E80 Final Project Presentation: Field Deployment of an Autonomous Underwater Vehicle

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Spring 2022

Meet the Robots

Meet Karen
RIP KAREN 2022-2022

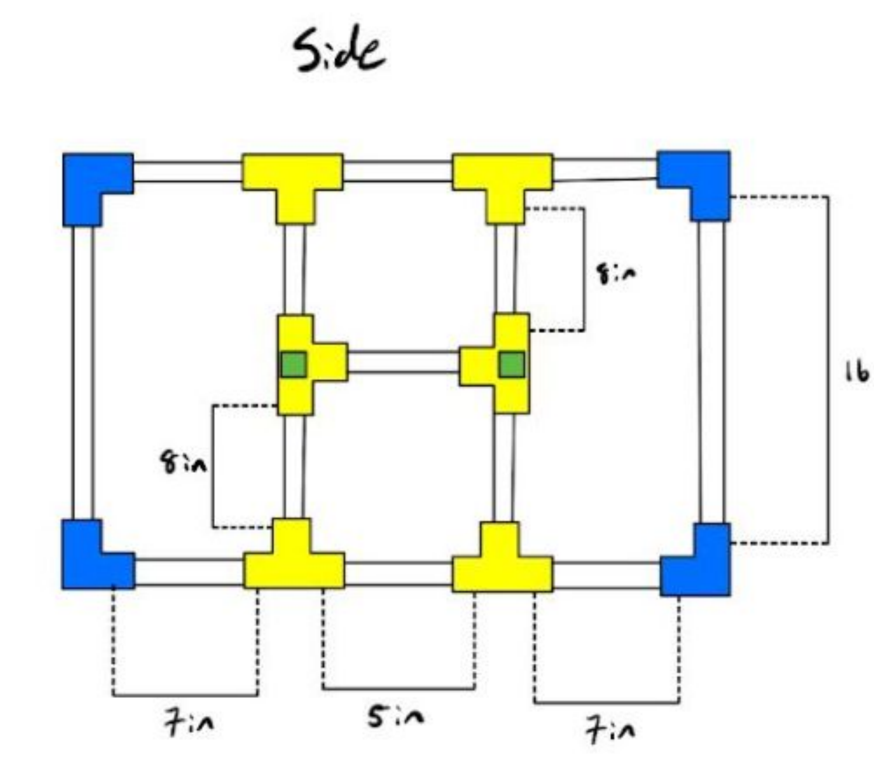
Meet Jeremy

Our Motivation and Approach

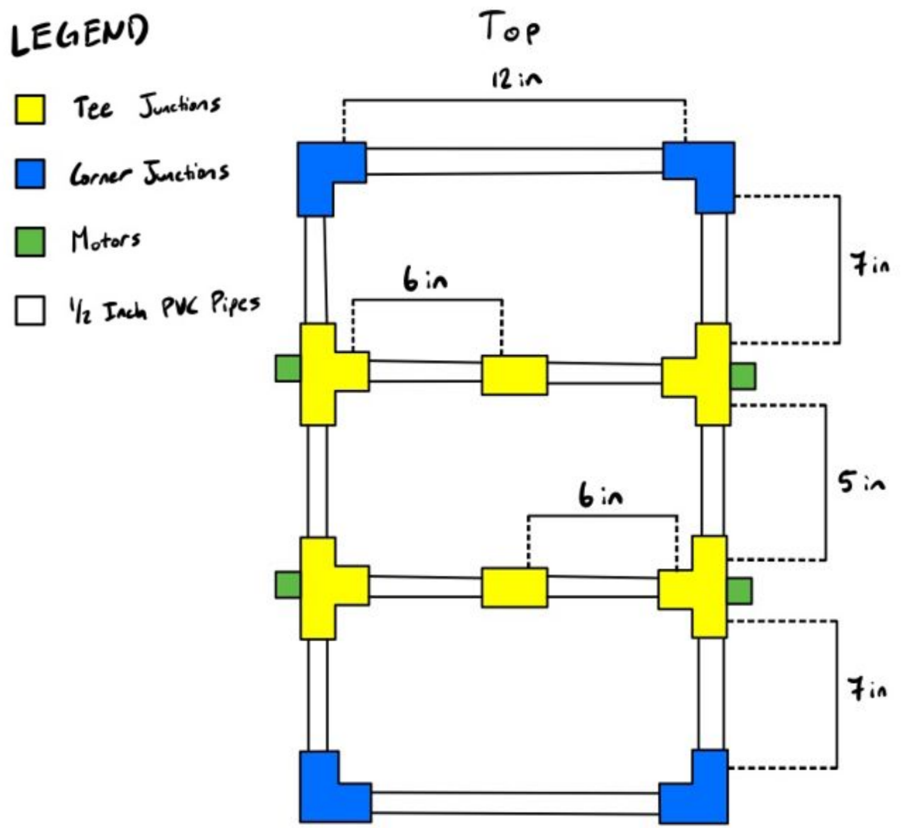
CLIMATE CHANGE

Robot Mechanical Design

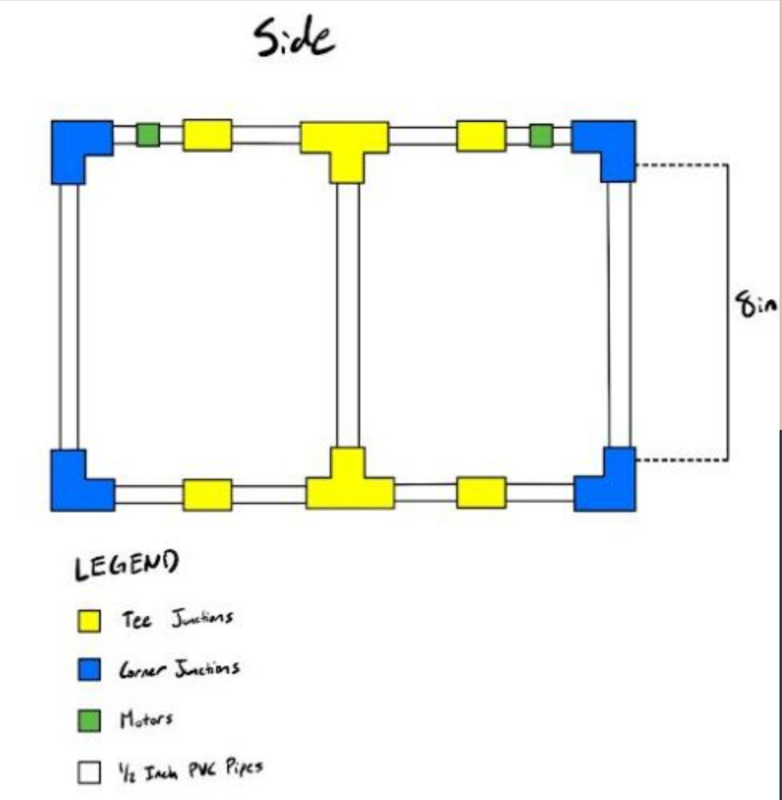
Design Process & Sketches



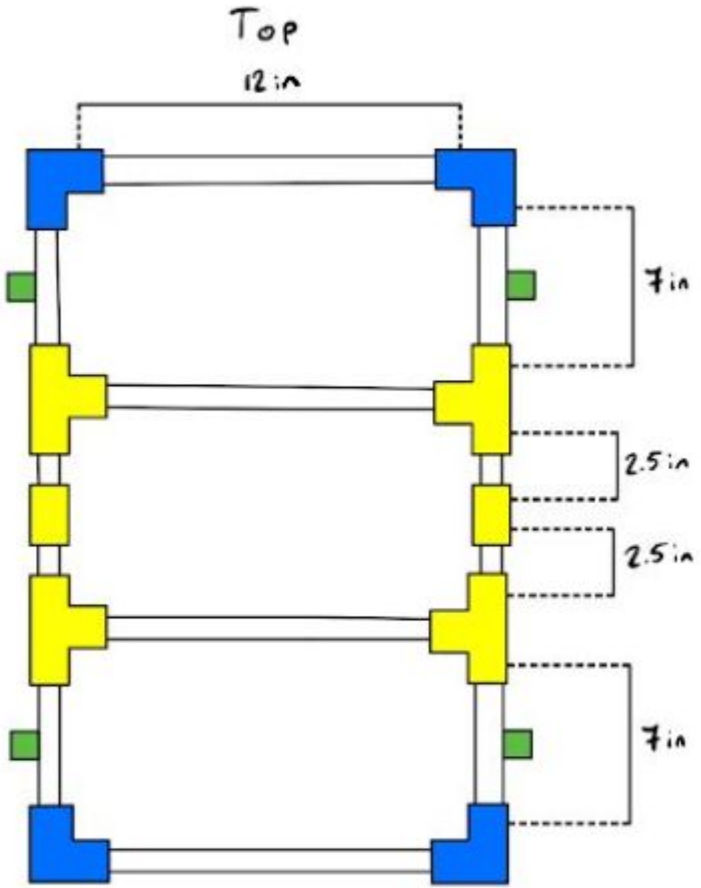
Initial Design: 19”x12”x16”



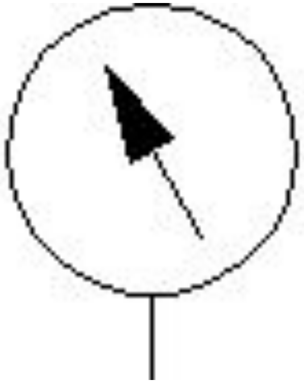
Final Design Chosen



Final Design: 19”x12”x8”



Sensor Selection & Circuit Design



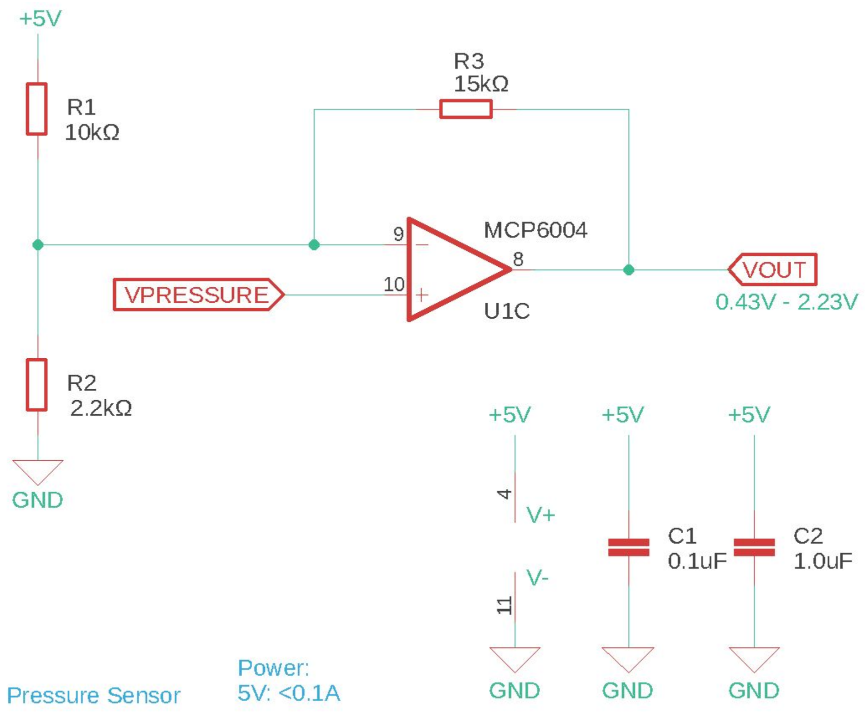
Pressure Sensor

- MPX5700ASX
- Piezoelectric transducer
  - Voltage is directly proportional to pressure

Goal: Design a circuit that appropriately amplifies the sensor's output for the robot's desired 0 - 3m depth range

Pressure Sensor Circuit

- Non-inverting amplifier with biasing
- Components selected based off of expected pressure sensor voltage
- Bypass capacitors connected to op-amp
    - MCP6004



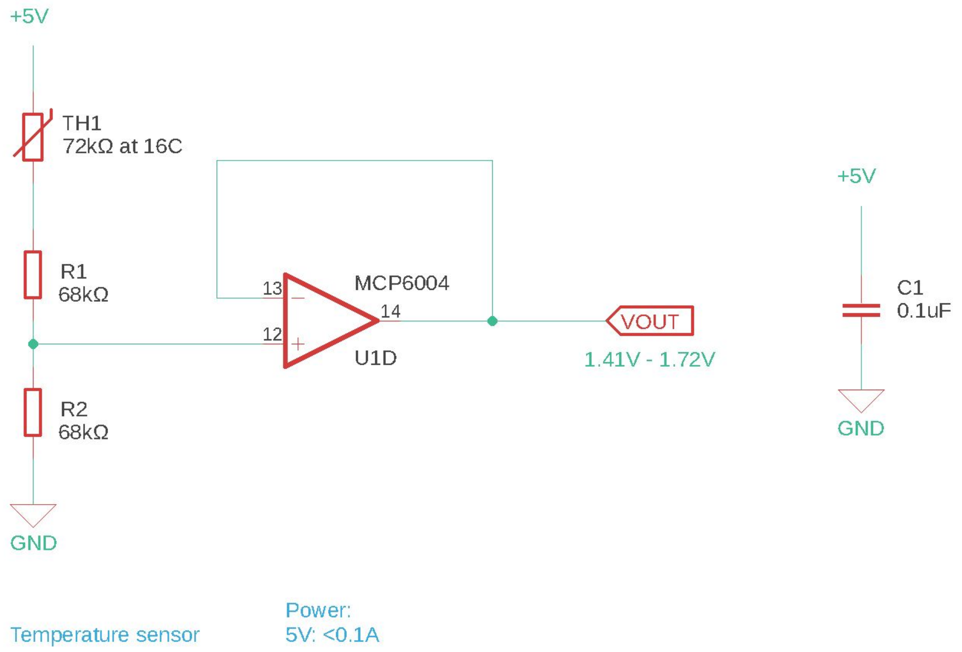
Temperature Sensor

- 47kΩ Murata-NXFT15WB473FA2B150
- Temperature dependent resistor
  - Resistance inversely proportional to temperature

Goal: Design a circuit that produces an output swing within a 0 - 3.3V range that models temperatures from 10.5 - 19.5°C

Temperature Sensor Circuit

- Voltage divider circuit
- Two biasing resistors used to prevent output from surpassing 3.3V
- Components selected based on expected conditions at Dana Point
- Divider output fed into op-amp buffer

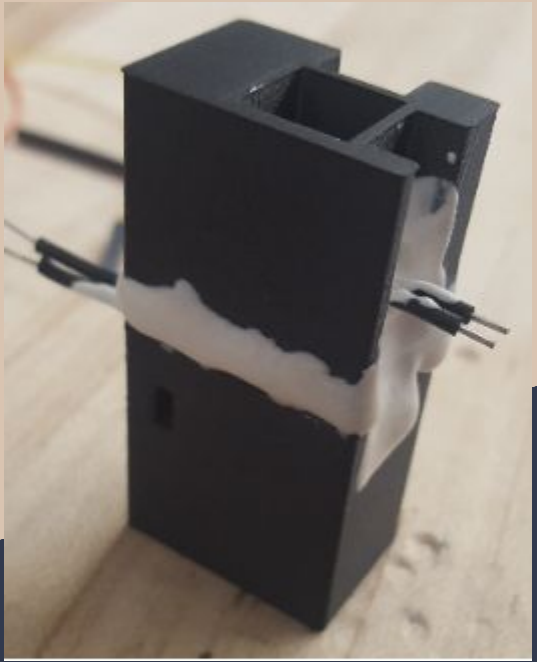


Turbidity Sensor

- IR1503 LED
- 950nm OP950 Photodiode
    - Controlled by 555 Timer

Goal: Design a circuit based on IR light readings that can appropriately model changes in turbidity

Turbidity Meter Construction



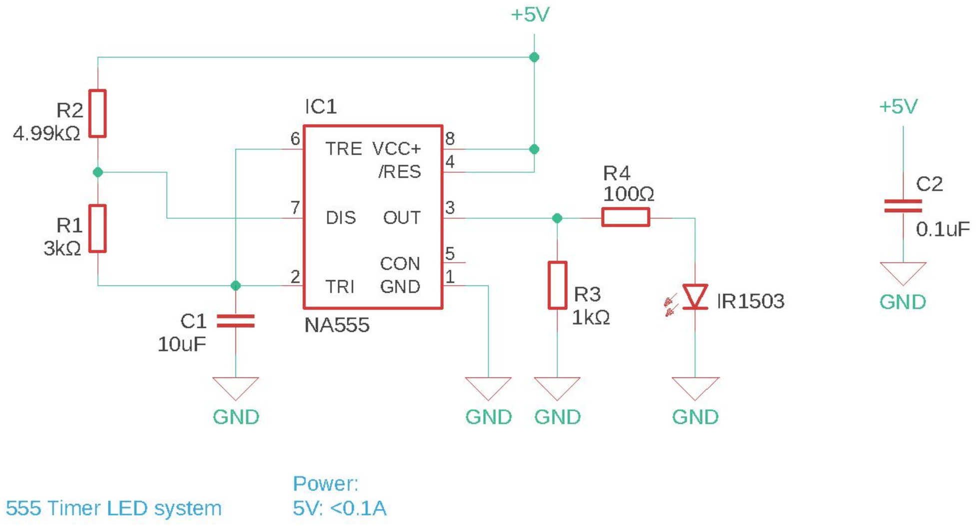
The first step involved soldering and heat shrinking stranded wire to the ends of the photodiode and LED.

Marine epoxy

Hole at top and bottom for water flow

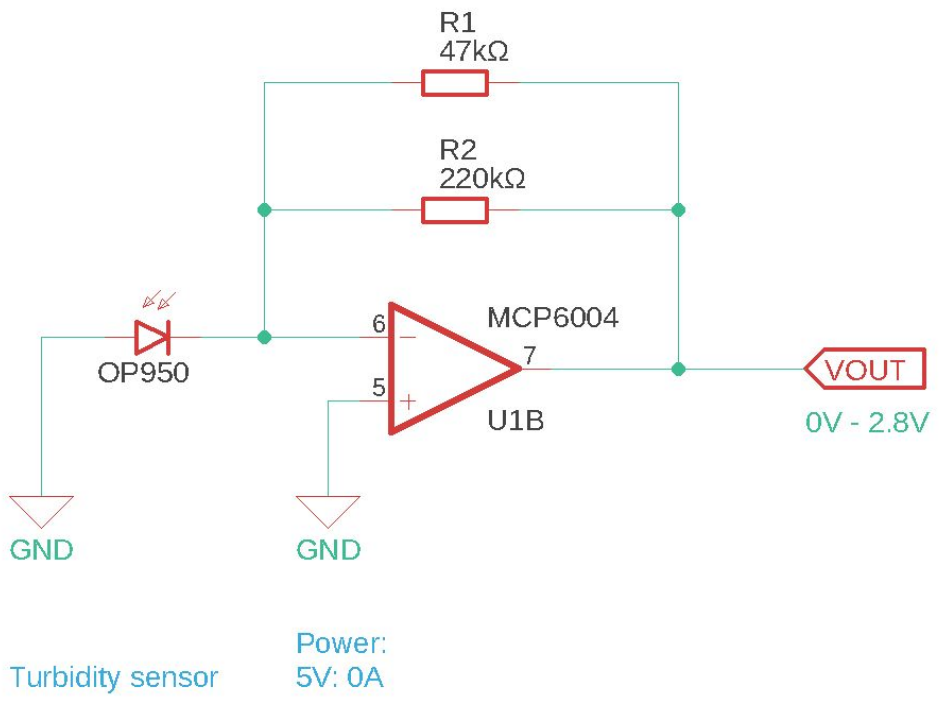
Turbidity Sensor Circuit + 555 Timer

- Design based off on the astable circuit design provided in the xx555 timer datasheet
- Current limiting resistor included to mitigate risk of LED burning out
- Output signal has a frequency of approximately 26Hz



Turbidity Sensor Circuit + 555 Timer (Cont.)

- Transimpedance amplifer
- Photodiode behaves like a current source, receiving IR light from the LED
- Adjusted feedback resistance to achieve desired output swing



Pre-deployment Modeling & Expected Measurements

Model Calculations

$$R = R_0 \exp B\left(1/T - 1/T_0\right) \quad \cdots\cdots (1)$$

R: Resistance in ambient temperature T (K)

(K: absolute temperature)

R_0: Resistance in ambient temperature T_0 (K)

B: B-Constant of Thermistor

Thermistor Info		Key
Thermistor Type	Murata NXFT15WB473FA2B150	Input
R0 [kohms]	47	Output
B constant [K]	4101	

Temp to Resistance	
To [K]	298.15
Tmin [C]	10.5
Tmax [C]	19.11
Average temp [C]	16
Rmin [kohms]	62.01352343
Ravg [kohms]	72.1160213
Rmax [kohms]	94.94378267

Voltage Divider Values	
VDD [V]	5
Standard R2 [ohms]	68000
Ideal R1 [ohms]	65944.58476
Closest Standard R1 [	68000

Teensy Spec Check	Result	Spec	Meets Spec?
Vout,min [V]	1.472219759	0	TRUE
Vout,max [V]	1.717054442	3.3	TRUE
Vout,midpoint [V]	1.633704113	1.65	

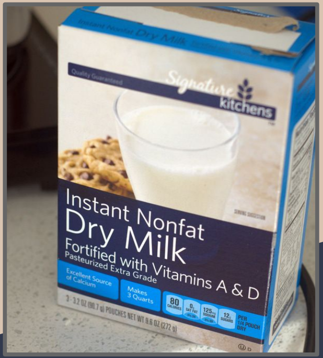
Output Voltage	
Goal Vout,midpoint [V]	1.65
Vout,min [V]	1.472219759
Vout,midpoint [V]	1.633704113
Vout,max [V]	1.717054442

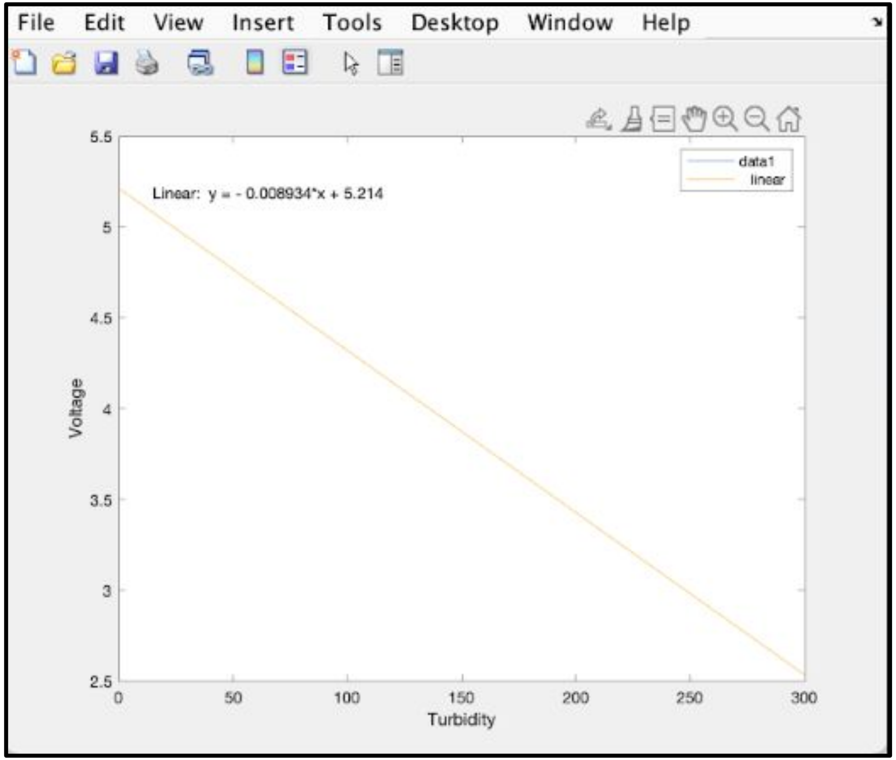
Checks if Output Voltages are below 3.3 Volts

Note 2: The following equation is the basis for the computation,
v_out = v_ps(R3/R2 + R3/R1 +1) - VDD(R3/R1)

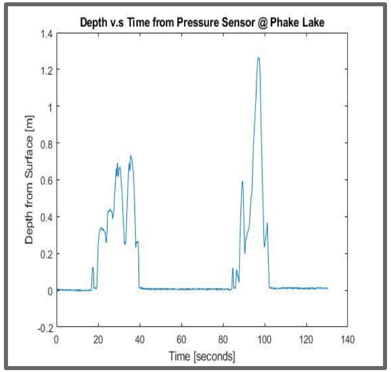
Environmental Parameters	
fresh water density [kg/m^3]	1023.6
g [m/s^2]	9.80655
Measured Circuit Parameters	
VDD [V]	5
R1[ohms]	10000
R2 [ohms]	2200
R3 [ohms]	15000
Single Point Check	
Vout [V]	0.3
Vps [V]	0.8370731707
P [kPa]	99.09366476
depth [m]	-0.2222891681

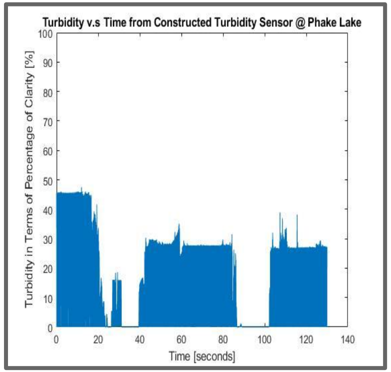
Model Calculations (Cont.)

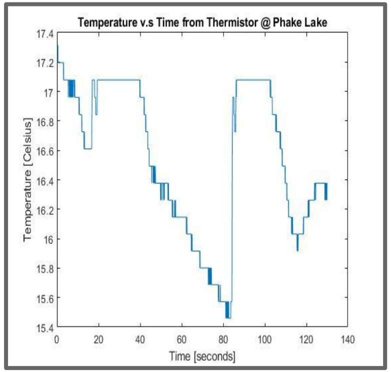


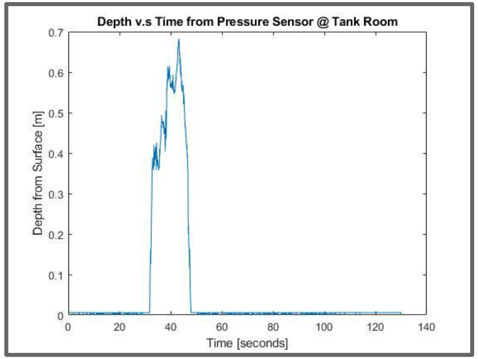


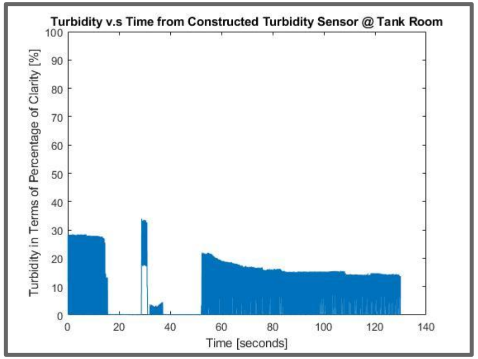
Testing Model w/ Phake Lake & E80 Tank Room

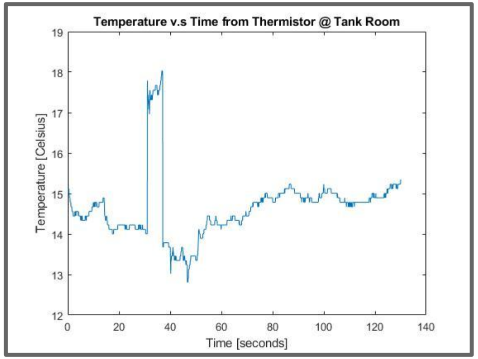






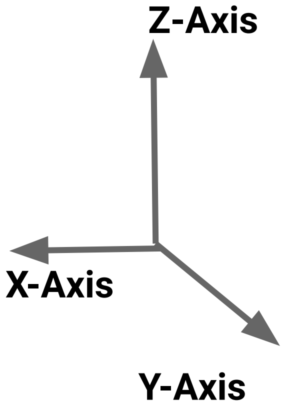






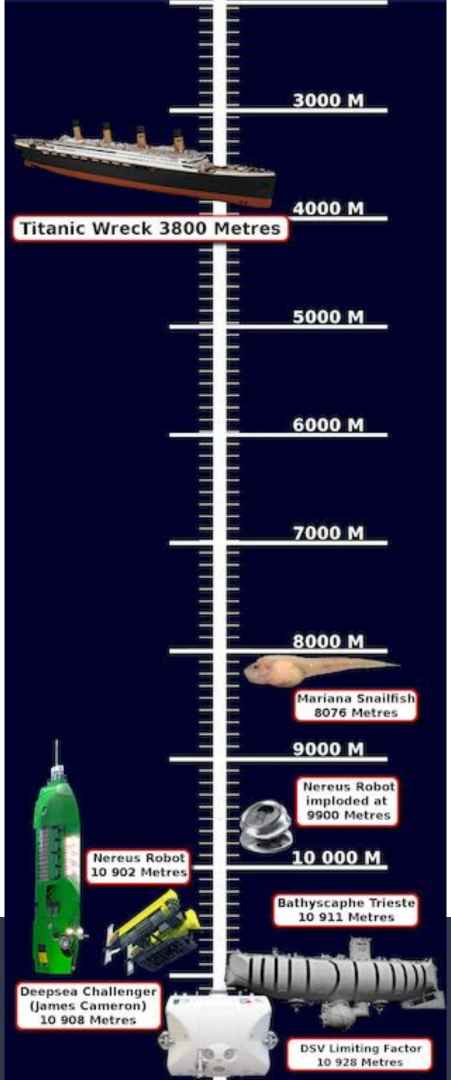
Revisions Made After Testing

- Changing Turbidity meter orientation from horizontal to vertical
- Size of robot’s dimensions changed minimally after our initial robot drowned in Phake Lake.
- Purchased a larger water-proof box for easier deployment.
- Turbidity calibration outputted 5 Volts, needed to adjust resistor values



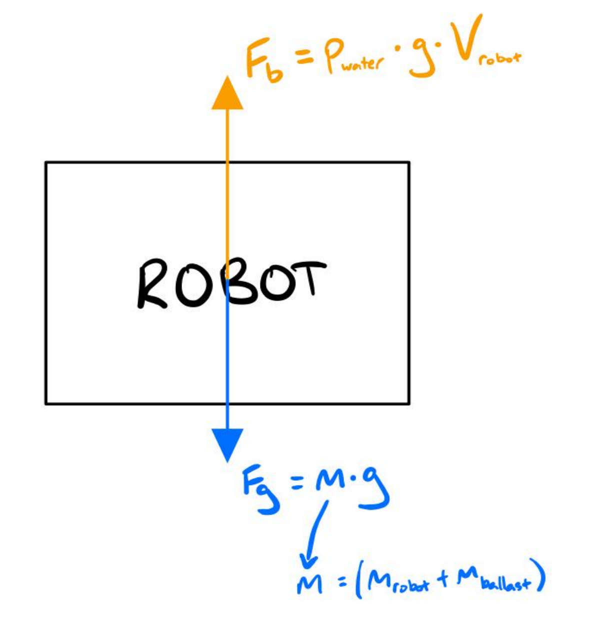
Dana Point Deployment

Dana Point Harbor



3000 M
4000 M
Titanic Wreck 3800 Metres
5000 M
6000 M
7000 M
8000 M
Mariana Snailfish
8076 Metres
9000 M
Nereus Robot
imploded at
9900 Metres
10 000 M
Nereus Robot
10 902 Metres
Bathyscaphe Trieste
10 911 Metres
Deepsea Challenger
(James Cameron)
10 908 Metres
DSV Limiting Factor
10 928 Metres

Schematics & Calculations



$F_b = p_{water} * V_{robot} * g$

$F_b = 1.027 \text{ kg/L} * 6.72 \text{ L} * 9.81 \text{ m/s}^2 = 67.69\text{N}$

$F_b = F_g = m_{system} * g$, $m_{system} = m_{robot} + m_{ballast}$

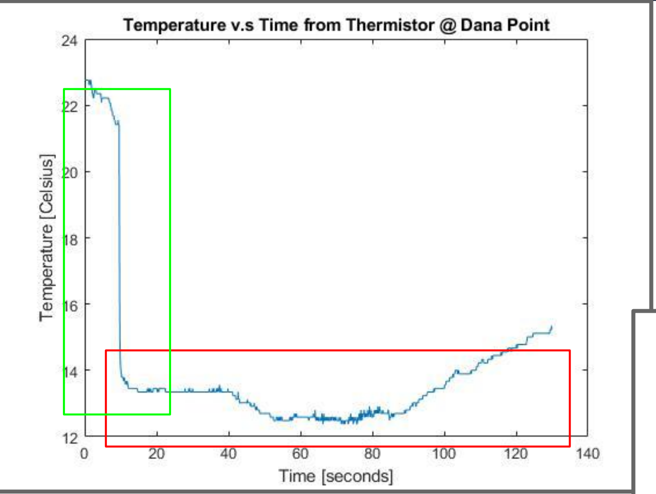
$67.69\text{N} = (m_{robot} + m_{ballast}) * 9.81 \text{ m/s}^2$

$67.69\text{N} = (3.83 \text{ kg} + m_{ballast}) * 9.81 \text{ m/s}^2$

$m_{ballast} = 3.08 \text{ kg}$

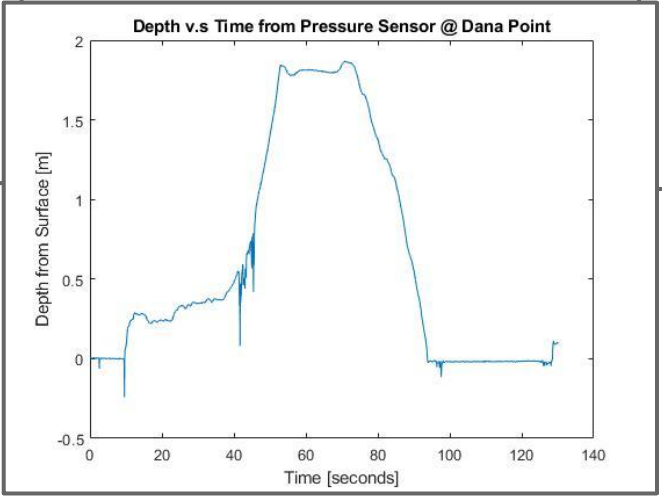
Post-Deployment Data Processing & Analysis

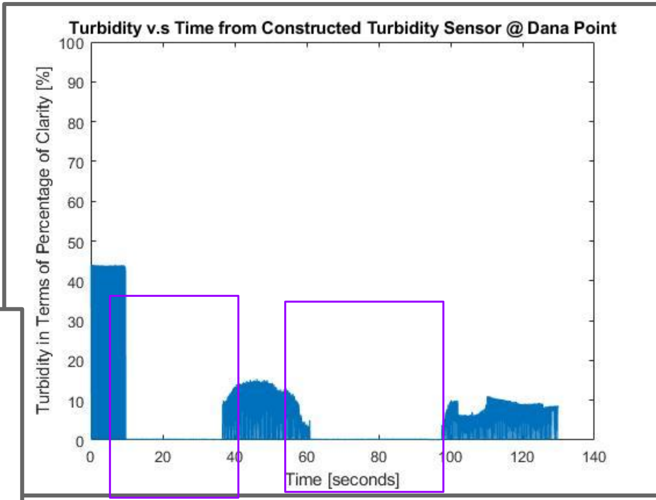
Processing Sensor Data (w/ Respect to Time)



Temperature v.s Time

Depth v.s Time

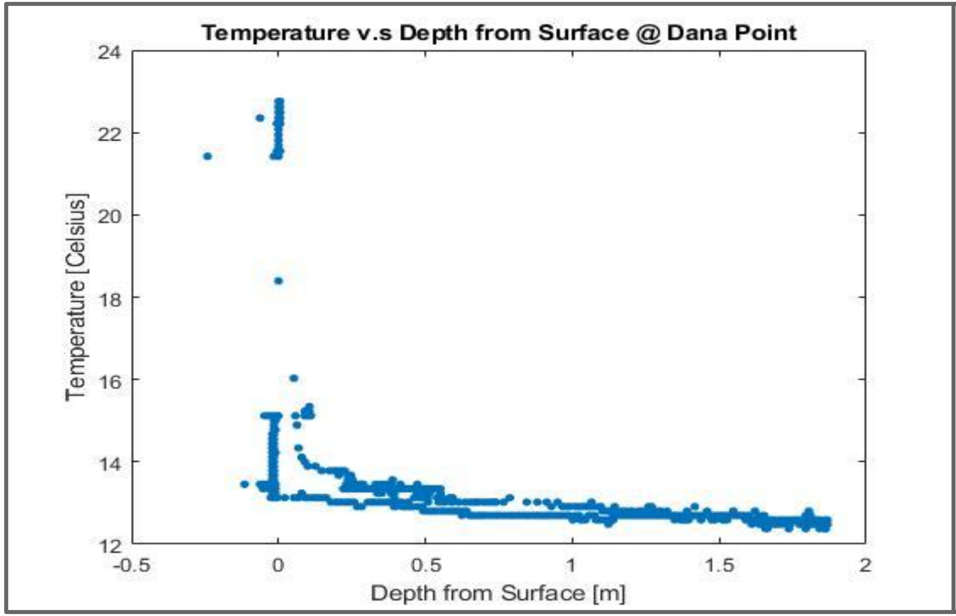


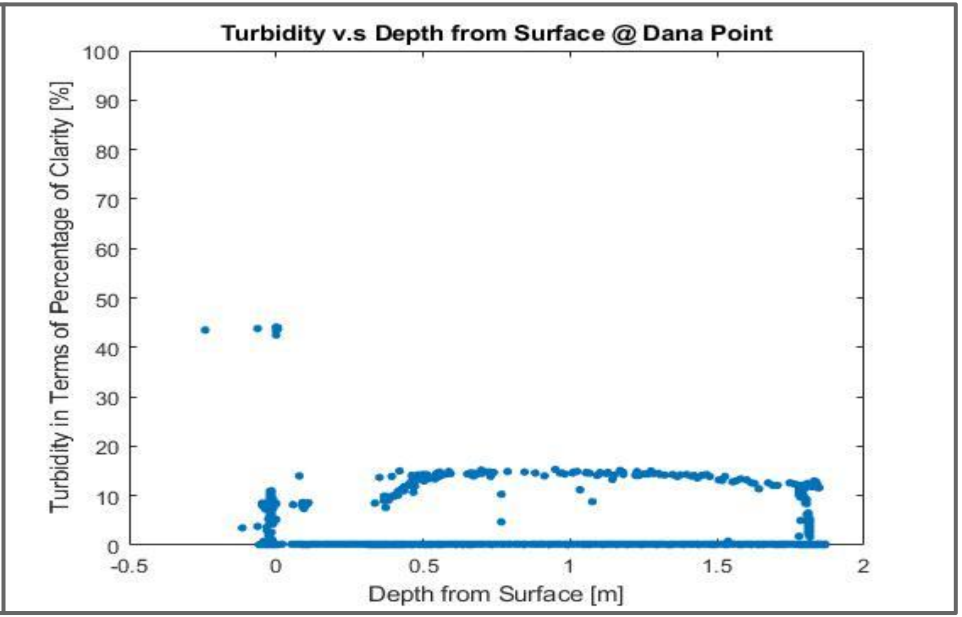


Turbidity v.s Time

Temperature vs. Depth from Ocean Surface

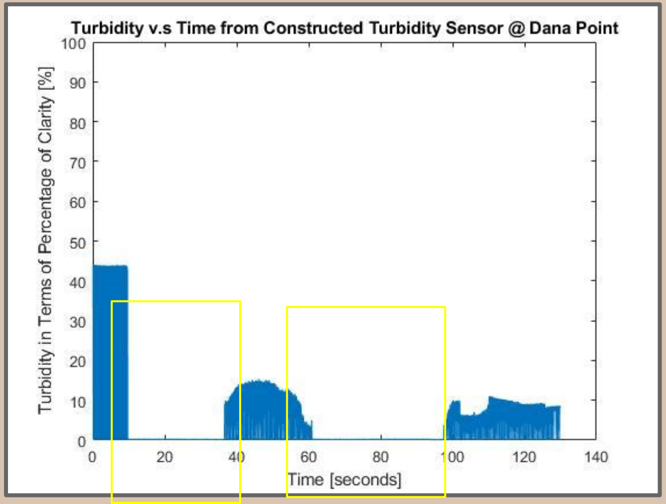
Turbidity vs. Depth from Ocean Surface





Future Work

Complications

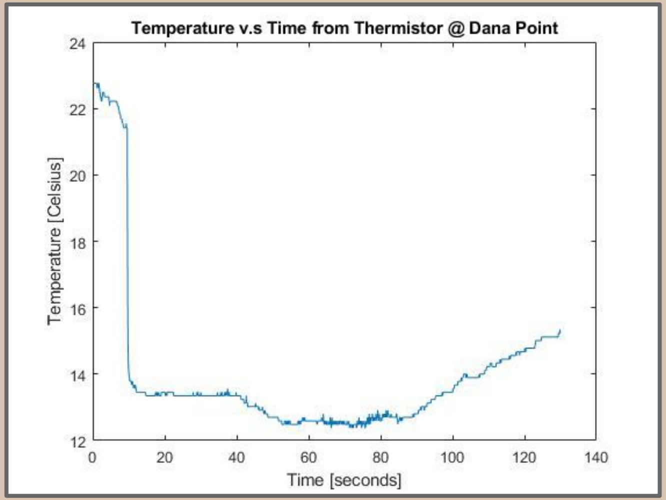


Turbidity v.s Time

Gaps in turbidity sensor data.

As the robot descended, turbidity decreased.

Future Work



Temperature Guild	Species	ILLT, ULLT	Optimal range
Coldwater	Arctic charr (*Salvelinus alpinus*)	0–19.7	6–15
	Atlantic salmon (*Salmo salar*)	−0.5–25	13–17
Coolwater	Walleye(*Stizostedion vitreum*)	0–30	20–23
	Striped bass(*Morone saxatilis*)	2–32	13–24
Warmwater	European eel (*Anguilla anguilla*)	0–39	22–23
	Channel catfish (*Ictalurus punctatus*)	0–40	20–25
Warmwater/ tropical	Common carp (*Cyprinus carpio*)	0–35.7	26.7–29.4
Tropical	Redbelly tilapia(*Tilapia zillii*)	7–42	28.8–31.4
	Guinean tilapia (*Tilapia guineensis*)	14–34	18–32

Increase the depth of the robot.

Implement sonar.

Test in warmer ocean waters.

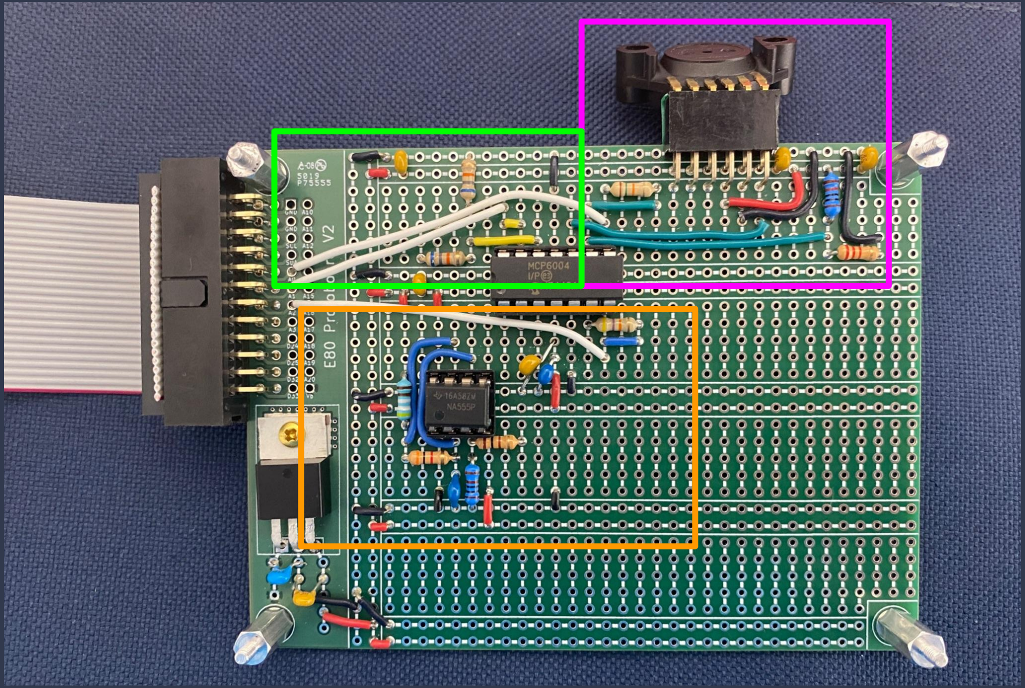
Acknowledgements

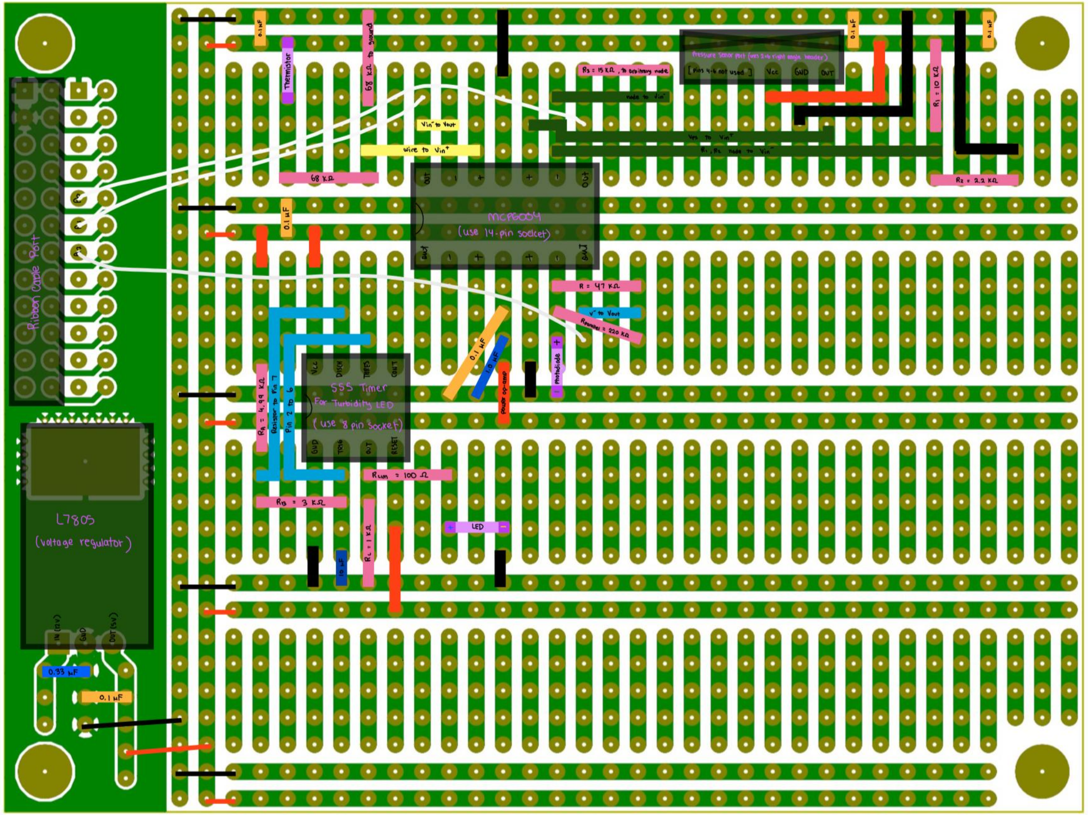
We would like to thank Lynn, Xavier, Professor Spjut, the proctors, and the entire teaching staff for helping us along the way in these unprecedented times.

Thank you!

Now we'll be fielding questions…

Putting it all together





Key:

Socket/Header (corresponding pins labelled internally)

- wire to ground
- wire to power
- internal wire : temp. sensor
- internal wire : turbidity sensor
- internal wire : pressure sensor
- output to Teensy pin

- Capacitor : 0.1 µF
- Capacitor : 0.33 µF
- Capacitor : 1.0 µF
- Capacitor : 10 µF

- Resistor
- Sensor part (LED, thermistor)

Note: capacitor and resistor values are written on each component