Aquaponics Smart Automation and Monitoring Control System – SMARTBAY

A Design Project Proposal presented to the School of Engineering

Asia Pacific College

In Partial Fulfillment of the

Requirements for the Degree of

Bachelor of Science in Computer Engineering

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ADVISER'S RECOMMENDATION SHEET

The design project entitled

SMARTBAY

Aquaponics Smart Automation and Monitoring Control System

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APPROVAL SHEET

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and submitted in partial fulfillment of the requirements of the Bachelor of Science in Computer Engineering degree, has been examined and recommended for acceptance and approval.

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As oral examination panel members, we certify that the project prototype and this paper has been examined and hereby recommend to be accepted as fulfillment of the design project requirement for the Degree Bachelor of Science in Computer Engineering.

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This design project proposal is hereby approved and accepted by the School of Engineering as partial fulfillment of the requirement for the degree of Bachelor of Science in Computer Engineering.

Sergio R. Peruda, Jr.
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DEDICATION

The researchers express their deep gratitude and heartfelt sincerity as they dedicate this thesis to the various pillars of their journey.

The researchers attribute their inspiration to their target market, particularly the dedicated farmers, aqua culturists, and agriculturists who support environmental sustainability, recognizing their unwavering commitment to nurturing the Earth's resources.

The researchers extend their tribute to their parents, whose steadfast and tireless support has consistently provided them with strength, acknowledging their love and sacrifices through this thesis.

The researchers recognize their skilled project adviser, whose solid commitment to helping them navigate every challenge and difficult moment has been a wellspring of inspiration. Throughout this endeavor, their adviser's wisdom and patience have illuminated their path.

The researchers extend their honor and gratitude to their cherished institution, Asia Pacific College, and its School of Engineering, for granting them the opportunity to work on the project and be a part of its enduring legacy.

The researchers deeply appreciate their subject instructor, whose reminders to carry out necessary tasks have served as their guiding compass throughout this academic journey.

The researchers' determination is signified by this thesis as it serves to fulfill the prerequisites for future internships and graduation, propelling them one step closer to their dreams.

Above all else, the researchers dedicate their achievements to Almighty God, acknowledging that his guiding presence has been their light in times of darkness, and they humbly recognize His hand in their accomplishments.

With profound appreciation, the researchers dedicate this thesis to everyone who has contributed to their success, acknowledging that their journey would have been entirely different without the support, guidance, and unwavering faith in their abilities.

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ABSTRACT

In the absence of Aquaponics, the food system would encounter heightened challenges, struggling to meet the demands of a growing global population while contending with resource limitations and environmental concerns. Aquaponics emerges as a pivotal innovation, providing a sustainable solution by efficiently utilizing fish waste to nourish plants and purify water. This significantly boosts food production while minimizing environmental impact and resource usage, thus playing a crucial role in securing the future food supply. The primary obstacle to the improper implementation of Aquaponics is the reliance on manual water parameter maintenance, a labor-intensive, error-prone, and logistically inconvenient process for effective and scalable operation. However, this study introduces a futuristic element to farming, as it takes control of pH levels, temperature, and water levels using intelligent sensors within the system to ensure the thriving of fish and plants. What adds to the excitement is the ability to observe this digital farming process through the Grafana Interface on the RasPad 3, making sustainable agriculture an engaging and visually captivating experience. Following extensive trials and tests, this system has demonstrated its Accuracy, Responsiveness, and Reliability performance. Furthermore, the study provides valuable recommendations and sensible explanations for any discrepancies that emerged in the data, making it a compelling resource for those seeking a better understanding of its performance. Considering all the information presented, this system has shown clear benefits for the intended audience, particularly for farmers aiming to implement Aquaponics to promote sustainability and environmental responsibility.

EXECUTIVE SUMMARY

An Aquaponics Smart Automation and Monitoring Control System – SMARTBAY is an integrated technology solution designed to oversee and regulate key aspects of an aquaponics system, particularly focusing on water parameters corresponding to pH, temperature, turbidity, and water level. It utilizes sensors, actuators, and automated processes to continuously monitor and adjust these parameters, ensuring optimal conditions for plant growth and fish health while minimizing manual intervention.

In giving a picture on how it functions effectively, the process operates as follows: Sensors collect data, an Arduino acquires and processes it with the assistance of Geany software, this data is then stored in phpMyAdmin or SQLite databases, and finally, Grafana retrieves this data to produce visual representations or graphs, making it easier to comprehend.

It stands as a promising solution for sustainable agriculture, benefiting farmers, governments, communities, and researchers with its potential to enhance food security, reduce environmental impact, and foster innovation.

This system is perfect for locations with limited access to arable land or water resources, making it a versatile and sustainable solution for food production in various settings.

The study's findings highlight a significant vulnerability in the system, as the RasPad device used to transmit and store data is susceptibility to lag, hang, or data interruptions leading to poor reliability and reliability ratings. However, one of its strengths lies in Responsiveness, apart from automation. Consequently, the proponents recommend exploring alternative devices that can better withstand the said issue or concern.

SMARTBAY's sensors are responsive in collecting the water parameter making the system highly effective in maintaining the desired parameters. However, the system's reliability rating is low due to limited resource supply particularly the pH solutions and water. The system still lacks other automation within the system and is still required for manual intervention when such resources are reduced. Regarding the reliability of the system, the system is not fully reliable due to the raspad occasionally halts or freezes that leads to data loss. Even though its accuracy and reliability run in some aspects, it falls short to its reliability which affects its ability to continuously monitor and control the parameters.

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Chapter 1

THE PROBLEM AND ITS BACKGROUND

1.1 Introduction

Aquaponics can contain issues in maintaining and sustaining the whole cycle of plants and marine life in it. The common problem in maintaining the quality of aquaponics is the lack of circulation, poor quality of water, unbalanced or insufficient lighting, pests, and disease issues. Because of these problems, it decreases the longevity of the system.

For two decades, the fame of Aquaponics has increased which in time improved the way of systemizing and determining the best way to cultivate aquatic and cultivation of plants at the same time. Aquaponics is a combination of Aquaculture (The Farming of Aquatic Organisms) and Hydroponic farming (The Cultivation of Plants) which can use technology sensors and actuators to determine the quality and effectiveness in monitoring, automation, and alike [1]. The involvement of using Smart Automation Systems and IoT (Internet of Things) in Aquaponics reduces human labor and improves monitoring systems, the quality of plants and aquatic animals, and sustainability. [2]

In creating Smart Aquaponics, it can utilize IoT to grant systems and machines the ability to communicate wirelessly by sending data to the IoT Server of the Aquaponics. With the help of IoT, it can send the measured pH level of the water, the measured height of the water, the turbidity level of the system, temperature of the water. In addition, using IoT can be freely accessed anywhere and anytime without human intervention using just your phone, laptop, and PC [3].

When Covid-19 was reported by the World Health Organization (WHO) on December 31, 2019. The World came to a halt, declaring that people should always stay at home. Many of them are not lucky/incapable of maintaining financial stability during and after the pandemic. With the increase in cases of Covid-19 starting from April – May of 2023, the DOH (Department of Health) explained how there is a chance that there will be a level 1 protocol and that everyone will go through an online set-up once again [4]. Urban Aquaponics during covid-19 and post-covid-19 can be helpful to farmers and people. Dr. Rayos explained that the pandemic has caused major issues that decline the global supply chain, and it affects the food system. With the help of Urban

Aquaponics, it can form a new approach to food production that farmers and even people can create. Aquaponics uses less water than conventional agriculture and the production of plants can be set up and help grow faster due to the fish waste as there is no need for fertilizing the plants [5].

1.2 Statement of the Problem

Before creating an automated aquaponics control system, maintaining it manually was difficult for people/personnels to do. In a normal aquaponics system, personnels requires the need to constantly check the system with regards to the water quality parameters (pH Level, Temperature, Turbidity, Water Level etc.) that uses different instrument to measure each parameter as well as its production of plants and aquatic animals. The need for checking was necessary to know if the system has any downside structure which can affect the production and water parameter of the system itself. Personnels are required to inspect and examine the aquaponics system regularly to determine if there are any problems that occurred within the system itself. Implementing/Improving an aquaponics system can be complex because of its components and requirements needed for automation especially the costs. Even though aquaponics is a sustainable and a natural method to grow species of plants and aquatic animals that allow people/personnels to cultivate, it needs to be improved because of its inefficiency to lessen workload to the technology we can use today to reduce manpower in maintaining the system.

SMARTBAY's recognizes the limitations of manual maintenance in traditional aquaponics systems, emphasizing the need for automation to reduce manpower and improve efficiency. Unlike AquaRam's, SMARTBAY's goes beyond addressing water quality parameters by identifying and rectifying the flaws in the design and structure of the aquaponics system. It highlights the drawbacks of using low-grade sensors and actuators, providing a detailed account of the vulnerabilities in the previous aquaponics group's system. The incorporation of industrial-grade sensors and actuators in SMARTBAY's is proposed as a solution, promising enhanced reliability, and quality. Furthermore, the redesign of the filtering system is suggested to lessen human labor and extend maintenance intervals. In contrast, AquaRam's primarily focuses on the declining production of specific fish species without delving into the structural and design issues that can impact the overall system's functionality. While both theses recognize the importance of automation, SMARTBAY's stands out for its comprehensive analysis, proposing solutions to not only monitor but also improve the overall reliability and efficiency of the aquaponics system.

In addition, the use of low-grade sensors and actuators can hinder the sustainability of Smart Aquaponics, the Filtering Systems which affects the quality of water circling through the whole Aquaponics, and the design of the System itself. This is based on the previous aquaponics group of CPE191 headed by Ms. Laureta and ECE191 headed by Mr. Reyes. Based on their weaknesses in Chapter 5, because of the minimal handiwork of design and structure of their chassis, the Arduino, power supply, and wirings of the sensors and actuators in the aquaponics inhibits formality and systemization. All the sensors are exposed for malfunctions/errors due to poor structural design. The turbidity sensor keeps getting wet inside its PCB/Chassis and is susceptible to circuit damage. The ultrasonic sensor (HC-SR04) keeps getting wet and because of this, there is a change in the values affecting the water level of the system. Lastly, the sensors should not be touched because it will execute the following actuator and the readings may be disrupted.

With the use of industrial-grade sensors and actuators, it can further improve the quality and reliability of sensors and actuators in Aquaponics. Re-designing the Filtering System will help improve the filtration system which in time lessens human labor and has longer days/weeks for the succeeding maintenance. The whole Smart Aquaponics Systems contains a physical monitoring system that is attached to the chassis of the sensors and actuators that can also be seen physically.

1.3 Objectives of the Study

1.3.1 General Objective

This project aims to develop and implement an advance aquaponics system that combines automation, monitoring, and web-based interface that will control and monitor the water quality parameters of the system to improve the production of Nile Tilapia and various plants including parsley, lettuce, red chili, and water spinach and maintain the water parameter.

1.3.2 Specific Objectives

1. To design an accurate system in acquiring the following data parameters in the aquaponics systems:

    I. pH Level

    II. Water Temperature

III. Turbidity Level

IV. Water Level

2. To develop a reliable system that control and monitor the water parameter, automated pH level up and down, temperature change and water level control gates.
3. To develop a responsive system that will store the data into the database in real-time.

1.3.3 Constraints

1. The Smart Aquaponics System should maintain and regulate the water parameters automatically.
2. The Smart Aquaponics System should use an industrial grade sensor.
3. The Smart Aquaponics System must be automated and should have less maintenance periods.
4. The Sensor Modules, wires or cables, actuator, display must not yield any electrical hazard according to ANSI/ISA S82.01:1994ts.

1.3.4 Metrics Description and Scale Measurement

Table 1.1. Metrics Description and Scale Measurement

OBJECTIVES	DEFINITIONS	METRICS	DESCRIPTION	SCALE
Accuracy	Capability of the system to measure pH of the water	This is determined by getting the percentage error between the standard pH meter values and the outputs of the pH sensor used in the aquaponic system.	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and below
	Capability of the system to measure temperature of the water	This is determined by getting the percentage error between the measured water temperature sensor values and the outputs of the	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%

		water temperature sensor used in the aquaponic system.	Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and below
	Capability of the system to measure turbidity of the water	This is determined by getting the percentage error between the standard turbidity meter values and the outputs of the turbidity sensor used in the aquaponic system.	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and below
	Capability of the system to precisely measure the distance of the water level	This can be determined by taking the relative difference between the distance tested and the measured distance of the water level.	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and below
Responsiveness	Ability of the system to process incoming data from the sensor into the database.	This can be determined by dividing the mean change by the standard deviation of the change.	High Responsiveness	<2 Seconds
			Moderate Responsiveness	3-4 Seconds
			Low Responsiveness	5 Seconds
Reliability	Ability of the system to maintain certain threshold of the water parameter. Water Parameters:	This can be determined by taking the number of correct maintaining over	Excellent	99.00% and above
			Very Good	95.00% - 98.99%

	pH: (pH 5.5 – pH 7.0) Temperature: (27 °C – 31 °C) Water Level: (23cm below)	the total number of maintaining trials.	Good	90.00% - 94.99%
			Fair	85.00% - 89.99%
			Poor	84.99% and below
	Ability of the system to collect and store data to the database from the sensor that measures pH, temperature, water level, and turbidity level.	This can be determined by taking the number of hours of down (system outage) and up (system running) time.	Excellent	0.00% - 5.00%
			Very Good	5.01% - 10.00%
			Good	10.01% -15.00%
			Fair	15.01% - 20.00%
			Poor	20.01% and below

The metrics in the given **Table 1.1** will be relied on by the researchers to evaluate how effectively the system meets the objectives. The following sections cover approaches to measure Accuracy, Reliability, and Responsiveness.

Accuracy of the Sensors

This implies the proximity of the sensor values to the measured values. The accuracy can be computed by getting the percentage error and excluding it from 100%. The provided equation below will be applied to calculate the error rate, where the sensor value is the value observed, and the measured value is the precise value. It will be classified as excellent, and so on too poor, depending on the ideal values for that sensor. This is to compute for the Accuracy of each sensor to measure the water quality parameter. The Accuracy is computed through the formula below where:

$$Percentage\ Error = \left(\frac{Measured\ Value\ of\ Sensor - Tester\ value}{Tester\ Value}\right) \qquad \textbf{Eq. 1.1}$$

$$Accuracy = \left(\frac{overall\ percentage\ error}{number\ of\ tested\ trials}\right) \times 100 \qquad \textbf{Eq. 1.2}$$

Equation 1.1 will be used to compute for the percentage error rate of sensors that will have distinct number of test procedures. It will need the measured value of the sensor minus the tester instrument value gather in the same procedure over the tester value again of the instrument parameter. Both measured value and tester value will simultaneously be collected and pair each other in finding the percentage error. While **Equation 1.2** will be used to get the summation of the overall percentage error of each water quality parameter over the number of tested trials per water quality parameter. The value will then be multiplied by 100 to output the Responsiveness Rate. And each water quality parameter will have a different number of tested trials.

Reliability of Control Gates

To have the reliability of the system the formula below will explain on how to calculate the reliability of each water quality parameter to the threshold values to have a consistent controlled system. The database stored to know the data maintained within the threshold.

$$Consistency = \frac{number\ of\ data\ within\ the\ threshold}{total\ no.of\ data\ in\ database} \times 100 \qquad \textbf{Eq. 1.3}$$

Equation 1.3 will be used to determine the reliability success rate of the control gates. It will measure the amount of data within the threshold of each water quality parameter over the total amount of data in the database. The value will then be multiplied by 100 to out the success rate of the control gate. The data will only be direct to the stored data that was sent to the database in 1 month and each water quality parameter has its own maintained threshold. Each water quality parameter will be transmitted every 1 minute to be stored in the database.

Reliability of the System to Monitor

To have the success rate of the system, the reliability of the system should monitor and maintain the water parameters without sudden freeze, hardware error, or system failure. In computing Reliability Success Rate, we will compute the formula before where:

$$Reliability = \left(\frac{number\ of\ data\ collected}{total\ no.of\ data\ in\ 1\ month}\right) \times 100 \qquad \textbf{Eq. 1.4}$$

Equation 1.4 is used to determine the reliability of controlling and monitoring the water quality parameter of the system and it will be measured by collecting the number of stored data over the total number of data gather in 1 month of testing and multiplying it to 100. The number of data collected is the amount of data information that was transmitted without any failures going to the database while the total amount of data in 1 month is the overall transmitted data per minute.

Responsiveness of Storing Data

The data will be gathered using Excels Feature: Sorting Function where each amount of data per trial will be gathered and will be calculated by the Average Function to collect the overall responsiveness average.

$$Responsive\ Total\ Average = \frac{Sum\ of\ Values}{Total\ Number\ of\ Values} \quad \textbf{Eq 1.5}$$

1.4 Significance of the Study

1.4.1 To Farmers/Aqua culturist/Agriculturist

The project will greatly help farmers reduce human labor in maintaining a farm since it is a system capable of handling two farms at once and these are: Aquaculture and Agriculture. This system also helps lower the demands of plants and aquatic animals since it is the system production. Since the system is self-regulating, the maintenance of the system is reduced.

1.4.2 To the Government

This project can greatly help the local government, mainly the Department of Agriculture since this project can be implemented for future purposes. It can be used as a reference in proving the current system which the government has for farming. Since the system can produce products in any place, this can be implemented in commercial areas.

1.4.3 To the Community

This project can be a useful service to the consumer since the products that have been raised in aquaponic system are organically raised, which means it doesn't contain any chemicals.

1.4.4 To the Environment

This project is environmentally friendly since the material that has been implemented is a non-polluting product and it has less usage of water since it recycles the water. The water used in the system can be safely disposed of since it contains no chemicals.

1.4.5 To Future Researchers

This project will give the future researcher the idea when they want to implement this kind of project. In addition, this will serve as a guide for those who want to enter and improve in the same subject.

1.5 Scope and Delimitations

1.5.1 Scope

This study focuses on improving the automated aquaponics system to reduce manual labor, maintain, and monitor the water quality parameter.

- In this scope, the aquatic animal that will be included in the Smart Aquaponics System is the Nile Tilapia (*Oreochromis Niloticus).*
- There will be a new set of plants that will be used in the Smart Aquaponic Systems, and these are the following:
    - Lettuce (Lactuca Sativa)
    - Spinach (Spinacia oleracea)
    - Parsley (Anthriscus cerefolium)
    - Red Chili (Capsicum annuum)
- A microcontroller will be used as the main controller for the sensors and actuators.
- The project will use a database that will act as the storage in collecting sensor values and graphs.
- The previous IBC (Intermediate Bulk Container) will still be used as the main container for the aquatic animals and plants.
- There will be a re-modeling and re-designing of the newly improved filtering system that will be implemented.
- A microprocessor will be used as the main component in transmitting the values of the sensors in the Smart Aquaponics System.
- An open-source analytics and interactive visualization web application will be used as the main graphical interface for the Smart Aquaponics System.
- For wireless connectivity, control, and monitoring, a graphical desktop sharing system will be used to control the microprocessor display.

1.5.2 Delimitations

- The system will need an Internet Connection/Cellular to wirelessly monitor and regulate the water quality parameters.
- The system will need an electrical power to work.

1.6 Conceptual Framework

INPUT		PROCESS		OUTPUT
Fish: Nile Tilapia **Planted Seeds:** Parsley, Lettuce, Red Chili, and Water Spinach **Water quality:** pH level Water Temperature Turbidity level Water Level	➡	-Transmit sensor values to the database -Perform data analysis -transmit data from database to the web interface -Adjust water quality and water parameters	➡	**Harvested Plants:** Parsley, Lettuce, Red Chili, and Water Spinach Smart System design Grafana Web interface Visual Module/Display Growth response of Consumables Plant and fish harvesting

Figure 1.1 Conceptual Framework

The system will have three primary inputs: First, the fish which are the Nile Tilapia. Second, the planted seeds are Parsley, Lettuce, Red Chili, and Water Spinach. And third, the water quality parameters namely pH level, water turbidity, water temperature, and water level. The system will be composed of an aquaponics tank that contains the fish and a floating raft that holds the plants. An installed monitor for real time visual assistance of water parameters and web application will be installed for viewing sensor value reports using charts and graphs. The system will have four main processes: *transmission of sensor values to the database, analysis of the values, transmit data from database to the web interface, and the adjustment in the water quality.* For the transmission of sensor values, the Temperature sensor, pH meter, turbidity sensor, and ultrasonic sensor will be utilized through the microcontroller Arduino Mega 2560. The values of each sensor will be sent through the VNC Viewer and will display the values of the water parameters in the system using the Raspberry Pi inside the **Raspad 3** (Touch Panel for the System/Computer). For the data analysis process, the system will compare the values set as constant by the user, and the values measured by the sensors. The third process is to transmit the data from the database to the graphical web interface of the system, this is to display the stored data to make it easier to see for the user using charts and graphs. Lastly for the fourth process which is the adjustment of the water quality level to satisfy the threshold values. The expected output of this system will be a SMART aquaponics design, a responsive web interface and the growth response of the fishes and plants.

1.7 Definition of Terms

Actuators – A device used to receive and output a signal that is coming from a physical environment.

Automation – A type of technique where a process or apparatus is made to operate itself reducing the presence of human labor in doing a certain task.

Aquaponics – Type of aquatic system that is designed to grow plants and aquatic animals in presence/absence of a person in monitoring and maintaining the system.

Arduino 2560 – A microcontroller that is the central processing unit of a system. This serves as the system's main processing unit and oversees data processing and transferring data. This can be used to control the pH level and water temperature.

BNC Interface – Used to quick connect/disconnect connector that is used in connecting the pH sensor probe.

Hydroponics – A method of agriculture that is designed used to grow plants using water based nutrient solutions rather than the conventional soil material. It uses rocks instead of soil; in aquaponics, rocks are utilized as substation for dirt.

pH Level – The measure of how acidic/basic a liquid or a mixture is. The DFRobot Gravity: Analog pH Sensor is responsible for gathering data about the present data about the pH level of the system, after the data has been given, it is sent to the Arduino Mega 2560 for processing and displaying the data over the RasPad and to the website.

Turbidity – The Analog Turbidity Sensor Module is the measure of how relative the clarity of a liquid is. It is responsible for gathering the data on how clean or dirty the water parameters are, the data will be given to the Arduino Mega 2560 for data processing and displaying it to the RasPad and website.

Raspberry Pi – A credit-card sized computer that acts as user interface for an automated system. For the system, RasPad is used to have a display/monitor for the system to oversee the data values for the sensors in the system. It offers real-time data information that is gleaned from a database.

VNC Server Viewer – A remote access program used to access a Raspberry Pi. This can be remotely accessing a certain PC/Laptop using the same IP address for your internet to have a wireless connection.

Sensors – Are components used to gather real-time data from different aspects/environment that provide information about the aquaponic system. The following data values that the sensor will display/give are pH level, turbidity, temperature, and water level.

Rotary Actuators – Relates to the pumps used in the system to flow the water across to the whole system. This generates a circulation across the different parts of the system especially to the filtration to dirt, excreted matter of fished, debris, etc.

Arduino Sensor Shield – An addition component used to conveniently add additional digital and analog I/O ports for sensors and actuators used for the system.

Ultrasonic Sensor (HC-SR04) -A type of sensor that is responsible for gathering data about the water level of the aquaponics. The data is then sent to the Arduino Mega 2560 for processing.

Relay Module (5V/12V) – It functions as a switch electrical devices and systems turning it on or off. In the system, relay modules are used to turn on or off a certain sensors/actuator depending on the amount of data values that is needed to maintain a certain degree.

Power Supply (5V/12V) – An electrical component that serves as a power source for several different electrical components; in aquaponics, the 5 V power supply is for connects to the Arduino that is connected to the sensors and actuators while the 12 V power supply is connected to the Solar Panel, and Water Pumps.

Web Application – An application software used as a web interface for displaying information about certain aspect about the aquaponics system.

PhpMyAdmin – is a free and open-source web-based application written in PHP that provides a graphical user interface (GUI) for managing and administering MySQL and MariaDB databases. It allows users to perform tasks such as database creation, table management, SQL query execution, and user management through a web browser interface.

Grafana - is an open-source data visualization and monitoring platform commonly used for creating interactive and customizable dashboards. It allows users to connect to various data sources, visualize data in real-time, and gain insights through graphs, charts, and alerts.

CHAPTER 2
REVIEW OF RELATED LITERATURES AND STUDIES

2.1 Local Literature

2.1.1 Smart Farming in the Philippines [1]

In an aquaponic system, water circulates to the system in which two farms are benefiting to it. hydroponic (growing plants in a water) and aquaculture (raising aquatic species). The symbiotic relationship in which the aquatic species produces by products that are nutrients for the plants while the plants filter out the water making it safe for the fish.

Parts of aquaponic are implemented from the automation.

Container for the fish

Can be any container that can be used to keep the fish mainly can be a fish tank or a plastic barrel. Depending on the plan on which how many fish plan to culture depends on the size of the container in which the fishes will be keep and maintained.

Air pump

It is necessary to supply oxygen to the fish and to keep the pH maintain because a lack of oxygen in the water can lead to a decrease of pH in which it may lead to mortality to both fishes and plants.

Mechanical filter

The function of this is to remove solid waste and food remains coming from the fish tank and to avoid any by product that may cause issue in the hydroponic farm.

Biofilter

This functions as a house for the bacteria that is responsible for the conversion of minerals into a nutrient for the plants.

Water pump

This functions as the connector to the farms in which it makes the water circulate through the filters onto the plants.

Hydroponic beds

This functions as the tank for the plant in which it will serve as a grow bed. Naturally it can be a plastic container enough to hold the bedding for the plant and water it.

2.1.2 Lettuce Cultivation in the Philippines

Lettuce (Lactuca sativa) is an annual plant in the Asteraceae family that is a valuable commercial crop. It typically reaches a height of 30 cm and is grown primarily for its leafy greens. Depending on the variety, lettuce can be any number of colors, including green, red, variegated, and even yellow or gold. On the ground or on a short stem, the plant grows a rosette of leaves. The number of leaves grows as the plant ages.

Lettuce is one of the vegetables most used in aquaponics because of its low requirement to grow in an environment in which setup the aquaponic can provide for it. Lettuce requires a pH of around 6.5 to 7 for proper development. The ideal temperature ranges from 15°C to 18°C. Head types need cooler temperatures between 10°C and 18°C; temperatures above 21°C. High temperatures can also cause tip burning. Furthermore, lettuce can thrive in environments with a relative humidity of 65 to 85%.

2.1.3 Water Spinach Cultivation in the Philippines [3][4]

Kangkong, also referred to as water spinach, is a leafy vegetable that thrives in wet areas like marshes and swamps. Scientifically speaking, it is known as Ipomoea aquatica and is a member of the morning glory plant family. Kangkong has long, hollow stems with dark green, arrow-shaped leaves. While its leaves float on top of the water's surface, its roots grow underwater. It can absorb nutrients from both water and air thanks to its distinctive growth pattern.

Water spinach is one of the vegetables that has a requirement that the aquaponic can provide. With the need of pH around 6.0 to 7.0 and an ideal temperature around 20°C to 30°C so that it can properly grow.

2.1.4 Tilapia Industry Production [7]

With a total production of 281,111 metric tons in 2021, tilapia was the Philippines' second most important cultured species. This was an increase from 2020, when total production was 263,871 metric tons, accounting for 20% of total aquaculture production in the country. With

136,218 metric tons, Central Luzon was the leading region in tilapia production. The most common species, the Nile tilapia, also known as gray tilapia, is bred in government and private hatcheries. It can survive in brackish water with salinities as high as 25 parts per thousand.

Due to its widespread acceptance and suitability for mass production in both backyard and commercial settings, plays an important role in ensuring food security in the Philippines.

2.2 Foreign Literature

2.2.1 Water Monitoring System of Aquaponic [6]

Aquaponics has received growing concern in modern times, and this reinforces its increasing impact on society as an innovative response to food security. Advancement of technology helps to provide monitorization to ensure that the byproduct produced by the farm is healthy for commercial uses. The time needed for maintaining a system of aquaponic is time consuming for it has many parameters needed to secure for its by product to be maintained clean and healthy. Parameters like the water quality needed for it to sustain the plants and fish to be able grow. Conditions like the pH level and water temperature are observed to ensure that the growth of the fishes and plants are maintained. To monitor such quality technologies like sensors and actuators are used in an aquaponic system.

Things use to monitor water quality:

pH sensor

pH sensor is commonly used for water quality monitoring. This type of sensor is capable of measuring alkalinity and acidity in water.

Temperature sensor [8][17]

Temperature sensors are vital in water quality because of how they can affect the measurement of different parameters. For example, water levels can be different based on the temperature because of the expansion of water molecules. Another example is to maintain the water temperature in which can be suitable for the fish like Nile tilapia requires a 27°C to 31°C temperature.

Turbidity sensor [9]

Turbidity sensor is used to measure how clear the water is. It uses the photosensor that interacts with the water to measure the scattered light across a certain field.

Grafana

Grafana graphical web interface is an open-source software that enables graphical and chart display and alert on that explores different metrics, logs, and traces wherever they are stored. It provides time-series database which help for monitoring.

Figure 2.1 Grafana Interface

PhpMyAdmin

PhpMyAdmin is a free software tool that intends to handle administration in creating a database, running queries, and adding user accounts. It can create, browse, edit, and drop database which can have maintenance server, database, and tables and proposal on server configuration.

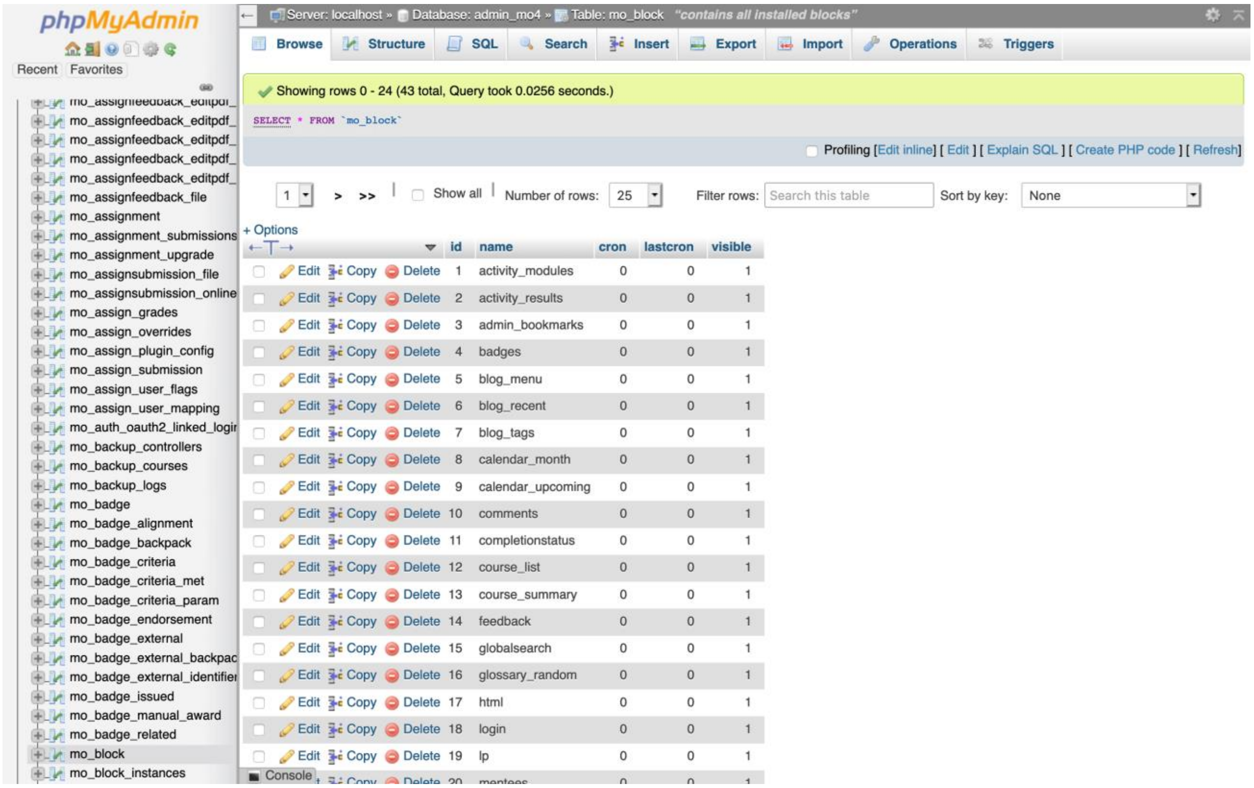


Figure 2.2 PhpMyAdmin Database

Geany

Geany is a small and lightweight Integrated Development Environment which is a small and can be a fast IDE which contains few dependencies for other packages. Its feature are supports multiple filetypes including C, Java, PHP, HTML, Python and etc. It can build a system that can compile and execute your code and can be a plugin interface.

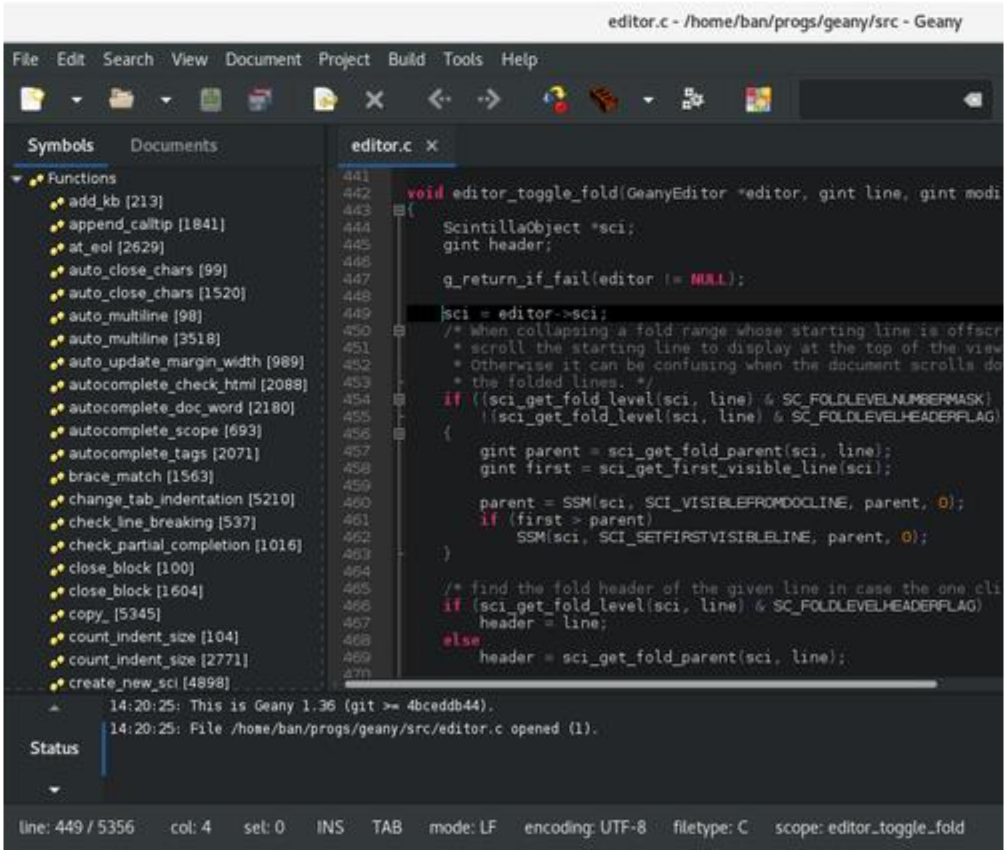


Figure 2.3 Geany Interface

2.2.2 Hydroponic Sub-System in an Aquaponic System [16]

In Aquaponic systems there are two farms that the system handles which are hydroponic and aquaculture. In the hydroponic system, this is where the plant is being cultivated but to have a more efficient in terms of the suitability of the plant on the environment. There are three different sub systems to use for hydroponic which are gravel, floating, and nutrient film technique. This sub system is used for the cultivation of plants in hydroponic.

The use of gravel in a hydroponic has no difference when using floating as a cultivation system but the cost for using floating is a lot more expensive than using gravel because of the material added in using for the hydroponic. The nutrient film technique is the least one of because it is less efficient in terms of nitrate removal that may cause problem for the fishes.

2.2.3 Aquaculture Management Practice

Most of the farm this day relies mostly in using processed feeds and bioactive compounds like hormones and antibiotics for the product like fishes and plants to grow but using this type of method of cultivation is not health for the human consumption. The practice in managing aquaculture is to be as natural as possible therefore the synergy between hydroponic and aquaculture is applied in cultivating a resource. In releasing traces of chemical, the plants act like a biofilter removing nitrate that may cause harm for the fishes if the chemical builds up in the system. In addition, gravel further increases the removal of the chemical.

It is still possible for the system to be contaminated when the fishes produce waste than the plant can intake or a sudden outside disturbance. When it happens, the automation will handle the changes until the system can balance its chemical value to its normal state.

2.3 Local Study

2.3.1 Sustainable Aquaponics with Solar-Powered IoT Monitoring [10]

The agriculture sector plays a vital role in our economy, yet it faces challenges due to industrialization and climate change, leading to reduced productivity and food shortages. To address these issues, innovative farming approaches are being introduced to help farmers adapt and cope. Aquaponics, a sustainable food production method, has been explored extensively, but few integrate renewable energy sources. This research delves into a system powered by solar energy and equipped with IoT-based monitoring capabilities, offering a sustainable method for agriculture. It has the potential to elevate agricultural productivity, strengthen food security, stimulate entrepreneurial prospects, and combat the harmful effects of climate change. The study involves an intriguing comparison between this solar-powered aquaponics system and an existing aquaponics investigation conducted at De La Salle University (DLSU). Impressively, the system demonstrated an outstanding 60.89% growth rate in lettuce within just one week of monitoring, surpassing the performance of the traditional method. Furthermore, the findings underscore the importance of maintaining adequate light exposure and emphasize the critical role of pH level monitoring in facilitating the growth of both lettuce and tilapia. This innovative approach provides a promising pathway to address the issues affecting the agriculture sector while simultaneously promoting sustainability and resilience in response to a changing climate.

2.3.2 Enhancing Vertical Farming with Automated Aquaponics Monitoring [11]

Aquaponics merges plant and fish cultivation in a single system, relying on the symbiotic connection between fish and bacteria. To ensure the thriving of fish, maintaining good water quality is crucial. Unfortunately, in current Philippine aquaponic setups, water quality isn't adequately supervised, leading to adverse effects on fish growth. This study introduces a device designed to automatically oversee and regulate water quality parameters within aquaponics systems, especially in vertical farming applications. The device aligns with ideal parameters essential for tilapia growth, including ammonia levels, dissolved oxygen, pH levels, temperature, and turbidity. Whenever any of these parameters deviates from the ideal range, the device responds accordingly, ensuring optimal conditions. Rigorous testing confirms the device's precision, with pH and temperature sensors boasting Responsiveness rates of 98.42% and 97.07%, respectively, ultimately offering reliable automated monitoring for enhanced vertical farming practices.

2.3.3 Automating Aquaponics Farming with Android-Based Monitoring [12]

The researcher aims to address a significant challenge in modern farming. Traditionally, farmers have relied on separate methods, involving soil, water, plants, and fish, to cultivate their produce. However, in recent years, the innovative practice of aquaponics has emerged, integrating aquaculture and hydroponics. This integration not only enhances the growth of plants but also incorporates advanced monitoring through an Android application. The application utilizes three essential sensors to collect essential data, measuring parameters such as temperature, turbidity, and pH levels. Moreover, to automate the feeding of fish, a servo motor is employed. The research followed a structured approach, employing a waterfall model and surveys to evaluate the study's effectiveness, dependability, and ease of use.

In essence, the researcher's objective is to streamline and enhance the aquaponics farming process by harnessing the power of Android-based monitoring. By integrating aquaculture, hydroponics, and sophisticated monitoring techniques, this research strives to offer farmers a more efficient and sustainable method for growing their crops and raising fish. The Android application and sensor-driven system provide valuable insights into the environment, fostering better decision-making and optimization of resources. In summary, this paper strives to bridge the gap between traditional farming and advanced technology, bringing the benefits of automation and monitoring to the world of aquaponics.

2.4 Foreign Study

2.4.1 Aquaponics Automated Water Monitoring and Alerts [13]

This paper addresses the challenge of efficiently monitoring water in aquaponics systems by introducing an innovative solution powered by an Arduino microcontroller. To tackle this issue, the authors utilize the Arduino Development Environment (IDE) software to create a program that facilitates communication between the microcontroller and an array of essential sensors and hardware components.

This system comprises pH and temperature sensors, a water sensor, a servo, a liquid crystal display (LCD), a peristaltic pump, solar panels, and a Global System for Mobile communication (GSM) module. By harnessing renewable solar energy and a rechargeable battery, this setup ensures consistent monitoring. When critical parameters like pH, temperature, or water levels deviate from their specified ranges, it promptly sends GSM alerts to mobile devices. Additionally, the system autonomously activates the peristaltic pump to restore pH balance, strategically positions water sensors to track water flow, and employs a servo mechanism for timely fish feeding while displaying real-time data on the LCD, ensuring that water conditions remain within the predefined parameters of pH 6 to 7 and a temperature range of 25°C to 30°C.

2.4.2 Aquaponics IoT-Enabled Wireless Sensor Monitoring [14]

In the realm of agriculture, aquaponics has emerged as a sophisticated method that merges fish and vegetable cultivation with precision. However, it comes with its set of technical challenges. The researcher focuses on resolving these issues by introducing a technical solution that employs wireless sensors and a communication network, accompanied by a user-friendly GUI application named AWSM. This innovative approach empowers farmers with real-time water quality alerts and recommendations, enabling them to monitor their aquaponics systems remotely. The implementation of the AWSM-based IoT application has demonstrated significant enhancements over traditional methods, making aquaponics farming more efficient and effective, bridging the gap between modern technology and sustainable agriculture.

2.4.3 Assessing Urban Aquaponics Sustainability through Energy Synthesis [15]

Aquaponics combines aquaculture and hydroponics to create a sustainable food production system, particularly beneficial for urban areas with limited land and water resources. This study, using energy synthesis, assesses the sustainability of urban aquaponics farms in Brazil, considering ecosystem services and disservices. Surprisingly, the choice of materials used in aquaponics infrastructure has the most significant impact on total energy demand, while electricity and fish feed have a lower influence, suggesting aquaponics' efficiency in feeding management compared to traditional aquaculture. Beyond food production, aquaponics contributes to education and tourism. The findings emphasize the importance of replacing water sources and materials to enhance the sustainability of urban aquaponics farms.

2.4.4 Importance of Turbidity measurement in natural water bodies [18]

One of the hardest parameters to measure in natural water body is turbidity. Turbidity can have many causes such as clay, algae, and other organic matter which can affect the clarity of water. In this article the researcher emphasizes the value of using turbidity as a surrogate measurement for various environmental factors.

Some of the measurement uses of the researcher are various turbidity measurement technologies in which some of it uses different kinds of detectors to compensate for different data interferences. The use of different measurement that every tool has its own interpretation which the researchers use to interpret the data correctly because of having many data as it references to create an accurate assumption and they can pinpoint the reliable data to use. The best practice for this is to know the proper tool to ensure that the data that is needed in the study is accurate.

2.4.4 Productivity between Controlled Environment and Natural Field

Aquaponics is a controlled environment system which actuator and sensor are monitoring and maintains parameters such as temperature, turbidity, pH, and water level. In the study shows the comparison of harvesting lettuces between natural field and controlled environment.

Table 2.1 Controlled and Natural Production

Production System	Natural Field	Greenhouse	Plant Factor
Land area for production, ha	101.00	0.45	0.8
Land area for non-production, ha	0.0	0.24	0.24
Total land area, ha	101.00	0.69	0.32
Cropping frequency analyzed	1 crop (summer)	Continuous	Continuous
Production amount analyzed, kg	7,144	454,685	454,685

In table 2.1 shows that even though the natural field have a large advantage over the size of land area for production, both Grean house and Plant Factor has the largest production amount. This shows a clear advantage of controlled environment in which it can have a continuous cropping of resource while the natural field has a seasonal based thus the production of lettuce in a natural field is limited in those time frame.

In production like the aquaculture, there is some method to increase the productivity of fishes in a controlled environment rather than in a natural environment. Research segregates the sexuality of the tilapia from male and female one. The result is that they grow approximately 40% faster than mixed sexes in a controlled environment. While there is also a method in which the research did 58 days feeding trial performed on the tilapia to see the effect of it. The result is that is the tilapia average weight increase significantly in which hugely affect their growing capabilities but in some scenario that the fish got overfeed the affect in which it wasted feed and degraded the water quality of the system. they conclude that increasing the feeding rate affects the growth efficiency and net yield of the tilapia and managing the feed frequency to lessen the wasted food and degradation in water quality. The impact of feed frequency on cultured Nile tilapia is briefed in Figure 2.4.

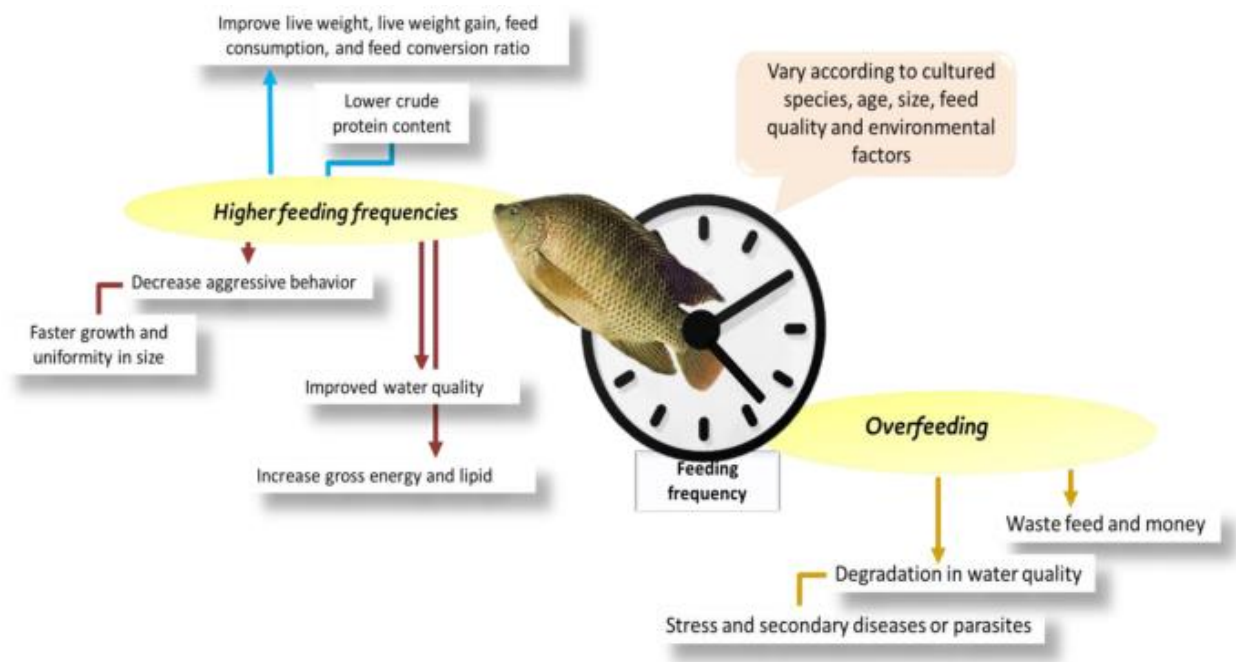


Figure 2.4 Feeding Frequency

2.5 Relevance of the Study

The integration of modern technology with aquaponics represents a significant advancement in agriculture, both locally and globally. In the Philippines, the adoption of smart farming methods has brought about a positive change in farming practices. For instance, when cultivating lettuce and water spinach, automated systems have been crucial in ensuring the right conditions for their growth, resulting in better crop yields. Similarly, the flourishing tilapia industry demonstrates the benefits of careful aquaculture management. A key aspect of success in these ventures is closely monitoring water conditions. By using advanced water monitoring systems within aquaponic setups and hydroponic subsystems, we can safeguard the well-being of aquatic life and improve crop production. Additionally, the use of sustainable technologies, like solar-powered IoT monitoring systems, reduces energy consumption and promotes environmental responsibility. The combination of automation and aquaponics, as seen in Android-based monitoring and IoT-enabled wireless sensors, exemplifies the synergy between technology and agriculture. In urban areas, the evaluation of aquaponics sustainability through energy synthesis highlights the critical importance of controlled aquaponics. The precise management of water parameters, made possible by smart automation and monitoring control systems, is central to achieving sustainable agriculture. It ensures that aquatic and plant life coexist. In summary, integrating these innovative technologies into aquaponics not only enhances agricultural productivity but also promotes responsible and eco-friendly farming practices, benefiting both local and global agriculture.

2.6 Responsiveness Tests on real-time assessment

In assessing the EQ02 system's sensitivity to changes between baseline and posttest, the utilization of the standardized response means (SRM) proved pivotal. An SRM value surpassing 0.8 signified a heightened responsiveness, while a range of 0.5 to 0.8 denoted a moderate level, and 0.2 to 0.5 indicated a lower degree of responsiveness, as delineated by established criteria. All tests adhered to a predetermined alpha level of 0.05. We can use the formula $SRM = \frac{X_2 - X_1}{S_d}$ where X_2 is the mean response time for the treatment condition and X_1 is the response time for the control condition. S_d is the standard deviation of the response time and using this formula standardizes the difference in mean by the variability within the data. Once you have the SRM value, you can interpret it based on your predefined criteria.

CHAPTER 3

CONCEPTUAL DESIGN

In this chapter, the components/elements for the implementation in improving the system will be discussed. In presenting the flow of the system, the functional analysis will be presented with its specifications and functions. The use of a Functional Analysis is to present the whole systems flow from each components/element and its function.

3.1 Functional Analysis

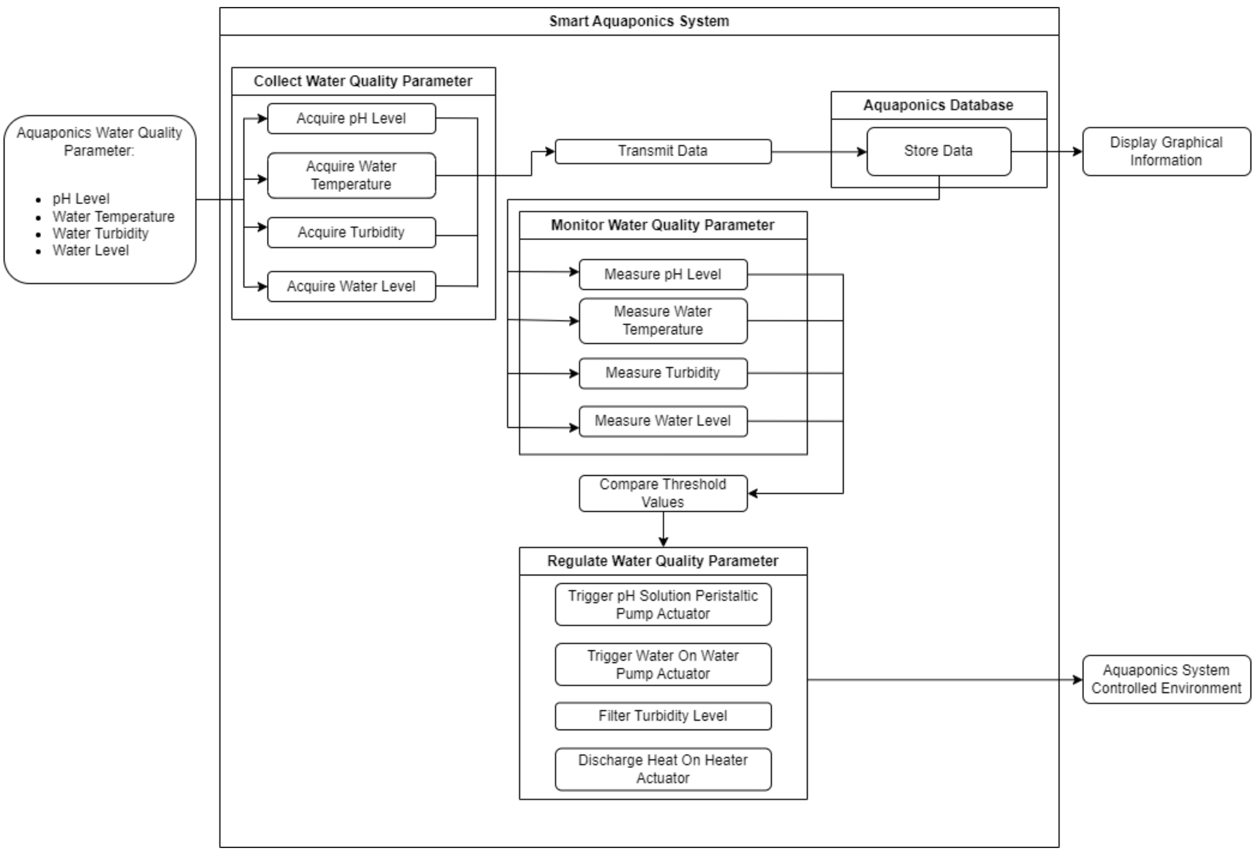


Figure 3.1 Functional analysis

In Figure 3.1, it shows the functions and processes on which the Smart Aquaponics System must execute. The first process in starting the system is to Acquire Water Quality Parameters: pH Level, Water Temperature, Turbidity, and Water Level by the Arduino sensors. The Arduino will then transmit the data to the geany to acquired data to the specific threshold value. Afterwards, it will transmit the data going to the PhpMyAdmin Database. In the PhpMyAdmin database, geany will use the acquired data within the database to activate the actuators to be maintained depending on the threshold values of system. The database will then transmit the data going to the Grafana - a Graphical Web Interface that displays data from phpMyAdmin database through using Charts and Graphs. The system will make use of different actuators which will maintain the water parameters (Water Level, pH Level, and Temperature). The system will Display Graphical Information and make the Aquaponics System be a controlled environment.

3.1.1 Black box

Black box testing refers to the manual testing method of the system, where the tester does not have any knowledge of the source code or what is happening inside of the system. This replicates the user's point of view where they do not know how the system works but can see what the system is taking in and taking out (input and output).

Table 3.1 Aquaponics System Method

Case	Script	Result
Collect pH value from the pH sensor from the main tank	The tester will test if the system will be able to collect the pH data from the pH sensor and will be able to store and display that data in the database.	The data collected from the pH sensor has successfully been stored and displayed in the database.
Collect Turbidity value from the turbidity sensor from the main tank	The tester will test if the system will be able to collect the turbidity value from the turbidity sensor and will be able to store and display that data in the database	The data collected from the turbidity sensor have been successfully stored and displayed in the database
Collect Temperature value from the temperature sensor from the main tank	The tester will test if the system will be able to collect the temperature value from the temperature sensor and will be able to store and display that data in the database	The data collected from the temperature sensor have been successfully stored and displayed in the database
Collect distance value from the ultrasonic sensor from the main tank	The tester will test if the system will be able to collect the distance value from the ultrasonic sensor and will be	The data collected from the ultrasonic sensor have been successfully stored and displayed in the database

	able to store and display that data in the database	
Display pH value from the database to a graph format	The Tester will test if the system will be able to display the pH value from the database to a graph format	The pH value from the database is successfully displayed in a graph format.
Display Turbidity value from the database to a graph format	The Tester will test if the system will be able to display the Turbidity value from the database to a graph format	The Turbidity value from the database is successfully displayed in a graph format.
Display Temperature value from the database to a graph format	The Tester will test if the system will be able to display the Temperature value from the database to a graph format	The Temperature value from the database is successfully displayed in a graph format.
Display Distance value from the database to a graph format	The Tester will test if the system will be able to display the Distance value from the database to a graph format	The Distance value from the database is successfully displayed in a graph format.
Activate pH down Peristaltic pump if reached pH value of above 7	The testers will test if the pH down peristaltic pump will activate for 5 seconds if the pH value of the water reached above 7	The pH down Peristaltic pump activated after reaching the pH level above 7
Activate pH up Peristaltic pump if reached pH value of bellow 5.5	The testers will test if the pH up peristaltic pump will activate for 5 seconds if the pH value of the water reached below 5.5	The pH up Peristaltic pump activated after reaching the pH level below 5.5
Activate the Water heater if the temperature of the water reaches below 28 degrees Celsius	The testers will test if the water heater activates after the water temperature reaches the below 28 degrees Celsius	The water heater activated when the water temperature reached 28 degrees Celsius
Activate the water pumps from the water reserve tank if the water surface level of the tank reaches 24 cm away from ultrasonic sensor	The testers will test if the water pumps will pump out water for 10 seconds and add it to the main tank if the water surface level of the main tank reaches 24 cm away from the ultrasonic sensor	The water pumps from the water reserve activated and added water from the water reserve to the main tank

Activate actuators (pH up pump, pH down pump, and water pump from reserve water) after every 5-minute intervals	The testers will test if the actuators (pH up pump, pH down pump, and water pump from reserve water) of the system activates after every 5-minute intervals	The actuators (pH up pump, pH down pump, and water pump from reserve water) are successfully activating after every 5-minute intervals.

In table 3.1.1 presents the systems black box input and output. The proponents will test the functionality of the entire system to see whether the right output will be given based on the input that is collected by the system. With this, the proponents will be able to see if the inner workings of the system are wrong or is properly working as it should be. The result of the testing is successful if the intended outcome of the system is right concluding the inner workings of the system are functioning.

3.1.1 Principal Functions

- Measure pH Level
- Measure Water Temperature
- Measure Water Turbidity
- Measure Water Level
- Compare Threshold Values
- Process Data
- Transmit Data
- Trigger pH Solution Peristaltic Actuator
- Trigger Water Pump Actuator
- Filter Turbidity Level
- Discharge heat in Heater Actuator
- Store Data to Database

3.1.2 Secondary Function

- Acquire Water Temperature
- Acquire pH Level
- Acquire Water Turbidity
- Acquire Water Level

Table 3.2 Functions and Specifications

Functions	Type	Specification	Classification
Measure pH Level	Principal	The pH sensor measures the current pH level of the aquaponics water.	Procedural
Measure Water Temperature	Principal	The temperature sensor measures the current water temperature of the aquaponics water.	Procedural
Measure Turbidity Level	Principal	The turbidity sensor measures the clarity of the water on how clear or dirty the aquaponics water.	Procedural
Measure Water Level	Principal	This determines the current value of the water level in the aquaponics water.	Procedural
Compare Threshold Values	Principal	This compares the current measured value of the water parameter to the controlled threshold value to main the water parameter of the aquaponics system.	Procedural
Transmit Data	Principal	The sensor values that were measured in the fish tank will be transmitted to the database.	Procedural
Trigger pH Solution Peristaltic Solution	Principal	There will be 2 peristaltic pump that can be triggered if there is a decrease or increase of pH value.	Procedural
Trigger Water Pump Actuator	Principal	A water pump will be the base as the actuator that extrudes water to the fish tank. It increases the water level depending on the threshold value.	Procedural
Filter Turbidity Level	Principal	In maintaining the turbidity level of the system, an improve filtration system that contains 3 stages of filtering out minerals and bacteria will be the basis of limiting the turbidity level for the system.	Procedural
Discharge heat in Heater Actuator	Principal	If the measured value of the water temperature attains lower, the heater will be triggered and will constantly	Performance

		discharge contains heat depending on the threshold value. The Heater can be set to 22 – 34 degrees Celsius with a temperature error within ± 1 degrees Celsius.	
Store Data to Database	Principal	The data will be managed to the database of the system. The Arduino data will transmit to Geany and will transmit data to PhpMyAdmin database to store the data.	Procedural
Acquire Water Temperature	Secondary	The use of the DS18B20 used to detect water temperature has a temperature range of x to x, has an Responsiveness of ±0.5°C, has a response time of 750 millisecond, and runs on 3v-5v voltage. This collects the current water temperature of the system, and it will be transmitted every minute.	Performance
Acquire pH Level	Secondary	The DFRobot Analog: Gravity pH Sensor is used to read the pH value of a certain liquid would have a range of ± 0.1pH, response time of 1 minute, runs of 5 volts, and has a range of 0-60 Celsius. Acquiring the pH level will be able to collect the current pH level of the system that will be transmitted every 1 minute.	Performance
Acquire Water Turbidity	Secondary	The DFRobot Analog: Turbidity Sensor Module is a sensor that detects if the water is clear or murky has an operating voltage of 5 volts, a response time of 5ms, a ratio range around 0~1000±30 (NTU), and a max current of 40 milliamperes. This collects the current Water Turbidity of the system, and it will be transmitted every 1 minute.	Performance
Acquire Water Level	Secondary	The HC-SRO4 ultrasonic sensors uses sonar waves to calculate the	Performance

		distance of a certain object with an operating voltage of 5 Volts and an operating distance of 2 centimeters to – 4 meters. This collects the current water level value of the system every minute.	

In table 3.2 shows the function and specifications of the aquaponics system water quality parameters. The table shows the flow of the program indicating the functions, type, specifications, and classification. In principal types refer to the core or central part of the processes, while the other function is the second process where is connected to the main function. The specification will be the output of the given function on what will it produce.

Function Means Tree

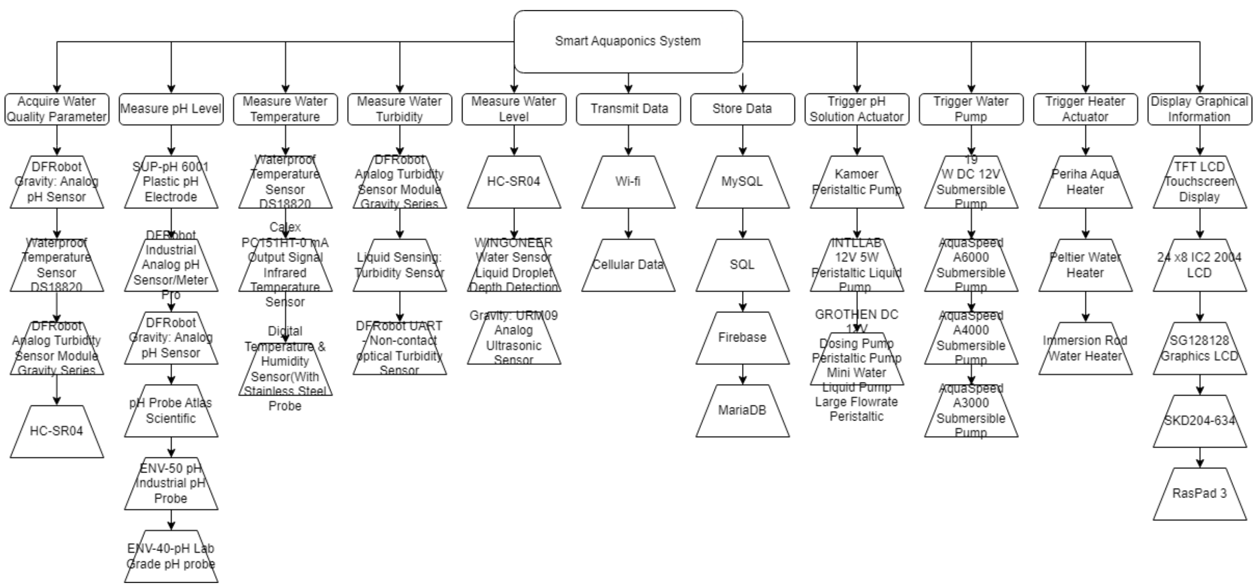


Figure 3.2 Function-Means Tree

In Figure 3.2 illustrates all the functions and means of the aquaponics system that will perform a specific objective that it presents for the systems expected output. It illustrates all the functions and means tree that the system will perform which are categorized into the specific objective it caters to achieve the system’s expected output. The breakdown of each function is arranged according to the procedures of the system beginning at the left, while each functions means as the candidates for the selection of means.

3.2 Design Alternatives

This section covers the main and alternative phases of this project that will meet the functions and standards provided in Table 3.1. This section also incorporates a discussion of the alternative means in relation to their respective functions as well as the summary of the desired means in the Selection Process.

Table 3.3 Design Space Engineering Standard/ISO

Functions	Engineering Standard	Standard Description	Means					
Acquire Water Quality Parameter	ISO 14006:2020	A standard that establishes and implement eco-design as part of an environmental management system.	DFRobot Gravity: Analog pH Sensor	Waterproof Temperature Sensor DS18820	DFRobot Analog Turbidity Sensor Module Gravity Series	HC-SR04		
Measure Water pH Level	ASTM D1293	A standard dealing with the accurate measurement of pH in water using at least two of seven standard reference buffer solutions for instrument standardization.	SUP-pH 6001 Plastic pH Electrode	DFRobot Industrial Analog pH Sensor/ Meter Pro	DFRobot Gravity: Analog pH Sensor	pH Probe Atlas Scientific	ENV-50 pH Industrial pH Probe	ENV-40-pH Lab Grade pH probe
Store Data	ISO/IEC JTC 1/SC 6	A standard for telecommunications and information exchange between systems.	PhpMyAdmin	MySQL	Firebase	MariaDB		
Measure Water Temperature	ISO 15839:2003	A standard that defines on-line performance testing and is applicable to the majority of water sensors/analyzing equipment.	DS18B20 Waterproof Sensor	Calex PC151HT-0 mA Output Signal Infrared Temperature Sensor	Digital Temperature & Humidity Sensor (With Stainless Steel Probe			
Display Graphical Information	IEEE 802.11	A standard used across the majority of residential and commercial networks that allows desktops,	TFT LCD Touchscreen Display	24 x8 IC2 2004 LCD	SG128128 Graphics LCD	SKD204-634	RasPad 3	

		laptops, printers, cellphones, and other devices to link up with each other and access the Internet without the need of connecting wires.				
Trigger Water Pump	ISO 15839:2003	A standard that defines on-line performance testing and is applicable to the majority of water sensors/analyzing equipment.	19 W DC 12V Submersible Pump	AquaSpeed A6000 Submersible Pump	AquaSpeed A4000 Submersible Pump	AquaSpeed A3000 Submersible Pump
Measure Water Level	ISO 15839:2003	A standard that defines on-line performance testing and is applicable to the majority of water sensors/analyzing equipment.	Gravity URM09 Analog Ultrasonic Distance Sensor	HC-SR04	WINGONEER Water Sensor Liquid Droplet Depth Detection	
Trigger Heater Actuator	ISO 19967-1:2019	A standard that tests the performance of the air source of the heat pump for water.	Periha Aqua Heater	Peltier Water Heater	Immersion Rod Water Heater	
Trigger pH Actuator	ISO/DIS 23497	A standard that determines the specifications for technical buffer solutions that are ideally used for the calibration and adjustment of technical pH measuring equipment.	Kamoer Peristaltic Pump	INTLLAB 12V 5W Peristaltic Liquid Pump	GROTHEN DC 12V Dosing Pump Peristaltic Pump Mini Water Liquid Pump Large Flowrate Peristaltic	
Measure Water Turbidity Level	ISO 7027-2:2019	A standard for the quality of water, turbidity measurement, and semi-quantitative means of assessing the	DFRobot Analog Turbidity Sensor Module Gravity Series	Liquid Sensing: Turbidity Sensor	DFRobot UART - Non-contact optical Turbidity Sensor	

		transparency of water.			
Transmit Data	ISO/IEC JTC 1/SC 6	A standard for telecommunications and information exchange between systems.	Wi-fi	Cellular Data	

Table 3.3 shows the engineering standards, descriptions and means of different functions of the project. The following functions contain its specific engineering standards/ISOs which contribute to a certain means. The function is then describing the standard information about the function and how it defines the functionality of the system.

System Flowchart

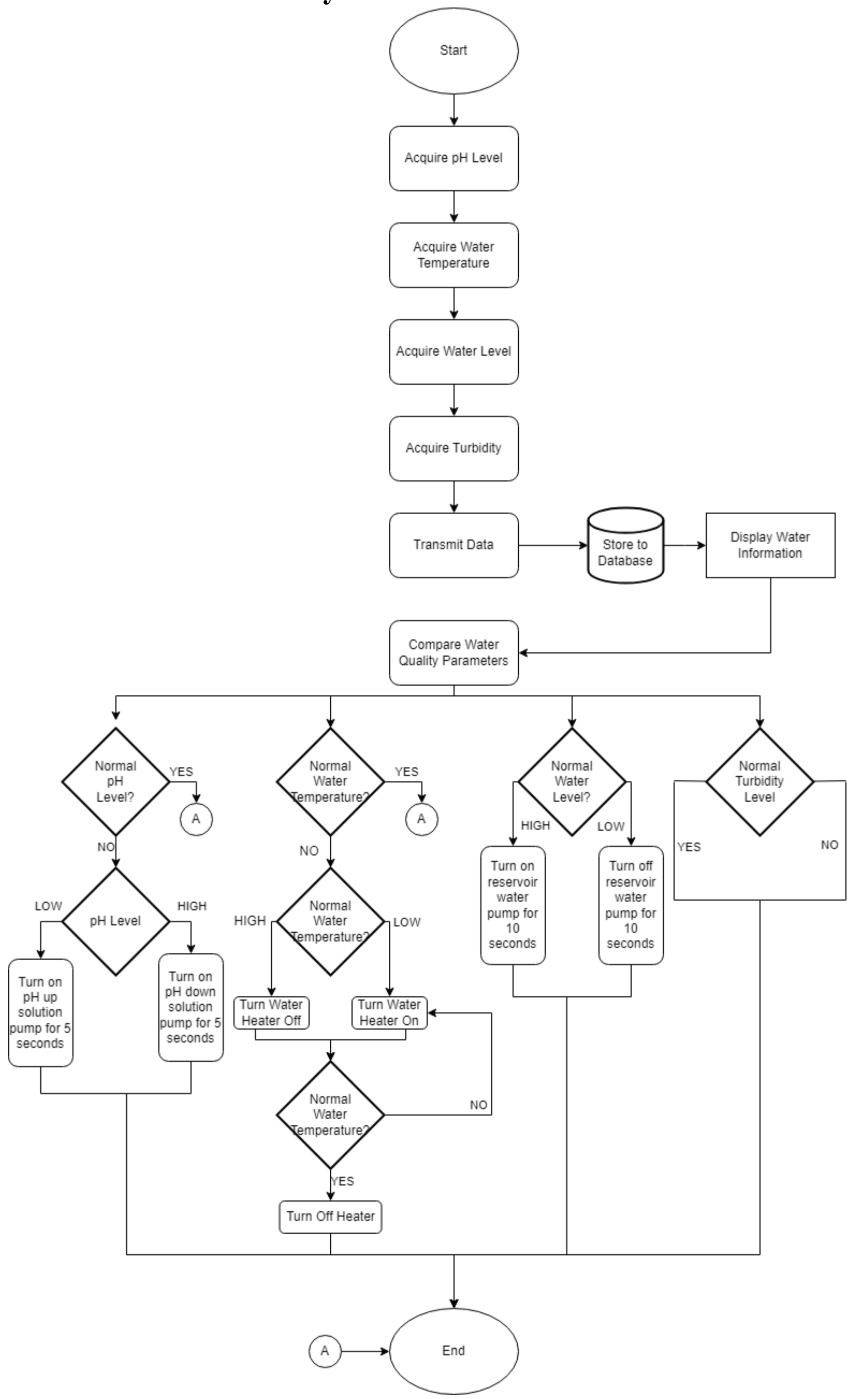


Figure 3.3 System Flowchart

Figure 3.3 shows the system flowchart of the system. The system process begins with the simultaneous acquisition of water turbidity level, water temperature, water level, and pH level. The acquired water information will then be transmitted and stored in the cloud database. This information will also be displayed in the web interface. The water quality parameters will be compared to the predefined threshold values. With the given values for comparison, the system will identify whether the water quality parameter falls under the normal level, else the actuator will initialize to achieve the normal water quality levels.

The system will acquire the Turbidity level of the Aquaponics to determine the turbidity of the water. The turbidity values that the researchers get will start from 0 to 3000(the lower the number, the cleaner the water and vice versa). At regular or normal value of the turbidity will be at a range of 0 to 1500. If the water turbidity reaches above the threshold, it will be the time to do a water change.

The system will acquire the water temperature of the aquaponics to determine the temperature of the water. The normal or regular water temperature of the aquaponics is from 28 to 32 degree Celsius. The water temperature threshold value will be compared with the water temperature sensor value to determine if the system will activate the water heater. The researcher opted to go with the water heater approach because the cooling of the water will be regulated be the water flow of the system and the temperature will be determined by the weather. If the water temperature reaches below the 28-degree Celsius margin, the water heater will activate to raise the water temperature back to the optimal value of 28 degrees Celsius. If the water temperature reached the optimal water temperature, the water heater will deactivate.

The system will acquire the pH level of the Aquaponics to determine the pH of the water. The pH value will be at a range of 0 to 14(0 being acidic and 14 being basic). The system will compare the threshold value of the pH and the acquired value of the pH sensor to determine of the system will be needing to turn on the pH up pump or the pH down pump. When the system determines what pump will be turned on, it will be active for 5 seconds to put in the pH up or down solution in the aquaponics.

The system will acquire the water temperature of the aquaponics to determine the temperature of the water. The normal or regular water temperature of the aquaponics is from 28 to 32 degree Celsius. The water temperature threshold value will be compared with the water temperature sensor value to determine if the system will activate the water heater. The researcher opted to go with the water heater approach because the cooling of the water will be regulated be the water flow of the system and the temperature will be determined by the weather. If the water temperature reaches below the 28-degree Celsius margin, the water heater will activate to raise the

water temperature back to the optimal value of 28 degrees Celsius. If the water temperature reached the optimal water temperature, the water heater will deactivate.

All the actions done will be recorded in the database and will then be displayed as history. The last part of the process for this would be the whole process going back to the start because the system is designed for real-time monitoring.

3.3 Selection Process

The section consists of the procedures involved in looking for the appropriate materials for the entire project. These parts include sensors, actuators, and data storage and transmission. The criteria for evaluating the means are based on Accuracy, Reliability, and Responsiveness. A priority number for each of the criteria appears on the means. The proponents define all priority ratings depending on the device specification and practicality of usage. In formulating total scores, the sum of the products of the Priority Number (%) and Priority Weight is determined per criterion. The means with a top score represents as the highest specification instrument for project implementation. In addition, the justifications for employing each instrument are furtherly discussed in the following tables. Each objective has equal priority weight of 33.33.

Table 3.4 Selection Process for Acquire Water Quality Parameter

Acquire Water Quality Parameter					
Priority Score Attainment		1st = 100%	2nd = 75%	3rd = 50%	4th = 25%
Design Constraints (C) and Objectives	Priority Weight	DFRobot Gravity: Analog pH Sensor	HC-SR04	Waterproof Temperature Sensor DS18820	DFRobot Analog Turbidity Sensor Module Gravity Series
		Score	Score	Score	Score
Accuracy (O)	33.33	33.33	25.00	16.66	8.33
Reliability (O)	33.33	Constraints			
Responsiveness (0)	33.33	Constraints			
Total Score	100	33.33	25.00	16.66	8.33

Table 3.4 showcases the selection process for the function of acquiring the water quality parameter via the use of 4 types of sensors. The three possible means for this function are: DFRobot Gravity Analog pH Sensor, Waterproof Temperature Sensor DS18820, HC-SR04, and DFRobot Analog Turbidity Sensor Module Gravity Series. The comparison is based on the required

specifications of Responsive (O). The DFRobot Gravity: Analog pH Sensor has the highest priority having a score of 33.33 because of its measurement in its Accuracy having ±0.1@25°C. The lower the value of its tolerance, the closer it is to the actual value in measuring the pH level having a price of 1,800 php is effective in acquiring it. Finding a suitable sensor in measuring the pH level is important to lessen the error rate while being a laboratorial grade sensor. The second highest gaining 25.00 in the priority score is the HC-SR04 where its Accuracy to the true value is ±0.3 @ 0.1 inches. Even though the HC-SR04 is cheap, its Accuracy to the true value is near. Though, its grade as a sensor limits its longevity and we still need to cover its body. The next mean that was computed is the Waterproof Temperature Sensor DS18B20 having a accuracy rate of ±0.5°C at -55 to 80°C. The reason why this ranks to be as the 3rd priority is because of its description and specification. Having a price of 99.75 php, it is still suitable for implementing it on the system because of its responsiveness without increasing the price. The last mean that was computed was the DFRobot Analog Turbidity Sensor Module Gravity Series marketing a price of 850 php and a responsive tolerance of ±10% Full Scale. The reason why this mean was the last priority score is because of its large tolerance rate that is not close to the true value than the other means and considering the marketing price. This means that the highest priority of the project is the pH sensor, this is to measure the acidity and alkalinity of the water of the fish tank, next is the level of the water for the Nile tilapia, next is the water temperature of the fish tank and the water reservoir and lastly the turbidity sensor to know the clarity of the water.

Table 3.5 Selection Process for Measure Water Quality via pH sensor

Measure Water Quality (pH Sensor)							
Priority Score Attainment		1st = 100%	2nd = 83.33%	3rd = 66.66%	4th = 49.99%	5th = 33.32%	6th = 16.65%
Design Constraints (C) and Objectives	Priority Weight	ENV-50 pH Industrial pH Probe	ENV-40-pH Lab Grade pH probe	pH Probe Atlas Scientific	DFRobot Gravity: Analog pH Sensor	DFRobot Industrial Analog pH Sensor/Meter Pro	SUP-pH 6001 Plastic pH Electrode
		Score	Score	Score	Score	Score	Score
Accuracy (O)	33.33	33.33	27.66	22.22	16.66	11.10	5.55
Reliability (O)	33.33	Constraints					
Responsiveness (0)	33.33	Constraints					
Total Score	100	33.33	27.66	22.22	16.66	11.10	5.55

Table 3.5 shows the selection process for measuring the water quality via pH Sensor. There are 6 possible means for this function where 6 pH sensors will be introduced. The comparison is based on the required specifications of Accuracy. The 1st score attainment of the mean is the pH Probe Atlas Scientific due its responsiveness rate of ±0.002 and the one of the nearest tolerance rates from the true value and being an industrial graded sensor, which is more durable than other pH sensors but is expensive. There is similar responsive rate specification not just the ENV-40-pH Lab Grade pH Probe but also the pH Probe Atlas Scientific, and ENV-50 pH Industrial pH Probe. Though, there are difference between them, for example the ENV-40 pH lab grade pH probe is a lab grade sensor but still functions similar with the 1st score attained having 0.002 tolerance rate. The next is the pH probe Atlas Scientific, its similarities are the same with the 1st and 2nd score priority, but the difference is it is the pH probe atlas is a scientific grade pH probe. In the 4th place is the DFRobot Gravity Analog pH Sensor. The DFRobot Gravity Analog pH Sensor is a laboratory grade sensor that contains a tolerance value of ±0.1 pH (25°C) and is still contains a value to the true value of the parameter. It simply is an open source, pH sensor that is easy to use and inexpensive. Lastly, the mean that will be considered is the SUP-pH 6001, it is a type of sewage and composite electrode that contains a pH-sensitive membrane that makes acquiring pH level be accurate with at least a conversion coefficient of greater than 98%.

Table 3.6 Selection Process for Store Data

Store Data					
Priority Score Attainment		1st = 100%	2nd = 75%	3rd = 50%	4th = 25%
Design Constraints (C) and Objectives	Priority Weight	Firebase	MariaDB	PhpMyAdmin	MySQL
		Score	Score	Score	Score
Accuracy (O)	33.33	Constraints			
Reliability (O)	33.33	Constraints			
Responsiveness (0)	33.33	33.33	25.00	16.66	8.33
Total Score	100	33.33	25.00	16.66	8.33

Table 3.6 showcases the selection process for storing data. The score stated in the table above were based on one category: Responsiveness of the database software application will be dependent of the specific use case, requirements, configurations, hardware limitans, software, version, and maintenance. The topic score attainment is the Firebase because of cloud-based database solutions as it is a serverless and focuses on real-time data Aswell as its response time. Though Firebase have a no-cost tier pricing plan, whenever you want to upgrade your plan especially when adding additional storage, you will need to pay. The 2nd place for the priority attainment is the use of MariaDB because of its reliability when it comes to scalable data. MariaDB offers a higher speed query speed when compared to PhpMyAdmin and MySQL. No matter how many data are there in the database their will be it will have a better optimization in storying the data. PhpMyAdmin is often known to have a user-friendly interface, SQL querying, data import and export, optimizing data in a column form is much easier to see data information. PhpMyAdmin is a powerful tool that provides an easy-to-use web interface for managing and storing your database. MySQL is the most word known open-source database that proves its responsive that phpMyAdmin as a portable web application.

Table 3.7 Selection Process for Measure Water Temperature

Measure Water Temperature				
Priority Score Attainment		1st = 100%	2nd = 66.67%	3rd = 33.34%
Design Constraints (C) and Objectives	Priority Weight	DS18B20 Waterproof Sensor	Digital Temperature & Humidity Sensor (With Stainless Steel Probe	Calex PC151HT-0 mA Output Signal Infrared Temperature Sensor
		Score	Score	Score
Accuracy (O)	33.33	33.33	22.22	11.11
Reliability(O)	33.33	Constraints		
Responsiveness (O)	33.33	Constraints		
Total Score	100	33.33	16.66	11.11

Table 3.7 showcases the selection process for measuring the water temperature in the system. The means for measuring the water temperature are different with each other and two brands are: Makerlab DS18B20 Waterproof Sensor and Calex PC151HT-0 mA Output Signal Infrared Temperature Sensor. Makerlab DS18B20 has an overall score of 33.33 based on responsiveness since it shows a precise measurement (±0.5°C over much of the range) and has a price of P134.00 which is cheap for a sensor. The Digital Temperature and Humidity Sensor has a temperature accuracy of ±0.5°C where it has anti-rust, robust, and can be applied to various fields. Though Calex Signal Infrared Temperature Sensor is best in measuring the temperature, the cost of the sensor is expensive and the precise measurement of acquiring the water temperature is ±1°C over much of the range that is much higher than the Makerlab DS18B20 and Digital Temperature.

Table 3.8 Selection Process for Display Graphical Information

Display Graphical Information						
Priority Score Attainment		1st = 100%	2nd = 80%	3rd = 60%	4th = 40%	5th = 20%
Design Constraints (C) and Objectives	Priority Weight	RasPad 3	TFT LCD Touchscreen Display	SKD204-634	SG128128	24 x 8 IC2 2004
		Score	Score	Score	Score	Score
Accuracy(O)	33.33	Constraints				
Reliability (O)	33.33	Constraints				

Responsiveness (O)	33.33	33.33	26.66	20.00	13.33	6.67
Total Score	100	66.66	53.32	40	26.66	13.34

In Table 3.8 showcases the selection process for Displaying Graphical Information in the system. In the system, measured sensor values are going to be displayed from a display to help visualize the system-maintained values or if there is a change in the system. In the table, the highest priority is the RasPad 3 with an overall score of 66.66. The RasPad 3 is an open-source, wireless tablet which contains a Raspberry pi 4. that can be able to transmit the data to the graphical web-interface. It also includes a IPS Touchscreen LCD Monitor that display as a mini system. It has 3 usb 3.0 ports that will be the connection between the Arduino Microcontroller, Sensors, and Actuators. I can be connected to a power-input, and it has a built-in battery. It also holds the database, and connections between the automation and monitoring system of the project. The following means TFT LCD Touchscreen Display, SKD204-634, SG128128, and 24 x 8 IC 2004 has similar specifications to each other but for TFT LCD it can be used as a monitoring display and can be able to control. Though its responsiveness in controlling monitoring the system is low because of its lack of functionality.

Table 3.9 Selection Process for Trigger Water Pump

Trigger Water Pump					
Priority Score Attainment		1st = 100%	2nd = 75%	3rd = 50%	4th = 25%
Design Constraints (C) and Objectives	Priority Weight	AquaSpeed A6000 Submersible Pump	AquaSpeed A4000 Submersible Pump	AquaSpeed A3000 Submersible Pump	19W DC 12V Submersible Pump
		Score	Score	Score	Score
Accuracy (0)	33.33	Constraints			
Reliability (O)	33.33	33.33	25.00	16.66	8.33
Responsiveness(O)	33.33	Constraints			
Total Score	100	33.33	25.00	16.66	8.33

In Table 3.9 showcases the selection process for triggering the water pump in the system. In the given table, the highest priority in Reliability (O) is the AquaSpeedA6000 Submersible

Pump having a score of 33.33, it comes with a powerful water circulation while saving energy, and can disperse water for about 6000L/H, it may be compact but can be good for the whole system. Higher Power Consumption can be able to continuously disperse water in the whole system faster. Though, having too much power can. The 2^{nd} and 3^{rd} priority are like the 1st priority but their only different is their power consumption and the amount of water they can pump-out. The last priority is the 19W DC 12V Submersible Pump that also has Energy Saving Capacity while using a low wattage. It has a flow capacity of 800L/H and has a Lift of 5 Meters. This process will be in the water reservoir tank and will trigger whenever the water level parameter below the threshold.

Table 3.10 Selection Process for Measure Water Level

Measure Water Level				
Priority Score Attainment		1st = 100%	2nd = 66.67%	3rd = 33.34%
Design Constraints (C) and Objectives	Priority Weight	HC-SR04	Gravity URM09 Analog Ultrasonic Distance Sensor	WINGONEER Water Sensor Liquid Droplet Depth Detection
		Score	Score	Score
Accuracy (O)	33.33	33.33	22.22	11.11
Reliability(O)	33.33	Constraints		
Responsiveness (O)	33.33	Constraints		
Total Score	100	33.33	22.22	11.11

In Table 3.10 presents the selection process for measuring the water level of the system. In the given table, the highest priority in Accuracy(O) having a score of 33.33 is the HC-SR04 that has a rating of ±0.035 and is the nearest value to the true value. Though, there is no protection between its pins and circuits, so it is necessary to use a protective shield while using. The 2^{nd} priority having a score of 22.22 is the Gravity URM09 Analog Ultrasonic Distance Sensor having rating of ±1% Accuracy tolerance rate meaning to say the rated value of measure when using Gravity is closer to the true value. Its design also differs from the other means due to it protect guard in its dual-probe and is durable. The last priority is the WINGONEER Water Sensor Liquid Droplet Depth Detection where it detects water droplet whenever there is a change in the water level. There are many functionalities that may affect the responsiveness of the sensor especially its range of acquiring data, temperature, and detection area.

Table 3.11 Selection Process for Trigger Heater Actuator

Trigger Heater Actuator							
Priority Score Attainment		1st = 100%		2nd = 66.67%		3rd = 33.34%	
Design Constraints (C) and Objectives	Priority Weight	Peltier Water Heater		Periha Aqua Heater		Immersion Rod Water Heater	
		Priority	Score	Priority	Score	Priority	Score
Accuracy (O)	33.33	Constraints					
Reliability (O)	33.33	33.33		22.22		11.11	
Responsiveness(O)	33.33	Constraints					
Total Score	100	33.33		22.22		11.11	

In Table 3.11 presents the selection process for triggering the heater actuator in the system. In the given table, the highest priority for Reliability is Peltier Water Heater having a score of 33.33. It contains a wide operating range and a precise temperature control of 0.1 degrees Celsius. It can balance out the temperature of the water by heating it and when the temperature exceeds the threshold, it will trigger cold temperature. The next priority is the Periha Aqua Heater having 22.22 as the overall score where it is an adjustable product that can change the current temperature of the water temperature. It has a capacity of 80 gallons of power than can be easily flow through the whole system. The actuator has its own stop program and sensor, if the current temperature of the water is reliability between the threshold, the actuator will stop. The actuator will continuously trigger if the value of the water temperature around it is not within its threshold value. and Immersion Rod Water Heater having 11.11 as the overall score. Bajaj Immersion Rod Water Heater It has a rated input of 1000 watts at 230 V AC, though controlling the temperature may be difficult because of its power output as well as the size of a vessel or bucket. It also presents notable instructions with regards to using it because of its high temperature output.

Table 3.12 Selection Process for Trigger pH Actuator

Trigger pH Actuator				
Priority Score Attainment		1^{st} = 100%	2nd = 66.67%	3rd = 33.34%
Design Constraints (C) and Objectives	Priority Weight	GROTHEN DC 12V Dosing Pump Peristaltic	Kamoer Peristaltic Pump	INTLLAB 12V 5W Peristaltic Liquid Pump
		Score	Score	Score
Accuracy (O)	33.33	Constraints		
Reliability (O)	33.33	33.33	22.22	11.11
Responsiveness(O)	33.33	Constraints		
Total Score	100	33.33	22.22	11.11

In Table 3.12 showcases the selection process for triggering the pH Actuator. The first mean that was presented is the Grothen DC 12 V Dosing Pump Peristatic where it has a flow rate up to 1700 mL/min. It is versatile and reliability designed for multiple procedures. The next priority is the Kamoer Peristaltic Pump where it has a range of greater than 70 mL/min, it is better in determine the missing pH value based on time. In addition, the kamoer is small, lightweight, and has a low power consumption. The last mean that was included in the table is the INTLLAB 12V peristaltic pump where has a flow rate of 19 to 100 mL/min and can easily dictate the direction of the liquid flow through its price is priced to be high than the kamoer peristaltic pump.

Table 3.13 Selection Process for Measure Water Turbidity Level

Measure Water Turbidity Level				
Priority Score Attainment		1^{st} = 100%	2nd = 66.67%	3rd = 33.34%
Design Constraints (C) and Objectives	Priority Weight	DFRobot Analog Turbidity Sensor Module Gravity Series	Liquid Sensing: Turbidity Sensor	UART Non-contact Optical Turbidity Sensor for Arduino
		Score	Score	Score
Accuracy (O)	33.33	33.33	22.22	11.11
Reliability (O)	33.33	Constraints		

Responsiveness(O)	33.33	Constraints		
Total Score	100	33.33	22.22	11.11

In Table 3.13 presents the selection process for measuring the water turbidity level of the system. The DFRobot Analog Turbidity Sensor Module Gravity Series is at the top priority, with 33.33 in the priority score. DFRobot Analog Turbidity Sensor Module Gravity Series marketing a price of 850 php and a responsive tolerance of ±10% Full Scale. The reason why this mean was the last priority score is because of its large tolerance rate that is not close to the true value than the other means and considering the marketing price. This means that the highest priority of the project is the pH sensor, this is to measure the acidity and alkalinity of the water of the fish tank, next is the level of the water for the nile tilapia, next is the water temperature of the fish tank and the water reservoir and lastly the turbidity sensor to know the clarity of the water. In addition, it has a range of 0 to – 3000 NTU. The next priority is the Liquid Sensing: Turbidity Sensor where it has a measurement range of 0 – 1000 NTU and based on its description, the tolerance spread can be wide that is why is it recommended to calibrate the sensor. The last priority is the UART Non-contact optical turbidity sensor for Arduino. Its description is attaining the turbidity level by detecting it in a range within 40-50mm and is susceptible to carrion from water or chemical. Though, its NTU rating is undetermined we must base it on the response time.

Table 3.14 Selection Process for Transmit Data

Transmit Data			
Priority Score Attainment		1st = 100%	2^{nd} = 50%
Design Constraints (C) and Objectives	Priority Weight	Wi-Fi	Cellular Data
		Score	Score
Accuracy (O)	33.33	Constraints	
Reliability (O)	33.33	Constraints	
Responsiveness (O)	33.33	33.33	16.66
Total Score	100	33.33	16.66

In Table 3.14 showcases the selection process for transmitting data from the system to wireless computers. In the given table the highest priority having 33.33 in the overall score is the Wi-Fi where multiple computers can be able to control the RasPad 3 containing all the necessary functions for the system to function. Wi-Fi can perform a set of functions determine by certain conditions for a specified operation time. Wi-Fi is faster because a computer can connect instantly when you come into the rage, and it acts as a local hub that allows you to connect many devices to a single network. Cellular Data, only multiple computers can be able to use as long as both the aquaponics system and another computer is connected to the same connection. Cellular Data has an unlimited range and is mobile. Though it may depend on the location where you are at. The farther you are at a Cellular Tower, the lower the bandwidth you have.

3.4 Function-Means Matrix

Table 3.15 Functions-Means Metric Table

MEANS						
Measure pH Level	SUP-pH 6001 Plastic pH Electrode	DFRobot Industrial Analog pH Sensor/Meter Pro	DFRobot Gravity: Analog pH Sensor	pH Probe Atlas Scientific	ENV-50 pH Industrial pH Probe	ENV-40-pH Lab Grade pH Probe
Measure Water Level	HC-SR04	WINGONEER Water Sensor Liquid Droplet Depth Detection	Gravity: URM09 Analog Ultrasonic Sensor			
Measure Water Temperature	Waterproof Temperature Sensor DS18B20	Calex PC151HT-0 mA Output Signal Infrared Temperature Sensor				
Measure Water Turbidity	DFRobot Analog Turbidity Sensor Module Gravity Series	Liquid Sensing: Turbidity Sensor				
Water Temperature Actuator	Periha Aqua Heater	Peltier Water Heater	Immersion Rod Water Heater			
Microcontroller	Arduino Mega 2560	Arduino Mega 328p				
Water Level Actuator	19 W DC 12V Submersible Pump	Decdeal Submersible Water Pump, DC 12V 5W				

pH Solution Actuator		Kamoer Peristaltic Pump					
Water Pump Main		AquaSpeed A6000 Submersible Pump	AquaSpeed A4000 Submersible Pump	AquaSpeed A3000 Submersible Pump	19 W DC 12V Submersible Pump		
Water Tank Filter		AquaSpeed A4000 Submersible Pump	AquaSpeed A3000 Submersible Pump	19 W DC 12V Submersible Pump			
Display Water Quality Parameter	**Physical Display**	TFT LCD Touchscreen Display	24 x 8 IC2 2004	SG128128 Graphics LCD	SKD204-634	RasPad 3	
	Graphical Display	Grafana	Atatus	Instana			
	Wireless Display	VNC Viewer					
Data Storing		PhpMyAdmin	MySQL	Firebase	MariaDB		
Transmit Data		Wi-Fi			Cellular Data		

Legend:

1st Option	2nd Option	3rd Option	4th Option	5th Option	6th Option

Table 3.15 presents the following means necessary for the system to function. Each mean contains different materials which was chosen as the highest option to be use in the project. Other options are reliable but due to other factors, the score of the materials lessens and lowers its priority/option.

3.5 Final Design Concept

The Smart Aquaponics System design, Schematic Diagram, and web graphical interface is shown in this section. The hardware design was created using TinkerCadd, while for the schematic diagram was created through Fritzing. Lastly for the web interface was created through Grafana directly.

3.5.1 Hardware Prototype Design

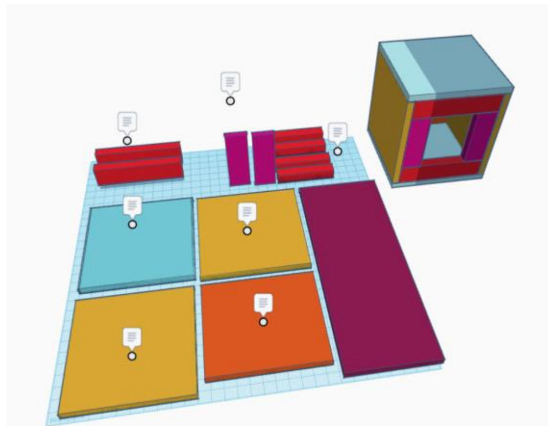


Figure 3.4 Overview of the whole chassis

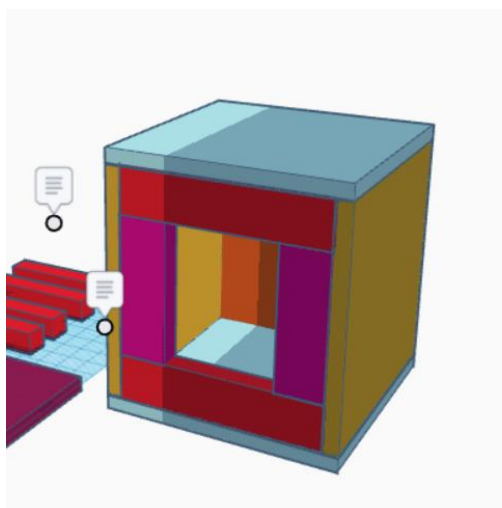


Figure 3.5 Right View of the System Chassis

In Figure 3.4 – 3.5 shows the chassis that contains all the necessary modules, circuits, power supply, and wirings of the actuators and sensors for the automated system. The dimension of the whole chassis is 10 inch in length, 12 inch in height, and 10 inch in width. This is the important part of the system because it serves as the brain of the whole system automation and keeping the functions of the system protected against natural climates. The chassis holds a significant role in display charts/graphs for the user to see. The material that will be using for the chassis is a 0.5-inch acrylic sheet and a 0.5 mm Plastic Sheet

Figure 3.6 Raspad 3 Touch-Screen Display

Figure 3.6 showcases the physical display for the smart aquaponics system. Its function is to display the acquired value through the sensors, manage as data storage for the sensor values, and communicate Arduino to python to communicate with the PhpMyAdmin Database. It has a dimension of 10.6 x 5 x 1.8 inches. It will be connected to the Arduino Mega 2560 Sensor. The Geany Application is used to control the actuators to maintain the threshold values that will be released to the system but first, you should put jumper wires connecting between the raspberry pi 4 to be connected to the relay board of the actuators.

Figure 3.7 55 Gallon Water Storage Drum

Figure 3.8 HC-SR04 Ultrasonic Sensor

Figure 3.9

12 V DC Submersible Pump

In Figure 3.7 showcases the 55 Gallon Water Storage Drum as a Water Reservoir for the system. Its function is to maintain the water level from the fish tank. Through using Figure 3.8 HC-SR04 Ultrasonic Sensor, it can determine the water level inside the water reservoir that will be displayed in Figure 3.9 RasPad3. If there will be a decrease in the water level of the fish tank, there will be a submersible pump that will pump water going to the fish tank.

Figure 3.10 Kamoer Peristaltic Pump

In Figure 3.10 focuses on the use of a two peristaltic pump for the pH level actuator. Each peristaltic pump has a different function when it comes to the pH actuator; to pump pH down, and pH up solution. The peristaltic pumps will be attached in the metal bars of the fish tank and near the system chassis.

Figure 3.11 Fish Tank HC-SR04

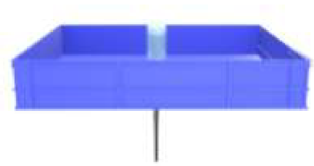


Figure 3.12

Plant Crate Bedding

The Figures above is the design for the Water level for the Water Level of the Fish Tank. The function of Figure 3.11 HC-SR04 is to determine the current water level of the fish tank and the area where the HC-SR04 will be put is below the Figure 3.12 plant crate bedding. Both Figure 3.7 and Figure 3.12 is protected by an Ultrasonic Shield to lessen the risk of getting wet and short-circuited.

Figure 3.13

Water Bucket Filtration

Figure 3.14

Bio-Balls Filter

Figure 3.15

Filter Pebbles

Figure 3.16 Mesh Sponge Filter

Figure 3.17 Sponge Cloth Filter

Figures 3.13 – 3.17 above presents the updated design and materials for the improvement of the filtration system. There will be 3 Filtration Systems that contains different materials. The filter will contain the combined Mesh Sponge Filter and Rock Pebbles. The next filtration will contain that Bio-Balls Filter that will leave out bacteria that will be needed for the fish tank. Lastly, is the Filtered Pebbles to remove impurities that the first and second filter missed out. The filters placement will be near the chassis and socket so that the wiring of the system will not be longer than a meter.

Schematic Diagram

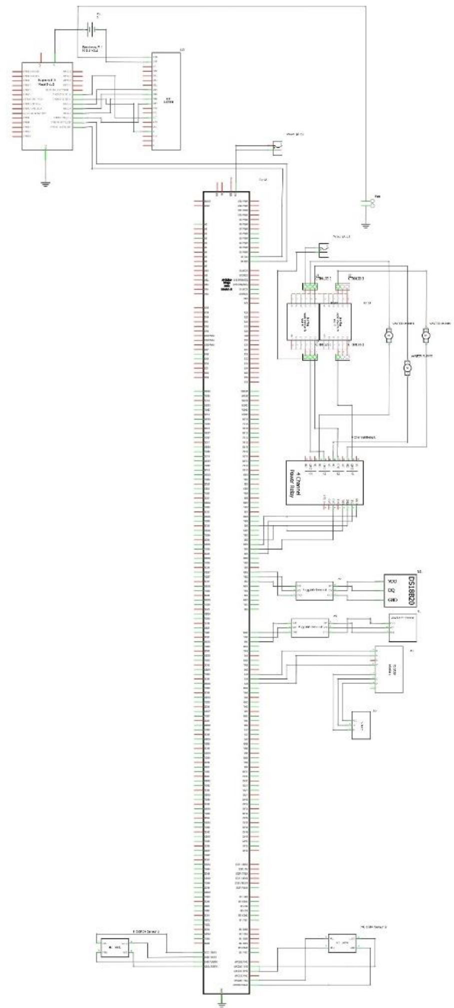


Figure 3.18 Aquaponics Schematic Diagram

Figure 3.18 presents the schematic diagram of the system that shows the functionality and connectivity of different components needed for the system to function. The schematic diagram is necessary to plan out the necessary planning for the system by placing connections accordingly. This includes the connections of the RasPad, Arduino, Relays, Sensors, Actuators, and Modules which will benefit the system.

3.5.2 Graphical Web Interface Design

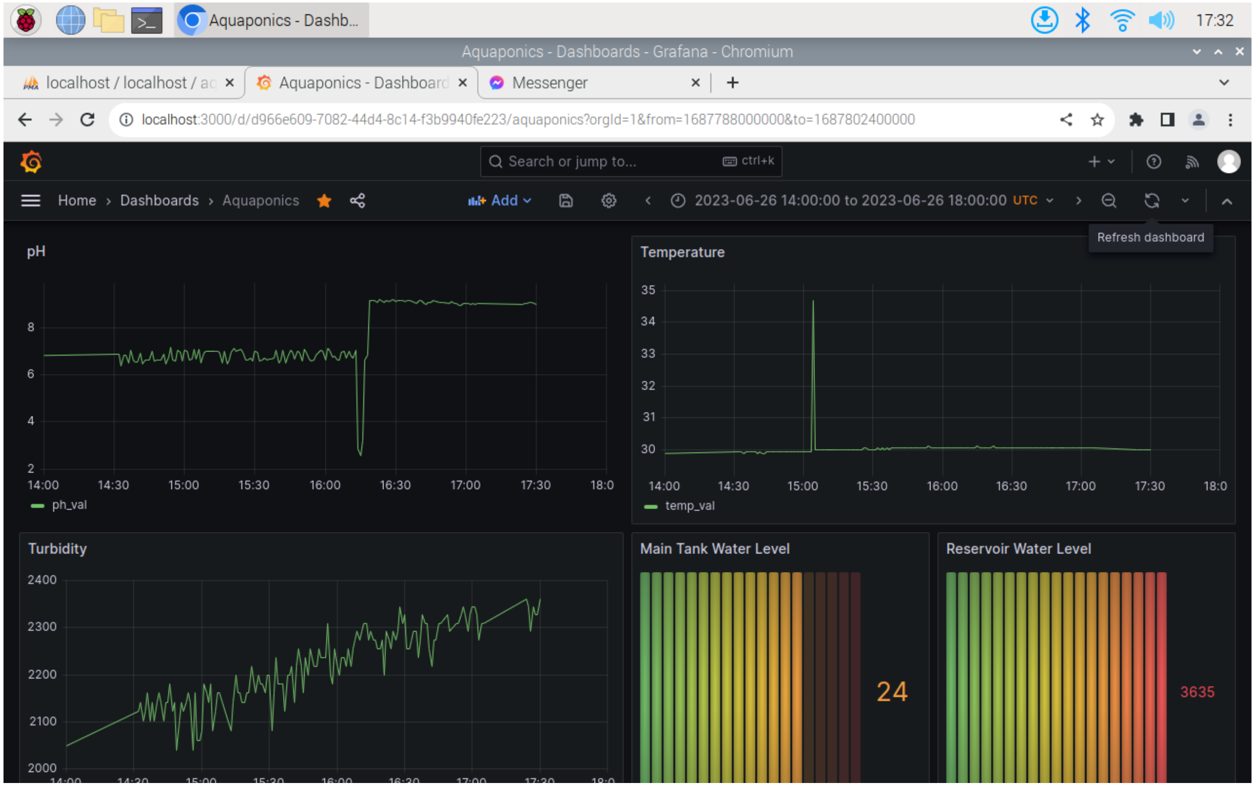


Figure 3.19 Grafana Web Interface Dashboard

Figure 3.19 shows the created web interface for the SMART Aquaponics using GRAFANA. The dashboard contains charts and graphs for the pH Level, Temperature Level, Turbidity Level, and Water Level of the system. Each of the following water quality parameters has its own section wherein each corresponding functionality of the systems is being displayed simultaneously. The web interface has options to maximize the capability of the interface, it can display a certain date from oldest to highest or a certain time as well as changing its display whatever the user wants.

3.5.3 System Block Diagram

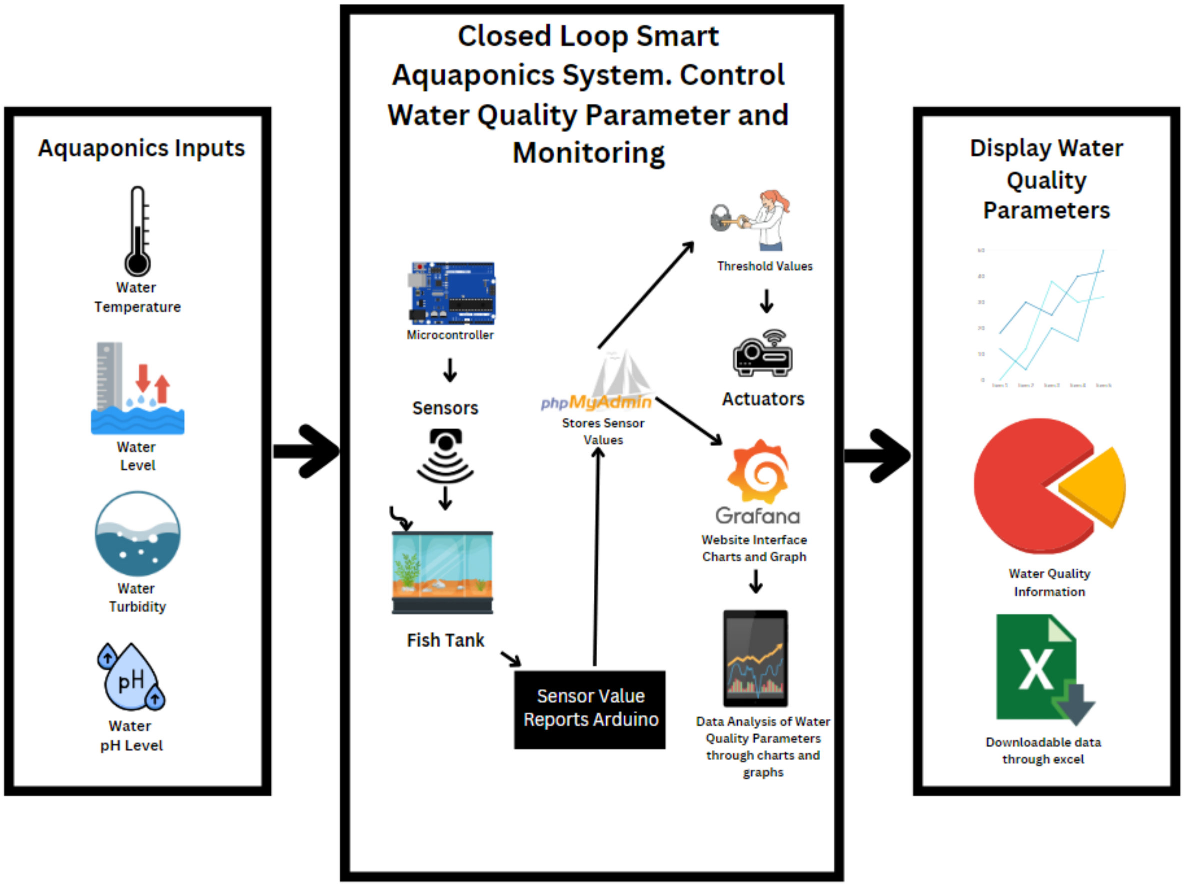


Figure 3.20 System Block Diagram

In Figure 3.20 shows the flow of the system input of the desired design project output. On the left diagram shows the variables for automation. The sensors for the water quality parameter are the input that will be transmitted in the database and can be displayed in the website interface. The information acquired from the system will be used for the analysis. The water quality parameters that exceed or unattained the threshold values need to be controlled. The actuators will function in a manner that cause the water quality parameters to change and falls under the threshold value/s. At the end of the diagram shows the data presentation and analysis of the whole sensor values accumulated in the system. The data can be download directly to an excel file to further sort the necessary information that the user wants.

3.6 CONSIDERATION RUBRICS

This section will show the appropriate design consideration for the creation of the smart aquaponics system. It will specify based on the five design considerations which are: Public Health and Safety, Economic, Environment, Social, and Ethical.

Table 3.16 Design Consideration Table

Design Consideration	Project Application
A. Public Health and Safety	Assure proper automated monitoring and regulation of water quality parameters
B. Social	Determine the sensor values on the website interface that will be accessible by the user
C. Ethical	Assure proper management of the automation system
D. Economic	Determine the proposed budget for the creation of the overall smart aquaponics system
E. Environmental	Identify if available resources are efficiently used

Table 3.16 depicts the design consideration and project application of the systems project. It displays five necessary design considerations including Public Health and Safety, Social, Ethical, Economic, Environmental. The considerations are important to the overall process of the smart aquaponics system that can affect its functionality and can hinder the performance of the system.

Table 3.17 Design Process in Relation to Design Consideration Table

Design Process	Description	Design Considerations				
		A	B	C	D	E
Define the problem	State the problem of the proposal	X	X			
Functionality of the Sensor	Collect necessary data and information through the sensors	X	X			
Analyze problem and Solution	Analyze and evaluate the appropriate solution for the system	X	X		X	X
Requirements	Essential functionality/characteristics of the project and design	X		X		
Test and implement the solution	Test the project and consideration for the project	X	X	X		

Table 3.17 presents the design consideration of the design process. Each of the following design process has its importance in achieving the appropriate consideration in the project. The marked “X” pertains to the required consideration to be achieved in the design process.

Table 3.18 Design Rubrics Consideration

Consideration	Parameters	4	3	2	1	Function /Means
Public Health and Safety	Complies/Follows electrical regulations of PEC (Phil Elec Code), ISA (Intern. Soc, Automation) and other electrical safety organizations.	The project was able to follow all the rules and regulations set by ISA, PEC, other organizations	The project was able to follow most of the rules and regulations set by ISA, PEC, other organizations	The project was able to follow few rules and regulations set by ISA, PEC, other organizations	The project fails to follow all the rules and regulations set by ISA, PEC, other organizations	Display Graphical information, Acquire and Measure parameters, and trigger actuators.
Social	Determine the sensor values on the website interface that will be accessible to the user	The sensor values and graphical interface, and database are accessible and readable	The sensor values graphical interface, and database are not accessible but readable	The sensor values graphical interface, and database are accessible but not readable	The sensor values are graphical interface, and database not accessible and not readable	Graphical Display Water Quality Parameter Sensors Storing
Ethical	Assure proper management of the automation system	The system was able to manage the well-being of sensors., display and actuators	The system was able to occasionally manage the well-being of sensors, display, and actuators	The system was able to rarely manage the well-being of sensors display and actuators	The system fails to manage the well-being of the sensors, display, and actuators	Data Storing/ Physical Display
Economic	Determine the proposed budget for the creation of the overall smart aquaponics system	The project costed below 10,000 PHP	The project costed between 10,001 PHP – 20,000 PHP	The project costed between 20,001 PHP – 30,000 PHP	The project costed more than 30,000 PHP	Budget Costs
Environmental	Identify if available resources are efficiently used	The resources are always used in a sustainable manner	The resource/materials are often used in a sustainable manner	The resources are rarely used in a sustainable manner	The resources are never used in a sustainable manner	Adjust Water Quality

Table 3.18 displays the parameters of each design. The project team base the performance of the project through a rating ranging from 4 as the highest and 1 being the lowest.

Public Health and Safety

- For public health and safety, a rating of 3 can be considered, the project should follow rules in implementing the project.

Social

- For Social, a rating of 4 can be considered because each sensor values and graphical interface, and database are accessible and readable.

Ethical

- For Ethical, a rating of 3 was able to occasionally manage the well-being of sensors, display, and actuators.

Economic

- For Economic, a rating of 3 is considered because the needed materials, necessities, sensor, and actuators are expensive and difficult to find.

Environmental

- For Environmental, a rating of 3 is considered because all the resources are used for the reliability, efficiency, and Responsiveness of the selection process.

3.7 PROJECT DEVELOPMENT

Table 3.19 Gantt Chart

Activities	2022					2023									
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct
Canvas Aquaponics Materials, Sensors, and Actuators	■	■													
Request Form Finance Funds			■	■	■										
Buy Components						■									
Blueprint Automation System					■	■	■								
Test Arduino Code for Sensor and Actuator							■	■							
Schematic Diagram								■	■						
Blueprint Chassis Design										■					
Canvas Aquaponics Materials											■				
RasPad3 testing and installing										■	■				

Database creation															
Graphical Interface Findings															
Graphical Testing															
Cleaning Aquaponics															

Table 3.19 shows the of the project development. The proponents used in creating the Gantt chart is based on the Collegiate Calendar AY 2022-2023 from Asia Pacific College as a monthly basis in scheduling the activities. The project will begin when the components requested in the logistics office has already been received and additional materials are going to be find in case the logistics did not find a more suitable material approved by the management. After finding the materials, the group will create a blueprint for the chassis and circuit diagram of the automation system. After that, there will be an important factor to consider and that is for the display. It took a while to search for the necessary functionality of the display because in case there is no server in the Engineering Floor, the only option is to use RasPad3. The RasPad 3 has all the necessary functions for the system project to move forward, the database and graphical interface in a website. The finalizing of hardware components will finish first before the database implementation to first know if there is an error occurred in the smart aquaponics system.

Table 3.20 Work Breakdown Structure

ACTIVITIES	RESPONSIBLE	DELIVERABLE	MATERIALS	INCLUSIVE DATE
Canvas Aquaponics Materials, Sensors, and Actuators	Carreon, Cabrera, Ellema, Manes, Gapay	Materials, Sensors, and Actuators on-hand	Temperature Sensor/Actuator, Water Level Sensor/Actuator, pH Sensor/Actuator, Turbidity Sensor, Arduino Mega 2560, Water Pumps, Materials	August-September
Request Form Finance Funds	Carreon, Manes, Gapay	Scale budget and summary	Requisition Form	October-December
Buy Components	Carreon, Cabrera, Ellema, Manes, Gapay	Sensors on-hand	-	January

Blueprint Automation System	Carreon, Manes	Functionality of the overall system	TinkerCadd	December-February
Test Arduino Code for Sensor and Actuator	Ellema, Gapay	Arduino Code of the System	Arduino	February-March
Schematic Diagram	Carreon, Gapay	System Diagram for the functional system	Fritzing	April
Blueprint Chassis Design	Manes	Design	TinkerCadd	May
Canvas Aquaponics Materials	Carreon, Manes	Additional necessities for the improvement of the system	-	April-May
RasPad3 testing and installing	Manes	Functional of the display	Raspberry Pi	May
Database creation	Carreon, Cabrera, Ellema, Manes, Gapay	Data storing	RasPad3	May-June
Graphical Interface Findings	Carreon, Cabrera, Ellema, Manes, Gapay	Graphical Display (Charts and Graphs)	RasPad3	June-July
Graphical Testing	Carreon, Cabrera, Ellema, Manes, Gapay	Functionality of graphical display	Raspad3	July-August
Cleaning Aquaponics	Carreon, Cabrera, Ellema, Manes, Gapay	Maintaining the health of the overall project	-	August 2022 – October 2023

In Table 3.20 shows the responsibilities of each member of the project. It shows the activities on who will undergo the responsibility/deliverables needed for the project. It also shows the following materials which will be needed in the project making and without this, the whole project will not be able to be complete. Each activity has a specific data when will be the time to make a certain activity. For the responsibilities of each member, we have conducted survey on which member is suited in a certain activity. Each activity has its own specific data to finish so that the project will be able to be complete at a certain data for the presentation. The starting data the activity will first go through in the month of august of 2022 ending the project in October of 2023.

Table 3.21 Budget Breakdown Proposal

QTY	Particulars / Purpose	Unit Cost	Total Cost
4	Bucket with Lids (20 Liters)	309 PHP	1,236 PHP + Shipping
2	32 mm piping	115 PHP	230 PHP + Shipping
5	32 mm Elbow Piping	11 PHP	55 PHP + Shipping
11	5 way (3/4) 32 mm Male and Female threaded Connector	49 PHP	539 PHP + Shipping
1	Clear Acrylic Sheet Pre Cut to Size Plastic Panel Plexiglass (Clear 6mm 21-inch x 8 in)	602.21 PHP	602.21 PHP + Shipping
2	Large – 50x40x2CM Corse Aquarium Filter Sponge	286 PHP	572 PHP + Shipping
4	Fine Aquarium Filter Sponge – 50 x 11 x 2 cm	69 PHP	276 PHP + Shipping
3	Medium - Fish Tank Aquarium Bio Balls with Filter Sponge Filter Media	154.23 PHP	462.69 PHP + Shipping
6	Lava Rock Nuggets	100 PHP	600 PHP + shipping
1	AQUASPEED Submersible Aquarium Pump (A6000)	1849 PHP	1849 PHP+shipping
6	Large Mesh Bags	65 PHP	390 PHP+Shipping
1	Bosny Premium Acrylic Plus Silicone Sealant 300ml B330 Clear Black White	133 PHP	133 PHP + Shipping
1	Hose (10 Meter length)	189.05 PHP	189.05 PHP+Shipping
1	Rubber O-Rings	228 PHP	228 PHP + SHIPPING
1	Gravity: Analog pH Sensor / Meter Pro Kit for Arduino	3,198 PHP	3,198 PHP
2	HC-SR04 Ultrasonic Sonic	49.75 PHP	99.5 PHP

1	Turbidity Sensor with Amplifier Board	595 PHP	595 PHP
1	Analog Turbidity Sensor Gravity Series	849.75 PHP	849.75 PHP
1	Temperature Sensor (DS18B20 Module Kit Waterproof)	134 PHP	134 PHP + Shipping
2	Artificial Light	853 PHP	1,706 PHP
3	Relay (4 Channel 5V Relay Module SPDT) 5V C-Voltage	158.75 PHP	476.25 PHP
		TOTAL	**14,420.45 PHP + Shipping's**

In Table 3.21 shows the budget proposal of the project. In the given table, it shows the following materials needed for the project. Though, not all the materials are included in the request form of the logistics. The group will use through their personal expenses in the project. The total amount of the project was marked to be at least P15,000,00 and if the group requests some additional materials, it will take longer than the desired date of the materials. While almost all the Sensor and some of the actuator was brought in Makerlab Electronics, some actuators was bought in PERIHA Manufacturing, and local fish stores.

3.8 Functional and Test Cases

3.8.1 Test Process

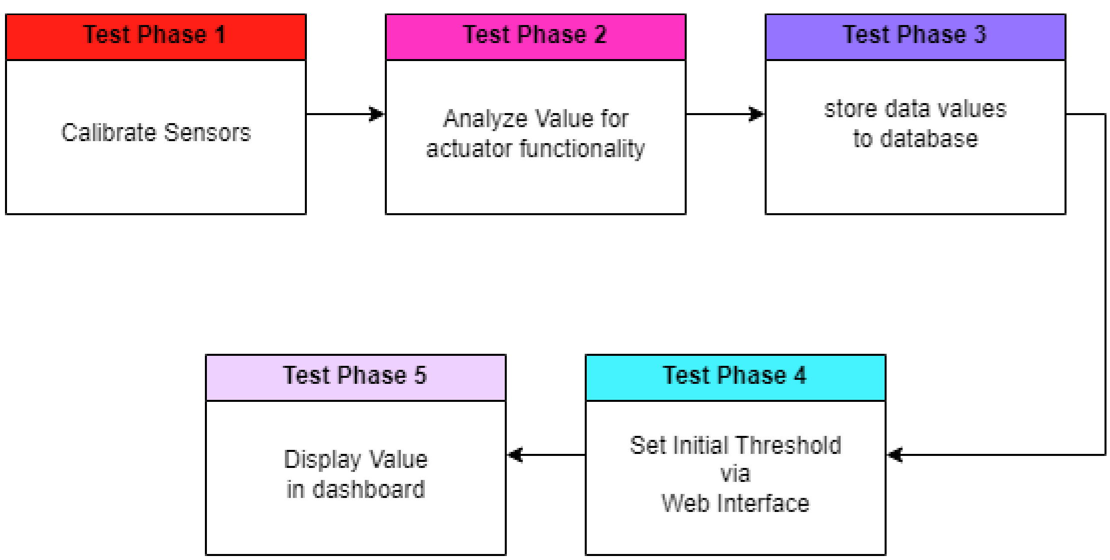


Figure 3.21 Function Test Phase

In Figure 3.21 showcases the test process of the system. the project will prepare 5 test phases to test each process of the system. The first test is calibrating first by comparing the sensor to a tester/laboratory to know the Accuracy of each sensor. Test phase 2 is then analyze the value for the actuator to conduct a procedure to measure its functionality. The next test is to store the sensor data to the database to be stored. Next is setting the initial threshold for the sensor to measure so that the actuator will be activate and maintain the threshold value of the water quality parameter and determine the Accuracy of the sensor to threshold if it sends data every 1 minute. Test phase 5 will display the data to web interface (Grafana) and will then display the transmitted data coming from the database to the dashboard using charts and graphs for the user to have an easier graphical display of the sensor values.

Table 3.22 Sensor Calibration Phase

Test Case	Phase 1	Phase 2	Phase 3
1	Acquires the water quality parameter of the system.	Sensor values are similar to commercially available measuring instrument values	Sensors respond to threshold values
2	Failed to Acquire the water quality parameter	Sensor values are not similar to commercially available measuring instrument values	Sensors do not respond to threshold values

Table 3.22 shows the test phase and test cases in measuring the sensor values from the threshold values to the sensor testers. In phase 1, the sensor will be evaluated through measuring instruments and laboratory tests. Test phase 1 should be completed before proceeding to test phase 2. Test phase 2 should be able to save the pre-initiated value of the system where in phase 3 will then be respond to the planned threshold value for the system to be maintained.

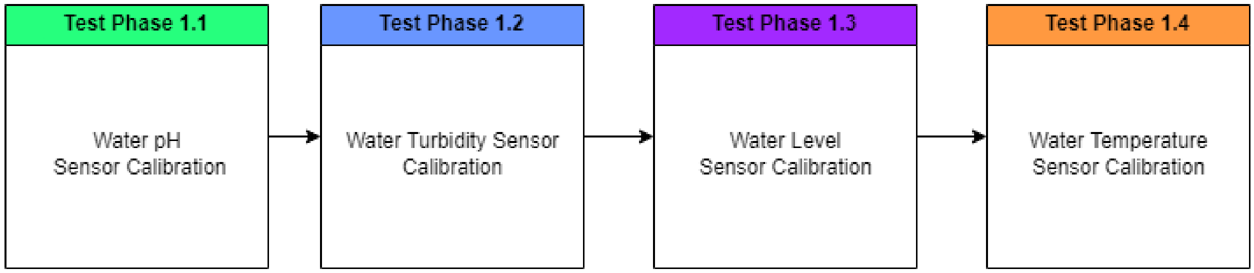


Figure 3.22 Calibration of Sensors

In Figure 3.22 shows the detailed test phase for calibrating the Sensor function. Where each test phase will have 20 trials conducting simultaneously on the sensor testers from the measured sensor of the system.

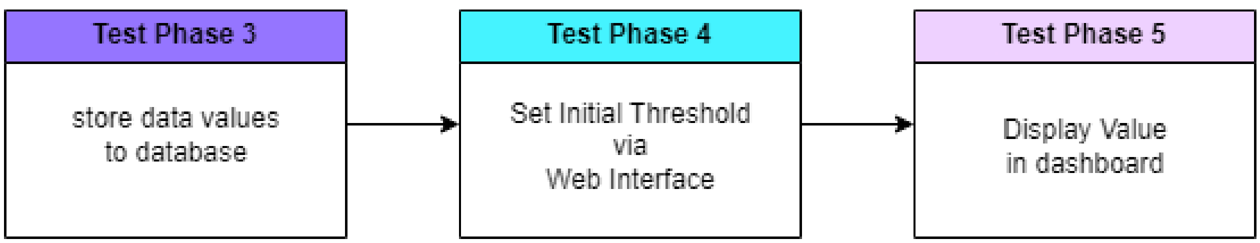


Figure 3.23 Function Test Phase for Transmitting, Storing, and Displaying Data

Figure 3.23 shows the overall detailed test phase for transmitting, storing, and displaying sensor values in the system. In test phase 5, the sensor will analyze the measured value in the system and determine the amount of threshold value released in the actuators. This will then transmit the measured value of the sensors and storing it into the database. It will then transmit into a web interface that will display a graphical representation of the measured value in the system.

Table 3.23 Functional Testing pH Calibration Testing (Test Phase 1.1)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error
		Sensor Measured	Tester Measured	
Type of Water (Distilled Water, Purified Water, Filtered Water, Aquaponics Water, NAWASA water, River Water, and Canal Water)	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
	17			
	18			
	19			
	20			

Table 3.23 shows the test phase 1.1 for calibration and comparing the measured pH from the sensor to the tester. This will compare the Accuracy of the sensor. For the functional testing of the pH Calibration, there will seven tests comparing each water based on their pH level and these are: Distilled Water, Purified Water, Filtered Water, Aquaponics Water, NAWASA water, River Water, and Canal Water. Each test will contain 20 trials comparing the sensor measured to the pH tester measured. It will then evaluate by computing the percentage error of the sensor measured over the tester measured over tester measured and multiplying it by 100%.

Table 3.24 Functional Testing Turbidity Calibration Testing (Test Phase 1.2)

FUNCTIONAL TESTING (Turbidity Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error
		Sensor Measured	Tester Measured	
Water Types (Canal Water, River Water, Distilled Water, and Aquaponics Water)	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			

	12			
	13			
	14			
	15			
	16			
	17			
	18			
	19			
	20			

Table 3.24 shows the test phase 1.2 for calibration and comparing the measured turbidity from the sensor to the tester. This will compare the Accuracy of the sensor. There will be 4 tests comparing the value to the tested value, these are: Distilled Water, Aquaponics Water, River Water, and Canal Water. This testing will determine the clarity of each test. In addition, the tested measure will be conducted in a laboratory to further improve its Responsiveness. Each test will contain 20 trials to further determine the Responsiveness of each test.

Table 3.25 Functional Testing Water Level Calibration Testing (Test Phase 1.3)

FUNCTIONAL TESTING (Water Level)	TRIALS	COMPARE Sensor Values		% Error
		Sensor Measured	Tester Measured	
Water Surface Level	1			
	2			
	3			

Table 3.25 shows the test phase 1.3 for calibration and comparing the measured water level from the sensor to the tester. This will compare the Accuracy of the sensor. It will only contain one testing having 3 trials. In the given table, the sensor should maintain a consistent value compared to the threshold value. The sensor value and measured value will only show the whole numbers for the entire activation time.

Table 3.26 Functional Testing Temperature Calibration Testing (Test Phase 1.4)

FUNCTIONAL TESTING (Temperature Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error
		Sensor Measured	Tester Measured	
Hot	1			
	2			
	3			
	4			
	5			
	6			
	7			
Cold	8			
	9			
	10			
	11			

	12			
	13			
	14			
Normal	15			
	16			
	17			
	18			
	19			
	20			

Table 3.26 shows the test phase 1.4 for calibration and comparing the measured temperature from the sensor to the tester. This will compare the Accuracy of the sensor. In this test, the group will have 3 tests to determine the measure of the sensor to the tester measured for: Hot, Cold, Normal. This will then determine the percentage error between the sensor measured and the tester measured.

Table 3.27. Sensor Actuator Phase

Test Case	Phase 1	Phase 2
1	Actuator/s activated	Actuator responds to the value measured to the threshold value
2	Actuator/s did not activate	Actuator do not respond to the value measured to the threshold value

Table 3.27 shows the test phase and test cases in measuring the actuator values from the threshold values. In phase 1, the actuators should turn on when the sensor value is below or above the threshold value. Test phase 1 should be completed before proceeding to test phase 2. Test phase 2 should respond to the value measured to the threshold value.

Table 3.28 Functional Testing pH Actuator Testing 1 (Test Phase 2.1)

FUNCTIONAL TESTING (pH Testing)	TRIALS	CHECKLIST			Remarks
		Sensor Value	Working	Defective	
pH UP	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	1				
	2				
	3				
	4				

pH DOWN	5				
	6				
	7				
	8				
	9				
	10				

In Table 3.28 shows the test phase 2.1 for testing the actuator. The researchers used a time base method of actuators activation time. This means that the actuators are only activated during a period based on the data that was compared with the threshold. The aquaponics setup holds approximately 550 liters of water (23cm away from the ultrasonic sensor). With this as the control number, we can amount of pH solution needed to be added to slowly increase/decrease the pH level. If the pH reached a certain level (above or below the threshold values) the pH up/down will activate for 10 seconds. The researchers set the time to 10 seconds for the pH actuators because of the type of pH solution that we are using recommending that we put 4-6 drops of pH solution per gallon of water. 10 seconds of activation time will give as an approximate 28ml of water being enough based on the volume of water.

$$ml = \left(\frac{aquaponics\ volume(litter)}{3.785}\ x\ 4\right)\ x\ 0.5ml \qquad \textbf{Eq 3.1}$$

In Equation 3.1 presents the formula in finding the amount of pH solution needed per gallon in ml in the aquaponics system. This ensures the stability of the pH do not exceed to out the parameter level. This will also be the standard measurement of the whole system when the pH actuator activates.

Table 3.29 Functional Testing pH Actuator Testing 2 (Test Phase 2.1)

FUNCTIONAL TESTING (pH Testing)	TRIALS	TIME ACTIVATION	pH UP OR DOWN SOLUTION OUTPUT	REMARKS
	1			
	2			

pH Up and pH Down Actuator pump	3			
	4			
	5			

Table 3.29 presents the test phase 2.1 for testing the actuator of the pH parameter. There will be 6 trials which corresponds to the time activation. There will be a duration of the activation time of the actuator and there will be an output on how much solution did the pH Up or Down solution outputted, it will then remark as: very consistent, consistent, and not consistent as the ranking. the pump will activate for 17 seconds being that the amount of pH solution being dispensed is just the right amount for the maintaining value of the aquaponics water volume. If ever the water lowers by a small amount (3 - 4 cm) the ratio of water to solution is not going to be affected too much because the instructions of the pH solution is to drop 4-6 drops per gallon. If the water volume lowers the proponents will still have a bit of leeway in the amount of pH going in the system

Table 3.30 Functional Testing pH Actuator Testing 3 (Test Phase 2.1)

Water Volume (Liters and Gallons)	Water Level (Based on Ruler Stick)	Water Level (Based on Ultrasonic Sensor)	Water in Gallons (gal)	Water in Liters (L)
pH Up and pH Down Actuator pump				

In table 3.30 presents the supporting phase of the pH Actuator testing 2. There will be 7 trials to be determine: First is Measuring the water level based on the instrument (Ruler Stick). The table represents the conversion from the height of the water to the Liters of the water then the litter of the water is them converted to gallons for the reason that the pH solution that the proponents are using indicates that the pH solution should be put in water in 4-6 drops per gallon.

Table 3.31 Functional Testing pH Actuator Testing 4 (Test Phase 2.1)

Needed Amount of pH Solution	pH Solution of 4 drops in milliliters (mL)	Water Volume (gal)	Need Amount of pH Solution
pH Up and pH Down Actuator pump			

The table 3.31 represents the computation of how much pH solution is needed based on the volume of water in gallon. A droplet of water is equal to 0.05 ml, based on that and the amount that is recommended to put in the water being 4-6 drops per gallon, the proponents set 4 droplets per gallon as a standard for the system to not overdose the system in pH solution resulting in 0.2 ml per gallon. Then 0.2 is multiplies with the gallon amount to get the final needed pH solution to be put in the water based on the volume by gallon of water.

Table 3.32 Functional Testing Temperature Actuator Test (Test Phase 2.2)

FUNCTIONAL TESTING (Temperature Test)	TRIAL S	Current Temperature	Check List		Remarks
			Active	Inactive	
Aquaponics Water	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				

Cold Water	10				
	11				
	12				
	13				
	14				

In Table 3.32 shows the test phase 1.4 for testing the actuator of the water temperature parameter. There will be 3 tests: Hot, Cold, and Normal Temperature. This will test whether the temperature actuator will be activated or not. The group will maintain the value of the water temperature actuator to 28 degrees Celsius. Each test will first determine the current state of the water and will check if the actuator is activated or not. There will be remarks with each trial conducted to know if the trials are consistent to maintain the water temperature of the system.

Table 3.33 Functional Testing Water Level Actuator Testing Test Phase (Test Phase 2.3)

FUNCTIONAL TESTING (Water Level)	TRIALS	COMPARE ACTUATOR VALUES			REMARKS
		ULTRASONIC SENSOR VALUE	WORKING	DEFECTIVE	
WATER PUMP	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				

Table 3.33 shows the test phase 1.3. The functional testing for the water level actuator will be based on the amount of outputted measurement to the specified measure of the water. The water pump activates for 2 minutes to maintain the water level 23cm below the ultrasonic sensor. It pumps 1.4 liters every 10 seconds, taking 2 hours to increase the water level by 1cm. Increasing activation time increases water output proportionally (e.g., 2.8 liters in 20 seconds). Researchers chose 2 minutes to minimize cycling, achieving a 1cm increase in 10 minutes.

Table 3.34 Functional Testing Set initial threshold value.

Trial	Dashboard Section	Reliability For Saving Values	Saves Initiated Values		Checklist		Remarks
			YES	NO	Complete	Incomplete	
1	pH level						
2							
3							
4							
5							
6	Water Level						
7							
8							
9							
10							
11	Water Temperature Level						
12							
13							
14							
15							
16	Water Turbidity Level						
17							
18							
19							
20							

In Table 3.34 shows the test phase 4 as that contain different test trials when determining the settings of initial threshold value. The values are determined per section of the graphical web interface of the proponents. Each Dashboard section will contain five trials to determine it is reliable to save the data in the dashboard and will continuously transmits data coming from the database. There will be a column for the checklist where the data is in a complete state and does not contain any incomplete data in presenting the sensor values coming from the database. It will be given a remark if the initial value were saved for specific factors.

3.9 System Test

3.9.1 Test Process

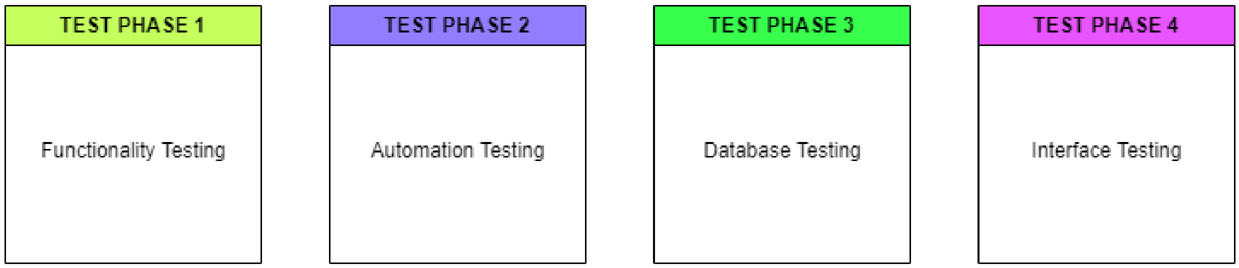


Figure 3.24 System Test Phase

In Figure 3.24 shows the overall system test phase. It shows the system's phase to test the overall Functionality, Automation, Database, and Interface testing. Once the flow is followed, the output of the system would determine if the objective has been achieved.

Table 3.35 Functionality Testing

FUNCTIONAL TESTING	TRIALS	Checklist		Remarks
		Working	Defective	
	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
	17			
	18			
	19			
	20			

In table 3.35 shows the sensor test flows. Test the reliability of the sensors and the function process. Testing is done to certify the sensor that it is working based on the requirements. The sensors that will be using is pH, Temperature, Water Level, Turbidity. In this table, each sensor will be test if it is working or defective during trial. It will be given remarks as a conclusion of the functional testing phase.

Table 3.36 Automation Testing

Automation Testing	TRIALS	Testing			Remarks
		Working	Incomplete	Not Working	
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				

In table 3.36 shows the automation test flows. Test the reliability of the sensor/actuator automation and the function process. Testing is done to certify the sensor that it is working based on the requirements. In the automation testing, all the sensor and actuator should be able to do the specific functions for the system to function properly. Any defective sensor or actuator during the testing will be certified working, incomplete or not working.

Table 3.37 Database Testing

Database Testing	TRIALS	Testing			Remarks
		Complete	Incomplete	No Data	
	n				

In table 3.37 shows the database test flows. Test the responsiveness of storing data from the sensor and the function process. Testing is done to certify the sensor that it is working based on the requirements. This test will be tested if the measured sensor value will be the same value if the data is transmitted to the database. If the data is stored all together it will be complete, if the data only contains half of the data it will serve as incomplete and if the data did not transmit any data to the database, it will show as no data.

Table 3.38 Interface Testing

Interface Testing	TRIALS	Testing			Remarks
		Accurate	Inaccurate	No Data or Graph	
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				

In table 3.38 shows the database test flows. Test the Responsiveness of displaying the data to the user and the function process. Testing is done to certify the graphical testing that it is working based on the requirements. For the interface testing, it will test if the data stored in the database will be outputted correctly in a chart or graph. If the data is transmitted to the web interface and contains all the necessary value, the testing would be accurate. If the data is presenting an inaccurate data will then be conclude as incomplete. If the data is transmitted to the web interface and did not present any chart or graphs to be displayed, the test will then be no data or graph.

3.10 EVALUATION PROCEDURE AND CRITERIA FOR OVERALL RESPONSIVENESS

Table 3.39 Evaluation for Accuracy in the water quality parameter.

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to a Design a system that is accurate in presenting (Measuring) Water Quality Parameter				

In Table 3.39 shows the evaluation for the Accuracy in presenting the water quality parameter. In calculating the Responsiveness of each sensor, we will be using this formula.

$$Average\ Percentage\ Error = \left(\frac{Measured\ Value\ of\ Sensor - Tester\ value}{Tester\ Value}\right) \qquad \textbf{Eq 3.2}$$

$$Accuracy = \left(\frac{overall\ percentage\ error}{number\ of\ tested\ trials}\right) \times 100 \qquad \textbf{Eq 3.3}$$

Equation 3.2 is used to calculate the Accuracy of each sensor for the water quality parameter. In the given formula, it determines the Accuracy of each criterion by dividing the number of successful trials by the overall trial. The result of the commutated data will then be multiplied by 100% to get the percentage rating, the result would show if the roles of the respective sensors were able to attain an accurate value based on the indicated measures. A higher Accurate rating suggests that the parameter is accurately within the desired limits, while a lower rating indicates poor. Moreover, the results would be interpreted using a 4-point scale, which will range from Excellent, Very Good, Fair, and Poor. Equation 3.3 is used to calculate the accuracy rate by getting the overall percentage error of each parameter over the number of tested trials and multiplying it by 100 to attain a percentage value.

3.10 EVALUATION PROCEDURE AND CRITERIA FOR OVERALL RELIABILITY

Table 3.40 evaluation reliability in the water quality parameter.

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values				

In Table 3.40 shows the evaluation for the reliability in presenting the water quality parameter. In calculating the reliability of each sensor, we will be using this formula.

$$Consistency\ Criteria\ Rating = \frac{number\ of\ data\ within\ the\ threshold}{total\ no.of\ data\ in\ database} \times 100 \quad \textbf{Eq 3.4}$$

Equation 3.4 is used to calculate the reliability of each sensor for the water quality parameter. In the given formula, it determines the reliability of each water quality parameter to the threshold values for the system. The system should maintain the data within the threshold value to have a consistent controlled system. The number of measurements within the threshold will show the following parameter: pH Level, Water Level, and Temperature. The reliability ratings will give you a percentage that indicates how often each parameter falls within the acceptable range (threshold). A higher reliability rating suggests that the parameter is consistently within the desired limits, while a lower rating indicates in reliability. Moreover, the results would be interpreted using a 4-point scale, which will range from Excellent, Very Good, Fair, and Poor.

In Table 3.40 shows the evaluation for the reliability in presenting the water quality parameter. In calculating the reliability of data being sent, we will be using this formula.

$$Reliability\ Criteria\ Rating = \left(\frac{number\ of\ data\ collected}{total\ no.of\ data\ in\ 1\ month}\right) \times 100 \quad \textbf{Eq 3.5}$$

Equation 3.5 is used to calculate the reliability of the system where it determines how reliable the system on data is being stored where it computes the successful trial recorded over the number of trials recorded multiplying it to 100% to have the percentage rate of the objective. Moreover, the results would be interpreted using a 4-point scale, which will range from Excellent, Very Good, Fair, and Poor.

It also shows the evaluation for the reliability in sending the data that will be stored in the database. In calculating the reliability. we will be using this formula:

$$df = Date\ and\ Time$$

Sort the Data Frame based on the datetime column:

$$df = df.sort\_values(by = 'Datetime') \quad \textbf{Eq 3.6}$$

Calculate the difference in time between consecutive rows:

$$df\ ['Outage\_Duration'] = df['Datetime'].diff() \quad \textbf{Eq 3.7}$$

Convert the difference to hours:

$$df\ ['Outage_{Duration'_{Hours}}] = \frac{df['Outage_{Duration'}].dt.total\_seconds()}{3600} \quad \textbf{Eq 3.8}$$

Calculate minimum, maximum, and average of the outage durations:

$$Min\ Outage\ Duration = df['Outage\_Duration\_Hours'].min()$$

$$Max\ Outage\ Duration = df['Outage\_Duration\_Hours'].max()$$

$$Average\ Outage\ Duration = df['Outage\_Duration\_Hours'].mean() \qquad \textbf{Eq 3.9}$$

The Equations above are mathematical representations of formulas used in Python to get the minimum, average, and maximum system outage duration the use of Panda library was also used because of its data manipulation and analysis. This provided the user to manipulate large datasets and analyze each parameter of the dataset.

Equation 3.6 is used to sort the data of Date and Time into an ascending order and chronological order. Equation 3.7 is used to calculate the time differences between the consecutive rows in the date and time dataset. Equation 3.8 is used to convert the differences in the outage duration into hours. This is done through extracting the total seconds and dividing it into 3600 seconds which is 1 hour. Equation 3.9 are the calculations done to get the minimum, average, and maximum data in the outage duration column.

Sample Computation (Using Mathematical Representation in Python):

```
import pandas as pd

# Sample data
data = {
    'Date': ['26/06/2023'] * 100,
    'Time': [
        '11:29:03 AM', '11:30:04 AM', '11:31:04 AM', '11:32:04 AM', '11:33:04
AM',
        # ... (the rest of your time entries)
    ]
}
# Create a DataFrame
df = pd.DataFrame(data)

# Combine 'Date' and 'Time' columns to create a datetime column
df['Datetime'] = pd.to_datetime(df['Date'] + ' ' + df['Time'])

# Sort the DataFrame based on the datetime column
df = df.sort_values(by='Datetime')

# Calculate the difference in time between consecutive rows
df['Outage_Duration'] = df['Datetime'].diff()
```

```python
# Convert the difference to hours
df['Outage_Duration_Hours'] = df['Outage_Duration'].dt.total_seconds() / 3600

# Calculate minimum, maximum, and average of the outage durations
min_outage_duration = df['Outage_Duration_Hours'].min()
max_outage_duration = df['Outage_Duration_Hours'].max()
average_outage_duration = df['Outage_Duration_Hours'].mean()

# Print the results
print("Min Outage Duration:", min_outage_duration, "hours")
print("Max Outage Duration:", max_outage_duration, "hours")
print("Average Outage Duration:", average_outage_duration, "hours")
```

Minimum Outage Duration:0.016 hours Average Outage Duration:0.508 hours

Maximum Outage Duration:1.0 hours

3.10 EVALUATION PROCEDURE AND CRITERIA FOR OVERALL RESPONSIVENESS

Table 3.41 Evaluation of the responsiveness in storing the data.

OBJECTIVE	# OF TRIALS	NUMBER OF SECONDS OF DELAY OR ADVANCE	TOTAL NUMBER OF DATA	OVERALL AVERAGE	Remarks
Ability to evaluate a Responsive system that will store the data into the database in real-time.					

Table 3.41 presents the evaluation of the responsiveness of the data was gathered using Excel sorting function where each amount of data per trial was gathered and was used to calculate using the Average function to collect the overall responsiveness average.

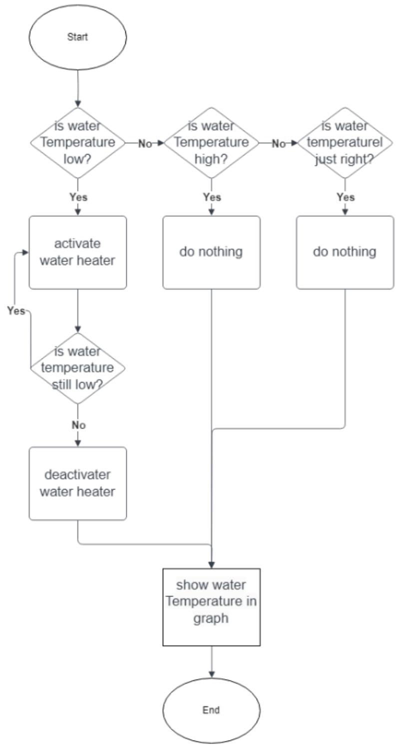
Chapter 4
Design Communication

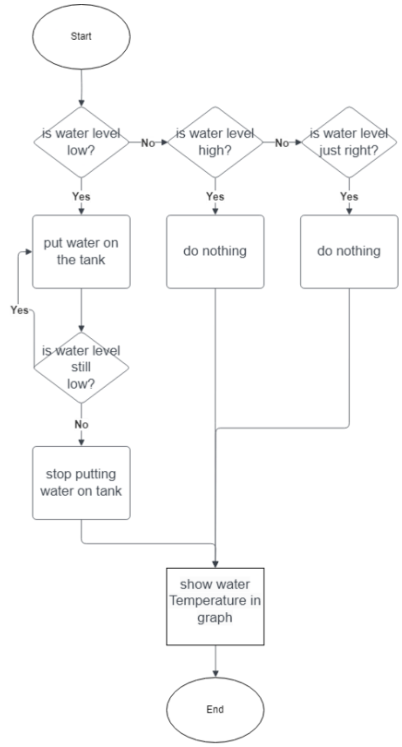
4.1 Project Design and Development

The project is composed of both hardware and software integration. The proponents that have used is Arduino Studio Integrated Drive Electronics Platform to program the automation of the of sensors and actuators of the hardware. The Arduino IDE is the primary driver of the system where it transmits the sensor values and gives instructions for when the actuator activates based on the determined data analysis of the water quality parameter. This also presents the given sensor values by monitoring the given data and transmits the data through the database. It also manages the data needed to be displayed in the Grafana Web Interface Application. Grafana is an open observability platform where it interacts data-visualization which allows users to see their data through using charts and graphs that is unified in a dashboard. This is to ensure for an easier interpretation and understanding of the data acquired by the Arduino. For wireless connection, VNC Viewer is an application where it is used for local computers and mobile devices you want to control where it can be installed to access and take control of a computer in another location.

There are following tests that are conducted for hardware are the following: pH Level, Water Level, Temperature Level, Turbidity Level, Water Level Actuator, pH Actuator, and Temperature Actuator, also for data storing and display data through the web interface for its graphical data representation of values. This correlates to the Accuracy, Reliability, Responsiveness, and Functionality overall. For the storage of data, PhpMyAdmin is utilized while for displaying of data while for the results is through using Grafana. The dashboard of the system has various sections wherein every functionality that needs to be monitors is displayed which are: pH Level, Water Level, Temperature Level, and Turbidity Level.

4.1.1 System Design





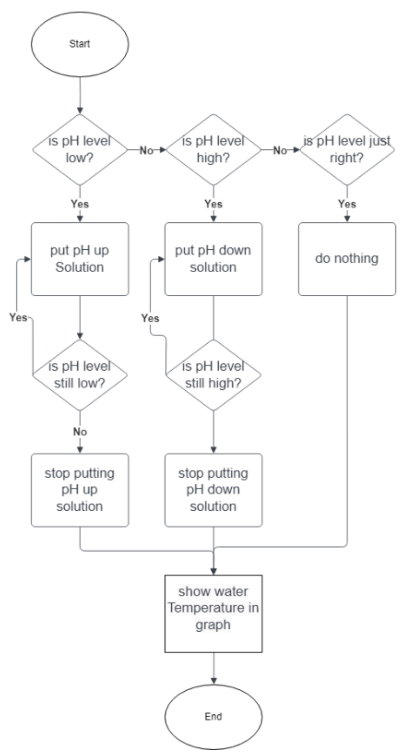


Figure 4.1 Program Flowchart

Figure 4.1 shows how to use the Arduino Integrated Drive Electronics platform to create the automation system. It will acquire first the water quality parameters and measures the data of the water. It will store the measured data first coming from the sensors and displays the data through Grafana Web Interface in its dashboard. This will compare each water quality parameter to its measured data to the threshold value of the system. If the pH Level is low, the pH UP actuator will trigger for 5 seconds and if the pH level is high, the pH down actuator will trigger. The next process is comparing the Water Temperature, if the water temperature is low, the temperature actuator will turn on and if the water temperature is high, the temperature actuator will not be activated. The next process is comparing water level, if the water level is below the threshold value, the water level actuator will activate and if the water level is above the threshold value, it will not activate. The turbidity level will not any actuator that will maintain to the threshold value, the solution that the group created is to have a better filtration system to lessen the maintenance time and for the system to maintain the water turbidity. the program flowchart shows how the different actuator parts of the system work or the parts that can change the system. the program flowchart simplifies the explanation of how the different parts work where in it can be understood by the public.

4.2 BUSINESS PLAN

4.2.1 Hardware Design

The proponents produced a business strategy for the developed hardware as computer engineering students. After such group brainstorming, the business was design to focus on system automation in terms of controlling the water quality parameter. The proponents develop a system automation where users can control, measure, and display the water quality parameter to ensure the safety of the aquaponics and maintain the current state of the system.

4.2.2 Executive Summary

SMARTBAY is a Smart Aquaponics System that allows you to automatically measure, control, and display the water quality parameter of the Aquaponics. The following sensors that are used in the system are: pH Level, Water Level, Temperature Level, and Turbidity Level. This also includes actuators that maintain the water quality parameters of the system. For Monitoring, there is also a display called RasPad 3 that monitors, controls and manage the system in terms of its graphical interface dashboard, data storing, system control, and configuration.

4.2.3 Problem

One of the problems that most people and farmers see in their aquaponics is maintaining, monitoring, and controlling the system itself. Another is from the previous group that hinders the projects due to lack of chassis design and with this, the sensors tend to be susceptible to circuit damage as well as connectivity issue in the system. The use also used low-grade sensors and actuators that can also affect the quality and sustainability of the Smart Aquaponics and lack of a better filtration system to manage the clarity of the water that takes longer human labor maintenance.

4.3.4 Project Development

The proponents are divided into three parts, each of which is fundamental in creating in the system's implementation. The proponents are divided depending on the following system design: Hardware Implementation is responsible for the hardware representation of the automation and monitoring, Software Implementation is responsible for the sensor data acquiring and measuring, determine threshold value, and actuator activation, data storing, and use of Third-Party Applications such as Arduino IDE, PhpMyAdmin, Grafana etc. Lastly, the Graphical Web Interface is responsible for Graphical Display of data acquired by the sensors which improves the data representation through using charts and graphs.

4.3.1 Hardware Implementation

Figure 4.2 SMARTBAY Aquaponics Setup (Front View)

Figure 4.4 SMARTBAY Aquaponics Setup (Side View)

Figure 4.3 SMARTBAY Aquaponics Setup (Side View)

Figure 4.5 SMARTBAY Chassis (Front View)

Figure 4.6 SMARTBAY Chassis (Back View)

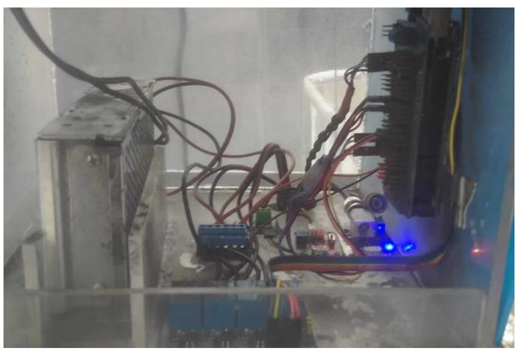


Figure 4.7 SMARTBAY Chassis (Interior)

Figure 4.8 SMARTBAY Aquaponics Set-up (Top View)

In Figure 4.2 to Figure 4.8 showcases the implementation of the hardware development. It is composed of different functions from the sensors which will detect the water quality parameter to the website graphical interface which will serve as the data representation of the system using charts and graph and to the actuators which will serve as the triggering reaction of the prototype to the measured parameter and to maintain the system. The main process of the system is to acquire and measure the current water quality parameter, display the given data to the web graphical interface and trigger the actuators to the measured sensor value in maintaining the water quality parameter through the threshold values. The sensors will give acquire and measure the pH level, Water Leve, Temperature Level, Turbidity Level.

4.3.2 Software Implementation

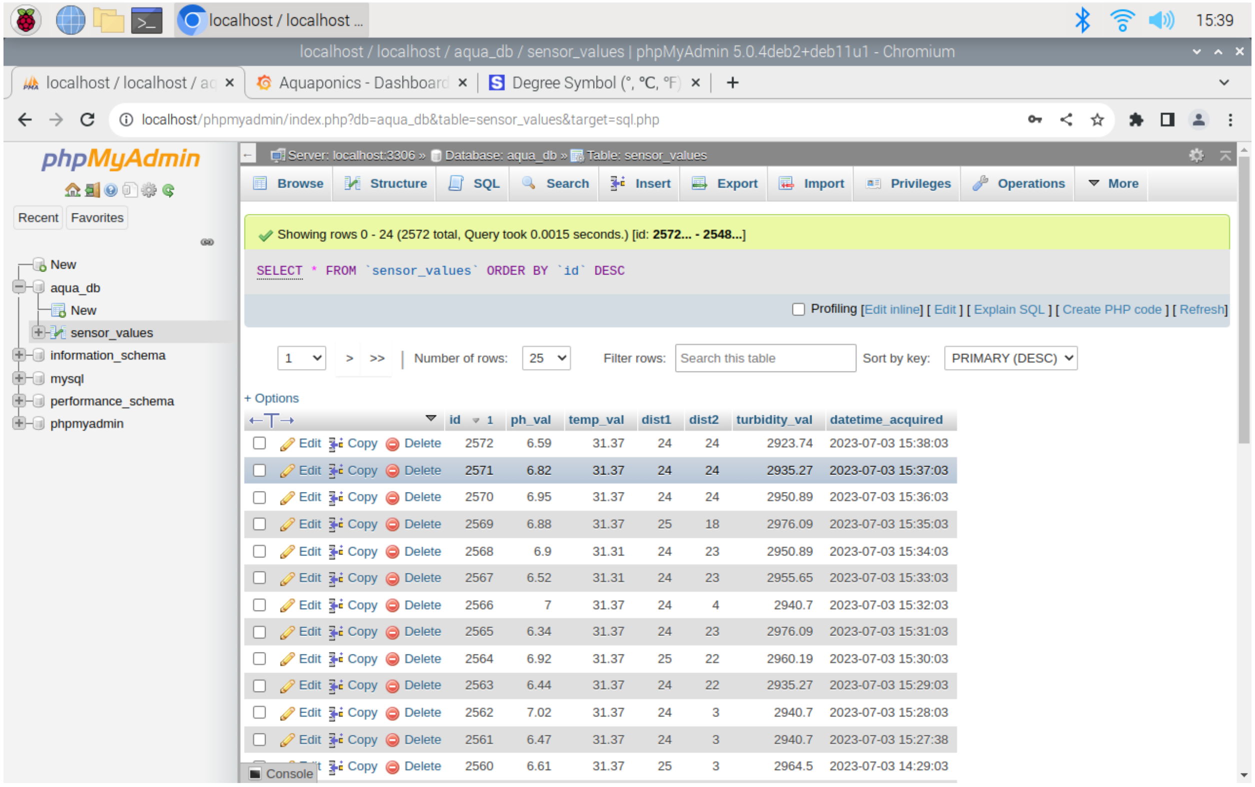


Figure 4.9 Data Storing

Figure 4.9 shows the phpMyAdmin Database where it stores the data coming from the Arduino aquaponics sensor. The database stores the receiving data from the Arduino every one minute which includes the following data: id number, pH Value, Temperature Value, Distance 1 (Fish Tank Level), Distance 2 (Water Reservoir Level), Turbidity Level, and the data and time acquired by the sensor. The database stores the data in a descending order to make data monitoring easier.

C++ programming language was used to control the sensor and actuator in the system. Arduino IDE was the primary application that has been used for the system to function. The Arduino Code contains the following water quality parameter code to set the sensor and to have a threshold value in each sensor. used for libraries, define directives, and variables used in the system. The Arduino code contains "*DallasTemperature.h*" is an Arduino library used for the DS18B20 temperature and *"OneWire.h"* is another Arduino library that is used for communication between sensor and microcontroller through a single wire interface. Define directives (#define) are C++ components that give the programmer the control to set constant variables before the program is compiled. The variables used in the system are used to indicate certain pins on the microcontroller that is connected to different sensors, and it is also used to store certain values. It also shows the software used for calculating average arrays of integers in the system. The Arduino code contains the following parameters that calculate the average array of integers with the use of formulas that take account for the maximum and minimum values to be excluded from the average calculation when appropriate. Dallas Temperature Function shows the software used for the DS18B20 Temperature sensor in the system. The Arduino code contains the following parameters that communicates with the DS18B20 Temperature Sensor, processes temperature data, converts temperature data to degrees Celsius, and returns the temperature data to float-point number. The Arduino code contains the following parameters that configures the function of pins as either input or output to and from sensor. Serial communication is used commonly for sending receiving data between the Arduino board and Raspberry Pi for monitoring and debugging purposes. The Arduino cone contains the following parameters the converts analog input from the pH sensor to voltage value then with the use of a formula calculates pH value with reference to the offset variable. Ultrasonic Distance Measurement Arduino code contains the following parameters that calculates the water level from the aquaponics and reservoir water tank with the use of echo and trigger pins. In the program shows the software used to round up or round down float-point values to a certain number of decimal places in the system. The Arduino code contains the following parameters that rounds up or rounds down floating-point values to a specified decimal point for formatting and presenting data purposes. In the program, we have used to measure the turbidity level of the water in the system. The Arduino Code contains the following parameters that calculates the turbidity level of the water in the Aquaponics system using an analog input from the turbidity sensor that is converted to voltage value then calculates it using a certain formula to create an output.In Figure.

The Arduino Code contains the following parameters that stores, defines constants, and controls the behavior of the system based on the pH reading coming from the pH sensor. In addition, it shows the software used to control the desired pH value of the Aquaponics system and to calculate the difference between the pH value attained and the desired range in the system. The Arduino Code contains the following parameters that uses relays to adjust the pH value of the Aquaponics system by adding pH-up or pH-down with the use of several formulas to maintain or achieve the desired pH range. The Arduino program shows the software used to check if relays of pH-up and pH-down pump are activated and if the activation period has elapsed in the system. The Arduino Code contains the following parameters if the relays are activated with reference to time and if the activation period has elapsed it turns off the relay and updates a certain variable. Lastly, the program shows the software used for sensor reading and control operation in the system. The Arduino Code contains the following parameters that incorporates multiple sensor readings and displaying them for monitoring and controlling purposes.

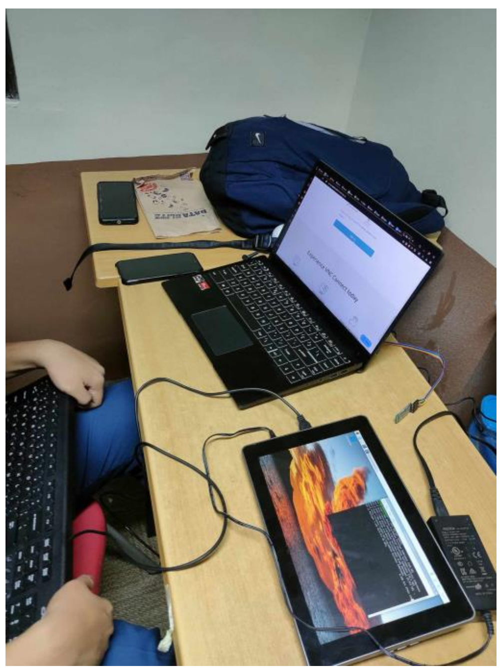


Figure 4.10 Configuring Raspberry Pi Interface

In Figure 4.10 shows the configuration of the RasPad 3, the following applications downloaded are necessary for the system to function. It installs the necessary functionality of the system. This also displays the test trials of the wireless connection between the RasPad 3 to device.

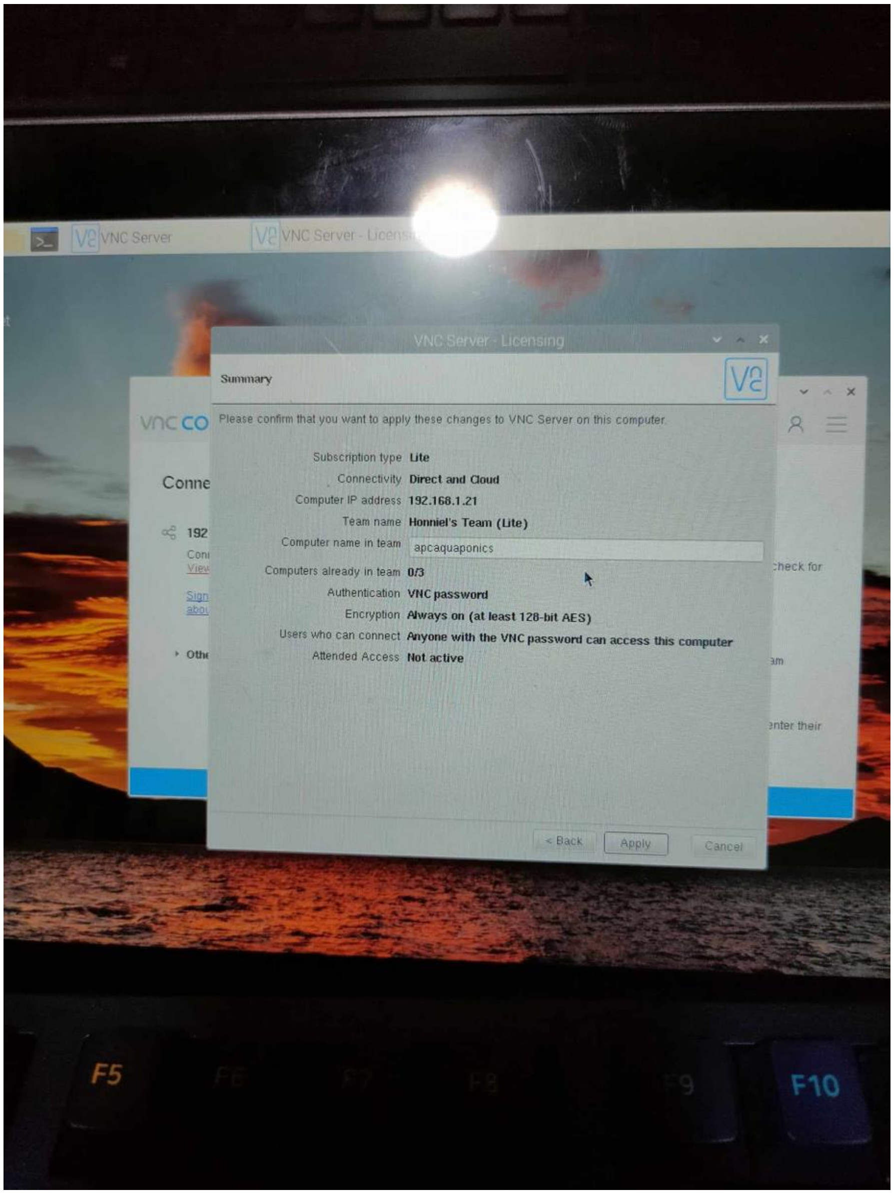


Figure 4.11 Third-Party Applications

In Figure 4.11 presents the following applications installed and configured in the RasPad 3 which are: VNC Viewer, Arduino IDE, Geany, and Python. This is where the sensors and actuators are coded as well as storing the sensor values using PhpMyAdmin. VNC Viewer has its own security in a 2-way display so that people in the same connection cannot use the same connection of your other device.

4.3.3 Graphical Web Interface

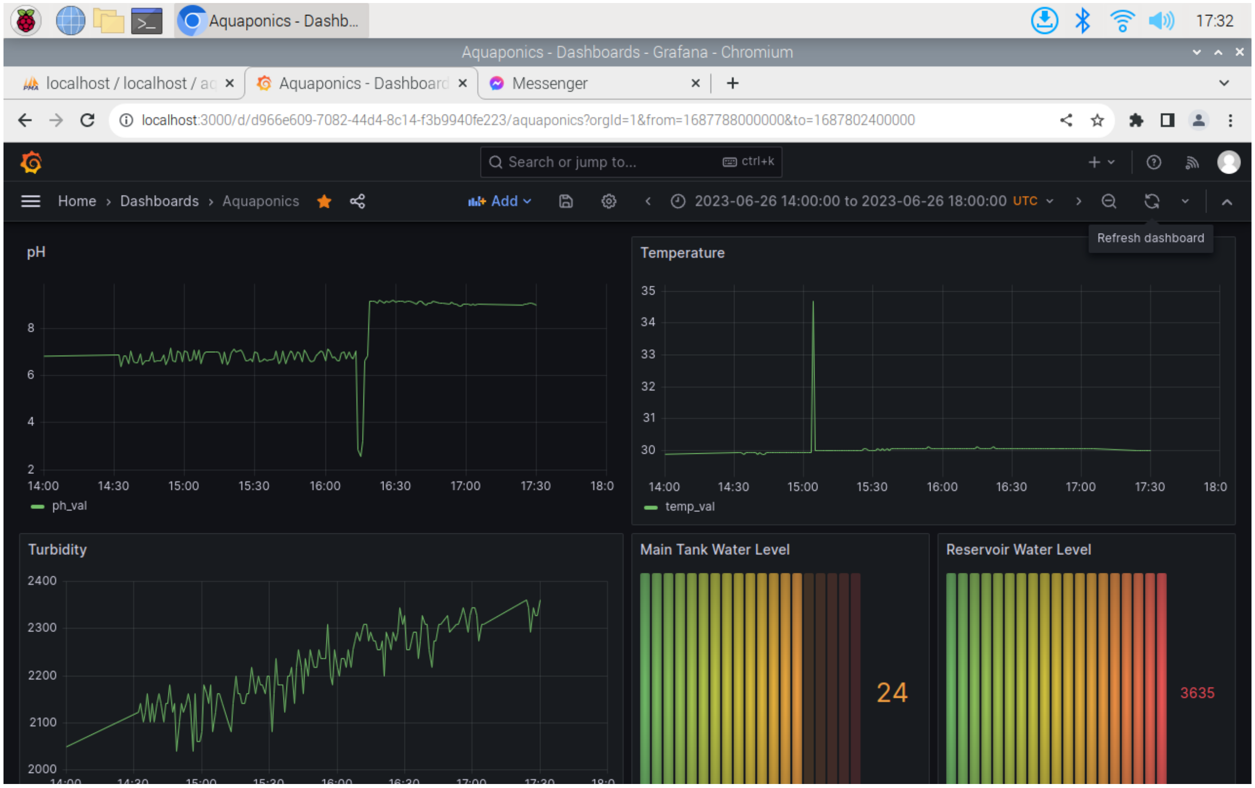


Figure 4.12 Aquaponics Graphical Web Interface

In Figure 4.12 showcases the graphical web interface of the system using Grafana. In the Grafana Dashboard shows the water quality parameters measured by the Arduino sensor which are: pH Line Graph, Temperature Line Graph, Turbidity Line Graph, Main Tank Water Level and Reservoir Column Graph. The dashboard time can be change depending on the user's desire, it can preview from 30 seconds ago, 30 minutes, 1-hour, up to the specific time and data and that the user wants. The Grafana dashboard can be change through its settings dashboard.

4.3.4 Sensors

Figure 4.13 pH Sensor

Figure 4.13 shows the pH sensor used for the system. DFRobot Gravity Analog pH Sensor is the sensor used for the system. This sensor designed for Arduino controllers which acquires the measurement at ± 0.1pH (25?). This sensor measures the pH level of the water tank as well as measuring for the test Responsiveness to the tester.

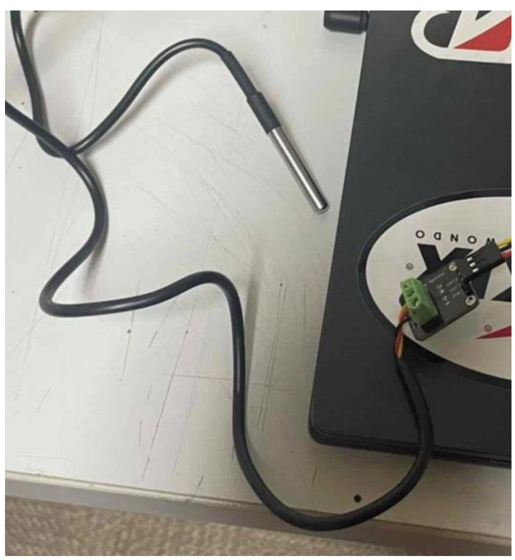


Figure 4.14 Temperature Sensor

In **Figure 4.14** shows the Temperature Sensor used in the system. The Waterproof Temperature Sensor DS18B20. The sensor is a rate up to 125° Celsius. This sensor measures the water temperature of the aquaponics system which will be the bases of the measurement.

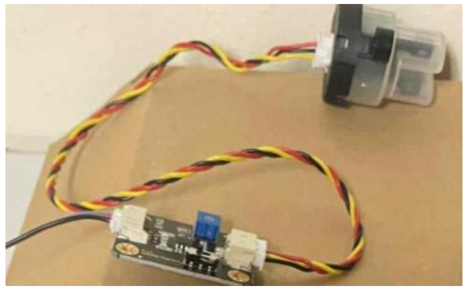


Figure 4.15 Turbidity Sensor

In **Figure 4.15** shows the turbidity sensor used in the system. The DFRobot Analog Turbidity Sensor Module Gravity is a sensor that detects the water quality by measuring the level of turbidity. It ables to detect suspended particles in water by measuring the light transmittance and scattering rate, it has a response time of <500 ms.

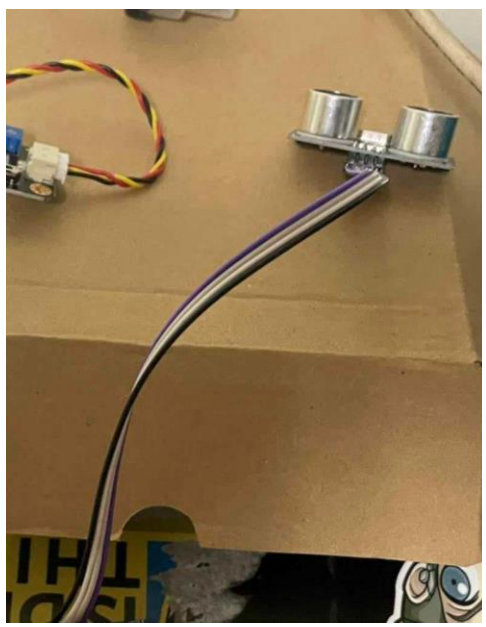


Figure 4.16 Ultrasonic Sensor

Figure 4.16 shows the Ultrasonic Sensor HC-SR04 which displays the water level of the system. It uses sonar to determine the distance to a certain object by using sound. Its operations are not affected by sunlight or dark material. It has 2 centimeters – 400 centimeters/1" – 13 ft of measuring capabilities.

4.4 Testing Procedures

This section discusses the testing procedures for each of the function and analysis of the results of functionality tested supported with the test plan and procedures in the previous chapter. During the system's testing, testing procedures were followed. The findings of the system testing were compared to the design function specification to evaluate the functionalities.

Table 4.1. Sensor Calibration Phase

Test Case	Phase 1	Phase 2	Phase 3
1	Acquires the water quality parameter of the system.	Sensor values are similar to commercially available measuring instrument values	Sensors respond to threshold values
2	Failed to Acquire the water quality parameter	Sensor values are not similar to commercially available measuring instrument values	Sensors do not respond to threshold values

Table 4.1 shows the test phase and test cases in measuring the sensor values from the threshold values to the sensor testers. In phase 1, the sensor will be evaluated through measuring instruments and laboratory tests. Test phase 1 should be completed before proceeding to test phase 2. Test phase 2 should be able to save the pre-initiated value of the system where in phase 3 will then be respond to the planned threshold value for the system to be maintained.

Table 4.2 Functional Testing: pH Sensor Calibration – Distilled Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
Distilled Water	1	5.12	4.98	2.81%	Excellent
	2	5.14	4.96	3.63%	Excellent
	3	5.02	4.99	0.60%	Excellent
	4	5.07	4.98	1.81%	Excellent
	5	5.05	4.99	1.20%	Excellent
	6	5.02	4.98	0.80%	Excellent
	7	5.09	4.98	2.21%	Excellent
	8	5.02	4.96	1.21%	Excellent
	9	5.05	4.98	1.41%	Excellent

	10	5.05	4.98	1.41%	Excellent
	11	4.99	4.99	0.00%	Excellent
	12	5.00	4.99	0.20%	Excellent
	13	5.04	4.99	1.00%	Excellent
	14	5.00	5.00	0.00%	Excellent
	15	5.04	5.00	0.80%	Excellent
	16	4.99	5.00	0.20%	Excellent
	17	5.02	5.00	0.40%	Excellent
	18	5.04	5.00	0.80%	Excellent
	19	4.99	5.00	0.20%	Excellent
	20	4.95	4.98	0.60%	Excellent
Average Error Percentage				**1.06%**	

Table 4.2 shows the functional testing results for the acidity or pH of distilled water. The pH Sensor Calibration of Distilled Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with distilled water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The results consistently demonstrate the excellent performance of the sensor, with percentage errors within the "Excellent" range, ranging from 0.00% to 3.63%, most of which are below 1%. This confirms the sensor's reliability and responsiveness in measuring the pH of distilled water, making it a highly dependable tool for such measurements. The average error percentage, calculated by summarizing the percent error of all trials, is 1.06% out of 100%.

Table 4.3 Functional Testing: pH Sensor Calibration – Purified Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
Purified Water	1	6.32	6.22	1.61%	Excellent
	2	6.28	6.18	1.62%	Excellent
	3	6.28	6.25	0.48%	Excellent
	4	6.16	6.23	1.12%	Excellent
	5	6.13	6.23	1.61%	Excellent
	6	6.25	6.23	0.32%	Excellent
	7	6.22	6.25	0.48%	Excellent
	8	6.20	6.25	0.80%	Excellent
	9	6.23	6.25	0.32%	Excellent
	10	6.22	6.26	0.64%	Excellent
	11	6.25	6.29	0.64%	Excellent
	12	6.27	6.27	0.00%	Excellent
	13	6.27	6.30	0.48%	Excellent
	14	6.27	6.31	0.63%	Excellent
	15	6.27	6.31	0.63%	Excellent
	16	6.23	6.32	1.42%	Excellent
	17	6.25	6.33	1.26%	Excellent
	18	6.23	6.33	1.58%	Excellent
	19	6.32	6.32	0.00%	Excellent
	20	6.34	6.35	0.16%	Excellent
Average Error Percentage				0.79%	

Table 4.3 shows the functional testing results for the acidity or pH of purified water. The pH Sensor Calibration of Purified Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with purified water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The results consistently demonstrate the excellent performance of the sensor, with percentage errors within the "Excellent" range, ranging from 0.00% to 1.61%, most of which are below 1%. This confirms the sensor's reliability and responsiveness in measuring the pH of purified water, making it a highly dependable tool for such measurements. The average error percentage, calculated by summarizing the percent error of all trials, is 0.79% out of 100%.

Table 4.4 Functional Testing: pH Sensor Calibration - Filtered Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
Filtered Water	1	7.29	7.57	3.70%	Excellent
	2	7.21	7.56	4.63%	Excellent
	3	7.34	7.58	3.17%	Excellent
	4	7.33	7.60	3.55%	Excellent
	5	7.43	7.60	2.24%	Excellent
	6	7.45	7.61	2.10%	Excellent
	7	7.48	7.62	1.84%	Excellent
	8	7.43	7.64	2.75%	Excellent
	9	7.5	7.64	1.83%	Excellent
	10	7.46	7.64	2.36%	Excellent
	11	7.53	7.67	1.83%	Excellent
	12	7.53	7.69	2.08%	Excellent
	13	7.5	7.69	2.47%	Excellent
	14	7.57	7.68	1.43%	Excellent
	15	7.51	7.70	2.47%	Excellent
	16	7.58	7.72	1.81%	Excellent
	17	7.62	7.72	1.30%	Excellent
	18	7.62	7.72	1.30%	Excellent
	19	7.55	7.76	2.71%	Excellent
	20	7.65	7.76	1.42%	Excellent
Average Error Percentage				2.35%	

In table 4.4 shows the functional testing results for the acidity or pH of filtered water. The pH Sensor Calibration of Filtered Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with filtered water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The results consistently demonstrate the outstanding performance of the sensor, with percentage errors within the "Excellent" range, ranging from 1.30% to 4.63%, with the majority below 2.5%. This confirms the sensor's reliability and responsiveness in measuring the pH of filtered water, making it a highly dependable tool for such measurements. The average error percentage, calculated by summarizing the percent error of all trials, is 2.35% out of 100%.

Table 4.5 Functional Testing: pH Sensor Calibration – Aquaponics Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
Aquaponics Water	1	4.71	4.53	3.97%	Excellent
	2	4.63	4.51	2.66%	Excellent
	3	4.58	4.51	1.55%	Excellent
	4	4.58	4.51	1.55%	Excellent
	5	4.52	4.51	0.22%	Excellent
	6	4.52	4.53	0.22%	Excellent
	7	4.52	4.52	0.00%	Excellent
	8	4.56	4.52	0.88%	Excellent
	9	4.58	4.52	1.33%	Excellent
	10	4.54	4.52	0.44%	Excellent
	11	4.54	4.52	0.44%	Excellent
	12	4.58	4.55	0.66%	Excellent
	13	4.61	4.54	1.54%	Excellent
	14	4.56	4.54	0.44%	Excellent
	15	4.56	4.55	0.22%	Excellent
	16	4.58	4.55	0.66%	Excellent
	17	4.54	4.55	0.22%	Excellent
	18	4.58	4.55	0.66%	Excellent
	19	4.56	4.55	0.22%	Excellent
	20	4.56	4.55	0.22%	Excellent
Average Error Percentage				0.91%	

Table 4.5 shows the functional testing results for the acidity or pH of aquaponics water. The pH Sensor Calibration of Aquaponics Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with aquaponics water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The results consistently demonstrate exceptional sensor performance, with percentage errors within the "Excellent" range, ranging from 0.00% to 3.97%. Most errors are below 2%, with some trials achieving a perfect match at 0% error. This confirms the sensor's reliability and responsiveness in measuring the pH of aquaponics water, making it a highly dependable tool for such measurements. The average error percentage, calculated by summarizing the percent error of all trials, is 0.91% out of 100%.

Table 4.6 Functional Testing: pH Sensor Calibration – NAWASA Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
NAWASA Water	1	7.33	7.59	3.43%	Excellent
	2	7.29	7.59	3.95%	Excellent
	3	7.34	7.62	3.67%	Excellent
	4	7.48	7.62	1.84%	Excellent
	5	7.48	7.63	1.97%	Excellent
	6	7.53	7.63	1.31%	Excellent
	7	7.55	7.66	1.44%	Excellent
	8	7.55	7.66	1.44%	Excellent
	9	7.48	7.66	2.35%	Excellent
	10	7.50	7.68	2.34%	Excellent
	11	7.57	7.70	1.69%	Excellent
	12	7.60	7.70	1.30%	Excellent
	13	7.55	7.70	1.95%	Excellent
	14	7.55	7.70	1.95%	Excellent
	15	7.62	7.70	1.04%	Excellent
	16	7.63	7.73	1.29%	Excellent
	17	7.65	7.72	0.91%	Excellent
	18	7.67	7.72	0.65%	Excellent
	19	7.60	7.75	1.94%	Excellent
	20	7.70	7.75	0.65%	Excellent
Average Error Percentage				1.86%	

Table 4.6 shows the functional testing results for the acidity or pH of NAWASA water. The pH Sensor Calibration of NAWASA Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with NAWASA water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The results indicate consistently good sensor performance, with very low percentage errors between the sensor and tester measurements. The pH values measured by the sensor range from 7.29 to 7.70, while the tester-measured values range from 7.59 to 7.75. The percentage errors across all trials range from 0.65% to 3.95%, highlighting the excellent accuracy and reliability of the sensor in assessing the water's acidity or pH. This confirms the sensor's reliability and responsiveness in measuring the pH of NAWASA water, making it a

highly dependable tool for such measurements. The average error percentage, calculated by summarizing the percent error of all trials, is 1.86% out of 100%.

Table 4.7 Functional Testing: pH Sensor Calibration – River Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
River Water	1	6.66	6.58	1.22%	Excellent
	2	6.68	6.59	1.37%	Excellent
	3	6.69	6.62	1.06%	Excellent
	4	6.73	6.63	1.51%	Excellent
	5	6.81	6.66	2.25%	Excellent
	6	6.75	6.67	1.20%	Excellent
	7	6.83	6.70	1.94%	Excellent
	8	6.83	6.71	1.79%	Excellent
	9	6.85	6.74	1.63%	Excellent
	10	6.83	6.74	1.34%	Excellent
	11	6.81	6.76	0.74%	Excellent
	12	6.83	6.76	1.04%	Excellent
	13	6.85	6.78	1.03%	Excellent
	14	6.93	6.81	1.76%	Excellent
	15	6.87	6.82	0.73%	Excellent
	16	6.97	6.88	1.31%	Excellent
	17	6.97	6.88	1.31%	Excellent
	18	6.99	6.92	1.22%	Excellent
	19	6.99	6.92	1.37%	Excellent
	20	7.00	6.94	1.06%	Excellent
Average Error Percentage				1.34%	

In table 4.7 shows the functional testing consistent and accurate results for the acidity or pH measurement of river water. The pH Sensor Calibration of River Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with river water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The functional testing results consistently show accurate pH measurements for river water. The sensor values closely match the tester values, with low percentage errors ranging from 0.73% to 2.25%, all classified as "Excellent." This confirms the sensor's reliability and responsiveness in measuring the pH of

NAWASA water, making it a highly dependable tool for such measurements. The average error percentage, summarizing the percent error of all trials, is 1.34% out of 100%.

Table 4.8 Functional Testing: pH Sensor Calibration – Canal Water (Test Phase 2)

FUNCTIONAL TESTING (pH Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Tester Measured		
Canal Water	1	6.83	6.75	1.19%	Excellent
	2	6.80	6.77	0.44%	Excellent
	3	6.88	6.78	1.47%	Excellent
	4	6.90	6.81	1.32%	Excellent
	5	6.92	6.82	1.47%	Excellent
	6	6.87	6.82	0.73%	Excellent
	7	6.88	6.89	0.15%	Excellent
	8	6.97	6.91	0.87%	Excellent
	9	6.92	6.94	0.29%	Excellent
	10	7.04	6.94	1.44%	Excellent
	11	7.00	6.96	0.57%	Excellent
	12	6.97	6.98	0.14%	Excellent
	13	7.04	6.99	0.72%	Excellent
	14	7.05	7.01	0.57%	Excellent
	15	7.09	7.04	0.71%	Excellent
	16	7.04	7.04	0.00%	Excellent
	17	7.04	7.06	0.28%	Excellent
	18	7.14	7.09	0.71%	Excellent
	19	7.14	7.12	0.28%	Excellent
	20	7.17	7.16	0.14%	Excellent
Average Error Percentage				0.67%	

Table 4.8 shows the functional testing results for the acidity or pH of canal water. The pH Sensor Calibration of Canal Water was performed by placing the DFRobot Gravity: Analog pH Sensor and pH meter in a cup filled with canal water. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the DFRobot Gravity: Analog pH Sensor were cross-checked in the database. It consistently met the specifications, accurately measuring the current pH level at that moment. The functional testing results reveal a high level of accuracy and reliability between the sensor-measured values and the tester-measured values. Throughout the 20 trials, the sensor's measurements closely matched the tester's measurements, with low percentage errors ranging from 0.00% to 1.47%. These results underscore the sensor's excellent performance in accurately

assessing the canal water's pH levels. Overall, this confirms the sensor's reliability and responsiveness in measuring the pH of NAWASA water, making it a highly dependable tool for such measurements. The average error percentage, summarizing the percent error of all trials, is 0.67% out of 100%.

Table 4.9 Functional Testing: Turbidity Calibration: Canal Water (Test Phase 2)

FUNCTIONAL TESTING (Turbidity Calibration)	TRIALS	COMPARE Sensor Values		Calibration Equation
		Sensor Measured	Tester Measured	
Canal Water	1	2081.36	400	167.98
	2	1955.33	400	160.39
	3	2141.35	400	171.60
	4	2101.58	400	169.20
	5	1889.29	400	156.40
	6	2180.22	400	173.94
	7	1751.16	400	148.08
	8	2617.27	400	200.29
	9	2604	400	199.49
	10	1727.35	400	146.65
	11	2291.46	400	180.65
	12	2394.63	400	186.87
	13	2680.29	400	204.09
	14	2489.74	400	192.60
	15	2060.91	400	166.75
	16	1866.82	400	155.05
	17	2040.24	400	165.51
	18	2218.20	400	176.23
	19	1343.37	400	123.50
	20	2326.75	400	182.78
Average Output Difference				15.45%

In Table 4.9 shows the functional testing for the turbidity calibration for canal water. The turbidity calibration of river water involved placing the DFRobot Analog Turbidity Sensor Module Gravity Series in a cup filled with the same canal water as submitted to Hi-Advance Philippines Inc. The sensor's results were compared with the Hi-Advance Philippines Inc. Laboratory data, affirming that the turbidity sensor met the specified standards for effectively assessing the transparency of the water. This calibration comprised 20 trials with an interval of 2 mins for each trial to align the sensor measurements with those of the laboratory. The laboratory's data indicated a turbidity level of 400 NTU, representing the highest turbidity level for the testing. A calibration equation was formulated to establish the correlation between the sensor and tester measurements. This is where first computation for the linear regression is whereas:

Formula:

Data Points:

Actual: [400, 94, 30, 0]　　　　Output: [2138.07, 850. 89, 531.37, 0]

Variables:

Actual = Tester Measured　　　　A * Data Point 4 = Output

B = Sensor Measured Data Point 4　　　　A = Output/Data Point 2

A = Sensor Measured Data Point 2

$$Output = A * Actual + B \qquad \textbf{Eq 4.1}$$

Equation 4.1 presents the following procedures to create a calibration equation for turbidity testing of canal water that will relate the output values to the actual values. The Actual values came from the tests of HiAdvance and the output value came from the average of the turbidity sensor measured of each water sources. The actual values will be the basis of our average difference between the actual and output. We will first calculate B by using Data Point 4 and the output of B is $= -705.52$. After that, we will use another Data Point in calculating A. We will use Data Point 2 as our formula in finding A. In Equation 4.2 will then be converted into $850.89 = A * 94 - 705.52$ and by adding 705.52 on both sides, we will have the then now have 1556.41 as our value for the next equation.

$$A = output/data\ point\ 2 \qquad \textbf{Eq 4.2}$$

Equation 4.2. is used to calibrate A. We will need to divide $A = \frac{1556.41}{94}$ and have the value as 16.59 and the formula would be $Output = 16.59 * Actual - 705.52$. That will be used to predict the output based on the actual value.

In expressing the calibration equation in terms of the output, we can rearrange it and we will add 705.52 on both sides then divide it by 16.59.

$$Actual = \frac{(Output + 705.52)}{16.59} \qquad \textbf{Eq. 4.3}$$

Equation 4.3 is the Calibration Equation based on Output. After Finding the Calibration Equation, you will average all the trial by using the Average Absolute Difference Formula. In this case we will use python to compute for Average Absolute difference:

```
import numpy as np

data = [167.98,
160.39,
171.60,
169.20,
156.40,
173.94,
148.08,
200.29,
199.49,
146.65,
180.65,
186.87,
204.09,
192.60,
166.75,
155.05,
165.51,
176.23,
123.50,
182.78

]
mean = np.mean(data)
absolute_differences = [abs(x - mean) for x in data]
average_absolute_difference = np.mean(absolute_differences)

print("Average Absolute Difference:", average_absolute_difference)
```

```
[Running] python -u "c:\Users\mhonn\OneDrive\Desktop\aw.py"
Average Absolute Difference: 15.451500000000001

[Done] exited with code=0 in 0.467 seconds
```

Figure 4.17 Average Absolute difference using Python for canal water.

Based on the computed average output difference between the sensor measured and laboratory measured, the average absolute difference for Canal Water is 15.45%

Table 4.10 Functional Testing: Turbidity Calibration – River Water (Test Phase 2)

FUNCTIONAL TESTING (Turbidity Calibration)	TRIALS	COMPARE Sensor Values		Calibration Equation
		Sensor Measured	Tester Measured	
River Water	1	721.19	94	85.99819
	2	784.97	94	89.84268
	3	847.24	94	93.59614
	4	847.24	94	93.59614
	5	816.04	94	91.71549
	6	816.04	94	91.71549
	7	752.97	94	87.9138
	8	689.000	94	84.05787
	9	689.000	94	84.05787
	10	878.22	94	95.46353
	11	784.62	94	89.82158
	12	816.04	94	91.71549
	13	847.24	94	93.59614
	14	939.50	94	99.15732
	15	969.81	94	100.9843
	16	969.81	94	100.9843
	17	969.81	94	100.9843
	18	969.81	94	100.9843
	19	939.50	94	99.15732
	20	969.81	94	100.9843
Average Absolute Output Difference				4.82%

In Table 4.10 shows the functional testing for the turbidity calibration for river water. The turbidity calibration of river water involved placing the DFRobot Analog Turbidity Sensor Module Gravity Series in a cup filled with the same river water as submitted to Hi-Advance Philippines Inc. The sensor's results were compared with the Hi-Advance Philippines Inc. Laboratory data, affirming that the turbidity sensor met the specified standards for effectively assessing the transparency of the water. This calibration included 20 trials with an interval of 2 mins for each trial to align the sensor measurements with those of the laboratory. The laboratory's data indicated a turbidity level of 94 NTU, representing the second highest turbidity level for the testing. A calibration equation was formulated to establish the correlation between the sensor and tester measurements, using linear regression where:

Formula:

Data Points:

Actual: [400, 94, 30, 0]

Output: [2138.07, 850. 89, 531.37, 0]

Variables:

Actual = Tester Measured

A * Data Point 4 = Output

B = Sensor Measured Data Point 4

A = Output/Data Point 2

A = Sensor Measured Data Point 2

. The formula and procedure in creating a calibration equation is similar to the Equation 4.1, 4.2, and 4.3 in Table 4.10 about the Functionality Testing on Turbidity Calibration of Canal Water. After Finding the Calibration Equation, you will average all the trial by using the Average Absolute Difference Formula. In this case we will use python to compute for Average Absolute difference:

```
aw.py    averasge.py    Workspace Trust
C: > Users > mhonn > OneDrive > Desktop > aw.py > ...
import numpy as np

data = [85.99819,
89.84268,
93.59614,
93.59614,
91.71549,
91.71549,
87.9138,
84.05787,
84.05787,
95.46353,
89.82158,
91.71549,
93.59614,
99.15732,
100.9843,
100.9843,
100.9843,
100.9843,
99.15732,
100.9843
]
mean = np.mean(data)
absolute_differences = [abs(x - mean) for x in data]
average_absolute_difference = np.mean(absolute_differences)

print("Average Absolute Difference:", average_absolute_difference)
```

```
PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL   COMMENTS   PORTS

[Running] python -u "c:\Users\mhonn\OneDrive\Desktop\aw.py"
Average Absolute Difference: 4.816905000000007

[Done] exited with code=0 in 1.211 seconds
```

Figure 4.18 Average Absolute difference using Python for river water.

Based on the computed average output difference between the sensor measured and HiAdvance laboratory measured, the average absolute difference for River Water is 4.82%

Table 4.11 Function Testing: Turbidity Calibration - Distilled Water (Test Phase 2)

FUNCTIONAL TESTING (Turbidity Calibration)	TRIALS	COMPARE Sensor Values		Calibration Equation
		Sensor Measured	Tester Measured	
Distilled Water	1	-737.56	0	-1.931
	2	-737.56	0	-1.931
	3	-1072.32	0	-22.11
	4	-300.69	0	24.40
	5	-861.42	0	-9.40
	6	-696.73	0	0.53
	7	-903.15	0	-11.91
	8	-696.73	0	0.53
	9	-456.42	0	15.02
	10	-945.11	0	-14.44
	11	-903.15	0	-11.91
	12	-819.91	0	-6.90
	13	-945.11	0	-14.44
	14	-1029.69	0	-19.54
	15	-861.42	0	-9.40
	16	-656.12	0	2.98
	17	-575.56	0	7.83
	18	-339.29	0	22.08
	19	-36.80	0	40.31
	20	-535.63	0	10.24
Average Absolute Output Difference				12.39%

In Table 4.11 shows the functional testing for the turbidity calibration for distilled water. The turbidity calibration of distilled water involved placing the DFRobot Analog Turbidity Sensor Module Gravity Series in a cup filled with the same distilled water as submitted to Hi-Advance Philippines Inc. The sensor's results were compared with the Hi-Advance Philippines Inc. Laboratory data, affirming that the turbidity sensor met the specified standards for effectively assessing the transparency of the water. This calibration comprised 20 trials with an interval of 2 mins for each trial to align the sensor measurements with those of the laboratory. The laboratory's data indicated a turbidity level of 0 NTU, representing the fourth turbidity level for the testing. A calibration equation was derived to establish the correlation between the sensor and tester measurements, using linear regression. The sensor and tester measured should be first formulate by calibration equation. This is first computation for the linear regression is:

Formula:

Data Points:

Actual: [400, 94, 30, 0] Output: [2138.07, 850. 89, 531.37, 0]

Variables:

Actual = Tester Measured

B = Sensor Measured Data Point 4

A = Sensor Measured Data Point 2

A * Data Point 4 = Output

A = Output/Data Point 2

The formula and procedure in creating a calibration equation is similar to the Equation 4.2, 4.3, and 4.4 in Table 4.9 about the Functionality Testing on Turbidity Calibration of Canal Water. After Finding the Calibration Equation, you will average all the trial by using the Average Absolute Difference Formula. In this case we will use python to compute for Average Absolute difference:

aw.py × averasge.py Workspace Trust

C: > Users > mhonn > OneDrive > Desktop > aw.py > ...

```python
import numpy as np

data = [-1.931,
-1.931,
-22.11,
24.40,
-9.40,
0.53,
-11.91,
0.53,
15.02,
-14.44,
-11.91,
-6.90,
-14.44,
-19.54,
-9.40,
2.98,
7.83,
22.08,
40.31,
10.24

]
mean = np.mean(data)
absolute_differences = [abs(x - mean) for x in data]
average_absolute_difference = np.mean(absolute_differences)

print("Average Absolute Difference:", average_absolute_difference)
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL COMMENTS PORTS

```
[Running] python -u "c:\Users\mhonn\OneDrive\Desktop\aw.py"
Average Absolute Difference: 12.391639999999999
```

Figure 4.19 Average Absolute difference using Python for distilled water.

Based on the computed average output difference between the sensor measured and laboratory measured, the average absolute difference for River Water is 12.39%

Table 4.12 Functional Testing: Turbidity Calibration – Aquaponics Water (Test Phase 2)

FUNCTIONAL TESTING (Turbidity Calibration)	TRIALS	COMPARE Sensor Values		Calibration Equation
		Sensor Measured	Tester Measured	
Aquaponics Water	1	-456.420	3	15.02
	2	-535.630	3	10.24
	3	-1646.890	3	-56.74
	4	-1646.890	3	-56.74
	5	-1510.930	3	-48.55
	6	-1421.420	3	-43.15
	7	-1288.820	3	-35.16
	8	-1245.080	3	-32.52
	9	-1072.320	3	-22.11
	10	-1158.250	3	-27.29
	11	-1115.170	3	-24.69
	12	-1072.320	3	-22.11
	13	-1029.690	3	-19.54
	14	-1029.690	3	-19.54
	15	-987.290	3	-16.98
	16	-945.110	3	-14.44
	17	-903.150	3	-11.91
	18	-903.150	3	-11.91
	19	-456.420	3	15.02
	20	-778.630	3	-4.41
Average Absolute Output Difference				15.53%

In Table 4.12 shows the functional testing for the turbidity calibration for aquaponics water. The turbidity calibration of aquaponics water involved placing the DFRobot Analog Turbidity Sensor Module Gravity Series in a cup filled with the same aquaponics water as submitted to Hi-Advance Philippines Inc. The sensor's results were compared with the Hi-Advance Philippines Inc. Laboratory data, affirming that the turbidity sensor met the specified standards for effectively assessing the transparency of the water. This calibration included 20 trials with an interval of 2 mins for each trial to align the sensor measurements with those of the laboratory. The laboratory's data indicated a turbidity level of 3 NTU, representing the third turbidity level for the testing. A calibration equation was derived to establish the correlation between the sensor and tester measurements, using linear regression.

Formula:

Data Points:

Actual: [400, 94, 30, 0]

Output: [2138.07, 850. 89, 531.37, 0]

Variables:

Actual = Tester Measured

B = Sensor Measured Data Point 4

A = Sensor Measured Data Point 2

A * Data Point 4 = Output

A = Output/Data Point 2

. The formula and procedure in creating a calibration equation is similar to the Equation 4.1, 4.2, and 4.3 in Table 4.9 about the Functionality Testing on Turbidity Calibration of Canal Water. After Finding the Calibration Equation, you will average all the trial by using the Average Absolute Difference Formula. In this case we will use python to compute for Average Absolute difference:

```python
import numpy as np

data = [15.02,
10.24,
-56.74,
-56.74,
-48.55,
-43.15,
-35.16,
-32.52,
-22.11,
-27.29,
-24.69,
-22.11,
-19.54,
-19.54,
-16.98,
-14.44,
-11.91,
-11.91,
15.02,
-4.41

]
mean = np.mean(data)
absolute_differences = [abs(x - mean) for x in data]
average_absolute_difference = np.mean(absolute_differences)

print("Average Absolute Difference:", average_absolute_difference)
```

```
ROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL   COMMENTS   PORTS
verage Absolute Difference: 15.5305
```

Figure 4.20 Average Absolute difference using Python for aquaponics water.

Based on the computed average output difference between the sensor measured and laboratory measured, the average absolute difference for River Water is 15.53%

Table 4.13 Turbidity Calibration Computation in Excel

Canal Water			River Water			Distilled Water			Aquaponics Water		
Sensor	Laboratory	Calibration	Sensor	Laboratory	Calibration	Sensor	Laboratory	Calibration	Sensor	Laboratory	Calibration
2081.36	400	167.98	721.19	94	85.99	-737.56	0	-1.93	-456.42	3	15.01
1955.33	400	160.38	784.97	94	89.84	-737.56	0	-1.93	-535.63	3	10.24
2141.35	400	171.60	847.24	94	93.59	-1072.32	0	-22.10	-1646.89	3	-56.74
2101.58	400	169.20	847.24	94	93.59	-300.69	0	24.40	-1646.89	3	-56.74
1889.29	400	156.40	816.04	94	91.71	-861.42	0	-9.39	-1510.93	3	-48.54
2180.22	400	173.94	816.04	94	91.71	-696.73	0	0.52	-1421.42	3	-43.15
1751.16	400	148.08	752.97	94	87.91	-903.15	0	-11.91	-1288.82	3	-35.15
2617.27	400	200.28	689.000	94	84.05	-696.73	0	0.52	-1245.08	3	-32.52
2604	400	199.48	689.000	94	84.05	-456.42	0	15.01	-1072.32	3	-22.10
1727.35	400	146.64	878.22	94	95.46	-945.11	0	-14.44	-1158.25	3	-27.28
2291.46	400	180.64	784.62	94	89.82	-903.15	0	-11.91	-1115.17	3	-24.69
2394.63	400	186.86	816.04	94	91.71	-819.91	0	-6.89	-1072.32	3	-22.10
2680.29	400	204.08	847.24	94	93.59	-945.11	0	-14.44	-1029.69	3	-19.54
2489.74	400	192.60	939.50	94	99.15	-1029.69	0	-19.54	-1029.69	3	-19.54
2060.91	400	166.75	969.81	94	100.98	-861.42	0	-9.39	-987.29	3	-16.98
1866.82	400	155.05	969.81	94	100.98	-656.12	0	2.97	-945.11	3	-14.44
2040.24	400	165.50	969.81	94	100.98	-575.56	0	7.83	-903.15	3	-11.91
2218.20	400	176.23	969.81	94	100.98	-339.29	0	22.07	-903.15	3	-11.91
1343.37	400	123.50	939.50	94	99.15	-36.80	0	40.30	-456.42	3	15.01
2326.75	400	182.77	969.81	94	100.98	-535.63	0	10.24	-778.63	3	-4.40
Average Absolute Difference %		**15.45%**	**Average Absolute Difference %**		**4.82%**	**Average Absolute Difference %**		**12.39%**	**Average Absolute Difference %**		**15.53%**
Average= 12.05%											

In table 4.13 presents the following computation in finding the Turbidity of each water sources. Each water sources have been computed by using the calibration equation. In creating the calibration equation to relate to the actual values to the output values in the case, we need to use linear regression equation to predict the value of an unknown data by using another related and known data value/s. Each water sources have 20 trials to determine its accuracy and reliability of the sensor. The NTU value of the sensor is different from the NTU of HiAdvance because the Arduino code has its own computation in acquiring the Turbidity Level. The description of NTU that HiAdvance used is the standard for scaling the Nephelometric Turbidity Units to measure the cloudiness of a fluid, the higher the NTU the lower the clarity and the lower the NTU the higher the clarity. Based on the table above, the average absolute difference of canal water in its sensor and laboratory test is 15.45% while for river water is 4.82%, distilled water is 12.39%, and while for the aquaponics water is measured at 15.53%

Table 4.14 Functional Testing: Water Level Calibration (Test Phase 2)

FUNCTIONAL TESTING (Water Level)	TRIALS	COMPARE Sensor Values		% Error	Remarks
		Sensor Measured	Tester Measured		
Water Surface Level	1	23 cm	24 cm	4.35%	Excellent
	2	24 cm	25 cm	4.17%	Excellent
	3	21 cm	22 cm	4.76%	Excellent

Table 4.14 shows the water level sensor (ultrasonic sensor) functionality test. The water level was performed by placing the HC-SR04 Ultrasonic Sensor above the aquaponics fish tank and placed the meter stick leveled with the front of the ultrasonic sensor where the prongs are to get the value from the front of the ultrasonic sensor to the surface level of the water of the aquaponics fish tank. The tester manipulated the amount of water by removing and adding some water inside the aquaponics system to try and simulate what is happening in the aquaponics throughout the day/week. Based on the functional testing, of the 3 trials all of the following contains an excellent remark.

Table 4.15 Functional Testing: Water Temperature Calibration Hot (Test Phase 2)

FUNCTIONAL TESTING (Temperature Calibration)	TRIALS	COMPARE Sensor Values		% Percentage Error	Remarks
		Sensor Measured	Test Measured		
Hot	1	59.56	53	12.38%	Good
	2	57.06	51	11.88%	Good
	3	54.56	50.5	8.04%	Very Good
	4	52.56	49.5	6.18%	Very Good
	5	50.25	45.5	10.44%	Good
	6	49.5	44	12.5%	Good
	7	47.88	43.5	10.07%	Good
	8	46.5	42.5	9.41%	Very Good
	9	44.94	41.5	8.29%	Very Good
	10	57.06	49	16.45%	Fair
	11	54.44	48.5	12.25%	Good
	12	52.5	47	11.70%	Good
	13	50.81	46	10.47%	Good
	14	49.31	44	12.07%	Good
	15	48.13	43	11.93%	Good
	16	46.56	42.5	9.55%	Very Good
	17	53.38	47.5	12.37%	Good
	18	51.94	47.5	9.35%	Very Good
	19	50.38	45	11.96%	Good
	20	47.44	42	12.95%	Very Good
Average Error Percentage				11.01%	

To test the functionality of the sensor to acquire the temperature of the water. In Table 4.15, the water temperature sensor calibration of how water was performed by playing the Waterproof Temperature Sensor DS18B20 and TDS&EC water temperature meter in a cup filled with hot water. Every 2 minutes, the TDS&EC water temperature meter was used to collect each trial, and the results from the Waterproof Temperature Sensor DS18B20 were cross-checked in the database. It met the specifications, accurately measuring the current water temperature level at that moment. The functional testing results show variable performance by the sensor compared to the tester measurements, with percent errors ranging from 6.18% to 12.95%. Most trials exhibit "Good" remarks, while trials 3, 4, 8, 9, 15, 18, and 20 exhibit "Very Good" remarks. Overall, the results provide reliable measurements of the hot water temperature, with most trials indicating responsive readings.

Table 4.16 Functional Testing: Water Temperature Calibration Aquaponics (Test Phase 2)

FUNCTIONAL TESTING (Temperature Calibration)	TRIALS	COMPARE Sensor Values		Percentage Error %	Result
		Sensor Measured	Test Measured		
Aqua	1	30.87	30.5	1.21%	Excellent
	2	30.87	30.5	1.21%	Excellent
	3	30.87	30.5	1.21%	Excellent
	4	30.87	30.5	1.21%	Excellent
	5	30.87	30.5	1.21%	Excellent
	6	30.87	30.5	1.21%	Excellent
	7	30.87	30.7	0.55%	Excellent
	8	30.87	30.5	1.21%	Excellent
	9	30.87	29.6	4.29%	Excellent
	10	30.87	29.3	5.36%	Excellent
	11	30.87	30.5	1.21%	Excellent
	12	30.87	30.5	1.21%	Excellent
	13	30.87	29.3	5.36%	Very Good
	14	30.87	30.5	1.21%	Excellent
	15	30.87	29.3	5.36%	Very Good
	16	30.81	29.3	5.15%	Very Good
	17	30.81	30.5	1.02%	Excellent
	18	30.81	29.6	4.08%	Excellent
	19	30.81	30.5	1.02%	Excellent
	20	30.81	30.5	1.02%	Excellent
Average Error Percentage				2.27%	

In Table 4.16 shows that the functional testing results for the aqua water temperature indicate variable performance by the sensor when compared to the tester measurements. The water temperature sensor calibration of aquaponics water was performed by placing the Waterproof

Temperature Sensor DS18B20 and TDS&EC water temperature meter in the aquaponics main tank filled with water. Every 2 minutes, the TDS&EC water temperature meter was used to collect each trial, and the results from the Waterproof Temperature Sensor DS18B20 were cross-checked in the database. It met the specifications, accurately measuring the current water temperature level at that moment. The functional testing results for the aquaponics water temperature indicate changing performance by the sensor compared to the tester measurements. The percent errors range from 0.55% to 5.36%, consistently showcasing "Very Good" and "Excellent" performance. This demonstrates that the sensor reliability provides responsive measurements, with a few instances showing slightly higher but still acceptable errors.

Table 4.17 Functional Testing: Water Temperature Calibration – Cold (Test Phase 2)

FUNCTIONAL TESTING (Temperature Calibration)	TRIALS	COMPARE Sensor Values		Percentage Error%	Remarks
		Sensor Measured	Test Measured		
Cold	1	23.94	26.6	10%	Very Good
	2	24.37	26	8.38%	Very Good
	3	24.69	26	5.04%	Very Good
	4	24.94	26	4.08%	Excellent
	5	25.19	26	3.14%	Excellent
	6	25.44	26	2.15%	Excellent
	7	25.75	27.5	6.36%	Very Good
	8	25.97	27.5	5.56%	Very Good
	9	26.06	27	3.48%	Excellent
	10	26.31	27	2.56%	Excellent
	11	23.19	25	7.24%	Very Good
	12	23.5	26.3	10.65%	Good
	13	24.44	27.5	11.13%	Good
	14	24.81	26	4.58%	Excellent
	15	25.25	27.5	8.18%	Very Good
	16	25.56	27.5	7.05%	Very Good
	17	26.12	27.5	5.02%	Very Good
	18	26.57	27.5	7.02%	Very Good
	19	26.12	27.5	5.09%	Very Good
	20	26.31	27	2.56%	Excellent
Average Error Percentage				5.96%	

Table 4.17 shows that the functional testing results for the water temperature indicate variable performance by sensor when compared to the tester measurement. The water temperature Sensor Calibration of cold water was performed by placing the Waterproof Temperature Sensor

DS18B20 and TDS&EC water temperature meter in a cup filled with cold water. Every 2 minutes, the TDS&EC water temperature meter was used to collect each trial, and the results from the Waterproof Temperature Sensor DS18B20 were cross-checked in the database. It met the specifications, accurately measuring the current water temperature level at that moment. The functional testing results demonstrate variable performance by the sensor compared to the tester measurement. It reveals consistent performance, with some trials showcasing "Excellent" remarks such as trials 4, 5, 6, 9, 10, 14, and 20, and a few trials displaying "Good" remarks like trials 12 and 13 Overall, the results provide reliable measurements of the hot water temperature, with most trials indicating responsive readings, with a few instances showing slightly higher but acceptable errors. Overall, these results suggest that the sensor consistently provides accurate measurements with few showing slightly higher but acceptable errors and has an average error percentage of 5.96% out of 100%

Table 4.18. Sensor Actuator Phase

Test Case	Phase 1	Phase 2
1	Actuator/s activated	Actuator responds to the value measured to the threshold value
2	Actuator/s did not activate	Actuator do not respond to the value measured to the threshold value

Table 4.18 shows the test phase and test cases in measuring the actuator values from the threshold values. In phase 1, the actuators should turn on when the sensor value is below or above the threshold value. Test phase 1 should be completed before proceeding to test phase 2. Test phase 2 should respond to the value measured to the threshold value.

Table 4.19 Functional Testing: pH Actuator Testing (Test Phase 2)

FUNCTIONAL TESTING (pH Testing)	TRIALS	CHECKLIST			Remarks
		Sensor Value	Working	Defective	
pH UP	1	4.5	✓		Actuator has been Activated
	2	4.6	✓		Actuator has been Activated
	3	4.7	✓		Actuator has been Activated

	4	5.0	✓		Actuator has been Activated
	5	5.4	✓		Actuator has been Activated
	6	5.1	✓		Actuator has been Activated
	7	4.3	✓		Actuator has been Activated
	8	4.4	✓		Actuator has been Activated
	9	5.2	✓		Actuator has been Activated
	10	5.3	✓		Actuator has been Activated
pH DOWN	1	7.1	✓		Actuator has been Activated
	2	7.9	✓		Actuator has been Activated
	3	8.0	✓		Actuator has been Activated
	4	7.5	✓		Actuator has been Activated
	5	9.0	✓		Actuator has been Activated
	6	7.6	✓		Actuator has been Activated
	7	8.1	✓		Actuator has been Activated
	8	7.2	✓		Actuator has been Activated
	9	9.1	✓		Actuator has been Activated
	10	7.7	✓		Actuator has been Activated

Table 4.19 shows if the pH actuators are functioning as intended based on the testers. We have tested the pH up and pH down peristaltic pumps if it is functioning based on the time that the testers set the pump to be activated. They have used a container as their base in putting pH solution in the water. Every trial conducted acquires the current pH level and there will be 10 trials in each functionality. This is to ensure its responsiveness and the actuator will be triggered once the pH level has changed its value outside the threshold value. Based on the trials conducted, the test was successful and both peristaltic pumps are working as intended.

Table 4.20 Functional Testing: pH Actuator Testing 2 (Test Phase 2)

FUNCTIONAL TESTING (pH Testing)	TRIALS	TIME ACTIVATION	pH UP OR DOWN SOLUTION OUTPUT	REMARKS
pH Up and pH Down Actuator pump	1	15 Seconds	26 mL	Actuator has been Activated
		16 Seconds	27.5 mL	Actuator has been Activated
		17 Seconds	30 mL	Actuator has been Activated
		18 Seconds	31 mL	Actuator has been Activated
		19 Seconds	33 mL	Actuator has been Activated
		20 Seconds	35 mL	Actuator has been Activated
	2	15 Seconds	26 mL	Actuator has been Activated
		16 Seconds	28 mL	Actuator has been Activated
		17 Seconds	30 mL	Actuator has been Activated
		18 Seconds	31.5 mL	Actuator has been Activated
		19 Seconds	33 mL	Actuator has been Activated
		20 Seconds	35 mL	Actuator has been Activated
	3	15 Seconds	26 mL	Actuator has been Activated
		16 Seconds	28 mL	Actuator has been Activated
		17 Seconds	30 mL	Actuator has been Activated

		18 Seconds	31.5 mL	Actuator has been Activated
		19 Seconds	33 mL	Actuator has been Activated
		20 Seconds	35 mL	Actuator has been Activated
	4	15 Seconds	26 mL	Actuator has been Activated
		16 Seconds	28 mL	Actuator has been Activated
		17 Seconds	30 mL	Actuator has been Activated
		18 Seconds	32 mL	Actuator has been Activated
		19 Seconds	33.5 mL	Actuator has been Activated
		20 Seconds	35 mL	Actuator has been Activated
	5	15 Seconds	26 mL	Actuator has been Activated
		16 Seconds	28 mL	Actuator has been Activated
		17 Seconds	30 mL	Actuator has been Activated
		18 Seconds	31.5 mL	Actuator has been Activated
		19 Seconds	33 mL	Actuator has been Activated
		20 Seconds	35 mL	Actuator has been Activated

Table 4.20 represents the different amount of pH solution being dispensed by the pH pump based on how long the pH pump is activated. The proponents tested the pH pump on how much pH solution in ml is it dispensing based on how long the pH pump is activated. The proponents have focused on this set of seconds because based on the previous computations that shows the needed amount of pH solution examples, the values shown there are in between the values 15 and 20 second margin of pH pump activation.

Table 4.21 Functional Testing: pH Actuator Testing 3 (Test Phase 2)

Water Volume (Liters and Gallons)	Water Level (Based on Ruler Stick)	Water Level (Based on Ultrasonic Sensor)	Water in Gallons (gal)	Water in Liters (L)
pH Up and pH Down Actuator pump	50.5 cm	26 cm	139.41	527.73
	51.5 cm	25 cm	142.17	538.18
	52.5 cm	24 cm	144.93	548.63
	53.5 cm	23 cm	147.69	559.08
	54.5 cm	22 cm	150.45	569.53
	55.5 cm	21 cm	153.21	579.98
	56.5 cm	20 cm	155.97	590.43

Table 4.21 represents the computation of water volume of the aquaponics water tank. The given is based on the measurement of the water tank itself; the height of the fish tank is approximately 62.5 cm high but for us to estimate how much pH solution we need to put in the water to not overdose the tank in pH solution, we need to measure what is the height of the water itself resulting in using 53.5 cm (water height) as the value for height. The other values presented are to show the different gallons of water in the tank for different height of the water level that will be used to solve how much pH solution is needed to put in the tank.

Formulas:

$$Volume\ of\ Tank\ (Liters) = Length\ (cm)\ x\ Width\ (cm)\ x\ Hight\ of\ Water\ Surface\ (cm) \quad \textbf{Eq 4.4}$$

$$Volume\ of\ Tank\ (Gallons) = \frac{Liters}{3.78541} \quad \textbf{Eq 4.5}$$

Given:

Length = 110 cm

Width = 95 cm

Height of tank = 62.5 cm

Height of water if distance is 23 to ultra = 53.5 cm

$$Volume\ of\ Tank\ (Liters) = 110\ cm\ x\ 95\ \ x\ 53.5\ cm$$

$$Volume\ of\ Tank\ (Liters) = 559.08$$

$$Volume\ of\ Tank\ (Gallons) = \frac{559.08}{3.78541}$$

$$\boldsymbol{Volume\ of\ Tank =\ 148\ Gallons}$$

Table 4.22 Functional Testing: pH Actuator Testing 3 (Test Phase 2)

Needed Amount of pH Solution	pH Solution of 4 drops in milliliters (mL)	Water Volume (gal)	Need Amount of pH Solution
pH Up and pH Down Actuator pump	0.2 ml	139.41	27.88 or 28 ml
	0.2 ml	142.17	28.43 or 28 ml
	0.2 ml	144.93	28.99 or 29 ml
	0.2 ml	147.69	29.54 or 30 ml
	0.2 ml	150.45	30.09 or 30 ml
	0.2 ml	153.21	30.64 or 31 ml

The table above represents the computed needed amount of pH solution based on the different volume of the water in gallons. The other values shown in the table is the estimated needed pH solution amount if the distance change.

Formulas:

$$1\ drop\ (pH\ Up\ and\ Down) = 0.05\ mL \qquad \textbf{Eq 4.6}$$

$$0.05mL\ drop\ of\ pH\ Up\ and\ Down\ x\ 4\ drops\ = 0.2mL\ \ pH\ Solution \qquad \textbf{Eq 4.7}$$

$$pH\ Solution\ x\ Water\ Volume\ (Gallons)\ x\ Water\ Volume\ (Gallons) = Needed\ Ammount\ of\ pH\ Solution$$

Computations:

$$0.05\ mL\ (1\ drop\ of\ pH\ Up\ and\ Down)x\ 4\ (drops) = 0.2mL$$

$$0.2\ mL\ \ x\ 147.69\ gal = 29.54\ mL\ or\ 30\ mL$$

The formula shows the computation of needed pH solution based on what is required by the producers of the pH solution. The pH solution indicated in the instruction of use that for every gallon we need to put in 4 – 6 drops of pH solution then test the water again for changes in pH. The proponents followed this instruction to maintain a stable pH. The proponents are only putting in 4 drops of pH solution per gallon in the tank to minimize overdosing the system with pH solution. A drop of water can be equated to the value of 0.05ml volume of water, with us needing 4 drops per gallon we multiply the amount in ml of 1 droplet to 4 resulting in 0.2ml of pH solution. this indicates that we need 0.2ml of pH solution per gallon of water. Then now we can get the needed amount of pH based on what is the volume of water by multiplying the value 0.2ml (4 drops of pH solution) to 147.69 gal (volume of water if distance is 23cm). By multiplying the two values we get 29.54 or 30ml of pH solution to be put in the tank if the distance of water is 23cm.

Table 4.23 Functional Testing: Temperature Actuator Testing (Test Phase 2.0)

FUNCTIONAL TESTING (Temperature Test)	TRIALS	Current Temperature	Check List		Remarks
			Active	Inactive	
Aquaponics Water	1	29.0		✓	Consistent
	2	30.5		✓	Consistent
	3	28.5		✓	Consistent
	4	29.3		✓	Consistent
	5	28.0		✓	Consistent
	6	29.0		✓	Consistent
	7	30.81		✓	Consistent
Cold Water	8	27.0	✓		Consistent
	9	28.0	✓		Consistent
	10	27.0	✓		Consistent
	11	28.5	✓		Consistent
	12	27.5	✓		Consistent
	13	26	✓		Consistent
	14	25.97	✓		Consistent

In Table 4.23 shows that the functionality of the water temperature actuator showcasing an overall consistent result. This shows that the system has exhibit consistent performance in terms maintaining the temperature. The first 7 trials show how the actuator will act on a maintained temperature then the last 7 trials show how the actuator will act on a cold-water temperature. Each trials have an interval of 5 minutes to see if the performance of the actuator keeps up with current environments.

Table 4.24 Functional Testing: Water Level Actuator Testing (Test Phase 2.0)

FUNCTIONAL TESTING (Water Level)	TRIALS	COMPARE ACTUATOR VALUES			REMARKS
		ULTRASONIC SENSOR VALUE	WORKING	DEFECTIVE	
WATER PUMP	1	22	✓		Water pump activated based on the threshold (working)
	2	19	✓		Water pump activated based on the threshold (working)
	3	20	✓		Water pump activated based on the threshold (working)
	4	21	✓		Water pump activated based on the threshold (working)
	5	18	✓		Water pump activated based on the threshold (working)
	6	23		✓	Water pump did not activate because it is above threshold. (working)
	7	25		✓	Water pump did not activate because it is above threshold. (working)
	8	26		✓	Water pump did not activate because it is above threshold. (working)
	9	24		✓	Water pump did not activate because it is above threshold. (working)
	10	27		✓	Water pump did not activate because it is above threshold. (working)

Table 4.24 shows the water pump actuator is activating correctly based on the water level sensor input value. The threshold or the activation value of the water pump actuator gives the water level sensor an input of above 23 cm away from the sensor. The tester tested the actuator by manipulating the water level so that the actuator will activate based on the parameters. If the sensor value gives an input of 23 and above, the actuator will activate for 10 seconds to add a small

amount of water in the system to slowly rise the water level. The actuator will not activate if the sensor input is 22 cm and below indicating that the water level is at a safe or int the threshold value that will not overflow the fish tank.

Table 4.25 Data Storing, Initial Value Web Interface, Display Value in Dashboard

Test Case	Phase 1	Phase 2	Phase 3
1	Store Data values to Database	Has maintained the value via web interface	Displays values in the dashboard
2	Did not store data values to database	Did not maintain the value via web interface	Did not display values in the dashboard

Table 4.25 shows the test phase and test cases in storing the data values, maintains the threshold value in the web interface, and display the value of the sensor to the dashboard. In phase 1 should store first the acquired sensor values. Test phase 1 should be completed before proceeding to test phase 2. Test phase 2 should then maintain the water quality parameter using the stored value in the database to specify the amount of value needed to be maintained. Lastly, for phase 3 the data should be then display in the Grafana dashboard to have the user have an easier monitoring.

Table 4.26 Functional Testing: Data Storing, Maintaining, and Display Data (Test Phase 2)

Trial	Dashboard Section	Reliability For Saving Values	Saves Initiated Values		Checklist		Remarks
			YES	NO	Complete	Incomplete	
1	pH level	5.87	✓		✓		Data has been stored, maintained, and displayed
2		5.87	✓		✓		Data has been stored, maintained, and displayed
3		5.98	✓		✓		Data has been stored, maintained, and displayed
4		5.96	✓		✓		Data has been stored, maintained, and displayed
5		6.13	✓		✓		Data has been stored, maintained, and displayed

6	Water Level	26	✓		✓		Data has been stored, maintained, and displayed
7		26	✓		✓		Data has been stored, maintained, and displayed
8		25	✓		✓		Data has been stored, maintained, and displayed
9		25	✓		✓		Data has been stored, maintained, and displayed
10		26	✓		✓		Data has been stored, maintained, and displayed
11	Water Temperature Level	29.81	✓		✓		Data has been stored, maintained, and displayed
12		29.87	✓		✓		Data has been stored, maintained, and displayed
13		29.87	✓		✓		Data has been stored, maintained, and displayed
14		29.87	✓		✓		Data has been stored, maintained, and displayed
15		29.81	✓		✓		Data has been stored, maintained, and displayed
16	Water Turbidity Level	-456.42	✓		✓		Data has been stored, maintained, and displayed
17		-535.63	✓		✓		Data has been stored, maintained, and displayed
18		-1646.89	✓		✓		Data has been stored, maintained, and displayed
19		-1646.89	✓		✓		Data has been stored, maintained, and displayed
20		-1510.93	✓		✓		Data has been stored, maintained, and displayed

In Table 4.26 shows the following test phase for the storing of data values into the database, maintaining the data to the threshold value, and displays the data in the Grafana web interface. The Reliability for saving values is the stored data from the database, while the saves-initiated value is where the actuator activates and maintains the water quality parameter. Lastly, the checklist is where the data is displayed in the Grafana web interface where it displays the data every minute, but in our testing, we have based it from 12:34 pm and counting every 2 mins. All the trials have been efficient in storing, maintaining, and displaying the data.

Table 4.27 Functionality Testing

FUNCTIONALITY TESTING (Sensors)	TRIALS	Checklist		Remarks
		Working	Defective	
pH	1	✓		The pH sensor is functional and is sending data to the database
	2	✓		The pH sensor is functional and is sending data to the database
	3	✓		The pH sensor is functional and is sending data to the database
	4	✓		The pH sensor is functional and is sending data to the database
	5	✓		The pH sensor is functional and is sending data to the database
Turbidity	1	✓		The Turbidity sensor is functional and is sending data to the database
	2	✓		The Turbidity sensor is functional and is sending data to the database
	3	✓		The Turbidity sensor is functional and is sending data to the database
	4	✓		The Turbidity sensor is functional and is sending data to the database
	5	✓		The Turbidity sensor is functional and is sending data to the database
Temperature	1	✓		The Temperature sensor is functional and is sending data to the database
	2	✓		The Temperature sensor is functional and is sending data to the database
	3	✓		The Temperature sensor is functional and is sending data to the database
	4	✓		The Temperature sensor is functional and is sending data to the database

	5	✓		The Temperature sensor is functional and is sending data to the database
Ultrasonic	1	✓		The Ultrasonic sensor is functional and is sending data to the database
	2	✓		The Ultrasonic sensor is functional and is sending data to the database
	3	✓		The Ultrasonic sensor is functional and is sending data to the database
	4	✓		The Ultrasonic sensor is functional and is sending data to the database
	5	✓		The Ultrasonic sensor is functional and is sending data to the database

Table 4.27 showcases the functionality of four sensors all together. This process tests the capabilities of each sensor and making sure the all the sensors and working simultaneously. The table contains 20 trials each of which divides into 4 categories: pH, Turbidity, Temperature, and Water Level having 5 trials each. Overall, the test has been functional where all the sensors are working and will continue to the automation phase.

Table 4.28 Automation Testing

Automation Testing (Actuators)	TRIALS	Testing			Remarks
		Working	Incomplete	Not Working	
pH UP peristaltic pump	1	✓			The pH up peristaltic pump activated and functioning as intended
	2	✓			The pH up peristaltic pump activated and functioning as intended
	3	✓			The pH up peristaltic pump activated and functioning as intended
	4	✓			The pH up peristaltic pump activated and functioning as intended
	5	✓			The pH up peristaltic pump activated and functioning as intended
pH DOWN peristaltic pump	1	✓			The pH down peristaltic pump activated and functioning as intended

	2	✓			The pH down peristaltic pump activated and functioning as intended
	3	✓			The pH down peristaltic pump activated and functioning as intended
	4	✓			The pH down peristaltic pump activated and functioning as intended
	5	✓			The pH down peristaltic pump activated and functioning as intended
Water Heater	1	✓			The water heater activated and functioning as intended
	2	✓			The water heater activated and functioning as intended
	3	✓			The water heater activated and functioning as intended
	4	✓			The water heater activated and functioning as intended
	5	✓			The water heater activated and functioning as intended
Water reserve pump	1	✓			The water reserve pump activated and functioning as intended
	2	✓			The water reserve pump activated and functioning as intended
	3	✓			The water reserve pump activated and functioning as intended
	4	✓			The water reserve pump activated and functioning as intended
	5	✓			The water reserve pump activated and functioning as intended

In Table 4.28 shows if the actuators that are present in the system and it is functioning as intended based on the testers. The testers will test the pH up and pH down peristaltic pumps if it is functioning based on the time that the testers set the pump to be activated. The testers will test the water heater if the water heater activates and heats up the water based on the temperature threshold that is set. The testers will test the water reserve pump if it is functioning based on the time that the testers set the pump to be activated. The test is successful and are all working as intended.

Table 4.29 Database Testing (PhpMyAdmin)

Database Testing	TRIALS	Time frame	Testing			Remarks
			Complete	Incomplete	No Data	
pH	1	6:00 am – 8:00 am		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	2	10:00 am – 12:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	3	2:00 pm – 4:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	4	6:00 pm – 8:00 pm		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	5	10:00 pm – 12:00 am			✓	No data gathered due to Raspad being frozen and cannot be reset by testers
Turbidity	1	6:00 am – 8:00 am		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	2	10:00 am – 12:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	3	2:00 pm – 4:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	4	6:00 pm – 8:00 pm		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)

	5	10:00 pm – 12:00 am			✓	No data gathered due to Raspad being frozen and cannot be reset by testers
Temperature	1	6:00 am – 8:00 am		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	2	10:00 am – 12:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	3	2:00 pm – 4:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	4	6:00 pm – 8:00 pm		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	5	10:00 pm – 12:00 am			✓	No data gathered due to Raspad being frozen and cannot be reset by testers
Ultrasonic	1	6:00 am – 8:00 am		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	2	10:00 am – 12:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	3	2:00 pm – 4:00 pm	✓			Raspad did not freeze resulting in complete data gathering
	4	6:00 pm – 8:00 pm		✓		Incomplete data due to Raspad being frozen from time to time. (not 100% reliable)
	5	10:00 pm – 12:00 am			✓	No data gathered due to Raspad being frozen and cannot be reset by testers

Table 4.29 shows if the data being gathered by the sensors that are fully stored in the database. The testers tested if the database is consistently storing the data of the sensors. The testers have observed that the database was not able to store all the data throughout the 24 hours of activation due to the RasPad freezing from time to time. This results in the database to only gather the data during there are testers that monitors whether the Raspad is unresponsive or not.

TABLE 4.30 INTERFACE TESTING

Interface Testing	TRIALS	Time frame	Testing			Remarks
			Accurate	Inaccurate	No Data or Graph	
pH	1	6:00 am – 8:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	2	10:00 am – 12:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	3	2:00 pm – 4:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	4	6:00 pm – 8:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	5	10:00 pm – 12:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
Turbidity	6	6:00 am – 8:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	7	10:00 am – 12:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	8	2:00 pm – 4:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	9	6:00 pm – 8:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	10	10:00 pm – 12:00 am	✓			Interface shows the data accurately based on the database

						(interface graph generation based on time)
Temperature	11	6:00 am – 8:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	12	10:00 am – 12:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	13	2:00 pm – 4:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	14	6:00 pm – 8:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	15	10:00 pm – 12:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	16	6:00 am – 8:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	17	10:00 am – 12:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	18	2:00 pm – 4:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	19	6:00 pm – 8:00 pm	✓			Interface shows the data accurately based on the database (interface graph generation based on time)
	20	10:00 pm – 12:00 am	✓			Interface shows the data accurately based on the database (interface graph generation based on time)

In Table 4.30 shows if the data from the database is being shown in a graph display format. The testers tested if the interface is accurately showing what was stored inside database and display a graph or chart. The testers have observed that the interface can visualize the data being gathered in a graphical display format. The interface shows the graph format in a time-based manner where in the graph, it is being shown based on what time the data have been gathered. If there is no data gathered inside the database, the Grafana interface will also show the missing data as a straight line from the previous data gathered to the current data in the interface. The testers concluded that the interface can accurately show the visualization of the data through a graph format.

4.4.1 Functional Testing Analysis

Table 4.31 Proposed Specification vs Actual Specification of Hardware

Functions	Type	PROPOSED Specification	Classification	Actual Specification	Status
Measure pH Level	Principal	The pH sensor measures the current pH level of the aquaponics water.	Procedural	The pH Sensor was able to measure the pH level and be able to compare within the threshold values of 5.5 – 7 pH	Done
Measure Water Temperature	Principal	The temperature sensor measures the current water temperature of the aquaponics water.	Procedural	The Temperature Sensor was able to measure the temperature and be able to compare within the threshold values of 28 – 30 degrees Celsius	Done
Measure Turbidity Level	Principal	The turbidity sensor measures the clarity of the water on how clear or dirty the aquaponics water.	Procedural	The Turbidity Sensor was able to measure the turbidity level	Done
Measure Water Level	Principal	This determines the current value of the water level in the aquaponics water.	Procedural	The Water Level Sensor was able to measure the Water Levell and be able to compare within the threshold values of 24 cm	Done
Compare Threshold Values	Principal	This compares the current measured value of the water parameter to the controlled threshold value to main the water parameter of the aquaponics system.	Procedural	All the sensors except the turbidity was able to compare the sensor measured to tested measured using Arduino and geany.	Done
Transmit Data	Principal	The sensor values that were measured in the fish tank will be transmitted to the database.	Procedural	All the Data were able to transmits the data going to the database using PhpMyAdmin	Done

Trigger pH Solution Peristaltic Solution	Principal	There will be 2 peristaltic pump that can be triggered if there is a decrease or increase of pH value.	Procedural	The pH solution has 2 peristaltic pumps that differentiates between pH up and pH Down. Each of which will pump depending on the amount of sensor values to the threshold increase or decrease	Done
Trigger Water Pump Actuator	Principal	A water pump will be the base as the actuator that extrudes water to the fish tank. It increases the water level depending on the threshold value.	Procedural	The Water Level has a water pump that triggers whenever there is a change in the sensors value measured within the threshold value. The pump will activate if the sensor value is below the threshold value.	Done
Filter Turbidity Level	Principal	In maintaining the turbidity level of the system, an improve filtration system that contains 3 stages of filtering out minerals and bacteria will be the basis of limiting the turbidity level for the system.	Procedural	The Turbidity level will be able maintain by re-designing the filtration system which will affect greatly the turbidity level of the system.	Done
Discharge heat in Heater Actuator	Principal	If the measured value of the water temperature attains lower, the heater will be triggered and will constantly discharge contains heat depending on the threshold value. The Heater can be set to 22 – 34 degrees Celsius with a temperature error within ± 1 degrees Celsius.	Performance	The Water temperature level has a heater actuator that will trigger if there is a decrease of water temperature of 28 degrees Celsius below.	Done
Store Data to Database	Principal	The data will be managed to the database of the system. The Arduino data will transmit to Geany and will transmit data to PhpMyAdmin database to store the data.	Procedural	The Acquired Sensor values will be stored in the PhpMyAdmin Database by geany and will be able to compare the threshold and be able to display the data to the graphical web interface	Done
Acquire Water Temperature	Secondary	The use of the DS18B20 used to detect water temperature has a temperature range of x to x, has a Responsiveness of ±0.5°C, has a response time of 750 millisecond,	Performance	The Water Temperature parameter was able to acquire by using the sensor DS18B20 which will be needed in measuring the water quality parameter of temperature. This will	Done

		and runs on 3v-5v voltage.		help measure and determine the necessary maintaining value of the system	
Acquire pH Level	Secondary	The DFRobot Analog: Gravity pH Sensor is used to read the pH value of a certain liquid would have a range of ± 0.1pH, response time of 1 minute, runs of 5 volts, and has a range of 0-60 Celsius.	Performance	The Water pH parameter was able to acquire by using the DFRobot Analog: Gravity pH Sensor which will be needed in measuring the water quality parameter of pH Level. This will help measure and determine the necessary maintaining value of the system	Done
Acquire Water Turbidity	Secondary	The DFRobot Analog: Turbidity Sensor Module is a sensor that detects if the water is clear or murky has an operating voltage of 5 volts, a response time of 5ms, a ratio range around 0~1000±30 (NTU), and a max current of 40 milliamperes.	Performance	The Water Turbidity parameter was able to acquire by using the DFRobot Analog: Turbidity Sensor Module which will be needed in measuring the water quality parameter of turbidity level. This will help measure and determine the necessary maintaining value of the system	Done
Acquire Water Level	Secondary	The HC-SRO4 ultrasonic sensors uses sonar waves to calculate the distance of a certain object with an operating voltage of 5 Volts and an operating distance of 2 centimeters to – 4 meters.	Performance	The Water level parameter was able to acquire by using the HC-SRO4 ultrasonic sensors which will be needed in measuring the water quality parameter of water level. This will help measure and determine the necessary maintaining value of the system	Done

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Project Testing and Evaluation

The preceding chapter discussed the subsequent trials or tests utilizing the developed design for the aquaponics system that these tests will determine if it met the following design specification, design objective, and the metrics such as Accuracy, Reliability, and Responsiveness. For Responsiveness, this will base on the reading of the programmed sensors and its testing measuring devices and be evaluated by using the Responsiveness Percentage Error. For Reliability, this will be depending on the system to control and monitor the water quality parameter where it can maintain a certain amount of data within the threshold this will be divide to the total amount of data in the database and will be evaluated by using the formula percentage error. Lastly, the Reliability, this will show the number of data collected by the System by the total amount of data in one month, each data is transmitted every 1 minute so the total amount of data in one month should be 43,200 data. This will be evaluated by using the percentage error. The results would be interpreted using a 4-point scale which will range from Excellent, Very Good, Fair, and Poor, each scale will fall on the objectives.

Table 5.1 Review of Objectives

OBJECTIVES	DEFINITIONS	METRICS	DESCRIPTION	SCALE
Accuracy	Capability of the system to measure pH of the water	This is determined by getting the percentage error between the standard pH meter values and the outputs of the pH sensor used in the aquaponic system.	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and above
		This is determined by getting the	Excellent	100% - 95.00 %

	Capability of the system to measure temperature of the water	percentage error between the measured water temperature sensor values and the outputs of the water temperature sensor used in the aquaponic system.	Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and above
	Capability of the system to measure turbidity of the water	This is determined by getting the percentage error between the standard turbidity meter values and the outputs of the turbidity sensor used in the aquaponic system.	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and above
	Capability of the system to precisely measure the distance of the water level	This can be determined by taking the relative difference between the distance tested and the measured distance of the water level.	Excellent	100% - 95.00 %
			Very Good	94.99 % – 90.00%
			Good	89.99% – 85.00 %
			Fair	84.99% - 80.00 %
			Poor	79.99% and above
Responsiveness	Ability of the system to process incoming data	This can be determined by dividing the mean change by	High Responsiveness	<2 Seconds
			Moderate Responsiveness	3-4 Seconds

	from the sensor into the database.	the standard deviation of the change.	Low Responsiveness	5 Seconds
Reliability	Ability of the system to maintain certain threshold of the water parameter. Water Parameters: pH: (pH 5.5 – pH 7.0) Temperature: (27 °C – 31 °C) Water Level: (23cm below)	This can be determined by taking the number of correct maintaining over the total number of maintaining trials.	Excellent	99.00% and above
			Very Good	95.00% - 98.99%
			Good	90.00% - 94.99%
			Fair	85.00% - 89.99%
			Poor	84.99% and below
	Ability of the system to collect and store data to the database from the sensor that measures pH, temperature, water level, and turbidity level.	This can be determined by taking the number of hours of down (system outage) and up (system running) time.	Excellent	0.00% - 5.00%
			Very Good	5.01% - 10.00%
			Good	10.01% -15.00%
			Fair	15.01% - 20.00%
			Poor	20.01% and above

Table 5.1 shows the specific objective of the proposed design, its definition and metrics, description, and scale. In review of the design objectives of this study., the Responsiveness was determined by dividing the mean change by the standard deviation of the change. The summary of testing and computation solution for the Responsiveness testing will be seen under 5.1.3 Section of chapter 5. For Reliability Testing which will determine the amount of data within the threshold over the total amount of data in the database multiplying it into 100%. This will determine the reliability of each water quality parameter to the threshold values for the system which are the following: pH level, water level, and temperature. The reliability ration will give a percentage that indicates how often each parameter falls within the acceptable range. For the reliability, it will determine how reliability the system on data being stored where it computes the successful trial recorded over the total amount of data in 1 month multiplying it to 100%

$$Average\ Percentage\ Error\ \% = \left(\frac{Measured\ Value\ of\ Sensor - Tester\ value}{Tester\ Value}\right) \quad \textbf{Eq 5.1}$$

$$Accuracy = \left(\frac{overall\ percentage\ error}{number\ of\ tested\ trials}\right) \times 100 \quad \textbf{Eq 5.2}$$

$$Reliability\ Criteria\ Rating\ \% = \frac{number\ of\ data\ within\ the\ threshold}{total\ no.of\ data\ in\ database} \times 100 \quad \textbf{Eq 5.3}$$

$$Reliability\ Criteria\ Rating\ \% = \left(\frac{number\ of\ data\ collected}{total\ no.of\ data\ in\ 1\ month}\right) \times 100 \quad \textbf{Eq 5.4}$$

$$Responsive\ Total\ Average = \frac{Sum\ of\ Values}{Total\ Number\ of\ Values}$$

The equations shown above are the following formula that will be use throughout the whole objective metrics testing. This will be used to get the average of a certain classification and testing conducted by the proponents Equation 5.1 pertaining to the Average percentage error of each water quality testing. Equation 5.2 pertains to the overall water quality parameter where it contains 7 categories. It pertains to the responsiveness of each sensor on how responsive it is with regards in acquiring the data. The lower the percentage error, the higher the responsiveness is. Equation 5.3 pertains to the reliability on the amount of data that is inside the threshold value and the total amount of data in the database.

Equation 5.4 pertains to the reliability rating of the RasPad on how responsive and reliable to control and monitor the system. All Formulas are multiplied by 100 to get the average for each identification.

Response Total Average is the formula for finding the average mean of a set of values where you will need to divide the sum of values by the total number of values.

5.1.1 Accuracy Testing

Table 5.2 Test for Accuracy for presenting pH value.

OBJECTIVE	Number of Trials	Number of Success Rate	Success Rate	Rating
Ability to a Design a system that is responsive in presenting pH Water Quality Parameter	7	140	98.72%	The pH sensor provided an accurate/excellent test.

Responsiveness Feedback:

Table 5.3 pH Calibration water source trials in finding the Average Percent Error

Functional Testing	Number of Trials	Water Source	Average Percent Error
pH Calibration	20	Distilled Water	1.06%
	20	Purified Water	0.79%
	20	Filtered Water	2.35%
	20	Aquaponics Water	0.91%
	20	Nawasa Water	1.86%
	20	River Water	1.34%
	20	Canal Water	0.67%
Average Percentage Error			**1.28%**

Formula:

$$Average\ Percent\ Error = \frac{Summation\ of\ Percent\ Errors}{Total\ No.Trials} \quad \textbf{Eq 5.5}$$

$$Success\ Rate = 100\% - Average\ Percent\ Error \quad \textbf{Eq 5.6}$$

Computation:

$$Average\ Percent\ Error = \frac{1.0645\%+0.79\%+2.3495\%+0.905\%+1.8555\%+1.344\%+0.6745\%}{7} \quad \textbf{Eq 5.7}$$

$$Average\ Percent\ Error\ (pH) = 1.283285714\% \quad \textbf{Eq 5.8}$$

$$Succes\ Rate = 100\% - \ 1.283285714\% \quad \textbf{Eq 5.9}$$

$$\boldsymbol{Succes\ Rate = 98.71671429\%}$$

Table 5.2 shows the average percent error for the pH testing. The testing has 20 trials of different water sources varying from distilled, purified, filtered, “Nawasa”, river, and water from the aquaponics system. Each water source had 20 trials conducted, overall, the number of trials conducted are 140 trials these trials consist of measured and tested values. The first question is determining the percent error of each trial and second is to determine the average percent error of the 20 trials conducted on the water source. The average percent error is equals to the success rate of the pH testing. Table 5.3 displays the water sources for pH calibration, each water sources trials concludes each average percentage error in finding the scale for the responsiveness of the pH Sensor. The average percentage error for the 7 trials is 1.28% gaining a scale of “Excellent”. The trials have both sensors measured as well as the tester or instrument measured. This will then be determined to find the average percentage error of the pH Calibration. The pH Sensor Calibration of Distilled, Purified, Filtered, Aquaponics, Nawasa, River, and Canal Water was performed by placing both the sensor and tester/instrument in a contain that has specific water sources in the testing. Every 2 minutes, the pH meter was held to obtain each trial, and the results from the sensors were cross-checked in the database. It consistently met the specifications, responsive measuring the current pH level at that moment. Equation 5.5 presents the formula for Average Percentage Error calculates the average percentage by which the measured values of a sensor differ from the expected or tester values. It does this by subtracting the tester value from the measured sensor value, taking the absolute difference, and then dividing it by the tester value. This result is then expressed as a percentage. In essence, it quantifies the overall Responsiveness of the sensor's measurements, indicating how closely they align with the expected values, with lower values indicating higher Responsiveness and higher values indicating less Responsiveness. Equation 5.6 the proposed formula used in calculating the Average percent error of the pH testing, it calculates the overall percent error of the said trials, by adding the average percent error of each water sources over the number of trials which is 7. Then the average percent error is subtracted to 100% to get the success rate. Equation 5.7 displays the computation in getting the average percentage error of each water quality trial. Each average percentage error will be used by dividing it by the number of trials which is 7. Equation 5.8 presents the outputted Average Percentage Error for the pH Calibration coming from Equation 5.7. Equation 5.9 display the computation in finding the success rate by subtracting 100% to the computed average percent error of 1.28 and the Success Rate of the pH Calibration will have a value of 98.72%.

Table 5.4 Test for Accuracy for presenting Turbidity Value

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to a Design a system that is responsive in presenting Turbidity Water Quality Parameter	4	80	87.95%	The turbidity sensor provided a good test rating.

Responsiveness Feedback:

Table 5.5 Turbidity Calibration water source trials in finding the Average Percent Error

Functional Testing	Number of Trials	Water Source	Average Percent Error
Turbidity Calibration	20	Canal Water	15.45%
	20	River Water	4.82%
	20	Distilled Water	12.39%
	20	Aquaponics Water	15.53%
Average Percentage Error			**12.05%**

Formula:

$$Average\ Percent\ Error = \frac{Summation\ of\ Percent\ Errors}{Total\ No.Trials} \quad \textbf{Eq 5.10}$$

$$Succes\ Rate = 100\% - Average\ Percent\ Error \quad \textbf{Eq 5.11}$$

Computation:

$$Average\ Percent\ Error = \frac{15.45\%+4.82\%+12.39\%+15.53\%}{4} \quad \textbf{Eq 5.12}$$

$$Average\ Percent\ Error\ (Turbidity) = 12.0475\% \quad \textbf{Eq 5.13}$$

$$Succes\ Rate = 100\% - \ 12.0475\% \quad \textbf{Eq 5.14}$$

$$\boldsymbol{Succes\ Rate = 87.9525\%}$$

Table 5.4 shows the average percent error for turbidity testing. The testing had 20 trials of different water sources varying from distilled, river, canal, and water from the aquaponics system. Each water source had 20 trials conducted, overall, the number of trials conducted are 80 trials these trials consist of measured and tested values. The first question is determining the percent error of each trial and second is to determine the average percent error of the 20 trials conducted on the water source. The average percent error is equals to the success rate of the turbidity testing. Table 5.5 presents the turbidity calibration with four water sources in finding the average percentage error for turbidity. The Turbidity Sensor Calibration of Distilled, Aquaponics, River, and Canal Water was performed to measure the value of the turbidity level according to the sensor.

In finding a comparison value of the turbidity, we have used a laboratory test trials to know the percentage error between the Turbidity Sensor and the Laboratory grade turbidity test and the results from the sensors were cross-checked and converted the sensor value of the NTU to the exact measurement of the laboratory test. We then use linear regression to know the unknown value of the turbidity Each water sources trials concludes each average percentage error in finding the scale for the responsiveness of the Turbidity Sensor. The average percentage error for the 4 trials is 12.05 gaining a scale of “Good”. Equation 5.10 is expressed as the formula in finding the average percentage error by the summation of the percentage errors in the four trials over the total number of data that is inside the database. Equation 5.11 is the proposed formula used in calculating the Average percent error of the turbidity testing, it calculates the overall percent error of the said trials by adding the average percent error of each water sources over the number of trials which is 4. Then the average percent error is subtracted to 100% to get the success rate. For the computation, equation 5.12 presents the 4 trials that will be used in finding the average percent error by the summation of the 4 trials over the number of tested trials in water sources for turbidity. Equation 5.13 is the output of the average percent error gaining a value of 12.05%. Equation 5.14 explains the computation for finding the success rate in the turbidity calibration. This is computing the rate of a perfect success rate which is 100% subtracting it with the total average percent error which is 12.05% The success rate for the turbidity calibration is 87.95%

Table 5.6 Test for Accuracy for presenting Temperature Value

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to a Design a system that is responsive in presenting Temperature Water Quality Parameter	3	60	93.59%	The Temperature sensor provided a very good test rating.

Responsiveness Feedback:

Table 5.7 Water Temperature Calibration water source trials in finding the Average Percent Error

Functional Testing	Number of Trials	Water Source	Average Percent Error
Temperature Calibration	20	Hot Water	11.01%
	20	Aquaponics Water	2.27%
	20	Cold Water	5.96%
Average Percentage Error			**6.41%**

Formula:

$$Average\ Percent\ Error = \frac{Summation\ of\ Percent\ Errors}{Total\ No.Trials} \quad \textbf{Eq 5.15}$$

$$Succes\ Rate = 100\% - Average\ Percent\ Error \quad \textbf{Eq 5.16}$$

Computation:

$$Average\ Percent\ Error = \frac{11.012\%+2.2655\%+5.9635\%}{3} \quad \textbf{Eq 5.17}$$

$$Average\ Percent\ Error\ (Temperature) = 6.413666667\% \quad \textbf{Eq 5.18}$$

$$Succes\ Rate = 100\% - \ 6.413666667\% \quad \textbf{Eq 5.19}$$

$$\boldsymbol{Succes\ Rate = 93.58633333\%}$$

Table 5.6 shows the average percent error for the temperature testing. The testing had 20 trials each different water sources varying from hot, cold, and water from the aquaponics system. Each water source had 20 trials conducted, overall, the number of trials conducted are 60 trials these trials consist of measured and tested values. The first question is determining the percent error of each trial and second is to determine the average percent error of the 20 trials conducted on the water source. The average percent error is equals to the success rate of the turbidity testing. Based on the given table the success rate of the responsiveness of the temperature is 93.59% or 6.41% percentage error rate that has a rating of “Very Good”.

Table 5.7 presents the feedback of the water temperature calibration in finding the average percentage error. The temperature calibration contains 20 trials in its water sources parameters. In computing for the average percentage error, we will need to combine the three average percent error then dividing it to the number of trials where is 3. The average percentage error rating presents to be as “Very Good” in the given tests. The following tests for the water temperature Sensor Calibration of hot water, aquaponics water, and cold water was performed by placing the Waterproof Temperature Sensor DS18B20 and TDS&EC water temperature meter in a cup filled with hot water, cold, and aquaponics water every 2 minutes, the TDS&EC water temperature meter was used to collect each trial, and the results from the Waterproof Temperature Sensor DS18B20 were cross-checked in the database.

Equation 5.15 explains the formula for the Average Percentage Error by which the measured values of a sensor differ from the expected or tester values. It does this by subtracting the tester value from the measured sensor value, taking the absolute difference, and then dividing it by the tester value. This result is then expressed as a percentage. In essence, it quantifies the overall Responsiveness of the sensor's measurements, indicating how closely they align with the expected values, with lower values indicating higher Responsiveness and higher values indicating less Responsiveness. Equation 5.16 presents the formula for finding the success rate by subtracting the average percentage error to 100%. For computation, equation 5.17 combined the three average percent error then dividing it to the total number of trials which is 3. In equation 5.18 is the outputted value in finding the average percent error then it will be used to determine the success rate of the temperature calibration. the proposed formula used in calculating We will then use the value that came from equation 5.18 to determine the success rate of the calibration. We will also about the percentage error of the calibration which is 6.41%

Table 5.8 Test for Accuracy for presenting water level Value

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to a Design a system that is responsive in presenting Water Level Parameter	3	3	95.57%	The water level sensor provided

				an excellent test rating

Responsiveness Feedback:

Table 5.9 Water Level Calibration trials in finding the Average Percentage Error

Functional Testing	Number of Trials	Water Source	Average Percent Error
Water Level Calibration	1	Aquaponics Water	4.35%
	1	Aquaponics Water	4.17%
	1	Aquaponics Water	4.76%
Average Percentage Error			**4.43%**

Formula:

$$Average\ Percent\ Error = \frac{Summation\ of\ Percent\ Errors}{Total\ No.Trials} \quad \textbf{Eq 5.20}$$

$$Succes\ Rate = 100\% - Average\ Percent\ Error \quad \textbf{Eq 5.21}$$

Computation:

$$Average\ Percent\ Error = \frac{4.35\%+4.17\%+4.76\%}{3} \quad \textbf{Eq 5.22}$$

$$Average\ Percent\ Error\ (Water\ Level) = 4.43\% \quad \textbf{Eq 5.23}$$

$$Success\ Rate = 100\% - \ 4.43\% \quad \textbf{Eq 5.24}$$

$$\boldsymbol{Succes\ Rate = 95.57\%}$$

Table 5.8 shows the average percent error for water level testing. The testing had 3 trials of similar measurement each of which will determine the water level of the system. Each water level had 1 trial conducted, overall, the number of trials conducted are 3 trials, these trials consist of measured and tested values. The first question is determining the percent error of each trial and second is to determine the average percent error of the 1 trial conducted on the water level test. The average percent error is equals to the success rate of the water level. In addition, the rating that was presented for the water level has rating of “Very Good” based on the metrics of the responsiveness objective.

In Table 5.9 presents the water level calibration trials in finding the average percentage error. All the trials conducted in the functional testing of the water level calibration are testing within the aquaponics system. We find an instrument that will be the basic our error rate of the measuring the water level response. A meter stick was used as the instrument for the water level calibration. The HC-SR04 Ultrasonic is the sensor that we will be using in measuring the water level. The sensor value was seen and stored inside the database while the use of a metric meter was to determine the current water level.

Equation 5.20 is the formula for Average Percentage Error calculates the average percentage by which the measured values of a sensor differ from the expected or tester values. It does this by subtracting the tester value from the measured sensor value, taking the absolute difference, and then dividing it by the tester value. This result is then expressed as a percentage. In essence, it quantifies the overall Responsiveness of the sensor's measurements, indicating how closely they align with the expected values, with lower values indicating higher Responsiveness and higher values indicating less Responsiveness. Equation 5.21 is used to find the success rate of the testing and subtracting the average percent error to the success rate which is 100%. Equation 5.22 was proposed to be formula used in calculating the Average percent error of the water level testing, it calculates the overall percent error of the said trials, by adding the average percent error of each water sources over the number of trials which is 3. Then the average percent error is subtracted to 100% to get the success rate. In Equation 5.23 is the output gather from finding the average percent error that is 4.43 %. After computing the following test, we will know the success rate of the parameter where 100% - 4.43 % is 95.57% in Equation 5.24.

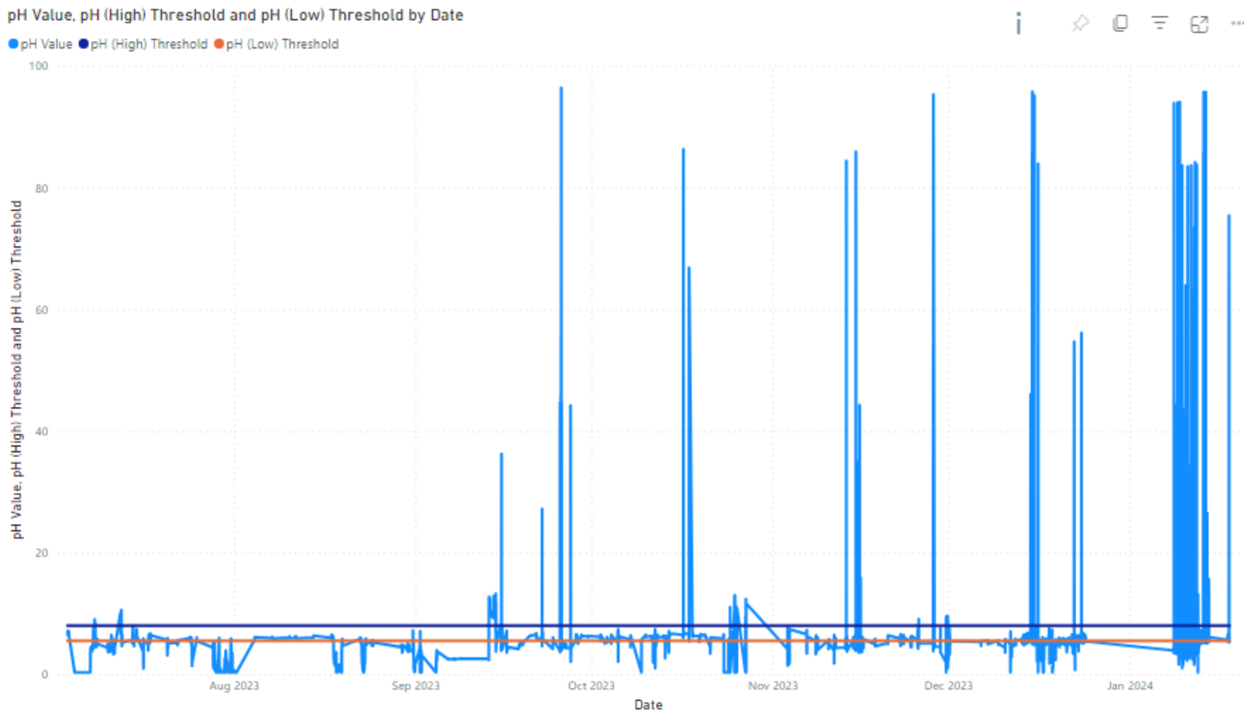


Figure 5.1 July 1, 2023 – January 18, 2024 (7-Month pH Actuator Reliability)

In Figure 5.1 presents the graph depicting the overall performance, several occurrences indicate instances where the RasPad3 experiences freezing, rendering it incapable of collecting data from the components but after installing a cooling system during December 13 to January 18, the freezing occurred less compared to the previous months. Additionally, the irregular movements in data delivery are observed in multiple instances. Notably, there are occurrences where the data exhibits sudden spikes (rapid increases followed by decreases) or dips (rapid decreases followed by increases), resolving itself after a brief period, typically one to two minutes. Analysis of the gathered data reveals that most values either fall below the threshold value or approach it closely, with occasional points falling within the threshold range. The graph illustrates that the threshold value consistently fluctuates among all the values or data collected throughout the entire testing period, yet these values do not consistently fall within the desired range.

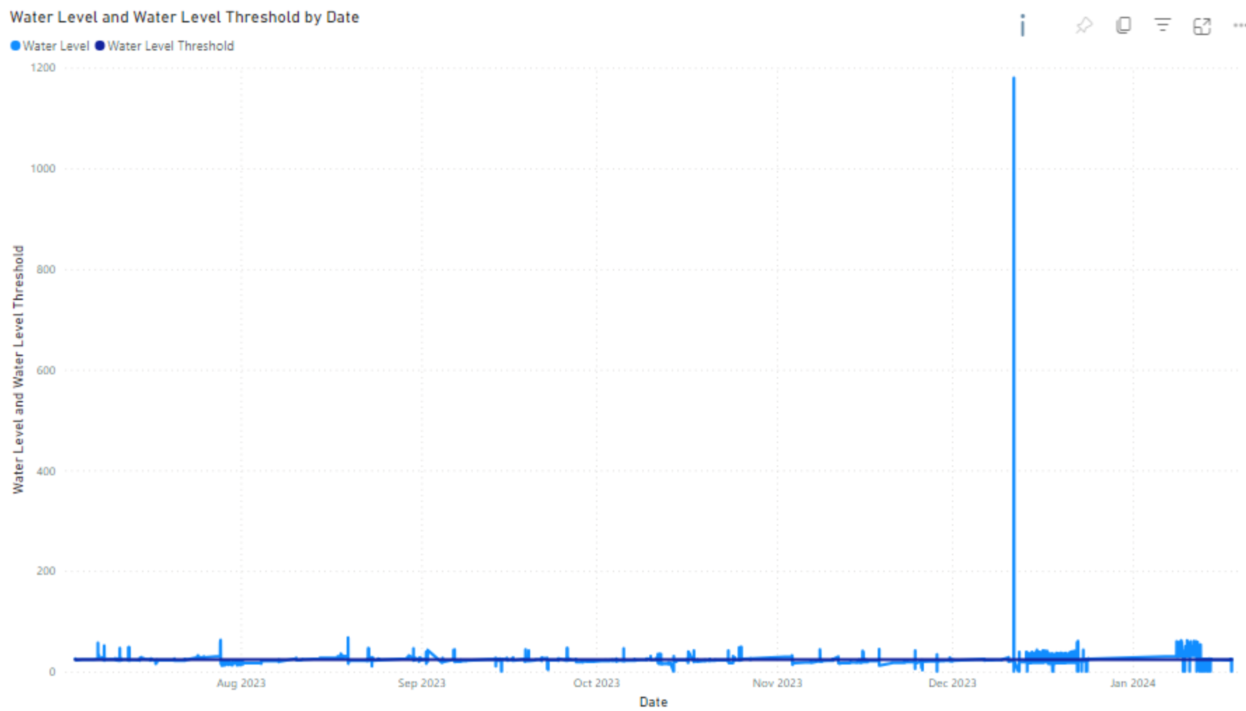


Figure 5.2 July 1, 2023 – January 18, 2024 (7-Month Water Level Actuator Reliability)

In the displayed graph representing the overall data from July to early December, numerous occurrences are evident where data collection abruptly ceases. This can be attributed to inadequate ventilation for the RasPad3, leading to frequent freezing and hindering data acquisition, furthermore after installing a cooling system during December 13 to January 18, the freezing accrued less compared to the previous months. Additionally, there are multiple instances of erratic fluctuations in data, suggesting potential malfunctions in the components. Such fluctuations may result from either specific malfunction occurring temporarily or the component being non-functional during those specific instances. The graph indicates that the output hovers around the threshold value, indicating a consistent fluctuation within proximity to the threshold. This suggests that the system is frequently teetering around the threshold value.

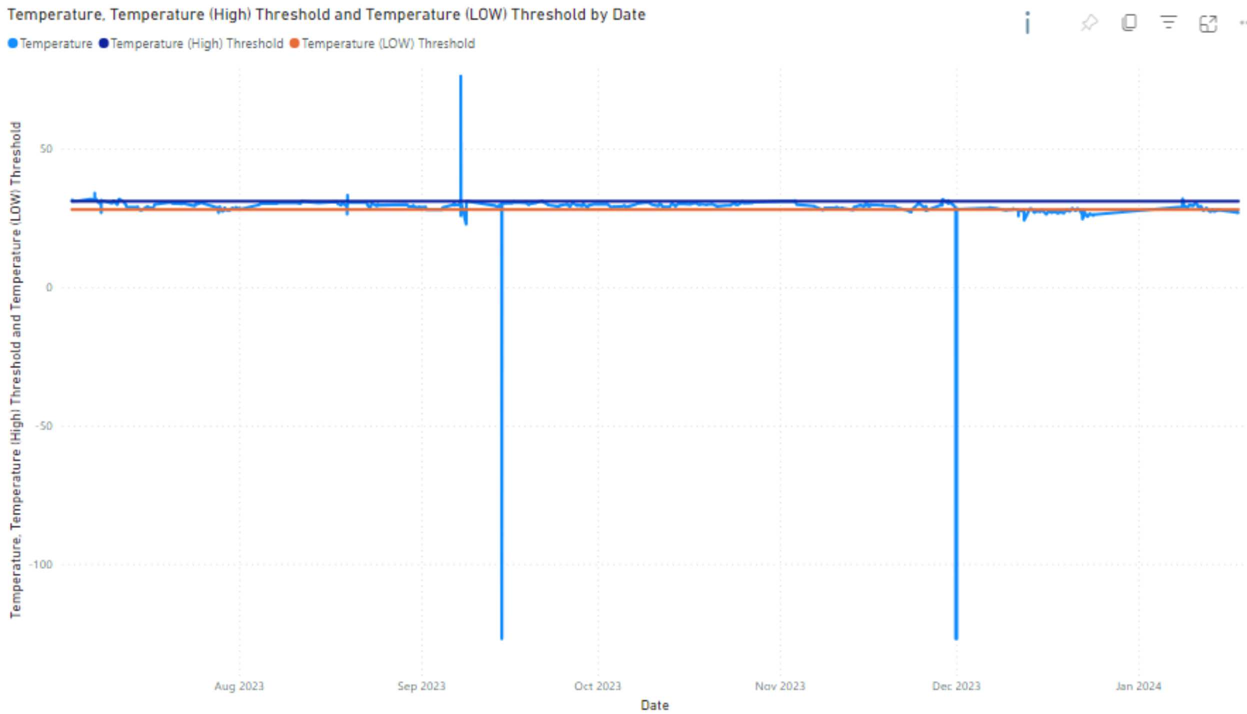


Figure 5.3 July 1, 2023 – January 18, 2024 (7-Month Temperature Actuator Reliability)

In the depicted graph illustrating the overall data, multiple occurrences of missing data are evident, stemming from the RasPad3's intermittent malfunctioning or freezing but after installing a cooling system during December 13 to January 18, the freezing accrued less compared to the previous months. These instances result in the RasPad3's inability to retrieve information from individual components. Notably, the graph shows fewer spikes compared to other graphs, suggesting that the components tend to experience malfunctions with prolonged usage. Furthermore, majority of data values fall within the threshold range, with some approaching the extremities of the maximum or minimum values. In summary, the graph indicates a relatively consistent temperature throughout the entire testing period.

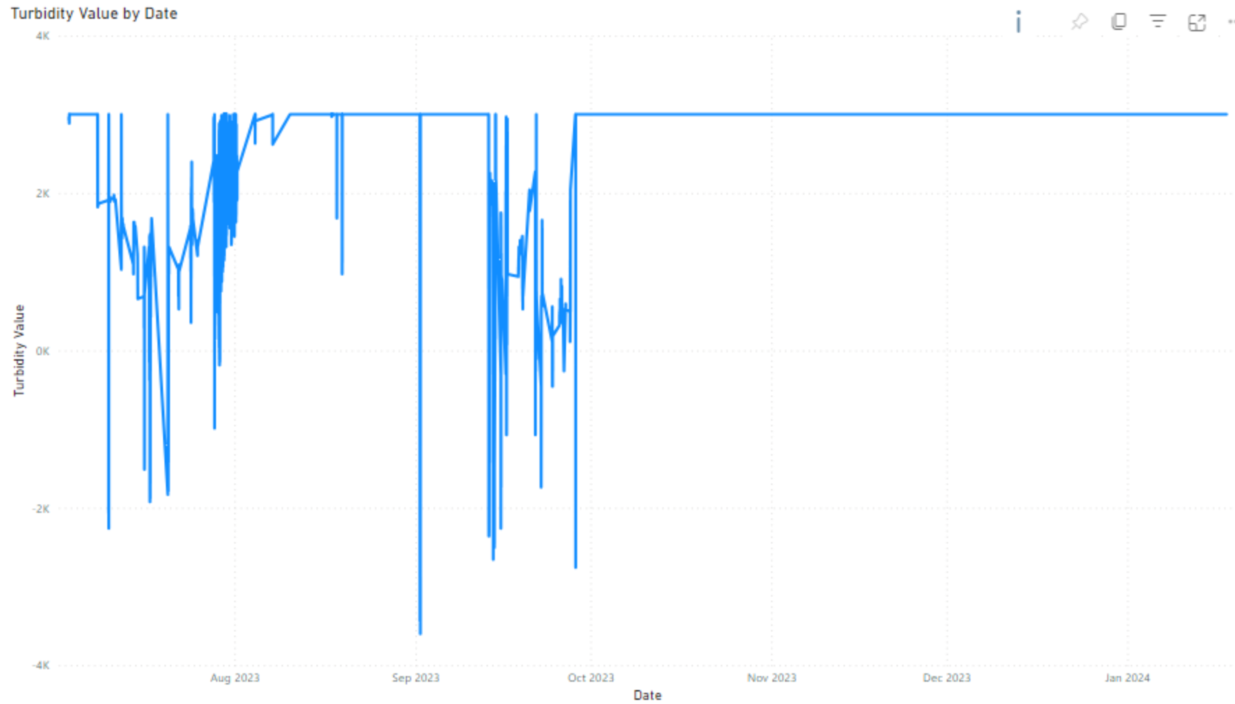


Figure 5.4 July 1, 2023 – January 18, 2024 (7-Month Turbidity Reliability)

In the presented graph depicting the overall data, numerous instances of missing data are evident, likely attributed to two main factors. First, the raspad may freeze, causing disruptions in data collection. Second, there seems to be frequent malfunctioning of components. A clear indicator of component malfunction is when the reading remains constant at 3000, which is the default output value. Consistently observing a value of 3000 indicates a malfunctioning component, including instances where the data spikes down but returns to 3000.

Based on the available data, a practical inference can be drawn regarding water cleanliness. If the component registers a value between negative and 1000, the water can be deemed relatively clean. However, if the value rises by several hundred to a few thousand, it suggests that the water is dirty and requires cleaning. This provides a valuable insight into water quality based on the observed data patterns.

5.1.2 Reliability Results

Table 5.10 7 – Months Test Results for Reliability in pH Level (July 1, 2023 – January 18, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of pH level threshold Values.	**55,159**	**21,183**	**38.40%**	The pH sensor has a poor reliability rating

Reliability Feedback:

- 1st trial: 55,159 (Total number of measurements within 7-month period of testing)
- 2nd trial: 21,183 (Number of measurements within threshold range)

Formula:

$$Consistency\ Criteria\ Rating = \left(\frac{No.of\ measurements\ within\ Threshold}{Total\ Number\ of\ Measurements}\right) \times 100 \qquad \textbf{Eq 5.25}$$

Computation:

$$Consistency\ Criteria\ Rating = \left(\frac{21{,}183}{55{,}159}\right) \times 100 \qquad \textbf{Eq 5.26}$$

$$= \mathbf{38.40352436\%} \approx \mathbf{38.40\%}$$

Table 5.10 shows the consistency criteria rating for pH testing. The testing had 55,159 trials that gathered from the aquaponics database for 7 months. The pH data was sorted based on the threshold range and value from 5.5 to 8 pH level. The pH data that is within the threshold range can be considered when calculating the reliability criteria rating. The total number that is within the threshold range is 21,183. The pH data was transmitted every 1 minute and if we are going to compute the overall data that should have been inside the database for 7 months should be 290,880. Though, for this test we will only conduct the test on how much data is currently stored in the database because this is where they will know the specific threshold that was changed. In addition, the number of trials and the number of success trials in pH level can be seen at the appendices.

Equation 5.25 is the formula for Reliability Criteria Rating calculates the rating or score that represents how consistent a dataset is with a specified threshold or criteria. It does so by counting the number of data points within the defined threshold and then dividing this count by the total number of data points in the database. This result is then multiplied by 100 to express it as a percentage. Essentially, it provides a measure of the proportion of data that meets the specified reliability criteria, with a higher rating indicating greater reliability and adherence to the criteria, while a lower rating suggests a dataset with more data points falling outside the specified threshold. Equation 5.26 calculates the reliability criteria rating of the pH test this can done by taking consideration the number of measurements within the threshold value which is 55,159 over the total number of measurements which is 21,183 then multiplied to 100 to get a percent outcome. The percent outcome can be considered the success rate of the said test. In conclusion with this computation, the final reliability rating is 38.40% or has a poor rating.

Table 5.11 7-Month Test Result for Reliability in Water Temperature (July 1, 2023 – January 18, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of Temperature threshold Values.	**55,159**	**48,097**	**87.19%**	The temperature has a fair reliability rating

Reliability Feedback:

- 1[st trial]: 55,159 (Total number of measurements within 7-month period of testing)
- 2[nd] trial: 48,097 (Number of measurements within threshold range)

Formula:

$$Consistency\ Criteria\ Rating = \left(\frac{No.of\ measurements\ within\ Threshold}{Total\ Number\ of\ Measurements}\right) \times 100 \qquad \textbf{Eq 5.27}$$

Computation:

$$Consistency\ Criteria\ Rating = \left(\frac{55{,}159}{48{,}097}\right) \times 100 \qquad \textbf{Eq 5.28}$$

$$= \mathbf{87.19701227\%}$$

Table 5.11 shows the consistent criteria rating for temperature. The testing had 55,159 trials that was gathered from the aquaponics database. These data consisted of pH, temperature, turbidity, water level, and water reservoir level, then these data were sorted with respect to their certain threshold range and value. Data that is within the threshold range can be considered when calculating the reliability criteria rating, the amount of data within the temperature that were able to maintain or achieve the threshold value in the total number of measurements within 7 months of testing is 48,097. In computing the reliability criteria rating, we need to divide the number of measurements within the threshold over the total number of measurements within 7 month of testing and multiplying it to 100. In addition, the number of trials and the number of successful trials in the temperature range can be seen at the appendices.

Equation 5.27 has a formula for Reliability Criteria Rating that calculates the rating or score that represents how consistent a dataset is with a specified threshold or criteria. It does so by counting the number of data points within the defined threshold and then dividing this count by the total number of data points in the database. This result is then multiplied by 100 to express it as a percentage. Essentially, it provides a measure of the proportion of data that meets the specified reliability criteria, with a higher rating indicating greater reliability and adherence to the criteria, while a lower rating suggests a dataset with more data points falling outside the specified threshold. Equation 5.28 calculates the reliability criteria rating of the temperature test this can done by taking consideration the number of measurements within the threshold value which is 48,097 over the total number of measurements which is 55,159 then multiplied to 100 to get a percent outcome. The percent outcome can be considered the success rate of the said test. The Success rate of the reliability rating with the temperature is 87.19%.

Table 5.12 7-Month Test Result for Reliability in Water Level (July 1, 2023 – January 18, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of Water Level to the Threshold Values.	**55,159**	**42,588**	**77.21%**	The Water level has a poor reliability rating.

Reliability Feedback:

- 1st trial: 55,159 (Total number of measurements within 1 month period of testing)
- 2nd trial: 42,588 (Number of measurements within threshold range)

Formula:

$$Consistency\ Criteria\ Rating = \left(\frac{No.of\ measurements\ within\ Threshold}{Total\ Number\ of\ Measurements}\right) \times 10 \qquad \textbf{Eq 5.29}$$

Computation:

$$Consistency\ Criteria\ Rating = \left(\frac{55{,}159}{42{,}588}\right) \times 100 \qquad \textbf{Eq 5.30}$$

$$= \mathbf{77.20952156\%}$$

Table 5.12 shows the consistent criteria rating for water level testing. The testing had 55, 159 trials that was gathered from the aquaponics database. These data consisted of pH, temperature, turbidity, water level, and water reservoir level, then these data were sorted with respect to their certain threshold range and value. The data that is within the threshold range can be considered when calculating the reliability criteria rating, the amount of data within the water level that were able to maintain or achieve the threshold value in the total number of measurements within 7 month of testing is 42,588. In addition, the number of trials and the number of successful trials in the water level range can be seen at the appendices.

Equation 5.29 is the formula for Reliability Criteria Rating that calculates the rating or score that represents how consistent a dataset is with a specified threshold or criteria. It does so by counting the number of data points within the defined threshold and then dividing this count by the total number of data points in the database. This result is then multiplied by 100 to express it as a percentage. Essentially, it provides a measure of the proportion of data that meets the specified reliability criteria, with a higher rating indicating greater reliability and adherence to the criteria, while a lower rating suggests a dataset with more data points falling outside the specified threshold. Equation 5.30 calculates the reliability criteria rating of the water level this can done by taking consideration the number of measurements within the threshold value, which is 42.588 over the total number of measurements which is 55,159 then multiplied to 100 to get a percent outcome. The percent outcome can be considered the success rate of the said test. The percentage outcome can be considered the success rate of the said test. The success rate of the reliability rating with the water level is 77.21%

Table 5.13 1-Month Test Result for Reliability in pH Level (December 13– January 11, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of pH level threshold Values.	**18,591**	**10,065**	**54.14%**	The pH has a poor reliability rating.

Reliability Feedback:

- $1^{st\ trial}$: 18,591 (Total number of measurements within 1 month period of testing)
- 2^{nd} trial: 10,065 (Number of measurements within threshold range)

Formula:

$$Consistency\ Criteria\ Rating = \left(\frac{No.of\ measurements\ within\ Threshold}{Total\ Number\ of\ Measurements}\right) \times 10 \qquad \textbf{Eq 5.31}$$

Computation:

$$Consistency\ Criteria\ Rating = \left(\frac{10{,}065}{18{,}591}\right) \times 100 \qquad \textbf{Eq 5.32}$$

$$= \mathbf{54.13909956\%}$$

Table 5.13 shows the consistent criteria rating for pH testing. The testing had 18,591 trials that was gathered from the aquaponics database. This trial was conducted for 30 days or 1 month to determine if the course of action in integrating another fan will change the output of the system. The data was with respect to the threshold range and value from 5.5 to 8 pH. The amount of data within the pH test was change from 30.51% that has 2,312 no. of measurements within the threshold and 7,580 total amounts of data from the previous 1 month testing during June to July Testing. The total number of measurements within the 1 month of testing with an additional fan is 10,065 within the threshold range. 18,591 was the total number of measurements within the 1-month period of testing.

Though, for this test we will only conduct the test on how much data is currently stored in the database because this is where they will know the specific threshold that was changed us went outside the threshold triggering the following actuator for the water quality parameter. In addition, the number of trials and the number of successful trials in pH Level can be seen at the appendices.

Equation 5.31 is the formula for Reliability Criteria Rating calculates the rating or score that represents how consistent a dataset is with a specified threshold or criteria. It does so by counting the number of data points within the defined threshold and then dividing this count by the total number of data points in the database. This result is then multiplied by 100 to express it as a percentage. Essentially, it provides a measure of the proportion of data that meets the specified reliability criteria, with a higher rating indicating greater reliability and adherence to the criteria, while a lower rating suggests a dataset with more data points falling outside the specified threshold. Equation 5.32 calculates the reliability criteria rating of the pH test this can done by taking consideration the number of measurements within the threshold value which is 10,065 over the total number of measurements which is 18, 591 then multiplied to 100 to get a percent outcome. The percent outcome can be considered the success rate of the said test. In conclusion with this computation, the final reliability rating is 54.14% or is still poor rating.

Table 5.14 1-Month Test Result for Reliability in Water Temperature (December 13, 2023 – January 11, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of Temperature threshold Values.	**18,591**	**18,238**	**98.10%**	The temperature has an excellent reliability rating

Reliability Feedback:

- 1st trial: 18,591 (Total number of measurements within 1 month period of testing)
- 2nd trial:18,238 (Number of measurements within threshold range)

Formula:

$$Consistency\ Criteria\ Rating = \left(\frac{No.of\ measurements\ within\ Threshold}{Total\ Number\ of\ Measurements}\right) \times 100 \qquad \textbf{Eq 5.33}$$

Computation:

$$Consistency\ Criteria\ Rating = \left(\frac{18{,}238}{18{,}591}\right) \times 100 \qquad \textbf{Eq 5.34}$$

$$= \mathbf{98.10123178\%}$$

Table 5.14 shows the consistent criteria rating for temperature testing. The testing had 18,591 trials that was gathered from the aquaponics database. This trial was conducted for 30 days or 1 month to determine if the course of action in integrating another fan will change the output of the system. The data was with respect to the threshold range and value from 28 – 31 degrees Celsius. The amount of data within the temperature test was change from 82.24 % that has 6,234 no. of measurements within the threshold and 7,580 total amounts of data from the previous 1 month testing from June to July Testing. The total number of measurements within the 1 month of testing with an additional fan is 18,238 within the threshold range. 18,591 was the total number of measurements within the 1-month period of testing.

Equation 5.33 has a formula for Reliability Criteria Rating that calculates the rating or score that represents how consistent a dataset is with a specified threshold or criteria. It does so by counting the number of data points within the defined threshold and then dividing this count by the total number of data points in the database. This result is then multiplied by 100 to express it as a percentage. Essentially, it provides a measure of the proportion of data that meets the specified reliability criteria, with a higher rating indicating greater reliability and adherence to the criteria, while a lower rating suggests a dataset with more data points falling outside the specified threshold. Equation 5.34 calculates the reliability criteria rating of the temperature test this can done by taking consideration the number of measurements within the threshold value which is 18,238 over the total number of measurements which is 18,591 then multiplied to 100 to get a percent outcome. The percent outcome can be considered the success rate of the said test. The Success rate of the reliability rating with the temperature is 98.10 %.

Table 5.15 1-Month Test Result for Reliability in Water Level (December 13, 2023 – January 11, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of Water Level to the Threshold Values.	**18,591**	**14,664**	**78.88%**	The Water Level has a poor reliability rating.

Reliability Feedback:

- 1st trial: 18,591 (Total number of measurements within 1 month period of testing)
- 2nd trial:14,664 (Number of measurements within threshold range)

Formula:

$$Consistency\ Criteria\ Rating = \left(\frac{No.of\ measurements\ within\ Threshold}{Total\ Number\ of\ Measurements}\right) \times 10 \qquad \textbf{Eq 5.35}$$

Computation:

$$Consistency\ Criteria\ Rating = \left(\frac{14{,}664}{18{,}591}\right) \times 100 \qquad \textbf{Eq 5.36}$$

$$= \mathbf{78.87687591}\%$$

Table 5.15 shows the consistent criteria rating for water level testing. The testing had 18,591 trials that was gathered from the aquaponics database. This trial was conducted for 30 days or 1 month to determine if the course of action in integrating another fan will change the output of the system. The data was with respect to the threshold range and value from 32. The amount of data within the temperature test was change from 51.41 % that has 3,897 no. of measurements within the threshold and 7,580 total amounts of data from the previous 1 month testing from June to July Testing. The total number of measurements within the 1 month of testing with an additional fan is 14,664 within the threshold range. 18,591 was the total number of measurements within the 1-month period of testing.

Equation 5.35 is the formula for Reliability Criteria Rating that calculates the rating or score that represents how consistent a dataset is with a specified threshold or criteria. It does so by counting the number of data points within the defined threshold and then dividing this count by the total number of data points in the database. This result is then multiplied by 100 to express it as a percentage. Essentially, it provides a measure of the proportion of data that meets the specified reliability criteria, with a higher rating indicating greater reliability and adherence to the criteria, while a lower rating suggests a dataset with more data points falling outside the specified threshold. Equation 5.36 calculates the reliability criteria rating of the water level this can done by taking consideration the number of measurements within the threshold value, which is 14,664 over the total number of measurements which is 15,591 then multiplied to 100 to get a percent outcome. The percent outcome can be considered the success rate of the said test. The percentage outcome can be considered the success rate of the said test. The success rate of the reliability rating with the water level is 78.88%

Table 5.16 1-Month & 1-Week Test Result of Reliability in Control & Monitoring with Additional Fan (December 13, 2023 – January 18, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Overall reliability of the system to control and monitor the water quality parameters	58,280	24,641	42.28%	The overall sensors delivered poor reliability.

Reliability Feedback:

- 1st Trial: 58, 280 (Total Number of Measurements)
- 2nd Trial: 24,641 (Number of Data Collected)

Formula:

$$Reliability = \left(\frac{Number\ of\ Data\ Collected}{Total\ Number\ of\ Measurement}\right) \times 100 \qquad \textbf{Eq 5.37}$$

Computation:

$$Reliability = \left(\frac{24{,}641}{58{,}280}\right) \times 100 \qquad \textbf{Eq 5.38}$$

$$= \mathbf{42.28037062\%}$$

Table 5.16 shows the overall reliability of the system to control and monitor water quality, this is done with the use of several sensors and actuators that provide the necessary action to control the water quality to a certain threshold level. The Number of data collected out of the 1-month and 1-week (36 days) period of testing is 7,580 and the overall data collected is 43,200. With these 2 parameters we can calculate the reliability percentage of the overall system. In additional, all the data that you want to find, see, can be seen in our appendices. The value 58,280 is the amount of data is being transmitted every minute and only 24,641 are collected in 1 month and 1-week (36 days)

Table 5.17 1-Month Test Result of Reliability in Control & Monitoring with Additional Fan (December 13, 2023 – January 11, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Overall reliability of the system to control and monitor the water quality parameters	43,200	18,591	43.03%	The overall sensors delivered poor reliability.

Reliability Feedback:

- 1st Trial: 43,200 (Total Number of Measurements)
- 2nd Trial: 18,591 (Number of Data Collected)

Formula:

$$Reliability = \left(\frac{Number\ of\ Data\ Collected}{Total\ Number\ of\ Measurement}\right) \times 100 \qquad \textbf{Eq 5.39}$$

Computation:

$$Reliability = \left(\frac{18{,}591}{43{,}200}\right) \times 100 \qquad \textbf{Eq 5.40}$$

$$= \mathbf{43.03472222\%}$$

Table 5.17 shows the overall reliability of the system to control and monitor water quality, this is done with the use of several sensors and actuators that provide the necessary action to control the water quality to a certain threshold level. The Number of data collected out of the 1-month (30 days) period of testing is 19,591 and the overall data collected is 43,200. With these 2 parameters we can calculate the reliability percentage of the overall system which is 43.03%. In additional, all the data that you want to find, see, can be seen in our appendices. The value 43,200 is the amount of data is being transmitted every minute and only 18,591 are collected in 1 month (36 days)

From the previous computation in the 1-month testing from June to July, the overall data collected was 43,200 but the amount of data that was only collected was only 7,580. There was a huge difference between the 1-month testing from June to July without the additional fan having an out of 17.54% only. While for the month of December 13, 2023, to January 11, 2024, has drastically increased the percentage of its reliability to store data and reduce hangs or freezes.

Table 5.18 1-Month Test Result of Reliability in Control & Monitoring with no additional Fan (October 1 – October 30, 2023)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Overall reliability of the system to control and monitor the water quality parameters	43,200	3,155	7.30%	The overall sensors delivered poor reliability.

Reliability Feedback:

- 1st Trial: 43,200 (Total Number of Measurements)
- 2nd Trial: 3,155 (Number of Data Collected)

Formula:

$$Reliability = \left(\frac{Number\ of\ Data\ Collected}{Total\ Number\ of\ Measurement}\right) \times 100 \qquad \textbf{Eq 5.41}$$

Computation:

$$Reliability = \left(\frac{3{,}155}{43{,}200}\right) \times 100 \qquad \textbf{Eq 5.42}$$

$$= \mathbf{7.303240741\%}$$

Table 5.18 shows the overall reliability of the system to control and monitor water quality, this is done with the use of several sensors and actuators that provide the necessary action to control the water quality to a certain threshold level. The Number of data collected out of the 1-month (30 days) period of testing is 3,155 and the overall data collected is 43,200. With these 2 parameters we can calculate the reliability percentage of the overall system which is 7.30. In additional, all the data that you want to find, see, can be seen in our appendices. Table 5.18 represents 1-Month of not integrating an additional fan. It can be seen that without the integration of an additional fan makes acquiring data more ineffective due to sudden hangs or freezes.

Table 5.19 7-Month Test Result of Reliability in Control & Monitoring w/o Additional Fan (July 1, 2023 – January 18, 2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Overall reliability of the system to control and monitor the water quality parameters	290,880	55,159	18.96%	The overall sensors delivered poor reliability.

Reliability Feedback:

- 1st Trial: 290,880 (Total Number of Measurements from July 1, 2023, to January 18, 2024)
- 2nd Trial: 55,159 (Number of Data Collected from July 1, 2023, to January 18, 2024)

Formula:

$$Reliability = \left(\frac{Number\ of\ Data\ Collected}{Total\ Number\ of\ Measurement}\right) \times 100 \quad \textbf{Eq 5.43}$$

Computation:

$$Reliability = \left(\frac{55{,}159}{290{,}880}\right) \times 100 \quad \textbf{Eq 5.44}$$

$$= \mathbf{18.96280253\%}$$

Table 5.19 shows the overall reliability of the system to control and monitor water quality, this is done with the use of several sensors and actuators that provide the necessary action to control the water quality to a certain threshold level. The Number of data collected out of the 7-month (201 days) period of testing is 55,159 and the overall data collected is 290,880. With these 2 parameters we can calculate the reliability percentage of the overall system which is 18.96 %. In additional, all the data that you want to find, see, can be seen in our appendices. The value 290,880 is the amount of data is being transmitted every minute and only 55,159 are collected in 7 month (201 Days).

5.20 Reliability of the System to Water Quality Parameters (December 13, 2023 – January 11,2024)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of Temperature threshold Values.	**18,591**	**18,238**	**98.10%**	The temperature has an excellent reliability rating
Ability to evaluate the reliability of pH level threshold Values.	**18,591**	**10,065**	**54.14%**	The pH sensor has a poor reliability rating
Ability to evaluate the reliability of Water Level to the Threshold Values.	**18,591**	**14,664**	**78.88%**	The temperature has a poor reliability rating.

Table 5.20 displays the result of the pH level, water level, and temperature that includes the additional fan. Based on the given parameters and data, the difference between the data from the previous 1-Month testing from June – July has drastically changed that can be seen in Table 5.20 below.

Table 5.21 Reliability of the system to water quality parameters (June – July 2023)

OBJECTIVE	# OF TRIALS	NUMBER OF SUCCESS RATE	SUCCESS RATE	RATING
Ability to evaluate the reliability of pH level, Temperature, and Water Level to the Threshold Values.				
Ability to evaluate the reliability of Temperature threshold Values.	**7,580**	**6,234**	**82.86%**	The temperature has a poor reliability rating
Ability to evaluate the reliability of pH level threshold Values.	**7,580**	**2,312**	**30.50%**	The pH sensor has a poor reliability rating
Ability to evaluate the reliability of Water Level to the Threshold Values.	**7,580**	**3,897**	**51.41%**	The temperature has a poor reliability rating.

Based on Tables 5.20 and 5.21 presents both different data from different months. Table 5.19 presents the data acquired from the system having 18,591 gather for the total data that should have acquired 43,200. Table 5.20 only have 7,580 as its number of acquired data from 1 month. Comparing each parameter can determine the difference between them. For Temperature has a 15.24% difference, pH Level 23.43% difference, and the temperature having the difference of 27.36%. Both Table 5.20 and Table 5.21 shows the overall reliability of the system to control the water parameters through its threshold value range, this is done with the use of several sensors and actuators that provide the necessary action to control the water quality to a certain threshold level.

Table 5.22 7-Month Test Result of Reliability in Outage/Blackout (July 1, 2023 – January 18, 2024)

# OF TRIALS	NUMBER OF SUCCESS RATE	NUMBER OF OUTAGES	Days, Hours, Minutes	Outage Rate
290,880	**55,159**	**235,721**	**163 Days, 20 Hours, 16 Minutes**	**81.01%**

In Table 5.22 shows the outages/blackout in the span of 7 months from July 1, 2023, to January 18, 2024.

$$Outage\ Rate\ = \left(\frac{Number\ of\ Failures}{Total\ Number\ of\ Trials}\right) \times 100 \qquad \textbf{Eq 5.44}$$

$$\left(\frac{235{,}721}{290{,}880}\right) \times 100 \qquad \textbf{Eq 5.45}$$

$$= \mathbf{81.01}\%$$

Based on the computation, there is a frequent outage during the 6-month span of the system. With the given output we can say that without integrating an additional fan can drastically increase the outages or blackout of the system. There is 163 Days, 20 Hours, 16 Minutes the system did not function well/outage.

Table 5.23 1-Month Test Result of Reliability in Outage/Blackout (December 13, 2023 – January 11, 2024) with Integrated Fan

# OF TRIALS	NUMBER OF SUCCESS RATE	NUMBER OF OUTAGES	Days, Hours, Minutes	Outage Rate
43,200	**18,591**	**24,609**	**17 Days, 21.6 Hours, 6 Minutes**	**56.90%**

In Table 5.23 shows the outages/blackout in the span of 1 month from December 13, 2023, to January 11, 2024.

$$Outage\ Rate\ = \left(\frac{Number\ of\ Failures}{Total\ Number\ of\ Trials}\right) \times 100 \qquad \textbf{Eq 5.46}$$

$$\left(\frac{24{,}609}{43{,}200}\right) \times 100 \qquad \textbf{Eq 5.47}$$

$$= \mathbf{56.90\%}$$

Based on the computation, there is a less outage during the 1-month span of the system. With the given output we can say that integrating an additional fan can drastically reduce the outages or blackout of the system. There is a total of 17 Days, 21.6 Hours, 6 Minutes the system did not function well/outage than Table 5.22 having 163 days of outage.

Table 5.24 1-Month Test Result of Reliability in Outage/Blackout (October 1 – 30, 2023)

# OF TRIALS	NUMBER OF SUCCESS RATE	NUMBER OF OUTAGES	Days, Hours, Minutes	Outage Rate
43,200	**3,155**	**40,045**	**27 Days, 19 Hours, 40 Minutes**	**92.75%**

In Table 5.24 shows the outages/blackout in the span of 1 month from October 1 to October 30, 2023, without the integration of an additional fan.

$$Outage\ Rate\ = \left(\frac{Number\ of\ Failures}{Total\ Number\ of\ Trials}\right) \times 100 \qquad \textbf{Eq 5.48}$$

$$\left(\frac{40{,}045}{43{,}200}\right) \times 100 \qquad \textbf{Eq 5.49}$$

$$= \mathbf{92.75\%}$$

Based on the computation, there is an increase outage during the 1-month span of the system. With the given output we can say that without integrating an additional fan for a month can drastically increase the outages or blackout of the system. There is a total of 27 Days, 19 Hours, 40 Minutes the system did not function well due to outage than Table 5.23 having 17 days of outage with an integration of an additional fan.

Table 5.25 Responsiveness of the System to store data parameters 6-Months.

JULY 01, 2023 – DECEMBER 12, 2023 (WITHOUT FAN)					
OBJECTIVE	NUMBER OF TRIALS	NUMBER OF SECONDS OF DELAY OR ADVANCE	TOTAL NUMBER OF DATA	OVERALL AVERAGE	REMARKS
Ability of the system to process incoming data from the sensor into the database.	1	58 Seconds	318	0.263 Seconds	HIGH
	2	59 Seconds	423		HIGH
	3	60 Seconds	20,655		HIGH
	4	61 Seconds	8,806		HIGH
	5	62 Seconds	12		HIGH
	6	68 Seconds	2		LOW
	7	69 Seconds	1		LOW
	8	76 Seconds	1		LOW
	9	77 Seconds	1		LOW
	10	95 Seconds	2		LOW
	11	104 Seconds	1		LOW

Minimum: 2 Sec (58 Seconds - Advance) **Maximum**: 44 Secs (104 Seconds - Delay)

In Table 5.25 presents the responsiveness of the System to store data which includes the following months without the integration of an additional fan. Based on the given table, the current process time to store the data is 60 seconds or 1 minute which almost all the data is correct having a constant value storing 20, 655 times. The reason why there is a sudden change of transmitting data is because of the RasPad3. Even though we program the system to only send data every minute or 60 seconds it may be possible that it can be a hardware error, or the system suddenly freezes for a brief period.

Table 5.26 Responsiveness of the System to store data parameters with Additional Fan

DECEMBER 13, 2023 – JANUARY 18, 2024 (WITH FAN)					
OBJECTIVE	NUMBER OF TRIALS	NUMBER OF SECONDS OF DELAY OR ADVANCE	TOTAL NUMBER OF DATA	OVERALL AVERAGE	REMARKS
Ability of the system to process incoming data from the sensor into the database.	1	58 Seconds	245	0.294 Seconds	HIGH
	2	59 Seconds	188		HIGH
	3	60 Seconds	14,939		HIGH
	4	61 Seconds	7,113		HIGH
	5	62 Seconds	73		HIGH
	6	63 Seconds	1		MODERATE
	7	65 Seconds	1		LOW
	8	68 Seconds	1		LOW
	9	69 Seconds	1		LOW
	10	71 Seconds	1		LOW
	11	73 Seconds	1		LOW

Minimum: 2 Secs (58 Seconds - Advance) **Maximum**: 16 Secs (73 Seconds -Delay)

Comparing Tables 5.25 and Table 5.26 there is a change between integrating an additional fan. Table 5.27 has 14,939 of data stored every minute while Table 5.26 stores only 20,655 for 6 months. In addition, when the system already integrated an additional fan, the amount of delay in sending data decrease from 104 seconds to 73 seconds.

TABLE 5.22 DESIGN CONSIDERATION RUBRICS

Consideration	Parameters	4	3	2	1	Function /Means
Public Health and Safety	Complies/Follows electrical regulations of PEC (Phil Elec Code), ISA (Intern. Soc, Automation) and other electrical safety organizations.	The project was able to follow all the rules and regulations set by ISA, PEC, other organizations	The project was able to follow most of the rules and regulations set by ISA, PEC, other organizations	The project was able to follow few rules and regulations set by ISA, PEC, other organizations	The project fails to follow all the rules and regulations set by ISA, PEC, other organizations	Display Graphical information, Acquire and Measure parameters, and trigger actuators.
Social	Determine the sensor values on the website interface that will be accessible to the user	The sensor values and graphical interface, and database are accessible and readable	The sensor values graphical interface, and database are not accessible but readable	The sensor values graphical interface, and database are accessible but not readable	The sensor values are graphical interface, and database not accessible and not readable	Graphical Display Water Quality Parameter Sensors Storing
Ethical	Assure proper management of the automation system	The system was able to manage the well-being of sensors., display and actuators	The system was able to occasionally manage the well-being of sensors, display, and actuators	The system was able to rarely manage the well-being of sensors display and actuators	The system fails to manage the well-being of the sensors, display, and actuators	Data Storing/ Physical Display
Economic	Determine the proposed budget for the creation of the overall smart aquaponics system	The project costed below 10,000 PHP	The project costed between 10,001 PHP – 20,000 PHP	The project costed between 20,001 PHP – 30,000 PHP	The project costed more than 30,000 PHP	Budget Costs
Environmental	Identify if available resources are efficiently used	The resources are always used in a sustainable manner	The resource/materials are often used in a sustainable manner	The resources are rarely used in a sustainable manner	The resources are never used in a sustainable manner	Adjust Water Quality

Table 5.22 shows the parameters of each design process. The proponents base the performance of the project through ratings. The rating starts from 1 being as the lowest and it end in 4 as the highest rating. For Public Health and Safe, there are changes from the last design consideration rubrics under chapter 3. Public Health and Safety, Ethical, and Environmental are rated at 3 while for economic is rated 2. While Social has the highest rated of 4.

5.2 Strengths and Weaknesses of the Final Design

After testing and evaluating the re-develop project of the proposed study that can automatically maintain the water quality parameters and monitor the water quality within its threshold, the proponents identified its strengths and weaknesses. The strengths are the significant points achieved in the project and during the testing, while the weakness are the aspects of the project which may still be improved or adjust.

5.2.1 Strengths

- The SMARTBAY system receives an excellent rating in responsiveness, particularly in measuring pH and water level.
- The SMARTBAY system demonstrates good responsiveness in assessing turbidity and very good responsiveness in monitoring temperature.
- The SMARTBAY system show high responsiveness in data storing, achieving an average response time of 0.022 seconds, meeting the objective of less than 2 seconds.
- The SMARTBAY system proves strength in public health and safety by consistently following all rules and regulations set by ISA, PEC, and other organizations.
- In the social aspect, the system ensures the sensor values, graphical interface, and database are accessible and readable on the website interface.
- Ethically, the system demonstrates strength by being able to manage the well-being of sensors, display, and actuators occasionally and rarely, supported by data storing and physical display.
- Environmental strength is evident by always using resources in a sustainable manner.

5.2.2 Weaknesses

- The reliability of pH measurements, temperature readings, and water level assessment within the SMARTBAY system is rated as poor.
- The reliability of control and monitoring functions within the SMARTBAY system is assessed as poor.
- The SMARTBAY system faces weaknesses in economic aspects, as the project cost exceeded the proposed budget of 30,000 PHP.

CHAPTER 6
SUMMARY OF FINDING, CONCLUSIONS, AND RECOMMENDATIONS

The researchers aim to develop an automatic control system that will maintain the water quality parameter to the desired threshold value and can be able to monitor and store the data. This is by designing an accurate system in measuring the following data parameters in the aquaponics systems, evaluate the reliability of the automated pH level up and down, temperature change and water level control gates, and test the overall reliability of the system to control and monitor the water parameters in the Smart Aquaponics System.

The proponents aim to develop an automated system that regulates the water parameters of the aquaponics system. The researchers have defined that the designed project must comply with the objectives of the research: accurately get data, consistently maintain parameters, and reliably control and monitor the aquaponic system.

SUMMARY OF FINDINGS

Table 6.1 Objective Summary of Findings (With Fan) (December 13, 2023 – January 11, 2024)

Objective	Minimum	Average	Maximum	Score	Scale	Rating
Accuracy: pH	0.32	5.58	10.57	98.72%	100% - 95.00 %	**Excellent**
Accuracy: Turbidity	36.58	2040.39	3003.83	87.95%	89.99% – 85.00 %	**Good**
Accuracy: Temperature	26.87°C	30.13°C	34.69°C	93.59	94.99 % – 90.00%	**Very good**
Accuracy: Water level	1	41	81	95.57%	100% - 95.00 %	**Excellent**
Reliability: pH	0.32	5.22	13.89	54.14%	84.99% and below	**Poor**
Reliability: Temperature	24.56°C	27.64°C	31.94°C	98.10%	84.99% and below	**Excellent**
Reliability: Water level	16	22.94	60	78.88%	84.99% and below	**Poor**
Reliability Control and Monitor	0.5 hours	27.75 hours	55 hours	43.03%	20.01% and above	**Poor**
Responsiveness of Data Storing	1 seconds	0.859 seconds	73 seconds	0.859 seconds	<2	**Excellent**

Table 6.1 displays an overview of the finding during the time of December 13, 2023, to January 11, 2024. The minimum, average, and maximum were based on the delay of the RasPad 3 to store data within the database where in the minimum delay is 0.5 hours when converted to into minutes gives us the value of 30 minutes, the average delay is 27.75 hours when converted to minutes gives us the value of 27 hours and 45 minutes, and lasty the maximum delay that was observed was around 55 hours which is 2 days and 7 hours.

Table 6.2 Outage/Blackout (December 13, 2023 – January 11, 2024) with Integrated Fan

# OF TRIALS	NUMBER OF SUCCESS RATE	NUMBER OF OUTAGES	Days, Hours, Minutes	Outage Rate
43,200	**18,591**	**24,609**	**17 Days, 21.6 Hours, 6 Minutes**	**56.90%**

Table 6.2 displays the outage or the blackout value of RasPad3 during the times of December 13, 2023, to January 11, 2024. Compared to the outage rate of the previous test without the integration of a fan on the RasPad3. It is significantly lower going to a 56 to 57% outage rate.

Table 6.3 Objective Summary of Findings (Overall) (July 1, 2023 – January 18, 2023)

Objective	Minimum	Average	Maximum	Score	Scale	Rating
Accuracy: pH	0.32	5.58	10.57	98.72%	100% - 95.00 %	**Excellent**
Accuracy: Turbidity	36.58	2040.39	3003.83	87.95%	89.99% – 85.00 %	**Good**
Accuracy: Temperature	26.87°C	30.13°C	34.69°C	93.59	94.99 % – 90.00%	**Very good**
Accuracy: Water level	1	41	81	95.57%	100% - 95.00 %	**Excellent**
Reliability: pH	0.32	4.26	12.95	38.40%	84.99% and below	**Poor**
Reliability: Temperature	22.69°C	29.36°C	34°C	87.19%	85.00% - 89.99%	**Fair**
Reliability: Water level	15	22.00	60	77.21%	84.99% and below	**Poor**
Reliability Control and Monitor	1.2 hours	40 hours	80 hours	18.96%	15.01% - 20.00%	**Fair**
Responsiveness of Data Storing	2 seconds	0.276 seconds	104 seconds	0.276	<2	**Excellent**

Table 6.3 displays an overview of the findings following a series of experiments undertaken by the researchers. It displays the objectives, as well as the metrics that were measured a scale, and rating. Test results of the Responsiveness for pH were excellent where it measures an accurate gathering of data. The responsiveness minimum, average, and maximum pH value collected within the 1-month period, where in the minimum data collected was 0.32 which is below the pH threshold level, the average value falls within 5.58 which is within the pH threshold value and a maximum value of 10.57 which is above the pH threshold value. For the Responsiveness for the turbidity, it collects the turbidity level at a fair rating, though it still can be accurate enough for the system. The responsiveness minimum, average, and maximum turbidity value collected within the 1-month period, where in the minimum data collected was 36.58 it should be considered that turbidity values that are negative can be considered as sensor error or malfunction, the average value falls within 2040.39 and a maximum value of 3003.83. The Responsiveness for the temperature has a very good rating in acquiring the water temperature of the system. The responsiveness minimum, average, and maximum temperature values collected within the 1-month period, where in the minimum data collected was 26.87 °C which is below the temperature threshold value, the average value of 30.13°C which falls within the temperature threshold value, and a maximum value of 34.69°C which is above the temperature threshold value. The Responsiveness of the Water level has an "Excellent" rating that will effectively maintain the water level of the system. The minimum, average, and maximum were based on the delay of the RasPad 3 to store data within the database where in the minimum delay is 1.2 hours when converted to into minutes gives us the value of 1 hour and 12 minutes, the average delay is 40 hours, and lasty the maximum delay that was observed was around 80 hours which is 3 days 7 hours and 55.2 minutes. Overall, with the data collected the system provides has an accurate rating this due to the calibration done to the pH, ultrasonic, and temperature sensor. The overall reliability of the system has a rating of poor this is due to hardware issues pertaining the Raspad 3 which overheats through unfavorable weather conditions. The overall responsiveness has a rating of high this due to the efficient software design where data is stored to the database efficiently. Even though our Accuracy and Responsiveness has a rating of at least a "Good Rating", "High Responsiveness", there are factors to consider in the systems reliability. One of which is the lack of resources and the tendency have freezes due to software failures another is in not directly connected to water parameter supplies like water.

Table 6.4 Outage/Blackout (July 1, 2023 – January 18, 2024) With Integrated Fan

# OF TRIALS	NUMBER OF SUCCESS RATE	NUMBER OF OUTAGES	Days, Hours, Minutes	Outage Rate
290,880	55,159	235,721	163 Days, 20 Hours, 16 Minutes	81.01%

Table 6.4 displays the outage rate of the entire testing period starting from the date of July 1, 2023, to January 18, 2024. During the period of the entire testing time, the RasPad3 only got a maximum of 28.99% of the overall data that should have been got throughout the testing period.

Table 6.5 Outage/Blackout (October 1 – 30, 2023) Without Fan

# OF TRIALS	NUMBER OF SUCCESS RATE	NUMBER OF OUTAGES	Days, Hours, Minutes	Outage Rate
43,200	3,155	40,045	27 Days, 19 Hours, 40 Minutes	92.75%

Table 6.5 displays the outage rate for the entire month of October being a comparison or a basis of what the outage looks like before the integration of a fan on the RasPad3 compared to the outage rate of the RasPad 3 after the integration of the fan. We can see from the data displayed that the outage rate of the time when the fan is integrated is significantly less compared to the outage rate of when the fan is not integrated yet. Resulting in a 35.85% difference, the integration of the fan clearly shows the improvement in data collection.

6.1 Conclusion

In conclusion, the aquaponics system that the proponents have made have shown that the system is accurate when it comes to the sensor value compared to other measuring devices. The proponents have tested the sensors in different scenarios and received values that are similar to the different sensor that was used to compare the main sensor. This concludes that the Accuracy of the sensors of the system is very good in the rating scale or is at an excellent rating. Unfortunately, some the system has not produced an optimal yield because of factors that can be seen in the full integration of the system. Pertaining to the integrations that affected the yield of the plant is the pH of the water not being consistent because of the low reliability rate of the system causing the actuators to not activate at the right moment when the system needs it. This is because if the RasPad stopped from putting data in the database, the system is going to activate based on what is the last information put inside the database. In that regard if ever the last information is considered as optimal and the RasPad froze, the system is going to think that it is in the optimal range and will not adjust based on the actual value of the system. Another factor for not having optimal yield is the lack of non-renewable supplies like the water from the water reserve and the pH up and down solutions running out at a fast rate. The other factors that are in line with not having the sufficient amount of resources is the lack of money in the system. The lack of money results in the system not having the right amount of resources that it needs to constantly grow and produce yield.

SMARTBAY's general objective focuses on developing and implementing an advanced aquaponics system with an emphasis on combining automation, monitoring, and a web-based interface to control and monitor water quality parameters for optimal production of Nile Tilapia and various plants. In contrast, AquaRam's general objective is more broadly stated, aiming to design and innovate an Aquaponics System without specifying the integration of automation and monitoring features. When examining specific objectives, SMARTBAY's lays out a detailed plan to design an accurate system for acquiring multiple data parameters, develop a reliable system for automated control, and implement a responsive system for real-time data storage. On the other hand, AquaRam's specific objectives are more limited, focusing on developing a web application for monitoring water quality parameters and creating a responsive interface for user-set threshold values. Therefore, SMARTBAY's comprehensive approach, encompassing automation, monitoring, and database integration, positions it as a more robust and advanced system compared to the relatively narrower objectives of AquaRam's.

Regarding to the difference and improvements that the system has compared to the previous system is that the current improved the water quality by implementing a new filter design to further filter out solid waste. Compared to the work of the previous group, the reliability and responsiveness of the previous group to read and input data in the database is much higher than what is produced today. This is because of the implementation of the raspad having freezes. The previous group have experienced difficulties in regard to continuing the data gathering of the system because of the water damages or malfunctions of the components causing it to not work. In the current group the components are not getting damaged but the implementation of the raspad had an effect in the overall responsiveness and reliability.

SMARTBAY's implementation of a Raspad addresses previous group limitations, enhancing reliability despite occasional freezing. It surpasses AquaRam in responsiveness, achieving an average response time of 0.022 seconds and outperforming in measuring pH and water level. While both systems display excellence in storing sensor values, SMARTBAY stands out for its superior reliability in control and monitoring functions, adherence to public health and safety standards, and commitment to environmental sustainability. SMARTBAY's well-designed graphical interface and database contribute to user accessibility, further emphasizing its advancements over AquaRam. Additionally, SMARTBAY manages economic challenges more effectively, costing between 20,000 PHP – 30,000 PHP, in contrast to AquaRam's expenses ranging from PHP 30,000 - 40,000, exceeding the proposed budget. In essence, SMARTBAY represents a more advanced and effective aquaponics system, integrating technical competence with ethical and economic considerations, surpassing the capabilities of AquaRam.

The system has been able to follow most electrical rules regulations in creating the system. The systems have been able to function without any hazardous effects to the user and the system has been able to continually work. The systems graphical interface and database has been accessible and easier to understand by users in monitoring the system which also occasionally manage the well-being of the sensors, display, and actuators. Though, there are times that the reliability of the system to monitor keeps freezing, minimizing its efficiency. Overall, the project costed between 20,000 PHP – 30, 000 PHP combined with the Financial Aid of the

Logistics/Finance Department and the Researchers themselves. Lastly is the systems efficiency in maintaining the resources sustainably. Though, the lack of resources needed for the system minimize its reliability. The reliability of the sensors, actuators, and other functions have been used accordingly and efficiently, without the need to replace some parts.

The system has been able to measure the water quality parameters (pH Level, Water Level, Temperature, and Turbidity) accurately and effectively having a rating of: “Excellent” in acquiring the pH, “Good” in Acquiring the Turbidity, “Very Good” in acquiring the Temperature, and “Excellent” in acquiring the water level. Though, the systems Reliability has been rated as “Poor” because of the factors to consider such as the limited sources to maintain the system, sudden temperature changes, water level due to not in direct connection to the water source, and sudden freezes due to systems failure and lack of ventilation. Though in storing the data in the database, it has a rating of “High Responsiveness” meaning that the system is able to store the data “real-time” and can determine the amount of input needed to main the threshold.

The automation of the system is functioning as expected and is responding as expected based on the threshold value that the proponents have set. The system that the proponents have made is an effective system if we are talking about maintaining the water parameters. It is easier for the user if they are using the system because the system only needs to have ample number of materials to fully maintain the parameters rather than the user having to check physically what are the parameters of the system is.

Over the course of 7 months, the aquatic environment has proven to be more conducive to growth, particularly for the fish population. The researchers observed that the fishes attained an ideal weight during this period, prompting them to initiate the harvesting process. In total, a remarkable 76 fish were successfully harvested, marking an impressive growth rate of 45.1% in comparison to the previous 2 harvest which are 24 on December 13 ,2022 and 27 on January 30, 2023. However, the hydroponic environment has proven to be less conductive to growth especially in July to October which the plant that were planted are Chili and Spinach. In November the researchers planted lettuce in the aquaponic and over the course of one month and 20 days, equivalent to approximately three weeks, the lettuce crop has exhibited a consistent growth pattern with an average increase of 0.64 cm per week. Despite this steady progress, the lettuce has not yet reached its optimal length for harvesting, indicating that more time and favorable conditions are required to achieve the desired maturity.

6.2 Recommendation

Through the process of developing and testing the project, the proponents can observe some aspects of the project that might be improved in the future. Listed below are the group's recommendations that may serve as reference to the coming researchers.

- The proponents suggest replacing RasPad3 with the implementation of an IoT device or another alternative device, such as tablets, dashboards, or small laptops, to ensure the system receives continuous updates on the database without experiencing freezing issues.
- The proponents propose integrating a graph display monitor into the system following the implementation of an IoT device, aiming to enhance real-time data visualization, analysis, and overall system performance monitoring.
- The proponents recommend establishing a direct water line connection from the main water supply to the aquaponics system to ensure a consistent water supply in the event of a decrease in water levels.
- The proponents advise improving chassis ventilation to minimize dust accumulation.
- The proponents advise maintaining a supply of pH solutions to ensure continuous pH regulation, as the absence of these solutions would leave the system unable to effectively manage pH levels.
- The proponents propose integrating a water-cooling mechanism, such as a Peltier system, to regulate and cool the water temperature in case it exceeds the recommended threshold.
- The proponents suggest enhancing the filtration system by introducing a radial flow separator, positioned between the mechanical filter and the filter inlet, which effectively separates solid waste and reduces the cleaning frequency of the mechanical filter.

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