Aquaponics Tank Sensing Kit

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ECE 445 Design Review - Spring 2018

TA: Yamuna Phal

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

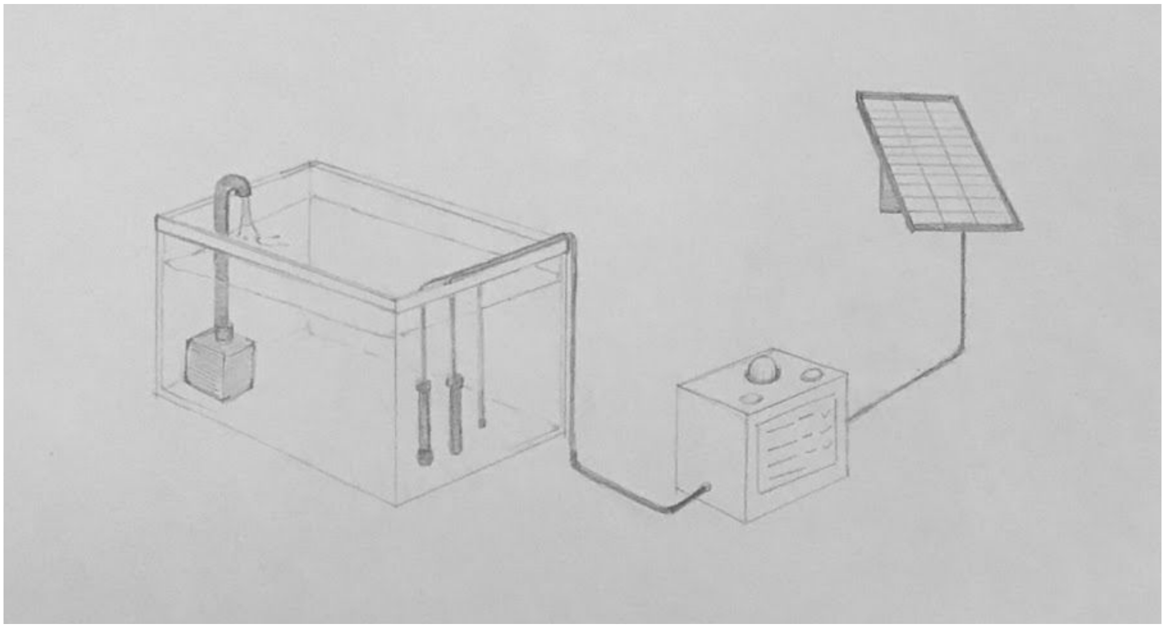


Figure 1: Physical Design

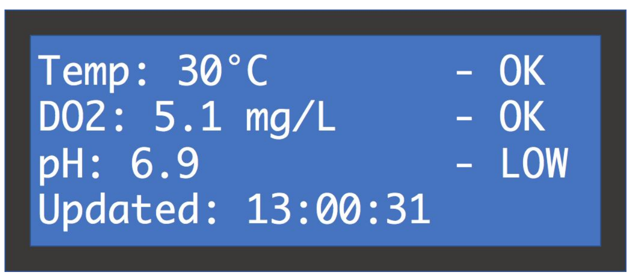


Figure 2: LCD Display Sample

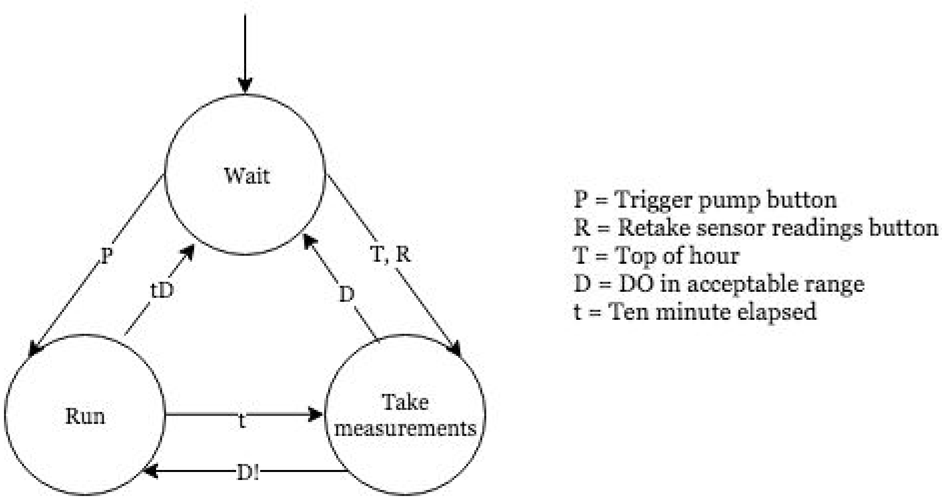
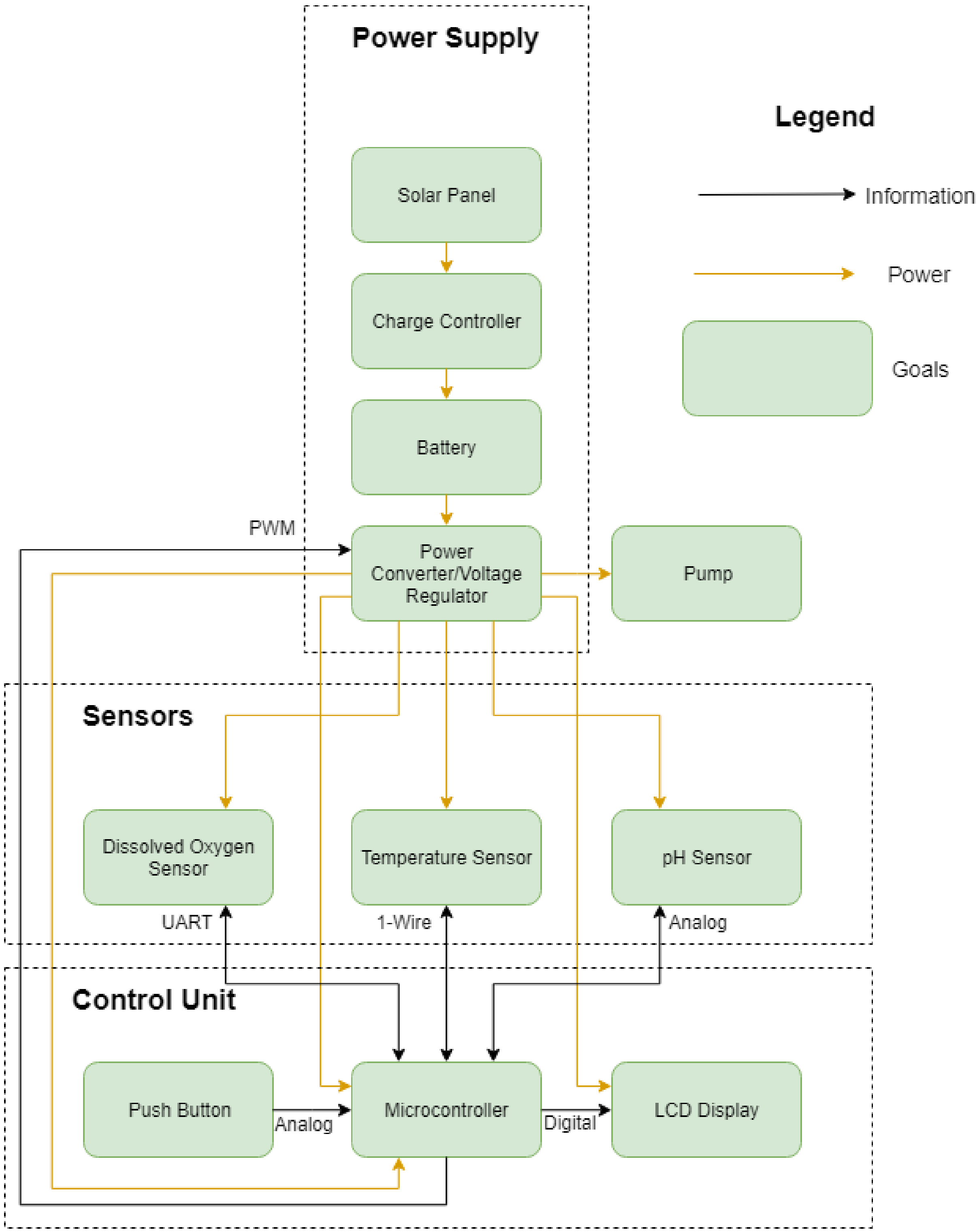


Figure 3: High-Level System Control Logic

2.1 Block Diagram



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 a 60 W panel, 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 pump in the future.

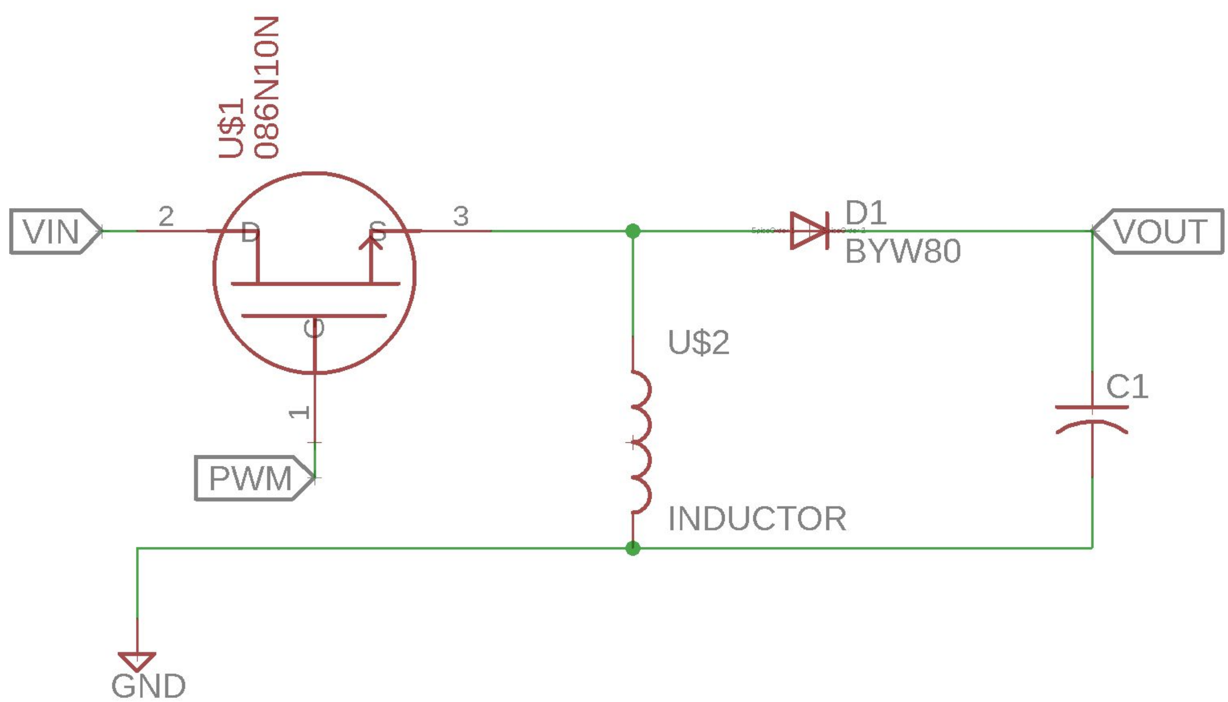
2.2.2 Charge Controller

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 each hour automatically. 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.

At the time of writing, the battery has not been chosen/purchased and is still up to debate between the team and requirements of the fish farm. The possibility of purchasing a 12 V, 7-9 Ah battery is under consideration. An oversized battery would allow for customization in the number of pumps added to each fish tank as well as reducing the number of deep discharges of the battery to prolong its lifespan.

2.2.4 Power Converter/Voltage Regulator



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 **[2]**. 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 **[3]**. 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:

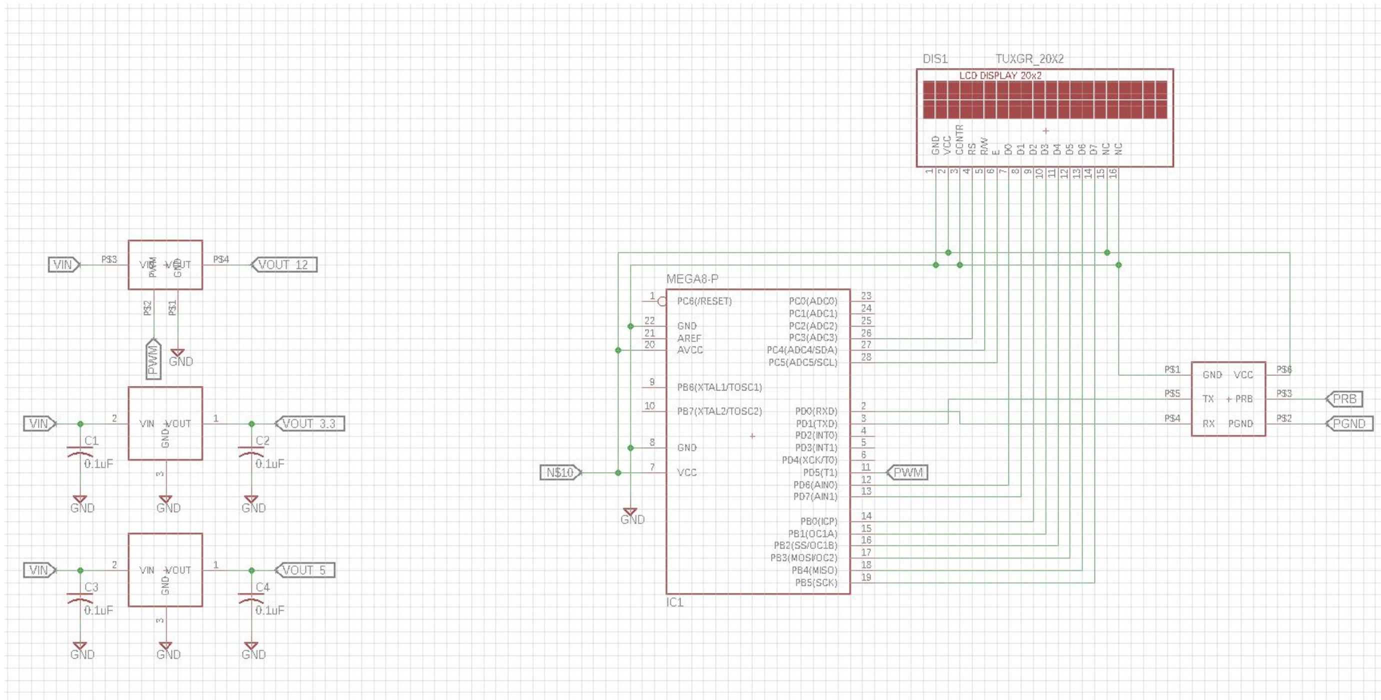
The dissolved oxygen readings (along with the other sensor readings) will be taken on the hour unless a button press is sensed. If the dissolved oxygen level reading is too low (below 4 mg/L **[3]**), then the pump will run for ten minutes. After, a second reading will be taken and the pump will run 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 **[3]**.

2.2.7 Push Button

In addition to taking measurements every hour, the user can refresh the measurements by pushing a button. There will also be a manual button that will turn the pump on or off.



2.2.8 Microcontroller

The ATmega328P 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 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.

2.2.9 LCD Display

The display will act as the main user interface showing the latest measurements taken of pH, dissolved oxygen, temperature, and the time the measurements were taken. It will be also indicate whether measurements are too high, too low.

2.2.10

2.2.11

2.2.12

2.3 Requirements and Verification

2.3.0 Power

2.3.1 Solar Panel

Requirements	**Verifications**
Based on current panels in use (per panel): Peak power: 40 W Minimum power voltage: 13.2 V Minimum power current: 1.1 A	1. Place solar panel in 111000 Lux sunlight. Check this valuing using a 1% photoresistor. 2. Find the maximum power point of this solar panel using a potentiometer and taking a series of voltage and current data 3. Check that at least 40W of power is being delivered at the maximum power point.

2.3.2 Battery

Requirements	**Verifications**
84-108 Wh battery for our single 15 W pump at a minimum	1. Attach battery to a 15W resistive load. 2. Wait 4 hours 3. Check charge level using a voltmeter and then comparing the voltage levels to the table in the link below. Check that the discharge depth has not exceeded 80%.

2.3.3 Charge Controller (PWM)

Requirements	**Verifications**

MPPT charge controller with a 60 W minimum capacity.	

2.3.4 Power Converter/Voltage Regulator

The power converter must be a DC-DC converter that is able to output 5V +/-10% at 5W (microcontroller), 12V +/-10% at 15W (pump).

Requirements	**Verifications**
Input: Solar panel 18-12V at 20W (per panel) Output: 5V +/-10% at 5W (USB port/microcontroller/sensors), 12V +/-10% at 15W (pump)	

2.3.5 Microcontroller (ATmega328P-PU)

Requirements	**Verifications**
Read and interpret sensor data, relay info to UI, and send control signal to pump and display	

2.3.6 Pump

Requirements	**Verifications**
15 W, 12 V pump must be able to pump water to a minimum height of 0.5 meters	1. Submerge the pump underwater and connect necessary tubes 2. Connect the pump to the power supply with the power supply turned off 3. Turn on the power supply and lift the tube 0.5m higher than water level 4. Leave the pump on for 10 minute and verify that water is being pumped for at least 10 minute

2.3.7 pH Sensor

Requirements	**Verifications**
pH sensor must sense a pH of 0-14 +/-0.5	

2.3.8 Dissolved Oxygen Sensor

Requirements	Verifications
Dissolved oxygen must be able to detect oxygen levels of 0.5-50 ppm	

2.3.9 Temperature Sensor

Requirements	Verifications
Temperature sensor must be accurate to within +/- 5 degrees Celsius	

2.3.10 LCD Display

Requirements	Verifications
Must clearly display numerical values of pH, dissolved oxygen and temperature and if the values are in range based on the signal from the microcontroller	1. Turn on the LCD display and display a random string of numbers. 2. Verify that the numbers can be read at a typical reading distance away. (15in)

2.3.11 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.

Requirements	Verifications
Must turn red when sensor values are outside of tolerance ranges and flash red when they are significantly outside of tolerance ranges. Otherwise, light will be off	1.

2.3.12 Push Button

Requirements	Verifications
Must be water-safe to protect against potential splashes. 2-buttons total. Button one: Must refresh the sensor measurements and then automatically run the pump if DO levels are too	

low. Button two: Start the pump for 10 minutes or stop the pump Account for bounce	

2.4 Tolerance Analysis

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	DelTran	1	Cabelas	79.99	79.99
MPPT Charge Controller		1			

Microcontroller	Atmel	1	Amazon	5.66	5.66
Testing Tank	N/A		WalMart	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					

Grand Total

Labor	**Parts**	**Total**
$54,000		

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	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 Order charge controller	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 Battery verification Prepare for design review	Prototype sensing unit on Arduino Prepare for design review	Prototype sensing unit on Arduino Prepare for design review
3/4/18 - 3/10/18	Begin PCB design 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 Solar panel + battery charge test	Begin development on ATMega	Complete prototype sensing unit on Arduino with working LCD display and switches Begin development on ATMega
3/18/18 - 3/24/18 (Spring break)	Solar unit load test (for 12V and 3.3V)	Continue microcontroller programming	
3/25/18 - 3/31/18	Solder and assemble PCB	Finalize control unit	
4/1/18 - 4/7/18			
4/8/18 - 4/14/18	Systems integration		
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 Finalize final report Practice presentation	Finish final presentation Finalize final report Practice presentation	Finish final presentation Finalize final report Practice presentation
4/29/18 - 5/1/18	Presentation	Presentation	Presentation

4 Ethics and Safety

4.1 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 **[4]**. 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".

4.2 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;". 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.

5 Citations

[1] Data.worldbank.org. (2018). *Kenya | Data*. [online] Available at: https://data.worldbank.org/country/kenya [Accessed 7 Feb. 2018].

[2] Bernstein, S. (2011). *Aquaponic gardening*. Gabriola, B.C.: New Society Publishers.

[3] Tilapia-farming.com. (2018). Environment Conditions for Raising Tilapia | Tilapia Farming. [online] Available at: http://www.tilapia-farming.com/2012/12/09/environment-conditions-for-raising-tilapia/ [Accessed 7 Feb. 2018].

[4] Sites.ieee.org. (2018). A Guide to Lithium Ion Battery Safety. [online] Available at: http://sites.ieee.org/pes-essb/files/2016/06/2015-WM-PN-A-Guide-to-Lithium-ion-safety-Jim-McDowall.pdf [Accessed 7 Feb. 2018].