigation indicates that closer to the surface, there is less nutrients for production

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Future Work

A

Improve Casing

Epoxied photodiodes and IR LEDS unreachable

C

Turbidity Circuit

Change resistance values

B

Add Connectors in Box

Allow for new connections to the motherboard

D

Travel to Deeper Depths

Identify greater light variance at different depth

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Summary

- Main Goal: Relationship of algae concentration with depth and temperature
- Sensors: Pressure, temperature, turbidity (only 90° worked during deployment)
- Mechanical Design: two vertical motors
- Conclusion: Algae increases with depth for a small distance away from surface
- Future Changes: improve practicality of circuits and sensor connections along with the capabilities of the AUV

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Acknowledgements

Special thanks to the E80 teaching staff for making this possible!

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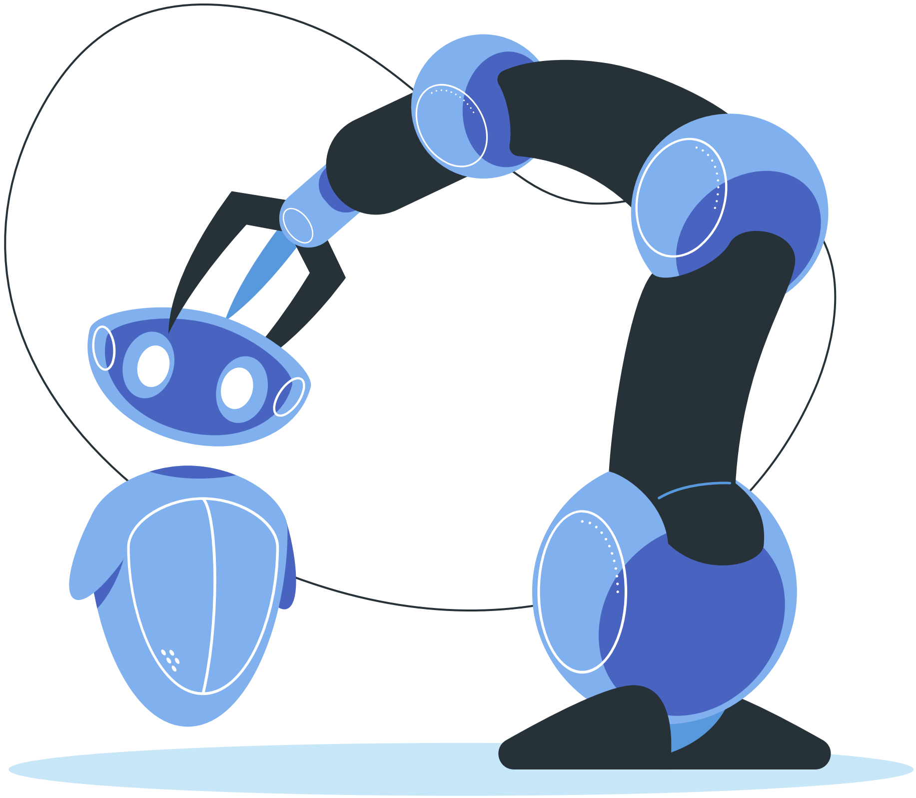
Thank You!



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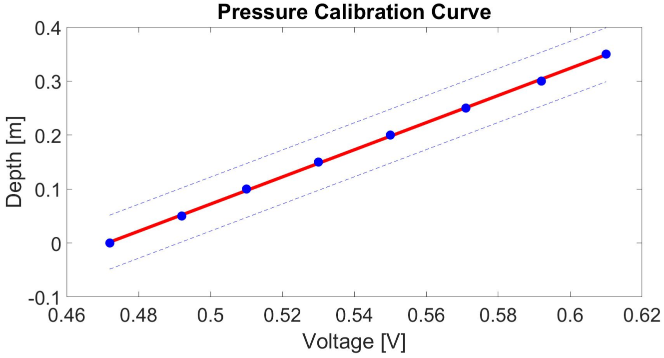
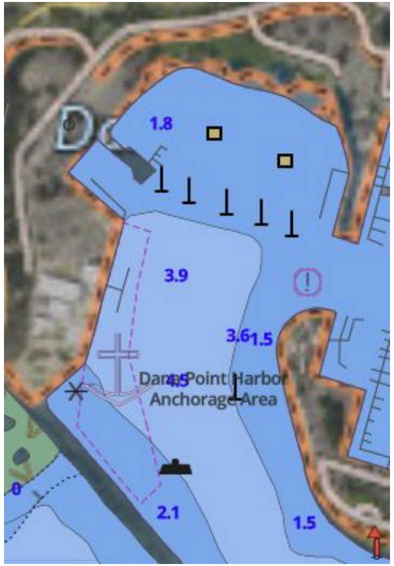
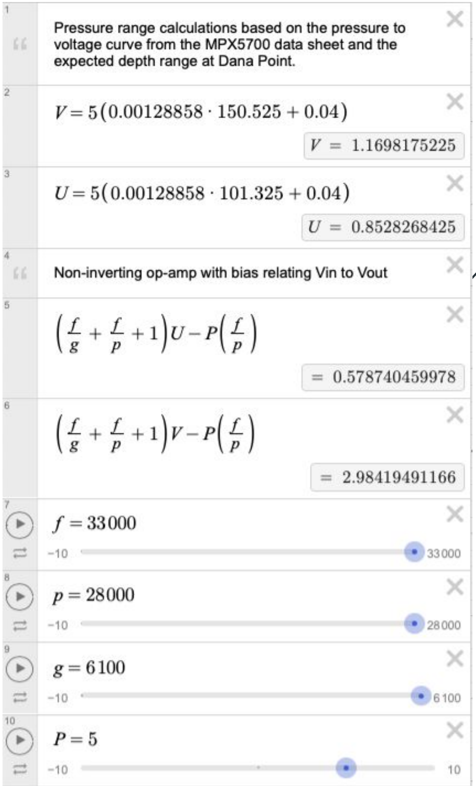
Pressure Sensor Process

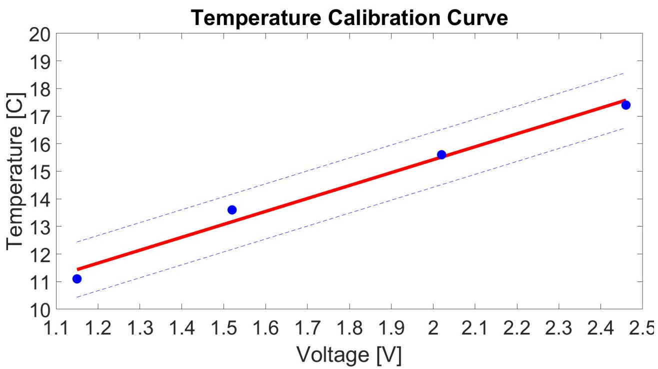


$D = 2.516V - 1.186.$

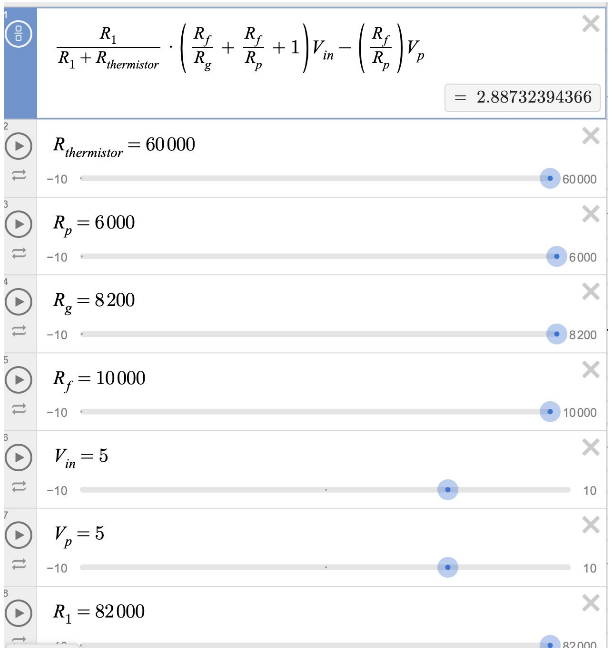


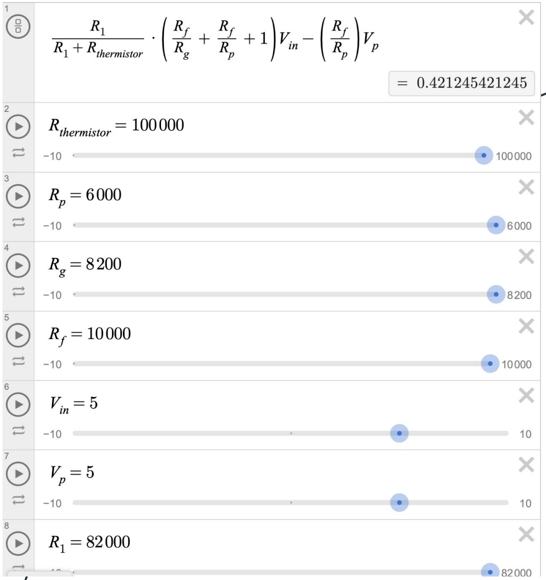


Temperature Sensor Process

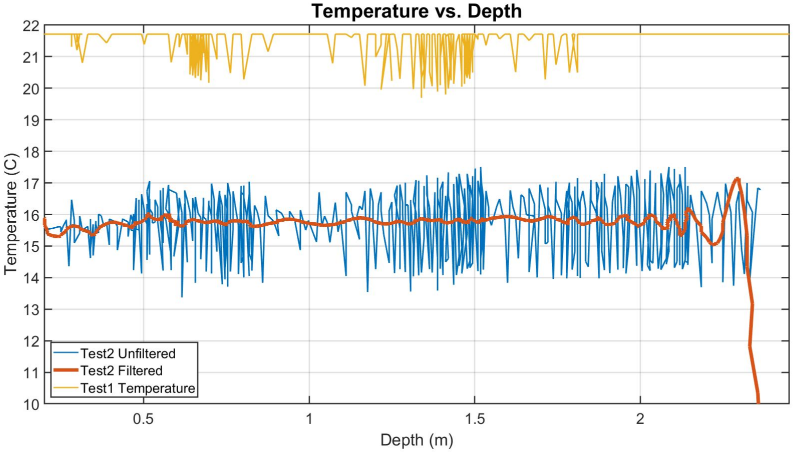


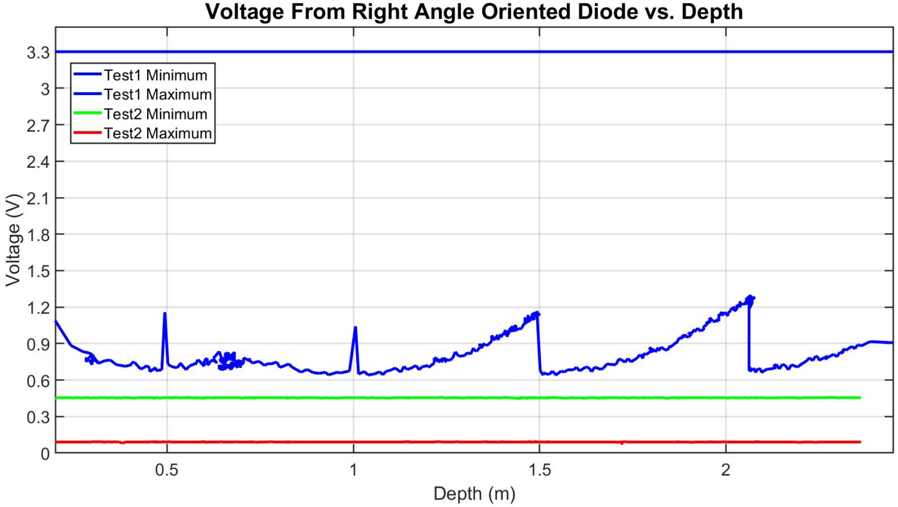
$T = 4.688*V+6.045$

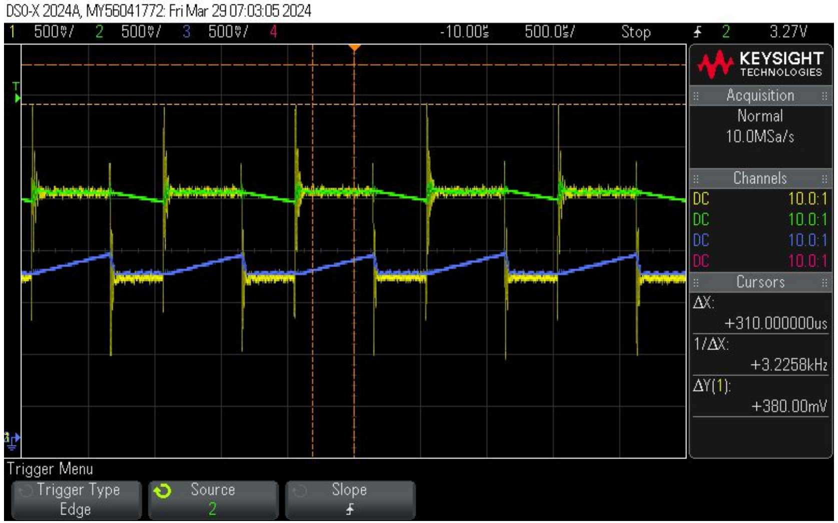




Data Analysis







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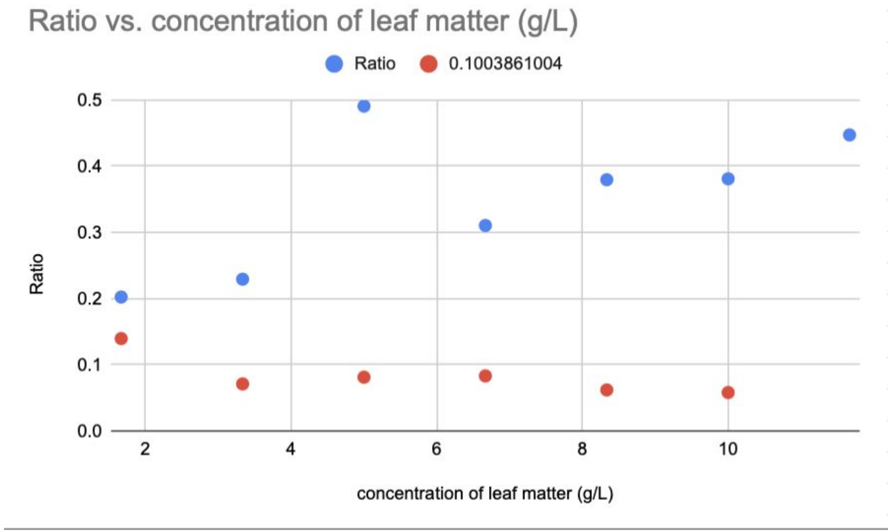
Turbidity Calib



Max Voltage with 1.66g/L of green matter: 2.025