EARTHQUAKE & ENVIRONMENTAL MONITORING & ALERTING SYSTEM (EEMAS)

By

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International College Penang

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Sincerely,
Kah Seng.

Declaration

Project Member 1

I, **Wong Kah Seng** of NRIC No. **041210070113**, hereby declare that this project, **Earthquake & Environmental Monitoring & Alerting System (EEMAS)**, being the requirement for the INTI International College Penang Diploma in Electrical and Electronics Engineering, session **April 2024**, is entirely of my own work except where due references are made.

Wong Kah Seng

Date: **12 / 6 / 2024**

Abstract

Hazardous environmental conditions, such as elevated temperatures and humidity, and natural calamities like earthquakes pose substantial threats to global communities. Systems for early identification and alerting are essential for reducing these hazards. To meet these challenges, the Earthquake and Environmental Monitoring and Alarm System (EEMAS) offers a complete and integrated system for continuous environmental monitoring and real-time earthquake detection.

To detect seismic activity, EEMAS uses an ESP32 Wi-Fi Module as its central processing unit, which interfaces with a gyroscope sensor and an MPU 6050 accelerometer. A DHT22 sensor is also incorporated into the system to detect a wide range of environmental factors, including temperature and humidity levels. Remote monitoring and notifications are made possible via the ESP32 Wi-Fi module's connection to the Blynk IoT platform. Local alerts are provided through a buzzer and LED indicator. Green for normal conditions and red for detected earthquakes. Remote alerts are sent to users via the Blynk app, ensuring immediate awareness of any hazardous conditions, even when users are not near the system.

Testing results also demonstrate the system's capability to accurately detect seismic activity and monitor environmental conditions, triggering appropriate alerts and notifications with detection accuracy above 97% for seismic activity and 98% for high-temperature warnings. The EEMAS project addresses a critical need for early warning systems in disaster-prone and environmentally sensitive areas. EEMAS provides a robust solution for enhancing safety and preparedness by integrating multiple sensors and leveraging IoT connectivity. Future work will focus on expanding sensor capabilities, improving data accuracy through machine learning algorithms, and developing a dedicated mobile application for enhanced user interaction and data visualization.

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1. Literature Review and Project Background

1.1 EARTHQUAKE DETECTION SYSTEM

Earthquake detection systems are critical for delivering early warnings and mitigating the effects of seismic activity. Seismographs, which detect ground motion using sensitive instruments positioned at key places, are the mainstay of traditional earthquake monitoring. These systems, however, can cost a lot of money and need a large infrastructure.

Countries like Taiwan, have a sophisticated earthquake monitoring system due to its location in a seismically active region, prone to earthquakes. The Central Weather Bureau (CWB) of Taiwan operates this system, which includes various seismic stations strategically placed across the island. Here are some key aspects of Taiwan's earthquake monitoring system. Taiwan has implemented an Earthquake Early Warning System (EEWS) to provide alerts to the public and authorities before the shaking from an earthquake reaches populated areas. The system calculates the location, magnitude, and expected intensity of an earthquake within seconds of its occurrence [1].

As for Malaysia, our Malaysian Meteorological Service (MMS) serves as a national information centre for seismology. MMS provides information, advice and consultation related to earthquakes to users such as engineers, architects and planners for the socio-economic development of the country. The MMS started to operate seismic stations in 1979 by installing four Kinemetrics Short Period (vertical component) seismographs at Petaling Jaya (KLM), Kluang (KGM), Ipoh (IPM) and Kota Kinabalu (KKM) [2]. So basically the earthquake monitoring system in most of the country mainly still relies on the seismology stations located in some densely populated areas which are networks connected. Through confirmation with the Malaysia Metrological Department, they have mentioned that the use of the seismometer is standardise and was fixed nationwide throughout the world. Based on a news article, MET Malaysia said SAATNM is now also equipped with a processing system called Advanced Decision and Dissemination Malaysia Seismic and Tsunami Information System (ADMIS) developed in Aug 2017, where the system can channel earthquake information to disaster management agencies and the public within eight minutes an earthquake is detected [3].

Other than the traditional seismograph, electronic companies such as OMRON have developed the D7S Seismic Sensor (*Figure 1.1.1: OMRON D7S Vibration Sensor*) which is pricey and specifically functions to detect high-precision seismic data through 3-axis acceleration sensors with a unique SI value calculation algorithm. Other than that, low- cost accelerometers, like the MPU 6050, have been performing the same feature compared with the OMRON D7S Vibration Sensor which able to detect 3-axis acceleration with additional built-in gyroscope as well. New developments in microelectromechanical systems (MEMS) have made it possible to create inexpensive accelerometers, like the MPU 6050, that may be included in morecompact and reasonably priced detecting systems [4].

Figure 1.1.1: OMRON D7S Vibration Sensor

Studies have shown that microelectromechanical accelerometers can effectively detect earthquake-induced ground motion, providing reliable data for early warning systems [5]. These sensors can be deployed in dense networks to enhance detection accuracy and coverage, especially in urban areas.

1.2 ENVIRONMENTAL MONITORING SYSTEM

Other than unexpected earthquakes happening throughout the year, heat waves are also one the environmental issue faced as well. Millions of people across South and Southeast Asia are facing sweltering temperatures, with unusually hot weather forcing schools to close for some of countries and threatening public health. Based on official Malaysia ministry reports, as of 14 April, there were 45 heat-related illness cases reported: 33 cases of heat exhaustion, 11 cases of heatstroke and one case of heat cramp[6]. Relative to that, real-time heat wave alarms and alerts will be necessary to provide warning to residents or personnel staying outdoors to be notified about this concerning environmental threats.

To monitor and detect the temperature and humidity of the surroundings, the accuracy and dependability of the DHT22 sensor measuring temperature and humidity make it a popular choice for environmental monitoring [7]. Real-time data collection and remote monitoring are made possible by the integration of environmental sensors with IoT systems. Because of its affordable price, robust connectivity, and ease of use, the ESP32 Wi-Fi module is a popular option for Internet of Things projects [8]. Research has shown that IoT-based environmental monitoring systems are useful for reducing the negative consequences of extreme environmental conditions by offering timely alerts and data visualisation[9].

1.3 IoT-BASED ALERT SYSTEM

The architecture of monitoring and alert systems has been completely transformed by the Internet of Things (IoT). Real-time data collection, processing, and transmission capabilities of IoT-enabled devices enable prompt reaction to identified threats. Blynk is an Internet of Things platform that makes it easier to create mobile applications for managing and keeping an eye on IoT devices. It is a flexible option for Internet of Things projects since it supports a range of microcontrollers and communication protocols.

Studies have highlighted the benefits of IoT-based alert systems in enhancing disaster preparedness and response. For example, IoT devices can provide early warnings for natural disasters such as earthquakes and floods, allowing for timely evacuation and risk mitigation [10].

2. Problem Definition

Based on research and study, most of the countries in the world currently still using seismographs and seismostation to detect earthquakes and seismic activity within the area itself. Examples for countries like Malaysia, Taiwan and our neighbour which currently they still relying on this system. Countries like Japan which have more frequent seismic activity from time to time, have set a more densely located seismometer around their countries to detect any seismic waves around the region. Upon confirmation, I have also contacted Jabatan Meteorologi Malaysia (MET) (0379678066 – Headquarter Office Number) to learn more and understand the operation of seismostation and earthquake detection in our country. The officer explained to me that, most of the countries in the world still using the traditional seismometer concept because the system was fixed nationally worldwide.

The task at hand is to design and develop the Earthquake and Environmental Monitoring and Alerting System (EEMAS) an Arduino-based monitoring system that can monitor temperature and humidity, in addition to detecting earthquakes and alerting users through visual indicators, Wi-Fi-connected app notifications, and audible alarms. To provide ongoing monitoring and prompt alerts in the event of seismic activity or environmental dangers, the system needs to be reasonably priced, simple to install, and autonomous which can be afforded and be easily applied in every building.

Key challenges to address include:

1. Construct strong algorithms for earthquake detection that can distinguish between seismic disturbances and regular vibrations.

2. Combining several sensors (temperature, humidity, and vibration) into a single, small-footprint monitoring device.

3. Creating user-friendly interfaces that provide consumers with real-time information and alerts, such as IoT applications.

4. Guarantee the accuracy, speed, and dependability of the system in identifying and warning about such threats.

5. Addressing environmental issues with manufacturing, energy use, material use, and electronic waste throughout the monitoring system's lifetime.

By tackling these issues, the Earthquake & Environmental Monitoring & Alerting System (EEMAS) project seeks to improve safety and resilience in communities that are susceptible to earthquakes, reduce environmental impact, and advance sustainability by offering an approachable and practical solution for earthquake and environmental monitoring.

3. Project Objectives and Product Scopes

3.1 PROBLEM STATEMENT

Natural disasters, particularly earthquakes, and extreme environmental conditions pose significant threats to human life and property. Despite advances in technology, many existing monitoring and alert systems are either too expensive, lack integration, or fail to provide real-time notifications. There is a need for an affordable, integrated system that can detect earthquakes, monitor environmental conditions, and provide timely alerts to users both locally and remotely.

3.2 PROJECT OBJECTIVES

The primary objectives of the Earthquake and Environmental Monitoring and Alarm System (EEMAS) are:

1. To develop a real-time earthquake detection system using the MPU 6050 accelerometer based on the Modified Mercalli Scale with a detection accuracy above 97%.

2. To develop a high temperature and heat waves detection system using the DHT22 Temperature and Humidity Sensor with a detection accuracy above 98%.

3. To develop an IoT-based seismic activity and heat wave detection system which able to provide real-time data visualization and notifications.

3.4 IMPLEMENTATION OVERVIEW

The project includes circuit design, microcontroller programming, and system integration with the Blynk IoT platform. While the DHT22 sensor continuously measures temperature and humidity, the MPU 6050 sensor is utilised to detect seismic activity. By connecting to Wi-Fi, the ESP32 module allows data to be transmitted in real time to the Blynk IoT app. A buzzer and LED indicators are used to deliver local alerts, guaranteeing prompt communication of any discovered threats.

3.5 EXPECTED OUTCOMES

The goal of the EEMAS project is to develop a thorough monitoring and alert system that improves safety by promptly identifying earthquakes and unfavourable environmental conditions. The system guarantees that users are informed and capable of taking suitable measures to reduce hazards by utilising IoT connectivity and combining different sensors. The project also seeks to illustrate the viability of using low-cost components to create effective monitoring solutions, which could benefit a wide range of applications, including residential, commercial, and industrial settings.

4. Methodology

4.1 OPERATION AND BLOCK DIAGRAM

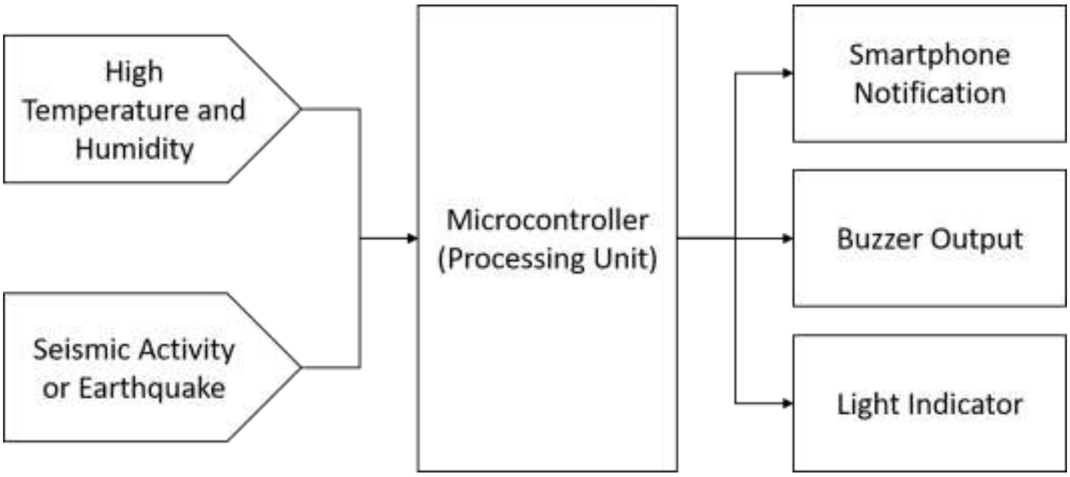

Figure 4.1.1: Operation Diagram of "EEMAS"

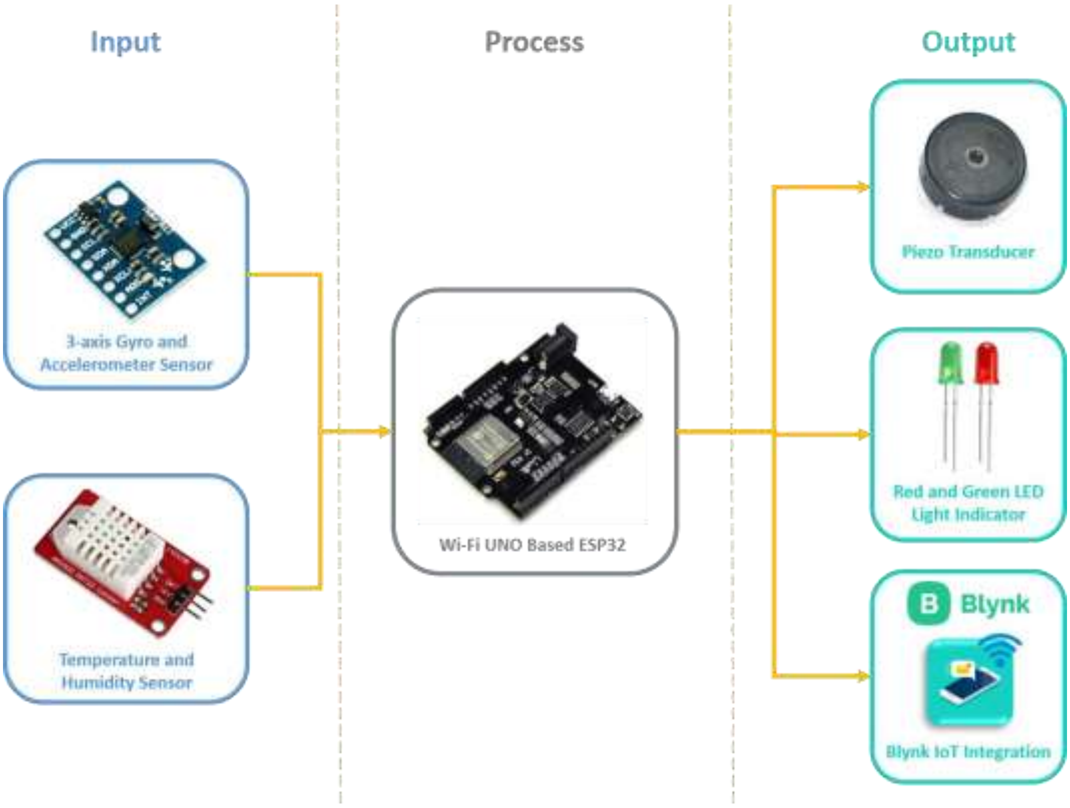

Figure 4.1.2: Functional Block Diagram of "EEMAS"

Figure 4.1.1 shows the basic concept or the operational diagram of the "EEMAS" which detects high temperature and humidity with seismic activity around the area. At the same time, data and alert will be notified through the smartphone IoT notifications with the device's light indicator and buzzer output. Moving on to the Figure 4.1.2, the functional block diagrams of EEMAS which illustrated the categories and type of component or sensors used which able to obtain the desire outcome or results produced by the system. By applying Blynk IoT integration with ESP32, smartphone user around the area will be also able to receive real-time notification and visualization on the environmental status or seismic activity around them.

4.2 SYSTEM COMPONENTS

The EEMAS project utilizes the following components:

Components	Functions and Features

ESP32 Wi-Fi Module

Figure 4.2.1: Wi-Fi UNO Based ESP32
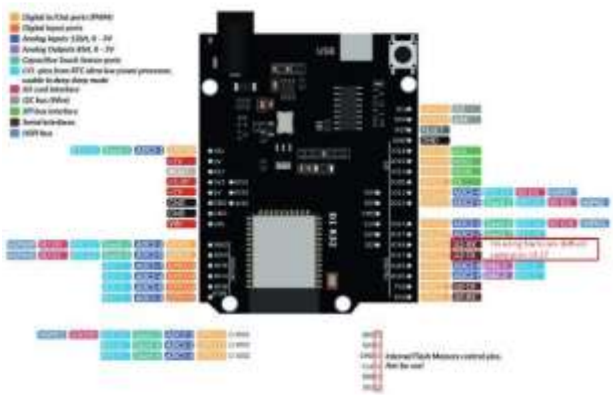
Figure 4.2.2: WeMos D1 R32 Pin Layout
	Functions: The central microcontroller unit that processes data from sensors and controls alerts which can also connect the system to the Blynk IoT platform for remote notifications.
	
	Specifications:
	• ESP32-WROOM-32 in Arduino UNO form factor
	• Working Voltage: 3.3V
	• DC Input Voltage: 5V - 12V DC
	• Wifi: 802.11 b/g/n/e/i (802.11n up to 150 Mbps)
	• Bluetooth: v4.2 BR/EDR and BLE specification
	• RAM: 520KB
	• Flash Memory: 32Mb (4M bytes)
	• Power consumption:
	  o Max current: 250mA
	  o Sleep current: 0.15mA
	  o Active without WiFi current: 20Ma
	• Operating Temperature: -40C > +85C

MPU 6050 Accelerometer and Gyroscope Sensor

 	
Figure 4.2.3: MPU6050 (3-axis Gyro and Accelerometer Sensor)
	Functions: Detects vibrations and movements indicative of earthquakes.
	
	Specifications:
	• **3-Axis Gyroscope**
	  o The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate.
	  o This voltage is digitized using 16-bit ADC to sample each axis.
	  o The full-scale range of output are +/- 250, +/- 500, +/- 1000, +/- 2000.
	  o It measures the angular velocity along each axis in degrees per second unit.

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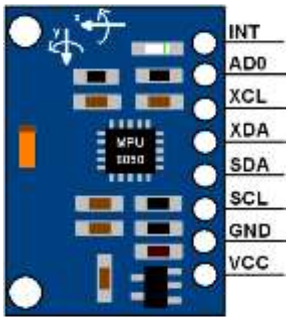

Figure 4.2.4: MPU6050 Module Pinout
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3-Axis Accelerometer

Acceleration along the axes deflects the movable mass.
This displacement of the moving plate (mass) unbalances the differential capacitor which results in sensor output. Output amplitude is proportional to acceleration.
16-bit ADC is used to get digitized output.
The full-scale range of acceleration are +/- 2g, +/- 4g, +/- 8g, +/- 16g.
It is measured in g (gravity force) unit.
When the device is placed on a flat surface it will measure 0g on the X and Y axis and +1g on the Z axis.

DMP (Digital Motion Processor)

To compute motion processing algorithms.

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<td>
DHT22 Temperature and Humidity Sensor

Figure 4.2.7: DHT22 Temperature and Humidity Sensor
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Function: Monitors environmental conditions.

Specifications:

3.3-6V Input
1-1.5mA measuring current
40-50 uA standby current
Humidity from 0-100% RH
-40 - 80 degrees C temperature range
+-2% RH accuracy
+-0.5 degrees C

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Buzzer and LEDs

Figure 4.2.8: Buzzer

Figure 4.2.9: LEDs
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Functions: Provide audible and visual alerts when any seismic activity or any heat wave detected around the environment.
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4.3 SYSTEM FUNCTIONALITY OF “EEMAS’

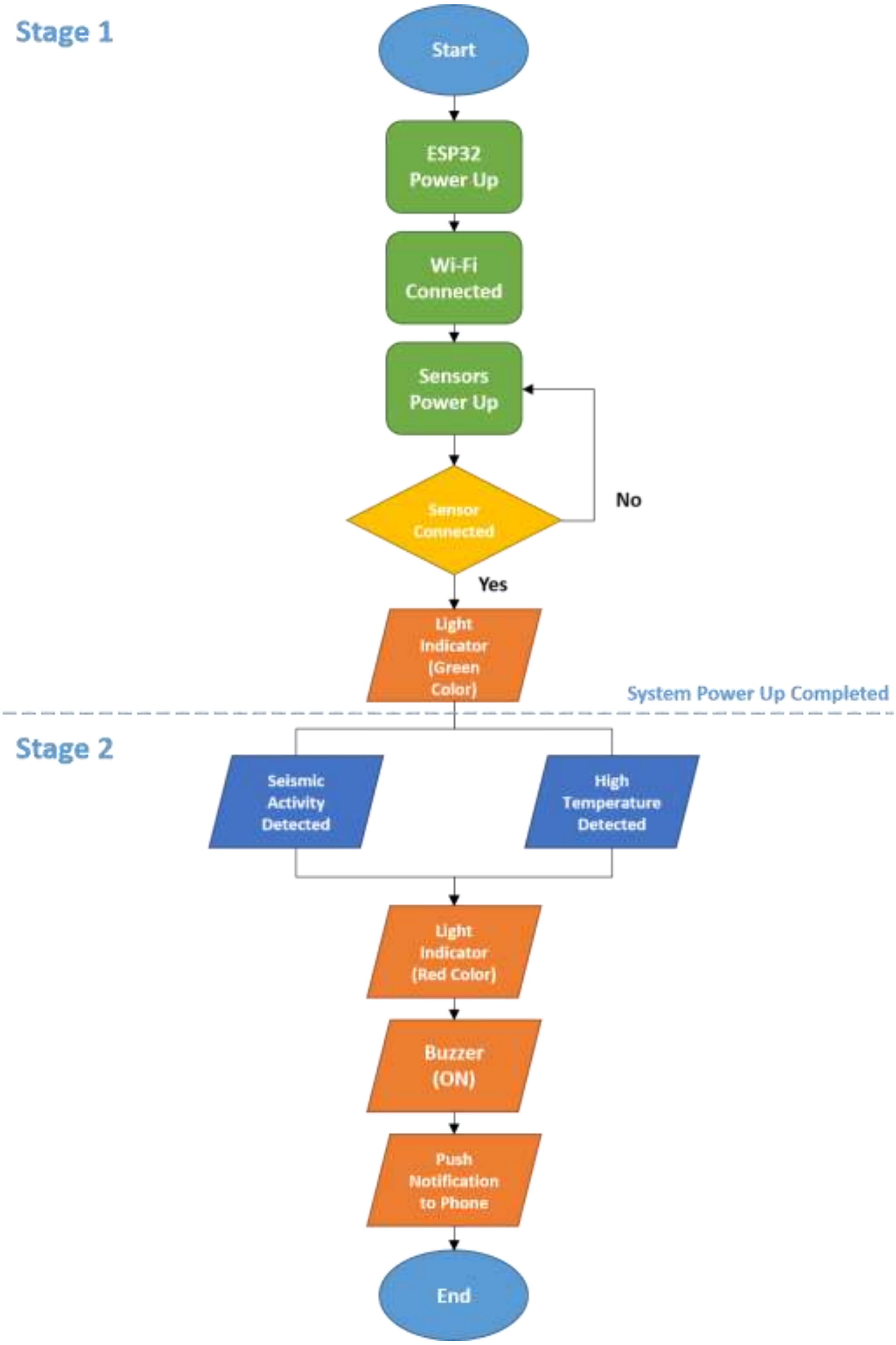

Figure 4.3.1: Detailed Process Flow of Operation of “EEMAS”

When the Earthquake and Environmental Monitoring and Alarming System (EEMAS) is connected to the power supply, the ESP32 Wi-Fi module will be powered up and start to run off with the program preset earlier in the system. By having the devices booted up, the system will then run a basic Wi-Fi connection to link the device with the IoT Blynk application. After the device is connected to the cloud, the system will power up the input sensors and try to detect the availability and connectivity of all of them. If any of the sensors were not connected, the system would reboot until the sensor was discovered and detected. If the system was working well till this stage, the green LED indicator light would light up to represent that the system was in an active status and was connected to the Internet.

After the early stage of the system power has been completed, the device is ready to detect real-time seismic activities and detect potential heat wave phenomena in the surroundings. Once any event is detected or triggered, the red light indicator will light up with the alarming buzzer immediately to notify the residents or the people of the surrounding for immediate evacuation or prevention. Meanwhile, the system will also push an alert notification to the smartphone user through the Blynk IoT Smartphone Application as well. The alert or warning notification has been categorized into different categories based on the seriousness and the environmental event itself. Users can also track back the events record referring back to the Blynk IoT interface for research or experimental purposes. Table 4.3.1 shows the list of event notifications based on their different parameters.

Other than notification alerts, the Blynk IoT interface would also enable the user to monitor real-time data and real-time notifications, no matter where they are. Through the interface, the user would be able to monitor the temperature and the humidity of the surroundings and even the peak acceleration of the surroundings detected by the devices.

Notification	Type	Conditions
Earthquake Alert	Critical	Peak acceleration ≥ **3.9g**
Heat Wave Alert	Critical	Temperature ≥ **40°C**
High-Temperature Warning	Warning	Temperature ≥ **32°C** ; Temperature < **40°C**
Major Seismic Activity	Warning	Peak acceleration ≥ **1.4g** ; Peak acceleration < **3.9g**
Minor Seismic Activity	Info	Peak acceleration ≥ **0.17g** ; Peak acceleration < **1.4g**

Table 4.3.1: Event Notification Parameters Detection

4.4 SEISMIC WAVE DETECTION AND CLASSIFICATION

It was necessary to perform formula calculations and derivations to get the actual data of the acceleration magnitude of the seismic wave observed to detect the emergence of seismic waves surrounding the area and the magnitude of the acceleration of the earthquake. The sensor can identify and sense force acceleration data from the X, Y, and Z 3-dimensional axes by using the MPU6050 accelerometer. It was necessary to introduce the formula below to determine the acceleration's magnitude from the three axes.

$$\text{Magnitude of acceleration} \qquad |a_{mag}| = \sqrt{a_x{}^2 + a_y{}^2 + a_z{}^2} \qquad (1)$$

By substituting the acceleration of the x-axis, a_x , acceleration of the y-axis, a_y , acceleration of the z-axis, a_z into the formula, the magnitude of the acceleration from the three axes will be obtained. Due to the natural gravitational pull from the ground, the acceleration value from the z-axis obtained will be identical to the acceleration value of the Earth's gravity which is approximately $9.81m/s^2$. Eventually, the magnitude of acceleration obtained will be around $9.81m/s^2$ as well when there is no seismic event appear in the surrounding due to gravitational pull. In order to detect the scale and the seriousness of the seismic activity or the earthquake, peak ground acceleration (PGA) will be used as the scale and data to differentiate the seriousness of the events. Peak ground acceleration can be given as a percentage or as fractions of g (the standard acceleration due to Earth's gravity, or g-force); in m/s^2 (1 g = 9. 81m/s^2). To obtain the peak ground acceleration of the surrounding, the acceleration force of the z-axis which is the gravitational acceleration needs to be subtracted to obtain the ground surface peak ground acceleration data. To detect swaying seismic activity surrounding and obtain the ratio or the percentage (%g) of the peak acceleration, further application and calculation of data needed to be done.

$$Peak\ acceleration \qquad a_{peak} = \frac{|a_{mag} - 9.81m/s^2|}{9.81m/s^2} \qquad (2)$$

To calculate the peak acceleration, the magnitude of acceleration needed to be substituted into the equation. By calculating the ratio of the peak acceleration using the change of acceleration, Δa compared with the Earth's gravitational force, the percentage ratio for the peak ground acceleration (%g) of the seismic wave can be easily obtained.

INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
Shaking	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Damage	None	None	None	Very slight	Light	Moderate	Moderate/ heavy	Heavy	Very heavy
Peak Acc	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Peak Vel	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16 -31	31-60	60-116	>116

Peak Acc = Peak ground acceleration (g), Peak Vel = Peak ground velocity (cm/s)

Table 4.3.2: Modified Mercalli Scale of Ground Shaking [11]

Standard USGS Conversion of MMI to PGA (%g) Values									
Near-Source Modified Mercalli Intensity (MMI)	I	II-III	IV	V	VI	VII	VIII	IX	X
Maximum Peak Ground Acceleration. (PGA) in %g	< .17	.17 – 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18	18 - 34	34 - 65	65 - 124	> 124
Perceived shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Moderate / Heavy	Heavy	Very Heavy

Table 4.3.3: USGS Typical Table Showing Approximate Correlation between MMI and PGA

By referring to the Table 4.3.2, the Modified Mercalli Scale of Ground Shaking and data references from Table 4.3.3 obtained from the United States Geological Survey (USGS) [12], we can classify the data by referring to the peak ground acceleration obtained after the data analysis. Referring to different ranges of peak acceleration, we can interpret and classify the shaking and the damage level of and identify the seriousness of the seismic waves detected.

Based on Table 4.3.1, the EEMAS will be triggered and notified through 3 category of notifications which is the “Minor Seismic Activity”, “Major Seismic Activity” and thirdly the “Earthquake Alert”. Firstly for the “Minor Seismic Activity”, the EEMAS will be triggered and notify when the peak acceleration detected is higher than 0.17g and lower than 1.4g which means that weak shaking or swinging is detected around the area. For the “Major Seismic Activity”, the EEMAS will be triggered and notify when the peak acceleration is within the range of 1.4g to 3.9g which light swaying or vibration detected around the area. Lastly for the “Earthquake Alert” detection, the system will triggered the Mercalli scale is above 3.9g which moderate shaking and swing will be experienced and the swaying will start to be more intense and noticeable above the range which equals to approximate 3 magnitude referring to the Richter Magnitude Scale. Referring to the Table 4.3.4, we can compare and understand the effects and the relationship of the Modified Mercalli Scale with the Richter Magnitude Scale tabled by the Department of Natural Resources of Missouri, United States [13].

Modified Mercalli Scale		Richter Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5 4
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4.5
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	5
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	5.5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	6
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	6.5 7
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	7.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air	8

Table 4.3.4: Relationship between Richter Magnitude and Modified Mercalli Scale

4.5 HEAT WAVES & HIGH TEMPERATURE DETECTION AND IDENTIFICATION

Based on data provided from World Health Organisation (WHO), heat wave is considered if maximum temperature of a station reaches at least 40°C or more for plains and at least 30°C or more for hilly regions [14]. As the project is mainly focus in the city urban area, the temperature reference for heat waves will be at 40°C. Other than heat wave notification alert, high environmental temperature is also very concerning nowadays. Heat cramps and tiredness may occur at temperatures between 90˚ and 105˚F (32˚ and 40˚C). Heat exhaustion is more common at temperatures between 105˚ and 130˚F (40˚ and 54˚ C)[15]. The EEMAS system will also notify people around the area when high temperature at a range above 32°C is detected. The DHT22 Temperature and Humidity Sensor will sense the temperature surrounding and humidity then project and update the values into the Blynk IoT network from time to time so the smartphones user will also be able to monitor the surrounding conditions as well.

4.6 BLYNK IoT INTERFACE PROGRAMMING & NOTIFICATION INTEGRATION

After the concept of the data collection has been completed, system programming and Blynk IoT integration will be conducted referring to the parameters set in the early stages of the project planning. By using the Arduino IDE application and codding, the basic functional operation system has been completed. Integrating the source code with the Blynk IoT Push Notification code library and the Blynk IoT ESP32 Wi-Fi connection code library, the system has been perfectly running within expectations.

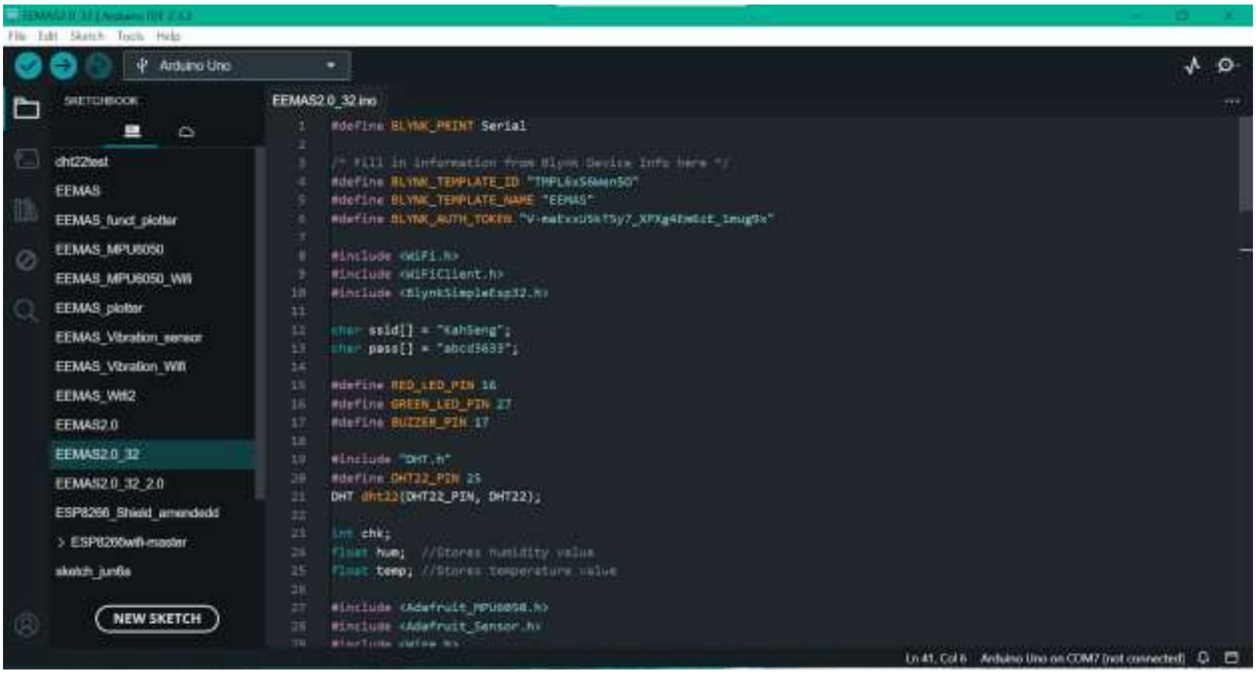

Figure 4.6.1: Snapshots on the Arduino Program of "EEMAS" with Blynk IoT Integration

The Blynk IoT interface and notification settings to pre-set the data and information display for the temperature, humidity, and acceleration magnitude will come next when the core functional coding for the Arduino has been finished. The interface will then show real-time data that has been acquired from the system by allocating distinct data streams to each of the variables. In addition, the description and the settings notification duration have been specified. A line graph displaying the peak ground acceleration recorded will be also displayed by the system based on the seismic activity data. Every environmental or seismic event that is triggered will likewise be noted in the system timeline for future reference.

Figure 4.6.2: Blynk IoT Webpage Interface of "EEMAS"

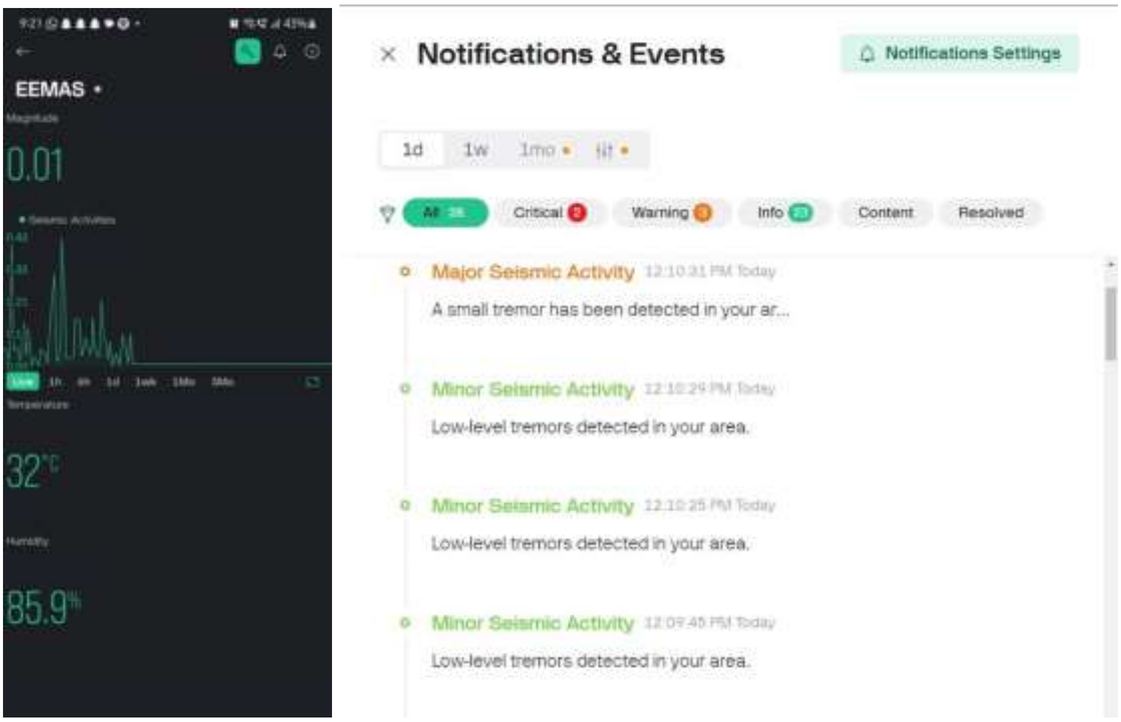

Figure 4.6.3: Blynk IoT Smartphone Interface of "EEMAS" with Events Timeline

Notification	Descriptions
Earthquake Alert (1 minute per notification)	A seismic event has been detected in your area. Please take immediate precautions to ensure your safety. Drop, cover, and hold on until shaking stops. Stay away from windows, heavy furniture, and potential falling objects. Be prepared for aftershocks. Stay safe! (Richter Scale: ~above 3.4 Magnitude)
Heat Wave Alert (15 minutes per notification)	Heat Wave Alert! Stay cool, hydrated, and indoors as much as possible. Avoid strenuous activities during peak sun hours. Drink plenty of water and keep shades drawn to reduce indoor temperatures. (Temperature: ~ 40 degree Celsius)
High-Temperature Warning (30 minutes per notification)	Extreme heat expected. Stay hydrated, seek shade, and check on vulnerable individuals. Stay safe! (Temperature: ~ 32 degree Celsius)
Major Seismic Activity (5 minutes per notification)	A small tremor has been detected in your area. Stay alert and prepared for potential aftershocks. Ensure your safety by taking precautions. Stay informed through local news sources. Stay safe! (Richter Scale: ~ 2.8 - 3.4 Magnitude)
Minor Seismic Activity (1 hour per notification)	Low-level tremors detected in your area. (Richter Scale: ~ 1.6 - 2.8 Magnitude)

Table 4.6.1: "EEMAS" Events' Notification Limits and Description

4.7 PCB DESIGNING AND FABRICATION

In order to simplify the system, the system's output section involving the LED light indicator and the buzzer have been designed and integrated into a single PCB board. To improve the connectivity quality of the circuit, PCB integration will be a better choice comparing to connecting through a breadboard. By use the Livewire to stimulate the output circuit needed and then converted to the PCB design layout through PCB Wizard. After the design was done, the track was printed out and proceeded for printing in campus's Project Lab 2 with the guidance of the lab assistant to go through the whole process from masking to etching of the PCB.

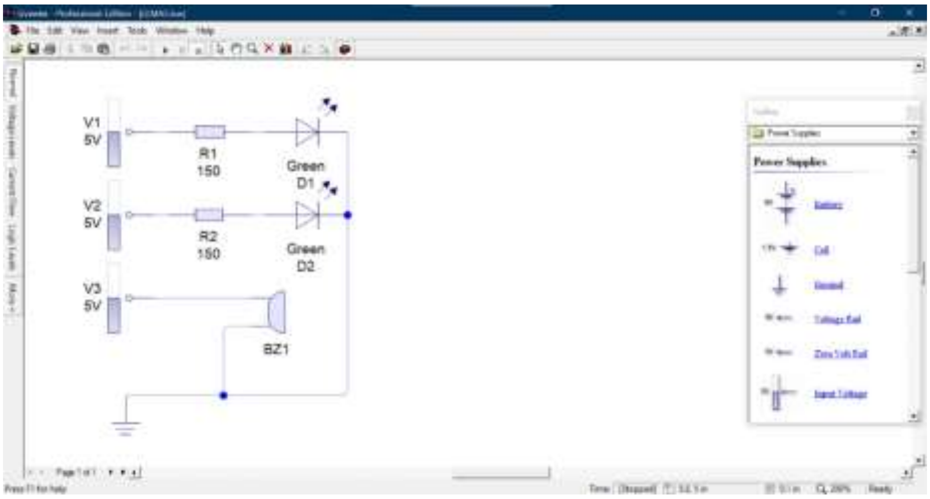

Figure 4.7.1: "EEMAS" Output Section PCB Circuitry Design using Livewire

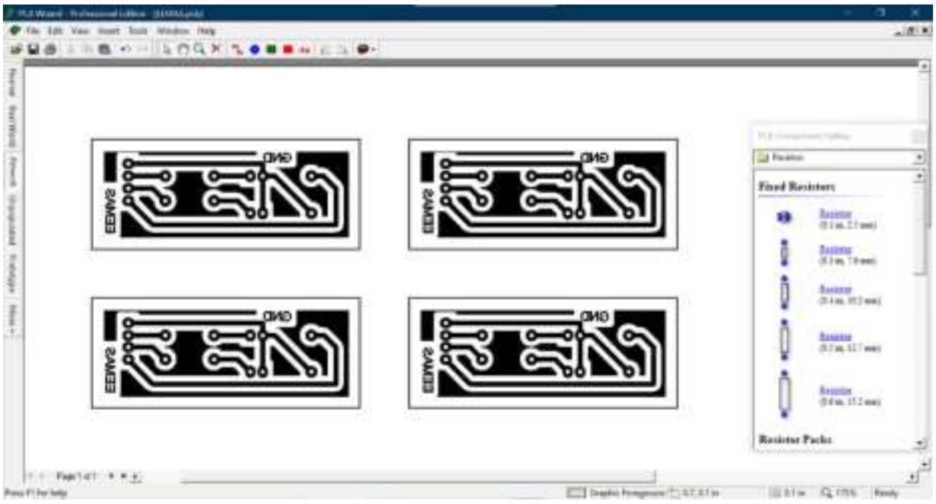

Figure 4.7.2: "EEMAS" Output Section PCB Track Layout using PCB Wizard

Figure 4.7.3: Assembled and Printed "EEMAS" Output Section PCB

4.8 CIRCUIT ASSEMBLY

By following the functionality and the system design earlier, with some application of basic circuit building technique, the components are being assembly together following to their specification and functionality. The connection and the wiring of the circuit can be referred to the diagram below.

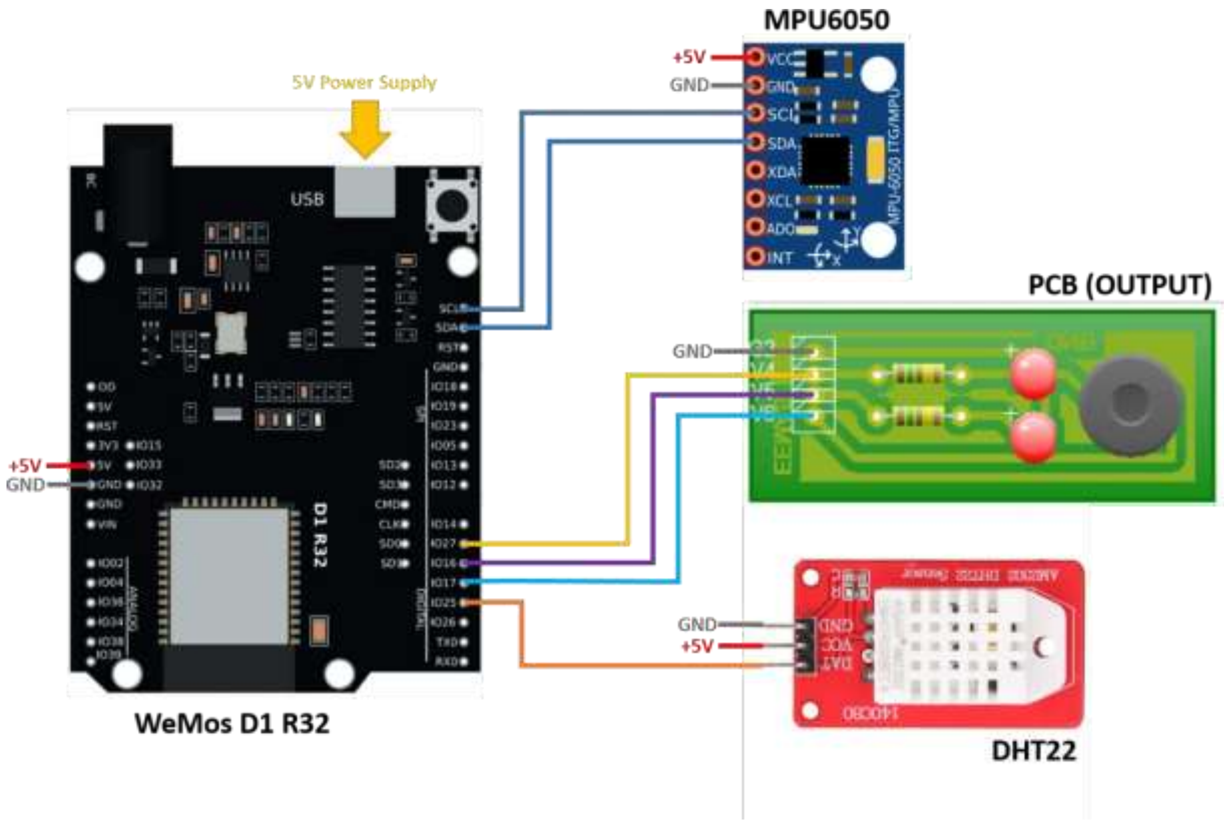

Figure 4.8.1: Circuit Diagram and the Wiring of "EEMAS"

4.9 CHASSIS DESIGN AND PRINTING

The chassis for the Earthquake and Environmental Monitoring and Alerting System "EEMAS" was meticulously designed using 3D modeling software which is TinkerCAD to meet the specific requirements of housing the electronic components securely and efficiently. Key design considerations included adequate space for the MPU 6050 accelerometer, DHT22 sensor, ESP32 module, buzzer, and LEDs. Ensuring proper ventilation for the DHT22 sensor was critical for accurate environmental condition measurement, and easy access to the USB port of the ESP32 module was necessary for programming and power supply.

Polylactic Acid (PLA) was chosen for the chassis material due to its ease of use in 3D printing, good mechanical properties, and biodegradability. PLA, a thermoplastic derived from renewable resources like corn starch or sugarcane, is an environmentally friendly choice, aligning with the sustainable goals of the project. The chassis was printed using a standard Fused Deposition Modeling (FDM) 3D printer. The process began with slicing the 3D model using slicing software to generate the G-code required for printing. Key parameters such as layer height, infill density, and print speed were optimized to balance print quality and time. The print was monitored to avoid issues such as warping or under-extrusion, and post-processing involved cleaning the printed chassis of any support material and smoothing out rough edges.

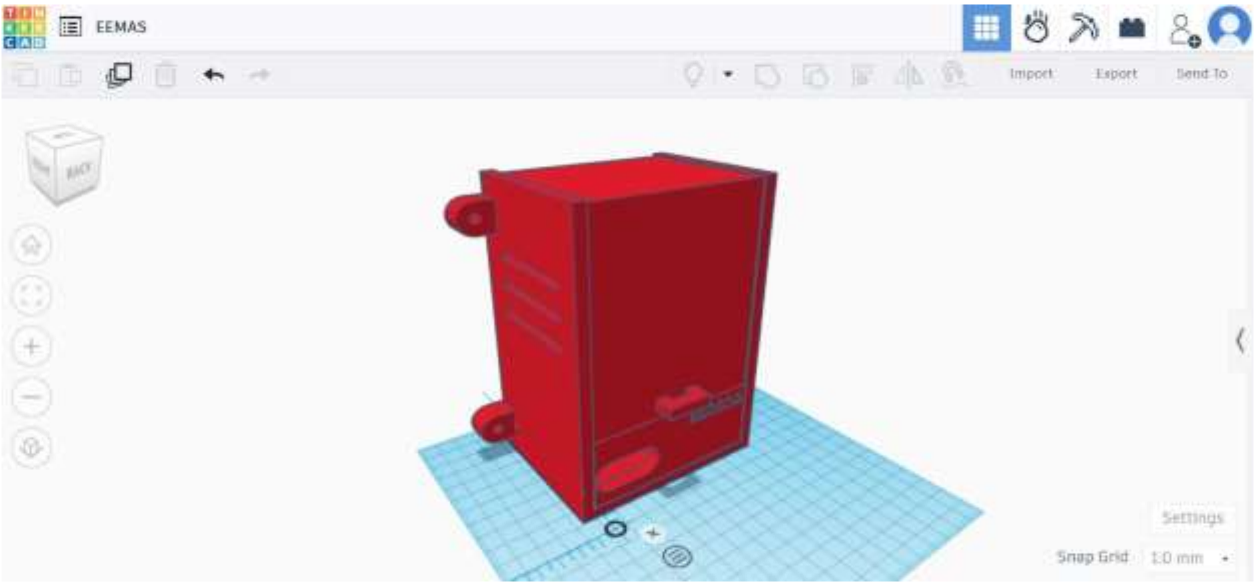

Figure 4.9.1: CAD Design of "EEMAS" Chassis using TinkerCad

Figure 4.9.2: 3D Object Viewer of "EEMAS" Chassis

4.10 CHASSIS ASSEMBLY

Before assembly, all components were individually tested to ensure proper functionality. This included verifying the performance of the sensors, Wi-Fi module, LEDs, and buzzer. Ensuring that each component was operational before integration helped prevent troubleshooting complexities later in the assembly process.

The assembly process began with mounting the ESP32 module in its designated space within the chassis using screws, followed by positioning and securing the MPU 6050 and the DHT22 sensor. Wiring and connections were then established, with the MPU 6050 connected to its designated SCA and SCL ports and the DHT22 sensor was connected to a digital pin. The PCB output interface, which included LEDs and a buzzer, was likewise connected to the digital pins of the ESP32 module and slotted into the chassis' front part.

The entire circuit was powered through the ESP32 module's USB port, providing a stable 5V power supply. A power distribution system was implemented to ensure each component received the correct voltage and current, crucial for the system's reliable operation. Cable management was an integral part of the assembly, ensuring that wires were routed through designated channels to keep the setup neat and avoid interference. Zip ties and adhesive cable clips were used to secure loose wires, enhancing the system’s overall organization and functionality.

After completing the assembly, the system underwent thorough testing to verify proper operation. Sensor data accuracy, LED indicator functionality, and buzzer sound output were all confirmed. The ESP32’s connectivity to the Blynk IoT platform was also tested to ensure seamless remote monitoring. The fully assembled circuit was enclosed within the 3D-printed chassis, and the cover was securely attached. The result was a compact, robust, and fully functional EEMAS unit ready for deployment. This integration of a 3D-printed PLA chassis with meticulous circuit assembly demonstrates a blend of modern fabrication techniques and practical electronics, ensuring the system’s reliability and ease of use for real-time monitoring and alerts.

Figure 4.10.1:“EEMAS” Final Prototype after assembly

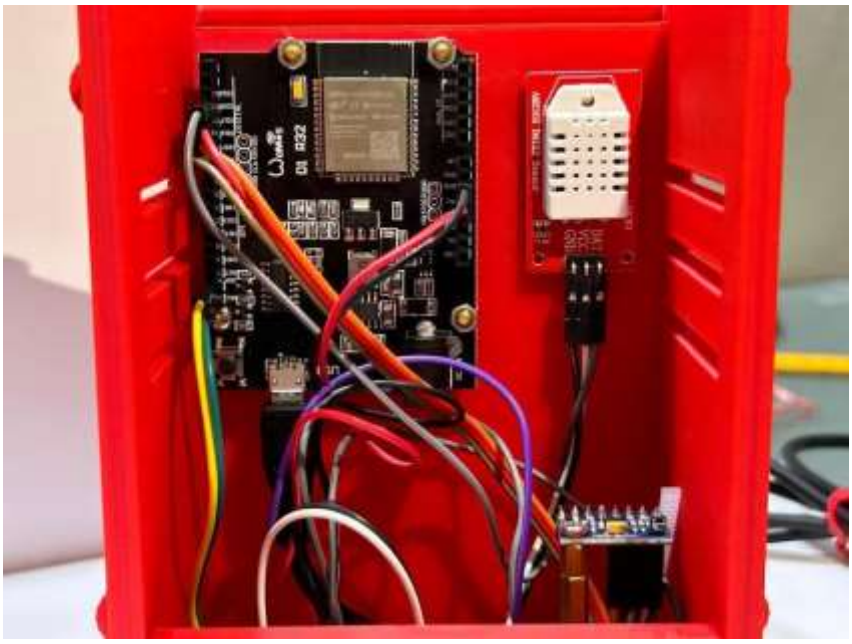

Figure 4.10.2: “EEMAS” Final Prototype Wiring and Circuitry

5. Results

Following the assembly and initial setup of the Earthquake and Environmental Monitoring and Alarm System (EEMAS), a 10-minute functional test was conducted to evaluate the system's performance and reliability. The test aimed to verify the correct operation of all integrated components, including the MPU 6050 accelerometer, DHT22 sensor, ESP32 module, LEDs, and buzzer. The results will be the data obtained and collected after the testing and will be used for further analysis and discussions.

<table>
<tr><th>Time</th><th>Peak Ground Acceleration (g)</th><th>Temperature (°C)</th><th>Humidity (%)</th><th>Events Triggered</th></tr>
<tr><td>11:00:30</td><td>0.04</td><td>31</td><td>85.5</td><td>-</td></tr>
<tr><td>11:01:00</td><td>0.05</td><td>31</td><td>85.5</td><td>-</td></tr>
<tr><td>11:01:30</td><td>0.03</td><td>31</td><td>85.5</td><td>-</td></tr>
<tr><td>11:02:00</td><td>0.17</td><td>31</td><td>85.5</td><td rowspan="2">Minor Seismic Activity</td></tr>
<tr><td>11:02:30</td><td>0.54</td><td>31</td><td>85.5</td></tr>
<tr><td>11:03:00</td><td>2.53</td><td>31</td><td>85.5</td><td>Major Seismic Activity</td></tr>
<tr><td>11:03:30</td><td>4.23</td><td>31</td><td>85.5</td><td>Earthquake Alert</td></tr>
<tr><td>11:04:00</td><td>0.45</td><td>31</td><td>85.6</td><td>Minor Seismic Activity</td></tr>
<tr><td>11:04:30</td><td>0.05</td><td>31</td><td>85.9</td><td>-</td></tr>
<tr><td>11:05:00</td><td>0.03</td><td>32</td><td>86.3</td><td rowspan="7">High-Temperature Warning</td></tr>
<tr><td>11:05:30</td><td>0.02</td><td>32</td><td>88.4</td></tr>
<tr><td>11:06:00</td><td>0.04</td><td>32</td><td>87.5</td></tr>
<tr><td>11:06:30</td><td>0.03</td><td>32</td><td>85.2</td></tr>
<tr><td>11:07:00</td><td>0.01</td><td>32</td><td>85.1</td></tr>
<tr><td>11:07:30</td><td>0.02</td><td>32</td><td>85.1</td></tr>
<tr><td>11:08:00</td><td>0.23</td><td>32</td><td>85.3</td></tr>
<tr><td>11:08:30</td><td>1.56</td><td>32</td><td>85.3</td><td>Major Seismic Activity</td></tr>
<tr><td>11:09:00</td><td>0.87</td><td>32</td><td>85.3</td><td>Minor Seismic Activity</td></tr>
<tr><td>11:09:30</td><td>0.11</td><td>32</td><td>85.3</td><td rowspan="2">High-Temperature Warning</td></tr>
<tr><td>11:10:00</td><td>0.07</td><td>32</td><td>85.3</td></tr>
</table>

Table 5.1: 10 minutes Functional Test Results of "EEMAS"

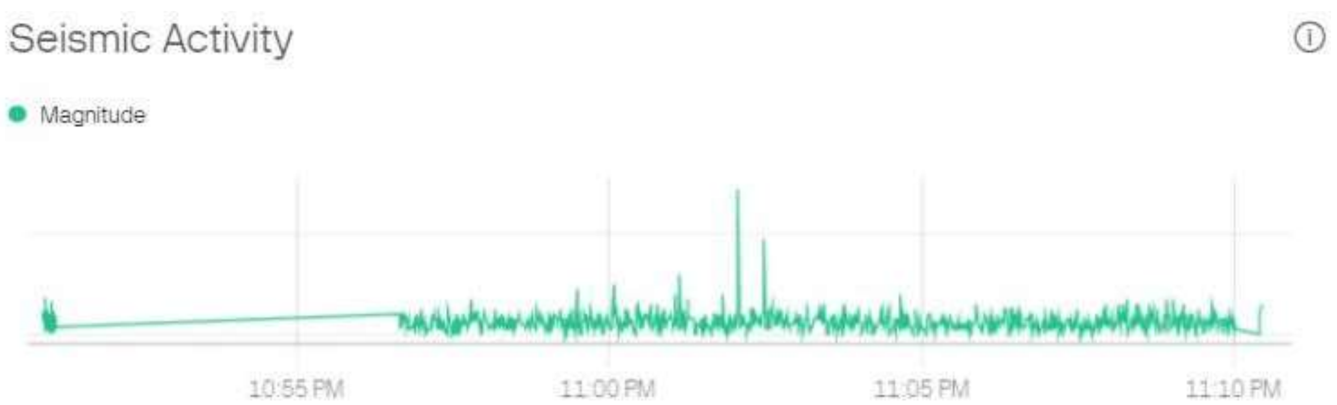

Figure 5.1: Seismic Activity Magnitude Peak Ground Acceleration Magnitude Graph of "EEMAS"

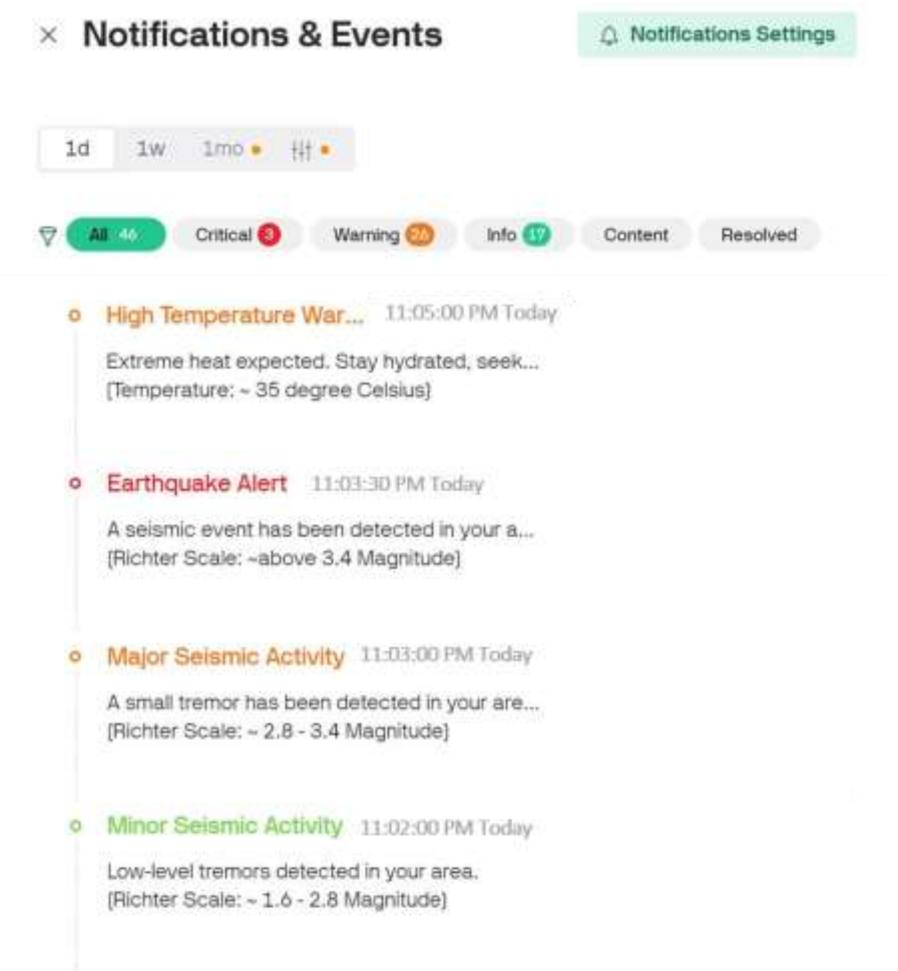

Figure 5.2: Blynk IoT Notifications & Events Timeline of "EEMAS"

Throughout the test, the MPU 6050 accelerometer was constantly monitoring for vibrations and probable seismic activity. The technology accurately identified normal background vibrations and only activated the earthquake alert when large motions were manually entered. When the threshold was exceeded, the red LED lit up, the buzzer sounded, and a notification was sent to the Blynk app. This demonstrated the accelerometer's sensitivity and the system's ability to distinguish between mild tremors and seismic events Nevertheless, the DHT22 sensor measured temperature and humidity levels consistently as well. The temperature and humidity readings were consistent and accurately mirrored the testing circumstances. The real-time data was successfully transferred to the Blynk app and shown on the dashboard. When the temperature rose over the predefined threshold of 32°C, the system appropriately delivered a high-temperature alert via Blynk, confirming the sensor's efficacy and reactivity to environmental changes.

The ESP32 module also maintained a stable connection to the Wi-Fi network, allowing for continuous communication with the Blynk IoT platform. The Blynk app received all messages triggered by the earthquake and high-temperature incidents almost immediately. The ESP32 module's faultless operation demonstrated the reliability of the remote monitoring and alerting system, which provided users with immediate updates on environmental and seismic conditions. The output and the indicator section which involved the LEDs and buzzer worked as planned throughout the test. The green LED stayed on during normal operation, showing that the device was engaged and monitoring the situation. When seismic activity was detected, the red LED and buzzer were activated, sending quick local alerts. These visual and audible signs were clear and easily visible, ensuring that consumers were immediately alerted to any possible hazards.

Throughout the 10-minute test, the "EEMAS" system performed reliably with no disruptions or faults. The 3D printed PLA chassis held all components securely, preventing any movement or disconnection during the test. The cable management system successfully organized the wiring, which improved the system's overall stability and reliability.

To evaluate its accuracy in detecting different types of seismic events, another data collection and testing was carried out as well which involved comparing the total magnitude of acceleration recorded by the MPU6050 sensor with the detected magnitude by the “Accelerometer” smartphone application, calculating the accuracy percentage for each trial, and determining the overall accuracy for each type of event.

For Minor Seismic Activity, ten individual tests were conducted. By referring to Table 5.2, with the MPU6050 sensor recording magnitudes ranging from 10.31g to 10.65g. The application's detected magnitudes were very close to the sensor readings, resulting in accuracy percentages ranging from 97.96% to 99.32%. The overall accuracy for detecting minor seismic activity was found to be 98.07%.

In the case of Major Seismic Activity, another set of ten tests was conducted. Referring to Table 5.3, the measured magnitudes from the MPU6050 sensor ranged from 12.54g to 13.69g, and the application's detected magnitudes closely matched these readings. The accuracy percentages for these trials ranged from 95.44% to 99.99%, with an overall accuracy of 98.21% for detecting major seismic activity.

For Earthquake Alerts, referring to Table 5.4, the system was tested with ten trials as well, where the MPU6050 sensor recorded magnitudes between 14.14g and 15.32g. The detected magnitudes by the application were very close to the sensor measurements, resulting in accuracy percentages ranging from 97.04% to 99.99%. The overall accuracy for detecting earthquake alerts was 98.08%.

These results indicate that the “EEMAS” is highly reliable for real-time seismic monitoring, with minimal deviations between the sensor measurements and the “Accelerometer” smartphone application's detections. The system's overall accuracy across different seismic event categories confirms its effectiveness in providing timely and accurate alerts for various seismic activities.

Figure 5.3: Screenshots on the data obtain from the “Accelerometer” Smartphone Application

Event	Trials	Magnitude (Acceleration)		Accuracy (%)
		MPU6050	"Accelerometer" Application	
Minor Seismic Activity	1	10.65	10.46	98.18
	2	10.12	10.34	97.87
	3	10.81	10.34	95.45
	4	10.18	10.34	98.45
	5	10.14	10.31	98.35
	6	10.46	10.64	98.31
	7	10.43	10.52	99.14
	8	10.91	10.79	98.89
	9	10.23	10.43	98.08
	10	10.52	10.31	97.96
			Overall Accuracy (%)	**98.07**

Table 5.2: Table of "Minor Seismic Activity" Overall Detection Accuracy

Event	Trials	Magnitude (Acceleration)		Accuracy (%)
		MPU6050	"Accelerometer" Application	
Major Seismic Activity	1	12.96	13.11	99.37
	2	13.69	13.7	99.93
	3	13.19	12.97	98.30
	4	12.61	12.34	97.81
	5	12.96	12.83	98.99
	6	12.87	12.43	96.46
	7	13.01	13.08	99.46
	8	13.23	13.41	98.66
	9	12.79	12.81	99.84
	10	12.54	12.63	99.29
			Overall Accuracy (%)	**98.81**

Table 5.3: Table of "Major Seismic Activity" Overall Detection Accuracy

Event	Trials	Magnitude (Acceleration)		Accuracy (%)
		MPU6050	"Accelerometer" Application	
Earthquake Alert	1	14.36	14.27	99.37
	2	15.13	15.2	99.54
	3	15.87	16.08	98.69
	4	13.8	14.1	97.87
	5	14.65	14.08	95.95
	6	15.85	16.43	96.47
	7	18.37	18.59	98.82
	8	16.83	17.08	98.54
	9	14.95	15.31	97.65
	10	15.38	15.74	97.71
			Overall Accuracy (%)	**98.06**

Table 5.4: Table of "Earthquake Alert" Overall Detection Accuracy

6. Analysis and Discussion

The 10-minute functional test and the accuracy test of the Earthquake and Environmental Monitoring and Alarm System (EEMAS) provided valuable insights into the system's performance and reliability. The test results, summarized in Table 5.1, demonstrate the system's ability to detect and respond to seismic activities and environmental conditions accurately while Table 5.2, Table 5.3 and Table 5.4 demonstrated the accuracy of the seismic activity detection compared to other accelerometers reading obtained.

6.1 SEISMIC ACTIVITY DETECTION

By referring to the results in Table 5.1 and Figure 5.1, show that the 10 minutes of Functional and System Testing for the "EEMAS". To generate the seismic waves, the box is placed on a table and vibration will be applied simultaneously to represent the earthquake movement in the real world. The accelerometer will detect the 3-dimensional acceleration movement by vibrating the table and convert it to the Peak Ground Acceleration (g) value. Due to limited integration and sources for real-life earthquake intensity simulation, the result can be only analyzed and identified through the intensity shaking force applied from soft sway to heavy shaking. Throughout the 10-minute test period, the EEMAS successfully detected multiple seismic events. The table indicates various levels of seismic activity, categorized as minor and major seismic activity, as well as an earthquake alert:

1. **Minor Seismic Activity:**
   - Detected at 11:02:30, 11:04:00, and 11:08:30 with peak ground accelerations of 0.54g, 0.45g, and 0.87g, respectively.
   - The system appropriately categorized these as minor seismic activities, triggering the minor seismic activity alert (yellow cells in the table).
2. **Major Seismic Activity:**
   - Detected at 11:02:00 and 11:08:00 with peak ground accelerations of 2.53g and 1.56g, respectively.
   - These events were correctly identified as major seismic activities, triggering the major seismic activity alert (yellow cells in the table).
3. **Earthquake Alert:**
   - Detected at 11:03:30 with a peak ground acceleration of 4.23g.
   - This significant seismic event triggered the earthquake alert, activating the red LED and buzzer and sending a notification via Blynk (red cell in the table).

The detection of seismic events at varying magnitudes and their correct classification demonstrate the EEMAS's sensitivity and accuracy in monitoring ground acceleration. The system's ability to differentiate between minor and major seismic activities, as well as issue an earthquake alert, underscores its effectiveness in providing timely warnings.

Other than that, "EEMAS" demonstrates high accuracy in detecting seismic activities across different magnitudes. The overall accuracy for Minor Seismic Activity detection is 98.07%, for Major Seismic Activity detection is 98.21%, and for Earthquake Alert detection is 98.08%. These results indicate that the EEMAS is highly reliable for real-time seismic monitoring, with minimal deviations between the sensor measurements and the application's detections. The system's overall accuracy across different seismic event categories confirms its effectiveness in providing timely and accurate alerts for various seismic activities.

6.2 ENVIRONMENTAL MONITORING:

The DHT22 sensor continuously monitored temperature and humidity levels during the test. The data collected showed stable readings, with temperature fluctuating between 31°C and 32°C and humidity ranging from 85.1% to 86.3%. The system responded to environmental conditions as follows:

1. **Normal Conditions:**
   - For most of the test period, the temperature remained at 31°C, and humidity levelswere stable around 85.5%.
   - No alerts were triggered during these periods, indicating that the system correctly identified normal environmental conditions.
2. **High-Temperature Warning:**
   - At 11:05:00, the temperature reached 32°C, exceeding the predefined threshold of 32°C.
   - The system triggered a high-temperature warning, sending a notification via Blynk (yellow cell in the table).

The stable operation of the DHT22 sensor and the accurate triggering of a high-temperature warning highlight the system's capability to monitor and respond to environmental changes effectively. To check the accuracy of the data of the temperature and the humidity obtained from the DHT22 Temperature and Humidity Sensor, environmental temperature and humidity have been obtained as well from online weather forecasts. By referring to the screenshot obtained, we can see that the temperature data obtained from the DHT22 sensor have an accuracy of 98.59% referring to the online weather forecast of the surroundings. For the humidity data obtained, there will be some discrepancy which is a range of ± 3-4% based on the different environmental conditions for both of the sensor detections. Overall, the accuracy of the data obtained from the DHT22 sensor was still beyond the range of acceptable.

Figure 6.2: Screenshot of the Regional Weather Forecast from Weather.com during Functional Testing

6.3 SYSTEM STABILITY AND PERFORMANCE

The overall performance of the EEMAS during the 10-minute test was stable and reliable. The ESP32 module maintained a continuous connection to the Wi-Fi network, ensuring seamless communication with the Blynk IoT platform. All local alerts (LEDs and buzzer) and remote notifications (Blynk app) were triggered accurately and promptly, validating the system's design and integration. The sensors involving input data collection and events detection such as the MPU6050 and DHT22 sensors function with detection accuracy above 98% which is within the data discrepancy range of ±2% referring to both of the sensors' datasheet.

6.4 CONCLUSION OF ANALYSIS AND DISCUSSIONS

The functional test results demonstrate that the "EEMAS" is a robust and reliable system for monitoring seismic activities and environmental conditions. The accurate detection of seismic events, effective monitoring of temperature and humidity, and prompt alerts and notifications confirm the system's operational effectiveness. The "EEMAS" is well-suited for deployment in real-world applications, providing enhanced safety and awareness in environments prone to earthquakes and adverse weather conditions. Future improvements, such as incorporating additional sensors and optimizing power consumption, could further enhance the system's capabilities and reliability.

7. Conclusions and Recommendations for Future Work

The Earthquake and Environmental Monitoring and Alarm System (EEMAS) has proven to be an effective tool for real-time monitoring and alerting of seismic activities and environmental conditions. The integration of the MPU 6050 accelerometer, DHT22 sensor, and ESP32 module within a 3D-printed PLA chassis provides a robust and reliable system capable of alerting users through both local indicators and remote notifications via the Blynk app. The successful implementation and testing of the EEMAS demonstrate its potential to enhance safety and awareness in environments prone to earthquakes and adverse weather conditions.

For future work, several enhancements are recommended to increase the functionality and versatility of the EEMAS. Incorporating additional sensors, such as gas and particulate matter sensors, could broaden the system's environmental monitoring capabilities. Implementing machine learning algorithms could improve earthquake detection accuracy and reduce false positives. Power optimization techniques, such as utilizing sleep modes, could extend the system's operational life in remote areas. Data logging and analysis features could provide valuable insights into environmental trends and earthquake patterns over time. Enhancing network connectivity options, such as GSM/GPRS and LoRa, could increase deployment versatility. Developing dedicated mobile and web applications with advanced features would enhance user engagement and experience. Lastly, creating a community-based monitoring network and improving the physical robustness and scalability of the system could provide comprehensive monitoring for larger areas or more complex environments. These recommendations aim to elevate the EEMAS into an even more powerful and user-friendly tool for environmental and seismic monitoring.

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Appendix

1. **Source Code:**
https://drive.google.com/file/d/1j_mkVYyELEZsMuEGnwV-zFunKlyNW0nv/view?usp=sharing

2. **List of Expenses:**

No.	Materials	Unit Price (RM)	Quantity	Price (RM)
1.	WiFi UNO Based ESP32	49.00	1	49.00
2.	GY-521 MPU6050 6DOF Accelerometer + Gyro	10.50	1	10.50
3.	DHT22 Temperature and Humidity Sensor Module Breakout	15.50	1	15.50
4.	Piezo Transducer	2.50	1	2.50
5.	Jumper Wire	3.60	3	10.80
6.	LED 5mm	0.10	2	0.20
7.	PLA 3D Printed Chassis	54.80	1	54.80
8.	M3 Male to Female Screw Thread and Nuts Set	11.99	1	11.99
Total Cost				**155.29**