# Aquaponics Tank Sensing Kit

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ECE 445 Design Review - Spring 2018

TA: Yamuna Phal

**Aquaponics Tank Sensing Kit**

# 1 Introduction

## 1.1 Objectives

Our goal is to build a low-cost, off-grid solar powered pump and sensor system to use as part of maintaining a multi-hundred gallon aquaponics system. We are trying to replace manual water chemistry tests with an automated sensor system. This issue was brought to our attention by Professor Brian Lilly. His work with tilapia farming to aid HIV-positive women in Kenya with the organization Living Positive Kenya is what motivates our project. Currently, their indoor farming setup has a capacity of about 300 fish per each of their four tanks. The future goals of the farmers is to have 600-900 fish per tank in order to increase profit margins and provide food for the community.

## 1.2 Background

In order to maintain a viable ecosystem for the fish, the water in the fish tank must be tested on a regular basis. Currently, all tests are done manually using chemical test strips. Unfortunately, due to the complexities of maintaining a viable ecosystem for the fish and vegetables, scaling up is not feasible in the current climate. As a result, we are working to develop a kit in order to monitor the pH, dissolved oxygen, and temperature of the water in each of the fish tanks and easily display the results and notify the farmers that a tank needs maintenance. Currently, measurements have to be done by hand with pH kits and they do not have similar automated monitoring equipment. The hope is that with an easier way to monitor the status and health of the fishes' environment, low income families/villagers will be able to scale up the amount of fish per tank and the number of tanks overall.

There already exists solutions for hobbyists and industrial scale fish farming. These existing kits either produce fish at a loss for hobbyists or rely on economies of scale to turn a profit at an industrial scale. The goal of our aquaponics kit is to give families and villages in Africa a viable and sustainable fish farming option to supplement their income. We believe that we can make a custom solar powered pump system that would be lower cost than commercial fish farming equipment and implement the necessary sensors to aid farmers in monitoring the fish tank. Not only are these sensing systems cost prohibitive to a nation whose average yearly income is $1,380 [1], but they are not sustainable.

For our monitoring system, we chose sensors that made sense based on importance for hydroponics and cost effectiveness. We chose to focus on measuring the pH, dissolved oxygen, and temperature of the farming tanks since these are the measurements that are required to be taken most often in order to maintain proper health of the system [2].

Another one of our objectives was to make this system off-grid such that it is completely solar powered. Current solutions, as mentioned above, rely on an AC power source. This system must be solar powered, as many communities in Africa do not have reliable power infrastructure and it is often unreliable. Since the regions where we are targeting do not have the proper education about the safe disposal of batteries, we had to consider what kind of components would go into our design so that we would only need one relatively small and long lasting battery per tank. We hope that our final product will be both economically viable and environmentally friendly.

## 1.3 High-Level Requirements List

- Farmers will be quickly be able to determine if the levels of the pH, dissolved oxygen, and temperature levels of each tank are out of range for tilapia.
- Based on hourly dissolved oxygen readings, the microcontroller should trigger the aqua pump to re-oxygenate the water.
- Kit will be completely solar powered.

# 2 Design

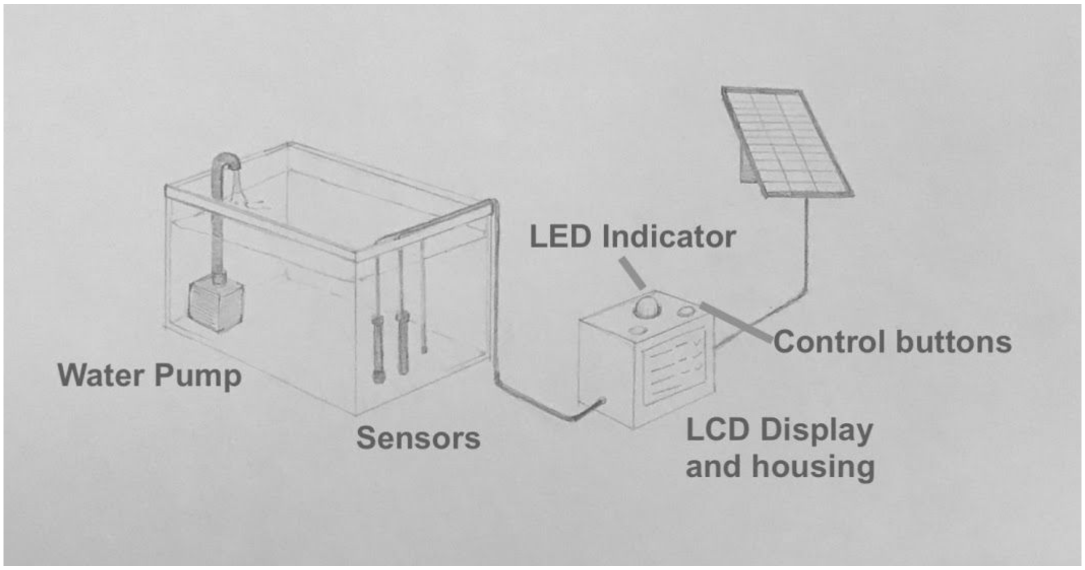


Figure 1: Physical Design

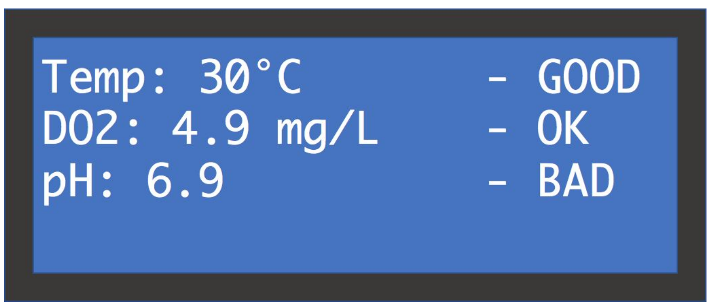


Figure 2: LCD Display Sample

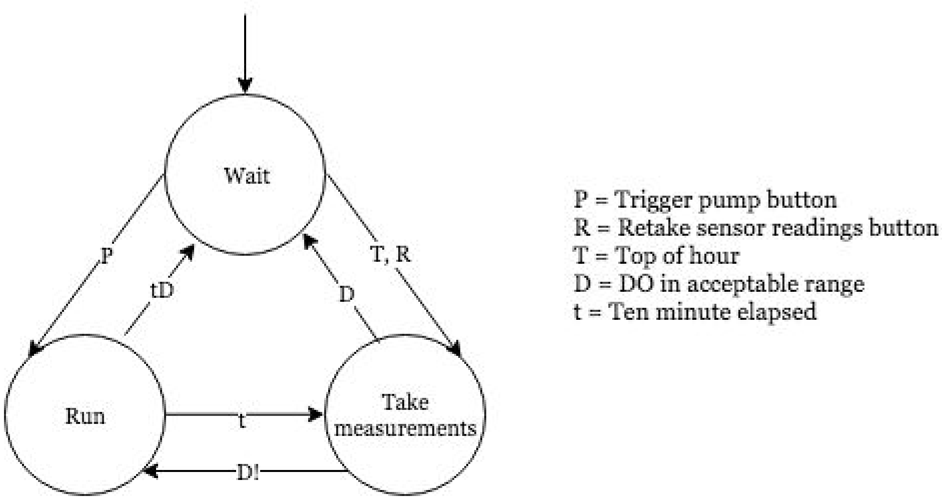


Figure 3: High-Level System Control Logic

## 2.1 Block Diagram

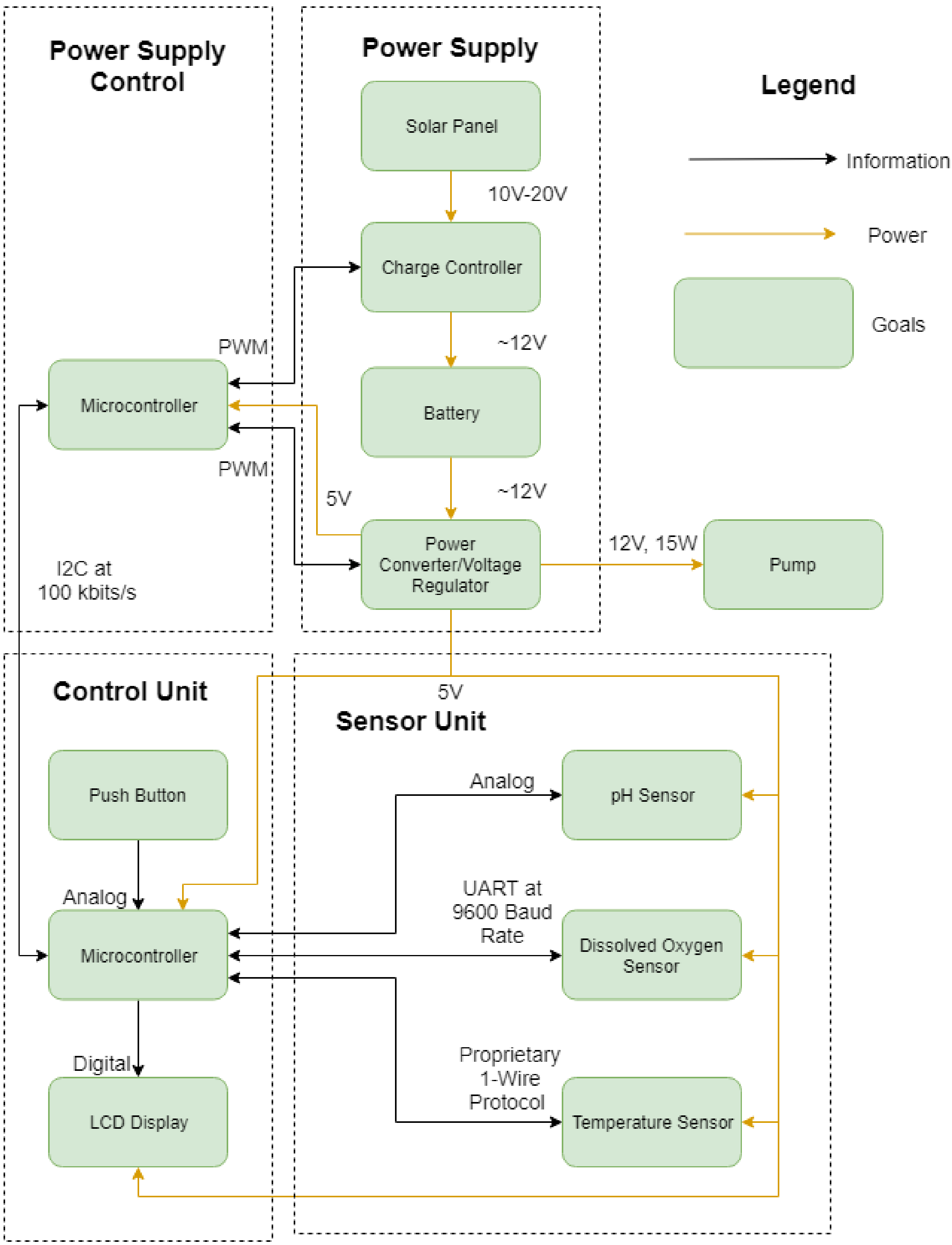


Figure 4. Complete Block Diagram with Voltage and Protocol Requirements

## 2.2 Block Descriptions

### 2.2.1 Solar Panel

Based on our high-level requirements and the needs of the farmers in Kenya, the Aquaponics Sensing Kit needs to be completed solar-powered. As such, we are using 3-20W solar panels in parallel, as provided by our sponsor, in order to provide enough energy to power our 15 W water pump, run the electronics, and charge our battery pack. ~60 W gives enough leeway for expansion of the Sensing Kit in the event that the consumer wants to add a secondary or more powerful pump in the future.

### 2.2.2 Charge Controller

With battery safety in mind, it was determined that we would need to use a microprocessor to act as our charge controller since off-the-shelf varieties were cost prohibitive. We will be using Constant Voltage charging method to charge the battery. The programmed charge controller, implemented in our first microprocessor (ATmega328P-PU) will prevent the battery from discharging after 75% of its maximum capacity. By using a current sensing breakout board (INA219), we will use the measured current and known resistance on the board in order to calculate the voltage. From there, the voltage will be used to determine the duty cycle of our DC-DC converter.

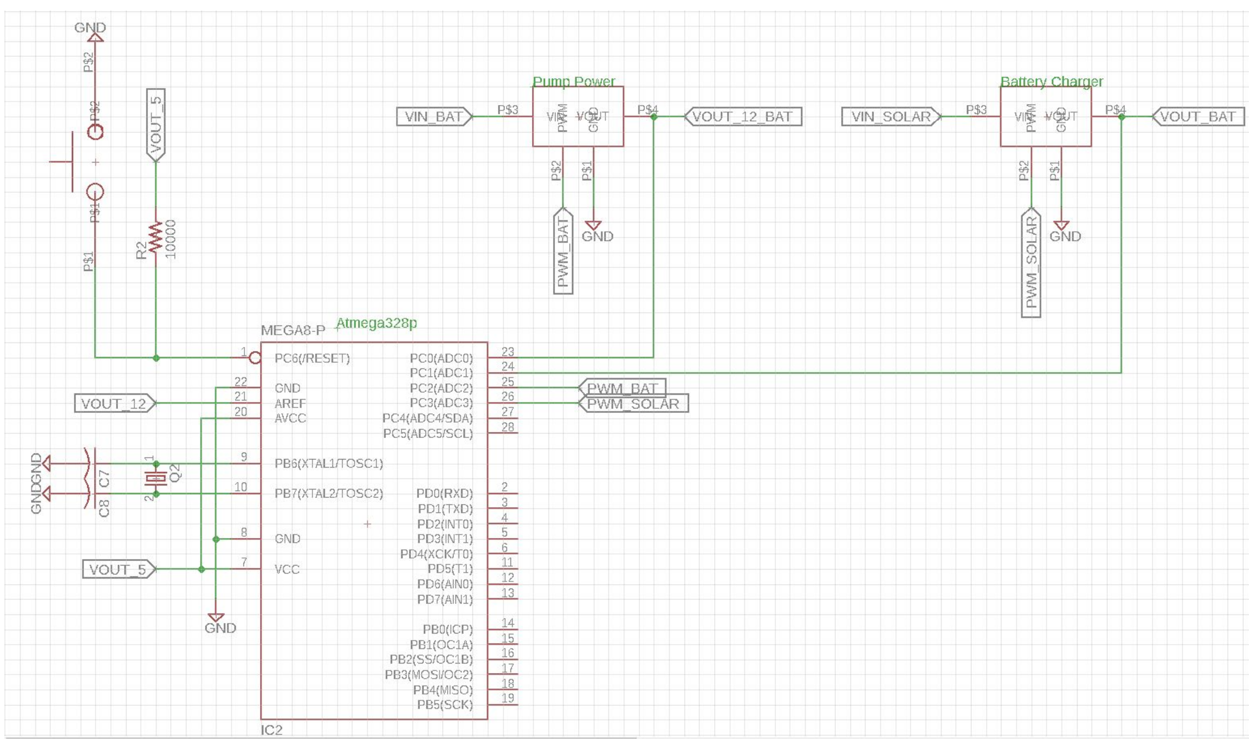


Figure 5. Charge Controller Schematic (Microprocessor 1)

### 2.2.3 Battery

Should power the system for 12 hours without sunlight. This translates to 4 hours of continuous operation since we are anticipating only running the pump for 10 minutes over one hour intervals. The 4 hours of continuous operation also includes another 2 watt-hours of operation for the other electrical components and the capacity to manually start the pump.

The battery that we have chosen to purchase is a 12V 10Ah Lithium battery. We chose this type of battery based on preliminary calculations that determined a minimum 7.10Ah at 16.032W. Lithium-ion batteries would be the most optimal due to their size but they were incredibly cost prohibitive. The battery we purchased from Dakota Lithium showed to be the best balance between cost and capacity after research.

### 2.2.4 Power Converter/Voltage Regulator

We will be using two DC-DC converters in our design using the buck-boost topology. The power converter/voltage regulator must be a DC-DC converter that is able to output 5V +/-10% at 0.5W (microcontroller) and 12V +/-10% at 15W (pump). The voltage will be supplied by the solar panel from a voltage between 0-26V. Figure 7, is based off of the TLV760 chip.

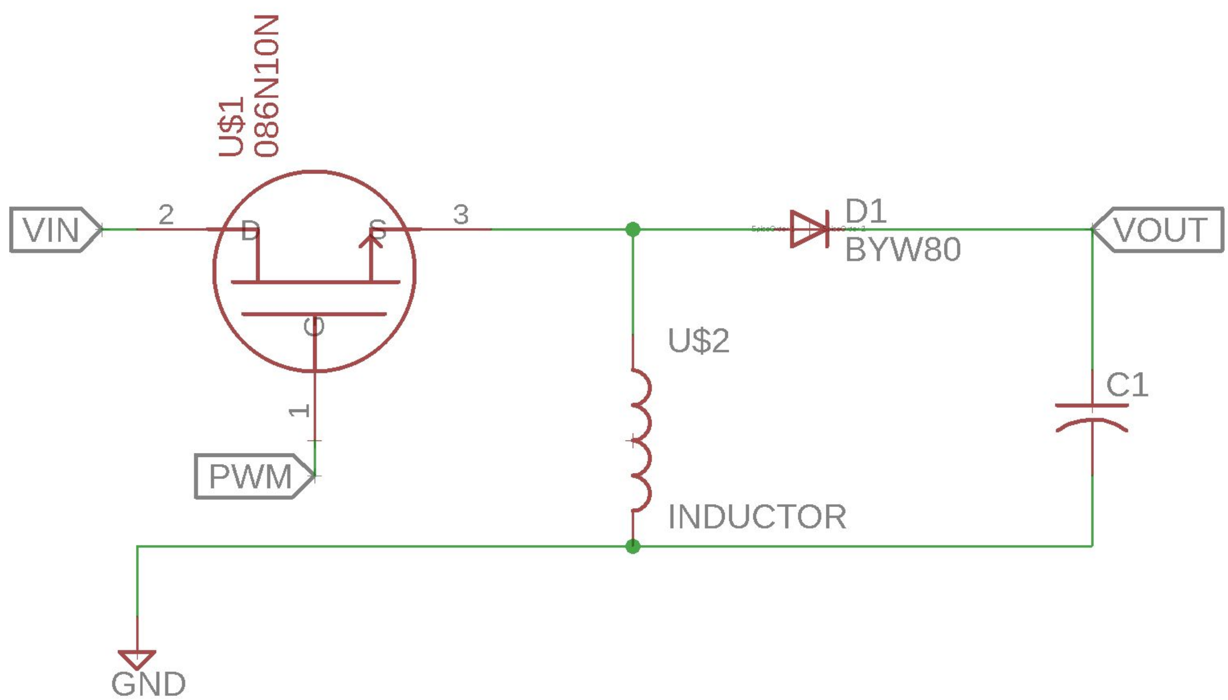


Figure 6. Buck-Boost Converter Schematic

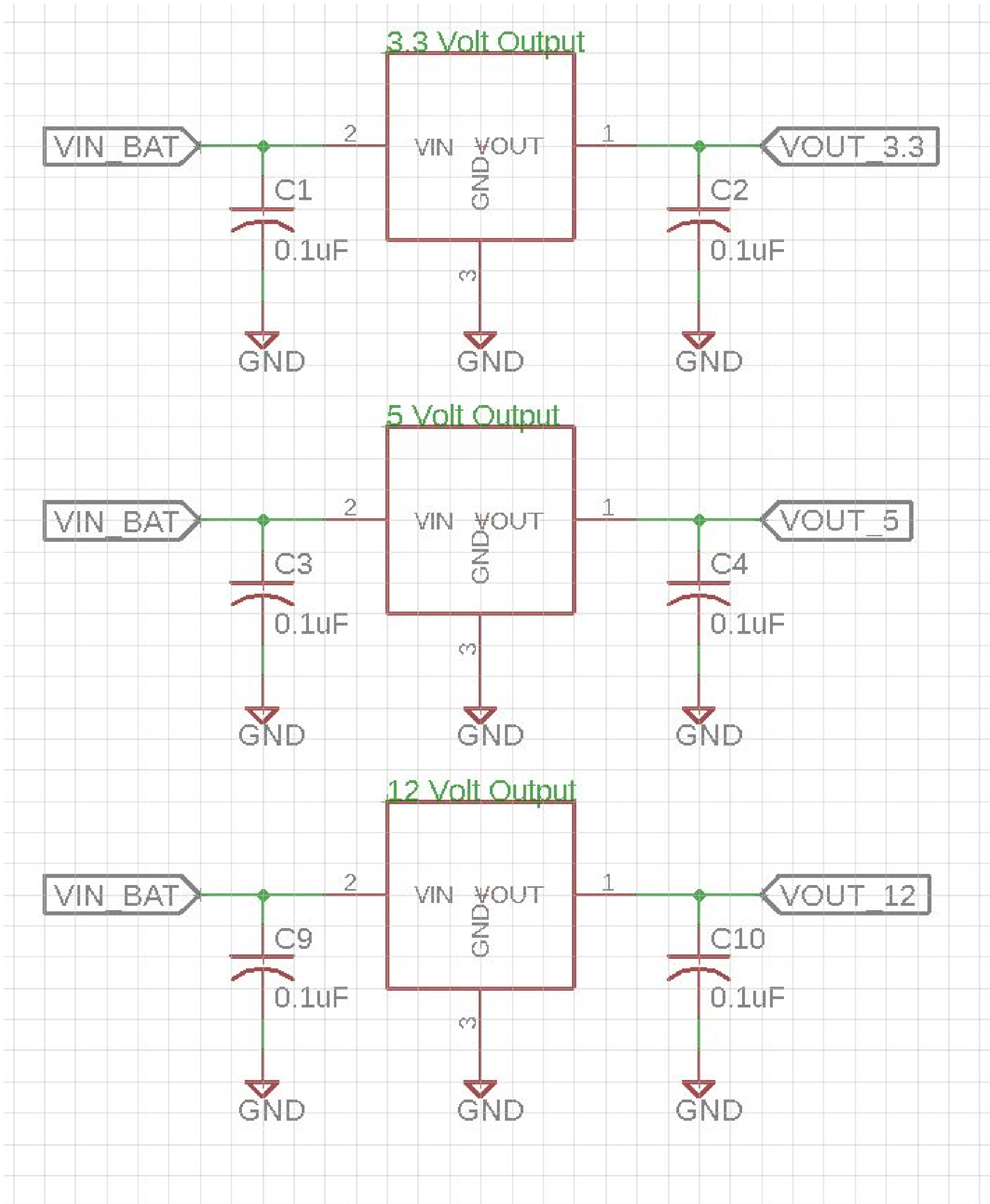


Figure 7. Linear Voltage Regulators (TLV760)

2.2.5 Pump

The off-the-shelf water pump collects water from its surroundings in the fish tank and expels it upwards to the surface to filter through a vegetable garden bed. The overflow from the vegetable bed drips back into the tilapia tank which effectively re-oxygenates the water by breaking the surface tension. For the purposes of testing and our final demonstration, we will bypass the plant bed and pump water directly back into fish tank. The variety of pump that is currently in use operates at about 15W and we are speccing our design to match it.

The microcontroller will take readings from the dissolved oxygen sensor and the 'Run' button in order to operate the pump in 10 minute intervals. In a normal operating condition, all three sensors will take data at the top of the hour. If the dissolved oxygen sensor reading is below our preset threshold of 4 mg/mL, then the microprocessor will send a signal back to the pump to run for ten minutes. A second reading of the three sensors will be taken after the ten minutes is up to determine if the pump needs to run for another 10 minutes or if it can just idle until the next top of the hour. If a 'Run' button press is sensed, then the pump will just run for 10 minutes and no additional sensor data is taken.

2.2.6 pH Sensor

The pH, dissolved oxygen (DO), and temperature are three pillars of aquaponics that are essential to the health of the system [3]. The health of the fish is most sensitive to these three criteria. Many aquaponics resources recommend checking the pH levels at least 3-4 times per week - our sensors alleviate the farmers of the need to physically go to each tank and make these measurements. The pH sensor will communicate with the microcontroller via analog signalling so that its data can then be digitally displayed on the blue-white LCD screen that will be placed on the front side of the sensing kit for easy viewing. The best growing conditions for tilapia are between a pH level of 7.0-7.5 [4]. Therefore, if the hourly measurement indicates a pH reading outside of this range, the LED indicator at the top of the sensing kit will glow red and the LCD display will read high or low. The pH readings will be taken at the top of each hour in addition to any time the 'Test' button is pressed.

2.2.7 Dissolved Oxygen Sensor

For the amount of fish that the farmers are trying to raise per tank, closely monitoring the dissolved oxygen levels in the tank is very important. Since current resources and infrastructure do not allow for frequent water changes, a balance between power usage and operating the water pump must be found based on frequent readings of the DO sensor. THe microcontroller communicates to the DO sensor via UART protocol and the operating conditions are given below:

The dissolved oxygen readings (along with the other sensor readings) will be taken on the hour unless a button press is sensed. If the dissolved oxygen level reading is too low (below 4 mg/L [4]), then the pump will run for ten minutes. After, a second reading will be taken and the pump will run or not based on the results. If the manual 'Run' button is pressed on the top of the display, then the pump will just run for 10 minutes and shut off. If the 'Test' button is pressed, then all of the sensors will take measurements and the water pump will operate as normal based on the conditions that the DO sensor has gathered.

### 2.2.8 Temperature Sensor

Lastly, it is important to monitor the temperature of the tanks closely and frequently since tilapia are sensitive to their surroundings and will cease eating, breeding, and have a significant increase in mortality from handling outside of certain temperature ranges [4].

### 2.2.7 Push Button

There will be a manual button that will turn the pump on for a 10 minute interval if it is not already running.

### 2.2.8 Microcontroller

The ATmega328P-PU microcontroller acts as the brain behind our aquaponics sensing kit. This microcontroller was chosen since it is the basis of the popular Arduino kits. Many of our sensors were chosen such that they work with Arduino/ATmega328P-PU to aid in the success of our overall design due to simplicity and resources available online.

The microcontroller will be used to control our logic for when the pump turns on (either manually through a button push or when the dissolved oxygen sensor reading is too low) and the control of our LED indicator (when any of the three sensors detect pH, DO, or temperature is out of range). The microcontroller will communicate with the dissolved oxygen sensor via UART, the pH sensor with analog signals, and the temperature sensor with 1-Wire. In addition to the LED indicator, the microcontroller will also output onto an LCD display the most recent data readings of the three sensors.

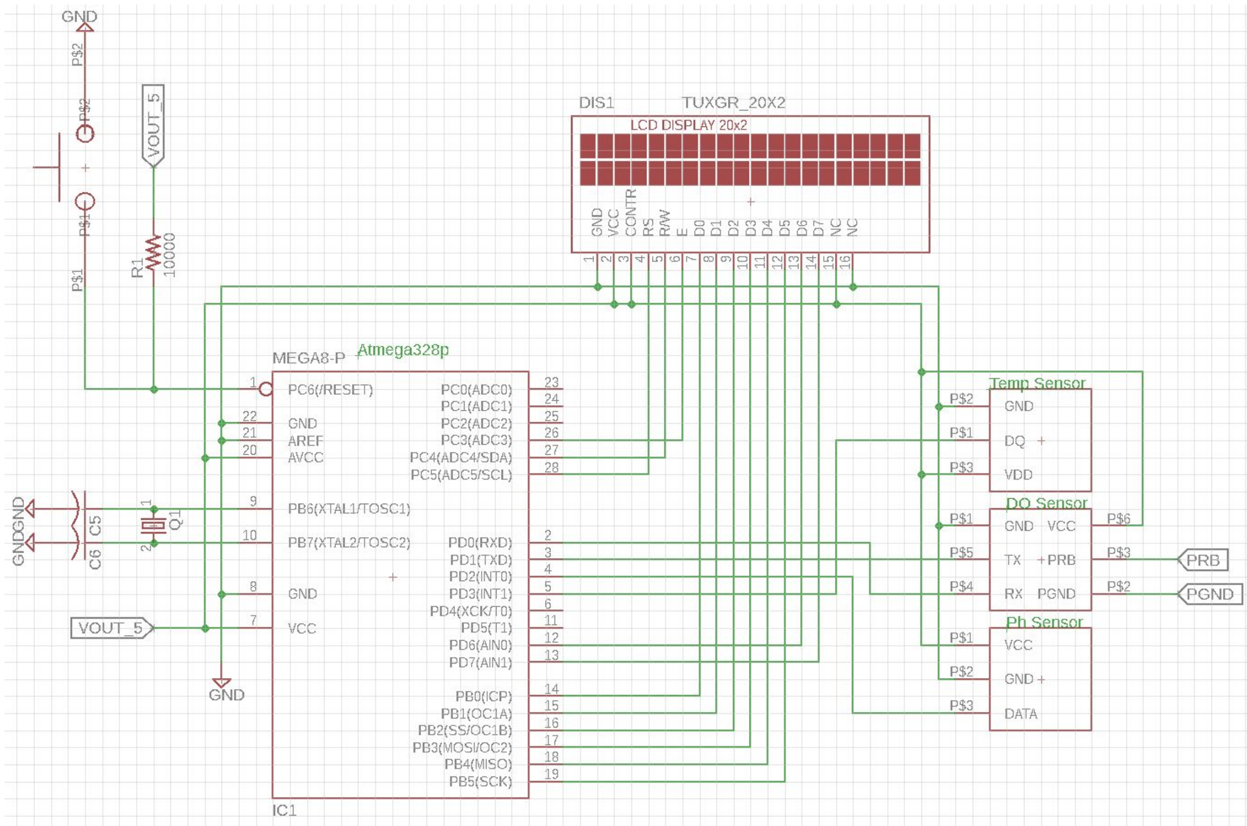

Figure 8. Schematic of Sensors (Microprocessor 2)

### 2.2.9 LCD Display

The display will act as the main user interface showing the latest measurements taken of pH, dissolved oxygen, and temperature. It will be also indicate whether measurements are great, good, or bad. “Bad” would indicate that the tank needs attention/maintenance.

## 2.3 Requirements and Verification

### 2.3.1 Solar Panel

| Requirements | Verifications |
|---|---|
| Solar Panel must provide at least 40W at a minimum of 12V full sunlight*.<br><br>*Note that the UV index in Champaign, IL during winter months is significantly less than Kenya's year-round, which is closer to the equator and has a sun angle closer to 90°.<br><br>**Points: 2 points** | 1. Place solar panel flat on the ground during full sunlight.<br>2. Using a multimeter, record the voltage across all 3 panels in parallel using a variable power resistor rated 1-25Ω.<br>    a. Perform resistive load sweep on maximum of 5Ω intervals.<br>3. Check results to ensure that ~40W of power is capable of being delivered at some power point of the solar panel. |

### 2.3.2 Battery

| Requirements | Verifications |
|---|---|
| 90-120 Wh battery for our system to run at a minimum of 3 continuous hours.<br><br>**Points: 2 points** | 1. Attach battery to a 15W resistive load.<br>2. Monitor for 3 hours and take measurements of current and voltage output every 30 minutes using multimeter.<br>3. At the end of the test check that the battery voltage does not drop below 11V (which indicates fully discharged). |

2.3.3 Charge Controller

| Requirements | Verifications |
|---|---|
| Charge controller provides a constant 14.5V +/-10% at a maximum of 3 +/-5% A from an input of 10V to 20V. The charge controller should limit the current to 3 A to safely charge the battery.<br><br>**Points: 10** | 1. Connect a DC source to the input side of the charge controller and set the input to 10 V.<br>2. Connect a battery charged to 12V +/- 5% to the output side of the charge controller.<br>3. Turn on the power supply and the charge controller.<br>4. Charge the battery until it is fully charged.<br>5. Check that the battery is charged at no more than 3 A and stops charging before 14.5V.<br>6. Repeat for an input of 20V from the source after discharging the battery for some time. |

2.3.4 DC-DC Converters

| Requirements | Verifications |
|---|---|
| 1st Converter:<br>Input: 10-25V at 30W (simulates solar panels at inputs)<br>Output: 14.5V +/-10% at 43.5W +/- 10% (simulates lithium battery)<br><br>2nd Converter:<br>Input: 11-15V (output of lithium battery)<br>Output: 12V +/-5% at 15W (DC pump)<br><br>**Points: 9 (4.5 each)** | For 14.5V converter:<br>1. Attach a 30W load.<br>2. Connect oscilloscope across the load.<br>3. Input 14.5V DC to regulator.<br>4. Ensure output remains between 14.5V +/- 10%.<br><br>For 12V converter:<br>1. Attach a 15W load.<br>2. Connect oscilloscope across the load.<br>3. Input 12V DC to regulator.<br>4. Ensure output remains between 12V +/-5%. |

2.3.5 Voltage Regulator

| Requirements | Verifications |
|---|---|
| Input: 10-25V<br>Output: 5V +/-10% at 0.5W (for microcontroller/sensors)<br><br>**Points: 1** | For 5V regulator:<br>1. Attach a 0.5W load.<br>2. Connect oscilloscope across the load.<br>3. Input 10V DC into 5V regulator.<br>4. Ensure output remains between 4.5V and 5.5V.<br>5. Repeat 1-4 for 25V DC input. |

2.3.6 Microcontroller (ATmega328P-PU)

| Requirements | Verifications |
|---|---|
| Read and interpret sensor data, relay info to UI, and send control signal to pump and display. Must be able to send data through UART at a Baud Rate of 9600.<br><br>The second microcontroller must be able to output a PWM signal. (Tonu)<br><br>**Points: 10** | A: UART verification<br>1. Connect the microcontroller to a serial terminal.<br>2. Set the Baud rate to be 9600.<br>3. Send and echo back a string of 100 numbers<br>4. Check that numbers match what was sent.<br>B: PWM<br>1. Connect the output of the PWM generator pin to an oscilloscope.<br>2. Set the duty ratio of the PWM to be 50%.<br>3. View and verify that the duty ratio is 50% on the oscilloscope. |

2.3.7 Pump

| Requirements | Verifications |
|---|---|
| 15W, 12V pump must be able to pump water to a minimum height of 0.5 meters<br><br>**Points: 2** | 1. Submerge the pump underwater and connect necessary tubes.<br>2. Connect the pump to the power supply with the power supply turned off.<br>3. Turn on the power supply and lift the tube 0.5m higher than water level.<br>4. Leave the pump on for 1 minute and verify that water is being pumped for at least 1 minutes. |

2.3.8 pH Sensor

| **Requirements** | **Verifications** |
|---|---|
| pH sensor must sense a pH of 0-14 in increments of at least 0.5<br><br>**Points: 2** | 1. Obtain test pH solutions of pH 4.01 , 6.86, 9.18 with accuracy of +/- 0.25 from buffer solution powder.<br>2. Submerge the pH probe in the solutions.<br>3. Check that the pH sensor reading is within 10% of the test pH solution. |

2.3.9 Dissolved Oxygen Sensor

| **Requirements** | **Verifications** |
|---|---|
| Oxygen sensor must be able to detect increases and decreases in oxygen levels in water.<br><br>**Points: 2** | 1. Leave 3 cups of water in the room for 30 minutes so that the temperature and dissolved oxygen levels reach equilibrium.<br>2. Submerge the probe in one of the cups and take the reading of the dissolved oxygen level.<br>3. Shake the second cup of water so that more oxygen dissolves in the water.<br>4. Submerge the probe in the second cup of water and check that the oxygen levels is higher than that of the first cup.<br>5. Dissolve a tablespoon of salt in the third cup and check with the probe that the dissolved oxygen level decreases. |

2.3.10 Temperature Sensor

| **Requirements** | **Verifications** |
|---|---|
| Temperature sensor must be accurate to within +/- 1 degrees Celsius<br><br>**Points: 2** | 1. Obtain a thermometer and put it into a cup of water at room temperature<br>2. Put temperature probe into the cup of water.<br>3. Check that the two readings agree to within +/- 2 degree Celsius. |

2.3.11 LCD Display

| Requirements | Verifications |
|---|---|
| Must clearly display numerical values of pH, dissolved oxygen, and temperature and say if the values are 'GOOD', 'OK', or 'BAD' based on predetermined tilapia farming statistics.<br><br>**Points: 3** | 1. Turn on the LCD display and have it display the pH, DO2, and Temp measurements on separate lines.<br>2. Verify that the numbers can be read at a typical reading distance away. (15in)<br>3. Watch as the LCD display updates the values from the sensors after 5 seconds. |

2.3.12 LED Indicator Light

There will be a red indicator light that will turn on when any measured value is out of acceptable range to alert the user of an imbalance. This is especially useful to alert the farm operators when DO2 levels are low so that they can come around and press the button to run the oxygenating pump.

| Requirements | Verifications |
|---|---|
| Must turn red when sensor values are outside of tolerance ranges (i.e. when LCD says "BAD" for any value). Otherwise, light will be off.<br><br>**Points: 2** | 1. Submerge the pH probe in a solution such that the readings would outside the tolerance range. Eg. pH of 4.1<br>2. Check that the red LED is on and can be seen from 1m away. |

2.3.13 Push Button

| Requirements | Verifications |
|---|---|
| Button should be a short circuit when pressed and open circuit when not pressed. | 1. Use a multimeter in continuity mode.<br>2. Check that the button is a short circuit when pressed and open circuit when not pressed. |
| Button should be debounced.<br><br>**Points: 1** | 1. Connect a resistor in series and a DC source across both the button and the resistor.<br>2. Connect the button to an oscilloscope.<br>3. Press the button and see that the signal has a smooth transition. |

## 2.4 Tolerance Analysis

Since the motivation behind this project was to be able to accurately and easily measure various conditions of the water in the tilapia farm, a tolerance analysis was performed on the most expensive sensor that would be used: the dissolved oxygen sensor. This sensor is the most expensive single component in our design so we chose to test its accuracy and gain further familiarity with it. Additionally, the results obtained by the DO sensor would be crucial to our logic for controlling when the water pump turns on and off during the daytime and at night. As such, the reliability of this sensor is of utmost importance such that we do not drain the battery of our solar-powered system.

The galvanic dissolved oxygen probe consists of a polyethylene membrane, an anode, and a cathode. The oxygen molecules in solution cross through the membrane and are reduced at the cathode where a small voltage is produced. The more oxygen that is present in solution, the more mV output there is. The DO sensor can also be used to detect the oxygen content in gases. This principle is useful when solving for our dissolved oxygen saturation level. Equation 1 is used to convert the measured voltage in water to a percent saturation. From there, the mg/L of DO in water can be found by referencing a solubility table (Figure 5). The Percent Saturation of Dissolved Oxygen depends on the temperature of the water and elevation of the water testing site [5]. In Champaign, IL at an altitude of 764’, a correction factor of 0.9727 is applied to the table.

**Solubility**: Amount of DO that distilled water can hold at a given temperature

| Temp. (C) | Solubility (mg/L) |
|---|---|
| 0 | 14.6 |
| 1 | 14.2 |
| 2 | 13.8 |
| 3 | 13.5 |
| 4 | 13.1 |
| 5 | 12.8 |
| 6 | 12.5 |
| 7 | 12.2 |
| 8 | 11.9 |
| 9 | 11.6 |
| 10 | 11.3 |
| 11 | 11.1 |
| 12 | 10.9 |
| 13 | 10.6 |
| 14 | 10.4 |
| 15 | 10.2 |
| 16 | 10.0 |
| 17 | 9.8 |
| 18 | 9.6 |
| 19 | 9.4 |
| 20 | 9.2 |

Figure 9. Solubility of Water Table [6]

$$Saturation\ (\%) = \left(\frac{mV\ \ in\ H2O}{mV\ \ in\ air}\right) * 100 \tag{1}$$

The DO sensor detected 47 mV in the air. We took the measurements listed below in Table 1. The water was sourced from a water fountain and the sink in the ECE 445 Senior Design lab. We assume that the temperature of both sources was 10°C.

Table 1. Testing of Dissolved Oxygen Probe

| **Test Number** | **Source of H2O, Amount Shaken (sec)** | **Voltage in H2O (mV)** | **Dissolved Oxygen Saturation (%)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|
| 1 | Fountain, 0 | 25 | 53.19 | 5.84 |
| 2 | Fountain, 5 | 31 | 65.36 | 7.24 |
| 3 | Fountain, 25 | 42 | 89.36 | 9.81 |
| 4 | Fountain, 0 | 30 | 42.55 | 4.67 |
| 5 | Fountain, 5 | 33 | 70.21 | 7.71 |
| 6 | Fountain, 25 | 43 | 91.48 | 10.04 |
| 7 | Sink, 0 | 17 | 36.17 | 3.97 |
| 8 | Sink, 5 | 40 | 85.10 | 9.34 |
| 9 | Sink, 25 | 45 | 95.74 | 10.51 |

Ultimately, we gathered that the dissolved oxygen sensor is precise enough such that it detects oxygen added to water by disturbances. It verifies our oxygenation method's effectiveness in producing discernible changes in dissolved oxygen concentrations. Given these observations, we can verify that our sensor is effective and stays within tolerance given controlled operating temperatures. For operation in Kenya, will we need to make readings based on the assumption that temperature will be approximately 30°C. Figure 9 demonstrates the relationship between temperature and dissolved oxygen in water, which will be the basis for our analysis. Operation significantly beyond this temperature range does not guarantee the same level of accuracy. Additionally, the altitude of Kenya is at 5197' which means a correction factor of 0.826 needs to be applied to the solubility values in Figure 9.

# 3 Cost and Schedule

## 3.1 Cost Analysis

Labor

| Name | Hourly Rate | Hours per Week | Cost for 16 Weeks x 2.5 |
|---|---|---|---|
| Shannon Kuruc | $30 | 15 | $18,000 |
| Emily Wang | $30 | 15 | $18,000 |
| Tony Xiao | $30 | 15 | $18,000 |
| **Total** | | | **$54,000** |

Parts List

| Description | Brand | Quantity | Retailer | Cost | Total |
|---|---|---|---|---|---|
| Solar Panels | ALEKO | 3 | Amazon | 33.99 | 101.97 |
| Temperature Sensor | Dallas Semiconductor | 1 | Sparkfun | 9.95 | 9.95 |
| DO Kit | Atlas Scientific | 1 | Sparkfun | 249.95 | 249.95 |
| pH Sensor | DFRobot | 1 | DFRobot | 29.50 | 41.50 |
| LCD Display | RioRand | 1 | Amazon | 7.99 | 7.99 |
| Battery | Dakota Lithium | 1 | Dakota Lithium | 99.99 | 114.00 |
| Microcontroller | Atmel | 2 | Amazon | 5.66 | 11.32 |
| Testing Tank | N/A | 1 | N/A | 0.00 | 0.00 |
| Waterproof Housing for Electronics | N/A | 1 | Machine Shop | 20.00 | 20.00 |
| Buttons (2) | PP-NEST | 1 | Amazon | 8.99 | 8.99 |
| Power converter | N/A | 2 | Amazon | 10.00 | 20.00 |
| Crystal oscillator | Mouser Electronics | 1 | Mouser | 1.00 | 1.00 |
| Other | N/A | N/A | N/A | 20.00 | 20.00 |
| **Total** | | | | | **606.67** |

Grand Total

| Labor | Parts | Total |
|---|---|---|
| $54,000 | $606.67 | $54,606.67 |

### Long-Term Cost Analysis - 2 Years

Analysis will be done over the course of 2 years. For our cost analysis, we will be limiting it to dissolved oxygen and pH, as those are the most labor and cost-intensive tests. Based on the recommended dissolved oxygen testing intervals, dissolved oxygen should be tested every day [7]. Our dissolved oxygen sensor cost $249.99, however after purchase we determined the included ADC was not necessary and the same functionality could be achieved using the microcontroller. One of the cheapest manual DO2 test kits were $13.40 for 15 tests, which is about $0.89 per test [8]. Over the course of two years, the cost of daily manual DO2 tests would be $652.13.

For pH testing, it is recommended to take measurements daily [9]. A freshwater pH testing kit costs $5.50 for 250 tests [10], which is about $0.02 per test. Over the course of two years, the cost of daily manual tests would be $14.86. The best option for the pH sensor costs $56.95, as it can be submerged indefinitely. The total cost of manual testing for two years is $666.99, and the total cost of our system is $606.67. After 2 years of use, our sensing kit pays for itself monetarily. In the meantime, the sensing kit is also saving on labor costs and allowing the farms to allocate their valuable time to expansion of their farm or tending to different aspects of it such as vegetable farming, selling, or marketing.

## 3.2 Schedule

| Week | Shannon | Emily | Tony |
|---|---|---|---|
| 2/11/18 - 2/17/18 | Mock Design Document: Add/edit Introduction, Cost and Schedule, Requirements and verification, Block Descriptions Schematic | Mock Design Document: Add/edit Schedule, Ethics and Safety, Cost and Schedule, Schematic, R&V | Mock Design Document: Add/edit Block Diagram, Physical Design, Cost and Schedule, Schematic |
| 2/18/18 - 2/24/18 | Complete the design requirements and verification | Schedule, unit drawings and mockup, find data sheets for sensors used, research microcontroller | Work on schematic for design and linear regulators |
| 2/25/18 - 3/3/18 | Solar panel verification<br>Prepare for design review | Prototype sensing unit on Arduino<br>Prepare for design review | Battery verification<br>Prepare for design review |
| 3/4/18 - 3/10/18 | Begin PCB design<br>Solar panel + battery charge test | Debug prototype sensing unit on Arduino with working LCD display and switches | Debug prototype sensing unit on Arduino with working LCD display and switches |

| | | | |
|---|---|---|---|
| 3/11/18 - 3/17-18 | Finish and order PCB design<br>Begin building charge controlling circuit hardware<br>Build voltage regulators | Begin development on ATMega328P-PU for sensing unit | Complete prototype sensing unit on Arduino with working LCD display and switches<br>Development on ATMega328P-PU |
| 3/18/18 - 3/24/18 (Spring break) | Solar unit/voltage regulator load tests (for 12V and 3.3V) | Continue sensing unit microcontroller programming | Build charge controlling sensing unit<br>Develop charge controller on microcontroller |
| 3/25/18 - 3/31/18 | Solder and assemble PCB | Finalize sensing control unit<br>Test sensing control unit | Test charging control unit |
| 4/1/18 - 4/7/18 | Total system tests | Test sensing control unit | Test charging control unit |
| 4/8/18 - 4/14/18 | Systems integration and environmental testing | Systems integration and environmental testing | Systems integration and environmental testing |
| 4/15/18 - 4/21/18 | Final environmental testing of integrated unit | Begin final presentation | Begin report |
| 4/22/18 - 4/28/18 | Finish final presentation<br>Finalize final report<br>Practice presentation | Finish final presentation<br>Finalize final report<br>Practice presentation | Finish final presentation<br>Finalize final report<br>Practice presentation |
| 4/29/18 - 5/1/18 | Presentation | Presentation | Presentation |

# 4 Ethics and Safety

## 4.1 Risk Analysis

The very nature of this water-based project poses some risks to the safety and completion of the project. We suspect that the most difficult part of this project would be the system integration and programming the embedded system to interface with the sensors. Additionally, we anticipate some added difficulty with the following:

- Embedded systems programming
- Systems integration
- Sensor compatibility

Another concern is testing our system using solar power. Majority of our development time is taking place during winter and early spring, when sun intensity and day length is limited. We are concerned that we will not be able to generate enough stored power to power the system.

One aspect not part of electrical engineering that may give us trouble is the water chemistry. We are trying to increase the dissolved oxygen levels through the splashing of water when we pump the water up into the trough where the plants grow. We might not be able to reach our target oxygen levels without using an actual oxygenator. The current system in Kenya uses this oxygenation method over a mechanical oxygenator.

## 4.2 Safety

Our project is designed to take measurements from a large tank of water. There are inherent safety concerns with any type of electronics equipment in water, including but not limited to moisture damage to components or electrocution.

There are a variety of hazards associated with lithium-ion battery use. This includes overcharging, overheating, and mechanical abuse [11]. Overcharging is the most serious hazard, however it is the least likely. We would need to implement safeguards such as an automatic shut off when the temperature is too high. We also need to consider mechanical abuse, as your average Kenyan does not know proper battery safety and disposal. Lilly expressed his concerns with batteries, however it is necessary for our project and the Living Positive Kenya facility is a controlled environment.

Generally, we are concerned with the impact of electronic equipment being disposed of improperly and toxins making their way into the environment. This potentially violates IEEE Code of Ethics #1: “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment”.

## 4.3 Ethics

A potential concern is with introducing this equipment is damage to the environment and people. IEEE Code of Ethics 7.8.5 states that the intent is "to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems;" [12]. Our intention is to empower and support individuals in their health. Introducing lithium ion batteries potentially violates 7.8.1 of IEEE Code of Ethics in terms of sustainability.

There are also ethical concerns with animal farming of any sort. However, our intent is to build a system that supports sustainable, humane farming to serve a group of people in need.

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