Faculty of Electronics & Computer Technology and Engineering

DEVELOPMENT OF SOLAR-POWERED EARTHQUAKE DETECTOR USING ESP32 FOR HOME USAGE

ALYA FARAHANA BINTI NOR AFFANDI

Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Computer Engineering Technology (Computer Systems) with Honours**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DEDICATION

To my beloved

Emy Suraya bt Ramli & Nor Affandi b Samsudin

And

Family members,

whose unwavering support and love have been my guiding light

Your belief in me has turned my dreams into reality

ABSTRACT

Natural disaster can be clarified as a major event caused by Earth's natural processes that results a consequence of natural hazards. It also has caused significant damage to the community such as degradation of environment, damage to infrastructure and loss of life. The examples of natural disasters include the earthquakes, volcanic activity, floods, tsunamis and few more. Earthquakes caused most devastated natural hazards as they strike without warning. The detector for the natural hazards is currently highly desired throughout the world, particularly in countries where they frequently occur. Therefore, a system that can detect the shaking of earthquake will be built as it is an essential tool for early warning that can save more lives and provides better preparation for the incoming seismic events. In this proposed designed device, scale will be set as the threshold appropriately. Nowadays, the majority of previous developments are not cost-effective for all residents to use in their homes and are not eco-friendly for all locations. Other than that, most of the devices uses the battery to run the system and it cannot be used for a long period of time, the most it can handle is up to only 2 years maximum. There are two parts of the planned framework: equipment and programming. For the equipment section consists of NodeMCU ESP32, ADXL355 accelerometer sensor, 12V rechargeable battery, LCD, Buzzer and solar panel. The Arduino IDE will be used for the programming section. Based from this implemented device, user can notice the ground motions early with the help of the sensor, and if the motions reach the threshold level required, the device will activate the buzzer alarm to notifies everyone immediately using the Telegram application. So, in the end of the device development, it can save many lives as they manage to secure their important belongings and safely evacuate as soon as the alarms activated.

ABSTRAK

Bencana alam boleh dijelaskan sebagai peristiwa besar yang disebabkan oleh proses semula jadi Bumi yang mengakibatkan akibat daripada bahaya alam. Ia juga telah menyebabkan kerosakan yang ketara kepada masyarakat seperti kemerosotan alam sekitar, kerosakan infrastruktur dan kehilangan nyawa. Contoh bencana alam termasuk gempa bumi, aktiviti gunung berapi, banjir, tsunami dan beberapa lagi. Gempa bumi menyebabkan kebanyakan bahaya semula jadi yang musnah apabila ia melanda tanpa amaran. Pengesan untuk bahaya semula jadi pada masa ini sangat dikehendaki di seluruh dunia, terutamanya di negara-negara di mana ia kerap berlaku. Oleh itu, sistem yang dapat mengesan gegaran gempa bumi akan dibina kerana ia merupakan alat penting untuk amaran awal yang boleh menyelamatkan lebih banyak nyawa dan menyediakan persediaan yang lebih baik untuk kejadian seismik yang akan datang. Dalam peranti reka bentuk yang dicadangkan ini, skala akan ditetapkan sebagai ambang dengan sewajarnya. Pada masa kini, majoriti pembangunan sebelum ini tidak kos efektif untuk digunakan oleh semua penduduk di rumah mereka dan tidak mesra alam untuk semua lokasi. Selain itu, kebanyakan peranti menggunakan bateri untuk menjalankan sistem dan ia tidak boleh digunakan untuk jangka masa yang lama, paling banyak ia boleh mengendalikan sehingga maksimum 2 tahun sahaja. Terdapat dua bahagian rangka kerja yang dirancang: peralatan dan pengaturcaraan. Untuk bahagian peralatan terdiri daripada Mikropengawal NodeMCU ESP32, sensor pecutan ADXL355, Sel PV, LCD, Buzzer dan panel solar. Perisian Arduino IDE akan digunakan bagi bahagian pengaturcaraan. Berdasarkan peranti yang dilaksanakan ini, pengguna boleh melihat pergerakan tanah lebih awal dengan bantuan penderia, dan jika gerakan itu mencapai tahap ambang yang diperlukan, peranti akan mengaktifkan penggera buzzer untuk memberitahu semua orang dengan segera dengan menggunakan aplikasi Telegram. Jadi, pada akhir pembangunan peranti, ia boleh menyelamatkan banyak nyawa kerana mereka berjaya mengamankan barang-barang penting mereka dan berpindah dengan selamat sebaik sahaja penggera diaktifkan.

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I would like to express my deepest gratitude to all those who made this project a success. First and foremost, my sincere thanks to Ts. Dr. Hasrul ‘Nisham bin Rosli for your precious guidance, words of wisdom and patient throughout this project. Your unwavering faith in my slow progress and constant encouragement did push me to exceed this project.

As I sit down to pen this acknowledgment, I realize that the most crucial recognition I owe is to myself. This journey, culminating in the completion of my final year project, has been one of immense growth, challenge, and self-discovery. I am proud of my ability to overcome obstacles and navigate the complexities of this project. There were times when the path seemed insurmountable, when the hours stretched long into the night, and the work seemed never-ending. In those moments, it was my own determination and commitment that carried me through.

Words cannot explain how grateful I am to my wonderful family for your unconditional love and unwavering support. You have been my foundation, constantly believing in me even when I doubted myself. Anis, Nukman and Harris, your laughter and companionship have been my stress relievers during this journey.

Last but not least, the presence of my friends, especially NFS, HH & NS, in my life has been a blessing to my friends, who have become more like a second family to me. Thank you for the numerous study sessions, much-needed breaks, and unending support. I am eternally grateful to each of you for your contributions to my personal and academic success.

Without the love, understanding, and support of my family and friends, this trip would have been much more difficult. You've all contributed to my accomplishment in ways that words can't express. This accomplishment is both yours and mine.

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CHAPTER 1

INTRODUCTION

1.1 Background

Natural disasters, encompassing catastrophic events of atmospheric, geological, and hydrological origins, frequently occur with significant variability in their frequency and the resultant death tolls from year to year. These severe and dangerous phenomena often strike with little or no warning, profoundly impacting people, property, and the environment as a whole. According to Our World in Data Organization, over the past decade, an average of approximately 45,000 people globally have perished each year due to natural disasters. As in the Figure 1.1 below, the decadal average number of deaths from natural disaster that happened in Malaysia are caused by flood. However, there is an earthquake events happened in the year 2000 to the year 2010 [1]. This statistic underscores the unpredictable and perilous nature of these events, highlighting the urgent need for effective preparedness and response strategies.

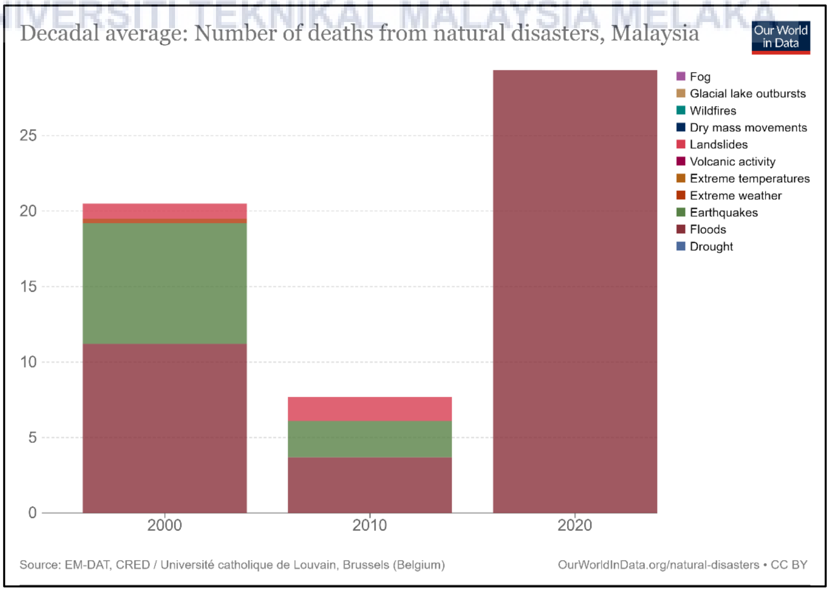


Figure 1.1: The decadal average number of deaths from natural disasters in Malaysia

1.2 Earthquakes

Natural disasters can be triggered naturally or through human activities. They often result from geological faults rupturing, alongside other catastrophes such as landslides, mine explosions, volcanic eruptions, nuclear tests, avalanches, and rapid-flowing rivers. These events disrupt the Earth's surface, leading to property damage and loss of life. Earthquakes, specifically, are natural phenomena caused by the movement and interaction of lithospheric plates within the Earth's crust. They occur when energy, accumulated over time due to tension and stress along fault lines, is suddenly released, causing the ground to tremble. Seismic events, varying in magnitudes and frequencies, are intrinsic to the Earth's geologic processes. Seismic waves are caused by abrupt movement inside the tectonic plates, disturbing the plates and breaking the planes in the region. Instruments like seismometers, geophones, and accelerometers record the amplitude and frequency of these waves, providing insights into the Earth's subsurface structures.

Earthquakes have the potential to inflict severe damage on infrastructure, cause fatalities, and disrupt the economy, as illustrated in Figure 1.2. The resulting loss of life, displacement, and daily life disruptions can lead to trauma, anxiety, and a heightened sense of vulnerability within communities. In the aftermath, it is imperative to rebuild communities and restore social cohesion. The recovery process involves substantial expenses, including the repair of damaged assets, reconstruction of infrastructure, and provision of relief to affected areas.


Figure 1.2: Damages done by the earthquake in Turkiye

Therefore, the development of solar-powered earthquake detectors represents a sustainable and efficient approach to monitoring seismic activities. Utilizing solar energy, a clean and renewable resource, these devices can function autonomously, which is particularly advantageous for remote or off-grid areas where power supplies are often unreliable. Their potential for compact and portable design further enhances their suitability for diverse locations. By relying on solar power, these detectors not only contribute to environmental sustainability but also ensure consistent and reliable earthquake monitoring.

1.3 Problem Statement

Earthquakes are among the most devastating natural disasters, striking suddenly with often little to no warning. The severity of an earthquake is assessed based on its magnitude, which varies according to the earthquake's size, nature, and location. With an effective warning system calibrated to these magnitude scales, the potential damage and fatalities can often be significantly reduced [2].

Once seismic events occur, it's too late for preparations if earthquake detectors are not already in place. Often, residential areas are better equipped with smoke alarms than earthquake detectors due to limited awareness of their importance. The proposed solar-powered earthquake detector is designed to measure the magnitude of ground motion in real-time. As the destructive power of an earthquake increases with its magnitude, this device would automatically alert residents to imminent quakes, allowing them to take appropriate safety measures based on the severity, thereby minimizing human injury and property damage.

Currently, most commercial earthquake detection devices are expensive, complex, and not easily accessible to the general public, limiting their effectiveness in preparing for and managing earthquake impacts. A viable solution is the development of a low-cost, user-friendly earthquake detector using an Arduino microcontroller. As an open-source platform, ESP32 microcontroller allows for extensive customization and modification. The incorporation of solar power in the device ensures its continual operation and reduces operational costs, making it an eco-friendly and sustainable option for widespread use.

1.4 Project Objective

The main aim of this project is to developed systemic and reliable system to detect the earthquake with the help of solar powered device. Specifically, the objectives are as follows:

a. To develop earthquake detection system using ESP32.

b. To implement the use of IoT to notify users of the earthquake tremor signal system.

c. To integrate solar power panel in the earthquake detection system.

1.5 Scope of Project

This project is dedicated to creating a functional and reliable earthquake detection device, with its scope divided into hardware and software development. In pursuing the optimal design for an earthquake detector, extensive research, including the review of articles and journals, has been conducted to thoroughly understand the project requirements and potential improvements. The hardware aspect involves a comparative analysis of various sensor detectors, aiming to design a user-friendly device suitable for community and home use. It is crucial to meticulously study the functionalities and compatibility of the components to ensure the successful assembly and operation of the hardware.

In terms of software, the project extends beyond technical development to also include an educational dimension, aimed at raising awareness about early earthquake warnings. The software is designed to send timely alerts to users upon detection of seismic waves, providing them with crucial seconds or minutes for emergency preparations and, if needed, evacuation. By establishing a networked system, the project aims to enhance the resilience and safety of communities, empowering them with real-time data and actionable insights during seismic events.

1.6 Summary

In conclusion, solar-powered earthquake detectors present a reliable and eco-friendly solution for earthquake monitoring, especially valuable in areas with limited access to electricity. Their ability to operate independently of external power sources enhances the robustness and accessibility of seismic data, ensuring uninterrupted operation and monitoring. These devices are indispensable tools for consistent and resilient seismic data collection, thanks to their energy self-sufficiency, environmental sustainability, and reliability in emergency situations. Furthermore, their versatility, portability, and potential for community involvement not only advance technological innovation but also foster awareness of renewable energy and disaster preparedness within communities.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Natural Disaster

Natural catastrophes, which are unexpected and devastating events caused by natural forces, are depicted vividly in Figure 2.1. These disasters are beyond human control, but their results intersect with the consequences of war or warfare. In both contexts, there is human suffering caused by damage to life, personal property, and infrastructure. Families are displaced and victims lose shelter. The impact of these natural events varies considerably, influenced by factors such as their magnitude, geographical location, population density, and the preparedness and response capabilities of the affected regions. Natural disasters manifest in diverse forms around the globe and, being largely beyond human control, are categorized into several types: geological risks (e.g., earthquakes, volcanoes), hydrological risks (e.g., floods, tsunamis), severe weather risks (e.g., hurricanes, tornadoes), and extreme cold weather events (e.g., blizzards, ice storms) [2].

Figure 2.1: Examples of natural disaster

2.2 Earthquakes Magnitude Level

Earthquake magnitude is a measure of the size or strength of an earthquake, and it is a critical parameter used worldwide to assess the potential impact of seismic events. Earthquake magnitude levels in Malaysia, while generally moderate compared to global standards, are important to consider due to the country's growing infrastructure and urbanization. The measurement of earthquake magnitudes in Malaysia, as in other parts of the world, is typically done using the Moment Magnitude Scale (MMS), like in Table 1 below. Moment Magnitude Scale (MMS) was developed to address certain limitations of the Richter scale, particularly its inaccuracy in measuring very large earthquakes. The magnitude of these seismic events might vary, with the worst earthquakes reaching levels that are difficult to comprehend.

Table 1: Earthquake Moment Magnitude Scale (MMS) in Malaysia

Magnitude Level	Earthquake Effects in Malaysia
Less than 4.0 Mw	Usually felt, but rarely causes damage.
4.0 to 4.9 Mw	Noticeable shaking indoor items, rattling noises.
5.0 to 5.9 Mw	Cause slightly damage to buildings, particularly in urban areas.
6.0 Mw and above	Potential for significant damage.

2.3 Earthquake Early Warning (EEW)

Early detection and timely response are vital in mitigating the impact of earthquakes and ensuring the safety of affected populations. Throughout history, there have been numerous powerful earthquakes that have had profound and lasting effects on the regions they struck. The level of seismic activity in an area is characterized by the frequency, type, and size of earthquakes occurring within a specific timeframe. Figure 2.2 depicts the devastation caused by a catastrophic earthquake in a Haitian neighbourhood. These seismic events can vary greatly in magnitude, with some reaching levels that are profoundly impactful. For instance, the 2010 Chile earthquake, with a magnitude of 8.8, resulted in intense shaking for three minutes, causing numerous fatalities and triggering a tsunami [3].

Figure 2.2: Aftermath of an earthquake

To enhance earthquake preparedness, local authorities in Malaysia should implement preventive measures, including public awareness programs to educate residents about earthquake risks and safety strategies. While precise prediction of earthquake timing remains elusive, the concept of Earthquake Early Warning (EEW) systems has become increasingly feasible due to advancements in processing power and network communication [4]. There is growing interest in developing earthquake detection systems that can provide accurate, real-time information about seismic activities. Consequently, the development of cost-effective and user-friendly earthquake detectors could provide crucial seconds or minutes of warning, enabling people to take protective actions before the arrival of strong seismic waves.

2.4 Earthquakes in Malaysia

Earthquakes in Malaysia, while relatively rare compared to global seismic hotspots, represent a natural phenomenon of significant concern due to the country's growing urbanization and infrastructure development. Geographically distant from major tectonic plate boundaries, Malaysia experiences less frequent and intense seismic activity compared to the Pacific Ring of Fire. However, as outlined in the research paper “Site-Suitability Analysis on Seismic Stations using Geographic Information Systems”, the country is not yet immune to seismic events as well as public’s awareness.

The research paper also includes that in Peninsular Malaysia, which lies on the stable Sunda Trench, seismic activity is generally low to moderate. Occasional tremors felt on the west coast are mostly attributed to distant earthquakes in Sumatra and the Andaman Sea. Local earthquakes, such as those in areas like Bukit Tinggi and Kuala Pilah, are typically minor, with magnitudes usually less than 4 Mw, and have not caused significant damage. In contrast, East Malaysia, particularly Sarawak, experiences more frequent earthquake activity. Local earthquakes from faults like Kelawit and Bukit Mersing are among them, as are distant earthquakes from the southern Philippines and the Celebes Sea. From 1874 to 2011, historical records show seismic events in Sarawak reaching up to VI on the MMI scale and magnitudes as high as 5.3 Mb. This data indicates that similar magnitude earthquakes are likely every 6-7 years.

While significant earthquakes in the last decade have not been a major concern in Malaysia, the potential for destruction escalates with increasing population density and ongoing development in building and infrastructure. This reality has encouraged Malaysian authorities and researchers to conduct a more complete investigation into the consequences of seismic activity. Collaborative initiatives, such as those undertaken by University Malaysia Sabah (UMS) and the Malaysian Meteorological Department, highlight the importance of earthquake-resistant structural designs, particularly in seismically active locations such as East Malaysia.

2.5 Understanding Roll, Pitch and Yaw

Roll, pitch, and yaw are essential features in motion detection and orientation. Roll refers to the rotation around the longitudinal axis, pitch is the up or down rotation around the lateral axis, and yaw is the left or right of the rotation around its vertical axis. In the context of an earthquake, they are not the standard terms in seismology for describing the movement of the ground itself, they are more focusses on the epicenter, magnitude and depth. Therefore, the three parameters can provide valuable insights into the nature of the seismic activity. An accelerometer can detect and measure the multi-directional pressures exerted during an earthquake by monitoring changes in roll, pitch, and yaw [5].

The purpose of these orientation factors becomes critical when combined into a solar-powered seismic detector. During an earthquake, the ground movement causes shifts in these parameters, which the accelerometer captures. By analyzing these shifts, the system can not only detect the occurrence of an earthquake but also infer its intensity and direction of movement.

2.6 NodeMCU ESP Microcontroller

Recent improvements in microcontroller technology have had a considerable impact on the Internet of Things (IoT) area, with Espressif Systems' ESP8266 and ESP32 being notable contributors (Smith, 2021; Johnson, 2022). The most commonly used ESP (Electronic Stability Programs) microcontrollers are the ESP8266 and ESP32. These microcontrollers, like in figure 2.3, they stand out for their Wi-Fi capabilities, affordability, and open-source support, making them ideal for various applications ranging from simple DIY projects to complex IoT solutions.

The ESP8266 is a popular choice for amateurs and projects with restricted budgets or processing requirements due to its low cost and Wi-Fi functionality and has become a standard in IoT applications for amateurs and low-cost projects (Brown, 2020). It contains a single-core processor, fewer GPIO pins, and one analogue input, making it appropriate for simpler applications. However, its processing power and I/O options are severely limited.

In contrast, the ESP32 offers a dual-core processor, a larger number of GPIO pins, and integrated Bluetooth, along with Wi-Fi. It supports more complex and demanding applications, but this comes with a slightly higher cost and increased power consumption. The ESP32's advanced features, such as touch sensors and cryptographic hardware acceleration, make it more versatile, although it might present a steeper learning curve for beginners compared to the more straightforward ESP8266. To conclude everything, the table figure 2.3, shows the differences of the two most used ESP in the industries.

Features	ESP8266	ESP32
MCU	Xtensa Single-Core 32-bit L106	Xtensa Dual-Core 32-bit LX6 600 DMIPS
Frequency	80 MHz	80-240 MHz
Wi-Fi	802.11 b/g/n	802.11 b/g/n
Bluetooth	No	BL v4.2, BLE
SRAM	160 kB	512 kB
Flash	SPI Flash, up to 16 MB	SPI Flash, up to 16 MB
GPIO	17	36
HW/ SW PWM	No/8 channels	1/ 16 channels
SPI/I2C/I2S/UART	2/1/2/2	4/2/2/2
ADC	10 bit	12 bit
CAN	No	1
Ethernet Mac interface	No	1
Touch sensor	No	Yes
Temperature sensor	No	Yes

Figure 2.3: Comparison of ESP8266 and ESP32

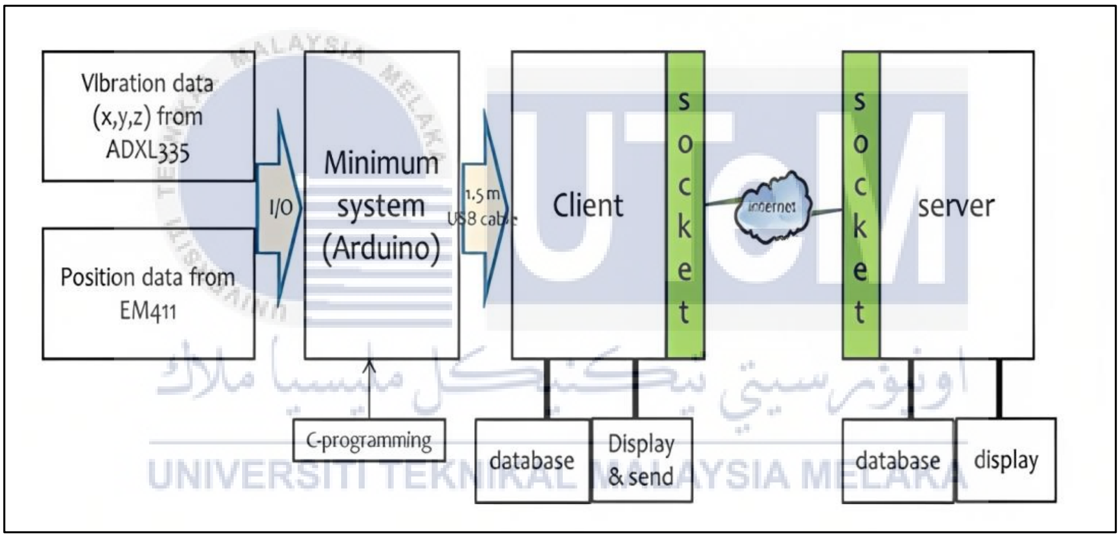
2.7 Development of Earthquake Early Warning System Using ADXL335 Accelerometer

This research paper focuses on developing an earthquake early warning system in Indonesia, an archipelago located in three earthquake belts. Due to the constant threat of earthquakes and the potential risks to human life, there are few aims of this study. It is to create an earthquake early warning system, making calibration of ADXL335 to obtain reference of vibration occurrence, how to handle loss or error occurred when data sent to the server, and also how to make transmission of data from sensor to client and client to server [6].

The researchers utilize the design of this project earthquake sensor system that consists of both hardware and software. The ADXL335 accelerometer used as seismic sensors, combined with an Arduino minimum system. Based from the Figure 2.4 below, two sensor data will be collected which is the location data from the EM411 and the vibration data (x, y, and z) from the ADXL335. The Arduino will first collect location data and input it into a port. It will collect vibration data (x, y, and z) and store it in a buffer for calibration. With the supplied zero_G and scale settings, the Arduino will calibrate the data in the buffer. When the sensor is stationary and not in reverse, the axis value is zero_G, and the scale represents the average change in all the axes.

The results show that the system is operating successfully. The ADXL335 sensor detects P wave data during the initial tremors of an earthquake. This data is then buffered, calibrated, transferred, and displayed on the server. To assure data accuracy in the event of transmission faults, the server starts a retransmission request.

Figure 2.4: Full block diagram of the project's earthquake sensor



2.8 Solar-Powered Microcontroller-Based Earthquake Detector with Automatic Alarm System

The system addresses the need for a cost-effective and sustainable solution for earthquake detector that can be deployed in areas with limited access to power supply [7]. The study emphasises the use of solar energy as a source of power for the earthquake detection system, highlighting its benefits such energy efficiency and grid independence. Even in remote or off-grid places, the system can run constantly by utilising solar energy. The core component of the system is a microcontroller, which serves as the central processing unit for data collection, analysis, and triggering the alarm system. When the microcontroller-based earthquake detector detects a ground motion of the predetermined intensity levels, it will broadcast a sound to alert individuals in the vicinity of the earthquake occurrence. The article emphasizes the system on the importance of having its own electricity-generating system to provide power. As a result, the system will continue to operate in the event of a power interruption before, during, or after the earthquake. Finally, this system makes sure that alerts are sent out promptly to lessen potential hazards and increase people's safety in areas that are prone to earthquakes.

2.9 A Smart IoT Device for Detecting and Responding to Earthquakes

The device which was developed by this system focuses on developing an earthquake alert device that can identify earthquakes and respond to them quickly to prevent fatalities and property damage [8]. Internet of Things (IoT) technologies nowadays also provide services and build powerful smart systems to analyse and monitor several real time systems [9]. IoT means a system of interrelated computing devices. Moreover, the stand-alone sensor was carefully select by comparing four sensor's acceleration to be the best sensor to be used. The decision made must adhere to the standards of dependability and accuracy while being the low-cost device. Between four acceleration sensors: ADXL355, LIS3DHH, MPU9250 and MMA8452, the most suitable sensor for the stand-alone earthquake detector device is the LIS3DHH sensor.

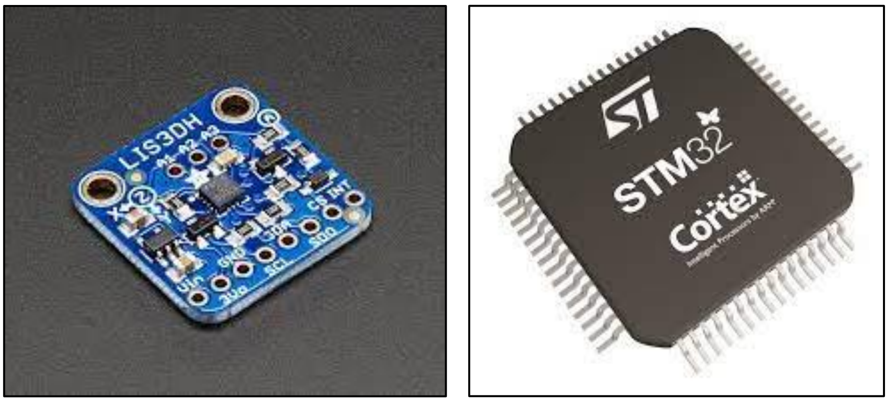


Figure 2.5: Main devices used in Smart IoT Earthquake device

(Left: LIS3DHH Sensor, Right: ARM Cortex-M3)

The created system includes a Bluetooth, Wi-Fi, a buzzer, an LED light, an ARM Cortex-M3 32-bit processor, because of its reasonable price and the manufacturer's support for development and also it has been implemented widely in the creation of numerous IoT devices over the past few years. The developed system operates as a standalone detector. It uses an earthquake detection algorithm which further uses a trained machine learning model to detect the earthquake signals recorded on the accelerometer. It detects the earthquakes and immediately sends an alarm as a response to nearby users.

2.10 Development of Earthquake Detection and Warning System Based on Sensors

This study focuses on the development of an earthquake detection and warning system utilizing sensor technology. The system aims to provide real-time earthquake detection and timely warnings to minimize the potential damage caused by seismic events [10]. The researcher said that earthquake is often accompanied by fires and toxic gas leakage. So, the study proposes a methodology that combines sensor networks, data analysis techniques, and efficient communication protocols to achieve accurate and rapid earthquake detection. They include the earthquake detector plus with the MQ series sensors and also the flame sensors for the proposed designed system to ensure the safety of people when earthquakes occur.

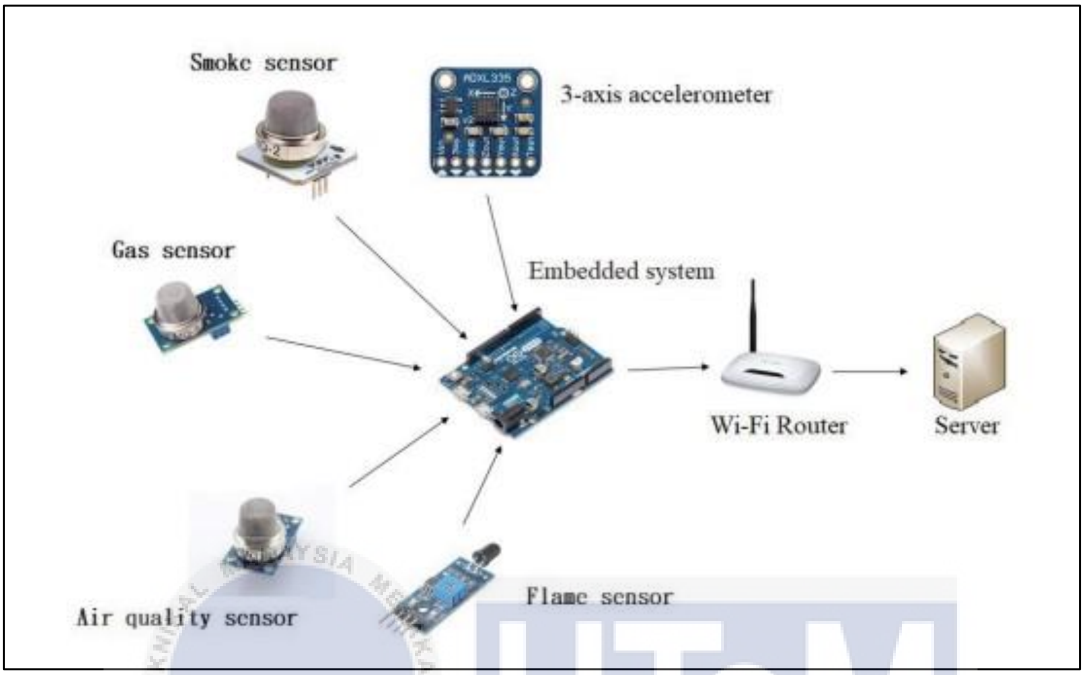


Figure 2.6: The architecture of the proposed system

Based from the Figure 2.6 above, the data centre or also known as server, used to build up the database system required for the design, store sensor data, and act as a monitoring interface to show data and respond to requests. The embedded system uses Arduino as its core. The sensing modules in the system are seismic and building tilt sensor modules, which use an ADXL345 three-axis accelerometer. The MQ-2, MQ-5, and MQ-135 sensors, are used to detect smoke, gases, and air quality accordingly, and the IR flame sensor, which is used to detect flames.

2.11 Comparison of Previous Project

Some research that had been done through the previous project, journals, articles and books to gather more information on this titled project. The Table 2.2 below shows the summary and comparison of the previous journal related to this project development.

No	Title	Summary	Applications	Benefits
1.	A Smart IoT Device for Detecting and Responding to Earthquakes [8]	They present an intelligent IoT device that can detect shaking caused by an earthquake and then send out appropriate warning messages according to the strength of shaking. The developed system operates as a standalone detector. It uses an earthquake detection algorithm which further uses a trained machine learning model to detect the earthquake signals recorded on the accelerometer. It detects the earthquakes and immediately sends an alarm (response) to nearby users.	Home Earthquake Appliances	• Make comparison of the best acceleration sensors. • Wise choosing device used. • Affordable equipment's used.
2.	Solar-Powered Microcontroller-based Earthquake Detector with Automatic Alarm System [7]	By leveraging microcontroller technology and sensor data analysis, the system provides accurate and timely information about seismic events, enhancing public safety and enabling effective emergency response strategies. The proposed solution presents a cost-effective and scalable earthquake detection system that can be deployed in various geographic regions.	Home / Public Appliances, Alarms	• Solar-powered sustainability. • Real-time earthquake detection. • Automatic alarm system.

		The integration of solar power ensures the system's independence from the electrical grid, making it suitable for remote or disaster-prone areas. The study concludes by emphasizing the importance of continuous improvement and evaluation of the system's performance to enhance its effectiveness in earthquake monitoring and alerting.		
3.	Development of Earthquake Early Warning System Using ADXL335 Accelerometer [6]	The research paper focuses on developing an earthquake early warning system in Indonesia, an archipelago located in three earthquake belts. Due to the constant threat of earthquakes and the potential risks to human life, the study aims to create a quick and accurate system using seismic wave data processing. The researchers utilize ADXL335 accelerometers as seismic sensors, combined with an Arduino minimum system.	Public Safety and Emergency Management (enable the execution of safety precautions), Infrastructure Protection	• Quick and accurate detection; using ADXL335. • Reduced casualties; by providing early warnings, potentially saving lives. • Preventing false requires data consistency from several sensors before setting off the alarm.

4.	Development of Earthquake Detection and Warning Systems using Sensors [10]	The development of this system is to create systems that can detect earthquakes and issue alerts in order to reduce any possible damage they may cause. In order to accomplish reliable and quick earthquake detection, the research proposed a system that integrates sensor networks such as fire and gas sensor, data analysis strategies, and communication protocols. They establish it due to the after-effect of the earthquake which can save more lives in the future hopefully.	Home appliances, Public Safety and Emergency Management.	• Taking measures of safety cautiously. • Early warning capability.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This project's exploratory technique offers a methodical approach to creating an efficient and reliable device. This methodology is essential for defining on the hardware used, software development and testing procedures. The methodology for the earthquake detector project outlines a structured approach to designing, developing, and implementing a solar-powered earthquake monitoring system using the ESP32 module. A well-defined methodology ensures that the results or outcomes obtained are reliable and successfully be implemented. The waterfall methodology also known as waterfall model, were mostly implied throughout this project, where it is a sequential approach to the software development lifecycle (SDLC) that flows like a waterfall through all phases of the project (analysis, design, development, testing and maintenance). The methods such as the Gantt Chart, Flow Chart and the functionalities of each components used for the system are all included and will be explained in the content.

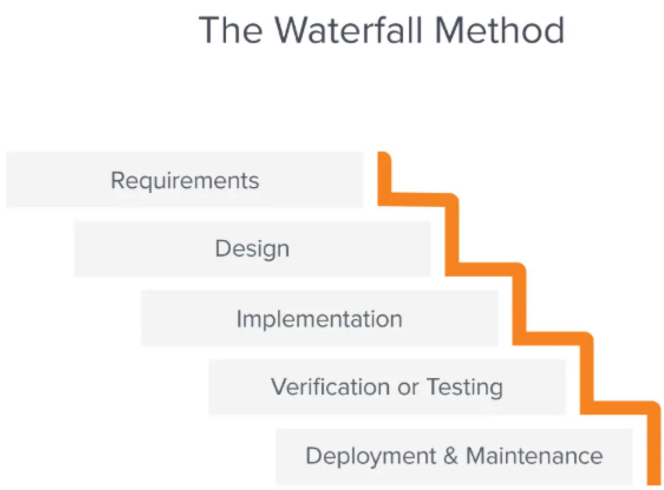

Figure 3.1: The waterfall stages apply in a project as an example

3.2 Process Workflow

The progress of this project will be covered in this section. There are few methods involved in this project involving ESP32, measures the tilt-sensing applications in the static acceleration of gravity, and movement, shock or vibration due to dynamic acceleration for giving the early alarm warning. For detecting the vibrations of earthquake, an ADXL335 sensor that robust against noise and high sensitivity are placed. To represent a higher level of understanding, a flow charts construction and block diagrams will be displayed.

3.2.1 Block Diagram

The illustration as shown as Figure 3.2 is the block diagram combines the hardware components that connected by lines or arrows to describe process, which also shows the input, process and output for the earthquake detector project. It also demonstrates that the electric current is generated by the solar panel when solar energy is transformed into electric energy. This electric current is then stored in the 12V rechargeable battery and utilised to power the ESP32 microcontroller by using the USB Boost Step-Down Voltage Regulator. The microcontroller will be interfacing with the ADXL335 GY-61 Accelerometer using the Arduino IDE platform. The ESP32 board also is connected to the Buzzer alarm, LCD display and the solar panel. So, when the ADXL335 accelerometer detects high tremor, the ESP32 alert and the buzzer will be alarmed as well as sends message notifications to the residents' user mobile phone through Telegram applications.

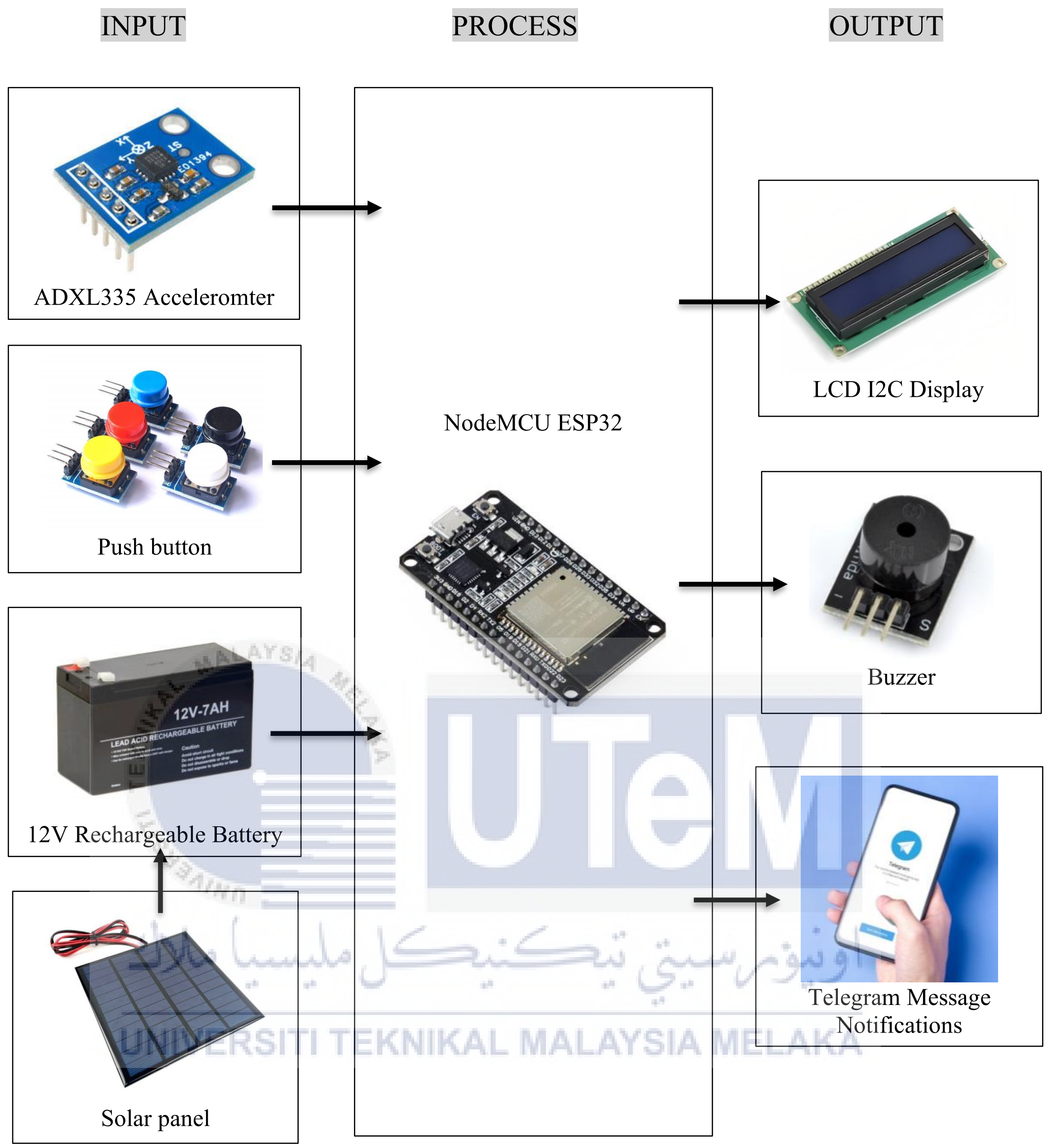

Figure 3.2: IPO diagram representing the earthquake detector system

3.2.2 Flowchart

Flowchart plays a crucial roles in a process of a project, offering both a graphic representation of a process and a framework for its analysis and improvement. It is widely used in the fields of development like in engineering, software development for planning and more. It also offers clear, visual presentations of project's procedure which simplifying the complex procedures. By highlighting the key steps, flowcharts are a valuable tool for process optimization and standardization since they help to detect inefficiencies and emphasize crucial steps, so guaranteeing the consistency and quality control of a project.

For Figure 3.3 shows the block diagram of how solar power worked in this system. This earthquake detector uses the solar power systems where the solar power operates by converting sunlight into electricity using solar panels composed of photovoltaic cells. When sunlight strikes these cells, it triggers the photovoltaic effect, causing electrons to be freed and create an electric current (direct current) and being controlled by the solar charger. This solar power can be stored in batteries, making this system a reliable renewable resources to environmental preservation.

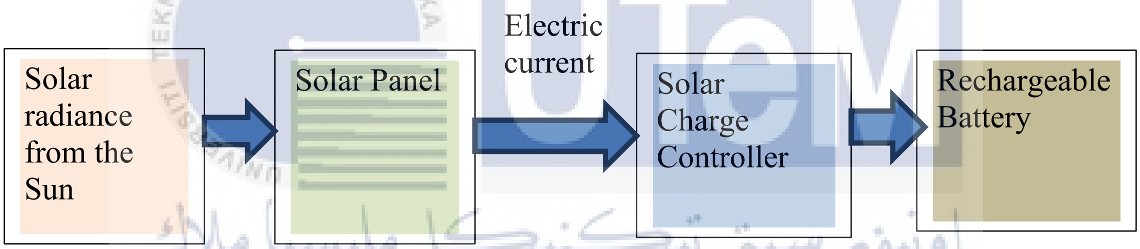

Figure 3.3: Solar power block diagram

Based from the Figure 3.4 below, shows the flowchart of earthquake detector system. The ESP32 microcontroller and ADXL335 accelerometer sensor that are connected to each other, began initializing and connecting to WiFi network. Within the main loop, the system continuously checks the state of the button. Concurrently, it reads the X, Y, and Z analog values from the accelerometer. These numbers are then utilised to compute the device's orientation in terms of roll, pitch, and yaw angles.

An alarm is generated when there is a large change in the roll angle, specifically an increase of more than 40 degrees from the preceding reading. If this is the first instance of such a change (controlled by the variable 'con'), the system updates the status to "Danger", activates the buzzer, and sends an earthquake alert message to a predefined user via Telegram. To prevent multiple alerts for the same event, the variable 'con' is set to 1. If the roll change is not significant, 'con' is reset to 0.

Additionally, the system updates an LCD display with the current roll value and the system's status. This display process happens with each loop iteration, providing real-time feedback. The loop has a 1-second delay at the end of each iteration to moderate the reading frequency. It is at the end of loop, so the system will continue running until it is powered off.

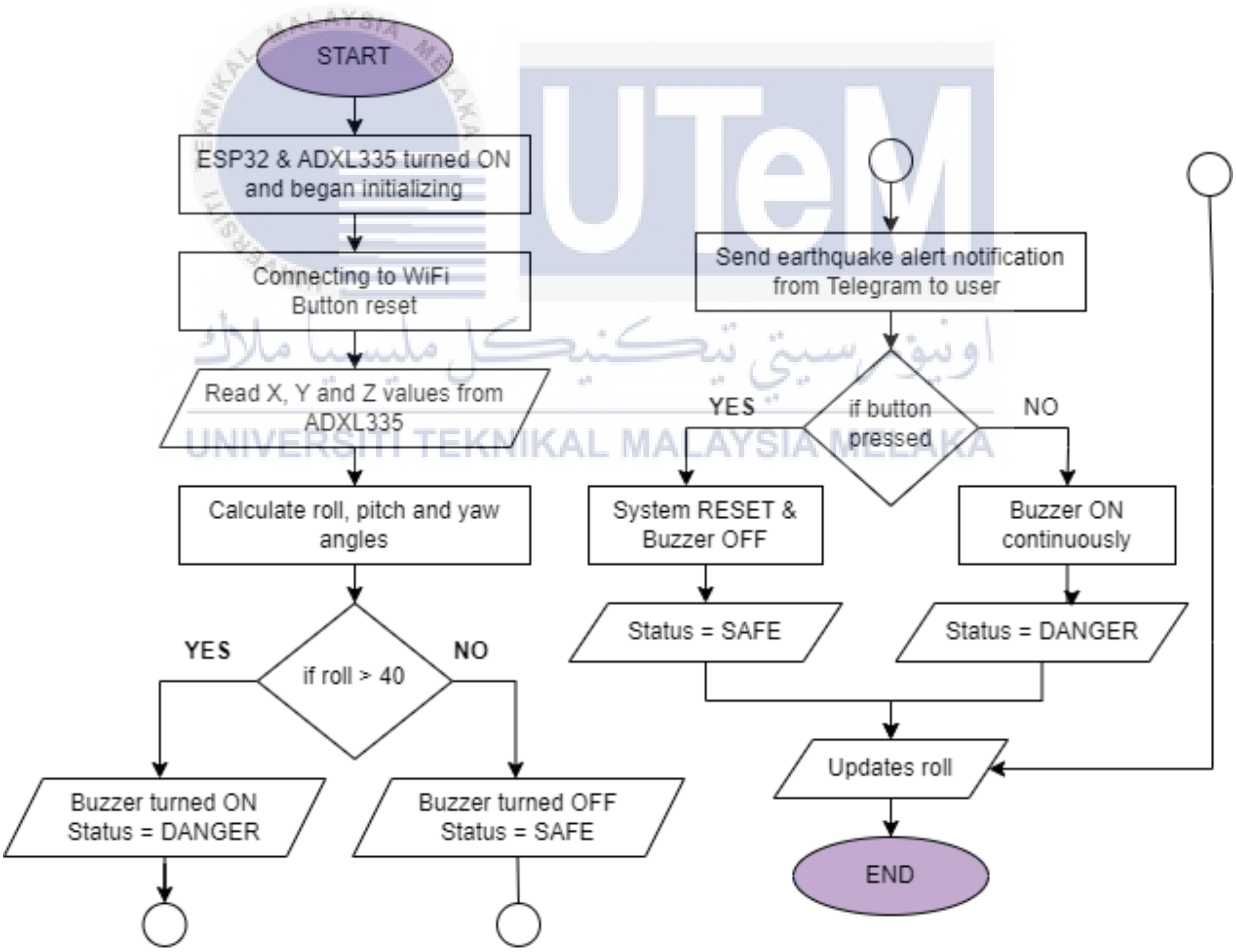

Figure 3.4: Flowchart of the earthquake detector system

3.3 Hardware Component Requirement

This section covers the whole framework's execution of the project, from ESP32 board and to other hardware parts. Each of the hardware components have a distinct function and together they will work in unison to enabled performing a wide range of task for this project.

3.3.1 NodeMCU ESP32 Microcontroller

Figure 3.5 illustrates the ESP32 microcontroller, highlighting its pinout specifications. The choice of the ESP32 microcontroller, specifically the ESP-WROOM-32 module powered by Espressif Systems' ESP32 chip, as a core component for the solar-powered earthquake detector is strategic due to its robust capabilities and suitability for complex IoT applications, such as smart homes, wearable health monitors, and automated factories. It boasts built-in Wi-Fi and Bluetooth features, including energy-efficient BLE, making it ideal for tasks requiring remote data transmission and control, which are crucial for sending timely alerts on seismic events.

Furthermore, it stands out for its extensive array of GPIO (General Purpose Input/Output) pins that supports variety communications protocol like SPI, I2C, and UART. While it doesn't have built-in USB ports, it can be programmed via USB-UART. This allows for a flexible and versatile sensor integration and data handling. The NodeMCU ESP32 board is particularly advantageous for this project due to its cost-effective implementation and optimized energy efficiency, which significantly reduces power consumption.

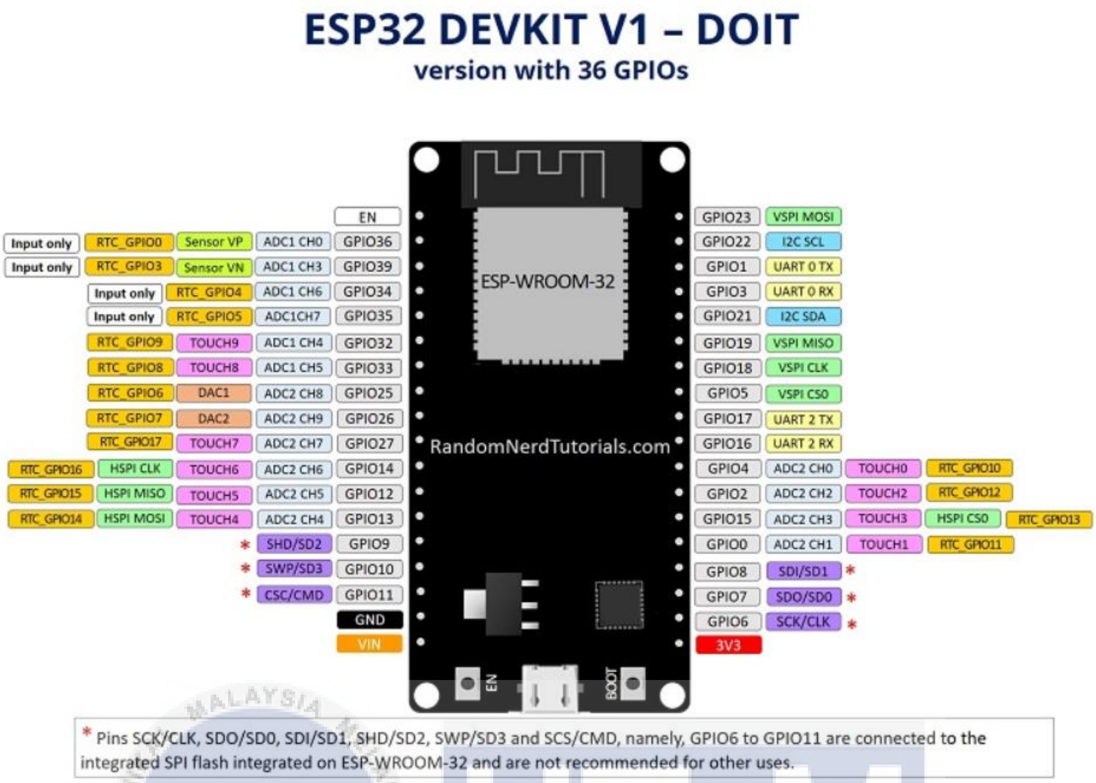

Figure 3.5: ESP-WROOM-32 Microcontroller with specifications and pin diagram

3.3.2 ADXL335 Accelerometer

The ADXL335 (GY-61) accelerometer is one of the components in a wide range of applications due to its ability to measure acceleration forces on three orthogonal axes: X, Y and Z. This feature is particularly beneficial in applications like earthquake monitoring, where it can discern acceleration and tilt across multiple planes. The ADXL335, like in Figure 3.7 below, is highly effective in sensing dynamic (motion or shock) and static (gravity) accelerations. Its significance is anchored in its versatility and reliability to furnish real-time data regarding orientation, tilt, and motion. Each of the axis has an output pin, allowing for the reading of analogue voltage values independently. Last but not least, ADXL335 is designed to operates on a supply voltage between 1.8V and 3.6V. The compact size of accelerometer allows for easy integration into various systems, while its low power consumption makes it suitable for battery-operated devices. This project where ADXL335 accelerometer sensor able to communicates with ESP32 microcontroller via the I2C (Inter-Integrated Circuit) protocol further enhances the sensor's efficiency.

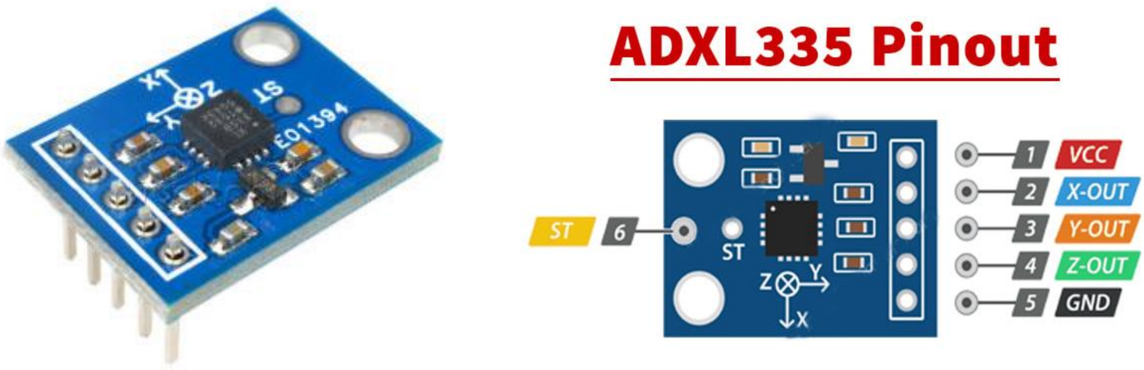

Figure 3.6: ADXL335 Accelerometer

3.3.3 Photovoltaic (PV) Panel

Figure 3.8 shows the Photovoltaic (PV) panels which usually referred to as solar panels, are devices that change sunlight into usable electrical energy. They are widely utilized to generate electricity for home, commercial, and industrial uses and play a key role in absorbing solar energy. When exposed to sunlight, solar panels generate direct current (DC) electricity. This direct current (DC) energy can be utilized to power electrical equipment directly, recharge batteries, or be transformed into alternating current (AC) by an inverter for use in conventional electrical systems.

Figure 3.7: Solar panels 12V

3.3.4 Voltage Regulator Step-Down

A DC-DC voltage regulator buck module is a versatile and efficient component used in electrical circuits to step down voltage from a higher to a lower level while keeping a constant output voltage. These modules are based on the buck converter theory, which reduces voltage by switching, storing energy in inductors, and filtering voltage, to be specifically it is a step down of 12V to 5V. It is in the connection between the solar charger output with the connection to the microcontroller

Figure 3.8: DC-DC Boost Converter Module with USB

3.3.5 16x2 I2C LCD Display

A 16x2 I2C LCD display is made up of two modules: an I2C module and a 16x2 LCD module. This Liquid Crystal Liquid (LCD) is utilized because it has two lines with 16 characters each, allowing it to display a total of 32 characters on the LCD screen, as illustrated in Figure 3.10. The I2C module includes a 16x2 LCD module, which helps to reduce the use of GPIO pins on the ESP32. There are four input signals in total: input, ground, clock signal (SCL), and data signal (SDA). The backlight's contrast can be changed by gently twisting the tiny trim potentiometer. It is used to show all messages, including

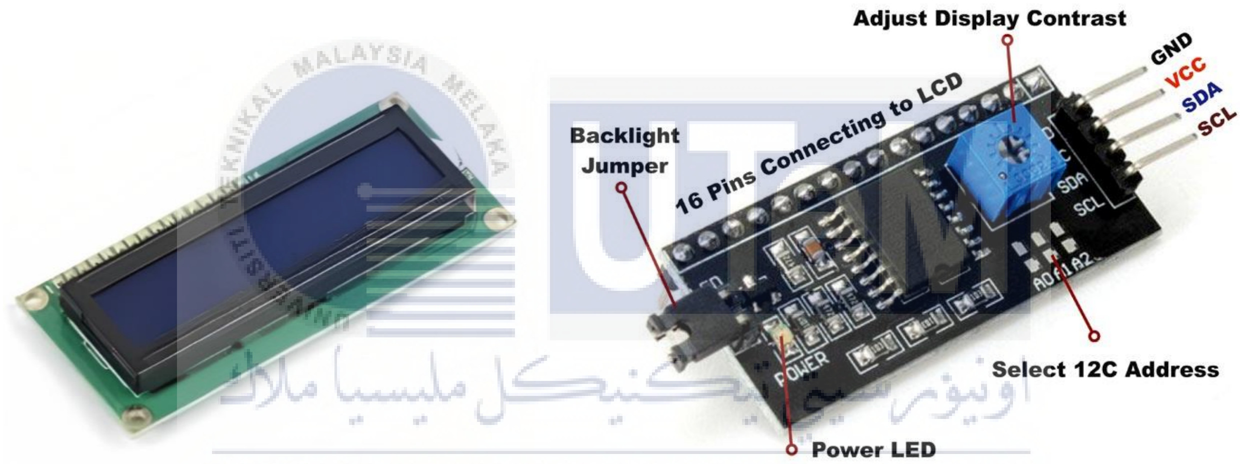

Figure 3.9: LCD and I2C pinouts

3.3.6 12V Rechargeble Battery

Figure 3.11 shows the 12V rechargeable battery which is a versatile and essential power source widely used in various applications, such as in automobiles, solar power systems, emergency lighting, and portable electronic gadgets. This feature not only makes it cost-effective by eliminating the need for frequent replacements but also renders it more environmentally sustainable compared to single-use batteries. In the context of an earthquake detector, the ability to recharge and reuse the battery aligns perfectly with the solar-powered design, ensuring a continuous and reliable power supply. Last but not least, their capacity to store substantial amounts of energy is another key factor, as it ensures that the earthquake detector can remain operational for extended periods, even in the absence of sunlight to power the solar panels.

Figure 3.10: 12V rechargeable battery

3.3.7 Buzzer (Passive)

A buzzer is a simple yet indispensable electronic component widely used in numerous applications for generating sound. Buzzer, such as shown in Figure 3.12, utilized to emit a loud noise as a signal for alert or warning. They are commonly used in alarm devices, timers, confirmation or alert sounds in electronic devices. It is the main output devices used in this system that helps to notify the user when earthquake happens.

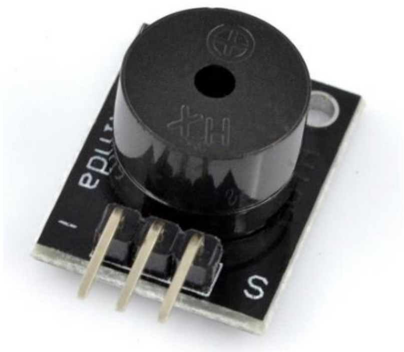

Figure 3.11: Passive buzzer use in this system

3.3.8 Push Up Button

Push buttons are versatile components in electronic devices and machinery, serving various critical functions. They primarily function as switches, establishing or breaking electrical connections and managing start/stop operations in machinery and electronic equipment. On this context of the system, the push button act as the reset button to status SAFE and will turns OFF the buzzer.

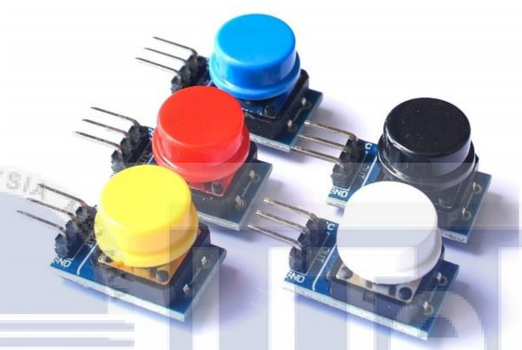

Figure 3.12: Push button module

3.4 Arduino IDE (Integrated Development Environment)

The Arduino IDE (Integrated Development Environment) is a valuable tool, even when not using Arduino hardware, due to its user-friendly interface, simplicity, and flexibility in programming microcontrollers. It supports a variety of languages, including C and C++, and provides a low barrier to entry for those new to coding and electronics. The IDE can programme a wide variety of microcontrollers and development boards, making it an excellent alternative for a variety of projects.

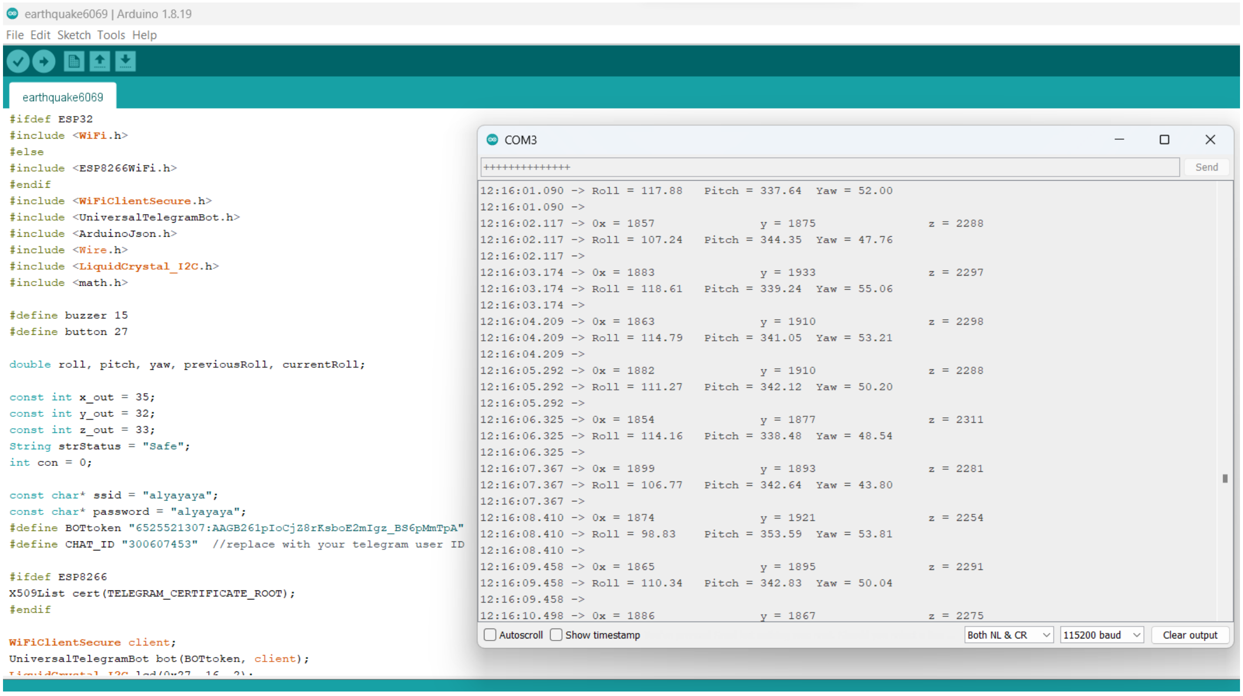

Figure 3.13: Earthquake detector system in Arduino IDE

Based from the figure 3.14, after initialized, it illustrates the analogue input for roll and also it status from the LCD display and Serial Monitor of Arduino IDE. If the roll of previous – current roll is more than the treshold of 40, the LCD will display 'Status = DANGER' and buzzer will automatically turned ON.

3.4.1 Defining NodeMCU Pins

NodeMCU ESP32 has been used for this system and the table 3.1 below, shows the components and its attached pins to the ESP32. Generally, the ESP32 has 34 General-Purpose Input/Output (GPIO) pins allowing it to interface with larger number of sensors or electronic devices.

Table 3.1: Electronic Devices and Pin attached to NodeMCU ESP32

Electronic Devices	Pin Attached
ADXL335 Accelerometer Sensor (X,Y,Z, VCC, GND)	D35, D32, D33, 3V3, GND
16x2 I2C LCD Display (SDA, SCL, VCC, GND)	D21, D22, Vin, GND
Buzzer (S, +, -)	D15, 3V3, GND
Button (VCC, OUT, GND)	Vin, D27, GND

Based from the table above, the ADXL335 accelerometer sensor uses the pin X-OUT, Y-OUT and Z-OUT where it is connected to the analog input pins of pins D35, D32 and also D33 on the ESP32. The analog readings from the X-OUT, Y-OUT, and Z-OUT pins are taken using analogRead(). These readings are then converted to 'g' values (gravitational acceleration). Based on these values, the orientation of the device in terms of roll, pitch, and yaw is calculated. A significant change in these values (particularly roll) is used as an indication of an earthquake or similar large movement.

3.4.2 Defining Solar Panels Pins

Each solar panel is made up of several solar cells connected in series within the panel. These cells are made of semiconductor materials such as silicon, which create energy when exposed to sunlight using the photovoltaic effect. The series connection boosts the voltage to the required level, whereas parallel connections increase the current.

Solar batteries are integrated into energy-storage systems. These batteries store extra energy generated during the day for later usage at night or during periods of low sunlight. A charge controller regulates the flow of electricity into and out of the batteries, preventing them from overcharging or draining excessively. The figure 3.15 below, shows of how the solar panels work.

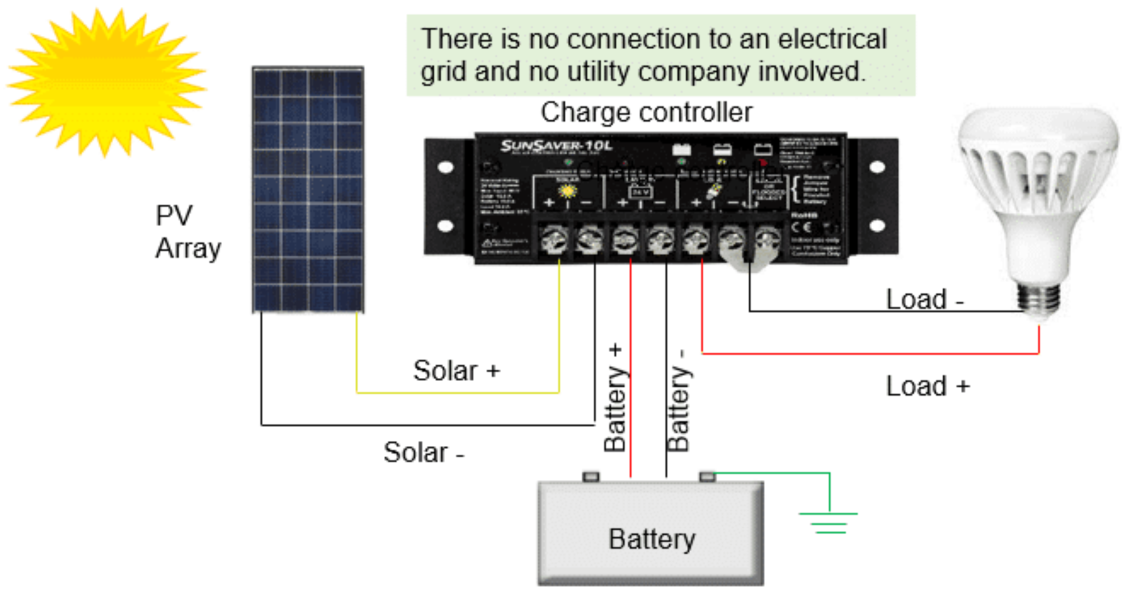

Figure 3.14: The connection of how solar panels work

3.4.3 WiFi Setup Function

The WiFi setup function, like in figure 3.15, of the NodeMCU ESP32 will be executed once it is powered on. The code initialize by the conditional compilation to import the WiFi libraries such as #include <WiFi.h> for the ESP32 and #include for the ESP8266. It also includes other essential libraries like WiFiClientSecure.h for secure HTTPS connections, UniversalTelegramBot.h for interacting with the Telegram Bot API, ArduinoJson.h for JSON parsing, a common data interchanging format, which often used in web APIs including Telegram. The Wi-Fi connection is initialized with WiFi.mode(WIFI_STA); and WiFi.begin(ssid, password);, where ssid and password should be predefined with your network credentials. For the ESP32, there's an additional line, client.setCACert(TELEGRAM_CERTIFICATE_ROOT);, which is crucial for establishing a secure SSL/TLS connection to Telegram's servers. The connection process involves a loop that continues until the ESP module successfully connects to the Wi-Fi network, indicated by WiFi.status() != WL_CONNECTED. Once connected, the ESP's IP address is output to the Serial Monitor with Serial.println(WiFi.localIP());.

```
#ifdef ESP32
#include <WiFi.h>
#else
#include <ESP8266WiFi.h>
#endif
#include <WiFiClientSecure.h>
#include <UniversalTelegramBot.h>
#include <ArduinoJson.h>

WiFiClientSecure client;

 // Connect to Wi-Fi
  WiFi.mode(WIFI_STA);
  WiFi.begin(ssid, password);
#ifdef ESP32
  client.setCACert(TELEGRAM_CERTIFICATE_ROOT); // Add root certificate for api.telegram.org
#endif
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi..");
  }
  Serial.println(WiFi.localIP());
}
```

Figure 3.15: WiFi Setup code

3.4.4 Setup Loop Function

The function starts by reading the state of a button (digitalRead(button)) and printing its state to the Serial Monitor. If the button is pressed (detected by if (bt == 1)), the strStatus is set to "Safe", and the buzzer is turned off as it write LOW.

The next block of code reads values from an accelerometer connected to analog pins (x_out, y_out, z_out). These values represent the acceleration along the X, Y, and Z axes. The raw analog values are then converted to acceleration in 'g' units (gravitational force units). The conversion takes into account the ADC (Analog to Digital Converter) resolution and the specific characteristics of the accelerometer (like sensitivity and zero-g bias). Using the acceleration values in 'g', the function calculates the orientation of the device in terms of roll, pitch, and yaw.

Furthermore, the ‘change in roll’ value were used to detect significant movement, such as that caused by an earthquake. If the change in roll (difference between currentRoll and previousRoll) exceeds a threshold which is 40, and if it's the first occurrence (con == 0), the status is set to "Danger", the buzzer is activated, and a message, “EARTHQUAKE DETECTED! PLEASE ENSURE YOUR SAFETY” is sent via the Telegram bot. This alert indicates an earthquake detection. The con variable ensures that the message and buzzer are triggered only once per event.

Lastly, the code updates an LCD display with the most recent roll value and status (lcdDisplay()), saves the current roll value for comparison in the next loop iteration, and then pauses for one second (delay(1000)), managing the rate at which the function is executed.

```
void loop() {
  int bt = digitalRead(button);
  Serial.print(bt);
  if (bt == 1) {
    strStatus = "Safe";
    digitalWrite(buzzer, LOW);
  }
  int x_adc_value, y_adc_value, z_adc_value;
  double x_g_value, y_g_value, z_g_value;

  x_adc_value = analogRead(x_out);
  y_adc_value = analogRead(y_out);
  z_adc_value = analogRead(z_out);
  Serial.print("x = ");
  Serial.print(x_adc_value);
  Serial.print("\t\t");
  Serial.print("y = ");
  Serial.print(y_adc_value);
  Serial.print("\t\t");
  Serial.print("z = ");
  Serial.print(z_adc_value);
  Serial.println("");

  x_g_value = ( ( ( (double)(x_adc_value * 3.3) / 4096) - 1.65 ) / 0.330 );
  y_g_value = ( ( ( (double)(y_adc_value * 3.3) / 4096) - 1.65 ) / 0.330 );
  z_g_value = ( ( ( (double)(z_adc_value * 3.3) / 4096) - 1.80 ) / 0.330 );

  roll = ( ( (atan2(y_g_value, z_g_value) * 180) / 3.14 ) + 180 );
  pitch = ( ( (atan2(z_g_value, x_g_value) * 180) / 3.14 ) + 180 );
  yaw = ( ( (atan2(x_g_value, y_g_value) * 180) / 3.14 ) + 180 );

  Serial.print("Roll = ");
  Serial.print(roll);
  Serial.print("\t");
  Serial.print("Pitch = ");
  Serial.print(pitch);
  Serial.print("\t");
  Serial.print("Yaw = ");
  Serial.print(yaw);
  Serial.print("\n\n");
```

```
  currentRoll = roll;
  if (currentRoll - previousRoll > 50) {
    if (con == 0) {
      strStatus = "Danger";
      digitalWrite(buzzer, HIGH);
      bot.sendMessage(CHAT_ID, "EARTHQUAKE DETECTED! PLEASE ENSURE YOUR SAFETY.");
      con = 1;
    }
  }
  else {
    con = 0;
  }
  lcdDisplay();
  previousRoll = currentRoll;
  delay(1000);
}
```

Figure 3.16: Loop functions for earthquake detector

3.5 Telegram Interface

The Telegram interface implemented is a critical component for this ESP32 microcontroller earthquake system, for remote communication and alerting. Using the <UniversalTelegramBot> library, the system is configured to interact with a Telegram bot, a feature that becomes particularly active in the event of significant orientation changes, like those expected during an earthquake. When such an event is detected — specifically when a substantial change in the 'roll' value is observed — the system triggers an alert mechanism. This approach requires sending a predefined message ("EARTHQUAKE DETECTED! PLEASE ENSURE YOUR SAFETY.") to a specified Telegram chat, for every one minute until the earthquake stops, which is identified by CHAT_ID. The bot.sendMessage(CHAT_ID, message) function is used to send this alert. Users who are linked to this bot receive instant alerts on their devices, allowing them to respond promptly to potential emergencies. This aspect of the project highlights the integration of Internet of Things (IoT) technologies with modern communication platforms to enhance safety and situational awareness.

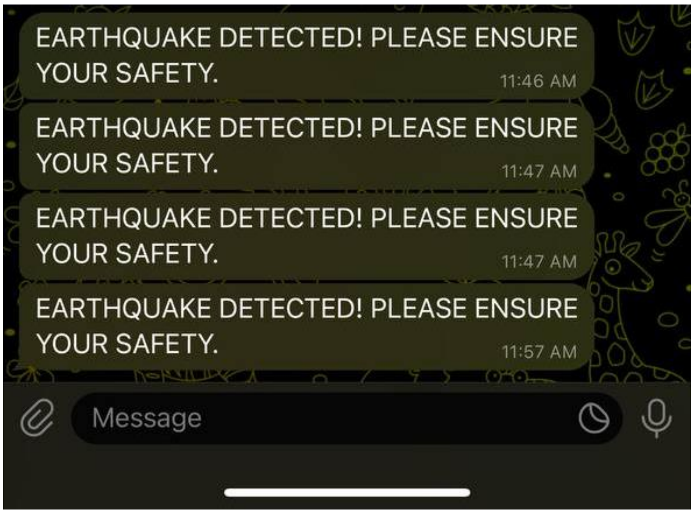

Figure 3.17: Message notifications for the alert

3.6 Project Planning

In order to execute a project on time, the project schedule and planning must be properly organized. A Gantt chart is a key project management tool that visually maps out the timeline and progress of a project. It clearly shows the start and end dates of various tasks, their sequence, and dependencies. This chart is invaluable for planning, allocating resources, and monitoring the ongoing progress of a project. To guarantee that no procedure is missed, the deadline for key schedules must be observed. As a result, Table 3.2 and Table 3.3 illustrate the FYP project activities or tasks sequence against timelines respectively.

Table 3.2 Gantt Chart for PSM1

Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Introduction & Project planning														
Chapter 2 – Literature review														
Articles and journals research														
Research for components / software														
Chapter 3 – Methodology														
Chapter 4 – Preliminary testing / Results														
Report writing														
FYP1 Presentation														

Table 3.3 Gantt Chart for PSM2

Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Buy / Receive components														
Development hardware design														
Preliminary testing components														
Development coding design														
Chapter 3 – Methodology														
Chapter 4 – Results & Discussion														
Chapter 5 – Conclusion														
Report writing														
Finalize report FYP2														
FYP1 Presentation														

3.7 Summary

To conclude for the methodology section, this chapter presents the proposed functional testing on solar-powered earthquake detector system using the appropriate components and software. This testing will be conducted, where unit testing and integration testing result must be ensured to meet all the expected output and requirements according to the aim of this project. If all the hardware and software components are linked together appropriately following the requirements, the Development of Solar-Powered Earthquake Detector Using ESP32 for Home Usage can be built.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The project of "Development of Solar-Powered Earthquake Detector for Home Usage" presented and analysed. After navigating the process of hardware testing, software testing and test of both software and hardware, the focus now changes to observing the outcomes acquired from testing under various settings. The data analysis is crucial to interpret the performance of solar system and earthquake detector as a whole.

4.2 Project Prototype

This section of the chapter explains the process throughout doing the prototype for the project. The prototype was done by using the waterproof casing box covered with lid, for component placing and the reason to choose this is because it is a home-based project, also all the components were placed inside the box to make it neater. The LCD display was placed on the lid of the casing box, so it would be easier to read. Other than that, few more holes are added for the push button and wired of battery voltage regulator to be installed neatly throughout the box. Figure 4.1 shows the casing that had being drilled and cut, for making hole, at a workshop due to lack of equipment. Figure 4.2 illustrates the view of fully assembled prototype of the solar powered earthquake detector, while Figure 4.3 shows the components, NodeMCU ESP32, buzzer and ADXL335 Accelerometer sensor that were kept inside the casing box. The other components such as 12V rechargeable battery, solar panel and also button were outside the box. Figure 4.4 shows the arrangement for the system especially solar panel to be deployed under the direct sun for the analysis to be recorded.

The last figure, Figure 4.5 exhibits the deployment of testing the earthquake detector without connecting to the power supply (battery).

Figure 4.1: Casing drilling and cutting

Figure 4.2: The overall view of prototype

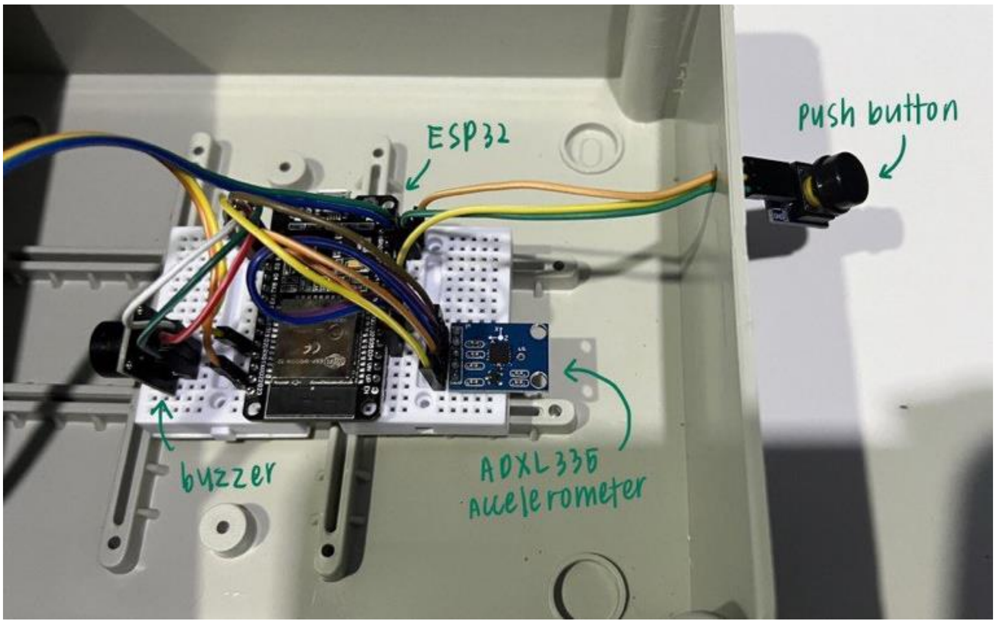

Figure 4.3: The components inside the casing box

Figure 4.4: Deployment test of the solar panel

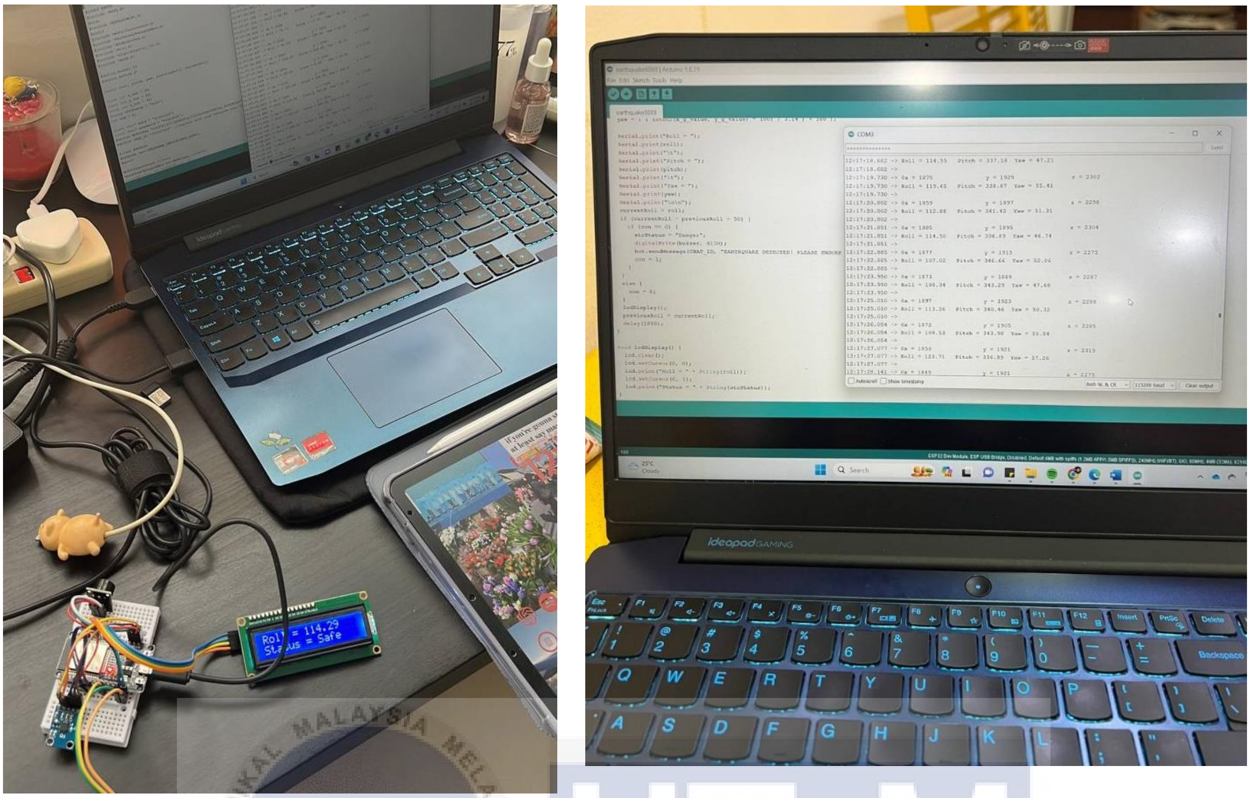

Figure 4.5: The deployment phase of earthquake detector

4.3 Results

This section talks about the output of overall system after the input power has been supplied with 12 Volts being step down to 5 Volts to the ESP32 board. The solar panel will charge the battery as it detects sunlight and the solar controller charger will blink up the values of the voltage also controls the amount of voltage to be used. Furthermore, the LCD display will turn on and displayed the roll values and status of the roll whether it is SAFE or DANGER. The figure 4.5, it is the output results that has been displayed on the serial monitor on Arduino IDE, while figure 4.6 illustrate the results on the LCD display.

Table 4.1: Coding for the solar-powered earthquake detector using ESP32 system

```
#ifdef ESP32
#include <WiFi.h>
#else
#include <ESP8266WiFi.h>
#endif
#include <WiFiClientSecure.h>
#include <UniversalTelegramBot.h>
#include <ArduinoJson.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <math.h>

#define buzzer 15
#define button 27

double roll, pitch, yaw, previousRoll, currentRoll;

const int x_out = 35;
const int y_out = 32;
const int z_out = 33;
String strStatus = "Safe";
int con = 0;

const char* ssid = "alyayaya";
const char* password = "alyayaya";
#define BOTtoken "6525521307:AAGB261pIoCjZ8rKsboE2mIgz_BS6pMmTpA"  // replace
this with your bot token
#define CHAT_ID "300607453"  //replace with your telegram user ID

#ifdef ESP8266
X509List cert(TELEGRAM_CERTIFICATE_ROOT);
#endif
```

```
WiFiClientSecure client;
UniversalTelegramBot bot(BOTtoken, client);
LiquidCrystal_I2C lcd(0x27, 16, 2);
void setup() {
        Serial.begin(115200);
        pinMode(buzzer, OUTPUT);
        pinMode(button, INPUT);
        digitalWrite(buzzer, LOW);
        lcd.begin();
        lcd.backlight();
        lcd.clear();

       #ifdef ESP8266
        configTime(0, 0, "pool.ntp.org");
        client.setTrustAnchors(&cert);
       #endif

        // Connect to Wi-Fi
        WiFi.mode(WIFI_STA);
        WiFi.begin(ssid, password);
       #ifdef ESP32
        client.setCACert(TELEGRAM_CERTIFICATE_ROOT); // Add root certificate for
api.telegram.org
       #endif
        while (WiFi.status() != WL_CONNECTED) {
         delay(1000);
         Serial.println("Connecting to WiFi..");
        }
        Serial.println(WiFi.localIP());
       }

       void loop() {
        int bt = digitalRead(button);
        Serial.print(bt);
        if (bt == 1) {
         strStatus = "Safe";
         digitalWrite(buzzer, LOW);
        }
        int x_adc_value, y_adc_value, z_adc_value;
        double x_g_value, y_g_value, z_g_value;

        x_adc_value = analogRead(x_out);
        y_adc_value = analogRead(y_out);
        z_adc_value = analogRead(z_out);
```

```
 Serial.print("x = ");
 Serial.print(x_adc_value);
  Serial.print("\t\t");
  Serial.print("y = ");
  Serial.print(y_adc_value);
  Serial.print("\t\t");
  Serial.print("z = ");
  Serial.print(z_adc_value);
  Serial.println("");

  x_g_value = ( ( ( (double)(x_adc_value * 3.3) / 4096) - 1.65 ) / 0.330 );
  y_g_value = ( ( ( (double)(y_adc_value * 3.3) / 4096) - 1.65 ) / 0.330 );
  z_g_value = ( ( ( (double)(z_adc_value * 3.3) / 4096) - 1.80 ) / 0.330 );

  roll = ( ( (atan2(y_g_value, z_g_value) * 180) / 3.14 ) + 180 );
  pitch = ( ( (atan2(z_g_value, x_g_value) * 180) / 3.14 ) + 180 );
  yaw = ( ( (atan2(x_g_value, y_g_value) * 180) / 3.14 ) + 180 );

  Serial.print("Roll = ");
  Serial.print(roll);
  Serial.print("\t");
  Serial.print("Pitch = ");
  Serial.print(pitch);
  Serial.print("\t");
  Serial.print("Yaw = ");
  Serial.print(yaw);
  Serial.print("\n\n");
  currentRoll = roll;
  if (currentRoll - previousRoll > 50) {
    if (con == 0) {
      strStatus = "Danger";
      digitalWrite(buzzer, HIGH);
      bot.sendMessage(CHAT_ID, "EARTHQUAKE DETECTED! PLEASE ENSURE YOUR
SAFETY.");
      con = 1;
    }
  }
  else {
    con = 0;
  }
  lcdDisplay();
  previousRoll = currentRoll;
  delay(1000);
}

void lcdDisplay() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Roll = " + String(roll));
  lcd.setCursor(0, 1);
  lcd.print("Status = " + String(strStatus));
}
```

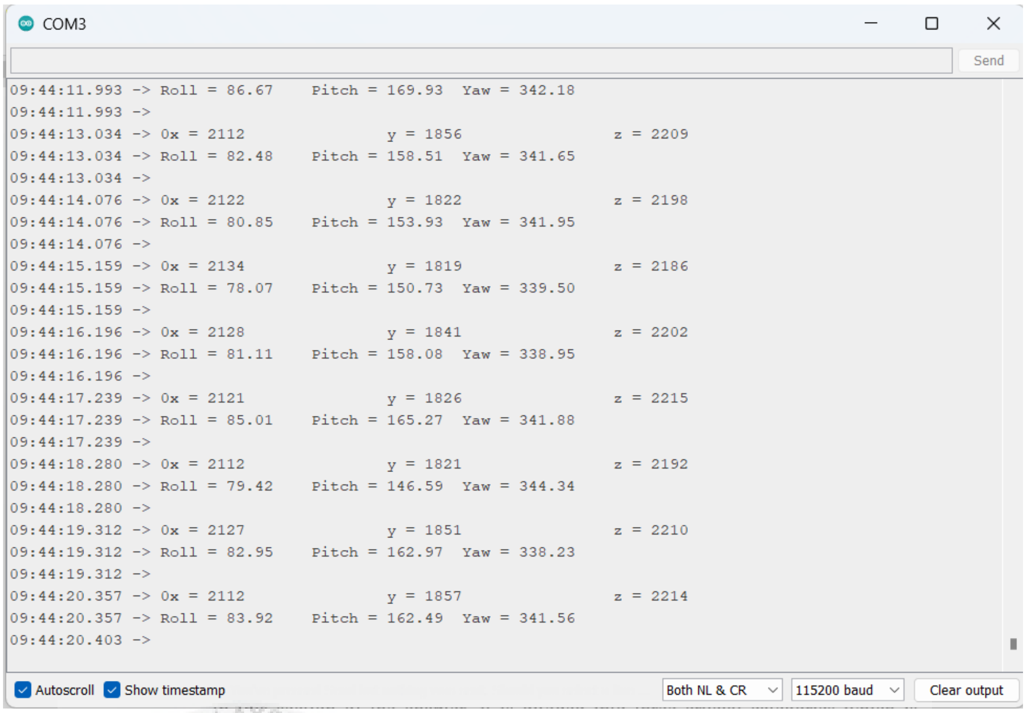

Figure 4.6: The serial monitor stated the roll results.

Figure 47.: The alert message notifications sending from ESP32 to Telegram and LCD display.

4.4 Analysis

In this section of the chapter, it is the analysis study that was conducted based on the earthquake detection with ADXL335 accelerometer sensor. Several tests have been conducted to analyse the outcome in achieving the aims of objectives.

The results or calculations of earthquake magnitude from accelerometer data isn't a straightforward conversion. It involves establishing a correlation between the readings from the accelerometer and actual earthquake magnitudes, which is usually done through empirical observation and analysis. The calculation depends on various factors, including the stability were to understand the sensitivity of the sensor to different levels of vibration were set up to check the safe level and danger level. For this project, the magnitude scaling that is relating the sensor readings to actual earthquake magnitudes through empirical calibration is quite different due to the different types of seismic waves with different characteristics.

4.4.1 Stability

Based from Figure 4.7 and Figure 4.8 below shows two different types of graph that indicates the safe level and danger level. Based from the roll that have been observed, the range of the SAFE level which is the first level of earthquake magnitude from 90 degrees to 130 degrees. The DANGER level contribute to the second level of earthquake magnitude in range from 10 degrees to 50 degrees. This level are observed based from Malaysia’s earthquake magnitude level.

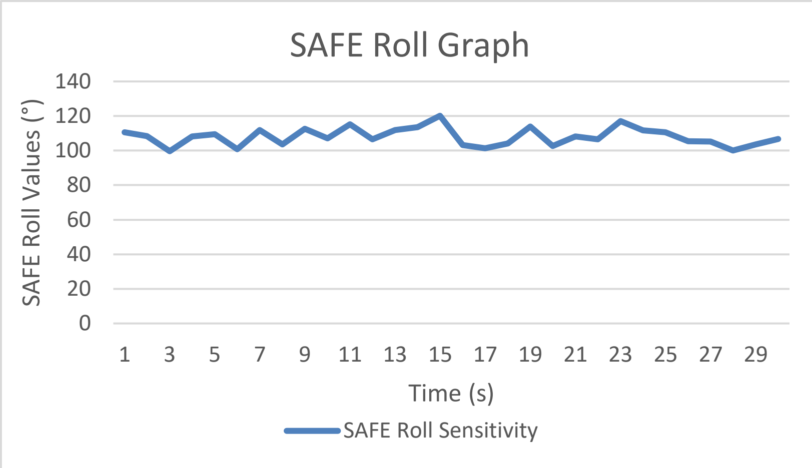

Figure 4.8: Safe Roll Values versus Time

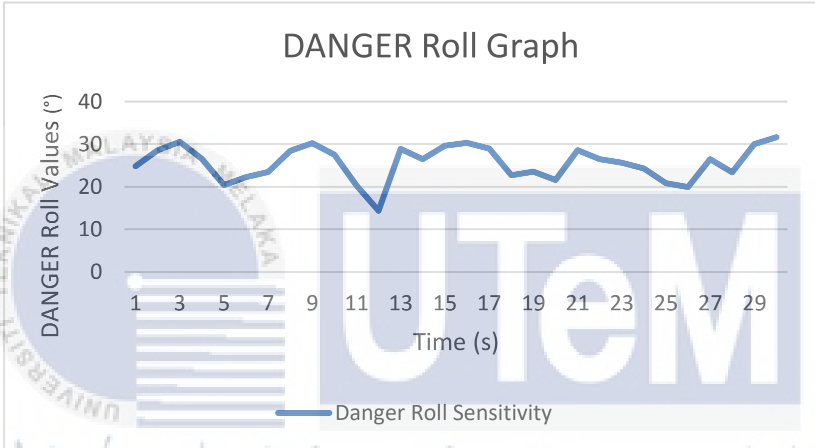

Figure 4.9: Danger Roll Values versus Time

The graph in Figure 4.8 labeled "SAFE Roll Graph," shows the SAFE Roll Sensitivity over a 30-second period. The SAFE Roll Values in degrees are represented on the vertical axis, and the time in seconds is plotted on the horizontal axis. The graph reveals that the SAFE Roll Sensitivity is quite stable, with only a minor fluctuation around a central value, and that it continuously stays within the 80 to 120-degree range during the observed period. This shows that the sensitivity is stable, with no substantial rise or reduction over time.

The graph for Figure 4.9 depicts the Danger Roll Sensitivity, which varies over the same 30-second time period. The DANGER Roll Values, which are likewise in degrees, vary from about 10 to 30. This system captured a tremor once, as you can see in Figure 4.8 at the

11th to 13th second of the period taken, and the buzzer will be triggered until the roll is safe again.

4.4.2 Battery Usage on Device System

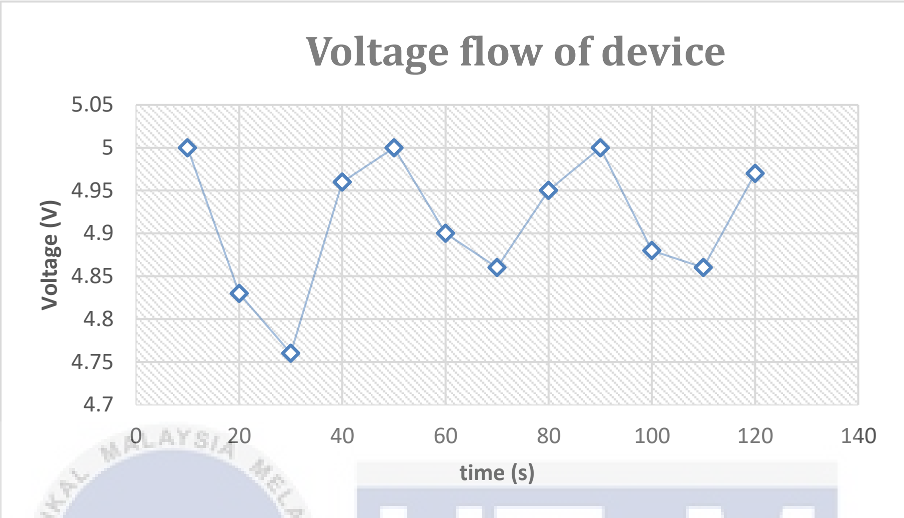

Figure 4.10: The voltage flow of device system

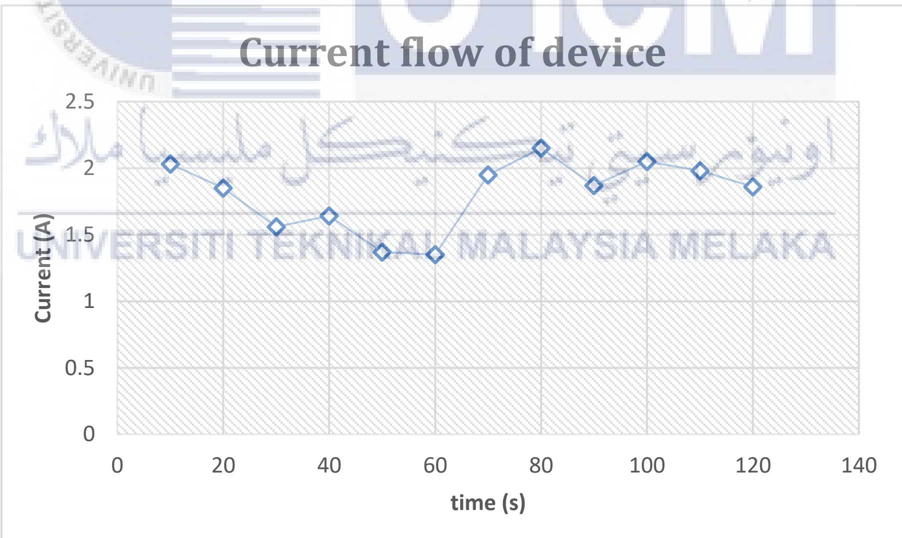

Figure 4.11: The current flow of device system

The graph in Figure 4.10 is titled "Voltage flow of device", plots the voltage in volts (V) on the vertical axis against time in seconds (s) on the horizontal axis, over a span of 140 seconds. The voltage fluctuates within a narrow range from approximately 4.7V to just over 5V. The pattern of fluctuation is somewhat regular, with the voltage peaking and dipping at nearly consistent intervals. The voltage does not show a clear upward or downward trend, indicating that the device operates with a relatively stable voltage supply within the timeframe observed.

The graph in Figure 4.11, is labelled "Current flow of device" where it shows the current in amperes (A) throughout the same 140-second timeframe. The current ranges between 1 A and around 2.5 A, with peaks and valleys that show some regularity, albeit this pattern is less stable than the voltage graph above. The current is similarly quite constant, with no discernible rising or downward pattern.

The calculation of how many hours the battery will last after being charged by the solar system which involves the consideration of capacity of the batteries and rate at using the stored energy. The estimated battery runtime (in hours) formula:

$$\boldsymbol{Battery\ Runtime} = \frac{\boldsymbol{Battery\ Capacity}\ (\boldsymbol{in\ mAh})}{\boldsymbol{Load\ Current}\ (\boldsymbol{in\ mA})}$$

- Battery Capacity - the entire amount of energy in this project is 12V, 2.6Ah
- Load Current – the amount of power consumed by the devices or appliances connected to your battery system for the system, which is commonly measured in milli-ampere (mA).
  - ❖ NodeMCU ESP32: 150mA
  - ❖ ADXL335 Accelerometer Sensor: 350mA
  - ❖ I2C LCD Display: 1.1mA

$$\begin{aligned} Load\ Current &= 150mA + 350mA + 1.1mA \\ &= 451.1mA \end{aligned}$$

$$Battery\ Runtime = \frac{2.6Ah}{451.1mA}$$

$$= 5.75hour$$

The battery system, with a capacity of 12V and 2.6Ah, can power a NodeMCU ESP32, an ADXL335 Accelerometer Sensor, and an I2C LCD Display for about approximately 5.75 hours. This estimate implies that the total load current drawn by these devices is 451.1 mA.

4.4.3 Usage of Solar Cell Charge

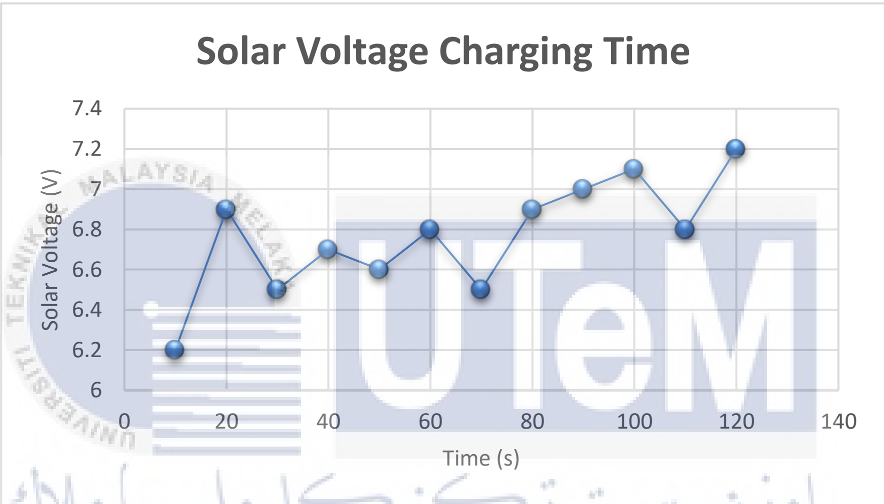

Figure 4.12: Solar Voltage Charging Time

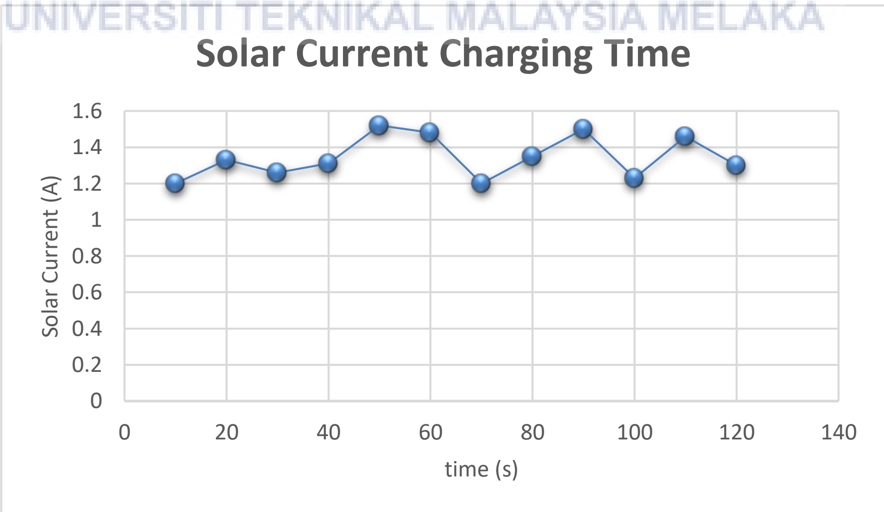

Figure 4.13: Solar Current Charging Time

The graph in Figure 4.12, titled as "Solar Voltage Charging Time" and shows the solar voltage in volts (V) on the vertical axis against time in seconds (s) on the horizontal axis. The voltage values fluctuate between approximately 6.4V and 7.2V over a period of 120 seconds. There is a general upward trend in the first half of the graph until around 60 seconds, after which the voltage experiences peaks and troughs but seems to stabilize around 7V towards the end of the measured time frame. The fluctuations could be due to changes in solar irradiance, cloud cover, or the charging state of the battery being charged by the solar panel.

The Figure 4.13 shows the graph that measures the solar current in amperes (A) over the same time period as the first. The current ranges between 1.0 and 1.5 amps. The current graph exhibits a more consistent pattern with less variability than the voltage graph. The current does not show an obvious long-term rising or dropping pattern, indicating a very stable charging current during this time frame.

These graphs show that the solar panel system provides a fluctuating but reasonably consistent voltage and current across the time period studied. The variations are common for solar panels, which can be influenced by external factors like as passing clouds, sun angle, and temperature changes.

- The battery capacity is 12V, 2.6Ah.
- Battery capacity in Watt hour, $P = I \times V$

$$P = 2.6Ah \times 12V$$

$$= 31.2\,Wh$$

- If Battery Discharge is 80%;

$$Power\ dischagre\ hours = Wh \times 80\%$$

$$= 31.2\,Wh \times 80\%$$

$$= 24.96\ Wh$$

- Pulse Width Modulation (PWM) Charge Controller (PWM:75%);

$$Solar\ Power\ Output = W\ \times 75\%$$

$$= 10W\ \times 75\%$$

$$= 7.5W$$

- So, estimated charge time:

$$hours = \frac{Power\ discharge\ hours\ (Wh)}{Solar\ Power\ Output\ (W)}$$

$$= \frac{24.96Wh}{7.5W}$$

$$= 3.33\ hours$$

To conclude the analysis, the demonstrate shows that a solar panel system with a PWM charge controller can recharge a 12V, 2.6Ah battery (equal to 31.2 Wh) in around 3.33 hours. This is assuming that the battery is discharged to 80% of its capacity (24.96 Wh) and that the solar panel, with a 10W capacity, functions at 75% efficiency due to the PWM controller, producing 7.5W of electricity. This means that the battery will charge relatively quickly and efficiently utilising solar power.

4.5 Project Limitation

- Lack of suitable locations to conduct system testing to obtain an exact level of magnitude or degrees of tremor. This is because of Malaysia's geographic location at this time, which is not prone to seismic events. As a result, the system struggles to produce an accurate finding.
- The system should reflect on another system that had calibrated their earthquake data to ensure the finding more correspond to real-world seismic event, but due to the limitation of seismic events that happened in Malaysia, the system is not the best to represent in term of accuracy.

4.6 Summary

The system under consideration here appears to be well-designed, with stable roll sensitivity being crucial for maintaining consistent performance. The device maintains a constant voltage and current, which is critical for electronic stability and endurance. The solar panel system can charge the battery in a respectable length of time, while actual performance will vary depending on climatic conditions.

To conclude, the calculated battery runtime and estimated charge time indicate that the system can sustain continuous operation for several hours and can be recharged effectively using the solar panel. However, these are theoretical values, and real-world factors such as battery age, actual load, and varying solar conditions could affect performance. It is vital to highlight that frequent monitoring and maintenance would be required to ensure that the observed performance is maintained.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

When an earthquake occurs, it takes only a few seconds available to find a safe location. It is crucial to give people early warnings, so they can seek shelter as soon as possible. They act as a constant reminder of the dynamic character of the Earth and the possible dangers of living in seismically active areas, including Malaysia in few more decades. As a result of the proposal 'Development of Solar-Powered Earthquake Detection Using ESP32 for Home Usage' is dependable solution that designed to heighten users or residents' awareness of the seismic activity that will occurs. This system was successfully designed to detect the earthquakes, triggers alarm as a signal and notify user on their mobile phones for early earthquake warnings, thereby fulfilling the objectives of this project. In the end, people can take preventive measures to reduce damages and save lives due to the implemented detector, which provides them with immediate notifications, real-time monitoring, and early warnings.

Using a solar power system has tremendous benefits, especially in terms of battery management and peace of mind. With solar power, customers no longer have to worry about emptying their battery supplies. Solar panels collect renewable energy from the sun, giving a reliable and environmentally friendly power source. This means that as long as there is sunlight, the battery will be constantly renewed, eliminating the need for external power sources or regular manual recharging. Furthermore, solar power systems are frequently outfitted with smart controllers that optimize charging and avoid overcharging, extending battery life and efficiency. Solar energy not only helps to make the environment greener by lowering carbon footprints, but it also provides a long-term, sustainable, and cost-effective solution for electricity demands. This autonomy in power generation allows customers to use their devices and appliances without interruption, which is especially useful in distant or off-grid settings where standard power sources are unavailable or unreliable.

5.2 Potential for Commercialization

Earthquake detector system have significant potential for commercialization, particularly substantially growing demand for home safety devices. This advancement satisfies the growing consumer need for home safety technology, particularly in seismically active areas. Its ecologically friendly, solar-powered design appeals to environmentally aware consumers, while its affordability and user-friendly features, such as mobile notifications.

There are a range of applications for solar-powered earthquake detectors technologies in various sectors, such as residential, educational institutions, healthcare facilities and more, including remote and rural sectors. For example, Individual residences, particularly in earthquake-prone areas such as California or Japan, can utilize these detectors to receive early alerts, allowing families to relocate to safer areas or take safety precautions such as turning off gas connections to prevent fires. Also, another example where these detectors might be installed in schools and universities to trigger automated lockdown processes, directing students and staff to safe zones during earthquake occurrences.

Beyond their immediate safety applications, solar-powered earthquake detector initiatives can also explore revenue generation through data licensing and forging strategic partnerships with entities in the private sector. Nevertheless, the imperative to capitalize on these opportunities must be carefully balanced against the necessity to maintain the accessibility and utility of these detectors for all stakeholders. Projects that prioritize sustainable practices and broad-based accessibility are poised to not only yield considerable economic returns but also to advance environmental integrity and social welfare. Such a holistic approach ensures that the benefits of solar-powered earthquake detection technologies extend beyond profit, fostering resilience and preparedness in the face of seismic risks while aligning with global sustainability goals.

5.3 Recommendations

In the future, the first features improvement that can be improvise to this project is to detect the locations of wherever that happens the seismic events. They can make the next earthquake detector using GPS module since it is easier to know the accurate location of the real-time accessing and monitoring data. Next, this project only consists of telegram notifications, so it is recommended to change the platform of the alert notifications that is more reliable to be access to all residents.

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