Evolution in Electrical and Electronic Engineering Vol. 1 No. 1 (2020) 357 - 367

EEEE

Homepage: http://penerbit.uthm.edu.my/proceeding/index.php/eeee
e-ISSN : 2756-8458

Aquaponic Monitoring System

Mok Jian Qin[1], Noor Azizi Bin Mardi[1]*

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Johor, MALAYSIA

DOI: https://doi.org/10.30880/eeee.2020.01.01.043
Received 01 August 2020; Accepted 06 September 2020; Available online 30 October 2020

Abstract: Aquaponics has always been hot topics in food sustainability and agriculture. To maintain an aquaponics system, attention is needed on the water condition of the system. With city expanding and human population increasing, there is less and less space available for agriculture and aquaculture to operate [10]. Aquaponics might be one of the solutions for the crisis but aquaponics requirement much more effort in maintaining than the traditional soil-based agriculture. In this project, a monitoring system for aquaponics is designed, enable user to remotely monitor the condition of aquaponics. The system comes with emergency alert function that can prevent the further loss on the aquaponics when problem occurs. Moreover, the data of the condition of the water in the aquaponics system are recorded for user to better identify the cause and solution for problems that occurs.

Keywords: Aquaponics, Monitoring System, Remotely Monitor

1. Introduction

Aquaponics has become increasingly popular as an indoor growing system in the past years [9]. Aquaponics is the marriage of aquaculture (raising fish) and hydroponics (growing plants in the water without soil) together in one integrated system [6][7]. It combines the wastewater treatment in recirculating aquaculture system (RAS) with the production of crop plants biomass [4]. Although the aquaponics system yields much more crops with less spaces needed [1], it requires much more attention towards the water parameter for maintaining a healthy aquaponics for optimum yield [5]. For the problem stated a monitoring system can be used to aid in maintaining an aquaponics system.

The aquaponics monitoring system used should reads the water temperature, pH and water level of the aquaponics system. An emergency alarming system is included to alert the user when the water parameters falls below safe range. For the data on the water parameters, not only that real-time value can be viewed by user remotely, the datas should be recorded and stored in online platform for user to view it at any time after. With the recorded data user can further understand the changes of the parameters of the system.

2. Materials and Methods

The study is focusing on the electronic hardware and components of the monitoring system. The materials for assembling the aquaponics system is dependent on the type of aquaponics system used. In this study, vertical tower aquaponics with lightweight expanded clay aggregates as media is used.

**Corresponding author: azizim@uthm.edu.my*

2.1 Materials

The microcontroller used in the study is NodeMCU ESP32. It has built in antenna for connecting Wi-Fi which are convenient for sending data to Cloud service. ESP32 works on 3.3V, so a separated power supply is needed from 5V sensors. Programming of microcontroller can be done using Arduino IDE in C++.

Sensors used in the monitoring system are pH sensor module E-201-C, waterproof temperature sensor DS18B20 and water level sensor switch. Water temperature sensor works with Maxim 1Wire, a type of serial communication and can works well with 3.3V input. For ph sensor, it works on 5V so external power supply is needed. Water level sensor switch is a submersible reed switch, whenever water level fall the float holding the magnet will lower to the reed switch which will close the switch.

Output for the monitoring systems are relay, submersible water pump, LED, buzzer and Firebase database. Relay is used to control the submersible waterpump. A single chanel 5V relay is enough to control the 14 Watt water pump with input voltage of 240AC. LED and buzzer is part of the alarming system to alert user. For the power supply, 12V AC to DC adapter and a 5V voltage regulator L7805 is used to supply the sensors and microcontroller.

2.2 Hardware architecture

NodeMCU ESP32 has 15 ADC pins available for usage of analogue sensor. The actuators in the project including the LED, buzzer, relay and submersible pump for the water recirculation system. While for the sensors there are water temperature sensors, pH sensor module and water level detector. NodeMCU ESP32 acts as the microcontroller (µC) to process input and execute output. The submersible pump will circulate the water to each plant cup and aquarium. The µC will turn off the water pump if water level fall beyond a predetermined level. The water level with pH and water temperature value will be send to cloud through Internet for user to view it remotely. User can observe the condition of their aquaponics systems via mobile as well. If the readings on the input exceed a safety range the LED as indicator and buzzer at aquarium will activate. Warning will be display on the mobile too.

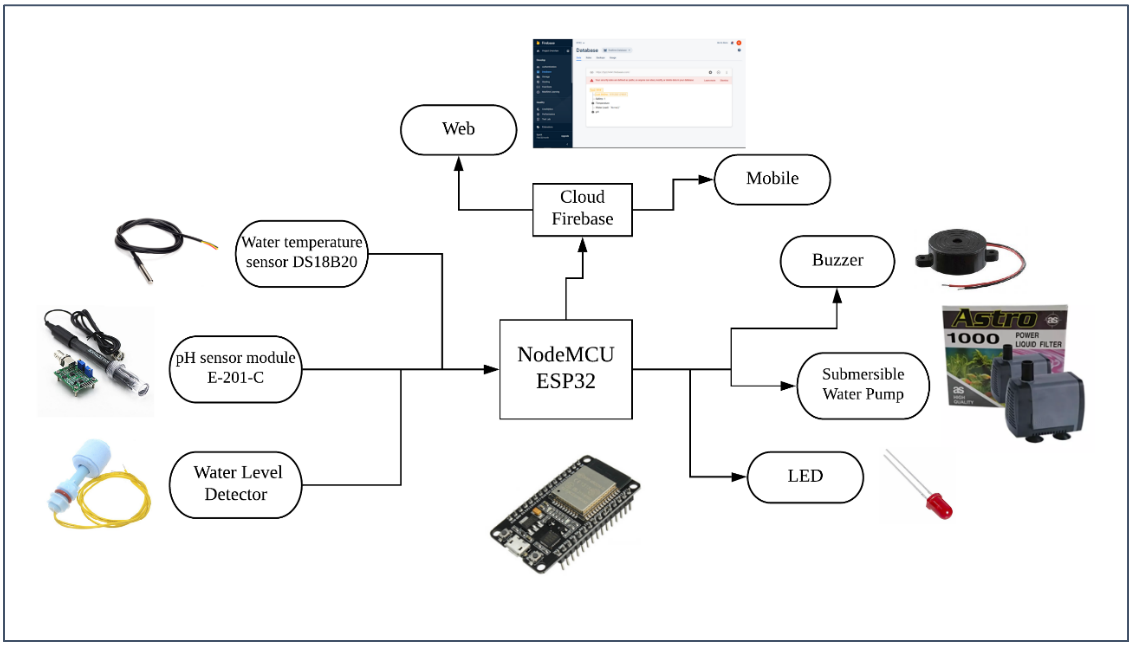

Figure 1: Hardware architecture

2.3 Hardware schematic

Figure 2 shows the schematic of circuit connection from the hardware architecture. The main power supply for the circuit is from a 12V DC adapter which then has its voltage regulated to 5V with the voltage regulator L7805CV. The adjusted 5V voltage from the voltage regulator act as power supply for both NodeMCU and pH sensor module. The second power supply is for the water pump, where the 240V AC power from outlet is connected to a relay before supplying the power to water pump. The water pump is connected to the normally close terminal of the relay, so the water pump gets power supply whenever the relay is not activated. For the water level indicator, it is made by submersible reed switch where when the water level fall below the indicator, the magnet in the float will attract and complete the circuit, a resistor of 10k ohm is used to prevent short circuit from Vcc and GND as well act as a pull down resistor. The pull-down resistor is connected to pin 4 of the NodeMCU as input. LED and buzzer are connected parallel to each other and can be activated by applying HIGH at output pin 16. Temperature sensor uses serial communication, it required a pull up resistor of 4.7k ohm at the data line connected to pin 2 for the NodeMCU to get the reading. Pin 34 of NodeMCU is for reading the analog input from the pH sensor module. Voltage divider consist of 1.1k ohm and 2k ohm are used at pin 34 as the output voltage for pH sensor module is 5V but the operating voltage for NodeMCU is 3.3V. NodeMCU activate the relay by giving a LOW output at pin 32.

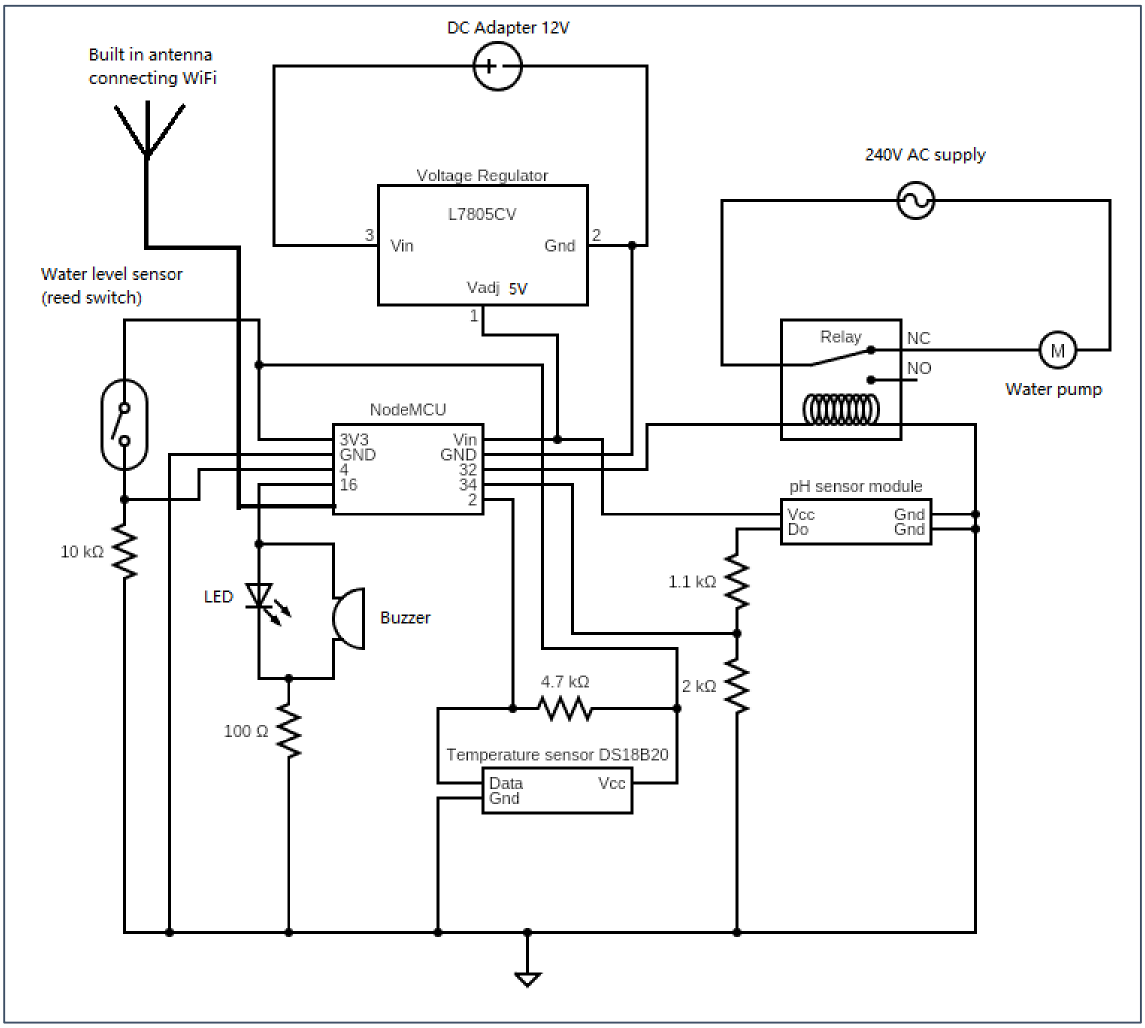

Figure 2: Schematic diagram

2.4 Programming flowchart

At the beginning of the program, NodeMCU will try to connect to the Wi-Fi. Then it will keep Firebase updated with its online timestamp. After the online timestamp is updated it will check on the timestamp whether it is the 1st, 16th, 36th or 46th minute of the hour. If the timestamp does match the condition, NodeMCU will take the temperature and pH reading, sending the readings to Firebase. Then, NodeMCU will take the reading of the water level indicator. If the water level is normal, the program will loop back to update the online timestamp. But if the water level is low, NodeMCU will read the safety setting tab in Firebase to decide whether to activate the emergency alarming system. If the safety tab reads the integer “0”, the program will not activate the emergency alarming system, else the program will turn on the buzzer and LED to alert people around the aquaponic set up, it will also activate the relay to cut off the power supply for water pump. A warning message is sent to Firebase to tell the user about the low water level in the aquaponic setup. The program is looping back to update the online timestamp and it runs continuously in loops.

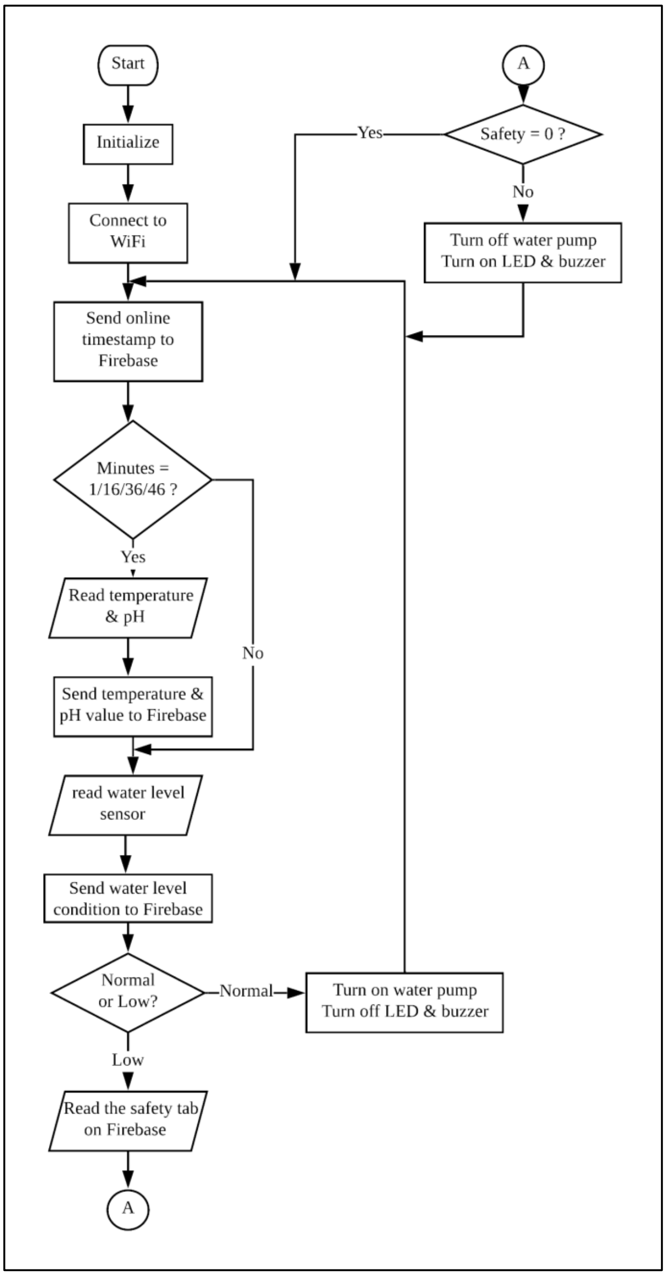

Figure 3: Programming flowchart

2.5 Aquaponics hardware setup

The aquaponics setup is assembled and kept running for 28 days. The electronic components including the sensors and actuators are assembled and modified throughout the 28 days.

The system is built on an 80litre water container with three 754 cubic metre vertical tower filled with 377 cubic metre of lightweight expanded clay aggregate (LECA). On each of the vertical tower are 4 extruded cups for the vegetables to grow. Germinated lettuce is planted on the vertical tower with coconut peat as support. The vertical towers are aligned at the top of the tank. Water pump is situated at the bottom of the tank, pumping water and fish waste from the tank to the top of each vertical tower through pipes. The water pipe at the top of the towers is connected in a ring shaped for the water pressure to distribute more evenly among the three outlets. In preliminary design there are six vertical towers but only three is built in the setup.

At the bottom of the tank, limestones of various size are added to help promote the growth of nitrifying bacteria as well as slightly raising the pH of water. Tap water that is left at least overnight is used to replenish the loss water in the tank. Three round holes is cut off from the lid for the vertical towers to fit in. The lid is purposely kept to reduce the amount of light entering the tank which promotes algae growth.

Figure 4: Aquaponics hardware setup

In the vertical towers are LECA ball as growing medium. At the bottom of the tower and near the plant cup, coconut coir is mixed into the LECA balls to further filter solid waste and provide extra support for plant root to grip. Earthworms are added in the towers to help digesting the solid wasted and uneaten fish food.

Each cup is planted with germinated lettuce while ten Red Nile Tilapia fingerlings is added into the tank at the first week after the hardware is set up. The aquaponics hardware is placed at a balcony-like environment, partially shielded from sunlight and rainwater. The system runs on two power sockets, one for the microcontroller with the sensor and actuators, another to power the water pump. The circuit is placed inside a polypropylene container and situated at the side of the tank.

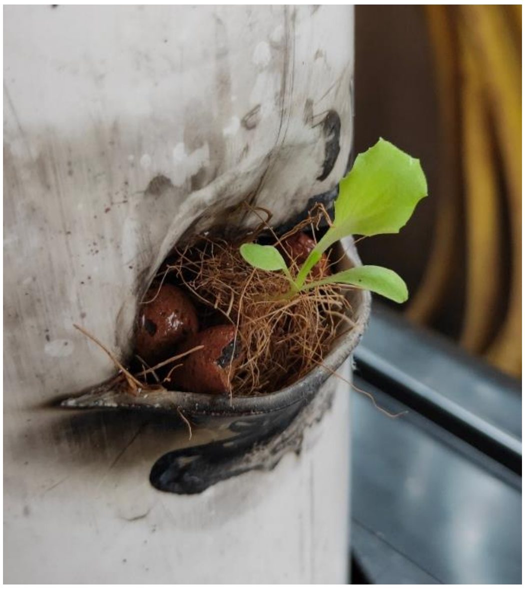

Figure 5: Lettuce seedling wrapped with coconut coir planted on vertical tower

The circuit for aquaponics system is assemble as in Figure 2, powered by an AC to DC 12V adapter with 5V voltage regulator L7805CV. Heat sink is added to the voltage regulator to improve the ability of the voltage regulator to release heat. The water pump has a separated power source directly from the 240V AC with 50Hz frequency, controlled by a single channel 5V relay connecting to NodeMCU ESP32. All the sensors including water temperature sensor DS18B20, pH sensor module and water level detector are situated on the inner side of the tank, with the sensing part dipped into the water.

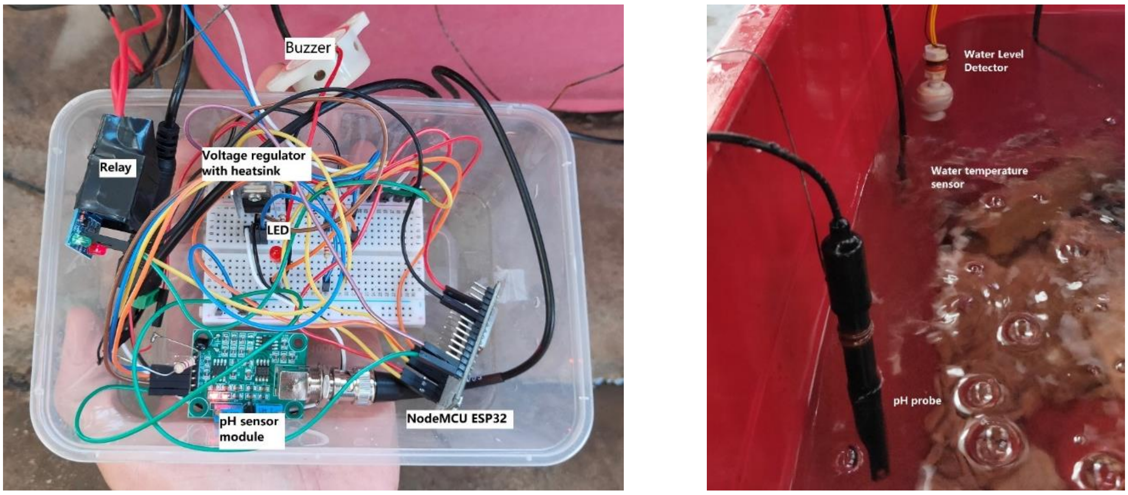

Figure 6: Assembled circuit(left) and location of the sensors in the tank(right)

3. Results and Discussion

3.1 Fish mortality and weight

At the beginning of the operation of the setup, ten Red Nile Tilapia fingerlings are put into the tank. Four fingerlings died in the first week, three more followed the second week and two more found death in the third week. Their average weight is measured and recorded every week. After the third week only one Red Nile Tilapia is alive in the tank. The tank is initially stocked with 10 fingerlings. The mortality rate per week is 0.225 which indicate that 2.25 fish died per week in a tank of 10 fish. Throughout the 4 weeks, the fish has average weight gain of 4 grams.

Table 1: Fish mortality

Week	0	1	2	3	4
Number of fish alive	10	6	3	1	1

Table 2: Average fish weight

Week	1	2	3	4
Weight of fish (g)	4	9	15	16

3.2 Plants

Twelve lettuce seedlings are planted on the three vertical towers. All the lettuce survived through the four weeks. Lettuces that are planted facing the sun grows larger than the lettuces on the shaded side. For comparison, some seedlings from the same patch is instead planted into soil and grow at the same time. The lettuces grow in soil are larger and greener than those planted in the aquaponics system. No fertilizer is added in both systems.

Figure 7: Comparison between lettuces grow in aquaponics (left) and soil (right)

3.3 Water temperature

Water temperature in does not have drastic change as Malaysia has warm and humid climate [2]. Water temperature reading is taken and recorded every 15 minutes on the 1st, 16th, 31st and 46th minute of the hour. Below is the sample trend of water temperature for a whole day taken on 3rd of July. The highest recorded water temperature is 29.375 °C at 2.31p.m. on 17th of July while the lowest is 23.875°C at 10.01 a.m. on 10th of July. The highest recorded water temperature is 29.375°C while the lowest is 23.875°C. The difference between the highest and the lowest is 5.5°C which is still around optimum range of 25°C to 30°C for Red Nile Tilapia [3].

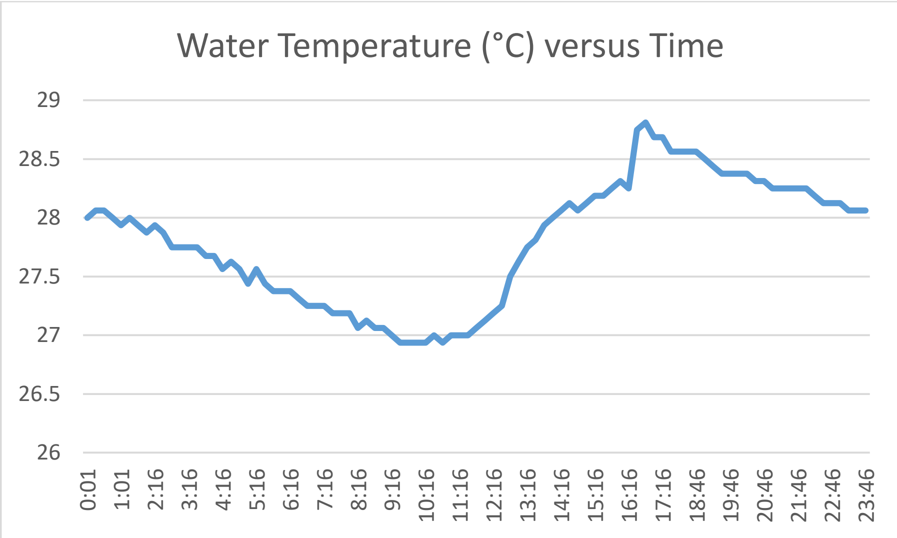

Figure 8: Aquaponics tank water temperature trend on 3rd of July

3.4 The pH of water

The pH of water in the aquaponics system is obtained with the pH sensor module that compare on the electric conductivity of tested liquid in relative with the solution in the probe. The sensor is calibrated with buffer solution of pH 4.00, 6.86 and 9.18 obtained by mixing distilled water with the corresponding buffer powder at room temperature. As the pH value fluctuate, universal indicator pH paper is used to test the water pH as a reference. The pH value obtained for the water in the tank falls around pH 7 which us tolerable to all three components in the systems [8].

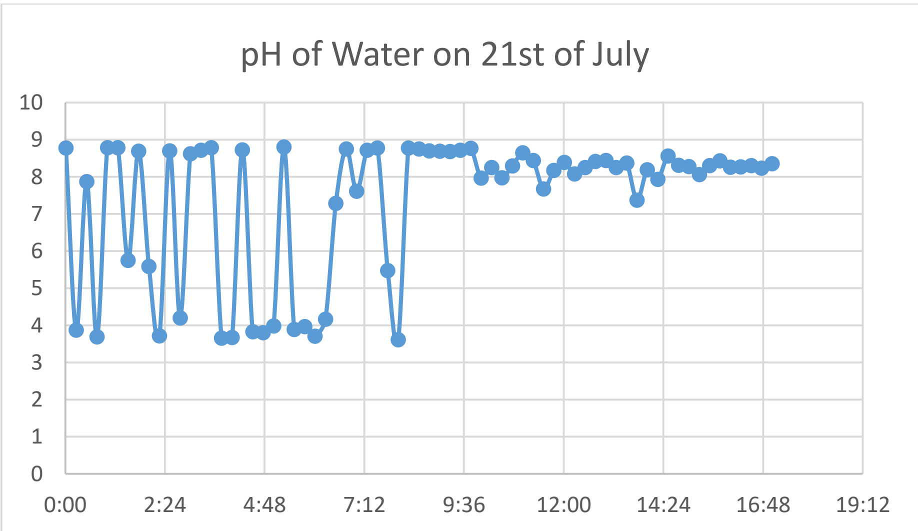

Figure 9: pH of water on 21st of july

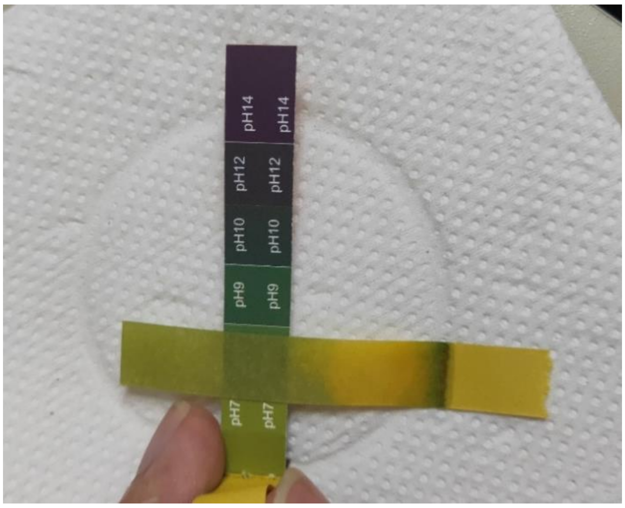

Figure 10: Testing on water pH using universal indicator pH paper

3.5 Firebase database

The Firebase database can record and store the data sent from NodeMCU ESP32 via internet. Water temperature, pH, water level and safety setting is recorded in Firebase in this project.

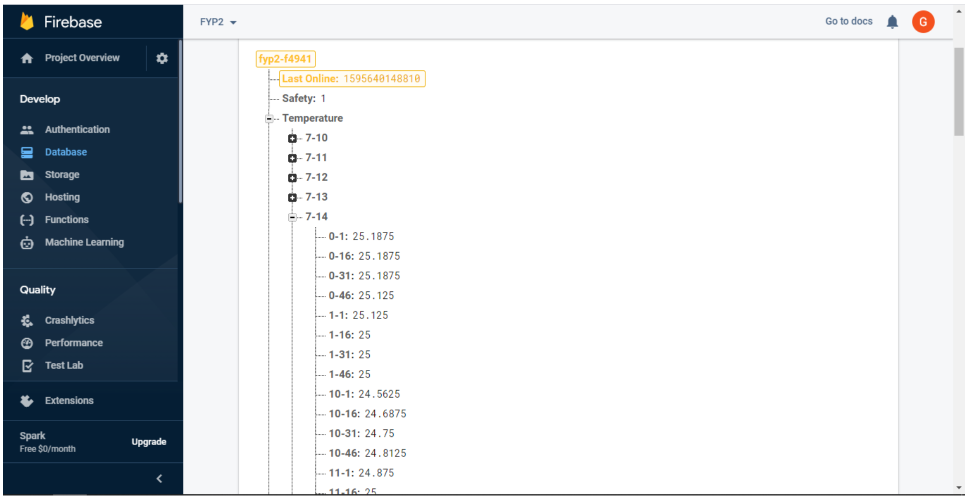

Figure 11: Firebase recording water temperature readings at 15 minutes intervals

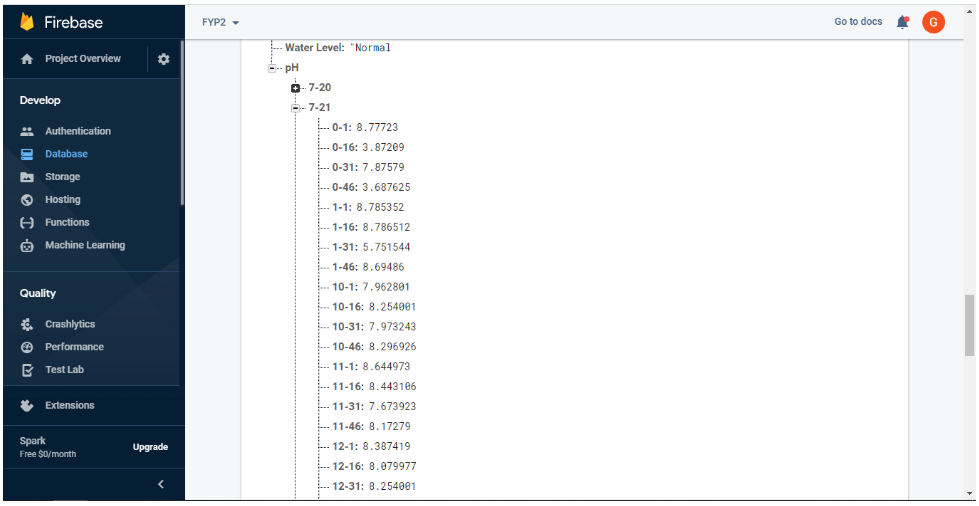

Figure 12: The pH value stored in firebase cloud platform

3.6 Emergency alarming system

The emergency alarming system consists of a LED, buzzer, and relay with control to the power supply for the water pump. When the water level fall below the water level indicator, the reed switch in the indicator will close and microcontroller will receive a HIGH input. Then the LED of red light and buzzer will turn on, water level tab on the Firebase database will show “Water Level: Low” to inform user. The system will also activate the relay which in turn cut off the power source for the water pump. Water pump is connected to the Normally Closed terminal of the relay, the relay is activated by feeding LOW input at the IN pin. To test on the alarming system, the water level indicator is lifted from the water, Figure 13 shows the LED is being turned on when the water level indicator is lifted out of water.

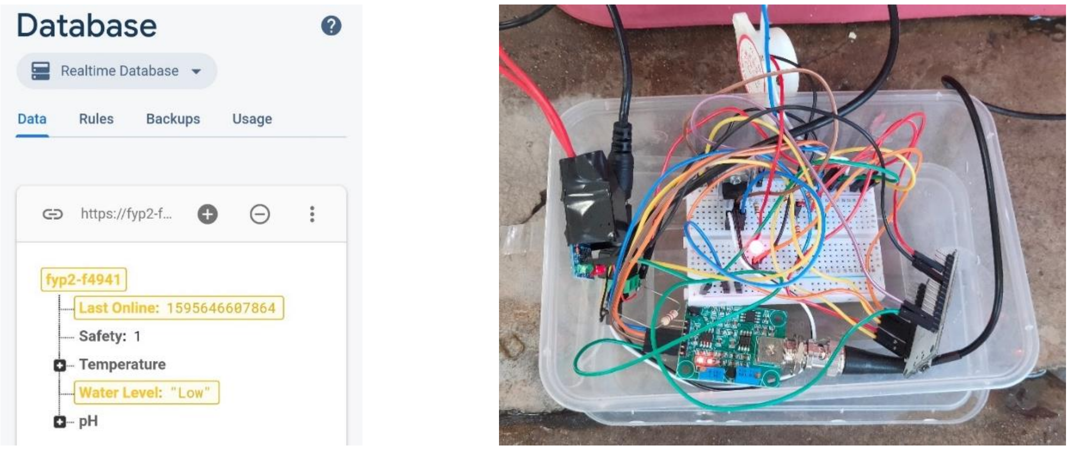

Figure 13: System informing user about low water level via mobile(left) and LED is turned on(right)

4. Conclusion

As conclusion, the project is successfully completed. The monitoring system for vertical aquaponics is designed and assembled. User is able to check on the condition of the aquaponics such as water temperature, pH and water level through internet by accessing the Cloud platform, Firebase Database even when user is away from the setup. The value of pH and temperature of water is automatically stored every 15 minutes. An emergency system is designed in case of water leakage. When the water level fall below the sensor, the system will stop the water pump from drawing water from the tank, turning on LED and buzzer to alert user, while showing warning message on Firebase. User can remotely disable the alarm when necessary. The pH value obtained from the system fluctuate with a high standard deviation. It can be said that the pH value obtained by the sensor is not reliable.

Acknowledgement

This research was made possible by funding from the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia.

References

[1] AlShrouf, A. (2017). Hydroponics, Aeroponic and Aquaponic as Compared with Conventional Farming. American Scientific Research Journal for Engineering, Technology, and Sciences, Volume 27, No 1, pp 247-255. Retrieved on September 25, 2020, from https://www.asrjetsjournal.org/index.php/American_Scientific_Journal/article/viewFile/2543/1028

[2] Department of Statistics Malaysia. (2017, December 28). Compendium of Environment Statistics 2017. Retrieved September 25, 2020, from https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=162&bul_id=VTBLVkpvQVJ1QnJtMWdBcUdCTzlwZz09&menu_id=NWVEZGhEVlNMeitaMHNzK2htRU05dz09

[3] El-Sherif, M. S., El-Feky, A. M. I., (2009). Performance of nile tilapia (Oreochromis niloticus) fingerlings. II. Influence of different water temperatures. Int. J. Agric. Biol., 11, pp. 301–305

[4] Graber, A., Junge, R. (2009). Aquaponic Systems: Nutrient Recycling from Fish Wastewater by Vegetable Production. Desalination, 246(1-3), pp.147-156. Retrieved on December 1, 2019, from doi: 10.1016/j.desal.2008.03.048

[5] Lennard, W., & Goddek, S. (2019). Aquaponics: The Basics. Aquaponics Food Production Systems, 113–143. doi:10.1007/978-3-030-15943-6_5

[6] Neverman, L. (2019). Introduction to Aquaponics: Growing Fish and Vegetables Together. Common Sense Home. Retrieved on October 1, 2019, from https://commonsensehome.com/introduction-aquaponics/

[7] North, D. (2016). What is Aquaponics and How Does it Work? Permaculture Research Institute. Retrieved on December 11, 2019, from https://permaculturenews.org/2016/05/30/what-is-aquaponics-and-how-does-itwork/

[8] Sallenave, R. (2016, October). Important Water Quality Parameters in Aquaponics Systems. Retrieved September 24, 2020, from https://aces.nmsu.edu/pubs/_circulars/CR680/welcome.html

[9] Sherriffs, C. (2019). Exciting New Gardening Trends For 2019. Garden Culture Magazine. Retrieved on October 1, 2019, from https://gardenculturemagazine.com/grow-your-own/exciting-new-gardeningtrends-for-2019/

[10] Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What Is Sustainable Agriculture? A Systematic Review. Sustainability, 7(6), pp.7833– 7865. doi:10.3390/su7067833