Journal of Experimental and Applied Physics
Journal Homepage: jeap.ppj.unp.ac.id
Vol. 1, No. 1, Juni 2023.
ISSN (Print): 2988-0378 ISSN (Online): 2987-9256

# Flood Early Warning System Using Ultrasonic and Rainfall Sensors IoT-Assisted with Smartphone Display

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**Article History**
Received : May, 25th 2023
Revised : June, 7th 2023
Accepted : June, 9th 2023
Published : June, 10th 2023

**DOI:**
https://doi.org/10.24036/jeap.v1i1.4

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**Abstract:** The increasing incidence of floods in Indonesia every year is in line with the losses they incur, thus requiring preventive measures such as an early warning system that is more effective than conventional systems. This early warning system uses Internet of Thing (IoT) technology which utilizes the internet so that information on potential floods can be accessed in real time on a smartphone and provides an alarm according to the potential for flooding obtained from two flood indicator data, namely rainfall and water level. This study uses NodeMCU ESP8266 as a microcontroller to read and process data from the ultrasonic HC-SR04 to detect water levels and tipping buckets to detect rainfall. The IoT system that is connected to the internet then reads and sends data that is processed by the microcontroller to be displayed on a smartphone via the Blynk application. Sensor testing was carried out by varying 10 data to obtain an average relative accuracy of 99.28% on ultrasonic and an average relative accuracy of 98.75% on tipping buckets. Overall, the system works well and provides accurate information if it is connected to the internet.

**Keywords:** Early Warning System, Ultrasonic HC-SR04, Tipping Bucket, Display Smartphone

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## 1. Introduction

Indonesia is said to be in the ring of fire with high risk of natural disasters. Indonesia has a high annual disasters history, especially hydrometeorological disasters such as floods and landslides [1]. The dominance of this hydrometeorological disaster is a result of Indonesia's geographical location, which is in a tropical climate with two seasons, namely the dry and the rainy seasons. In addition, Indonesia is an archipelagic country, so it has a high evaporation rate of seawater, resulting in prolonged rains. This condition can cause extreme weather changes that trigger hydrometeorological disasters such as floods [2]. Referring to the infographic of the BNPB data, it is noted that the history of hydrometeorological disasters dominates every year, especially floods. In 2021, 1581 floods occurred, which resulted in 781,054 people being displaced. Meanwhile, in 2021, 715 flood disasters occurred, which resulted in 409,692 people being displaced [3].

Natural disasters have characteristics that occur randomly, dynamically change the environment, and are difficult to overcome. The high history of flood disasters is critical for mitigation to reduce the possibility of damage due to disasters and provide fast and appropriate assistance to victims so that recovery can be achieved appropriately and effectively. One of the preventive measures that can be taken to reduce the risk of flooding is to create a flood early warning system [4-5]. The early warning system aims to empower individuals and groups before a disaster occurs or when they are threatened with danger to act appropriately to take preventive and rescue actions to reduce the possibility of causing fatalities and physical or material damage due to disasters [6]. Several previous studies discussed early warning systems. In previous research, the early warning system (EWS) was carried out by providing information on potential floods that had been integrated into the IoT system [7–11].

Most of these studies use one parameter, such as water level and short message service communication media [11], but it is expensive. Rainfall is an essential trigger for flood disasters but is still very rarely used as an early warning parameter for flood disasters. Referring to these problems, the solution that can be proposed is the development of EWS is to add climatological parameters, and this is done because extreme climate change, such as prolonged rain, causes high rainfall, which results in a high potential for flood disasters [2]. The rapid development of internet technology is in line with the need for all kinds of work related to the internet so that work can be done correctly, effectively, and monitored anywhere and anytime [12]. IoT is used for automation and data acquisition so that data can be accessed in real-time remotely with an internet connection [13-14].

Data information related to potential disasters is reported using the Blynk platform, which can store, control and visualize data via the internet. The platform is very portable because it can access and visualize data in real-time on a smartphone or the web. In addition to displaying data using a smartphone, Blynk can also provide notifications or warning messages on smartphones and emails [10-15]. Therefore, to prevent and reduce the risks caused by floods, it is necessary to develop an early warning system for floods using ultrasonic sensors and rainfall, assisted by IoT with a smartphone display.

## 2. Materials and Method

This study uses the Research and Development (R&D) method. The R&D method is a research method used to produce specific products and test their effectiveness. This method uses the Four-D (4-D) development model. This development model consists of four stages define, design, develop and disseminate [16]. This system consists of software, hardware, and system block diagrams. The diagram block flowchart of system can be seen in Figure 1 and software flowchart in Figure 2.

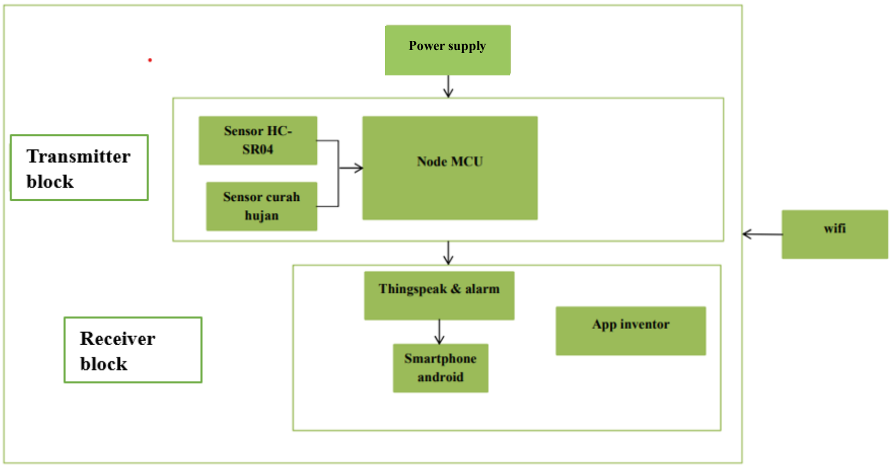


Figure 1. Block diagram.

Based on the flowchart in the Figure 2, the flow or steps can be explained the working of the software. The first step is to connect the Node board MCU to existing WiFi (WLAN) transmitter. When first used, WiFi transmitter first declares its SSID and password for connected. If the board is not connected, the process will start again from start until it is connected and if it is connected to the WiFi transmitter this board can access the internet then sensor data can be read on the board as well as the data sent to the internet (Blynk). In Blynk the data is displayed in the form of a status water level and rainfall in real-time.

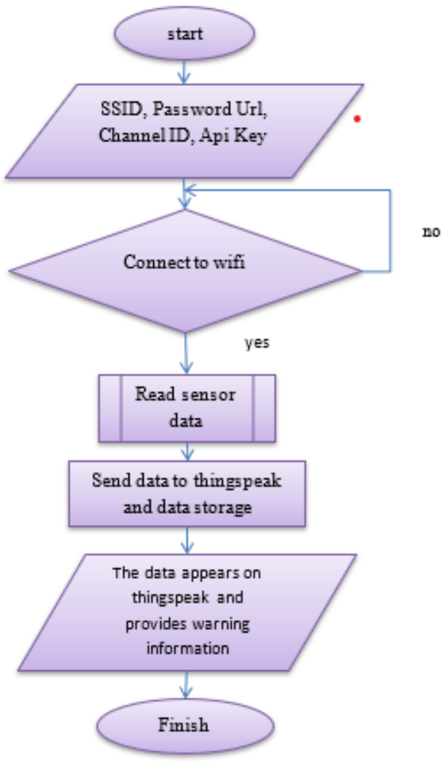


Figure 2. Software Flowchart

An overview of the hardware and its parts can be seen in Figure 3. This system is designed to read data from sensors that will be processed by the microcontroller to be displayed using a smartphone. The microcontroller used in this tool is NodeMCU ESP8266 which is programmed using the Arduino IDE programming language and will be displayed on a smartphone using the Blynk application.

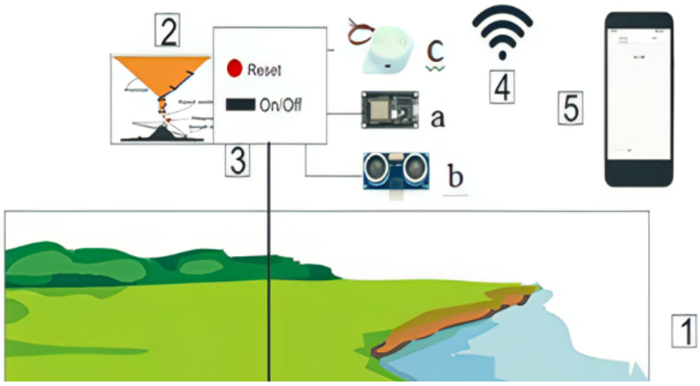

Figure 3. Hardware design

Figure 3 describes the parts of the system hardware consisting of (1) a prototype box that resembles a flood-prone environmental condition (land and hills are only accessories). (2) tipping bucket rain gauge as a sensor for measuring rainfall to determine weather conditions by measuring the detected flow volume. (3) a microcontroller box consisting of components and a series of tools such as (a) ultrasonic sensor, (b) NodeMCU ESP8266, and (c) buzzer as an alarm. (4) an IoT system in the form of WiFi as a media for sending data from the Blynk application tool, and (5) a smartphone as a data display. Then, the development stage aims to produce a product for developing a flood disaster EWS based on the design and performance following the specification objectives.

## 3. Results and Discussion

The data generated in this study include the results of making instruments to determine design specifications based on the design stage and testing tools to see the device's performance specifications. Measurement result data is displayed in the form of tables and graphs. The results of the system design can be seen in Figure 4.


Figure 4. Flood EWS design result

Figure 4 is the result of designing flood EWS using ultrasonic sensors to detect water levels and tipping buckets to detect rainfall assisted by IoT with smartphone displays. EWS testing is done with a prototype scale, as shown in Figure 4. The prototype set has a box to hold water and a 30 cm long pipe to support the sensor. There is an adapter port on the tool to connect the instrument to the power supply. The USB port is used to upload programs when changing or repairing programs. There is also a button on the instrument that is used to operate the instrument. This EWS works by reading data using ultrasonic sensors and tipping buckets processed by a microcontroller, namely NodeMCU ESP8266, which can be connected to the internet via WiFi. When the device is connected to WiFi and received by the microcontroller, the data is sent to the Blynk server. The data sent on the Blynk server is then displayed on a smartphone with the Blynk application installed. The data display is shown in Figure 5.

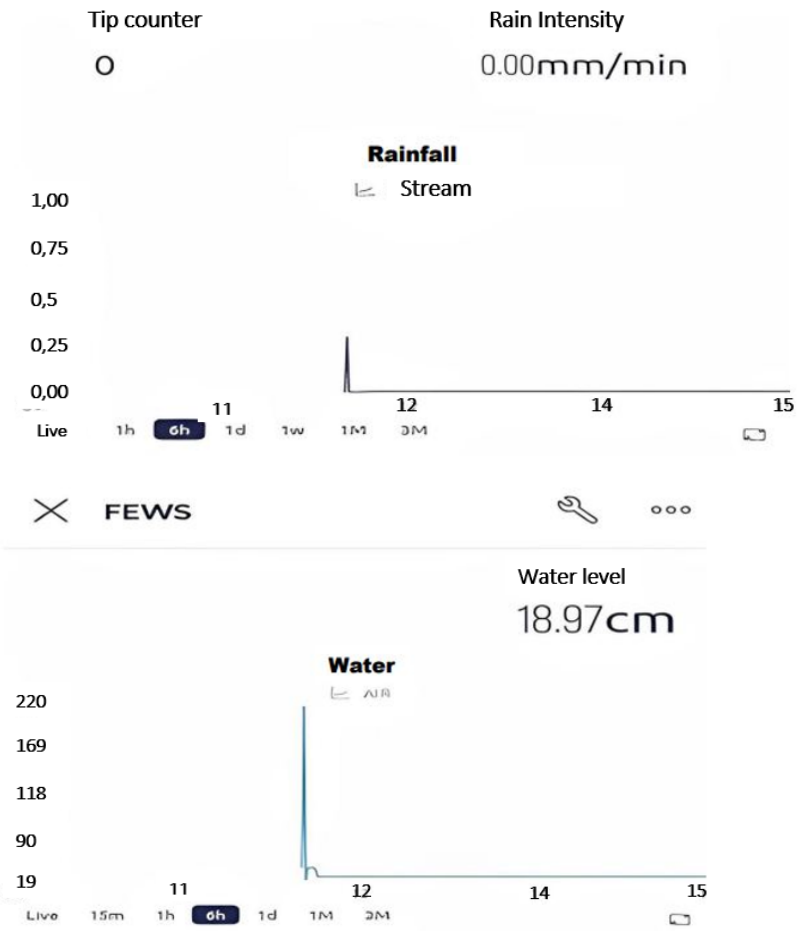


Figure 5. Interface data.

The interface data display is shown in Figure 5. The display shows water level data from ultrasonic; below it is a water movement graph. Data on the number of water tips calculated by the tipping bucket, rainfall intensity, and the graph below are also displayed. The data graph shows real-time data and data for the last 1 hour, 6 hours, 12 hours, day, week, and month. Other results were obtained from the testing process. The test was conducted to determine the instrument's performance in detecting potential flood disasters by implementing EWS on a flood prototype designed to resemble a flood-prone area. Instrument testing is carried out to determine the accuracy, precision, and measurement error of the ultrasonic sensor and tipping bucket. Measurement of water level is done by comparing the results of ultrasonic sensor measurements with the results of measurements using a ruler. The instrument's accuracy is tested by comparing the measurement results with the standard instrument. Accuracy testing is done by varying the 11th water level data. The results of the comparison of these measurements are provided in Figure 6.

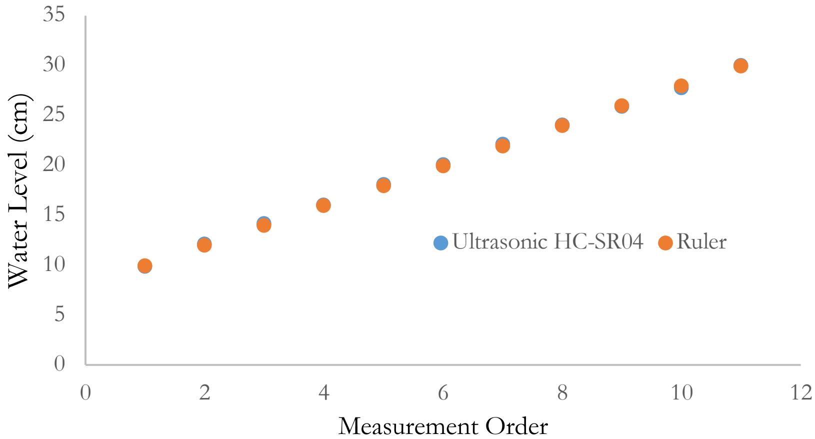


Figure 6. The graphic of ultrasonic accuracy testing.

It can be seen in Figure 6. that the comparison of the measurement results of the two instruments shows the same value. From these tests, the average accuracy is 99.28%, with a measurement error of 0.72%. So it can be concluded that the ultrasonic sensor HC-SR04 is quite accurate as a water level detector. Testing the instrument's precision is done by making repeated measurements under the same conditions. The accuracy test on the ultrasonic sensor was carried out ten times at 30 cm. The graph of the instrument precision test results is presented in Figure 7.

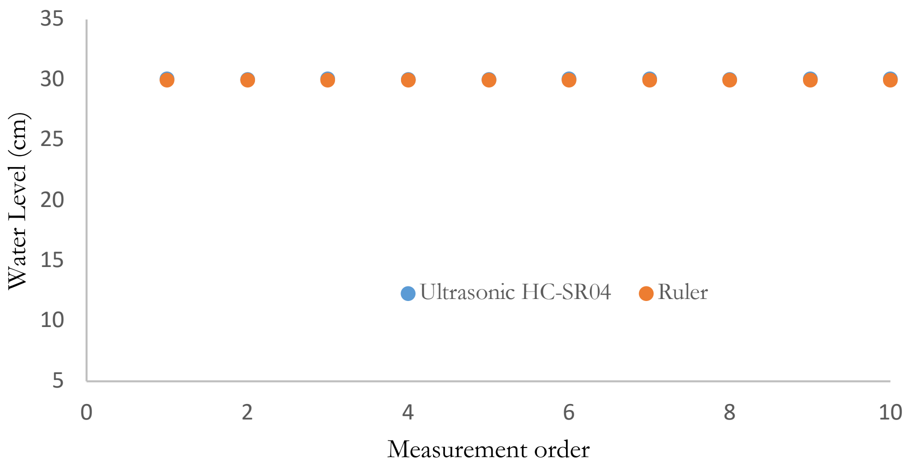


Figure 7. The precision graphic of Ultrasonic HC-SR04

Figure 7 shows the results of repeated data testing to obtain precision data from the HC-SR04 ultrasonic sensor, where the data obtained is almost the same as the actual distance. From the measurement data, the average percentage of ultrasonic sensor accuracy is 99.74%. These data indicate that the ultrasonic sensor HC-SR04 is quite precise in measuring the water level. The same test was also carried out on the tipping bucket sensor. The accuracy test is done by comparing the measurement results of the tipping bucket sensor with a beaker to measure the volume of water. The test was carried out by varying the 10th data volume of water. The data of the accuracy test results can be seen in Figure 8.

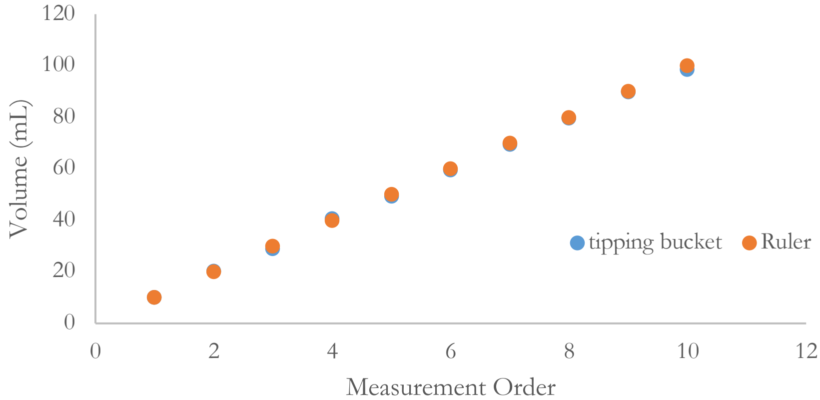


Figure 8. The graphic of Tipping bucket accurate testing.

Figure 8 shows the data from the tipping bucket accuracy measurement. Based on this data, the comparison of instrument measurement data shows almost the same value. In addition, it is also obtained from the average percentage of accuracy obtained is 98.75%, with an error percentage of 1.25%. This data shows that tipping accurately measures the volume of water. The precision testing on the tipping bucket sensor is carried out through repeated measurements at the same volume. Precision testing on the tipping bucket sensor was carried out 10 times at a volume of 100 mL. The graph of precision data testing is presented in Figure 9.

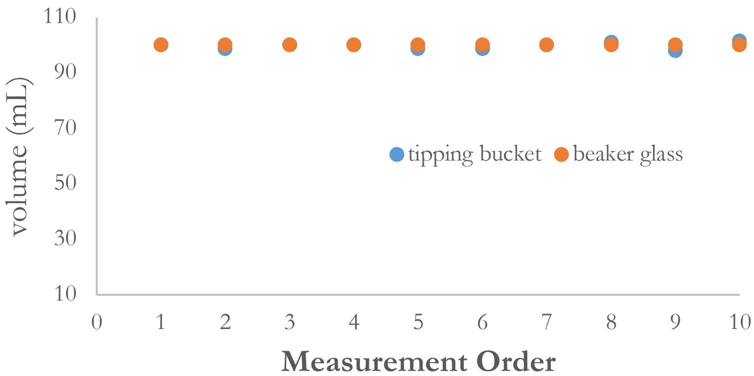


Figure 9. The graphic of tipping bucket precision testing.

Figure 9 shows the results of repeated measurements on the tipping bucket so that precision data is obtained. from these measurements, it was found that the results of repeated measurements of the tipping bucket obtained almost the same value. The precision value of the tipping bucket sensor is relatively high, as seen from the average precision percentage of 99.76%. These data indicate that the tipping bucket sensor is quite appropriate to use. This instrument provides information about potential disasters as an early warning system. Providing disaster potential information is designed or programmed with two alarm indicators on ultrasonic sensor measurements and two on tipping bucket sensor measurements. The alarm indicator on the ultrasonic sensor is in the form of alert and danger, while the tipping bucket sensor is in the form of heavy rain and hefty rain. Information on potential flood disasters is provided in the form of sound by a buzzer and notifications displayed on smartphones and registered emails. An example of alarm notification for potential flood disasters is shown in Figure 10.

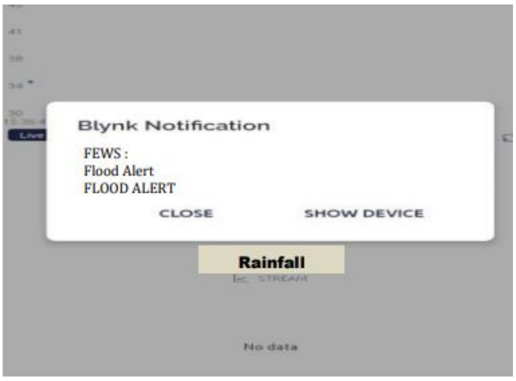


Figure 10. Notification from Blynk application

## 4. Conclusion

Based on the results of measurement, testing and analysis of a flood early warning system using ultrasonic sensors and IoT-assisted rainfall with smartphone displays, from the test data obtained precision percentage of 99.74% and accuracy of 99.28% for ultrasonic sensors in detecting water levels and percentage of precision of 99.76% and accuracy of 98.75% as well as sending information on smartphones in real time and buzzers according to the criteria for the level of the disaster that occurred. the level of disaster criteria given is in the form of alert and alert which are processed based on the criteria of rainfall and water level. However, the information on the smartphone will experience a delay when the internet network is unstable. this system works very well, is valid and also practical so that it can be used by all groups. Therefore, this system can be an alternative that can be used as a flood early warning system which of course needs to be supported by good and stable internet access and a good understanding of disaster information.

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