Aquaponics Tank Sensing Kit

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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

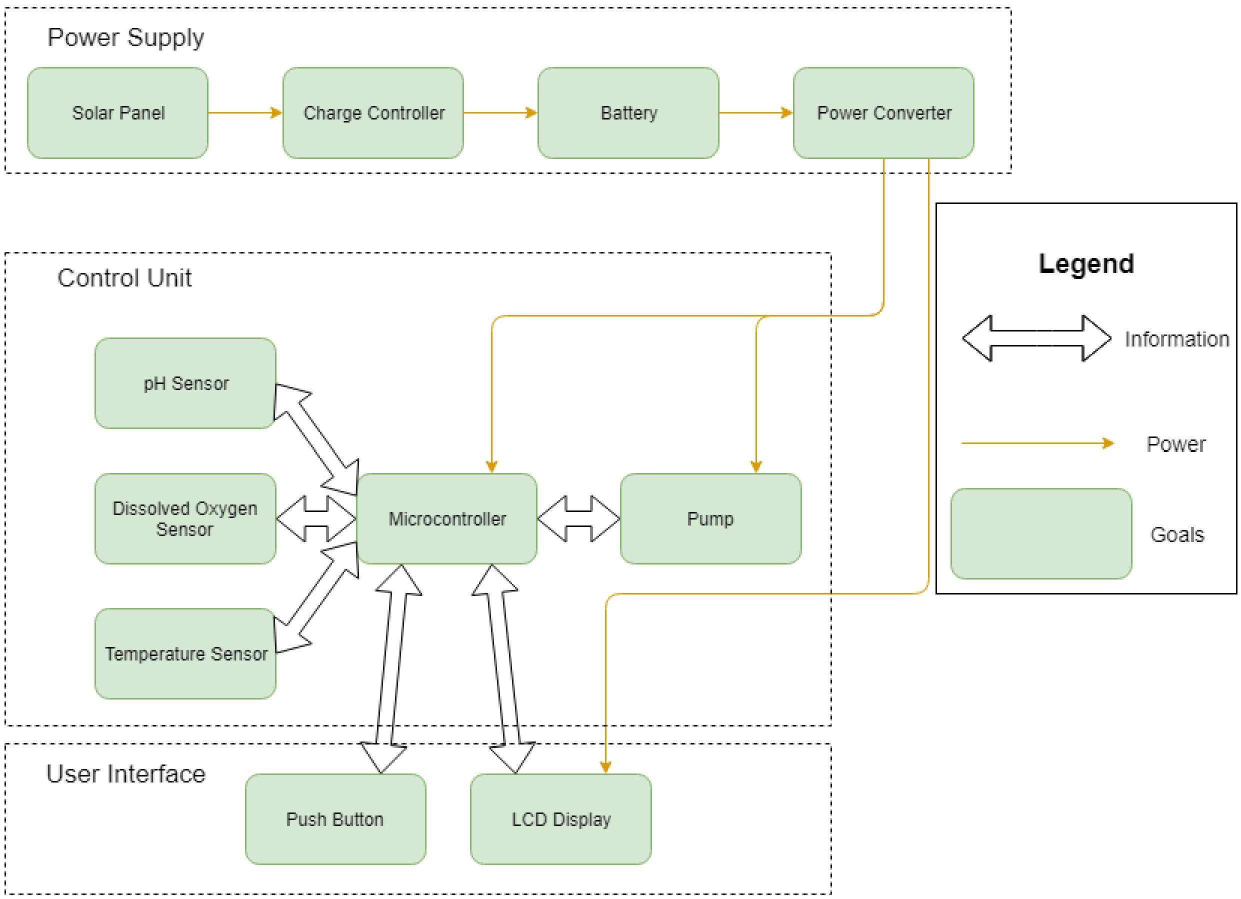

Figure 1: Block Diagram

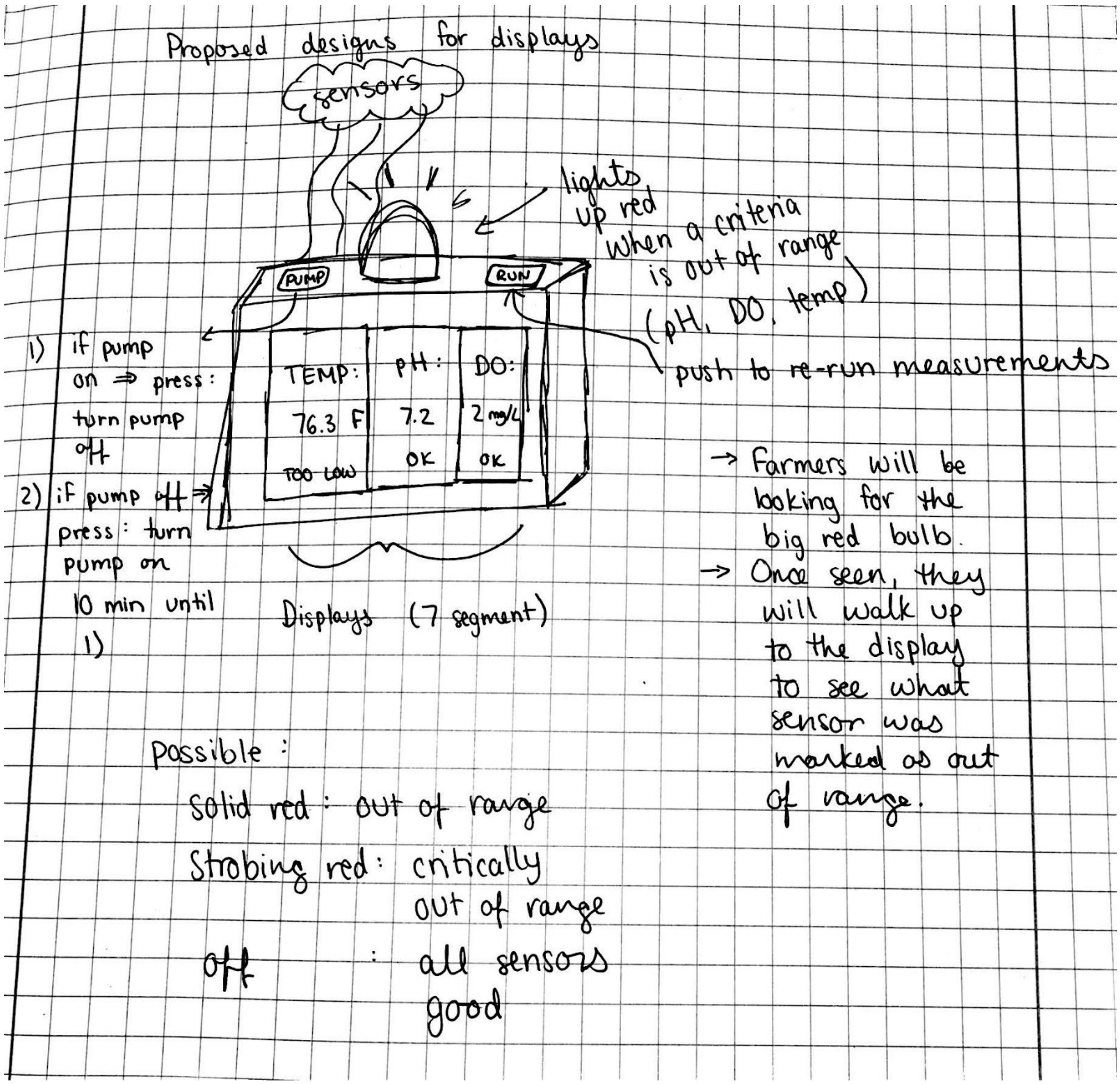

Figure 2: Proposed UI sketch with commentary from notebook

Block Requirements

2.1 Power Source

The power supply is necessary to manage powering the system when the sun is down. The system will alternate between charging the battery using solar panels and utilizing the solar panels to power the pump intermittently.

2.1.1 Solar Panel

Solar energy will be used to power the system during the day and battery charge will be used to power the system at night when the sun goes down or on a cloudy day. We do not intend on powering the system 24/7, and it is estimated to run the pump for 15-30 minutes each hour. We will be using up to 3-20 W flexible solar panels which output 12V for a combined 60 W output.

Requirement: Based on current panels in use (per panel):
- Peak power: 20 W
- Maximum power voltage: 17.6 V
- Maximum power current: 2.14 A

2.1.2 Lithium Ion 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 and include another 2 watt-hours of operation for the other electrical components and being able to manually start the pump. May overspec in actual design to allow for expansion of the pump system.

Requirement: 60 Wh battery for our single 15 W pump at a minimum.

2.1.3 Lithium Ion Battery Charge Controller (MPPT)

This battery charger needs to be able to charge a 12V lithium ion battery. We will be using an off-the-shelf battery charge controller to use with the solar panel so that we can actively charge the battery and discharge the battery in the even that the pump needs to run simultaneously.

Requirement: MPPT charge controller with a 60 W minimum capacity.

2.1.4 Power Converter

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

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

2.2 Control Unit

2.2.1 Microcontroller ATmega328P

The brain behind our aquaponics sensing kit. The microcontroller will be used to control our logic for when the pump turns on (either manually or when the dissolved oxygen level 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).

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

2.2.2 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. In our case, 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.

Requirement: 15 W, 12 V pump. Must be able to pump water to a height of 0.5m.

2.2.3 Sensors (pH, DO, Temperature)

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. For the amount of fish that the farmers are trying to raise per tank, closely monitoring the dissolved oxygen levels in the tank are very important. Since resources 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. 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]**.

Requirement 1: pH sensor must sense a pH of 0-14 +/-0.5.
Requirement 2: Dissolved oxygen must be able to detect oxygen levels of 0.5-50 ppm.
Requirement 3: Temperature sensor must be accurate to within +/- 5 degrees Celsius.

2.3 User Interface

2.3.1 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.

Requirement: 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.

2.3.2 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.

Requirement: 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.

2.3.3 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.

Requirement: 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.

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.

3 Ethics and Safety

3.1 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".

3.2 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.

4 References

[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].