ECE 445: SPRING 2026

CIRCLE OF LIFE: AUTOMATED DESKTOP AQUAPONICS SYSTEM

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Project 73

Abstract

This proposal is a more in-depth understanding and visualization of our project Circle of Life: Automated Desktop Aquaponics System. This project is the senior design project for Anjali Aravindhan, Aishwarya Manoj, and Estela Medrano-Gutierrez and will be completed in the Spring 2026 semester of ECE 445: Senior Design at the University of Illinois Urbana-Champaign.

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1. Introduction

1.1 Problem

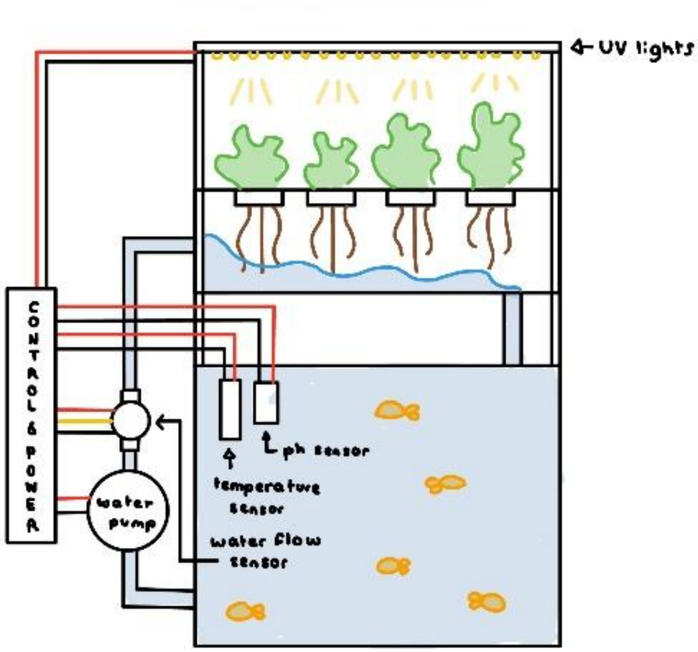
Urban living and limited indoor space make it difficult for individuals to grow fresh produce sustainably. Aquaponic systems offer an efficient solution by combining fish cultivation and plant growth in a closed-loop ecosystem, but existing systems require frequent manual monitoring and maintenance. Current desktop-scale aquaponics kits often lack intelligent control features and are cost-and-space-prohibitive for individual users.

1.2 Solution

This project proposes the design and construction of a small desktop smart aquaponics system integrating automated environmental and fluid control. The system consists of a compact fish tank and plant grow bed forming a closed-loop water circulation path. An electronically controlled pump circulates water between the tank and grow bed, while a motorized dispensing mechanism provides automated fish feeding. A programmable grow-light module delivers controlled lighting cycles for plant growth. Embedded sensors monitor key system conditions such as water flow, ph level and water temperature. A microcontroller schedules feeding and lighting and processes sensor data. Depending on budget and difficulty, we may add capabilities.

Our target customers are younger urban apartment residents and students with an interest in convenience, aesthetics, wellness, and/or sustainability but have limited time to care for plants. Our project would allow these consumers to be able to raise fresh herbs and leafy greens at home without requiring frequent maintenance.

1.3 Visual Aid

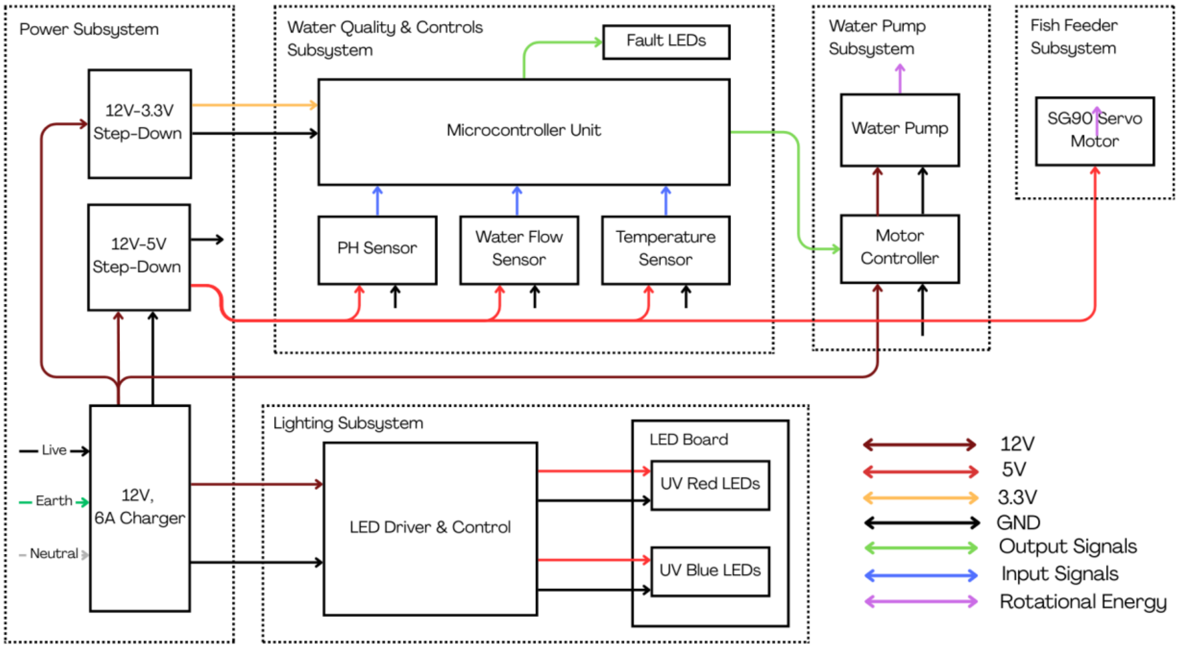


1.4 High Level Requirements

- Sensor readings should be measured once an hour for the water flow sensor and at least once every 10 seconds for the pH and temperature sensors, where abnormal readings will be displayed via LEDs (Outside of 6-8 pH, 78-80 degrees Fahrenheit, and rate of 3–5x the total tank volume per hour)
- All motorized subsystems such as the fish feeder and water pump will operate for at least 24 hours without issue, in which time the fish feeder should dispense food once and water pump will turn over the volume of the tank at least three times per hour.
- All visual indicators (LEDs) both used in the lighting schedule & displaying sensor abnormalities will be updated/checked at least every 10 seconds

2 Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Fish Feeder Subsystem

A simple automated fish feeder will be implemented using a servo motor operating between two angular positions, one away from the fish tank and another towards the fish tank for dispensing food. A custom 3D-printed food container will be mechanically coupled to the servo shaft using screws and will include a small outlet opening that allows food to dispense when the container is rotated downwards. The servo motor will be controlled via PWM signals generated by a microcontroller [8] [11]. This microcontroller will also serve as the controller for the other subsystems [7].

2.2.2 Water Quality Subsystem

This subsystem monitors water quality through various sensors and allows us to ensure that the aquaponic system is working properly. The three main components of this subsystem are the water flow sensor, the water PH sensor, and the water temperature) As we have a water pump pushing water up through our aquaponic system and bringing water to the plants above the fish tank, we need to measure the flow rate of the water to ensure that this component is operating effectively. The water flow sensor will thus measure the flow of water and ensure that the water is pumping effectively up the system [10]. Alongside this, we will have a PH sensor to measure the PH of the water, which is critical for the health of both the fish and the plants. As we aim to have beta fish in the tank, that requires a PH of roughly 6.8 to 7.5, and we will have plants that require that slightly acidic to neutral PH range as well. If the PH is outside of this range, we will have an LED indicator (sourced from our component kit) so that the user knows it is time to change the water [6]. Finally, we will have a sensor measuring the temperature of the water to ensure that it is habitable for the fish. Again, for beta fish this requires a temperature of 76 to 85 degrees Fahrenheit. The temperature sensor will measure the temperature of the water in the tank and if it is too high or too low, an LED indicator will be triggered, allowing the user to change the water or the temperature of their room [14].

2.2.3 Lighting Subsystem

The lighting subsystem serves as artificial light sources for plants in our desktop aquaponics system. The purpose of this subsystem is to make sure plants will get the correct amount of light and intensity per day to simulate growth due to sunlight from the Sun. The lighting subsystem will use LED colored lights with alternating blue and red colors to simulate sunlight and promote photosynthesis. We plan on using red and blue LEDs connected to an LED driver to both control the lighting system and step down the input voltage of the PCB to 12V needed by the lights. This LED driver will be in the same PCB as the microcontroller system and will use the same microcontroller. It will be mounted above the plants and the aquarium portion of the aquaponics system and shine down upon the plants [3].

2.2.4 Water Pump Subsystem

The water pump will be in series with the water flow sensor, sending the water from the fish tank up to the plants. We will be using a circulation pump that is waterproof, and depending on the water flow sensor's outputs, we will be controlling the speed of the circulation pump by PWM modulating the supply voltage using a MOSFET [5].

2.2.5 Power Subsystem

The power subsystem's main goal is to provide power to the other subsystems in this project, including but not limited to the lighting, fish feeder, water quality, and pump. The project will be powered using an external AC-DC 12V, 6A charger. We will be using different power conversion methods to step down the 12V to 5V and 3.3V for their corresponding components [4].

2.3 Subsystem Requirements

2.3.1 Fish Feeder Subsystem

1. The automated fish feeder must be able to supply the tank with food once every 24 hours.
2. The servo motor will have three wires coming into it, one for ground, one for power, and one for the PWM signal [7].
3. The microcontroller will output the PWM signal received by the motor, and using the duty cycle of the signal, we will control the motor's rotation so that it rotates only 180 degrees clockwise to feed and then 180 degrees counterclockwise to reset [8][11].

2.3.2 Water Quality Subsystem

1. The pH sensor must accurately measure the pH of the water in the fish tank within ± 0.1 pH, and it outputs a voltage reading corresponding to the pH it reads (the table of these associations is in the datasheet for the sensor) [6].

1. The microcontroller will take in the voltage output of the sensor through an ADC pin for a range of pH of 6 to 8. If pH reading is outside of that range, the LED indicator of a poor pH will turn on (the LED indicator is connected to the microcontroller).
2. The pH sensor should be powered by 5V [6].
3. The temperature sensor must accurately measure the temperature of the water within ± 0.5 degrees Celsius, and it will output the temperature reading into the temperature register, which the microcontroller will read from. Based on this temperature reading, if the temperature is outside of 76 to 85 degrees Fahrenheit (around 24.4 degrees Celsius to 29.4 degrees Celsius is what would be read) our LED indicator for poor temperature for fish will turn on [14].
4. The temperature sensor should be powered by a range of 3.0V to 5.5V [14].
5. The water flow sensor must measure the flow rate within an accuracy of 3%. The water flow rate must be at a rate of 3—5x the total tank volume per hour [10].
6. The water flow sensor must take in a voltage of 4.5V to 5V [10].

2.3.3 Lighting Subsystem

1. The lighting subsystem will be used to provide artificial sunlight for the plants situated on top of the fish tank. The lighting subsystem will be made up of red and blue LEDs which are directly connected to the power subsystem. All of lighting will also be connected to an LED driver which will be using the microcontroller unit to create a lighting routine/schedule that mimics the daily patterns of the sun [3].
2. Due to the sensor value LEDs being updated every 10 seconds, the lighting pattern will also be updated every 10 seconds. Overall, the main requirement of the lighting subsystem is to be able to light up in a daily sequence and have LED values updating every 10 seconds [3].

2.3.4 Water Pump Subsystem

1. The water pump subsystem is used to circulate water between the fish tank and the plants located on top of the fish tank. The water pump will circulate water which will result in the tank volume being replaced at least 3-5 times per hour [5].
2. The water pump subsystem will also be connected to the power subsystem where a voltage of 6-18 V is needed by the pump depending on the water flow rate [5].
3. The pump should be operational for at least 24 hours without issue as well [5].

2.3.5 Power Subsystem

1. The circulation pump ranges from 6V to 18V and has a current rating of 65mA to 500mA. We will power 12V directly to the water pump and the LEDs [3].
    a. For 8 LEDs with 200mA each, we will be supplying a total of 1.6A for the LEDs. We will be using two colors of LEDs, Deep Red and Royal Blue. Our LEDs will be put in alternating order.
2. We will be using a 12V-5V buck converter through a regulator for all the sensors & servo motors [12].
    a. The water feeder servo uses 5V [7].
    b. The water temperature sensor's power is between 3.0V to 5.5V [14].
    c. The PH sensor also requires an input voltage of 5V [6].

   d. The water flow rate sensor requires an input voltage of at least 5V [10].
3. We will be using an LDO to step down from 5V to 3.3V for the microcontroller unit, either a STM32- or an ESP32-class IC, since it requires 3.3 volts [8] [11].
4. The circulation pump ranges from 6V to 18V. We will be using several LDOs and power regulators in the following way

2.3 Tolerance Analysis

1. Due to the presence of water in our system, we will need to ensure the mechanical design is robust and all electronics are well isolated from moisture. This includes sealed enclosures, proper cable routes and a clear separation between wet and dry zones.
2. We will need a DC-DC step down stage from 12V-5V to power most of the low voltage and logic electronics. We will be using a switching buck regulator IC that meets our voltage and current requirements. An example of an option is the TPS565242DRLR, which is capable of up to 5A output. We will have to be careful with the PCB layout [12].
3. We must also account for the power requirements of the 12V loads, specifically regarding the LED grow light array and the pump. For the LED array, each LED is driven at approximately 200mA. We plan to arrange the LEDs in series, with 3 Royal Blue and 5 Deep Red LEDs. Using the voltage forward of each LED, we get 3 * 3.08V = 9.23V for the Royal Blue string and 5*2.25V = 11.25V for the Deep Red string. We will most likely be using a constant-current LED driver to maintain stable current and brightness rather than powering directly to the 12V.

5. Conclusion

5.1 Ethical considerations

5.1.1 Societal Impact

Our project creates an impact in various aspects of society. With the rising costs of fresh fruit and vegetables in the country, aquaponics provides an alternative to families to grow fresh produce with limited space and nutrient costs. [2] On top of providing a way to grow plants that can sustain families, it also generates a source of protein in the fish located in the aquarium underneath. Using aquaponics promotes a clean-living system and addresses worldwide concerns of water pollution and plastic waste that is affecting wildlife in the ocean today. Aquaponics, specifically on the smaller scale like our project, directly brings nutrient rich food to climates that might not be naturally suitable for that kind of plant/animal growth [13].

5.1.2 IEEE Code of Ethics

As a group, we are committed to following the IEEE Code of Ethics and incorporating it into our project. We are going to uphold ethical professional conduct standards as we conduct our senior design project, especially the following from the IEEE Code of Ethics:

1. “To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest, and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others” [9]

   To uphold this ethical standard, our senior design group has various avenues for taking in honest feedback and using it to correct our errors. First off, our team is committed to peer-reviewing each others’ work. When one teammate designs something or writes up a draft, the remaining teammates read over the work so that we have multiple people verifying validity and accuracy. Furthermore, we regularly communicate with our assigned project TA, who provides us with detailed feedback on our writing and project progress. Again, this acts as a peer-review source that ensures that our project has accurate technical information. Alongside this, we are committed to properly crediting contributions and claims from external sources. We regularly cite all of our sources and ensure that we keep a running record of external sources used so that we can clearly identify where we are getting our information from.

2. “To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations” [9]

   To uphold this ethical standard, our senior design group is committed to improving and growing our technical skills and only conducting technical work if we have appropriate training or supervision. Before first entering the lab, all our team members completed lab safety training to ensure that we knew how to use lab materials safety. Furthermore, all members of our group have completed our soldering training, and we are committed to following lab safety guidelines while soldering our PCB. We will wear goggles, use the flux fan, and conduct ourselves with care so that nobody is harmed or injured. Before using any new tools or technologies we have not used before, we will reach out to our TA to ensure that we are appropriately trained to use them and know how to use them in safe ways.

3. “To treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression” [9]

   Our team is extremely committed to treating each other, and everyone around us, with respect and kindness. When we conduct our team meetings, we make sure every person’s voice is heard. We give each team member space to voice their opinions on decisions we are making, through asking for feedback from each member. At the end of our group meetings, we do a quick check-in to see how each member is feeling. If there are concerns or a teammate feels that they were overlooked, we talk about what changes can be made for next time and how we can improve our communication.

5.1.3 General Ethical & Safety Concerns

General ethical concerns for our project are the well-being of the fish in the fish tank located underneath. Due to the system not having an oxygen pump for the fish, we are relying on both the fish breed being resistant to low oxygen environments and using the falling water from the plant trough to create movement of the water on the surface to promote oxygen flow. Also, due to the nature of the project there is also potential for the fish to face harm from any electrical components not being sealed off from the water properly. Safety concerns regarding our project stem from the use of electronic components near a body of water. With any incorrect sealing, it could present a risk to both the fish inside the tank or anyone handling the tank to replace the water, checking the status LEDs, etc. Over time, any sealant may also degrade, so that is also a concern we are considering when building our project.

References

1. Aqueon. “Betta.” *Aqueon*, https://www.aqueon.com/resources/care-guides/betta. Accessed 13 Feb. 2026.

2. Beecher, Lance. “Introduction to Aquaponics.” *Land-Grant Press | Clemson University, South Carolina*, lgpress.clemson.edu/publication/introduction-to-aquaponics/.

3. Broadcom Limited. “ASMW-LL00-NKM0E.” *DigiKey*, www.digikey.com/en/products/detail/broadcom-limited/ASMW-LL00-NKM0E/9740413. Accessed 13 Feb. 2026.

4. COOLM. “12V 6A Power Supply Adapter - AC Adapter 100–240V 50–60HZ DC 12 Volt 6A 72W Power Converter Transformer Charger 6amp 5.5mm x 2.5mm DC Plug for LED Strips Lighting, Router CCTV Camera COOLM.” *Amazon*, www.amazon.com/12V-Power-Supply-Adapter-Transformer/dp/B07DMFN2YN. Accessed 13 Feb. 2026.

5. DFRobot. “FIT0563.” *DigiKey*, www.digikey.com/en/products/detail/dfrobot/FIT0563/8827828. Accessed 13 Feb. 2026.

6. DFRobot. “SEN0161.” *DigiKey*, www.digikey.com/en/products/detail/dfrobot/sen0161/6579368. Accessed 13 Feb. 2026.

7. DFRobot. “SER0006.” *DigiKey*, www.digikey.com/en/products/detail/dfrobot/SER0006/7597224. Accessed 13 Feb. 2026.

8. Espressif Systems. “ESP32-S3.” *DigiKey*, www.digikey.com/en/products/detail/espressif-systems/ESP32-S3/15822445. Accessed 13 Feb. 2026.

9. IEEE. (2020). *IEEE Code of Ethics | IEEE*. Ieee.org.

   https://www.ieee.org/about/corporate/governance/p7-8. Accessed 12 Feb 2026.

10. Seeed Technology Co., Ltd. “314150005.” *DigiKey*, www.digikey.com/en/products/detail/seeed-technology-co-ltd/314150005/5488047. Accessed 13 Feb. 2026.

11. STMicroelectronics. “STM32G431KBT6.” *DigiKey*, www.digikey.com/en/products/detail/stmicroelectronics/STM32G431KBT6/10231564. Accessed 13 Feb. 2026.

12. Texas Instruments. “TPS565242DRLR.” *DigiKey*, www.digikey.com/en/products/detail/texas-instruments/TPS565242DRLR/16585653. Accessed 13 Feb. 2026.

13. United Nations. "Aquaponics: Ancient Wisdom for New Food Production." *United Nations Western Europe*, 5 July 2021, unric.org/en/aquaponics-ancient-wisdom-for-new-food-production/.

14. "Waterproof 1-Wire DS18B20 Digital Temperature Sensor." *Adafruit*, www.adafruit.com/product/381. Accessed 13 Feb. 2026.