E80 Autonomous Robot for Depth-Based Sensing of Light Intensity, pH, and Temperature

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E80: Experimental Engineering, SP 26

Problem Statement

The water quality at Dana Point has been in question for years after being in close proximity with a sewage pipe creating a potentially dangerous enviroment for the organisms living there. Environmental water quality varies with depth, but collecting depth-resolved data is difficult without complex equipment. There is a need for an autonomous underwater vehicle (AUV) that can measure key environmental variables such as light intensity, temperature, and pH as a function of depth in real-world conditions.

Impact

- Data of pH, temperature, and light allows for easy identification of areas with bad water quality
- Strong data can create priority for change and action in water quality at Dana Point
- Detecting dangerous areas quickly can help protecting local organisms from being in unsafe conditions

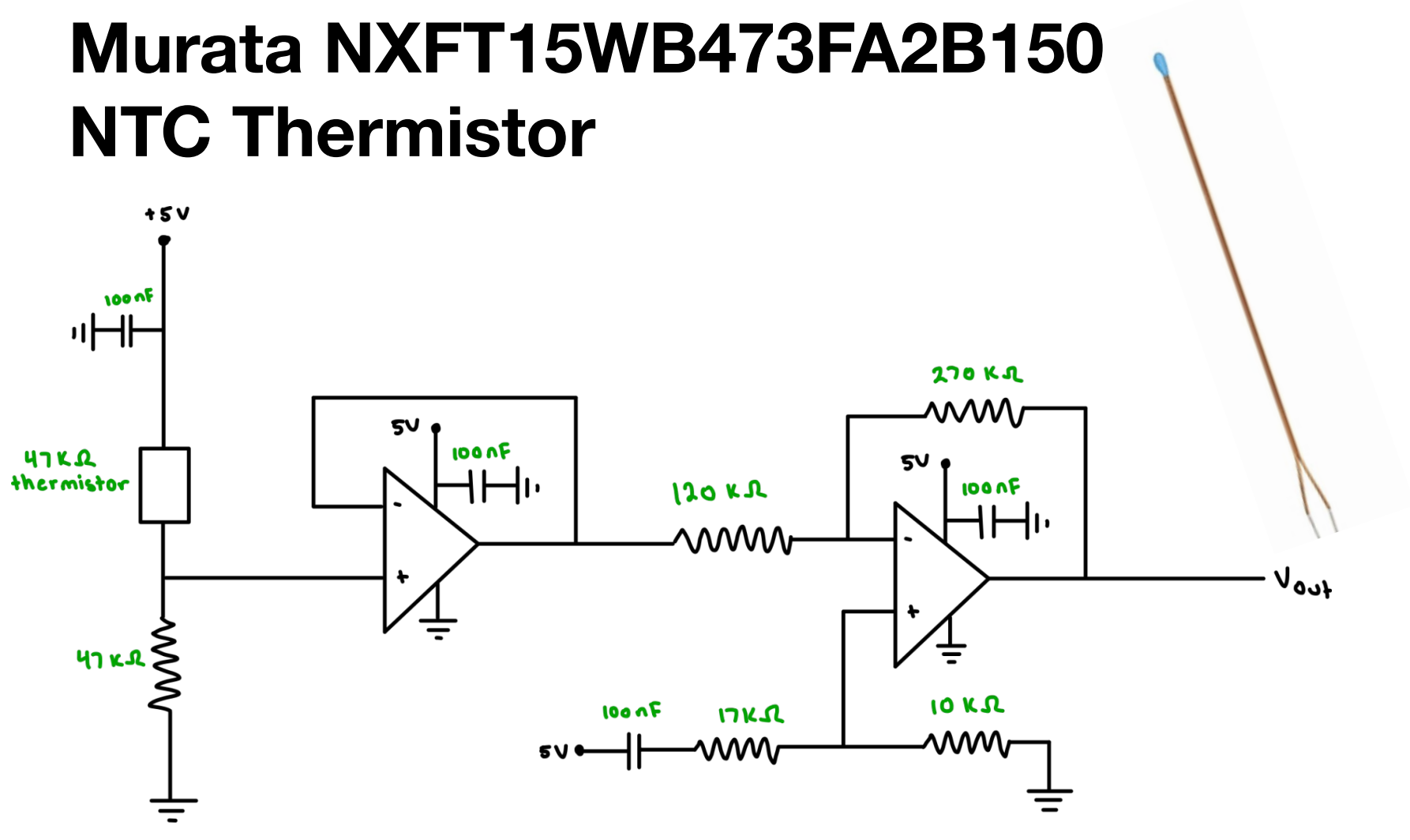
Future Work

- Improvement of pH sensor to refine data and revise interpretations
- Research on liveable conditions for marine life in bodies of water similar to Dana Point
- Test local organism health at Dana Point to see expected vs actual results

Autonomous Underwater Vehicle (AUV) Features

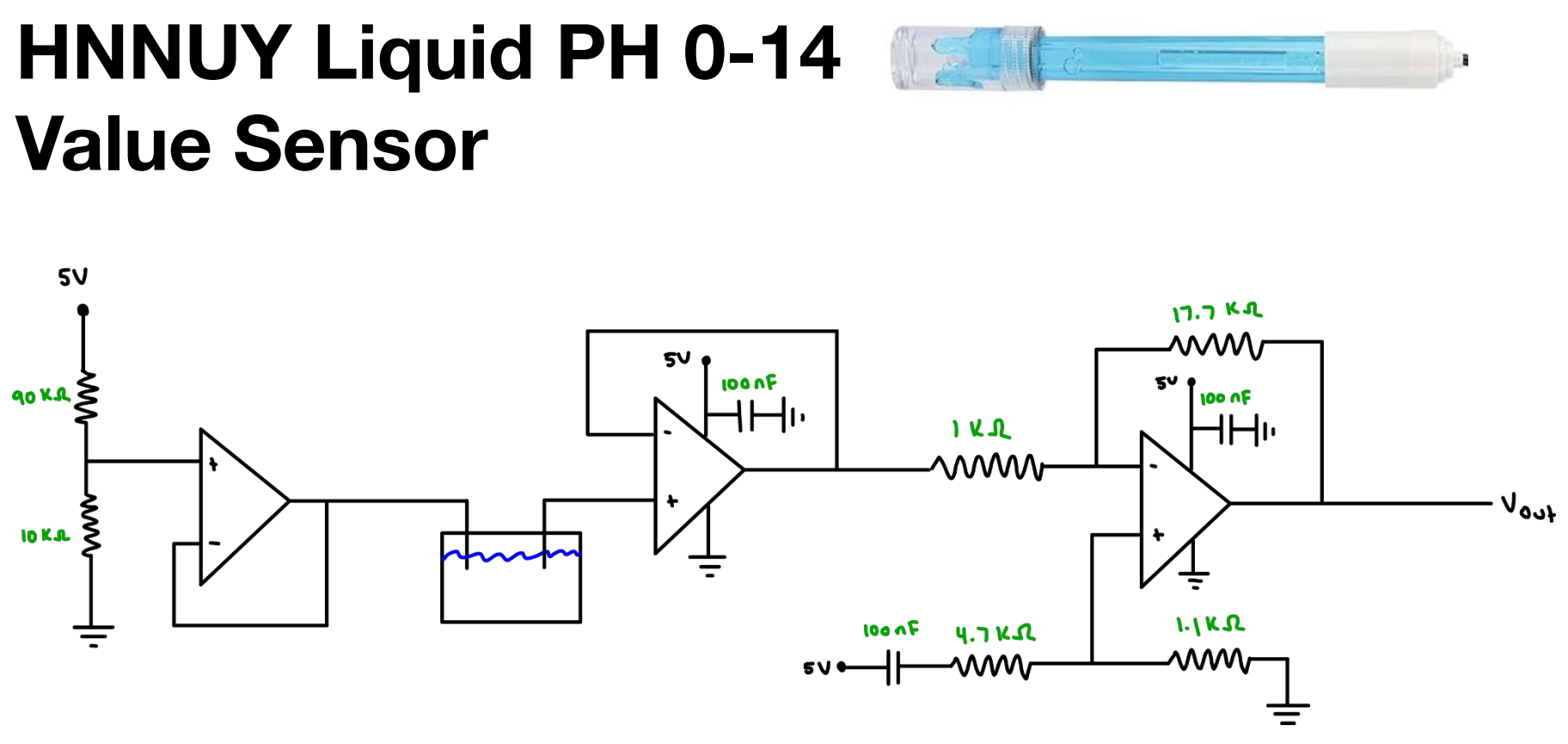
Electrical Schematic & Sensors

Murata NXFT15WB473FA2B150 NTC Thermistor



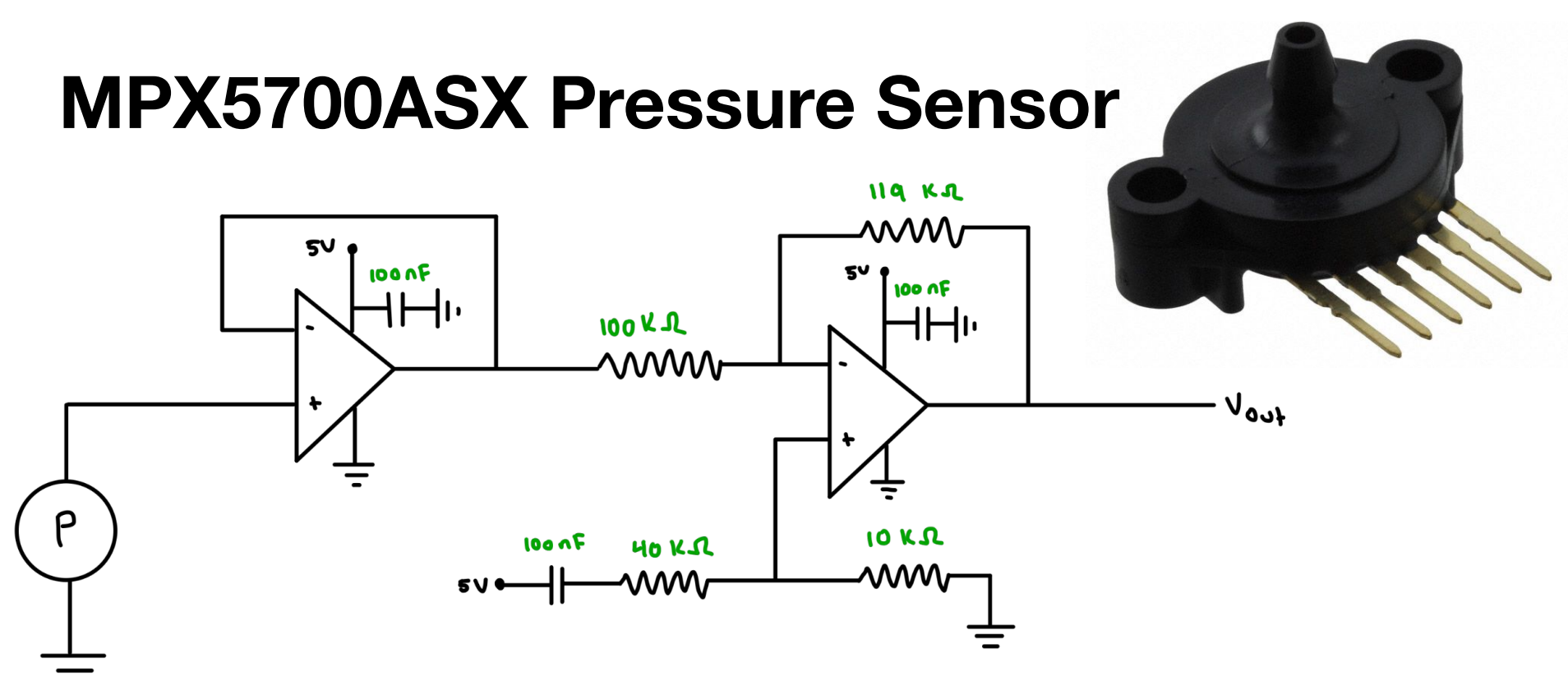
Expected input of sensor: 47k - 95.5k
Expected output of circuit: 0.5 - 2.7 V

HNNUY Liquid PH 0-14 Value Sensor



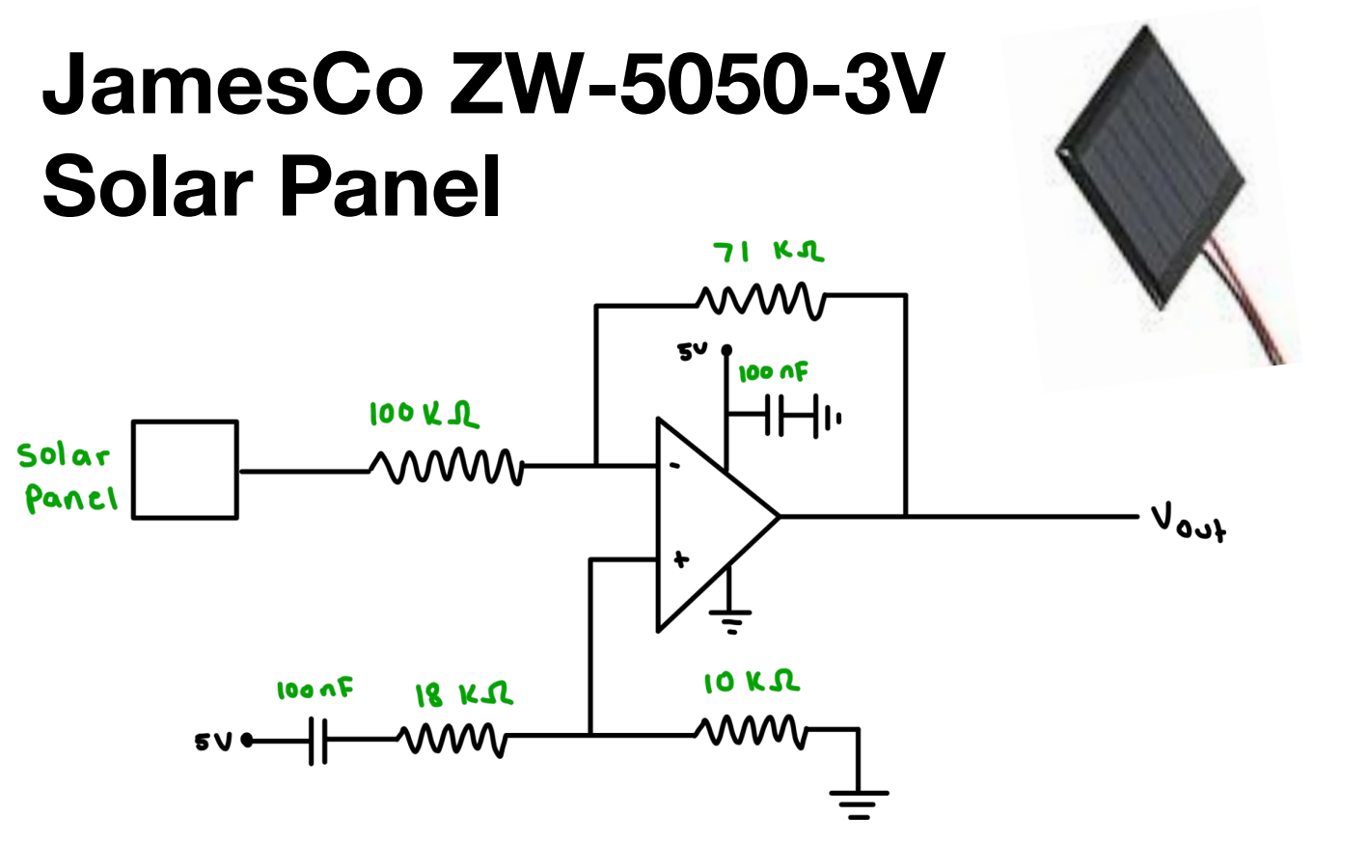
Expected input of sensor: 0.779 - 0.9 V
Expected output of circuit: 0.5 - 2.7 V

MPX5700ASX Pressure Sensor



Expected input of sensor: 0.851 - 1.040 V
Expected output of circuit: 0.5 - 2.7 V

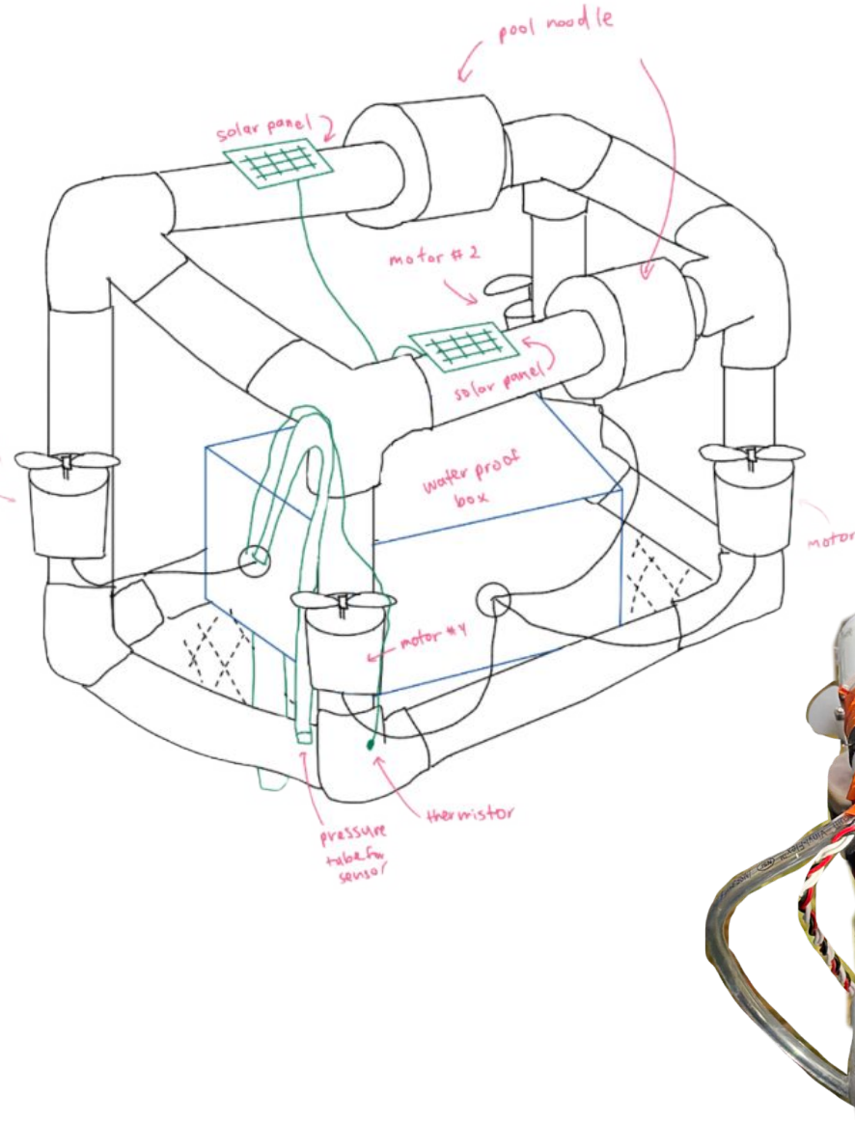
JamesCo ZW-5050-3V Solar Panel



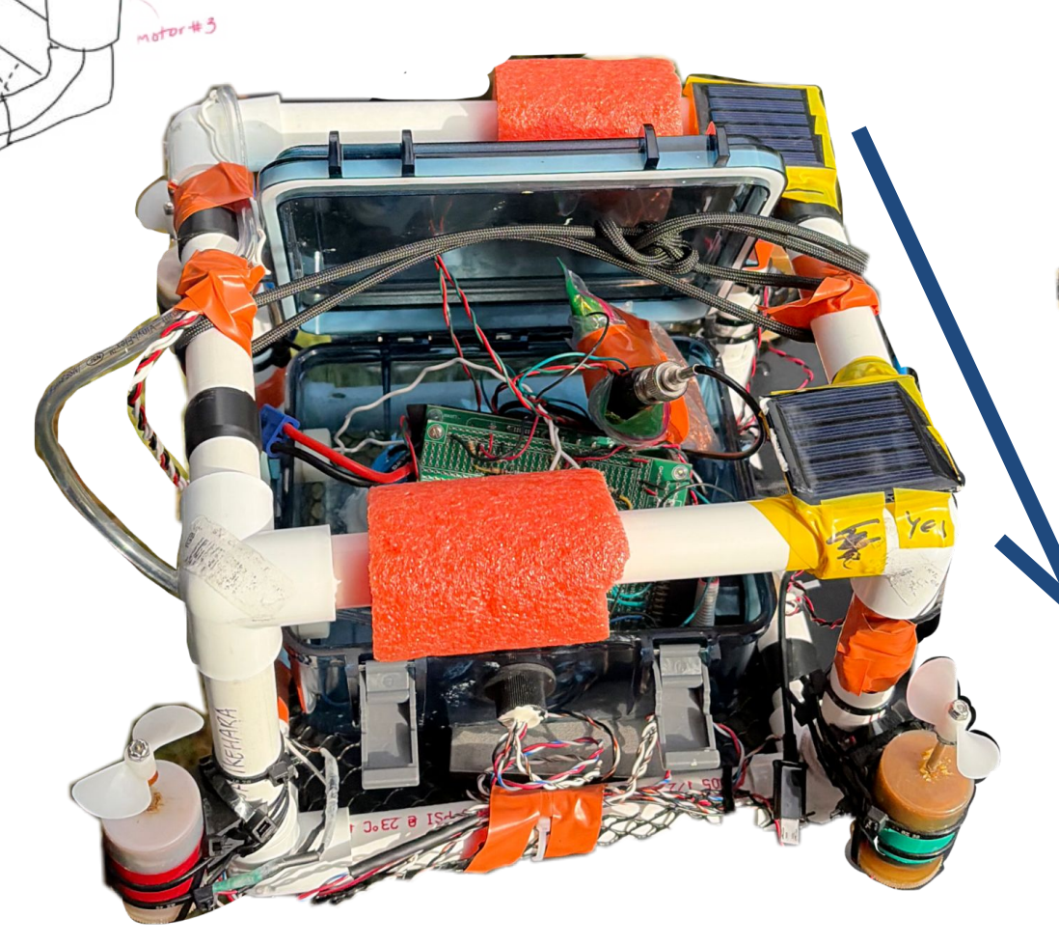
Expected input of sensor: 0.5 - 3.6 V
Expected output of circuit: 0.5 - 2.7 V

Mechanical Design & Integration

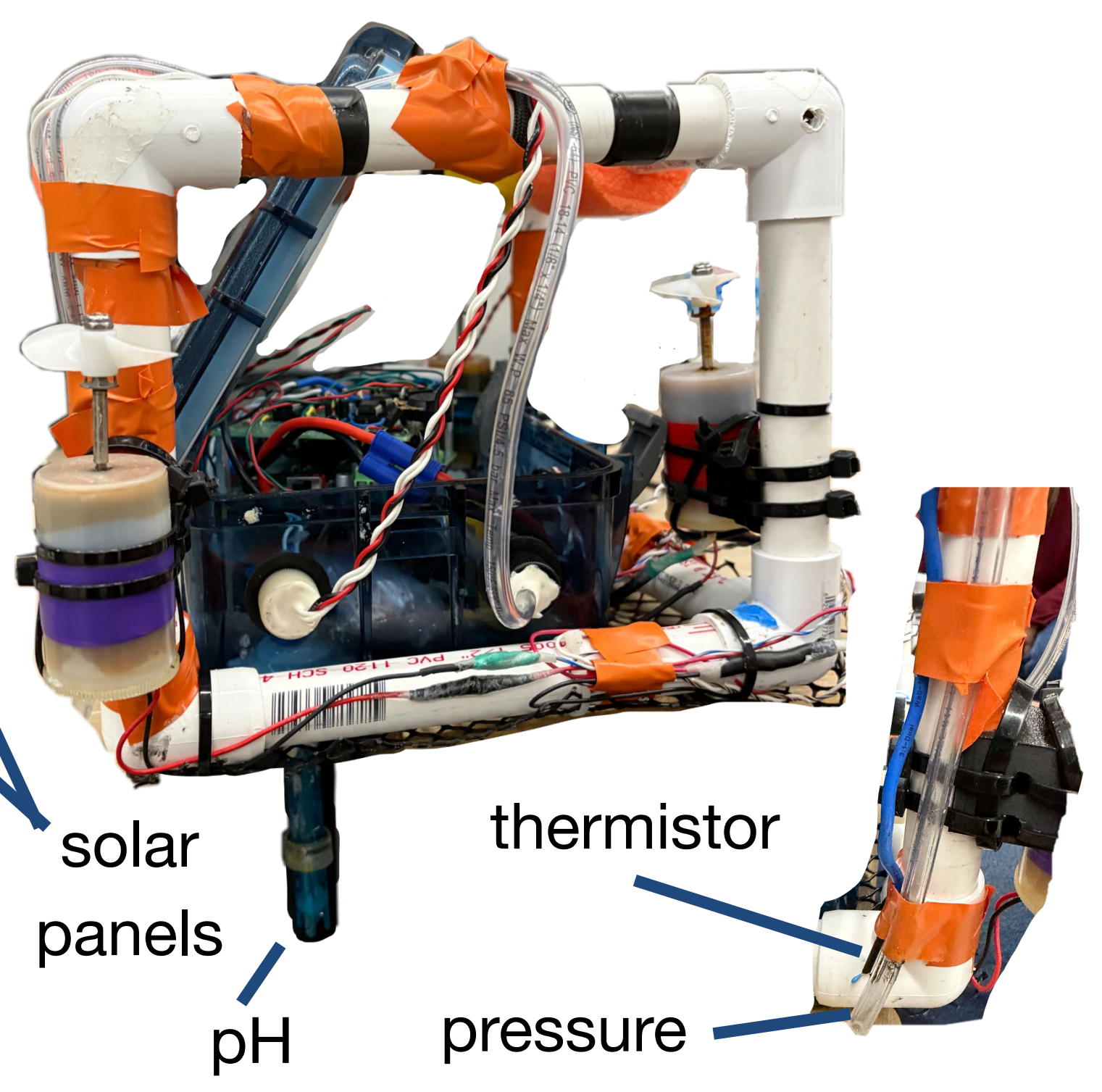
Mechanical drawing



Aerial view



Side view of various sensors



Design goal: stable vertical motion while maintaining consistent sensor orientation and waterproofness during deployment

The pressure sensor and thermistor were placed downard to measure hydrostatic pressure and temperature in flowing water, the solar panels were oriented upward to catch incident light, and pH probe was isolated due to output impedance and oriented downard to measure water acidity.

Experimental Data and Results

Sensor Calibration

Pressure	Thermistor	pH	Solar Panel
Calibrated in Roberts Pool (0 to 3 m), linear fit	Calibrated with water baths (10 to 25 C), linear fit	Calibrated with buffer solutions (pH 7 to 9), linear fit	Calibration using iPhone flashlight (lumens), quadratic fit
h = -1.471 V + 3.9223	T = -11.854 V + 32.433	pH = 0.912 V + 6.538	I = 88.58 V^2 - 427.97 V + 512.27
Se = 0.0462 m	Se = 4.131 C	Se = 0.0899	R^2 = 0.9803

Ground Truth Measurements

Atmospheric pressure	101.25 kPa
Surface ocean temperature	18.7 C
Ocean pH	~7.4
UV	2-3

Pressure matched expected depth trends. Temperature showed moderate cooling with depth and light intensity decreased with depth. pH trends observed but not quantitatively validated with depth.

Results & Conclusions

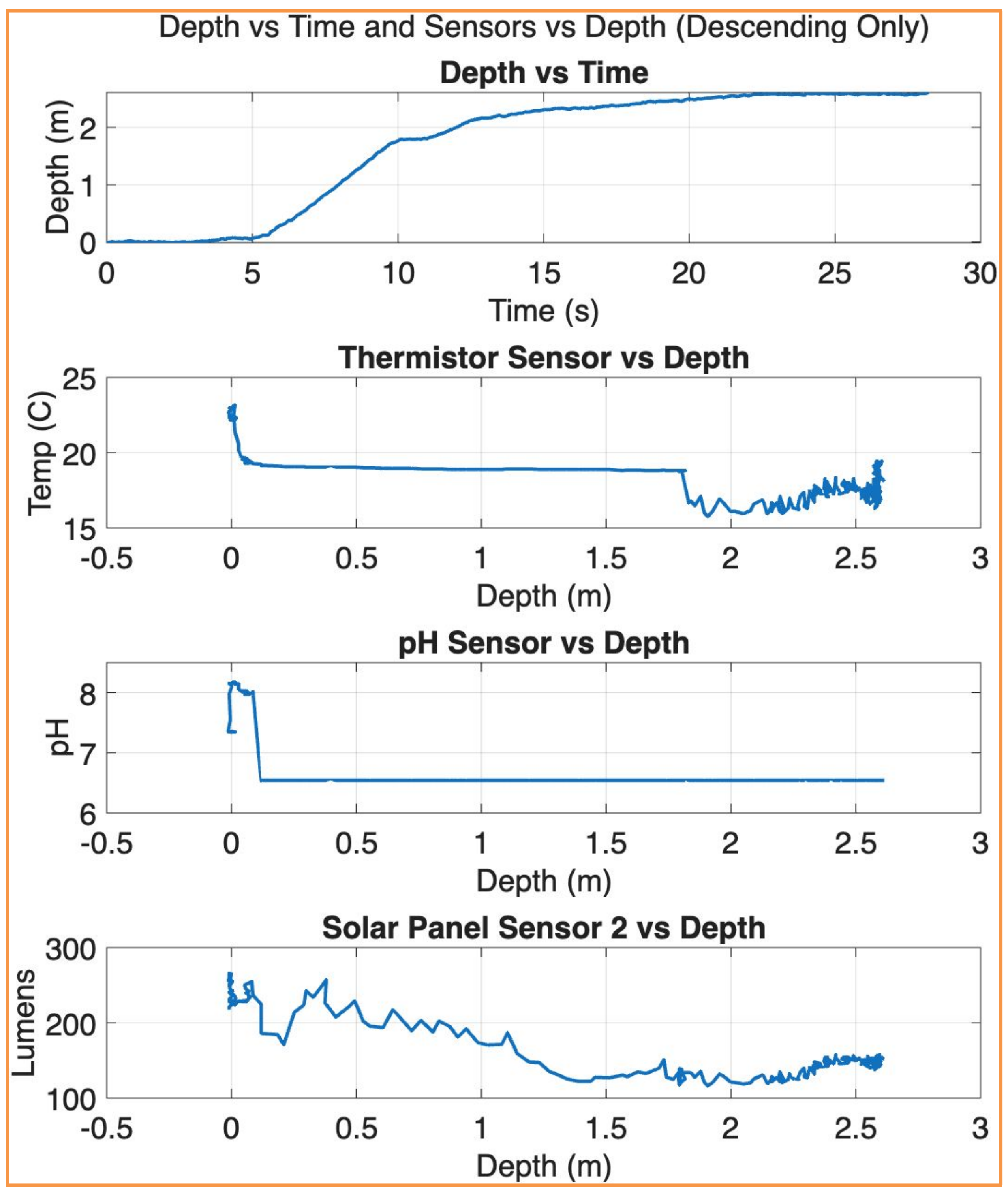
Pressure Sensor (Depth)
- Reached maximum depth 3m
- Depth increases with time

Thermistor Sensor (Temperature)
- Thermistor settles to then decreases to 16°C as robot dove
- 14.4% decrease in temperature from ground truth measurement 18.7°C at surface

pH Sensor
- Sensor railed out at deployment
- Ground truth of 7.4 pH, forensic result in lab showed around 6.5 pH with a tolerance of ±1 pH.
- Error attributed to glass electrode error in salt water.

Solar Panel (Light Intensity in Lumens)
- Panels show a 52% decrease in light intensity with depth

Depth vs Time and Sensors vs Depth (Descending Only)



Acknowledgements

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Deployment Details

Location(s): Dock at Dana Point, California

Testing Protocol: Before deployment, we made sure that all of the outputs were transferring data to the analog pins by connecting the Teensy to the Serial monitor in Arduino IDE and checking the real-time data.

Deployment safety was addressed by waterproofing the electronics box, making sure there are no obstructing wires, using a delayed motor start, and recovering the robot immediately after the run.