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DEVELOPMENT OF A LOW- COST EARTHQUAKE EARLY WARNING AND POWER CUT-OFF SYSTEM USING AN EMBEDDED MICROCONTROLLER

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Abstract:

Earthquakes pose significant threats to human safety and electrical systems, especially in small-scale buildings where conventional seismic monitoring systems are often economically impractical. Most current earthquake early warning systems only send out a few alerts and don't usually have built-in electrical power control. This raises the risk of secondary hazards like electrical fires, damage to equipment, and electric shock during seismic events. These gaps underscore the importance of an affordable, integrated solution that addresses both seismic detection and electrical safety simultaneously. In this research, an embedded microcontroller is used to construct a low-cost earthquake early warning and power cut-off system. The proposed system is designed to offer a single, compact, and cost-effective platform that can be used to provide real-time seismic detection, automatic electrical isolation, and occupant evacuation signals. The innovation of this work is the integration of multi-sensor seismic detection with embedded power management and human-presence-based alerting, which enables both immediate electrical protection and proactive warning at the device level. The system utilises an ESP32 microcontroller and incorporates a SW-420 vibration sensor for initial tremor detection, alongside an ADXL335 accelerometer to assess three-axis acceleration and determine total ground motion. A logic algorithm categorises occurrences into safe and hazardous conditions according to established thresholds. Overcurrent protection is executed by a relay-controlled power interruption system, confirmed through simulated current fluctuations. The presence of individuals is identified by an infrared sensor, which activates evacuation alarms through an Internet of Things (IoT) platform, supplemented by visual and auditory local notifications and a real-time status display. The findings showed that the proposed system achieved detection accuracy of 98.2 % and average relay activation time of 68 ms. The system provides a cost-effective solution for enhancing electrical safety and earthquake preparedness in seismic-prone and resource-constrained environments.

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Keyword:

Low-Cost Seismic Detection, Automatic Power Cut-Off, Earthquake Early Warning System, Electrical Safety, Embedded Microcontroller

Introduction

There are few natural disasters as devastating as earthquakes, which can damage or even destroy buildings and power grids. Secondary hazards, including electrical fires, apparatus failure, and power instability, have significantly contributed to post-earthquake damage and casualties in numerous seismic events. Therefore, ensuring early warning and electrical safety, especially in homes, schools, and low-rise buildings, is essential for reducing disaster risks. New developments in embedded systems and the Internet of Things (IoT) have made it possible to create small, low-cost monitoring systems that can improve safety reactions in real time when resources are limited.

Conventional earthquake monitoring systems have primarily depended on centralised monitoring infrastructures and high-precision seismometers. These systems have been extensively implemented for regional seismic analysis (Pieruccini et al., 2024). However, they are still prohibitively costly, complex, and insufficient for small-scale or individual building applications (Vatteri et al., 2021). Consequently, cost-effective alternatives utilising micro-electro-mechanical systems (MEMS)-based sensors have garnered interest (Bag et al., 2022). Previous studies have demonstrated that inexpensive accelerometers and vibration sensors can identify early seismic activity and deliver prompt notifications. Previous research has demonstrated that MEMS accelerometers can identify principal seismic waves and issue early warnings before the occurrence of catastrophic ground motion (Liao et al., 2025). Other research has also investigated IoT-based seismic alarm systems that provide notifications via mobile applications or cloud services (Zhang et al., 2025).

Despite these advances, several limitations remain in existing earthquake early warning systems. First, most reported systems focus primarily on seismic detection and electrical protection as independent domains (Pérez-García et al., 2025). Second, automatic power cut-off mechanisms are generally implemented as standalone circuit breakers without real-time integration with seismic sensing and occupant detection (Salvador et al., 2025). Third, previous study implemented in MEMS seismic sensing requires an improved low-frequency seismometer that is difficult to detect with standard sensors (Ingate & Berger, 2005). The author also highlights the challenges in this area which indicates that the sensors are capable of low-frequency measurements. To enhance the sensitivity and power consumption of their sensors, advanced signal processing and auto-tuning equipment are required to maintain the performance of the sensor (Wang et al., 2021). Finally, many existing commercial solutions remain costly and rely on centralized monitoring infrastructure, limiting their suitability for residential and small-building applications. These limitations demonstrate the need for low-cost embedded system capable of integrating earthquake detection, electrical protection and occupant safety into a single platform.

To address this research gap, this study aims to proposes a low-cost earthquake early warning and electrical protection system that integrate multiple safety functions within a single platform. The suggested system aims to consolidate real-time earthquake detection, automatic power disconnection, and occupant-oriented evacuation notifications into a unified embedded platform. The proposed system combines with vibration sensing and three-axis acceleration analysis for earthquake detection, automatic electrical power isolation to reduce secondary hazards, human-presence detection to improve evacuation safety and IoT- based notification for real-time monitoring. Unlike previous studies, which typically address seismic monitoring and electrical protection separately, the proposed system integrates these functions into a unified embedded architecture capable of local decision making. This integrated system approach provides a practical and affordable solution for enhancing earthquake safety in residential buildings and other small-scale facilities.

This research aims to design and implement a cost-effective embedded seismic detection system utilising low-cost sensors, establish an automatic power cut-off mechanism for electrical hazard reduction, and assess the system's performance through simulation and hardware validation. This work is significant for its potential to mitigate secondary earthquake dangers and enhance access to seismic safety equipment in economically disadvantaged areas. The novelty of the proposed system resides in its integrated multi-layer safety architecture, which simultaneously addresses seismic detection, electrical protection, and human presence–based alerting. In contrast to current methodologies, the system facilitates localised decision-making and physical safety responses independent of centralised infrastructure.

This paper contributes a practical and scalable embedded solution that bridges the gap between earthquake early warning systems and electrical safety mechanisms. The remainder of this paper is organised as follows: Section 2 examines pertinent literature on seismic detection and power management systems, Section 3 delineates the system structure and methodology, Section 4 highlights the results and discussion, and Section 5 ends the paper with a conclusion and recommendations for future research.

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Literature Review

Traditional earthquake detection and reactions are based on expensive seismometers and extensive infrastructures in the centralised format, which is not suitable and inaccessible to small buildings like houses, schools, and offices. Most of the current systems are primarily concerned with the delivery of warning signals without automatic control of the electrical power in the seismic scenario, which may predispose the electrical fire, shock threat, and equipment damage. Hence, the necessity to have a system that can be able to sense the tremors in real time and at the same time reduce the electrical risks during earthquakes is on the increase, particularly for small-scale use.

Earthquake alarms and a power management system that can effectively detect the seismic waves and act in a timely manner in the protection of the occupants and the electrical systems by using ESP32 (Sedhuraman et al., 2020). A previous study has explored the use of embedded microcontrollers and IoT technology for real-time safety monitoring systems. For example, a low-power IoT-based system utilising an ESP32 microcontroller and sensors was developed to monitor hazardous gases and provide early warning alerts in confined spaces. This article illustrates how sensor-based monitoring systems can enhance safety through automated detection and alert mechanisms (Ali et al., 2025).

It has been noted that the development of affordable real-time earthquake early warning systems is important in past studies to reduce the loss of life and damage to structures, especially in less resourceful regions (Karthikeyan & Verma, 2024). Meanwhile, seismic qualification guidelines highlight the importance of sound electrical protection equipment during earthquakes as a precaution against system failures and occupational risks ("IEEE Standard for Seismic Qualification Testing of Protective Relays and Auxiliaries for Nuclear Facilities," 2014), where IoT-based warning systems have high potential opportunities but are often falsified and do not have automatic power control capabilities (Bhanuteja et al., 2023; Kim et al., 2021). IoT-based monitoring systems are commonly used to collect real-time data and transmit it for system control and monitoring. For instance, an ESP32-based hydroponic monitoring system integrates multiple sensors to measure environmental parameters and automate system responses (Nyuak et al., 2025).

To tackle these issues, a system that may detect seismic activity and take safety measures to prevent such activity, including automatic power shutoff, evacuation warning, and live status monitoring, needs to be developed. The limitations in the existing solutions are also overcome by the proposed Advanced Seismic Alert and Power Management System, which offers a low-cost ESP32-based design based on real-time tremor detection, overcurrent protection, visual and audible feedback, and IoT notifications. The system is also targeted at small buildings and is designed to improve the safety of occupants in the event of an earthquake, as well as provide electrical protection, which would improve the development of smart infrastructure and the elimination of disaster risks in the future.

Materials and Methods

Research Design

This study provides a prototype-based experimental research design that focuses on the structure design, implementation and performance validation of a low-cost earthquake early

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warning and automatic power cut-off system intended for small-scale buildings. The methodology consists of system modelling, hardware integration, algorithm formulation, simulation validation and experimental performance that is illustrated in the results.

The research design shown in Figure 1 consists of 4 main phases: system conceptualisation and modelling, hardware and software development, simulation validation and prototype implementation. Phase 1, the functional architecture of the proposed system is defined. A block diagram model is developed to describe the interaction between sensing, processing, control, and alert subsystems. The sensing layer integrates an SW-420 vibration sensor and an ADXL335 three-axis accelerometer for seismic detection, along with an IR motion sensor for occupancy detection and a potentiometer to simulate current monitoring. The ESP32 microcontroller is modelled as the central processing unit responsible for signal conditioning, threshold comparison, and control logic execution. Then, the physical integration of hardware components and embedded firmware development using C/C++ within the Arduino IDE environment is involved in phase 2 (Hardware and Software Development). Pin mapping, threshold parameter configuration, and communication protocols (I2C and Wi-Fi) are implemented. Noise filtering and vibration counting logic are embedded to minimise false triggering, ensuring system stability under minor disturbances.

In phase 3 (Simulation-Based Validation), the product is validated using simulation platforms such as Wokwi and Tinkercad. The operational scenarios like SAFE condition, DANGER condition, SAFE with overcurrent and DANGER with overcurrent are tested. The simulation enables controlled acceleration values, vibration inputs, and current thresholds to verify algorithm correctness and response logic without any physical risk. In phase 4 (Prototype Implementation and Experimental Testing), a physical prototype is constructed and assembled into a small-scale building mock-up. The experiment is evaluated regarding to Detection reliability, Response time, Power cut-off effectiveness and Alert synchronisation (LED, buzzer, LCD, IoT notification). The performance of the proposed product is repeated to ensure it is consistent and robust.

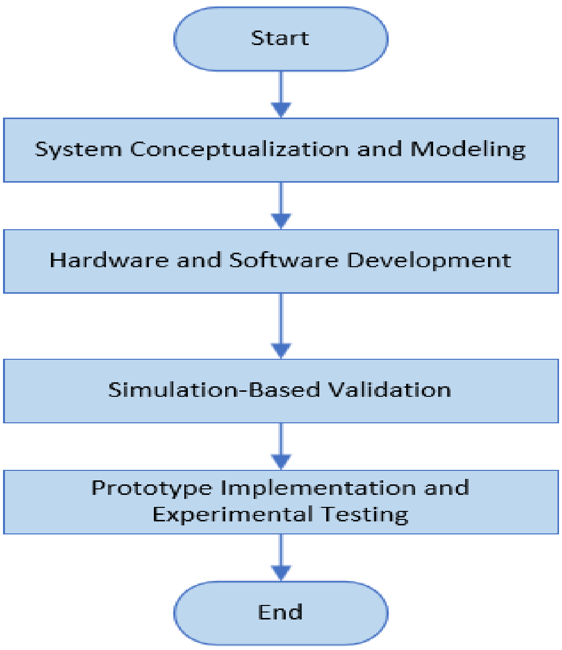

Figure 1: The Process Of Product Research Design

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System Model and Architecture

The overall system of the proposed embedded earthquake early warning and electrical protection system is illustrated in Figure 2. It is organised into input, central unit (control section) and output unit. The ESP microcontroller functions as the primary processing, decision-making, and communication unit. The architecture follows a layered embedded system model to ensure modularity, scalability, and fault-tolerant operation. The primary inputs, like an ADXL335 three-axis accelerometer, an SW-420 vibration sensor, an infrared (IR) motion sensor, and a potentiometer, are used to emulate current sensing during overcurrent testing. The SW-420 sensor serves as an initial vibration trigger to reduce unnecessary computational load, while the ADXL335 provides quantitative acceleration measurements along the X, Y, and Z axes for seismic intensity estimation. The IR sensor enables occupancy-aware alert activation, and the potentiometer allows safe validation of the overcurrent protection mechanism.

The SP32 microcontroller performs real-time signal acquisition, vibration filtering, acceleration vector computation, threshold comparison, and state classification into SAFE or DANGER conditions. The control layer incorporates a relay module responsible for automatic electrical isolation during hazardous conditions. A priority-based logic structure ensures that overcurrent protection overrides other system states when necessary. In this project, the multi-modal feedback through LEDs, a buzzer, an I2C LCD display, and IoT-based is under an alert interface layer that notifies via the Blynk platform. This layer ensures that safety even occur is submitted and avoids communication failure.

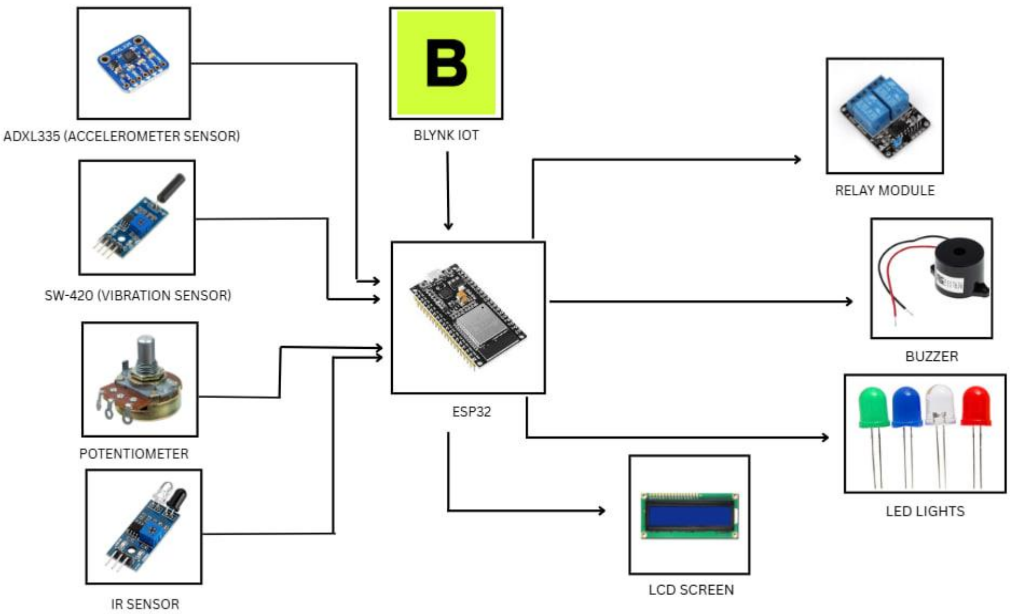

Figure 2: Block Diagram of The Proposed Low-Cost Earthquake Early Warning

Hardware Configuration

The details of electrical connections for the proposed project are illustrated in Figure 3. The ESP32 microcontroller serves as the central embedded processing unit, interfacing with both analogue and digital peripherals through dedicated General-Purpose Input/Output (GPIO) pins. The hardware configuration is designed to ensure reliable signal acquisition, deterministic control response, and electrical stability. The component of the SW-420 vibration sensor is connected to GPIO 19 and functions as the primary digital trigger for tremor detection. It is a trigger minimises unnecessary analogue processing during quiescent conditions and enhances computational efficiency. When the system is active, the data from the ADXL335 accelerometer that is connected to the analogue input channels, GPIO 35 (X-axis), GPIO 32 (Y-axis), and GPIO 33 (Z-axis) is acquired. These inputs make classification of seismic intensity and enable real-time three-axis acceleration sampling for resultant ground acceleration (g-force) computation.

A potentiometer is used to validate the overcurrent protection mechanism under controlled laboratory conditions through GPIO 34 to emulate the current sensing input. This allows safety verification of hazardous load conditions. Besides, the safety occupancy awareness is also implemented by using an infrared motion sensor. This sensor was connected to GPIO 15. This configuration is to ensure evacuation alerts. The IoT notifications are conditionally triggered only when human presence is detected, thereby reducing unnecessary alarm propagation.

The output part and the protection system consist of visual and electromechanical actuators. This part also functions as a primary electrical disconnection device, isolating the load under hazardous tremor or overcurrent conditions. Table 1 represents the indicator's visualisation. An alert buzzer that is connected to GPIO 13 will activate during seismic danger or any electrical fault condition. This alert mechanism is used to provide immediate acoustic warning.

To show system real-time data, which include tremor state, relay state and current, an I2C LCD is connected to the system with the following configuration, SDA at GPIO 21 and SCL at GPIO 22 to display system information in real time and hence users can easily monitor the system and ensure the entire system is a complete safety and power protection system.

Table 2 summarises the performance analysis for earthquake early warning and power cut-off of the proposed system. The system reached a detection accuracy of 98.2 %, indicates that it is reliable to identify this seismic event under the tested conditions. Besides, the average response of time analysis about 0.42 s enabled rapid hazards detection. The relay activation time about 0.68 ms that ensured prompt electrical isolation to minimise secondary hazards. Furthermore, an IoT notification transmitted with average delay of 1.3 s that allows timely alerts to occupants. The low false alarm rate is about 1.7% demonstrates the effectiveness of the threshold-based decision algorithm in reducing unnecessary activations.

Overall, this hardware is mapping prioritizes signal integrity, modular interfacing, and deterministic control execution. The schematic design reflects a scalable and deployable embedded safety system suitable for small-scale infrastructure applications in seismic-prone environments.

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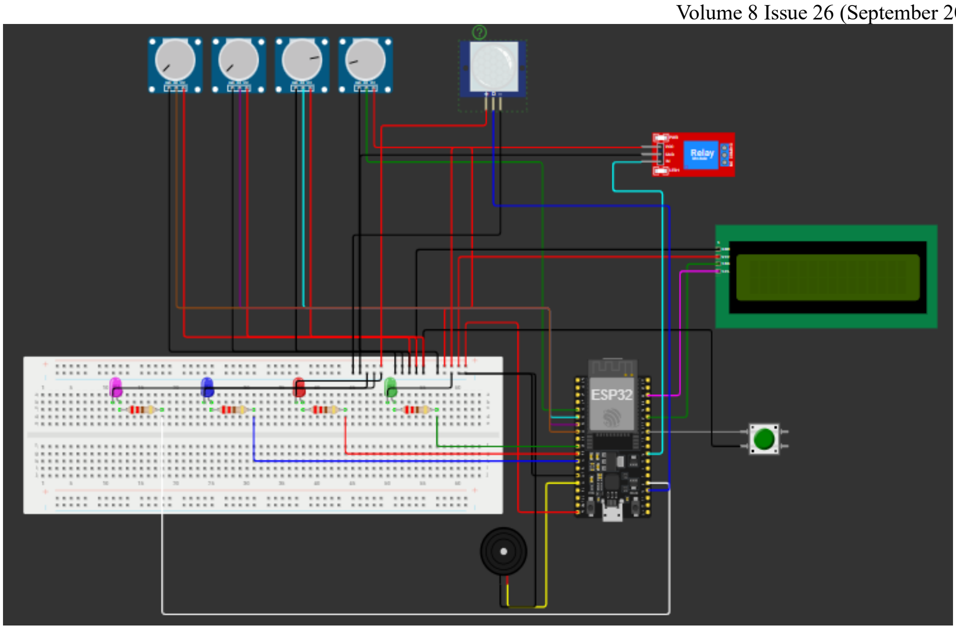

Figure 3: Schematic Diagram Of the Advanced Seismic Alert And Power Management System

Table 1: Visual status indicators available at GPIO

GPIO	Colour Code for LED	Condition
GPIO 26	Green	SAFE condition
GPIO 27	Red	DANGER condition
GPIO 14	Blue	Overcurrent or fault indication
GPIO 2	White	Evacuation and communication backup indicator

Table 2: Accuracy Of The Proposed System

Parameters	Results
Detection accuracy	98.2 %
Response time	0.42 s
Relay activation	68 ms
IoT notification	1.3 s
False alarm rate	1.7 %
Successful tests	30/30

Algorithm Design and Control Logic

The proposed system was designed, and its printed circuit board (PCB) layout is demonstrated in Figure 4. It was created in Proteus 8 Professional. The design was made so that it provided proper placement of the components, efficient routing and the design was done to perform well in the electrical sense. In the ESP32 development module, the microcontroller is placed at the centre of the PCB, and the length of signal paths between the microcontroller and the peripheral components is reduced. Special header pins are allocated to take input devices, which include vibration sensor, accelerator, IR sensor, and potentiometer, whereas different connectors are assigned to take output, among them the LEDs, buzzer, relay module, or I2C LCD. Besides, the AC to DC 5 V, 6 A power supply includes power and ground traces that are well-routed to provide uniform voltage across the system. Power lines where needed are marked with wider traces to provide support to higher current flow, less voltage drop, and electrical noise reduction. The PCB has mounting holes on the four corners to enable it to be mounted. The PCB design created in Proteus 8 is, in general, a compact, well-organised, and reliable hardware implementation that could fit in small-scale safety applications.

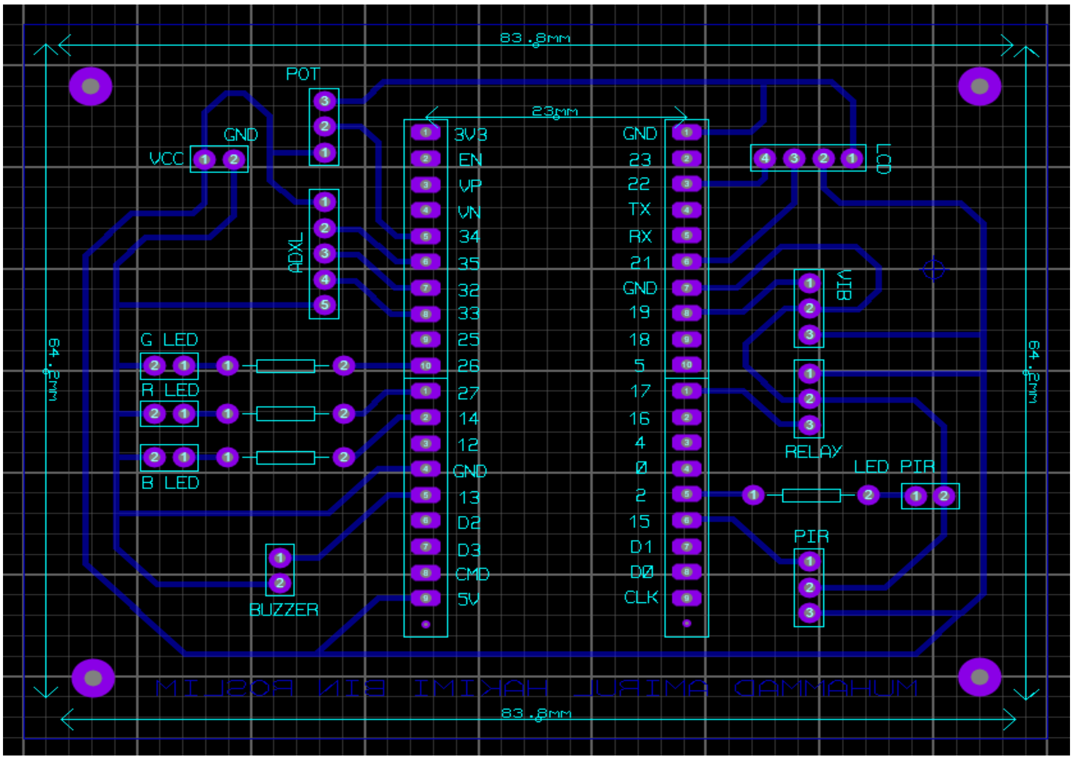

Figure 4: PCB Layout using Proteus 8 Professional

Cost Analysis and Funding

Cost efficiency is an important design for earthquake early warning systems that are used in residential homes, schools and low-rise buildings. This project was created using inexpensive, commercially available electronic components to maintain affordability while preserving functionality. Table 3 below shows the comprehensive cost analysis of the hardware components utilised in the prototype development.

The ESP 32 microcontroller acts as the primary processing, while the ADXL335 accelerometer and SW-420 vibration sensor are employed to accomplish seismic sensing. By combining these devices offer three-axis motion detection and initial tremor triggering, which can reduce cost compared to traditional seismometers. The relay modules, LEDs, buzzers, and LCD display are low-cost components that are guaranteed with minimal financial risk. Meanwhile, the supporting components like jumper wire, breadboard and power supply units are included in this electrical connection. This low cost demonstrates the proposed project's feasibility and scalability.

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Table 3: Cost Of The Component Involved

No.	Component	Quantity	Unit Price (RM)	Total Cost (RM)
1.	ESP 32	1	28	28
2.	ADXL335 Accelerometer Sensor	1	20	20
3.	Potentiometer	1	3	3
4.	SW-420 Vibration Sensor	1	5	5
5.	LCD 16x2 Display	1	9	9
6.	Relay Module	1	6	6
7.	Buzzer	1	2	2
8.	Breadboard	2	3	6
9.	Jumper Wires	2	7	14
10.	LED's (red, green, blue, white)	4	1	4
11.	IR Sensor	1	4	4
12.	3 Core Cable	1	8	8
13.	Power Supply (5V/6A)	1	15	15
14.	Plug	1	2	2
	Total	**19**		**126**

Results and Discussion

Functional Scenario and Threshold Performance Analysis

The analysis of the product regarding operational scenarios has been summarises into Table 4. This table demonstrates the integration of seismic detection and electrical protection mechanisms. Under SAFE conditions signal that there is no vibration trigger was detected, and the resultant acceleration remained below the defined threshold. This SAFE condition allows the relay to remain energised while only the green LED indicates normal operation. If the seismic thresholds were exceeded, the system activated visual and audible alerts while maintaining power supply in the absence of electrical faults under DANGER conditions. In overcurrent scenarios, the relay was immediately de-energised to isolate the load, with the blue LED indicating electrical fault status. The system executed hierarchical protection logic by disconnecting power while maintaining an alarm signal when both tremor and overcurrent occurred simultaneously.

Table 4: System Response Analysis Based On Different Operational Scenarios

Scenario	Vibration Trigger	G-force > Threshold	Overcurrent	Relay Status	LED Status	Buzzer
SAFE	No	≤ 3.0 g	No	ON	Green ON	OFF
DANGER	Yes	> 3.5 g	No	ON	Red ON	ON

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SAFE + Overcurrent	No	≤ 3.0 g	Yes	OFF	Blue ON + Green ON	ON
DANGER + Overcurrent	Yes	> 3.5 g	Yes	OFF	Red ON + Blue ON	ON

The proposed threshold-based decision mechanism is demonstrated in Table 5. It illustrates the SAFE and DANGER condition classification across all tested scenarios. During SAFE simulations (vibration count less than 15) and resultant acceleration did not exceed 3.0 g, and the system maintained stable operation without unintended alarm activation. Under these conditions, a low false-trigger tendency under baseline conditions is indicated. If the vibration counts exceeded 15 and resultant acceleration surpassed 3.5 g, the system consistently transitioned to DANGER classification and activated the corresponding alert mechanisms, suggesting reliable threshold discrimination and deterministic decision behaviour. Furthermore, if the simulated current input exceeded the 10 A threshold, the relay was immediately de-energised. This confirms the correct execution of the embedded electrical protection logic and demonstrates effective hierarchical fault prioritisation. Compared with traditional centralised seismic monitoring systems that rely on high-precision seismometers and external infrastructure. Nevertheless, the validation was conducted using simulated tremor and current inputs rather than real earthquake waveform data. The statistical performance metrics, such as sensitivity, specificity, and response time distribution, were not formally quantified, indicating the need for extended field-based validation and probabilistic performance assessment in future work.

Table 5: Threshold Classification Parameter

Parameter	Safe Threshold	Danger Threshold	Observed Response
Vibration Count	< 15	≥ 15	Correct classification
Resultant G-force	≤ 3.0 g	> 3.5 g	Accurate detection
Current Level	< 10 A	≥ 10 A	Relay isolation activated

Cost Functionality Assessment

The comparative functional coverage and economic feasibility of the proposed system relative to conventional standalone seismic alert devices is summarized into Table 6. The results demonstrated that the proposed systems provided tremor detection capability, additional protective functions and IoT-based remote notification. The occupancy-based alert logic ensured that remote notifications were transmitted only when human presence was detected, reducing unnecessary alarm dissemination. The proposed product provides a total hardware cost of approximately RM 126 with a system that achieved expanded safety functionality without substantial financial burden, indicating strong cost–functionality efficiency for small-scale deployment.

The finding of the initial hypothesis states that integrating low-cost sensors with embedded threshold-based control logic would produce a multifunctional and economically viable earthquake early warning and electrical protection solution. Besides, the results showed that functional completeness was achieved without reliance on expensive centralised monitoring infrastructure. The limitations of the previous product bring advantages to the proposed system in integrated hazard mitigation, affordability, and scalability for residential and low-rise building applications. Overall, the physical implementation confirmed that the proposed embedded system operated as designed and validated the feasibility of integrating low-cost seismic detection with automatic electrical protection in a compact residential-scale prototype.

Table 6: Comparison Of Functional Coverage And System Cost

Feature	Proposed System	Typical Seismic Device
Seismic detection	Yes	Yes
Automatic power cut-off	Yes	Rare
Occupancy-based alert	Yes	Rare
IoT notification	Yes	Optional
Total cost	RM 126+	Significantly higher

Hardware configuration

The overall assembled printed circuit board (PCB) integrated within the developed earthquake indicator unit and mock-up residential environment is illustrated in
Figure **5**. The proposed system embedded from the experiment was successfully transferred from conceptual design to real functional hardware. The main component, the ESP32 microcontroller, operated as the central processing unit, executing real-time data acquisition, threshold-based decision logic, and output control, which was observed in communication instability.

Referring to
Figure **5** (a), the SW-420 vibration sensor positioned at the rear base of the mock-up structure was used to respond to simulated ground disturbances and triggered acceleration analysis only when vibration thresholds were exceeded. The ADXL335 accelerometer (mounted within the earthquake indicator unit) provided three-axis motion measurements. This accelerometer is used to compute resultant acceleration values for tremor classification. The IR motion sensor was installed inside the house model to detect occupant presence and conditionally activate remote notification logic during simulated seismic events. The relay module demonstrates reliable electrical isolation under overcurrent conditions. The power cut-off mechanism operated deterministically without a delayed response under test conditions. The green, red, and white LED illustrated as visual indicators for normal operation, dangerous tremor conditions and evacuation indicator, respectively. The blue LED consistently indicated the presence of an electrical fault during overcurrent simulations. Besides, the component likes buzzer and LCD display, as shown in the figure below, provides a warning in all hazardous states and reports tremor classification.

The prototype below demonstrated that the proposed system could be deployed in small-scale residential configurations without requiring complex installation infrastructure. The design integrates the sensing, processing, and protection components within a compact enclosure that highlights features. An automatic electrical isolation with seismic detection demonstrated a multifunctional safety mechanism beyond conventional standalone earthquake alert devices. However, mechanical stress testing, electromagnetic interference analysis, and long-term durability assessments were not conducted.

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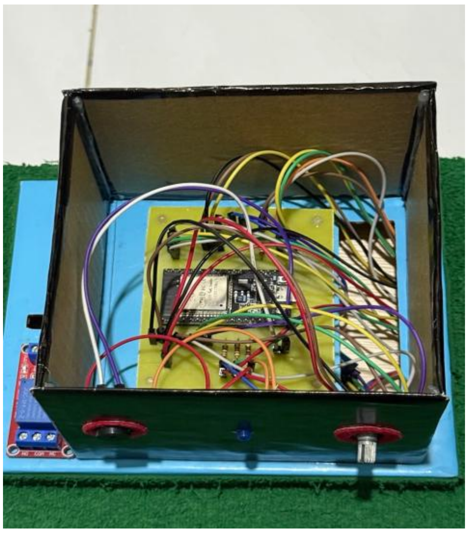
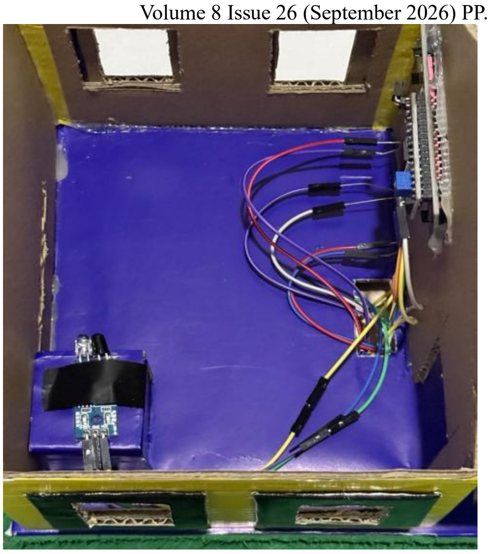


Indicator system unit



Home section (yellow house)

Overall design configuration

Figure 5: Overall Circuit Design Implementation

Conclusion

This study developed and experimentally validated a low-cost embedded earthquake early warning and automatic power cut-off system that suitable designed for small-scale residential applications. The proposed system integrates vibration-based triggering, three-axis acceleration measurement, overcurrent protection, occupancy-aware alert activation, and IoT-based notification. Based on experimental results, the system is successfully classified into SAFE and DANGER conditions using predefined vibration and acceleration thresholds and isolated electrical loads during simulated overcurrent events. The prototype was implemented using commercially available components with total hardware cost of RM126, demonstrating the feasibility of an affordable integrated safety solution. Unlike conventional standalone earthquake alert systems, the proposed solution incorporated hierarchical protection logic that prioritised electrical isolation while maintaining tremor alert function. The dual-sensor threshold approach enhanced classification robustness, reducing false-trigger activation under controlled SAFE conditions. Additionally, the occupancy-aware notification mechanism introduced context-sensitive alert dissemination, thereby improving practical deployment efficiency. Long-term durability, electromagnetic interference resistance, and field deployment testing were beyond the scope of the present study. The identification of an SW-420 vibration sensor and an ADXL335 accelerator were combined as a single unit to attain this aim of detecting the seismic tremors by processing the vibration patterns and the overall acceleration. An IR sensor is used to identify the presence of people within the house, and if a life-threatening tremor is detected, evacuation notifications are sent using the Blynk IoT platform. Besides mobile notifications, there is a wall-dedicated white LED that serves as an alternative visual alert to the occupants in the case of communication problems or loss of the internet. A potentiometer could have been used to simulate the input current and have the overcurrent protection facility tested without the real high-current load. A pseudo-current is detected when abnormal current, upon which power to the device is cut off, a relay disconnects the power, a blue LED flashes and a buzzer on the earthquake alert unit shows that there is an abnormal current. The status of the system, such as tremor condition, relay operation and real-time I2C LCD display, allows occupants to view the state of the system quickly by using wall-mounted LEDs and an I2C LCD display. All in all, the system worked as per the plans and achieved the aims of the project by integrating real-time seismic sensors, device protection, notification to occupants, and IoT-based sensors. The proposed system therefore contributes to improving electrical safety by combining multiple protection function in a compact and low-cost embedded platform suitable for residential buildings, school and other small-scale facilities. The findings reveal that the suggested system is efficient, convenient, and applicable in residential premises, schools and the low-rise constructions within seismic-prone regions.

Future Contribution

Future work should concentrate on the integrated calibration of current sensing modules, statistical performance analysis and large-scale deployment testing in seismic-prone regions. The reliability of the detection can be further improved by integrating machine learning-based threshold optimisation. In general, the embedded system that has been proposed is a practical and economically viable method for enhancing the electrical safety and earthquake preparedness of small-scale built environments.

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Ethics Statement:	This study did not involve any human participants, animals, or sensitive data requiring ethical approval. The authors confirm that the research was conducted in accordance with accepted academic integrity and ethical publishing standards.
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