Evolution in Electrical and Electronic Engineering Vol. 2 No. 2 (2021) 775-782

EEEE

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

Automated pH Monitoring and Controlling for Hydroponics Cultivation

Mohamad Raihan Rahim[1], **Rohaida Mat Akir**[1*,]

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

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2021.02.02.092
Received 04 July 2021; Accepted 03 August 2021; Available online 30 October 2021

Abstract: Hydroponics is a plant cultivation method that does not involve any use of soil. It just requires a solvent that contains nutrients. pH concentrations are critical to ensure that plants consume the optimum nutrient needs and late action in controlling the pH level may impact on plant quality and growth rate. As recommended, pH levels required by the most hydroponic plant are between 5.5 to 6.5. Using Arduino Uno as the primary microcontroller, the project develops a prototype of an automated IoT hydroponics system. A pH sensor is used throughout the entire project development to monitor the pH level. The NodeMcu is used to interconnect system devices to the Blynk Apps, a platform used for this project to implement the Internet of Things (IoT). The experiment was carried out to evaluate the accuracy of the pH sensor as well as another important component, the water pump. From the results, the system has lower error range which is below ± 5% and has better tolerance when compared to pH tester. Within 14 days observation, the system able to maintain the pH level at the recommended range. Based on the experiment sequences for each component and a full functionality experiment of the pH automated system, the system met the project's goal.

Keywords: Automated pH Monitoring , Hydroponics Cultivation, IoT

1. Introduction

Hydroponics is a technique of plants cultivation without using soil. It only requires a solvent contain nutrient. Hydroponics can be done in a variety of ways. For example, deep-water culture, aeroponics, drip irrigation, EBB and flow (food and drink) irrigation systems, N.F.T (Nutrient Film Technique), and wick irrigation systems. Water, which has displaced soil, acts as a medium for supplying nutrients to plants via their roots. Nutrients derived from water are critical in enhancing the quality of plant development. Additionally, temperature, pH, water, light, and humidity all contribute to the plant's quality. Each species of plant requires a certain pH level of water, and if the pH level of the water is not within the appropriate ranges, plant growth is compromised. It is recommended that the pH level of water used in hydroponics be between 5.5 and 6.5.

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

pH is a measure of the concentration of hydrogen ions in a solution. The acidic solution contains a greater proportion of hydrogen ions that are disassociated by its components and released as hydrogen ions or react with water to form hydrogen ions, whereas the alkaline solution contains a greater comparable number of hydroxyl ions that are disassociated by its components and released as hydroxyl ions or react with water to form hydroxyl ions [1].

The pH level in the water solution should be monitored to prevent harm to the plant because the pH value can affect plant photosynthesis activity [2]. A major factor influencing the intake of several nutrients is the pH of the plant root environment [3]. The pH solution of nutrients is typically handled by inserting either diluted acid or base for the value. It is referred to as solutions pH up and pH down [4] Traditionally, the hydroponic growth technique lacked an automated device capable of maintaining a pH level in a water solution, and the user was required to manually adjust the pH level in the water solution. pH values must be monitored and maintained as the plant requires from time to time. In industrial, pH solutions comprising acid or alkaline are employed to regulate the pH value. The pH solution is alkaline (pH up), and the pH solution is alkaline (pH up) (acid). There are two types of pH solutions. To ensure that plants have the proper pH values, an exact pH solution must be provided.

At the end of the project, the system should be capable of monitoring and controlling the pH level. The reading of the pH will be recorded from time to time and the data can be accessed through Blynk application. The Arduino Uno Microcontroller, NodeMCU, pH sensor and water pump will be used. The pH sensor connected to both Arduino Uno and NodeMCU. Besides, the user will be able to monitor the pH level even when they are at another place. This can be achieved by connecting the pH sensor to NodeMCU which enables pH data to be transmitted from the microcontroller to Blynk application. Another connection is formed between the pH sensor, Arduino Uno and water pump which enable the microcontroller to control the pH level using the pH buffer.

2. Materials and Methods

Arduino Uno was used as the microcontroller for this project development. This project can be monitor by smartphone using Blynk Apps. The monitoring section consists of three elements such as data sensing, data processing and data communication module. The data sensing module include of pH sensor which change the data to the respective parameters and the data processing is the code algorithm process.

The data communication module is used to transfer data between person and equipment. The project use NodeMCU for communication module and need internet connection to upload the data. In the meantime, the controlling section takes place in Arduino Uno. Once the data received form the data sensing module, the code algorithm process started. The microcontroller generates the output to control the water pump based on the current water tank pH level.

2.1 Hardware Development

All of the components bought at a very reasonable price. Table 1 shows the list of components used in the project while Figure 1 shows the connection of the component in the project.

Table 1: Components used in the project

Components	Amount
pH Sensor	1
pH Module	1
Arduino Uno	1
NodeMCU	1
5V Water Pump	2

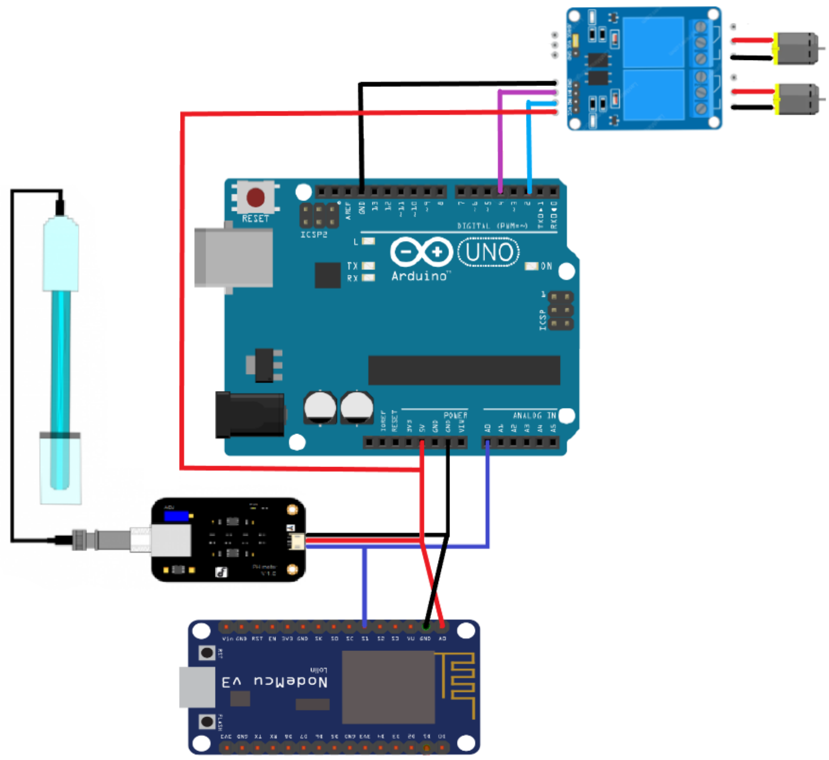

Figure 1: Connection of component

2.2 Software Development

On the software development of the project, Arduino IDE software is used to write and upload the code to the microcontroller board. Those microcontrollers are NodeMcu and Arduino Uno. In writing the code, the algorithm must be able to achieve the objective of the system.

This project has two code programs which are written for NodeMcu and Arduino Uno. The code program is verified before it is able to upload to the microcontroller board. The pH reading is successfully demonstrated by the Serial monitor of Arduino IDE software as shown in Figure 2.

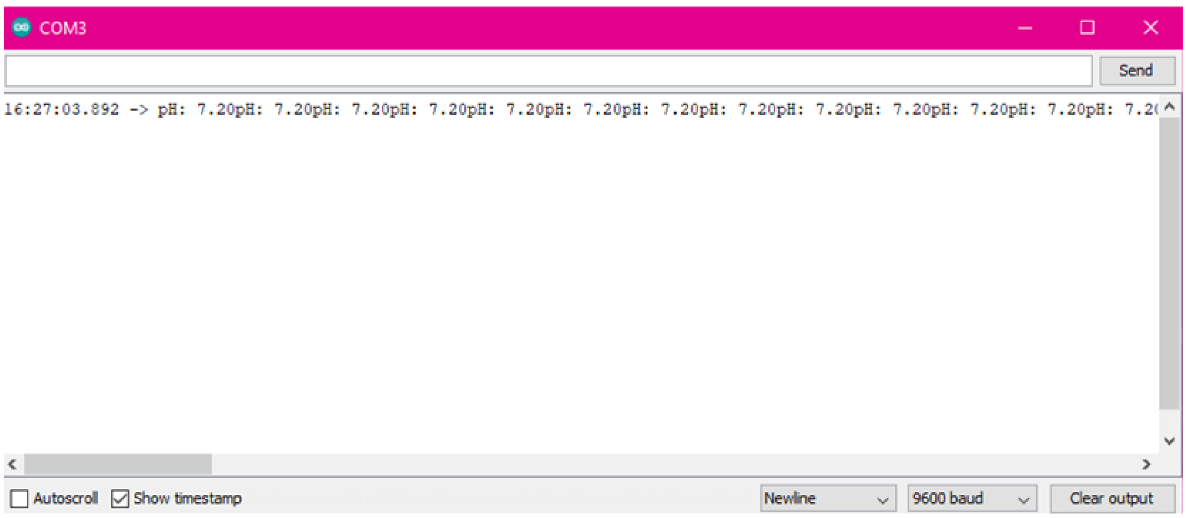

Figure 2: pH Reading on Serial Monitor

2.3 Methods

This project needs to follow the several processes to complete the system as shown in Figure 3, Figure 4, Figure 5 and Figure 6.

In a particular measurement, the sensor will record ten readings, and the microcontroller will execute a calculation to obtain the average reading from the measurement. This is to ensure the system to display the approximate reading for each take. Figure 3 shows the code sequence to obtain the average readings.

```
void loop()
{
  Blynk.run();
  for(int i=0;i<10;i++)
 {
  buffer[i]=analogRead(analogInPin);
  delay(30);
 }
 for(int i=0;i<9;i++)
 {
  for(int j=i+1;j<10;j++)
  {
   if(buffer[i]>buffer[j])
   {
    temp=buffer[i];
    buffer[i]=buffer[j];
    buffer[j]=temp;
   }
  }
 }
```

Figure 3: Code Sequence

Figure 4 shows the block diagram of the monitoring application in order to enable the user to check pH level through the Blynk Apps. Technically, pH sensor will measure the pH level of the water in plant reservoir. As the data measured by the pH sensor is in analog form, the pH module will convert the data to digital signal form. Hence, Blynk Apps can directly read and view the data it receives from NodeMCU.

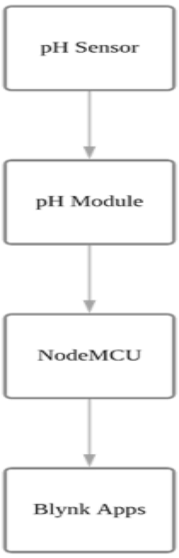

Figure 4: Block diagram of monitoring application

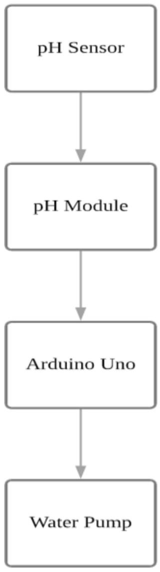

Figure 5: Block diagram of pH controlling

Next, Figure 5 shows the block diagram of the pH controlling in order to maintain the water tank pH level at the best range. Technically, pH sensor will measure the pH level of the water in plant reservoir. As the data measured by the pH sensor is in analog form, the pH module will convert the data to digital signal form. Therefore, Arduino Uno decides whether the water pump needs to be on or off. Hence, pH level of water tank can be maintained from time to time.

Figure 6 shows how the system works as the pH sensor, pH module, Arduino Uno, NodeMCU and the water pump are attached altogether. Initially, pH sensor measures the pH level of water at plant reservoir. The pH module will convert the measured data from electrical potential to absolute value form. The NodeMCU will transmit the data to the Blynk Apps.

In the meantime, Arduino Uno will process the data to execute pH controlling by pumping the buffer to the plant reservoir. The pH level must be in between 5.5 to 6.5. If the pH level is below the range, pH buffer solution will be pumped to increase the water pH value and vice versa. In case of the pH level is in range, no pH buffer solution will be pumped.

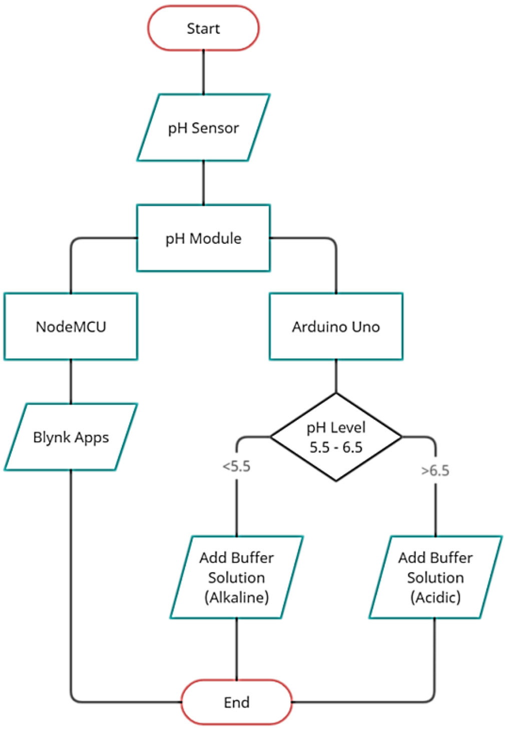

Figure 6: Flowchart of the project

2.3 Equations

The error obtained after the value differences between pH sensor and pH measuring device are divided by the value pH measuring device.

$$Error: \frac{pH\ sensor\ value - \ pH\ measuring\ device\ value}{pH\ measuring\ device\ value}\ x\ 100\% \qquad Eq.1$$

3. Results and Discussion

3.1 Results

For this section, the output of system is compared and discussed. The pH measuring device and pH sensor are used to check the measuring accuracy of the system. For the setup, green spinach is planted in 2 separated tank which is Tank A and Tank B. Tank A is equipped with the automated system, while Tank B is not equipped with automated system. pH value of both water tank is measured. The recorded data is tabulated and shown below.

3.1.1 pH Sensor Error Test

For the error of the system's pH reading, pH tester and pH sensor are compared. The tests are repeated three times for both different solutions which are 4.00 pH buffer and 6.86 pH buffer. The reading values are compared to evaluate the error of the system as shown in Table 2.

Table 2: Range of Error

pH Buffer Solution	Instrument	Error Range
4.00	pH Sensor	± 2.550
	pH Tester	± 4.750
6.86	pH Sensor	± 2.012
	pH Tester	± 3.061

Figure 7 shows the both sensors have low error which is below ±5% but, the system has lower error range compared to the measuring device. Hence, the system is better since the error range is minimal compared to measuring device. This indicates that the pH reading of the system are reliable and accurate. Aside, objective of the project which is to design a monitoring system to monitor the water pH level is accomplished.

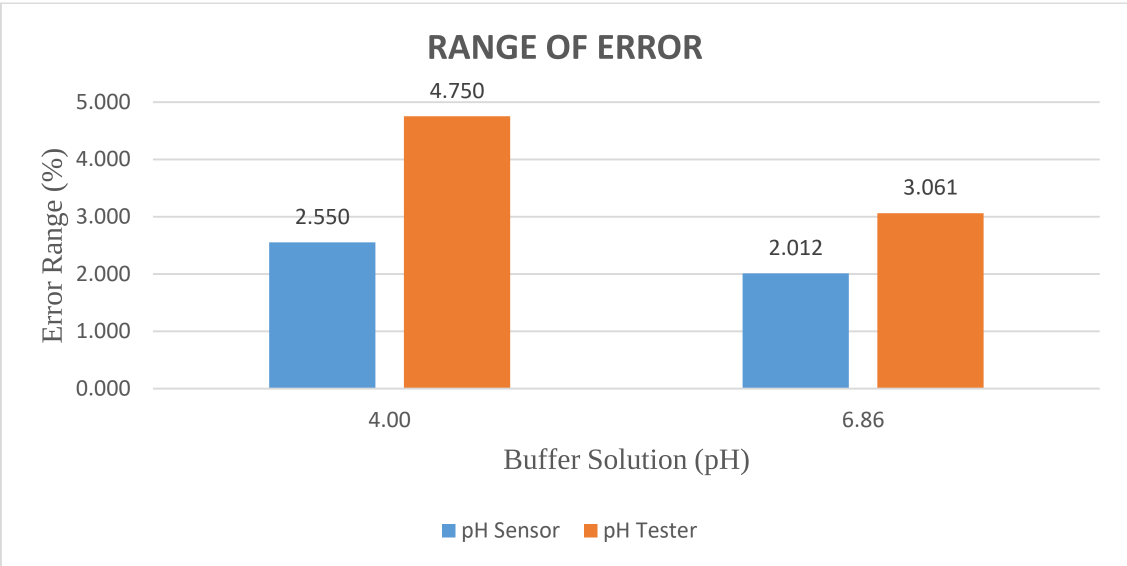

Figure 7: Bar Chart of Range of Error

3.1.2 Water Tank pH Value

Water tank pH value of Tank A is monitored online with the help of NodeMCU and Blynk Apps. In the meantime, the pH value is controlled by Arduino Uno and water pump. The water pump fills up the water tank either with pH Up or pH Down solution which is later decided based on the current pH value with the help of Arduino Uno. Throughout the process, the pH value of Tank A is maintained at the recommended range. At the end, the pH value of Tank A (Table 3) and Tank B (table 4) were compared throughout the time.

Table 3: Tank A pH value

Days	pH
1	6.5
2	6.3
3	6.0
4	5.8
5	6.1
6	6.3
7	6.0
8	5.9
9	5.8
10	6.0
11	5.7
12	5.6
13	5.8
14	6.0

Table 4: Tank B pH Value

Days	pH
1	7.0
2	6.7
3	6.5
4	6.3
5	5.9
6	5.7
7	5.4
8	5.2
9	5.8
10	6.1
11	6.4
12	7.0
13	7.0
14	6.7

3.2 Comparison of Water Tank pH Value

From the observation, the pH value of Water Tank A maintained at the recommended range which is in between 5.5 to 6.5. Meanwhile, the pH value of Water Tank B rapidly changes day by day. This occurred as the Tank A is attached with the Automated System which helps to maintain the pH value of water. The data are shown in Figure 8. The pH level may fluctuate due to variety of variables. As the nutrient solution reduced, the solution concentration increased. As a result, pH levels fluctuate a lot. On the other hand, algae and bacteria are the most common organic matter that affects pH level. If the pH rises in the morning and drop later in the day, algae may be one of the reasons. As algae consumes the acidic carbon dioxide, the pH drop drastically. In simply, bacteria from root disease cause a dramatic drop in pH level. Hence, the objective to develop automated system using the Arduino that able to control the water pH level when needed is achieved.

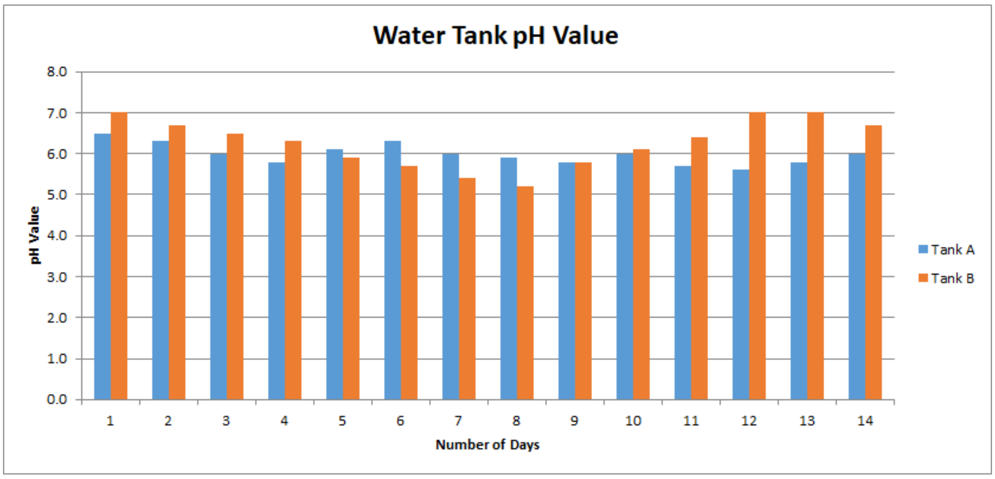

Figure 8: Bar Chart of Tank A & Tank B pH Value

4. Conclusion

In conclusion, this project was able to achieve the objective of the project based on sequences of an experiment for each of the components and full functionally experiment of the pH automated system. The first objective is achieved based on result experiment sensor error performance. The low error percentage shows that the system monitoring ability is reliable. The second objective is accomplished by maintaining the pH level between the recommended ranges. The automated system can choose which buffer solution need to be injected to the water tank once the pH level is not in range. The last objective to monitor hydroponic cultivation using IOT system succeeds by several creating the apps which enable the user to monitor the pH level. Therefore, the purpose for this project can be defined successful because all of the objectives are achieved.

A lot of things can be added into this hydroponics automated system in future. First is auto-fertilizing, it is importance to increase the growth rate. Second, improve designing wireless hydroponics automated system to more simple and easy to troubleshoot if has any component failure. This is because old designing has difficulties for checking any failed component.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] T. Kaewwiset and T. Yooyativong, "Estimation of electrical conductivity and pH in hydroponic nutrient mixing system using Linear Regression algorithm," in 2017 International Conference on Digital Arts, Media and Technology (ICDAMT), 2017, pp. 1-5.

[2] M. Wang, C. Dong, and W. Gao, "Evaluation of the growth, photosynthetic characteristics, antioxidant capacity, biomass yield and quality of tomato using aeroponics, hydroponics and porous tube-vermiculite systems in bio-regenerative life support systems," Life Sciences in Space Research, vol. 22, pp. 68-75, 2019/08/01/ 2019.

[3] M. R. Talukder, M. Asaduzzaman, H. Tanaka, and T. Asao, "Light-emitting diodes and exogenous amino acids application improve growth and yield of strawberry plants cultivated in recycled hydroponics," Scientia Horticulturae, vol. 239, pp. 93-103, 2018/09/15/ 2018.

[4] M. F. Saaid, N. A. M. Yahya, M. Z. H. Noor, and M. S. A. M. Ali, "A development of an automatic microcontroller system for Deep Water Culture (DWC)," in 2013 IEEE 9th International Colloquium on Signal Processing and its Applications, 2013, pp. 328-332.