Design of a Monitoring and Nutrient Management System Based on Internet of Things (IoT) for Hydroponic Method Using MIT App Inventor

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Intisari* – Hidroponik adalah metode pertanian yang menggunakan media tanam dengan kandungan nutrisi yang rendah. Dalam hidroponik, diperlukan nutrisi. Nutrisi ini sangat penting untuk pertumbuhan tanaman pada hidroponik. Jika tanaman hidroponik kekurangan nutrisi maka tanaman hidroponik akan mati. Kebutuhan air pada Tandon hidroponik juga perlu diperhatikan, sehingga air pada hidroponik tetap stabil. Faktor lain seperti suhu air juga penting pada metode hidroponik. Suhu yang tinggi dapat menghambat pertumbuhan tanaman dan dapat mempengaruhi tanaman untuk tumbuh lebih cepat (bolting). Oleh karena itu, dibuatlah perancangan monitoring suhu, serta manajemen nutrisi dan ketingggian air pada tandon hidroponik berbasis Internet of Things (IoT). Alat ini dapat mengelola sistem hidroponik secara efisien, serta mudah dioperasikan karena berbasis IoT, sehingga petani dapat melakukan monitoring dan manajemen hanya lewat Smartphone pada aplikasi MIT App Inventor. Metode penelitian ini ada beberapa tahapan penting, yaitu analisis kebutuhan alat dan bahan, perancangan alat, pengujian fungsional alat, dan analisis data. Pada sistem akan mengukur nilai nutrisi, suhu air, dan ketinggian air. Dari data tersebut maka akan diolah dan diatur untuk monitoring dan manajemen pada hidroponik. Hasil proyek akhir ini adalah rata - rata error sensor TDS (Total Dissolved Solids) yaitu 3,9232 %, rata - rata error sensor ultrasonik HC-SR04 yaitu 3,53 %, rata - rata error sensor suhu DS18B20 yaitu 2,7513 %. Alat ini mampu untuk melakukan monitoring dan manajemen nutrisi pada hidroponik yang terintegrasi IoT dengan baik, karena error yang dihasilkan di bawah 5 % dan sistem berjalan dengan baik.

***Kata kunci* – Hidroponik, internet of things, MIT App Inventor, monitoring dan manajemen**

Abstract – Hydroponics is an agricultural method that uses a growing medium with low nutrient content. In hydroponics, nutrients are required. These nutrients are very important for plant growth in hydroponics. If hydroponic plants lack nutrients, they will die. Water needs in hydroponic reservoirs also need to be considered, so that the water in hydroponics remains stable. Other factors such as water temperature are also important in the hydroponic method. High temperatures can inhibit plant growth and can cause plants to grow faster (bolting). Therefore, the design of temperature monitoring, as well as nutrient management and water level in hydroponic reservoirs based on the Internet of Things (IoT) is made. This tool can manage hydroponic systems efficiently and is easy to operate because it is IoT-based, so that farmers can monitor and manage only via Smartphone on the MIT App Inventor application. This research method has several important stages, namely analysis of the needs of tools and materials, tool design, functional testing of tools, and data analysis. The system will measure the value of nutrients, water temperature, and water level. From this data, it will be processed and arranged for monitoring and management in hydroponic. The results of this final project are the average TDS sensor error of 3.9232%, the average HC-SR04 ultrasonic sensor error of 3.53%, the average DS18B20 temperature sensor error of 2.7513%. This tool can perform monitoring and nutrient management in IoT-integrated hydroponics well, because the resulting error is below 5% and the system runs well.

Keywords – Hydroponic, internet of things, MIT App Inventor, monitoring and management

I. INTRODUCTION

Hydroponics is an agricultural method that uses a growing medium with low nutrients [1]. If hydroponic plants experience nutrient deficiencies, they may fail to thrive or even die [2]. Not only nutrition, the water needs in the reservoir in hydroponics also needs to be considered. This can keep the water demand in hydroponic reservoirs stable [3]. Therefore, an effective management system is required to ensure a balanced supply of nutrients and stable water levels in hydroponic reservoirs.

Additionally, other factors, such as water temperature, must also be considered in hydroponic cultivation. Ideally, you should maintain the hydroponic nutrient solution's temperature above 18–20 °Celsius and below 28 °Celsius. High temperatures can inhibit plant growth and may cause plants to bolt, leading to rapid flowering. Rapid chemical reactions at elevated temperatures can disrupt physiological processes in plants, resulting in poor growth and a bitter taste in vegetables such as lettuce [4].

The implementation of monitoring and nutrient management systems in hydroponics has been the subject of extensive research. Researchers [2] used TDS meter sensors and an ESP8266 module to control and monitor the water nutrient conditions in hydroponic plants. This study resulted in a successful nutrient monitoring and control system, accessible through a Things Board website. Additionally, studies [5-7] focused on the control and monitoring of nutrients in hydroponics, making it easier for hydroponic farmers to manage their systems. The Blynk application received the results from the TDS meter sensor, which measures the part per million (ppm) value. Meanwhile, research [8] involved controlling nutrient levels, monitoring pH, and observing temperature around the hydroponic setup using the Blynk application.

Research [9] developed a pH control and monitoring system for water using an ESP32 microcontroller and the Blynk application. Research [10] focused on pH and water temperature monitoring in aquaponics with IoT. This system uses Firebase and the MIT App Inventor application as a sensor data viewer. Research [11] used a DHT11 sensor, a 4502C pH sensor, and an HC-SR04 ultrasonic sensor to keep an eye on and change the nutrients and temperature in NFT (Nutrient Film Technique) hydroponic systems. Research [12] focused on monitoring nutrient and water availability in hydroponic reservoirs with the MIT App Inventor application. Research [13] developed an IoT-based water monitoring automation system for hydroponics, which allows hydroponic plant owners to automatically regulate and control pH, nutrients, temperature, and water levels.

Therefore, this article will discuss the design of temperature monitoring as well as nutrient management and water levels in hydroponic reservoirs based on the Internet of Things (IoT). The Internet of Things (IoT) is a technology that allows objects around us to be connected to the internet [14]. In making this tool using the MIT App Inventor application. Mit App Inventor is a platform that makes it easy for users to create simple applications without using many programming languages [15]. Using the MIT App Inventor as an interface allows for interactive data visualization, making it easier for users to operate and control the hydroponic system remotely.

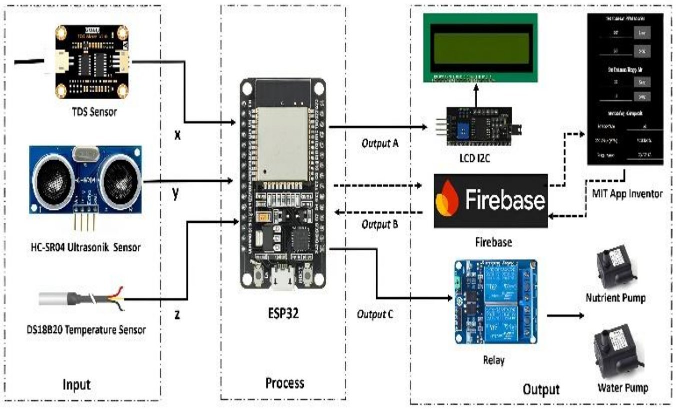
This research is different from previous studies. This research uses the ESP32 microcontroller, which offers better capabilities, and more input/output options compared to other microcontrollers. This research uses a combination of several sensors. The sensors used include a TDS meter to measure nutrient levels, an HC-SR04 ultrasonic sensor to measure water levels, and a DS18B20 temperature sensor to measure the water temperature. This study uses the MIT App Inventor application that researchers have created with a simple display. The goal is to make it easier for farmers to operate the system. The appearance of this application displays TDS values, water levels, and water temperature and is equipped with features to control nutrient and water levels by setting upper and lower limit values. System testing was carried out for three days to evaluate the performance and reliability of the system in real conditions. The results of the study showed that the system successfully reads sensor data in real time and displayed it on the MIT App Inventor application.

II. METHODHOLOGY

The design of the final project tool, titled "Design of a Monitoring and Nutrient Management System Based on Internet of Things (IoT) for Hydroponic Method Using MIT App Inventor," is detailed in this chapter. The discussion covers the creation of block diagram designs, hardware design, software design, mechanical box design, hydroponic installation design, and data analysis methods. The following sections provide a detailed explanation of the stages involved in developing this tool:

A. Block Diagram Design

This block diagram design illustrates the workflow of the Internet of Things (IoT)-based monitoring and nutrient management system for hydroponic methods. It explains the working principle of the tool. In the block diagram, there is an explanation of the components used. The diagram also details the system's input, process, and output stages. The system input serves as data input for the microcontroller, the process stage handles data processing, and the system output presents the results of this data processing. This device has several inputs. The TDS sensor checks the amount of nutrients (variable x) in parts per million (ppm), the HC-SR04 ultrasonic sensor checks the level of water (variable y) in centimeters (cm), and the DS18B20 temperature sensor checks the temperature (variable z) in degrees Celsius (°C) in the hydroponic reservoir. Figure 1 shows the block diagram design.



Description :

- Cable Connection = ⟶
- Wireless = ⋯⋯▸
- Variable x = Measure nutrient value (*part per million*)
- Variable y = Measure water hight (cm)
- Varible z = Measure water temperature (°C)
- *Output* A = Display of x, y, and z values
- *Output* B = Monitoring and control of x, y, and z values
- *Output* C = Pump control of x and y values

Figure 1. Block diagram design

B. Hardware Design

This section describes the electronic system design of the IoT-based hydroponic nutrient monitoring and management system. The design details the wiring of the sensors for the ESP32 microcontroller and specifies the pins used. This system connects its sensors to the ESP32 on a PCB board. The system output consists of two pumps, which function to add nutrients and water to the reservoir. A 16x2 LCD screen displays the sensor readings. Additionally, Firebase and the MIT App Inventor application display data from the ESP32 readings online. This hardware design integrates all components onto a PCB board to strengthen their connections and prevent disconnection. Figure 2 shows the system circuit.

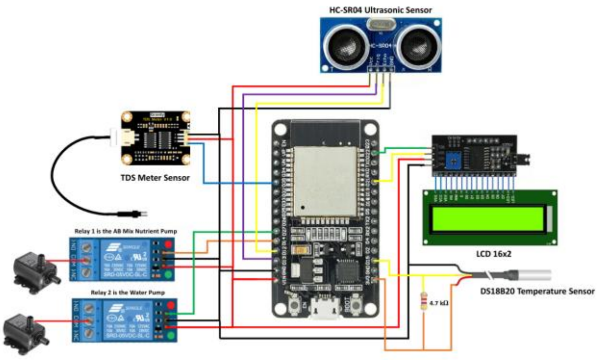


Figure 2. System circuit

C. *Software Design*

This section describes the software design of the IoT-based monitoring and nutrient management system for hydroponic methods. The discussion focuses on developing programs in the Arduino IDE. The Arduino IDE program gathers data from the TDS sensor, HC-SR04 ultrasonic sensor, and DS18B20 temperature sensor. The results of sensor readings are sent online to Firebase (as a database) and then forwarded to the MIT App Inventor application for display. Figure 3 shows the system flowchart.

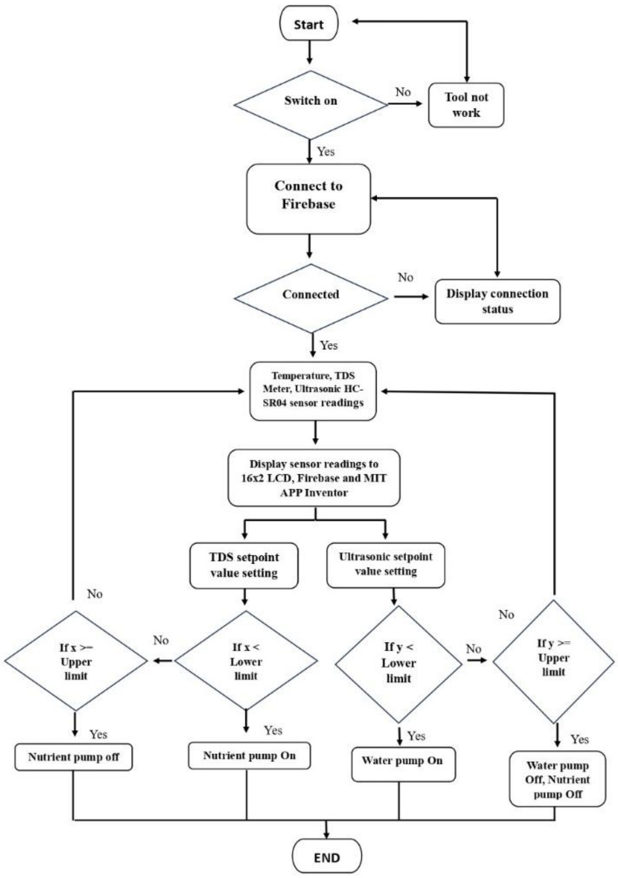


Figure 3. System flowchart

1) *Realtime Database:* At this stage, a Realtime Database is created on Firebase. The purpose of creating this Realtime Database is to facilitate data transfer between the ESP32 microcontroller and MIT App Inventor application. The ESP32 microcontroller collects sensor reading data and sends it to the Realtime Database. The MIT App Inventor application can then read the sensor data stored in the Realtime Database. When there is a change in the sensor data, the MIT App Inventor application automatically receives an update. The sensor data read includes the variables x, y, and z. Figure 4 shows the Realtime Database.

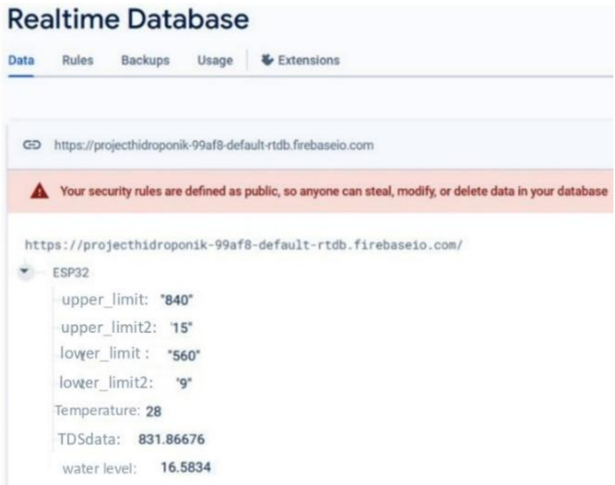


Figure 4. Realtime Database

2) *MIT App Inventor:* The MIT App Inventor application functions as a viewer for the variable, reading values of x, y, and z. This application also includes a feature for setting the lower and upper limits. This feature serves to control the nutrient pump and water pump. Users can use this application remotely to monitor and manage hydroponic systems.

MIT App Inventor features a Designer page that facilitates the design of applications intended for smartphone screens. This Designer page includes a palette, a viewer, component properties, and media features. We can create all these features according to our wishes. Figure 5 shows the Designer page.

In the MIT App Inventor, the Blocks page serves to execute commands or programs within the application. The Blocks page contains the block code. The block code operates similarly to a command within the application. Drag and drop the block code to arrange it according to your desired logic. Figure 6 shows the Blocks Page.

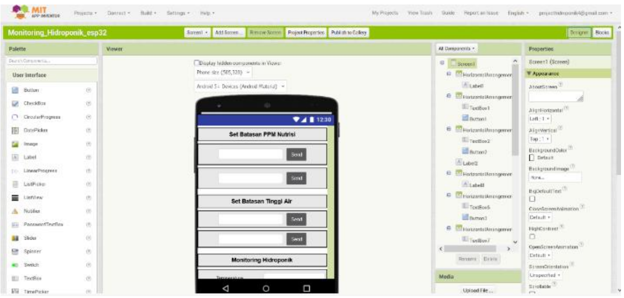


Figure 5. Designer page

Figure 6. Blocks page

D. *Mechanical Box Design*

This section describes the design of the mechanical box on the IoT-based hydroponic monitoring and management system. The box protects the electronic circuit from water and solid objects. The box is 14 cm long, 10 cm wide, and 5 cm high. This mechanical box is made of plastic that has been made to adjust the size of the LCD and input/output cable holes. The design of this mechanical box using SolidWorks software. Figure 7 shows the mechanical box design.

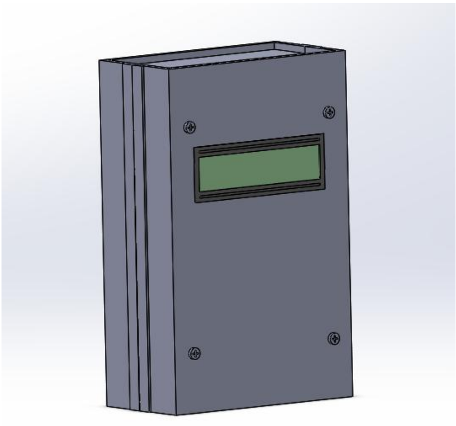


Figure 7. Mechanical box design

E. *Hydroponic Installation Design*

The hydroponics design uses the NFT (Nutrient Film Technique) method. This method is a way of flowing hydroponic nutrients continuously to the roots of the plants. The initial stage of designing this hydroponic installation involves using SolidWorks software. The design process aims to identify the necessary components, understand the installation form, and streamline the manufacturing process. Figure 8 shows the hydroponic installation design.

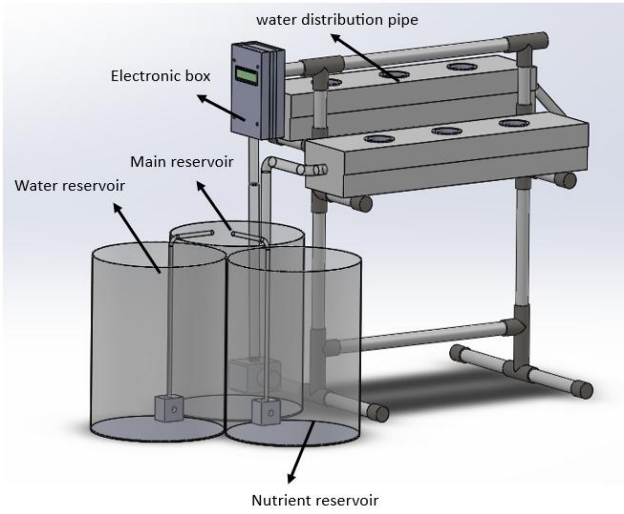


Figure 8. Hydroponic installation design

F. *Data Analysis Method*

1) *Calibrate The TDS Meter Sensor:* TDS sensors need to be calibrated. The purpose of calibration is that the TDS meter sensor has the same value as the standard TDS meter. The calibrated sensor is a TDS V1.0 sensor made by DF Robot. To calibrate the TDS meter sensor by inserting it into the calibration solution with a value of 500 ppm. To calibrate the value of the TDS meter sensor with a calibration solution, follow these steps: Open the serial monitor on the Arduino IDE and type "enter." Then, enter the command "cal:500" (where 500 is the calibration solution value of 500 ppm). Next, type "exit" to save the reading data in the ESP32 EEPROM. After the calibration is complete, the TDS meter sensor value will be the same as the calibration solution and standard TDS meter. Figure 9 shows the TDS meter sensor calibration result.

Figure 9. TDS meter sensor calibration result

2) *Calculation of The Error Value:* The aim of testing the IoT-based hydroponic nutrient monitoring and management system is to ensure its functionality as expected and analyze any errors that arise. Use the manufacturer's sensor or a standard tool to compare the sensor error reading. The TDS meter sensor reading should be as accurate as the standard TDS meter. Equation (1) contains the sensor error reading formula.

$$\%error = \left|\frac{sensor\ value - standard\ value}{standard\ value}\right| \times 100\% \quad (1)$$

The read value is the sensor value, which is the measured value of x, y, and z variables. The manufacturer's TDS meter sensor yields the standard value. Divide the result of subtraction between the read value and the standard value by the standard value. Next, multiply the result by 100%.

After reading the error on each sensor, then the average error is read. The average error sensor is an important parameter in assessing the performance and reliability of the sensors used. The average error is calculated by taking several sensor readings, calculating the error for each reading, and taking the average by dividing each sensor error and then dividing by the total number of readings. The formula for calculating the average error is in (2).

$$\overline{\%error} = \frac{\sum_i^n = 1\ \%error_i}{n} \quad (2)$$

III. RESULTS AND DISCUSSION

In this section, the results of hardware design, software design, hydroponic design, and testing of the tool will be shown. The data obtained will be a reference for whether this tool can function properly. Testing is done with the functional testing method of the tool. This test aims to verify the readiness and expected functionality of the manufactured tools in a hydroponic installation. With the functional testing of this tool, conclusions can be drawn about the working system of the tool that has been made.

A. *Hardware Design Result*

This section describes the hardware design, namely the manufacture of electronic circuits. This electronic circuit is placed in a box to protect it from water splashes during the hydroponic system operation. This electronic circuit consists of several important components, namely the TDS meter sensor, DS18B20 temperature sensor, HC-SR04 ultrasonic sensor, ESP32, MH Mini 360, relay, and 16x2 LCD with I2C. The ESP32, serving as system control, connects all these components. Figure 10 shows the hardware design result.

B. *Hydroponic Installation Design Result*

The design of this hydroponic installation employs two PVC gutter pipes arranged in stages, each measuring 53 cm in length, 12 cm in width, and 8 cm in height, with a spacing of 15 cm between each hole. This hydroponic installation uses 1/2-size PVC pipes. The pipe functions to channel nutrients to the plants. The design of this hydroponic installation utilizes the NFT system, a hydroponic method that continuously distributes hydroponic nutrients to the plant roots. The NFT system distributes water from the main reservoir to the plant roots via a pump before returning it to the main reservoir. Inside the main reservoir, there are several sensors that will measure the x, y, and z variables. The main reservoir will carry out the nutrient management process, ensuring that the water pump and nutrients operate in accordance with the specified setpoints. This NFT system ensures proper plant nutrition. Figure 11 shows the hydroponic installation result.

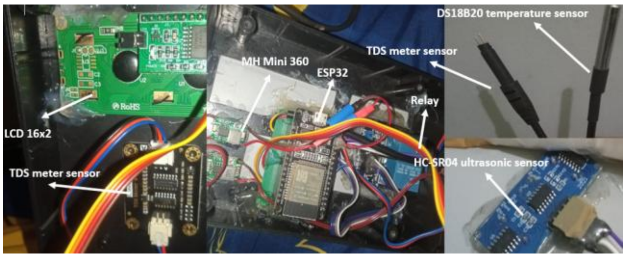


Figure 10. Hardware design result

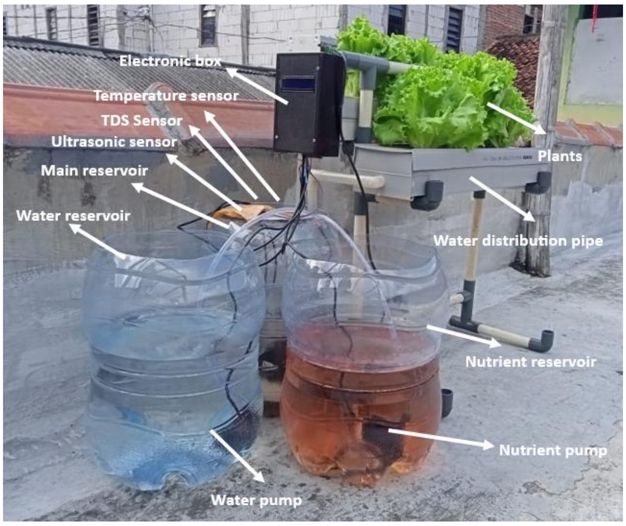


Figure 11. Hydroponic installation result

C. *Testing Firebase View*

Testing the ESP32 display with Firebase to confirm its online connection and readiness for use in the MIT App Inventor application. The ESP32 communicates with Firebase through Wi-Fi media by inputting the SSID address and Wi-Fi password. To be able to connect with Firebase, a Web API Key and Firebase URL are required, which are obtained from Firebase and then written in the Arduino IDE. When ESP32 and Firebase are connected, Firebase displays the real-time results of each sensor reading. Figure 12 shows the results of sensor readings in Firebase.

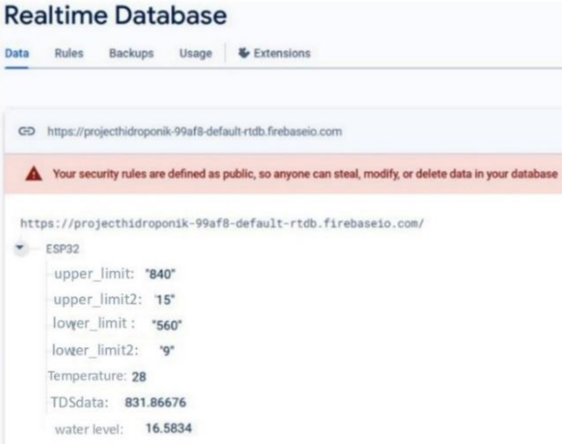


Figure 12. Sensor readings in firebase

D. *Testing MIT App Inventor View*

Firebase displays the reading results of each sensor. The next step is to create the MIT App Inventor application. After creating the MIT App Inventor app, proceed to connect it to Firebase. Firebase and MIT APP Inventor can be connected by writing a Firebase token, Firebase URL, and Project bucket contained in Firebase. Once connected, the Firebase displays real-time sensor reading results. Figure 13 shows the results of sensor readings in MIT App Inventor.

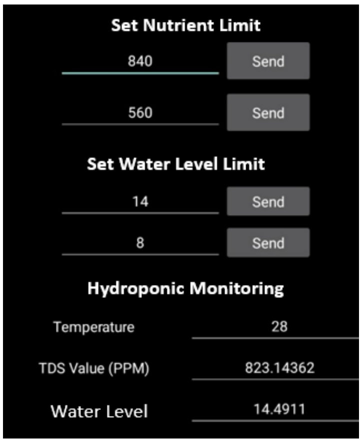


Figure 13. Sensor readings in MIT App Inventor

E. *TDS Sensor Reading Test*

In this section, the reading of the x variable by the TDS meter sensor is tested. The sensor used is the TDS meter sensor version 1.0, made by DF Robot. This sensor has a measurement vulnerability of 0-1,000 ppm. TDS meter sensor testing is done by reading variable x by adding AB Mix nutrients to the hydroponic water reservoir. Table 1 shows the results of the TDS sensor readings.

After getting the results in Table 1, a discussion is carried out regarding the reading of the x value by the TDS meter sensor. The table reads the value of the x variable from 380 ppm to 954 ppm. After the experiment is carried out, the results of the TDS meter sensor reading are obtained, and the percentage error is calculated with equation (1). The best reading results are obtained in the 7th test with an error of 0.8871%, and the worst reading is in the 5th reading with an error of 5.7096%. The results of equation (2) were obtained with an average error of 3.9232%.

Table 1. TDS sensor reading results

No	TDS Meter Sensor (ppm)	Standard TDS Meter (ppm)	%Error
1	380	393	3.3078
2	420	438	4.1095
3	507	482	5.1867
4	553	584	5.3082
5	648	613	5.7096
6	711	689	3.1930
7	782	789	0.8871
8	840	816	2.9411
9	932	906	3.3259
10	954	1007	5.2631
Average error			**3.9232**

F. *DS18B20 Temperature Sensor Reading Test*

In this section, we tested the reading of the z variable with the DS18B20 temperature sensor. This sensor has a measurement range of -55°C to 125°C. This sensor has waterproof properties and is placed in a hydroponic water reservoir. The reading of the z variable is done by comparing the value of the DS18B20 temperature sensor with the manufacturer's TDS meter, which already has a temperature reading on the device. The researcher conducted six readings of the z variable over a period of three days, specifically from Sunday, 9 June 2024, to Tuesday, 11 June 2024. The researcher conducted the experiment at 07:00 (UTC+7) and 16:00 (UTC+7). Table 2 shows the results of the DS18B20 temperature sensor readings.

After the experiment was carried out, the results of the DS18B20 temperature sensor reading were obtained. To calculate the percentage error, use equation (1), where the smallest error reading is obtained at 0,0000% and the largest error is at a value of 4.7619%. The results of equation (2) were obtained with an average error of 2.7513%. This DS1820 temperature sensor has the advantage that the probe has waterproof properties.

Table 2. DS18B20 temperature sensor reading results

No	Date	Time (UTC + 7)	DS18B20 Sensor (°C)	Standard TDS Meter (°C)	%Error
1	June 9, 2024	07:00	28	27	3.7073
		16:00	31	31.5	1.5873
2	June 10, 2024	07:00	30	31	3.2258
		16:00	31	31	0.0000
3	June 11, 2024	07:00	30	31.5	4.7619
		16:00	32	31	3.2258
Average error					**2.7513**

G. HC-SR04 Ultrasonic Sensor Reading Test

In this section, the reading of the y variable in the hydroponic reservoir is tested with the HCSR-04 ultrasonic sensor. This sensor has a measurement range of 2 cm to 400 cm. The reading of the y variable is done by comparing the HC-SR04 ultrasonic sensor value with a ruler to get accuracy according to the standard. The researcher took readings of the y variable 10 times with different heights. Table 3 shows the results of the HC-SR04 ultrasonic sensor readings.

Table 3. HC-SR04 ultrasonic sensor reading results.

No	HC-SR04 Ultrasonic Sensor	Ruler (cm)	%Error
1	9.89	10.5	5.80
2	11.49	12	4.25
3	13.44	14	4
4	14.15	15	5.66
5	15.55	16	2.81
6	17.30	18	3.88
7	19.05	19.5	2.30
8	21.42	22	2.63
9	22.05	22.5	2
10	24.01	24.5	2
Average error			**3.53**

After the experiment was carried out. The results of the variable y value read on the ultrasonic sensor were obtained from a value of 9.89 cm to 24.01 cm. To calculate the percentage error. use equation (1). Then the reading results obtained the smallest error of 2% and the largest of 5.80%. The results of equation (2) were obtained with an average error of 3.53%.

H. Water Pump Test

In this section, the performance of the water pump is tested. which functions to keep the variable y stable in the hydroponic water reservoir. The pump used is a 9 VDC pump. The researcher tested the performance of water pumps five times with different setpoints. At the setpoints there is a lower water limit and upper limit, when the y variable is less than the lower limit. Then the pump will work and stop when it is at the upper limit. Table 4 shows the results of testing the water pump in a hydroponic reservoir.

Table 4. Water pump testing results

No	Setpoints (cm)	HC-SR04 Ultrasonic Sensor (cm)	Ruler (cm)	%Error
1	9-11	11	11.5	4.3478
2	12-16	16.5	17	2.9411
3	17-20	20.5	21	2.3809
4	21-24	25	24	4.1666
5	25-27	27	28	3.5714
Average error				3.4815

Based on the results of Table 4, the performance of the water pump has been tested. To get the error results can be calculated by equation (1). Based on these trials, the error results were obtained. namely the smallest error occurred in the 3rd experiment with an error value of 2.3809%, and the largest error occurred in the first experiment with an error value of 4.3478%. The results of equation (2) were obtained with an average error of 3.4815%.

I. Nutrient Pump Test

This section tests the performance of the nutrients pump. The nutrient pump will work when the x variable contained in the hydroponic reservoir is less than the minimum limit and will stop when it has reached the maximum limit. The nutrient pump uses a 9 VDC pump. The researcher tested the performance of the nutrient pump five times with different setpoints. Table 5 shows the result of testing the performance of the nutrient pump on the hydroponic reservoir.

Table 5. Nutrient pump testing results

No	Initial Conditions (ppm)	Setpoints (ppm)	TDS Meter Sensor (ppm)	Standard TDS Meter (ppm)	%Error
1	211	300-400	414	420	1.4285
2	414	450-550	553	515	7.3786
3	553	650-750	770	727	5.9147
4	770	800-900	900	866	3.9260
5	900	950-1,000	971	924	5.0865
Average error					**4.7468**

In Table 5, the performance of the nutrients pump has been tested. This pump work system has setpoints with lower and upper limits. Based on the results of Table 5, the test was carried out five times with a setpoint value of 300 – 1,000 ppm. Based on these results, the error is obtained in accordance with the calculation of equation (1). The smallest error occurred in the first test with an error value of 1.4285%. and the largest error value occurred in the 2nd measurement with an error value of 7.3786%. The results of equation (2) were obtained with an average error of 4.7468%.

J. System Test

In this section, the process of testing the hydroponic nutrient monitoring and management system is carried out. The purpose of this test is to ensure that the TDS sensor DS18B20 temperature, and HC-SR04 ultrasonic are functioning properly, as well as testing the durability and stability of the system. This testing process is for 3 days. The experiment was conducted at 07:00 (UTC+7) and 16:00 (UTC+7). In this process, the researcher gave the x variable setpoint. namely with a lower limit of 560 ppm and an upper limit of 840 ppm, as well as the y variable setpoint with a lower limit of 8 cm and an upper limit of 14 cm. Table 6 shows the result of system testing.

In Table 6, system testing has been carried out. It was found that the x variable was in stable condition. still between 560 - 840 ppm. and the y variable was stable with a height of around 14 cm. Variable z readings tend to change depending on environmental temperature conditions. The data that has been read on the sensor is successfully displayed on the MIT App Inventor application with the same value.

Table 6. System testing results

Testing		Sensors			MIT App Inventor		
Date	Time UTC + 7	TDS (ppm)	HC-SR04 (cm)	Temp (ºC)	TDS (ppm)	HC-SR04 (cm)	Temp (ºC)
1st day	07:00	873	15.54	29	873	15.54	29
	16:00	830	16.24	29	830	16.24	29
2nd day	07:00	823	14.83	28	823	14.83	28
	16:00	746	14.47	27	746	14.47	27
3rd day	07:00	877	14.13	27	877	14.13	27
	16:00	860	13.79	28	860	13.79	28

IV. CONCLUSION

This monitoring and nutrient management system for hydroponics can make it easier for farmers to monitor and manage their nutrients. They only monitor their plants through the MIT App Inventor application on a smartphone. In this way, it can make it easier for hydroponic farmers to carry out agricultural activities. With this tool, it can improve the quantity of hydroponic agricultural products. The results of this system are an average TDS sensor error of 3.9232%, an average HC-SR04 ultrasonic sensor error of 3.53%, and an average DS18B20 temperature sensor error of 2.7513%.

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