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Prototype of early warning system for flood disaster detection and mitigation based on internet of things

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Abstract

This research aims to design an early warning system to detect floods. This is motivated by flood disasters that often occur unexpectedly and without warning so people cannot make preparations to avoid these disasters. This research uses the wireless sensor network method to integrate several sensors and the Internet of Things in its monitoring. The purpose of this effort is to provide communities vulnerable to flooding with fast and accurate alerts, enabling remote and immediate communication during flood events. This research aims to create a prototype system that can replace the human role in monitoring the dam water level condition at any time by developing an integrated system between hardware and software using IoT (Internet of Things). This research uses the HC-SR04 ultrasonic sensor to detect the distance of the water surface level, the water flow sensor is used to detect the flow of water to provide the value of water discharge and volume. LED is a notification of water level status, and the Buzzer is turned on at a certain water level status. The results are displayed on LCD and Blynk. The developed system consists of the HC-SR04 ultrasonic sensor (distance) and NodeMCU ESP8266 microcontroller. This system serves to measure the water level at any time and send data in real time to the internet. The test results of this research obtained an average error on the HC-SR04 ultrasonic sensor of 1.70% when detecting solid objects and an average error of 3.17% when detecting the height of the water surface. The water flow sensor obtained an average error when calculating water discharge of 6.59% and calculating water volume of 3.48%. The LED will light up and the Buzzer will sound according to the status of the water level, namely SAFE, WARNING, and DANGER. The results will be displayed in real-time on the LCD and Blynk application as an early warning for flood detection and mitigation.

Keywords

Flood, Internet of things, HC-SR04 Ultrasonic sensor, Water flow sensor

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Introduction

Flooding is one of the most common natural disasters in Indonesia. Flooding is a natural phenomenon that usually occurs in an area that is heavily flowed by rivers. In simple terms, flooding can be defined as the presence of water in a large area so that it covers the surface of the area [1][2]. Flooding can occur because the discharge or volume of water flowing in a river or drainage channel exceeds its drainage capacity. What often happens in Indonesia, flooding not only threatens human safety, but can also cause large economic and environmental losses and can even cause casualties [3]. One of the most common natural disasters in Indonesia is flooding. Floods are events that usually occur in areas where there are rivers. Flooding can occur when the capacity of a river or drainage channel to accommodate the discharge or amount of water flowing through it exceeds its capacity [4][5]. Floods are often caused by natural events or human activities. Floods often occur unexpectedly and without warning, so people cannot make preparations to avoid the disaster. What usually happens is that there seems to be no effective prevention method to reduce the loss of life and property, and the lack of a system to provide early warning of the presence of floods so that the level of loss can be minimized.

Along with the advancement of technological science today, various technological innovations continue to be developed to facilitate human life [6]. One of the fields of technology that is growing rapidly and can help humans process data and produce quality information is information technology [7][8]. The flood early detection system is one solution that can help detect the risk of flooding quickly and accurately. In general, people can only analyze directly by paying attention to whether the water will overflow or not, making it difficult to predict. So, when the water suddenly overflows without knowledge, the community cannot prepare to evacuate if a flood disaster occurs [9][10]. Therefore, the flood early detection system can help to give early warning to the community when the water has reached a certain level or status by using the Internet of Things method connected to a smartphone with the Blynk application installed so that data on the level or status of water can be monitored in real-time from a distance. Flood early detection system is one of the solutions that can help detect the risk of flooding quickly and accurately [11][12]. Flood early detection systems can help people to evacuate early and reduce the risk of loss of life and damage to property. In addition, the flood early detection system can also help the community to monitor or monitor the flood situation [13]. In general, people can only analyze directly by seeing whether the water will overflow or not, making it difficult to predict [14][15]. So, when the water suddenly overflows without knowledge, the community cannot prepare themselves to evacuate if a flood disaster will occur [16]. Therefore, a flood early detection system can help to provide early warning to the community when the water has reached a certain level or status [17][18].

Method

In this study, the design of an early warning system for flood detection based on the Internet of Things has several design stages, namely hardware design, software design, and testing of measurement results.

Hardware design

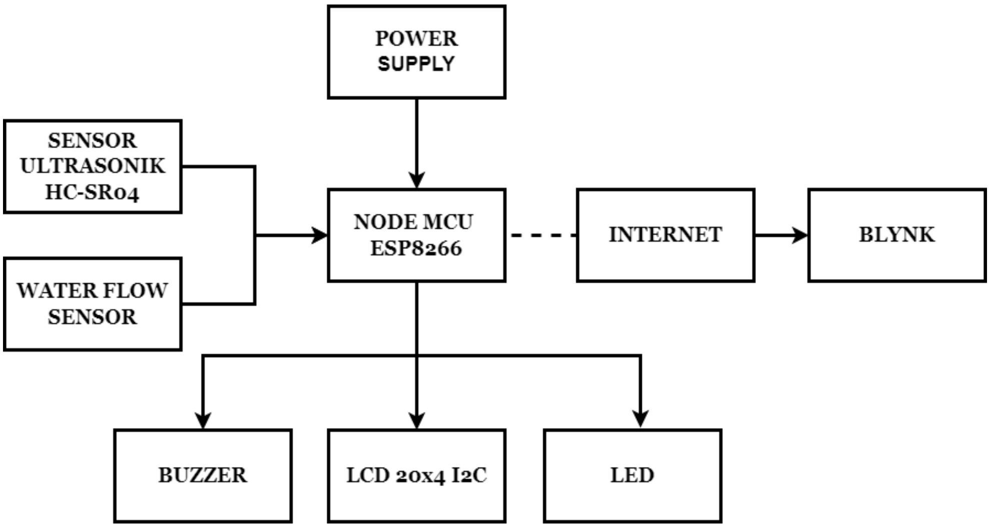

Figure 1. Block diagram of designing an early warning system for flood detection based on the internet of things

Figure 1 is a block diagram of the design of an early warning system for flood detection based on the Internet of Things. The explanation of the block diagram is that the HC-SR04 ultrasonic sensor will measure the distance value of the water level, and the water flow sensor will calculate the discharge and volume of water. The readings from both sensors will be transmitted to the NodeMCU ESP8266 microcontroller, which will analyze the information and display it on a 20x4 LCD screen as well as on a smartphone using the Blynk app. Furthermore, the Buzzer and LED will turned on according to the condition when it reaches a certain height measurement.

Software design

Software design is a program flow designed to ensure the proper operation of the system. Arduino IDE software will be used to create the program. The system flowchart is shown in Figure 2.

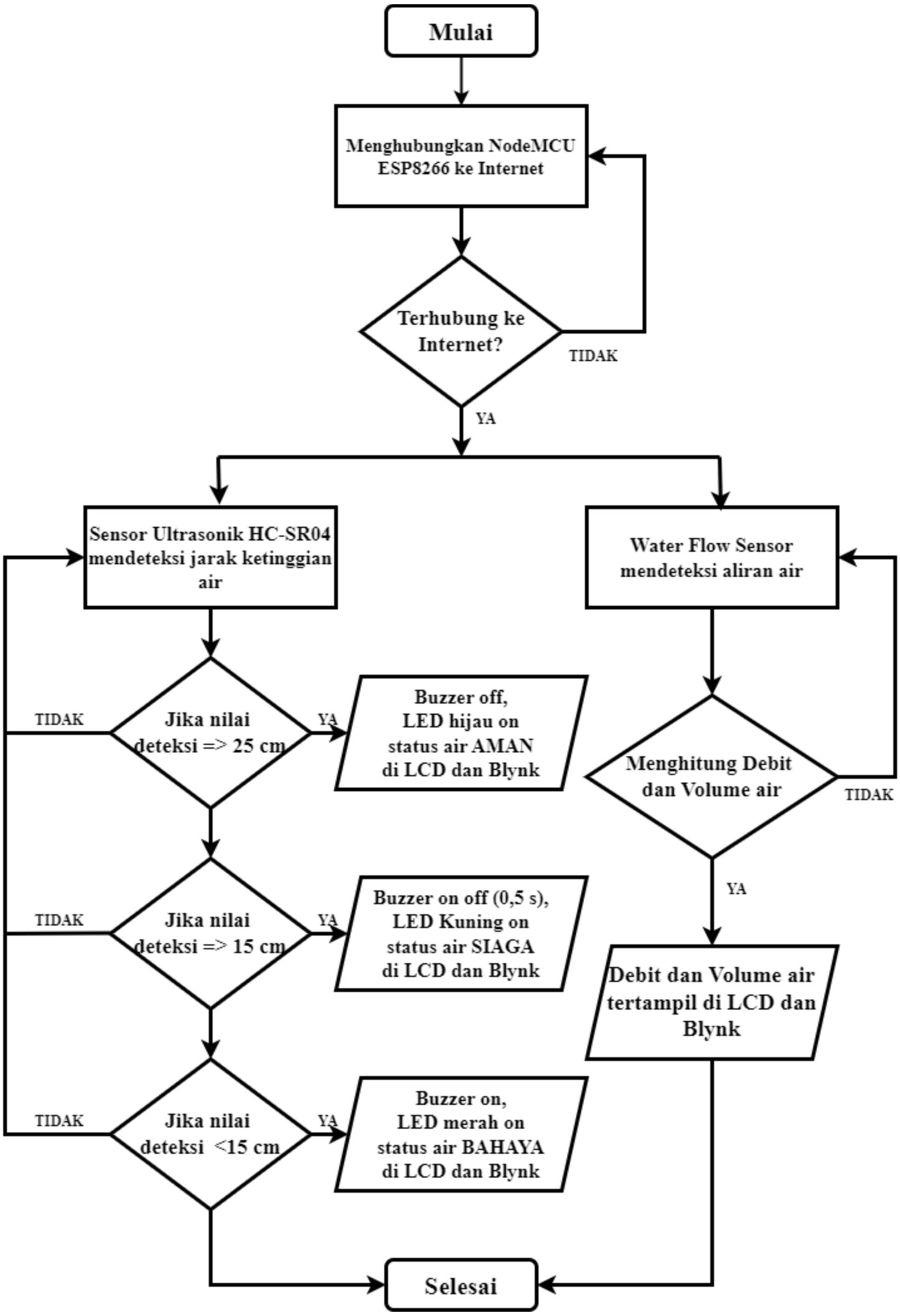

Figure 2. Flowchart of designing an early warning system for flood detection based on the internet of things

The flowchart for designing an early warning system for flood detection based on the Internet of Things starts by connecting an internet connection for the NodeMCU ESP8266. NodeMCU ESP8266 will reconnect to the Internet if it is not yet connected. NodeMCU ESP8266 will read the input value of the condition of the HC-SR04 ultrasonic sensor and water flow sensor after being connected when the reading of the HC-SR04 ultrasonic sensor detection value => 25 cm the water condition status is declared SAFE and the green LED is on if the detection value => 15 cm the water condition status is declared SIAGA 1 and the yellow LED is on, and when the detection value <15 is declared DANGER then the Buzzer will sound and the red LED is on, and the NodeMCU ESP8266 will read the input value of the Water Level sensor reading where the sensor will calculate the discharge and volume of water, then all these results will be displayed on the 20x4 LCD and BLYNK application on the smartphone.

Results and Discussion

HC-SR04 Ultrasonic Sensor Testing

HCSR-04 ultrasonic sensor testing in this study was carried out by detecting the distance of solid objects compared to the distance of a ruler with a length of 30 cm to compare the actual distance with the distance read by the HC-SR04 ultrasonic sensor. The test is shown in Figure 3.

Figure 3. Ultrasonic sensor testing detecting solid objects

HC-SR04 ultrasonic sensor testing is carried out to determine the average error obtained by the distance sensor when detecting solid objects. The test results are shown in Table 1.

Table 1. Ultrasonic sensor testing results when detecting solid objects

No	Ruler Distance	HC-SR04 Ultrasonic Sensor distance when solid object detection	Error%
1	1 cm	2,13 cm	0%
2	2 cm	2,13 cm	6,5%
3	3 cm	3,13 cm	4,33%
4	4 cm	4,10 cm	2,5%
5	5 cm	5,03 cm	0,6%
6	6 cm	6,00 cm	0%
7	7 cm	7,00 cm	0%
8	8 cm	8,26 cm	3,25%
9	9 cm	9,30 cm	3,33%
10	10 cm	10,32 cm	3,2%
11	11 cm	11,37 cm	3,36%
12	12 cm	12,07 cm	0,58%
13	13 cm	13,11 cm	0,84%
14	14 cm	14,16 cm	1,14%
15	15 cm	15,22 cm	1,46%
16	16 cm	16,22 cm	1,37%
17	17 cm	17,17 cm	1%
18	18 cm	18,44 cm	2,44%
19	19 cm	19,40 cm	2,10%
20	20 cm	20,37 cm	1,85%
21	21 cm	21,33 cm	1,57%
22	22 cm	22,58 cm	2,63%
23	23 cm	23,17 cm	0,73%
24	24 cm	24,60 cm	2,5%
25	25 cm	25,18 cm	0,72%
26	26 cm	26,06 cm	0,23%
27	27 cm	27,49 cm	1,81%
28	28 cm	28,07 cm	0,24%
29	29 cm	29,22 cm	0,75%
30	30 cm	30,02 cm	0,06%
		Average Error %	1,70%

Based on the value of the distance results in Table 1, the actual distance is carried out by detecting solid objects detected by the HC-SR04 ultrasonic sensor compared to a ruler to compare the actual distance with a total of 30 trials, the test results obtained a average error of 1.70%, but there is a difference in value when the HC-SR04 ultrasonic sensor reads at a distance of 1 cm, a distance of 1 cm is the blind spot of the HC-SR04 ultrasonic sensor because based on the datasheet of the HC-SR04 ultrasonic sensor it only detects from a distance of 2 - 400 cm.

Testing of the HC-SR04 ultrasonic sensor is carried out by detecting the water level distance which aims to measure changes in the distance of the water surface height to the position of the sensor and determine the ability of the sensor to read the height of the water surface, the comparison of the distance is detected by the HC-SR04 ultrasonic sensor with a 30 cm ruler in an aquarium. The HC-SR04 ultrasonic sensor is directed to the water in a container containing a certain water level. The volume of water in the container is added gradually to obtain variations in the water level. The test is shown in Figure 4.

HC-SR04 ultrasonic sensor testing is carried out to determine the average error produced by the distance sensor when detecting the water level distance. The test results are shown in Table 2.

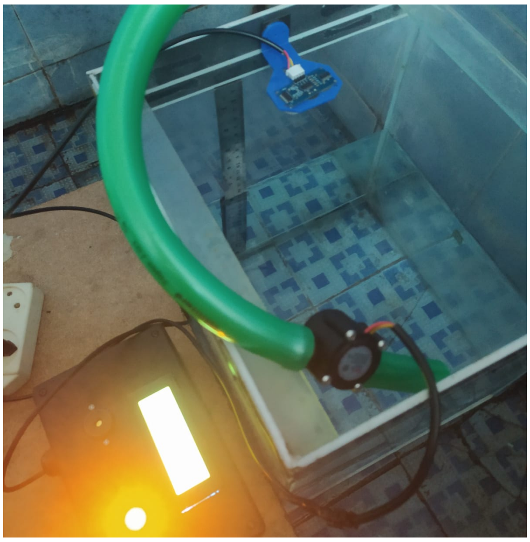

Figure 4. HC-SR04 ultrasonic sensor testing when detecting water level distance

Table 2. HC-SR04 Ultrasonic Sensor Test Results detecting water level distance

No	Ruler Distance	HC-SR04 Ultrasonic Sensor distance when solid object detection	Error%
1	1 cm	2,16 cm	0
2	2 cm	2,16 cm	8
3	3 cm	3,42 cm	14
4	4 cm	4,39 cm	9,75
5	5 cm	5,05 cm	1
6	6 cm	6,03 cm	0,5
7	7 cm	7,33 cm	4,71
8	8 cm	8,26 cm	3,25
9	9 cm	9,30 cm	3,33
10	10 cm	10,69 cm	6,9
11	11 cm	11,71 cm	6,45
12	12 cm	12,09 cm	0,75
13	13 cm	13,48 cm	3,69
14	14 cm	14,16 cm	1,14
15	15 cm	15,22 cm	1,46
16	16 cm	16,24 cm	1,5
17	17 cm	17,83 cm	4,88
18	18 cm	18,46 cm	2,55
19	19 cm	19,43 cm	2,26
20	20 cm	20,69 cm	3,45
21	21 cm	21,66 cm	3,14
22	22 cm	22,59 cm	2,68
23	23 cm	23,19 cm	0,82
24	24 cm	24,62 cm	2,58
25	25 cm	25,48 cm	1,92
26	26 cm	26,08 cm	0,30
27	27 cm	27,51 cm	1,88
28	28 cm	28,08 cm	0,28
29	29 cm	29,53 cm	1,82
30	30 cm	30,06 cm	0,2
		Average Error %	3,17%

Based on the value of the distance results in Table 2, it is done by reading the distance of the water level by the HC-SR04 ultrasonic sensor with a total of 30 trials, the test results obtained an average error of 3.17%, but there is a difference in value when the HC-SR04 ultrasonic sensor reads at a distance of 1 cm. A distance of 1 cm is the blind spot of the HC-SR04 ultrasonic sensor because based on the datasheet of the HC-SR04 ultrasonic sensor it only detects from a distance of 2 - 400 cm.

When detecting the height of the water surface, ultrasonic sensors sometimes detect the bottom of the surface if the water is too clear, this is also obtained from research [9], which analyzes ultrasonic sensors on solid and liquid objects at various times, that ultrasonic sensors can detect the bottom when the water is too clear and able to detect objects around.

After that, an experiment was conducted by giving or changing the color of the water. The ultrasonic sensor can detect the surface of the water well and the bottom of the water surface no longer able to be detected. This is based on the characteristics of ultrasonic sensors, which can detect all objects that reflect sound and measure the time transmission, and reception of reflected sound signals including transparency and color.

Testing the water flow sensor

In testing the water flow sensor, testing is carried out, namely testing the discharge and volume of water that will be received by the water flow sensor which then becomes an input signal and is converted into water discharge and volume. Data collection is taken by flowing water from the tap by comparing the water flow data detected or read by the water flow sensor with a container that has a maximum capacity of 1000 mL.

Testing the water flow sensor includes testing the discharge and volume of water and then calculating the water flow time using a timer or stopwatch. Water flow sensor testing is shown in Figure 5.

Figure 5. Water flow sensor testing

After testing with the test results shown in Table 2, it can be seen the graph in Figure 6.

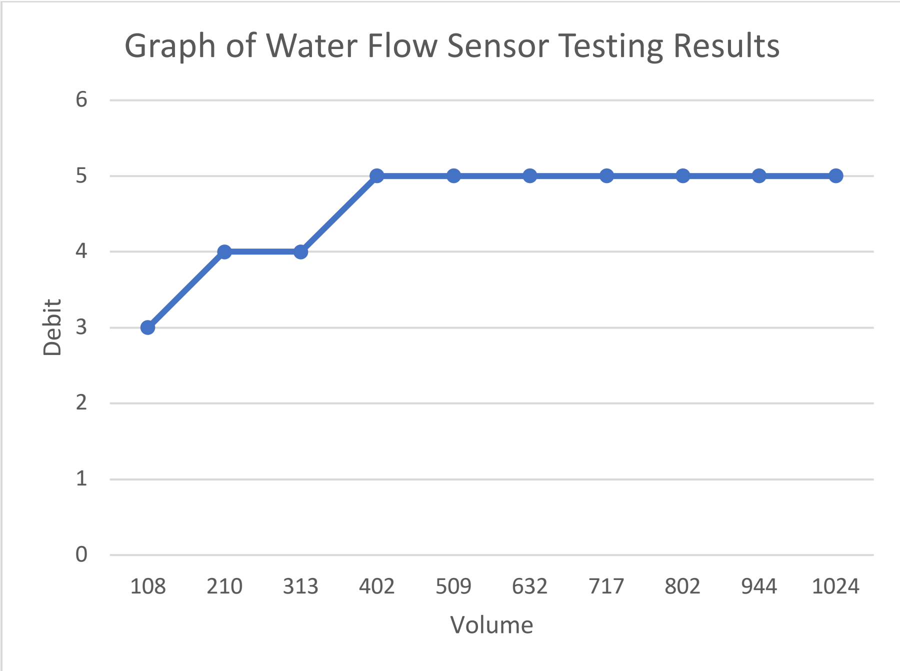

Figure 6. Graph of water flow sensor test results

Based on the results of the water flow sensor test displayed in Table 2 and Figure 6, the water volume test is carried out by calculating the amount of water discharge with a constant using the program, so that a different volume pattern will be obtained for each water discharge passed by the sensor. The detected discharge reaches a constant number for the detected water flow takes a short time, the water tap can affect the discharge of water and can also affect the results of the sensor reading value depending on the speed of the flowing water.

Volume testing

After testing the results using a water flow sensor, then perform calculations to get the average volume error read by the water flow sensor compared to the maximum capacity container of 1000 mL. The calculation results are shown in Table 3 below.

Table 3. Testing volume comparison

No	Volume of water in 1000 mL container	Volume of water read by the sensor	Error%
1	100 mL	108 mL	8
2	200 mL	210 mL	5
3	300 mL	313 mL	4,33
4	400 mL	402 mL	0,5
5	500 mL	509 mL	1,8
6	600 mL	632 mL	5,3
7	700 mL	717 mL	2,42
8	800 mL	802 mL	0,25
9	900 mL	944 mL	4,88
10	1000 mL	1024 mL	2,4
	Average Error %		3,48 %

Based on Table 3, a comparison test has been carried out between the volume value read by the water level sensor and the maximum capacity container of 1000 mL. Based on the results of these calculations, the volume of water read by the water flow sensor that has been compared with a container that has a maximum capacity of 1000 mL has an average error of 3.48%.

Discharge testing

After getting the results of the comparison of the volume of the water flow sensor, then calculate the water discharge using the formula to test the comparison of the water discharge read by the water level sensor, the water discharge is the speed of the liquid per unit time. The formula for calculating water discharge is,

Debit = Volume/Time

Comparing the results detected by the sensor with the formula calculation to find out the difference in the results of both. The comparison results are shown in Table 4.

Table 4. Comparison of calculation of water flow sensor discharge with formula

No.	Water Debit	Volume of water read by the sensor	TIme (s)	Calculated Debit
1.	3 L/min	108 mL	2,34 s	2,76 L/min
2.	4 L/min	210 mL	3,44 s	3,66 L/min
3	4 L/min	313 mL	4,62 s	4,0 L/min
4.	5 L/min	402 mL	5,04 s	4,78 L/min
5.	5 L/min	509 mL	6,42 s	4,75 L/min
6.	5 L/min	632 mL	8,03 s	4,72 L/min
7.	5 L/min	717 mL	9,67 s	4,44 L/min
8.	5 L/min	802 mL	10,67 s	4,50 L/min
9.	5 L/min	944 mL	11,98 s	4,72 L/min
10.	5 L/min	1024 mL	13,27 s	4,62 L/min

Based on the calculation results from Table 4, namely comparing the detected sensor value with the formula. These results are compared with the following calculations.

Discharge = Volume/Time

Discharge = (108 mL)/(2.34 s)

Discharge = 46.15 mL/s

Discharge = 2.76 L/min

In the calculation of the formula, the measured debit in the form of mL / s units is then converted into L / min units.

After getting a comparison of the water discharge read by the water flow sensor with the formula, a calculation is made to get the average error of the water discharge read by the water flow sensor. The calculation results are shown in Table 5.

Table 5. Debit comparison testing

No	Water Debit	Calculated Debit	Error%
1	3 L/minn	2,76 L/minn	8
2	4 L/minn	3,66 L/minn	8,5
3	4 L/minn	4,0 L/minn	0
4	5 L/minn	4,78 L/minn	4,4
5	5 L/minn	4,75 L/minn	5
6	5 L/minn	4,72 L/minn	5,6
7	5 L/minn	4,44 L/minn	11,2
8	5 L/minn	4,50 L/minn	10
9	5 L/minn	4,72 L/minn	5,6
10	5 L/minn	4,62 L/minn	7,6
	Average Error %		6,59 %

Based on the data in Table 5, namely the water flow sensor discharge test, the average error is 6.59%.

From the results of testing the volume and discharge of water, different results are obtained in each comparison of experiments that have been carried out. The precision of the water flow sensor is impacted by various factors, particularly pressure and the flow rate of the water itself. The water flow sensor uses a type of Hall effect sensor type that converts magnetic information into electrical signals, the magnetic field in the rotor will affect the Hall effect sensor and produce a pulse signal in the form of voltage (PWM). So, when the water flow sensor is given a flow and then the water from the tap is stopped, the rotor on the sensor is still rotating due to the remaining water that is still flowing (making the rotor rotate) so that the value is still calculated.

Buzzer, LCD display, and LED testing

Buzzer and LED testing is taken based on the distance value read by the HC-SR04 ultrasonic sensor the buzzer will sound when the sensor detection value is less than 15 cm indicating that the water status is DANGEROUS then the red LED lights up, the buzzer will sound and the yellow LED lights up alternately with a delay time of 0.5 seconds when the sensor detection value is equal to or more than 15 cm indicating SAFE, and the buzzer will turn off when the sensor detection value is more than or equal to 25 cm then the green LED lights up. The test results can be seen in Table 6.

Table 6. Testing buzzer, LCD, and LED conditions

No	Distance Ultrasonic Sensor HC-SR04	Buzzer Condition	LED Condition	Water status and LCD Display
1	< 15 cm	ON	Red LED	Danger
2	>= 15 cm	ON/ with delay 0,5 second	Yellow LED	Standby
3	>= 25 cm	OFF	Green LED	Safe

Blynk testing

Display testing on Blynk is conducted on a smartphone with the Blynk application installed. Blynk is used in the design of an early warning system for flood detection based on the Internet of Things to display the distance reading value of the HC-SR04 ultrasonic sensor and the status of water conditions as well as the volume and discharge of water read by the water flow sensor, in addition, there is also a water condition status based on LEDs so that it can be used to monitor water conditions remotely. The initial display of Blynk is shown in Figure 7.

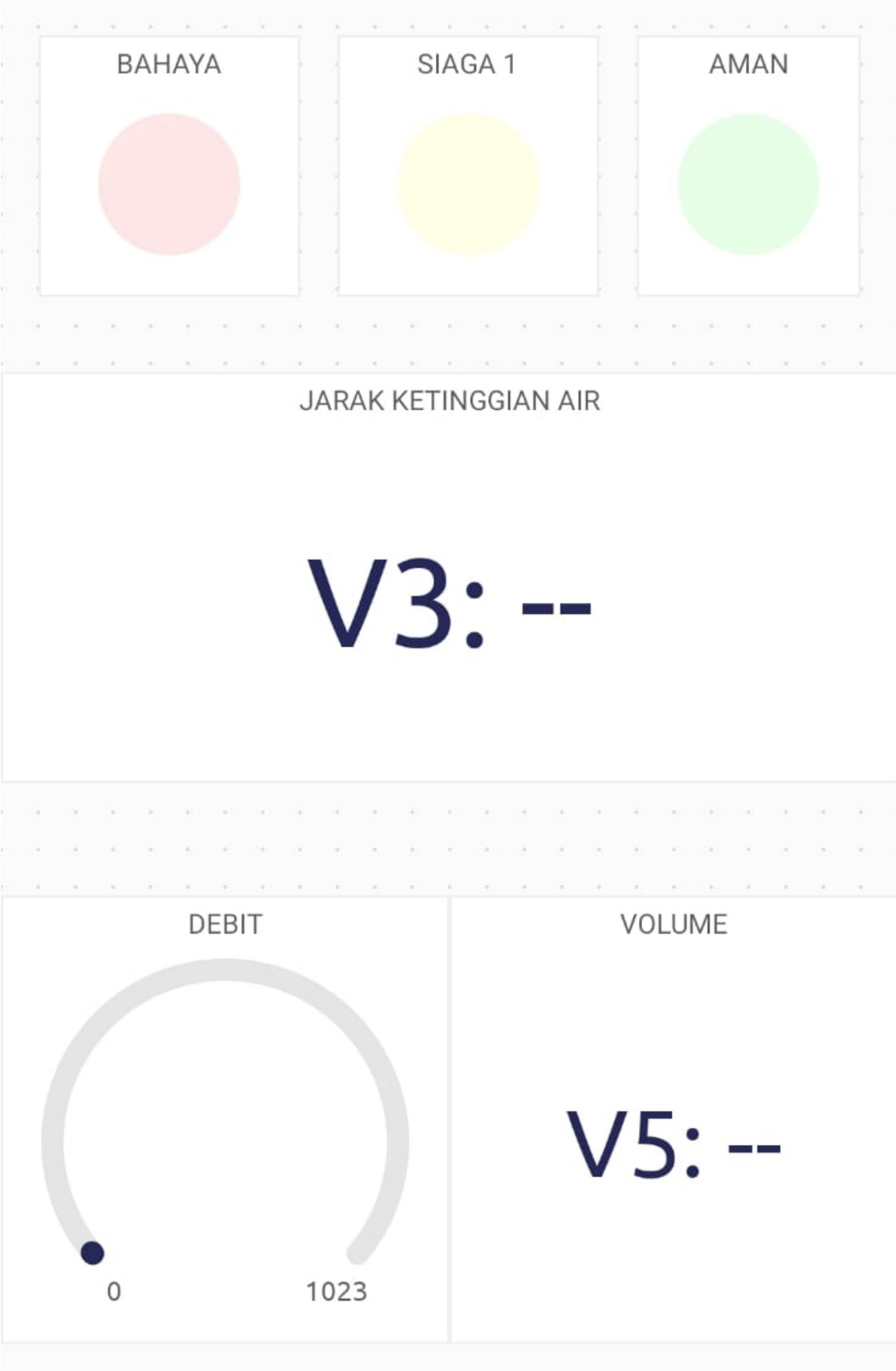

Figure 7. Blynk display

Conclusion

The implementation of the design of an early warning system for flood detection based on the Internet of Things has been obtained with good results. The HC-SR04 Ultrasonic Sensor used in the design of the Internet of Things-based flood detection early warning system has an average error of 1.70% when detecting solid objects and an average error of 3.17% when detecting the height of the water surface. The water Flow Sensor obtained an average error of 6.59% when calculating water discharge and 3.48% when calculating the volume of water. The water status color indicator when detecting a distance of => 25 cm shows a green indication indicating SAFE, when detecting a distance of => 15 cm shows a yellow indication indicating SAFE then the buzzer sounds then turns off with a delay of 0.5 seconds, and when detecting a distance of < 15 cm shows a red indication indicating DANGER then the buzzer will sound.

Acknowledgement

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