Flood monitoring system using ultrasonic sensor SN-SR04T and SIM 900A

Sixtinah Dswilan*, Harmadi and Marzuki

Department of Physics, Faculty of Mathematics and Natural Sciences, Andalas University, Padang 25131, Indonesia

*sixtinha@gmail.com

Abstract. A flood monitoring system using ultrasonic sensors JSN-SR04T and SIM 900A have been designed. The system consists of solar panels as a source of electrical energy, JSN-SR04T as a water level detector and SIM 900A as a sent of flood information. The test results prove that the JSN-SR04T has been able to detect 20 cm to 600 cm of distances. The results of the water level produced were 5.0314 mV/cm of sensitivity and 0.9996 of regression value. The sensitivity states that for every 1 cm of water level there was a change 5.0314 mV of voltage and a regression value close to 1 cm indicated that the sensor was worked properly. The test results also prove that used a buoy produced a smaller of error percentage than not used a buoy, but the measurement not used a buoy can minimize errors when tested in the field. Measurement error caused by increased water discharge when it rains which can affect the buoy send a signal to JSN SR04T. The tested overall has been able to detect water levels, water level conditions and sent information, so that it is beneficial for the community to flood monitor the river flow.

1. Introduction
Flood is a hydrometeorological event that occurs because the volume of river water or drainage channels exceeds its drainage capacity. The increase of the water volume is caused by rainfall intensity along the river flow. Rainfall has a significant relationship to changes in river discharge fluctuations [1]. River discharge tends to follow the dynamics of rainfall and 97% of river discharge is influenced by water level [2].

The events increase of rainfall intensity and river water level cause flooding along the river basin. In the last ten years, the area and frequency of floods have increased with greater losses [3]. Based on the results of the risk assessment, the total number of flood victims in Indonesia reached 40.690.352 people with a potential loss of Rp. 2.210 trillion [4].

The impact of flood can be minimized by monitoring river water levels. Monitoring river water levels can be done by installing floodgates in the river flow. The height of the river water level can be regulated by opening or closing the floodgates which were done manually through the guard gate of the floodgates located on the river bank. The water level was divided into five states namely alert 4, alert 3, alert 2, alert 1, and danger [5]. Manually measuring water level measurements was considered ineffective because the gatekeepers must carry out direct monitoring when it rains, so the design of river water level gauges was automatically needed for flood mitigation.
The water level detection devices using ultrasonic sensors HC-SR04 have been designed. \cite{6}. Research on water level measurements to floods monitoring using ultrasonic sensors HC-SR04 was often found because of their simple used and low prices. The sensor has a drawback because of the narrow distance detection range and very vulnerable when used to detect river water levels during rain. Rainwater splashes on the sensor will affect the sensor's performance because there was a source of electrical voltage in detecting water levels. Subsequent research from Andang \cite{7} conducted a test to see the ability of the ultrasonic sensor JSN-SR04T to detect floods based on river water levels. The use of the ultrasonic sensor JSN-SR04T gives more accurate results because it can detect distances up to 6 meters. The JSN-SR04T can also be placed higher and safer in the event of rain because the sensor and control systems are in separate modules. The study still has shortcomings because the data collection conditions were carried out when there was no rainfall and the surface of the river water was not bumpy. Corrugated water surfaces can affect river water levels. The design of tools to measure water level was expected to be developed in calculating the surging surface of the river.

The design of tools to detect floods has also been observed using fuzzy logic and simple additive weighting. \cite{8}. The system design used a water level sensor, a rain module sensor, servo motor, and Arduino Uno Mega 2650. Fuzzy logic was used to determine the opening of flood gates based on the height of the water level sensor acquisition results and rainfall data obtained from the acquisition of the rain module sensor. Simple additive weighting method was used to determine which creeks were the best alternatives for water flow. The results of this study prove that the higher of rainfall intensity, the higher of water level so that the floodgates can be opened. Research conducted by Prasetya \cite{8} still has shortcomings because it was only limited to the design of flood detection models. The use of a water lever sensor only allows the detection of water at an altitude of less than 5 cm so that it cannot be used to detect water levels in a river flow. Fuzzy logic was used to determine the opening of flood gates based on the height of the water level sensor acquisition results and rainfall data obtained from the rain sensor acquisition results. Simple additive weighting method was used to determine which creeks were the best alternatives for water flow. The results of this study prove that the higher the intensity of rainfall, the higher the water level so that the floodgates can be opened. Research conducted by Prasetya \cite{8} still has shortcomings because it was only limited to the design of flood detection models. The water lever sensor only used to allows the detection of water at an altitude of less than 5 cm so that it cannot be used to detect water levels in a river flow.

Based on the problems and research results that have been carried out by several previous studies, a study was conducted on the Flood Monitoring System Using Ultrasonic Sensor JSN-SR04T and SIM 900A. The monitoring system was designed using a power source that is stored on a solar panel so that it can measure water levels and send information via SMS. The water level was detected by the ultrasonic sensor JSN-SR04T. The sensor was resistant of the water splashes because the sensor and control system parts were in separate places with a range of up to 6 m. The designed tool system was tested on river flow for flood disaster mitigation.

2. Method
The design of ultrasonic sensor JSN-SR04T characterization circuit aimed to obtain the transfer function of the relationship between the output voltage and the distance read by the sensor. The characterization circuit used an input voltage source from a power supply of 9 volt. The signal conditioning circuit used LM7805 to stabilize the voltage and the IC NE555 was used as a pulse generator.

The ultrasonic sensor JSN-SR04T aims to detect the presence of objects. The ultrasonic sensor trigger module received a trigger signal and emits that signal with a frequency of 40 kHz. The ultrasonic sensor module will received the reflection of the signal sent by the sensor transmitter. The reflection of the received signal has the same frequency as the one emitted before that was 40 kHz. The output voltage obtained was read using a multimeter. Following the series of ultrasonic sensor JSN-SR04T was characterization in Figure 2.1.
If the transfer function of the ultrasonic sensor JSN-SR04T had been obtained, an overall sensor test was performed. The ultrasonic sensor was tested performed using the ultrasonic sensor JSN-SR04T which was connected to the Arduino Uno R3. Ultrasonic sensor JSN-SR04T has four pins namely VCC, TRIG, ECHO and GND. The sensor testing step was to connect the pins on the ultrasonic sensor JSN-SR04T with the Arduino Uno R3. The VCC pin was connected to pin 5 V on the arduino uno R3, the TRIG pin was connected to pin 9 on the arduino uno R3, the ECHO pin was connected to pin 10 on the arduino uno R3, the GND pin was connected to the GND pin on the arduino uno R3.

JSN-SR04T consists of two parts, namely the sensor and the control module. The sensor system has two main components, namely the ultrasonic transmitter and the ultrasonic receiver. The function of the ultrasonic transmitter is to emit ultrasonic waves with a frequency of 40 KHz then the ultrasonic receiver captures the results of the ultrasonic waves that hit the object. The travel time of the ultrasonic waves from transmitter to receiver was proportional to twice the distance between the sensor and the reflected plane.

The principle of measuring the distance using the ultrasonic sensor JSN-SR04T when a trigger pulse was given to the sensor, the transmitter will start emitting ultrasonic waves and at the same time the sensor will produce an upward transition TTL output. This output indicates the sensor starts calculating the measurement time. After the receiver receives the reflection generated by an object, the time measurement will be stopped by producing a down transition TTL output. If the measurement time is $t$ and the speed of sound is 340 m/s, then the distance between the sensor and the object can be calculated using Equation 1.

$$s = t \times \frac{340 \text{ m/s}}{2}$$  

where $s$ is the distance between the sensor and the object (m), and $t$ is the travel time of the ultrasonic waves from the transmitter to the receiver (s).

The designed ultrasonic sensor JSN-SR04T circuit was placed at the top of the water surface to detect water level. The tests were carried out when there were and no buoys. This test aims to prove how effective the buoy was in reflecting the sound waves from the transmitter unit to the receiver unit. The buoy used was a buoy coated with ceramic material. These buoys would reflect waves in the ultrasonic wave range. Ultrasonic wave reflection will determine the height detected by the sensor. If you determine the height of the water, then the difference between the model height and the height was read by the sensor. The design to detect water level can be seen in Figure 2.2.
The data transmission system consists of two units, the transmitter unit and the receiver unit. The transmitter unit used a 900A SIM module and the receiver unit used a wavecom module (Figure 2.3 and Figure 2.4). The test was done by calculating the time when the program was successfully uploaded until an SMS in the form of data received by wavecom module. The test was carried out at several different locations and distances. Testing with several locations aims to determine whether the SIM 900A and wavecom module can still function with variations in the increasingly farther distance. The variations used were 1 m, 10 m, 100 m, 1 km, and 10 km of distance.

SIM 900A module used Arduino IDE software on the computer, jumper cable and Arduino Uno R3. The first step was to create a SIM 900A module testing program using the Arduino IDE software. The testing program that has been created was uploaded into Arduino R3. The next step was to connect the TX and RX to the SIM 900A module with ports 2 and 3 on the Arduino R3. The last step was to run the uploaded program. If the program run screen was written "Program Success!", It means the program was running and the SIM 900A module can be used. If the program run screen says "Program Error", it means that there was still an error in the program written. If the program was successful, then the test ability of the components, the time to send an SMS was calculated by varying the distance the SMS was sent.
The design of software system aimed to process the input signal from the ultrasonic sensor JSN-SR04T so that the resulting data can be sent via the 900A SIM module. Programming in this study consisted of the source code embedded in the arduino uno R3 microcontroller using C language. The embedded program will determine the order of work performed by the microcontroller. Water level measurements were made based on the total height of the river model that was equal to 70 cm. Standby status was grouped into 5 namely aleart 4, aleart 3, aleart 2, aleart 1 and danger. Each aleart status has a water height range of 10 cm. Every data generated was sent in real time to the receiver unit. The membership function of the variable water level can be seen in Table 1.

![Figure 4. The scheme of wavecom M1306B](image)

### Table 1. Information on water level variable membership functions

| No. | Parameter | Water Height (cm) |
|-----|-----------|-------------------|
| 1   | Aleart 4  | <= 10             |
| 2   | Aleart 3  | 10 <S <= 20       |
| 3   | Aleart 2  | 20 <S <= 30       |
| 4   | Aleart 1  | 30 <S <= 40       |
| 5   | Danger    | > 40              |

Each water level parameter was conditioned to detect the flood. The output value of the water level was processed to flood mitigation, so the factors that flood influenced can be determined. The value and condition of the water level were sent to the receiver unit. The receiver unit then received information so that it can be used to monitor the flood.

### 3. Summary and Result

#### 3.1 Characterization of JSN-SR04T Ultrasonic Sensor

Figure 3.1 shows a graphic characterization of the ultrasonic sensor JSN-SR04T. Characterization used a program and a multimeter to get the transfer function between the distance and the output voltage detected by the sensor. The output voltage was directly proportional to the distance detected by the ultrasonic sensor JSN-SR04T, the further distance detected by the sensor, the greater output voltage generated, the shorter distance sensor detected, the smaller output voltage produced. Transfer function $y = 5.0314x + 5.0104$ where variable $y$ is the output voltage and variable $x$ is distance. The transfer function produces a sensitivity value of 5.0314 mV/cm which states that any change in distance of 1 cm results in an increase in the output voltage of the ultrasonic sensor JSN-SR04T by 5.0313 mV. The value of 5.0144 mV was the offset value which states that the initial voltage of the ultrasonic sensor JSN-SR04T when the distance 5.0144 mV was zero. Correlation coefficient values close to 1 (0.9996) indicate that the sensor works very well.
The ultrasonic sensor JSN-SR04T can detect the distances in the range of 20 cm - 600 cm. The results of characterization tests have been carried out in accordance with the datasheet. Output voltage values below 20 cm and above 600 cm experience significant changes because they are in the saturation region.

3.2 Ultrasonic Sensor JSN-SR04T Testing

Figure 3.2 and Figure 3.3 shows a chart test of the ultrasonic sensor JSN-SR04T using a buoy and without a buoy. This test using a buoy produced an error percentage of 0.49 %. The error percentage was smaller than the test without using a buoy which has an error percentage of 1.1 %. The difference percentage was due to the influence of water fluctuations when detected by the ultrasonic sensor JSN-SR04T. The used of a buoy produced better reflection from the transmitter unit to the receiver unit because it was a solid object, but when not using an ultrasonic sensor JSN-SR04T the buoy can still detect water levels with a percentage of less than 5 %.
A buoy usage was produced a smaller errors percentage compared to unused a buoy, but when tested directly to the field it was recommended not to use a buoy. The use of a buoy that was inside a PVC pipe did not have a stable position when there was an increase in water discharge. PVC pipes follow waves of water so that it can affect sensor performance. The error percentage in measurement of water level not using a buoy can be minimized by taking the average values of the water level and the exit voltage detected by the ultrasonic sensor JSN-SR04T. Based on tested that has been done, the system was developed without using a buoy to minimize errors in the field.

### 3.3 Data Transmission System Test Results

Table 2. shows the results of testing the data transmission system from the transmitter unit to the receiver unit. The test was carried out using a 900A SIM located in Lubuk Lintah Padang and wavecom module was in the location according to the test distance. Test results proved that sending data from SIM 900A was successfully sent to the wavecom module. The distance variation does not affect the time of data transmission because SIM 900A as the sender and mobile as the receiver uses electromagnetic waves which have the same speed as the speed of light which is $3 \times 10^8$ m/s.

| No. | Distance | Delivery Time (s) | Information |
|-----|----------|-------------------|-------------|
| 1   | 1 m      | 1                 | Success     |
| 2   | 10 m     | 1                 | Success     |
| 3   | 100 m    | 1                 | Success     |
| 4   | 1 km     | 1                 | Success     |
| 5   | 10 km    | 1                 | Success     |

### 3.4 Flood Detection Modeling Testing Results

The results of flood detection equipment testing are showed by the value of the water level detected by the ultrasonic sensor JSN-SR04T. The test was carried out by raindrop models through PVC pipes which have been perforated with a hole diameter of 3 mm and 4 mm. The river model used had a height ratio of 1: 5 to the actual height of river water. The number and diameter of the holes between the rain detector and the height of the water are made the same in each position, so that when the flood detector operates, several variables such as the time of occurrence of water level, and water level
conditions for flood mitigation modeling are obtained. The results of testing with several conditions can be seen in Table 3

Table 3. The results of modeling tests for flood detection devices

| Time       | Water Height (cm) | Condition |
|------------|-------------------|-----------|
| 3:25:47 PM | 5                 | Aleart 4  |
| 3:27:42 PM | 11                | Aleart 3  |
| 3:31:35 PM | 22                | Aleart 2  |
| 3:36:26 PM | 32                | Aleart 1  |
| 3:41:16 PM | 41                | Danger    |

Table 3 shows the results of modeling the flood detection device in the initial "aleart 4" condition resulting in a water level reaching 5 cm. The volume of water increases with increasing water droplets in PVC pipes, so that the increase in water volume can determine the conditions for flood mitigation. The generated information would be sent to wavecom via SIM 900A, so that it can be received by the observation post.

4. Conclusion
This research has succeeded in developing a flood monitoring tool based on the ultrasonic sensor JSN-SR04T. The test results proved that the water level using the JSN-SR04T ultrasonic sensor has a sensitivity value of 5.0314 mV/cm with a range of 20 cm to 600 cm. However, the test was still needed by considering other factors causing flooding in the river flow.

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Reference

[1] Muchtar A, Abdullah N 2007 Analisis Faktor-Faktor Yang Mempengaruhi Debit Sungai Mamasa Jurnal Hutan dan Masyarakat vol 2 pp 174-187.
[2] Setiawan A, Susanto E 2019 Penentuan Liku Kalibrasi Debit (Rating Curve) Pada Musim Hujan Di Daerah Alian Sungai (DAS) Deli Jurnal Rekayasa Pertanian dan Biosistem vol 7 pp 157-165.
[3] BNPB 2012 Peraturan Kepala Badan Nasional Penanggulangan Bencana Nomor 2 Tahun 2012 Tentang Pedoman Umum Pengkajian Risiko Bencana BNPB Jakarta.
[4] BNPB 2014 Rencana Nasional Penanggulangan Bencana 2015-2019 BNPB Jakarta.
[5] BPBD MUBA 2012 Pedoman Penyusunan Sistem Peringatan Dini dan Evakuasi Banjir BPBD MUBA Palembang.
[6] Natividad J G, Krejcar J M 2018 Flood Monitoring and Early Warning System Using Ultrasonic Sensor Materials Science and Engineering vol 35 pp 1-6.
[7] Andang A, Hiron N, Chobir A, Busaeri N 2019 Investigation of Ultrasonic Sensor Type JSN-SR04T Performance as Flood Elevation Detection Materials Science and Engineering vol 50 pp 1-7.
[8] Prasetya A E, Hanafi M H, Prastio B H 2018 Rancang Bangun Pengendali Pintu Air Sungai Dengan Menggunakan Logika Fuzzy dan Simple Additive Weighting Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer vol 2 pp 2414-2422.