Auto-Aquarium

ECE 445 Design Document

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1. Introduction

1.1 Problem

Owning an aquarium requires a lot of maintenance, especially for users that own tropical fish that require a very specific range of variables like water temperature or pH levels to survive. This requires the aquarium owner to constantly purchase testing kits and devices in order to monitor the quality of the aquarium water. Oftentimes, aquariums are put in hard to reach places within rooms, making it difficult to manually test the quality of the tank water.

1.2 Solution

Our product solution allows an automated experience in monitoring temperature, pH, and water quality (through conductivity). Our product is a modular, small, and easy to install design that doesn't intrude on the aesthetic of the aquarium. Our solution consists of a set of sensors that relay the current temperature, pH, and conductivity of the aquarium water to a mobile app via WiFi. This app will show the user the current data, along with acceptable ranges of sensor data which correspond to specific types of aquatic life. In addition, an LED will be attached to the device that will light up when any of the monitored variables is outside the acceptable range.

1.3 Physical Design

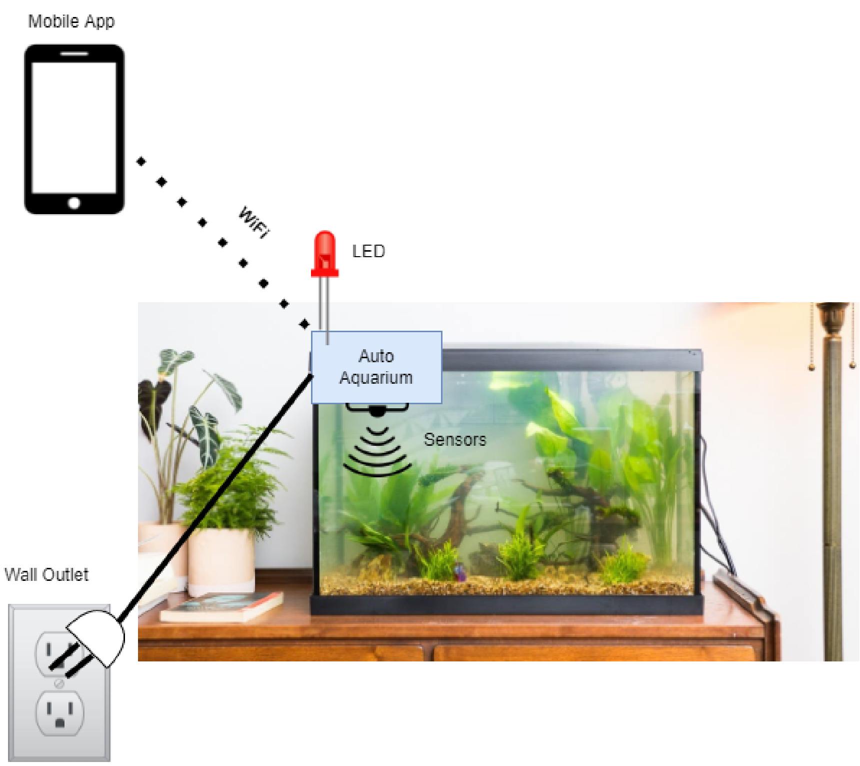

Figure 1: Overview of the Auto Aquarium components

1.4 Objective and Background

Goals and Benefits:

- Create a cost effective add-on to any aquarium that helps automate mundane maintenance tasks
- Alerts owner real time of any potentially hazardous living conditions in the aquarium via app and LEDs
- Combines monitoring of multiple variables (temperature, pH, conductivity) into one small product so it can sit in the corner of aquarium and not be aesthetically intrusive
- App allows user to set tolerance levels for each of the variables, and show the range of acceptable values for each variable based on the profile that the user sets

1.5 High Level Requirements:

- The device must be able to detect temperature, pH, conductivity within the tolerances shown below
    - Temperature: (±2°C)
    - pH: (± 0.5)
    - Conductivity: (±20ppm)
- The mobile app will receive temperature, pH, and conductivity values from the wireless transmitter within 30 seconds. It must be able to alert the user of dangerous conditions by sending a notification from the app and lighting an LED on the fishtank
- The device must be modular and portable, no larger than 20 inches on any side with a tolerance of 3 inches

2. Design

2.1 Block Diagram

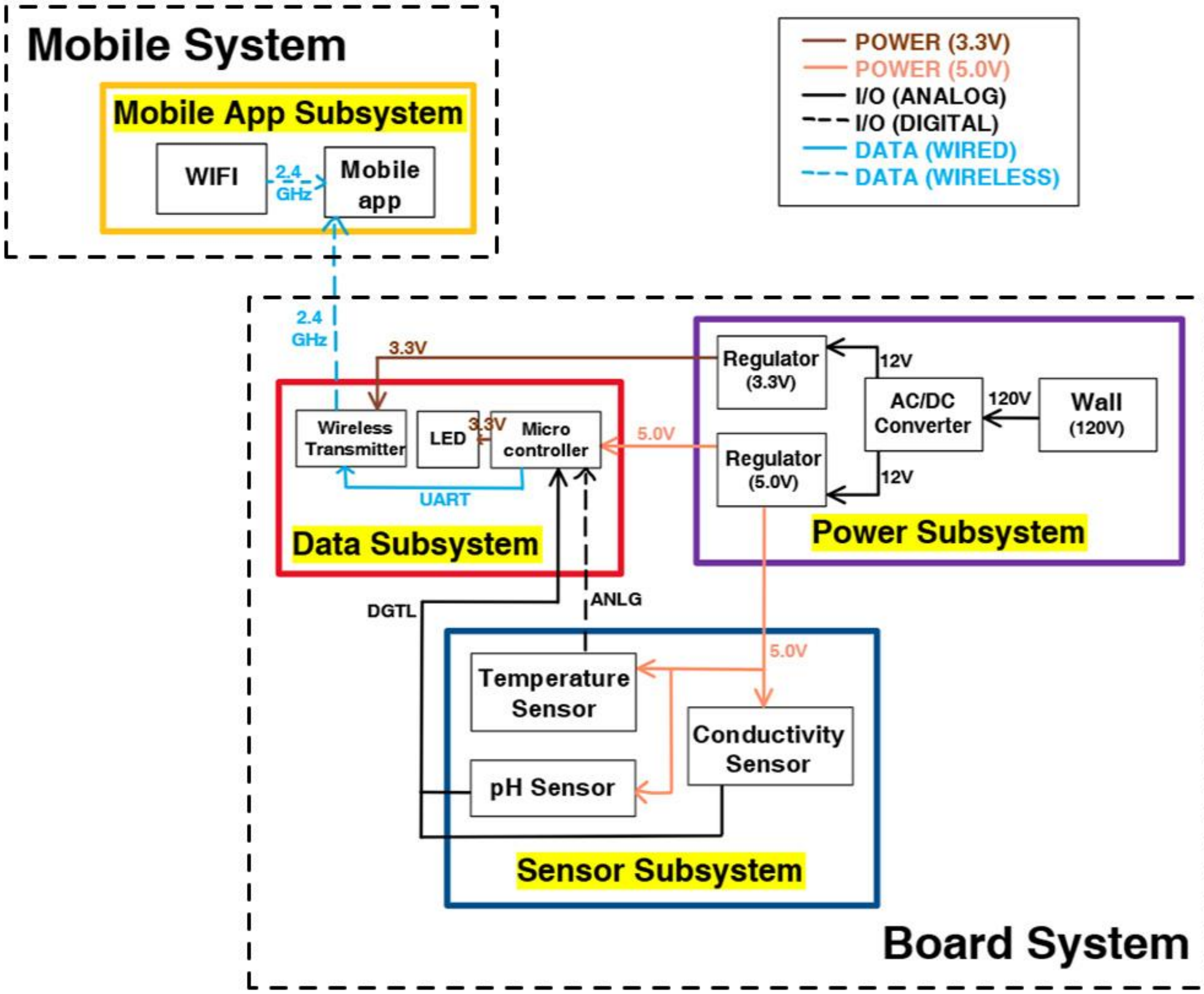

Figure 2: Block diagram of each subsystem and their components

2.2 Block Descriptions

2.2.1 Sensor Subsystem:

- The sensor unit receives and manages the information from each of the sensors (temperature, pH, and conductivity). This subsystem communicates with the data module by constantly sending variable data to the microcontroller and receives power for each of the sensors from the power subsystem. Because this subsystem will be submerged in the aquarium water, every part of this subsystem will be waterproof.
    - **Temperature:** The Waterproof DS18B20 Digital temperature sensor will constantly measure and report the aquarium water's current temperature.
    - **pH:** The SEN0169 pH sensor will relay current pH levels of the aquarium water to be transmitted and displayed on the app. Typically, the acceptable pH ranges for tropical fish is between 6.8 and 7.8.

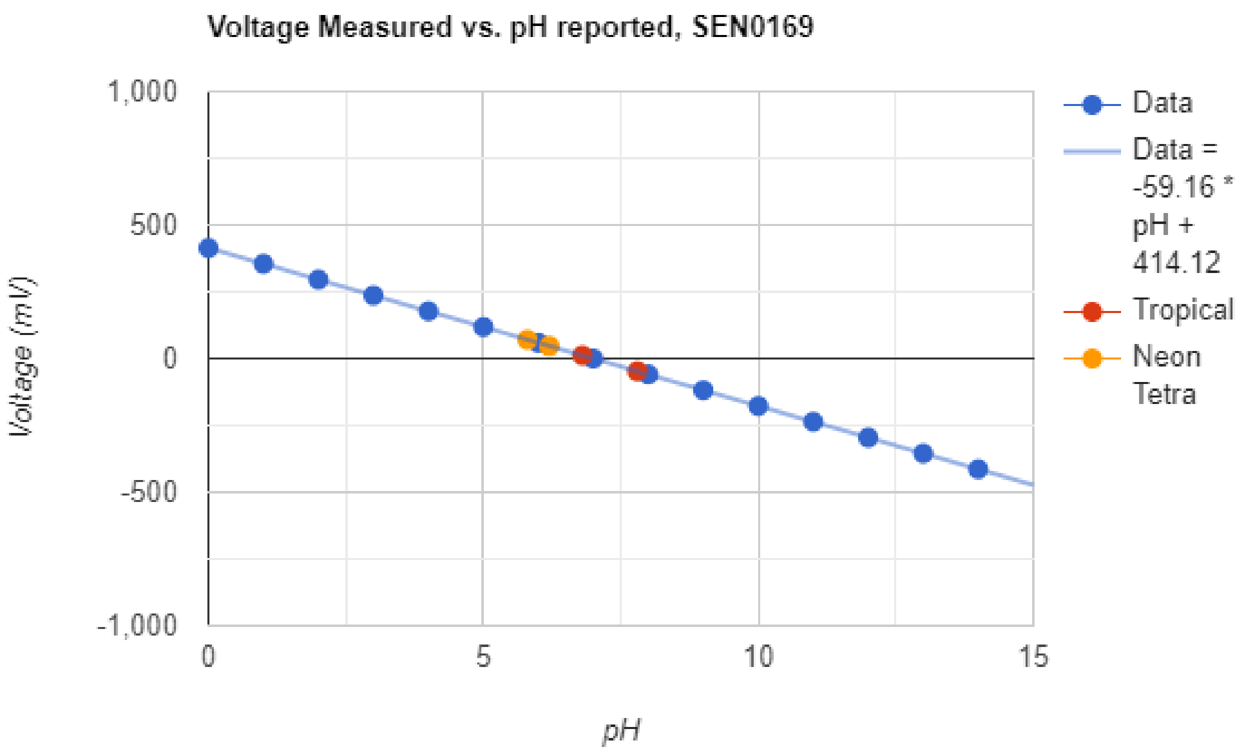

Figure 3: Example pH ranges for fish types

- **Conductivity:** The SKU SEN0244 water conductivity sensor measures the quality of the water based on the total dissolved solids (TDS) dissolved in one liter of the water. Pure distilled water is a poorer conductor of electricity than water with dissolved minerals [2].

Requirements	Verification
1. Temperature sensor must constantly measure temperatures in the range 23°C to 27°C (±2°C) at an operating voltage of 5.0V (±0.5V) 2. pH sensor must measure pH in the range of 6.8 to 7.8 (±0.5) at an operating voltage 5.0V (±0.5V) in temperatures ranging from 23°C to 27°C (±2°C) 3. TDS sensor must measure conductivity in the range 70ppm - 120ppm (±20ppm) at an operating voltage of 5.0V (±0.5V) in temperatures ranging from 23°C to 27°C (±2°C) 4. Sensors must have a query time of < 1000ms (±250ms)	Verifying Requirement 1: ● Place additional thermometer in water ● Use multimeter to ensure sensor is receiving 5.0V (±0.5V) ● Place sensor in water and compare results shown in software to that of the additional thermometer ● Ensure the measurements match with a tolerance of ±2°C Verifying Requirement 2: ● Ensure water temperature falls within threshold. ● Use multimeter to ensure pH sensor is receiving 5.0V (±0.5V) ● Measure the water with a handheld pH meter and ensure that the value it produces is the same as that of the sensor in software (±0.5) Verifying Requirement 3: ● Ensure water temperature falls within threshold. ● Use multimeter to ensure TDS sensor is receiving 5.0V (±0.5V) ● Measure water with handheld TDS meter and ensure the value it produces is the same as that of the sensor in software (±100pm) Verifying Requirement 4: ● For each sensor in the water, log the time it takes the microcontroller to receive a temperature reading using timing libraries in a hardware programming IDE (e.g Arduino IDE) ● Ensure query times fall within stated thresholds

2.2.2 Power Subsystem

- The power subsystem will provide 12V via an AC/DC converter to the components in the sensor and data subsystem. The converter will derive 120V of AC power from a wall outlet and output 12V which will enter both a 5V and 3.3V voltage regulator in parallel to provide power to the other subsystems. The sensors and microcontroller will receive 5V power, while the wireless transmitter will receive 3.3V power.
  - 5V Regulator: LM7805
  - 3.3V Regulator: LM1117-3.3
  - AC/DC Converter: YU1201 Wall plug to barrel jack converter

<u>Requirements</u>	<u>Verification</u>
1. AC/DC converter must convert 120VAC (±100VAC) from a wall outlet into 12VDC (±0.5VDC) 2. LM1117-3.3 must output 3.3V (±0.2V) and 200mA (±50mA) with an input voltage of of 12V (±0.5V) and input current of 500 mA (±50mA) 3. LM7805 must output 5V (±0.2V) and 300mA (±50mA) with an input voltage of 12V (±0.5V) and input current of 500 mA(±50mA)	Verifying Requirement 1: ● Plug AC/DC converter into a wall outlet and plug the barrel jack into a female port linked to a breadboard ● Use a multimeter to measure the output voltage and ensure it reads within the threshold listed Verifying Requirement 2: ● Feed 12V into the LM1117-3.3 using an external power supply at 500mA of current ● Using a multimeter, ensure the output of the LM1117-3.3 is within the threshold listed Verifying Requirement 3: ● Feed 12V into the LM7805 using an external power supply at 500mA of current ● Using a multimeter, ensure the output of the LM7805 is within the threshold listed

2.2.3 Data Subsystem

- The data subsystem will be responsible for managing the constant stream of data from the sensor subsystem and sending it via the wireless transmitter to the mobile app.
  - **Microcontroller:** The ATmega328–MMH microcontroller receives 5V power from the power subsystem, and receives data from the sensor subsystem. It is responsible for communication via UART protocol to the wireless transmitter.
  - **Wireless Transmitter:** The ESP8266 wireless transmitter receives 3.3V from the power subsystem, and receives processed data from the microcontroller. It then sends this information in an HTTP request via WiFi to the connected mobile app on a 2.4 GHz channel.
  - **RGB LED**: The WP154A4SUREQBFZGW LED receives 3.3V from the microcontroller and indicates sensor values exceeding acceptable values (determined by user).

Requirements	Verification
1. Wireless transmitter must be able to interface between the microcontroller and mobile app and send updated data at a rate of at most 30 seconds per cycle 2. Data subsystem must be able to communicate with the mobile subsystem via WiFi 3. LED must light up when data measured is outside of acceptable range	Verifying Requirement 1: ● Send a test message (001 in binary) from microcontroller to the wireless transmitter, and verify it displays on the mobile app Verifying Requirement 2: ● Ensure that both the Auto Aquarium and mobile app are on the same WiFi ● Display log statements in Arduino IDE console from the microcontroller code that shows the data to be sent via the wireless transmitter Verifying Requirement 3: ● Use the mobile app to set a range that is smaller than the current temperature measured (ex. 0-10℃ for room temperature water) ● LED must light up within 30 seconds of this change.

2.2.4 Mobile Subsystem

- The mobile subsystem consists of a mobile app that connects to the data subsystem via a 2.4 Ghz signal. In the app, the various data (temperature, pH, and conductivity) are received via the wireless transmitter from the data subsystem. The data is fetched via API and HTTP requests, updating every 30 seconds at the maximum.
    - **Dangerous Conditions:** The app displays the received data along with the acceptable ranges based on the profile the user sets. When a variable is larger or smaller than the accepted range, the mobile app will send a notification to alert the user, as well as light up the LED in the data subsystem.
    - **User Profiles:** The user can specify a profile, and for each profile can set the custom ranges for each variable (i.e. pH from 6.8 to 7.8). This user profile data will be stored in a database.

Requirements	Verification
1. The mobile app must update the displayed information within 30 seconds after it receives it from the wireless transmitter 2. The mobile app should allow the user to adjust the ranges of tolerance of variables	Verifying Requirement 1: ● Execute microcontroller code function that sends test data for temperature to 999. ● Check the visualized data ranges in the mobile app and see if the displayed data has been updated. Verifying Requirement 2: ● Adjust temperature range on the mobile app to 0-10℃, when actual aquarium water is room temperature ● Verify that the mobile app sends dangerous condition notification.

2.3 Circuit Schematic

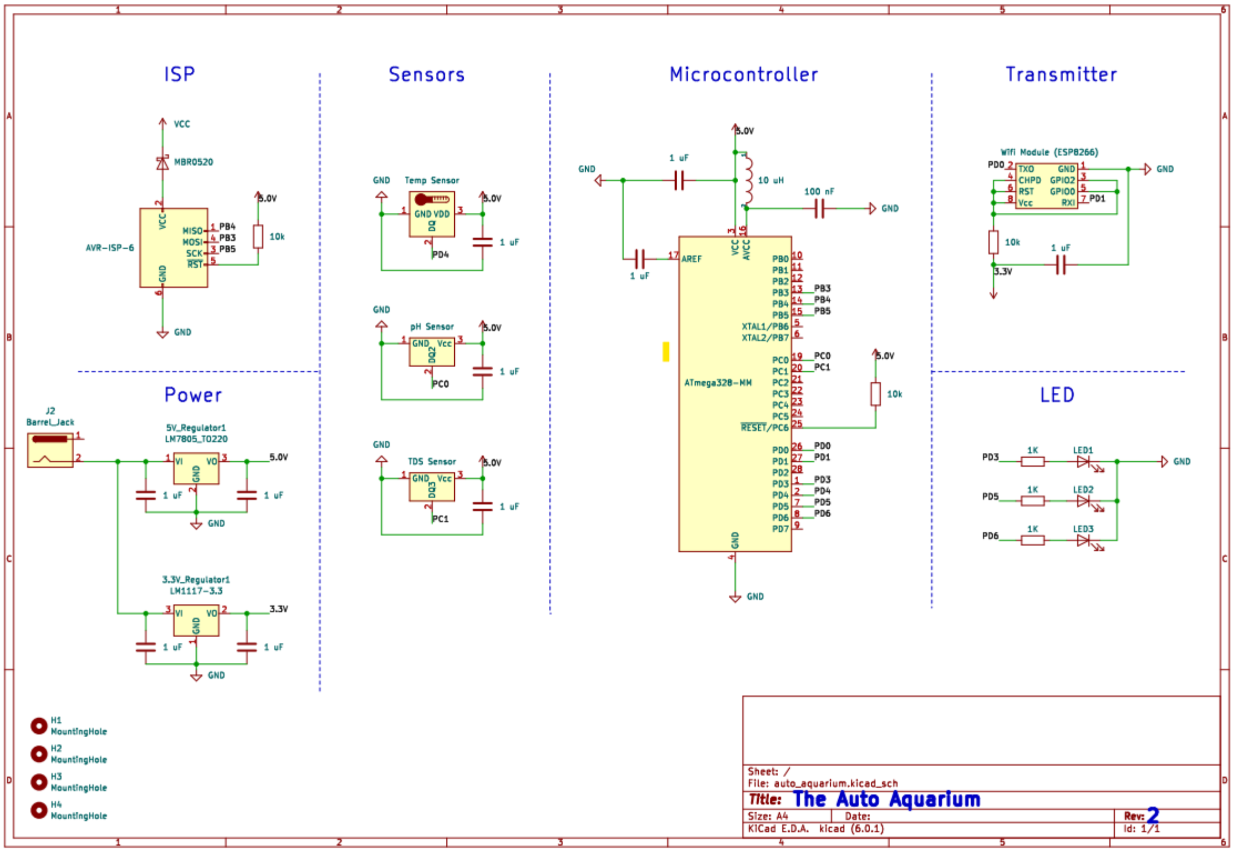

Figure 4: PCB circuit schematic of microcontroller, sensors, LED and wireless transmitter

2.4 PCB

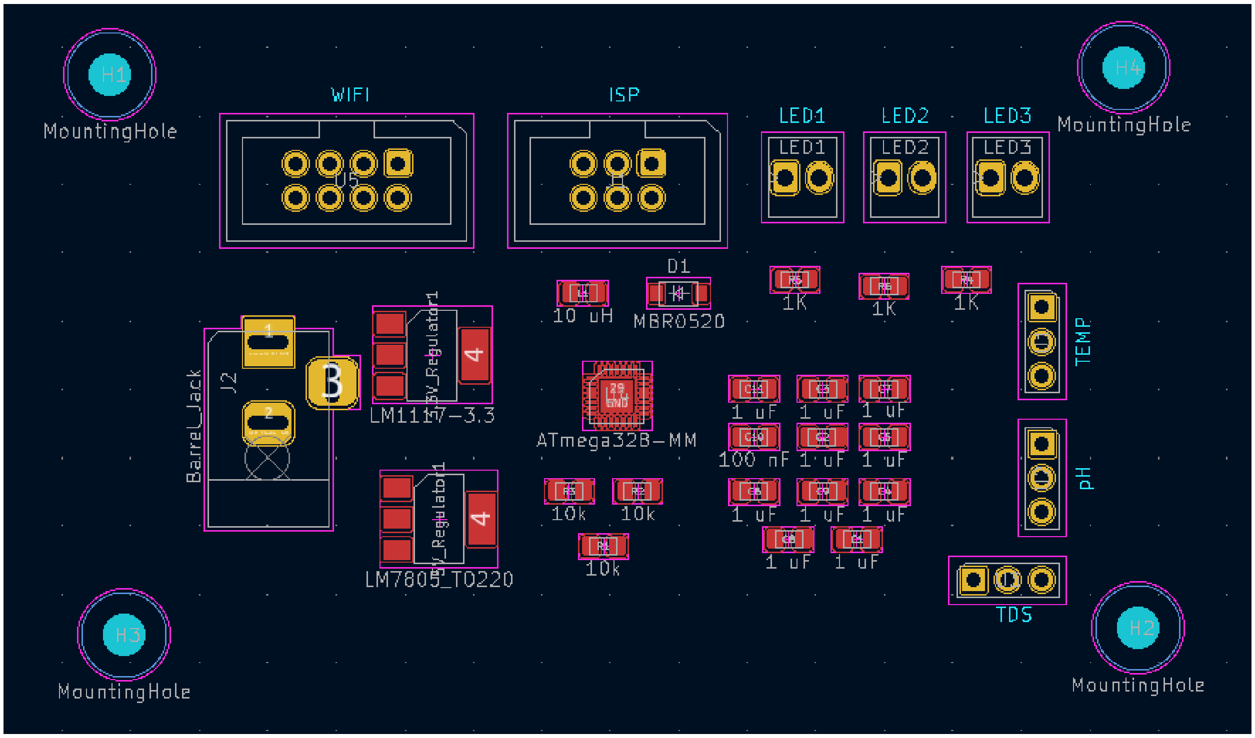

Figure 5: Version 1 PCB

2.5 Tolerance Analysis

The sensor subsystem poses the greatest risk to a successful completion of the project, due to sensor failure. According to the datasheet for the SEN0161, in 25 Celsius pure water, the pH electrode probe will only last 6 months of continuous testing [1]. After that, inaccuracies in the amount of millivolts detected by the electrode probe may occur, which in turn would inaccurately report pH data.

VOLTAGE (mV)	pH value	VOLTAGE (mV)	pH value
414.12	0.00	-414.12	14.00
354.96	1.00	-354.96	13.00
295.80	2.00	-295.80	12.00
236.64	3.00	-236.64	11.00
177.48	4.00	-177.48	10.00
118.32	5.00	-118.32	9.00
59.16	6.00	-59.16	8.00
0.00	7.00	0.00	7.00

Figure 6: SEN0161 datasheet voltage measured vs. pH

Given that the acceptable pH range of tropical fish is between 6.8 and 7.8, we can extrapolate this data from the sensor datasheet to calculate the range of acceptable voltage. Based on the above data in Figure 5 [1], we can create a linear relationship between voltage measured by the electron probe and pH value to be:

$$V = -59.16pH + 414.12$$

Thus, the acceptable voltage for 6.8-7.8 pH is from 11.832mV to -47.328mV, or a range of 59.16mV. With an inaccuracy of mV which would occur due to the lifespan of the electron probe, it is easy for our device to inaccurately report pH levels. A feasible solution for this is to utilize the SEN0169 sensor for our design. According to the SEN0161/SEN0169 datasheet, the SEN0161 and SEN0169 sensor usages and specifications are the same, yet for continuous testing, SEN0169 works for two years, while SEN0161 will only last for 6 months [1]. It is also critical that we properly clean the pH probe between tests with distilled water to ensure that the probe readings don't become skewed, as mentioned in the specifications. Additionally, it's imperative that only the waterproof parts are submerged for measurements to prevent damage to the sensors.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Given a semester of 16 weeks, each of the three members will work on 15 hours per week on this project. Wage rates were given based on the average salary of an undergraduate student from UIUC with a Computer Engineering or Electrical Engineering degree. According to annual reports from Illini Success, a part of the University of Illinois, the average salary for a UIUC graduate with a computer engineering bachelor's degree is $99,145, or $47.67/hr. For a graduate with an electrical engineering bachelor's degree, the average salary is $76,129, or $36.60/hr [4].

Name	Caleb	Sihun	Irfaan
Wage ($/hr)	$47.67	$47.67	$36.60
Total Hours (in 16 weeks)	15 hrs/week x 16 weeks = 240 hrs	15 hrs/week x 16 weeks = 240 hrs	15 hrs/week x 16 weeks = 240 hrs
Individual Total	$11,440.80	$11,440.80	$8,784.00
GRAND TOTAL			**$31,665.60**

3.1.2 Cost of Parts

Part Name	Qty	Price per unit	Total
Microcontroller (ATMEGA328-MMH)	1	$2.47	$2.47
Wireless Transmitter (ESP-8266)	1	$7.50	$7.50
pH Sensor (SEN-0169 DFRobot)	1	$29.50	$29.50
TDS Conductivity Sensor (SEN-0244)	1	$14.77	$14.77
Temperature Sensor (Waterproof DS18B20)	1	$9.95	$9.95
3.3V Regulator (LM1117-3.3)	1	$1.89	$1.89
5V Regulator (LM7805)	1	$1.50	$1.50
Wall Plug Adapter (YU1201)	1	$12.99	$12.99
RGB LED (WP154A4SUREQBFZGW)	1	$1.89	$1.89
GRAND TOTAL			**$82.46**

3.2 Schedule

Week	Goals	Members Assigned
2/20 - 2/26	1. Finalize Design Document 2. Rough Draft for PCB	All
2/27 - 3/5	1. Design Review 2. Finalize PCB Design 3. PCB Board Approval	All
3/6 - 3/12	1. Solder PCB board, Power Subsystem 2. Develop mobile app frontend/database	1. Irfaan, Sihun 2. Caleb
3/13 - 3/19	Spring Break	All
3/20 - 3/26	1. Solder validation and PCB debugging 2. Connect frontend/database, finalize frontend design	1. Irfaan, Sihun 2. Caleb
3/27 - 4/2	1. Finalize PCB, begin sensor subsystem 2. Finalize mobile subsystem with sample data 3. Individual Progress Reports	1. Irfaan, Sihun 2. Caleb 3. All
4/3 - 4/9	1. Sensor subsystem 2. Waterproof sensor subsystem enclosure	All
4/10 - 4/16	1. Debug full subsystems (power, data, mobile, sensors) 2. Finalize demo procedure	All
4/17 - 4/23	1. Mock Demo 2. Final Presentation Rough Draft	All
4/24 - 4/30	1. Demonstration 2. Mock Presentation	All
5/1 - 5/7	1. Final Presentation 2. Finish Final Paper	All

4. Ethics and Safety

This project will follow proper ethical and safety protocol by creating a device that will prove to be non-toxic and harmless to both humans and animals. Section I.1 of the IEEE Code of Ethics [3] states for us “to hold paramount the safety, health, and welfare of the public” (IEEE p.1 I.1). This means that in our practices, we must uphold the necessary requirements to create a safe product for anyone to use. Since our device will be suspended in water, it should not leak any material into the water that could be harmful to the fish inside. All circuitry components should be airtight to ensure no water damage can occur to the device. No wire should be exposed underwater to ensure that a current cannot enter the aquarium. In the event where a component malfunctions, the sensors are not able to change any values, such as temperature, pH level, and conductivity, in the aquarium itself. If someone were to misuse the product, they would only be able to damage the sensors or circuitry of our device. This will not be able to affect the water and will not harm any of the fish inside.

To ensure proper safety when creating our device, we must follow the proper guidelines for electrical, mechanical, and lab safety. We should never work alone in the lab, bring food or drinks, and should always clean up after ourselves and clear our lab stations. We must report any broken equipment and properly dispose of any materials not needed. When building our device, potential hazards and things that we must be careful of are glass, soldering equipment, electrical components, and batteries. Once the device is complete the user will only need to make sure that no components are broken when placing the device into their aquarium. If something were to be broken, the possible dangers are exposed electrical wires, broken glass, or sharp plastic.

Citations and References

[1] DFRobot, “SEN0161 SEN0169 DFRobot Datasheet”, SEN0169 datasheet, 2017. https://www.application-datasheet.com/pdf/dfrobot/sen0161.pdf (accessed Feb. 9, 2022).

[2] T. Scherer and M. Meehan, “Using Electrical Conductivity and Total Dissolved Solids Meters to Field Test Water Quality”, North Dakota State University, July 2019, [Online]. https://www.ag.ndsu.edu/publications/environment-natural-resources/using-electrical-conductivity-and-total-dissolved-solids-meters-to-field-test-water-quality. (accessed Feb. 10, 2022).

[3] IEEE. “IEEE Code of Ethics.” IEEE Code of Policies, Section 7 - Professional Activities (Part A - IEEE Policies). June 2020. https://www.ieee.org/about/corporate/governance/p7-8.html. (accessed Feb. 10, 2022).

[4] Illini Success. “Annual Report 2019-2020”, https://uofi.app.box.com/s/1t8xj69117lrsqm7753ujnrg8yyrtcwn (accessed Feb. 24, 2022).

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Espressif Systems, “Espressif Smart Connectivity Platform: ESP8266”, ESP8266 datasheet, Oct. 12, 2013, [Online]. https://nurdspace.nl/images/e/e0/ESP8266_Specifications_English.pdf (accessed Feb. 21, 2022).