

Initial Design of Earthquake Early Warning System With Smartphone Display

Washilla Audia, Yulkifli Yulkifli*, and Yohandri Yohandri

Department of Physics, Departement of Physics Faculty of Mathematics and Natural Sciences Universitas Negeri Padang,
Jl. Prof. Hamka, Padang, 25131, Indonesia

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This research presents the preliminary design of an automatic vibration detection system that can be used as an earthquake early warning system using the Internet of Things and a smartphone display, and to investigate the relationship between vibration acceleration and vibration intensity and magnitude. Earthquake early warning is an important tool to reduce the danger of earthquakes and is a form of earthquake mitigation. This system is designed using MPU6050, ESP8266, Arduino IDE, Buzzer, LCD, and Smartphone sensors. The relationship between variations in vibration intensity and magnitude with vibration acceleration is directly proportional. This system has 96% accuracy and the accuracy of vibration acceleration read on the system is 92%. This system can be a simple earthquake early warning solution in earthquake-prone areas to minimize the risk of earthquake natural disasters and can be used as a basis for developing earthquake disaster mitigation systems.

Keywords: Earthquake, Early Warning System, MPU6050, Smartphone Display



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1. INTRODUCTION

In era Globalization, natural disasters occur due to the loss of balance between nature and humans (Saptorini and Ema, 2020). Several information systems have been created in the past ten years to lessen the effects of natural catastrophes on their respective populations and infrastructure. (Nuzzo *et al.*, 2022). Of all natural disasters, earthquakes pose one of the greatest threats to modern society (Fu *et al.*, 2019). The study of earthquakes is a critical task (Maldonado Flores *et al.*, 2017). In highly seismic countries, the study of earthquakes is a critical task (Maldonado Flores, Guzman and Poblete, 2017). The "Ring of Fire" region, where Indonesia is situated, is vulnerable to tsunamis, particularly those brought on by earthquakes. (Adityawan *et al.*, 2023). Indonesia is a country that has quite a lot of earthquake sources (Sujono, 2019).

An earthquake is a movement or shaking of earth's surface caused a shift in earth's crust (earth plates) (Ishomyl, Waluyo and Mustafa, 2020). Earthquakes are difficult to predict when they will occur (Bahari and Sugiharto, 2019). One of the natural calamities that might result in several fatalities is an earthquake. (Novianta, 2014). In earthquake science, reducing seismic risks has always been a long-term endeavor (Song *et al.*, 2023b). Table 1 shows an earthquake disaster in Indonesia in the last three years.

Problems when an earthquake occurs, many people are often trapped in their homes due to late knowledge of an earthquake, resulting in many casualties and material losses. Some earthquake information displays in the United States, according to a study by Daniel *et al.* (2022), do not provide instructions on how to get ready for earthquakes or related safety precautions. Real-time assessment of potential damage following an earthquake is crucial (Song *et al.*, 2023a). Notifications and evacuation routes are still very rare in Indonesia (Akhoondzadeh and Marchetti, 2022). A disaster early warning and

*Contact Author: yulkifliamir@fmipa.unp.ac.id

disaster management information system is required to enable possibilities for self-rescue so that losses can be minimized in order to prevent further losses (Siswanto *et al.*, 2022).

Table 1 Earthquake Disasters In Indonesia In The Last Four Years (BNPB, 2023)

Year	Region	Mag	Died	Injured	Broken House
2021	Mamuju, Sulawesi Barat (West Sulawesi)	5,9	11	11124	4099
2022	Pasaman Barat, Sumatera Barat (West Sumatra)	5,2	13	381	2993
2022	Cianjur, Jawa Barat (West Java)	5,6	602	7810	56278
2023	Kepulauan Tanimbar (Tanimbar Islands), Maluku	7,9 SR	0	1	223

One of the crucial strategies for reducing the risk of earthquakes is earthquake early warning (Meng *et al.*, 2023). Early warning systems are implemented globally (McBride *et al.*, 2020). Countries globally develop earthquake early warning systems (McBride *et al.*, 2023). In October 2019, California became the first US state to fully activate the public earthquake early warning system (Bostrom *et al.*, 2022). Systems for Earthquake Early Warning (EEW) can issue alerts before shaking occurs (Dallo *et al.*, 2022). An early warning system's objective is to give the public a quick, timely response to protect themselves (Anwar, 2011). With the existence of an earthquake detection device, it can anticipate or minimize the loss of life due to earthquakes, this is very much needed by residents both in earthquake-prone areas and areas where earthquakes rarely occur (Ramadhan and Royhan, 2017).

The Internet of Things (IoT) system and the development of technology that is all practical and online are the subjects of extensive research on android-based control (Audia *et al.*, 2022). For the implementation of an early warning system for natural disasters, appropriate technology is needed (Audia *et al.*, 2022). Internet of Thing (IoT)-based disaster warning information system which has many advantages including being able to work automatically and work realtime 24 hours (Bahri and Utomo, 2018). Social networks, distributed networks, and real-time systems, which are the foundational components of the Internet of Things (IoT), are starting to take shape (Zambrano *et al.*, 2017). According to the International Telecommunication Union, the Internet of Things is "a global infrastructure for the information society, enabling advanced services to exist by connecting things (physical and virtual) based on existing and developing information and communication interoperability technologies" (Chen *et al.*, 2020). IoT connects trillions of objects to handle the enormous data storage required (Mehta, Sahni and Khanna, 2018). IoT is expanding as microcontroller technology advances (Shull, 1977). IoT-based systems can provide solutions in providing fast and precise actions in disaster management efforts (Usmanto and H.S.U, 2018). Despite practical constraints, a survey of earthquake early warning system applications around the world reveals that the increased warning time provided by these systems has the potential to lessen the impact of earthquakes on numerous societal sectors (Galasso *et al.*, 2023).

Sensors are tools that translate electrical quantities from physical quantities (Ramli *et al.*, 2018). In previous research, testing of the MPU6050 sensor was carried out where the system was tested by making small and medium vibrations with a distance of 10 cm, 20 cm, and 30 cm from the system and results of this test showed accelerometer reading was almost the same as the earthquake intensity scale table (Kurniawati and Murti, 2021). The advantage of this system is that it can obtain data accurately through the MPU6050 sensor. Furthermore, if the data has been obtained, it will be displayed on the LCD of the device and the sound output on the Buzzer which is controlled by ESP8266 so that the display on android and its notification are also obtained.

Based on these issues, researchers created an earthquake early warning system that uses the MPU5060 sensor, IoT, and a smartphone display that is both effective and efficient. The usage of an Android application to track power and the device's capability to deliver notifications when it senses vibrations are both novel aspects of this research. Additionally, this research can lessen earthquake damage. The system is built with an ESP8266 microcontroller acting as a data processor and transferring data to an Android device, an MPU6050 sensor, and having an LCD and Buzzer as system output.

2. METHOD

2.1 Hardware Design

The developed equipment is designed in this stage. The overall system design can be seen in Figure 1 block diagram system. In the block diagram, there is a hardware design and software design. In this hardware design there are several components used in the system consisting of sensor MPU6050, ESP8266, Power Supply, LCD and Buzzer.

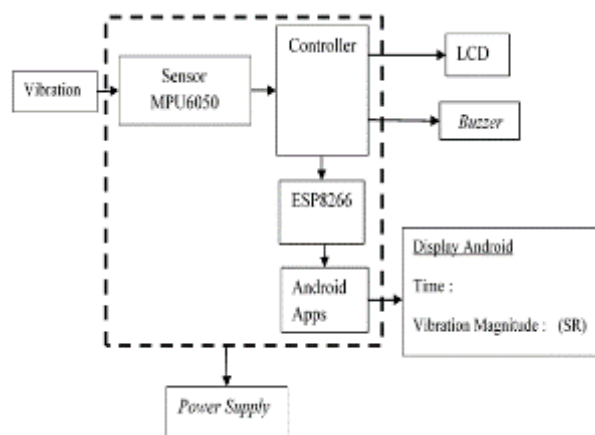


Figure 1 Block Diagram System

Five components of the system, shown in Figure 1, each having a unique role to play in the system's proper operation. Each of these components is described in the paragraphs that follow:

1. MPU6050 sensor functions as a vibration sensor.
2. ESP8266 functions as a system controller and transmitter to send data to thingspeak.
3. The Power Supply provides the components with electric current.
4. LCD functions as a display of data output read on the sensor.
5. Buzzer functions as a vibration indicator in the form of a sound source.

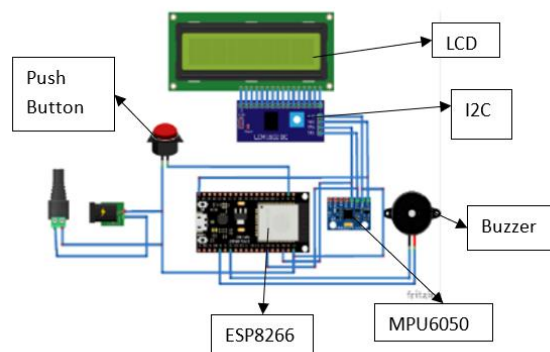


Figure 1 Schematic of the System's Primary Component

In this research, the system is programmed using a microcontroller in the form of ESP8266 which can be an IoT-based data transmitter to manage the system both input, process and output. An object that transforms physical quantities into electrical quantities is a sensor. (Yulkifli *et al.*, 2018). The ESP8266 was used to transmit data to the web server in Android-based smartphone (Nofriandi *et al.*, 2023). ESP8266 device proceed the data and data is readable in Android application (Septa and Berlian, 2023). When a vibration is detected on the sensor, the sensor will give a signal to the microcontroller which then the programming will work according to the program that has been made. The incoming data will be processed so that the output is obtained in the form of vibration acceleration in m/s² and magnitude in SR units. According to the functional block diagram, the MPU5060 sensor, ESP8266, LCD, and Buzzer make up the majority of the MPU6050 sensor-based earthquake early warning system helped by IoT with smartphone display. The circuit arrangement for the major parts of the data processing system is shown in Figure 2.

Installing a vibration sensor that can identify when a vibration takes place allows the system to function. When a vibration is detected on the sensor, the system will operate in accordance with the programming entered into the system, resulting in an output in the form of an LCD display and sound from a buzzer. Additionally, there is an IoT role since an Android application can be used to monitor the data display. Programming using ESP8266. Due to the fact that ESP8266 is a complete chip with a processor, memory, and access to GPIO, it may easily replace Arduino and immediately handle wifi connections (Shull, 1977).

The vibration sensor used in this research is the MPU6050 sensor. The system's input reading sensor is this vibration sensor. The MPU6050, sometimes referred to as a 6 degrees of freedom (DOF) IMU, is the first motion tracking system in the world to include 6 axes and a chip that contains a 3-axis accelerometer (acceleration sensor) and 3-axis gyroscope (balance regulator). (Firman, 2016). MPU6050 sensor is equipped with three 16 bit ADC (Analog Digital Converter) converters to convert the gyroscope output and three 16 bit ADC converters to convert the MPU6050 output (Artha, Rahmadya and Putri, 2018).

A wifi module is necessary because processing of the data is necessary before the power measurement data can be sent to Thingspeak and displayed on the android app. The wifi module used in this investigation is the ESP8266. Telemetry is a technology that remotely measures and reports information to the system designer or operator (Yulkifli, Yohandri and Affandi, 2016). IoT (Internet of Thing) is when we connect things that are not operated by humans, to the internet (Siswanto *et al.*, 2022). The ESP8266 chip's on-board processing and storage capabilities allow it to be connected with sensors or specific tool applications via input output pins with just a few lines of programming. (Kurnialensya and Saputra, 2023).

In this system the output is displayed in the LCD on the device, the sound produced by the buzzer on the device and the android application display. A liquid crystal display called a liquid crystal display (LCD) controls the light that is already present or the LED flame (Kusuma *et al.*, 2023). Buzzer is an electronic component whose role is to convert electrical signals into sound waves. Buzzers use resonance to amplify sound intensity (Yuliono *et al.*, 2019).

Vibration data from the MPU6050 sensor-based earthquake early warning system is displayed as values on a smartphone, and data analysis and interpretation are presented as graphs.

The accuracy level of the sensor measurement results on the system is carried out, and the % error is computed, by comparing the measurement results read on the application with the measurement results manually taken using standard measuring equipment. Graphs are then utilized to measure the relationship between magnitude and vibration acceleration once data processing is completed to gauge the system's level of precision and accuracy.

Testing the tool carried out on a labor scale with a varied vibration source ranging from weak, medium to strong. Implementing the tool on a table that vibrates to produce vibrations is how tools are tested. The test is run to see how well the tool works at picking up vibrations that are present in the vibration. The accuracy of the MPU5060r sensor, the accuracy of the MPU5060 sensor, and the simulation of vibrations are among the tool tests that were conducted. By contrasting the employed sensor with industry-standard instruments, accuracy testing is performed. Accuracy testing is done by giving the same treatment to the sensor and taking repeated data during these conditions.

2.2 Software Design

The software flow can be illustrated using the flowchart in Figure 5. The NodeMCU ESP8266 board must be installed on the Arduino IDE before starting the software design with the first step of connecting the Node-MCU board to an existing Wifi transmitter. In the first time process, the Wifi transmitter will display the SSID and password before the system is connected. If the board is not connected then the procedure will be repeated until it is connected and if it is connected to the Wi-Fi transmitter, it will be able to access the internet. The sensor data is then read and sent to the web server through the board. The data is stored on the web server.

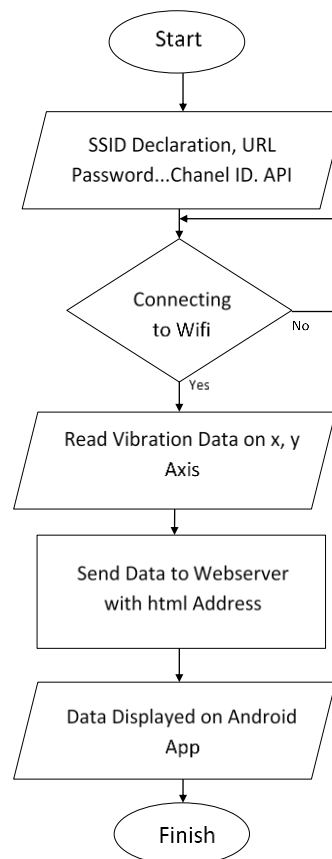


Figure 3. Software Design

The flowchart in Figure 3 starts with declaring the SSID and password for the NodeMCU microcontroller. Once the internet network is connected to the microcontroller, data acquisition will run. The system relies heavily on the internet connection sending data from the MPU6050 detection to the webservice. The data that has been sent to the webservice can then be accessed via a smartphone by typing in the IP address on a search engine browser.

3. RESULTS AND DISCUSSION

To deal with proper earthquake mitigation, it is necessary to analyze the right and accurate tools. This system is designed as an initial design in the development of an automatic vibration detection system that can be used as an earthquake early warning and analyze the relationship between vibration acceleration and vibration intensity and magnitude. In customizing the research subject, a comparison of similar earthquake early warning tables is given in Table 2.

The result of design MPU5060 sensor-based earthquake early warning system assisted by IoT with a smartphone display is a black acrylic box containing an electronic circuit. A sensor has been programmed into the electronic circuit within the acrylic box to detect a vibration, perform data processing so that the data output is in the form of acceleration (m/s²) and magnitude strength (SR) connected to IoT so that the display can be seen from the LCD on the device and smartphone display. The following results of the design of the MPU6050 sensor-based earthquake early warning system assisted by IoT with a smartphone display can be seen from Figure 4.

Table 2 Earthquake early warning system and their specification

Specification	Fatimah <i>et al.</i> (2025)	Wikantama <i>et al.</i> (2024)	Yulkifli <i>et al.</i> (2024)	Dini (2021)	Bahri (2017)	Present Study
Sensor Used	MPU6050	Sensor Getar SW420	MPU6050	ADXL345.	Sensor SW42	MPU6050
IoT Integrated	Arduino Nano 33 IoT	ESP32	ESP8266	-	ESP32	ESP8266
Sensor Output Scale	SIG	-	PGA	PGA	-	Mag(SR) and Vib Acc (m/s ²)
Sumaltion Ebility	Earthquake	Earthquake	Earthquake	Earthquake	Earthquake	Earthquake
Vibration Graph	-	-	Graph on each axis	Vibration graph	-	Earthquake vibration graph
Android Monitoring Notification	-	-	✓	-	-	✓
Android	-	✓	-	-	-	✓

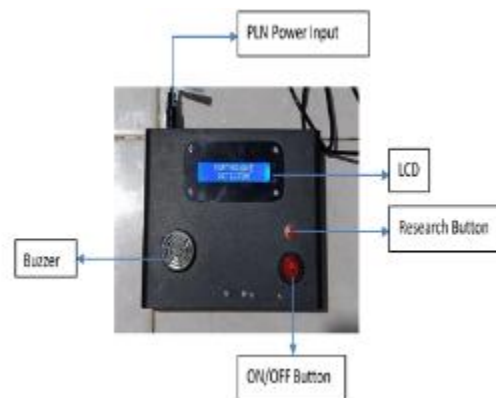


Figure 4 MPU6050 Sensor-Based Earthquake Early Warning System

Testing of the tool is done by varying the vibration as a disturbance given to the tool. The results obtained after conducting the test are as follows:

Table 3 Vibration Acceleration Data

Variation of Vibration Intensity	Read on Tool		Read on Android		Standard Measuring Instrument (m/s ²)
	Mag (SR)	Vib Acc (m/s ²)	Mag (SR)	Vib Acc (m/s ²)	
Weak	3,66	2,06	3,66	2,06	2,1
Medium	4,33	2,56	4,33	2,56	2,7
Strong	4,92	3,12	4,92	3,12	3

Table 3 shows that the first measurement, which had a magnitude value of 3.66 SR and a vibration acceleration of 2.06 m/s², had the lowest magnitude value. This is because in the 1st measurement the vibration variation given to the vibration intensity variation system is weak. The highest magnitude value is found in the 3rd measurement, namely 4.92 SR with vibration acceleration of 3.12 m / s². This is because in the 3rd measurement the vibration variation given to the system varies high intensity vibration. Figure 5 is a graph of the relationship between variations in vibration intensity and vibration acceleration. The vibration acceleration value increases with increasing vibration intensity delivered to the system while decreasing vibration intensity gives rise to reduced vibration acceleration value. So it can be concluded that the relationship between variations in vibration intensity and vibration acceleration is directly proportional.

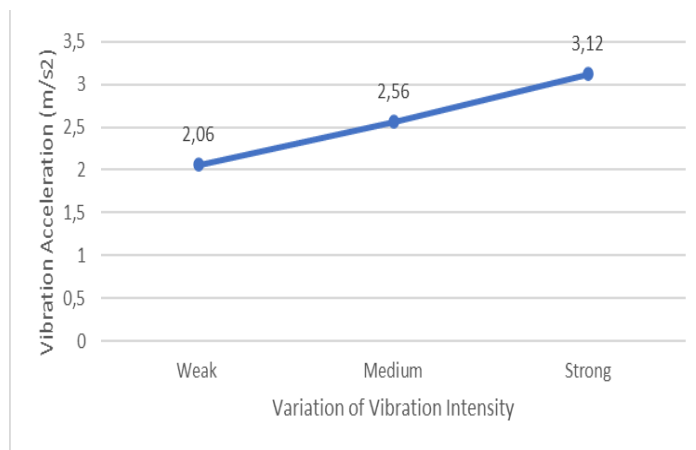


Figure 5 Graph of the Relationship of Vibration Intensity Variations with Vibration Acceleration

Figure 6 is a graph of the relationship between magnitude and vibration acceleration. The former is measured in units of the Richter Scale (SR), while the latter is measured in meters per quaternary second (m/s²). From the graph it can be concluded that the higher the magnitude of the detected vibration, the greater the vibration acceleration value and vice versa or the relationship between magnitude and vibration acceleration is directly proportional.

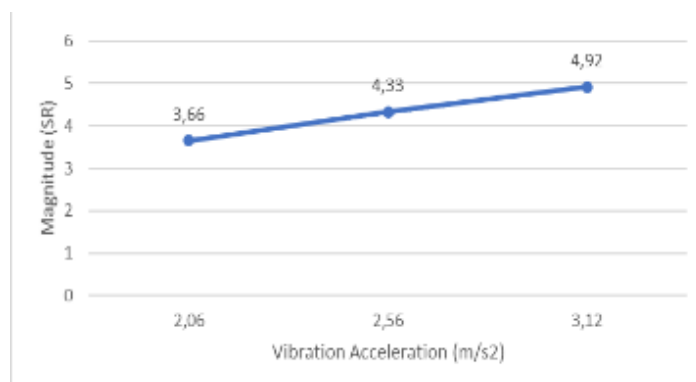


Figure 6 Graph of Magnitude Relationship with Vibration Acceleration

So with the MPU6050 sensor component, an IoT-assisted earthquake early warning system can be made with a smartphone display that can detect vibrations that occur with the output of magnitude and vibration acceleration. Thus this system is very suitable for areas prone to earthquakes.

Performance specifications are specifications for how well a device performs. The results of the MPU6050 sensor-based earthquake early warning system backed by IoT are displayed on a smartphone in Figure 6. In this system circuit, an acrylic box with the measurements 15 cm x 15 cm x 4 cm is used. The PLN AC voltage is converted to 12 volts DC using the 12 volt power source. This system additionally needs a stepdown transformer to reduce the voltage from 12 Volts to 5 Volts in order to supply electricity to the circuit. In this system, the vibration variation given to the tool is the input of the system. The MPU5060 sensor will work to detect vibrations. ESP8266 was used to program the device, serving as the primary sensor programming controller, experimental system, and internet interface so that the android application could monitor the detected data. Figure 7 displays the outcomes of using a smartphone display to monitor the MPU6050 sensor-based earthquake early warning system helped by IoT.



Figure 7 System Monitoring on Android

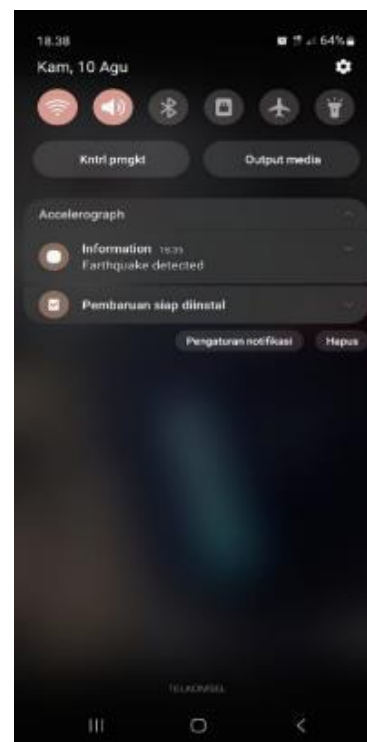


Figure 8 System Notification on Android

This system is also equipped with a notification on the android application that will appear if a vibration is detected on the sensor can be seen in Figure 8. The experiment's precision and accuracy results are included in the design specifications. The definition of accuracy is the amount of resemblance between a collection of measurements or a collection of instruments. Precision has to do with a person's desire to guide a target toward a certain goal.

Precision data on the measurement of the resulting vibration acceleration is taken as much as 3 vibration variations and compares the results of vibration acceleration readings on the tool by sensors on the system with standard measuring instruments, namely vibration meters. Which has pretty good accuracy. The results of testing the precision of the tool against standard measuring instruments are as follows:

Table 4 System Precision Data

Vibration Variation	Vibration Acceleration (m/s ²)	
	Read on Tool	Standard Measurement Tool
Weak	2,06	2,1
Medium	2,56	2,7
Strong	3,12	3

By processing the system precision data, the precision of the MPU6050 sensor-based earthquake early warning system monitoring system assisted by IoT with a smartphone display is obtained with average of 96%. The MPU6050 sensor-based earthquake early warning system monitoring system, aided by IoT with a smartphone display, is designed to have results that are close to the readings on the conventional vibration meter measuring equipment, so the data obtained is nearly accurate.

Measurement accuracy is the degree to which a set of measurements have similar prices. The reliability of the monitoring system of the MPU6050 sensor-based earthquake early warning system supported by IoT with a smartphone display and 10 repeated measurements of the acceleration of vibration read on the system and the magnitude read on the system. The vibration acceleration read on the system and the magnitude read on the system have good enough accuracy. The following are the outcomes of comparing the tool's accuracy to the system:

Table 5 System Accuracy Data

Measurement	Vibration Acceleration Read on Tool (m/s ²)
1	1.45
2	1.45
3	1.65
4	1.45
5	1.45
6	1.55
7	1.45
8	1.65
9	1.55
10	1.45
% Accuracy	92 %

By processing the system accuracy data, the accuracy of the MPU6050 sensor-based earthquake early warning system monitoring system assisted by IoT with a smartphone display is obtained with an average vibration acceleration read on the system of 92%. Because of the modest percentage inaccuracy, measurements taken from system readings 10 times the data transfer are nearly exact.

The MPU5060 sensor-based earthquake early warning system aided by IoT with smartphone display can be employed as an earthquake early warning, according to the research findings. This system is simpler since a microcontroller module manages it. This study also includes internet of things (IoT) technology, which enables system monitoring findings to be shown on an Android application and equipped with notifications when a device vibrates. This research is still limited in system comparison tools and still needs to be developed again data comparison tools so that the vibration data obtained is more accurate. This research is expected to be developed with better media as an earthquake simulator and using seismic vibration sensors with higher accuracy so that the detected vibrations can be more accurate. This research can be an early development of an earthquake early warning system that has been integrated with IoT both in monitoring and notifications connected directly to Android and can reduce the impact of earthquake disasters where this system can support earthquake disaster mitigation.

4. CONCLUSION

According to the findings of the investigation, it can be said that: MPU6050 sensor-based earthquake early warning system assisted by IoT with smartphone display can be used as an earthquake early warning. The relationship between vibration intensity variation and vibration acceleration is directly proportional. The higher the magnitude of the detected vibration, the greater the vibration acceleration value and vice versa or the relationship between magnitude and vibration acceleration is directly proportional. The Internet of Things (IoT) and smartphone displays were used in the design of the MPU6050 sensor-based earthquake early warning system. It features small, portable, compact screens, Android notifications, LCD patches, and buzzers. This system has a precision of 96% and the accuracy of vibration acceleration read on the system is 92%. With the MPU6050 sensor-based earthquake early warning system assisted by IoT with a smartphone display, this can be a simple earthquake early warning solution in earthquake-prone areas to minimize the risk of earthquake natural disasters.

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