Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 16, Issue. 1: 2025
ISSN : **1906-9685**

EARTHQUAKE DETECTOR USING ARDUINO

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ABSTRACT

An earthquake is an unpredictable natural phenomenon which happens suddenly and cannot stop it but can be alerted from it. Vibration sensor is used to detect the pre-earthquake vibrations. When the vibrations occur, accelerometer senses and converts them into equivalent ADC values.

Then these digital values are read by microcontroller Arduino. Then Arduino compares these values with threshold value that is already predefined. If Arduino finds the sample value is greater than the threshold value, then Arduino trigger the buzzer and displays a message showing the status of alert over the 16x2 LCD and a LED also turned on.

Using GSM module, the SMS alert message is sent to the respective registered mobile number. Also two other sensors are used, for detecting fire and any gas leakage in the building can be sensed using flame and gas sensor respectively. If detected SMS alert is sent to the corresponding registered mobile numbers.

Keywords: -Earthquake Detector, Arduino, Seismic Activity, Vibration Sensor,

1 INTRODUCTION

An earthquake is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves. This release of energy typically occurs when stress builds up along fault lines (cracks in the Earth's crust), causing the rocks to break or slip.

When the rocks move, the energy travels through the Earth as seismic waves, which we feel as ground shaking. Earthquakes can vary in size, from minor tremors that are barely noticeable to large quakes that can cause significant destruction.

They usually occur along plate boundaries, but can also happen within the interior of tectonic plates. The magnitude of an earthquake is measured on the Richter scale, and its effects can be destructive depending on factors like its strength, depth, and proximity to populated areas.

1.1 Seismic Waves:

1.1.**1. Primary Waves (P-waves):** P-waves are the fastest seismic waves, traveling at speeds of around 5 to 8 km/s (depending on the medium they travel through).These waves move in a compression-expansion motion, similar to sound waves. The particles of the material (rock, soil, etc.) move back and forth in the direction of wave propagation.P-waves can travel through both solids and liquids. This is why they are the first waves to be detected by seismic instruments.

- They cause the ground to move in a back-and-forth motion (compression and decompression).
- P-waves are the first to be recorded by seismographs because they are the fastest.

1.1.2. Secondary Waves (S-waves): S-waves are slower than P-waves, traveling at speeds of about 3 to 5 km/s.S-waves move the ground in an up-and-down or side-to-side motion, perpendicular to the direction of wave travel. This is why they are also called shear waves.S-waves can only travel through solids. They cannot move through liquids, which is why they don't appear in data from seismic stations that are located in areas with liquid layers, like Earth's outer core.

- S-waves cause the ground to shake side to side or in a vertical motion.
- S-waves are slower than P-waves and, therefore, are the second waves to be detected.

1.1.3. Surface Waves: Surface waves are slower than both P-waves and S-waves, typically traveling at speeds of about 2 to 4 km/s.These waves travel along the Earth's surface and move in a rolling or side-to-side motion, which causes the most damage during an earthquake.

1.2 The Importance of Early Detection:

Saving Lives: Early detection can provide critical seconds or minutes to warn people, allowing them to take protective actions such as dropping to the ground, taking cover, and holding on. This can prevent injuries and fatalities, especially in densely populated areas.

Minimizing Damage: With early warning systems in place, infrastructure like buildings, bridges, and roads can be prepared or temporarily shut down. Power grids, gas lines, and factories can be turned off to reduce the risk of fires or explosions. This can significantly reduce the physical and economic damage caused by an earthquake.

Public Safety: Early warnings allow for the evacuation of vulnerable areas or the suspension of dangerous activities (e.g., trains, nuclear plants, etc.) in advance of the quake. This helps prevent more severe consequences, such as train derailments or nuclear plant malfunctions.

Improved Emergency Response: Emergency services can be better prepared to respond in the immediate aftermath of an earthquake. Knowing where the earthquake is centered and its magnitude can help direct resources to the most affected areas.

Psychological Preparedness: Early warning systems help communities feel more prepared and less anxious about earthquakes, knowing that there is a safety net in place. This can lead to better overall resilience and quicker recovery in the aftermath.

Supporting Research and Preparedness: Continuous monitoring of seismic activity provides valuable data for researchers, improving our understanding of earthquakes and helping to refine building codes and disaster preparedness plans over time.

1.3 Overview of Earthquake Detection Methods

1.3.1 Seismometers (Seismic Sensors)

Seismometers are the primary tools used for detecting earthquakes. They measure ground motion caused by seismic waves. These instruments can detect even tiny movements and are often placed in arrays to monitor a wide region.

1.3.2 Seismic Networks

A network of seismometers is often set up in earthquake-prone areas to detect and track seismic activity. These networks consist of hundreds or even thousands of sensors strategically placed on the ground and sometimes underwater.

1.3.3 Earthquake Early Warning Systems (EEWS)

EEWS use real-time data from seismic sensors to detect the initial seismic waves (P-waves) that travel faster than the more destructive shock waves (S-waves). These systems can issue warnings seconds to minutes before the damaging waves arrive.

1.4 Earthquake causes damages to lives and property

An earthquake is an unpredictable natural phenomenon which happens suddenly and cannot stop it but can be alerted from it. Here Accelerometer ADXL335 is used which is highly sensitive to detect the pre-earthquake vibrations. It is highly sensitive to shakes and vibrations along all the three axes. Accelerometer after sensing the vibration converts them in to equivalent ADC values. Then these values are read by Arduino and shown over the 16x2 LCD. First calibrate the Accelerometer by taking the samples of surrounding vibrations whenever Arduino Powers up. Then need to subtract those sample values from the actual readings to get the real readings hence it will not show alerts with respect to its normal surrounding vibrations. After real readings are found, Arduino compares these values with predefined max and min values. If Arduino finds any changes from the predefined values of any axis in both direction (negative and positive) then Arduino trigger the buzzer and shows the status of alert over the 16x2 LCD and also LED also turned on as well. Sensitivity of the earthquake detector can be adjusted changing the predefined values in Arduino code. Using GSM module, the SMS alert message is sent to the respective registered mobile number. Also, two other sensors are used, for detecting fire and any gas leakage in the building can be sensed using flame and gas sensor respectively. If detected SMS alert is sent to the corresponding registered mobile numbers.

1.5 Significant catastrophic events include earthquakes:

The rapid arrival of energy in the Earth's interior is causing earthquakes, which most usually manifest as rocks exploding after being subjected to stresses that exceed their flexible breaking point. When two of the earth's outer layers rub up against one another, an earthquake is caused. As a result, the quake's odd position and prognosis for various places may help to lessen the havoc that it caused due to the tremors. In this research, a sensitive vibrator that can detect vibrations and a small regulator Arduino Mega is used to create a quake pointer. Vibrators are quite susceptible to earthquakes. The simple voltage produced by vibrators is identical to a forced speed increase. Any vibration caused by a change is detected by the vibrator, which then notifies the miniature regulator. The vibrator is connected to the Arduino Uber Simple to Advanced Convertor (ADC) pins. A light, which serves as both a warning and an indicator of seismic tremor, appears when elements in the center of a tremor are large enough to pass a value known as edge esteem. Although the alert can be used for modern purposes, it can also be used for family rules. The LCD has been added as a device for advising caution, making the framework effective and simple to use.

2. Literature Study

R. Singh et al. (2016) designed an earthquake detection system using the Arduino Mega with a GSM module and an ADXL345 accelerometer. Their system could detect tremors and send SMS alerts to users.

A. Verma & S. Sharma (2018) implemented an Arduino Uno-based system using the MPU6050 sensor. It processed acceleration data to determine seismic activity and activated alarms for alerting.

P. Ghosh et al. (2019) worked on a wireless earthquake monitoring network using Arduino and RF modules. The focus was on decentralizing the system for a larger geographical area.

2.1 objectives:

Arduino-based earthquake detection systems are a promising alternative for areas lacking access to advanced seismic equipment. While they are not replacements for professional-grade systems, they provide valuable educational, research, and localized warning capabilities. Ongoing research aims to improve sensor accuracy, data filtering, and networked detection for more reliable performance.

3. Embedded System

3.1 Embedded System

An Embedded System is a combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a specific function. An embedded system is a microcontroller-based, software driven, reliable, real-time control system, autonomous, or human or network interactive, operating on diverse physical variables and in diverse environments and sold into a competitive and cost-conscious market.

An embedded system is not a computer system that is used primarily for processing, not a software system on PC or UNIX, not a traditional business or scientific application. High-end embedded & lower end embedded systems. High-end embedded system - Generally 32, 64 Bit Controllers used with OS. Examples Personal Digital Assistant and Mobile phones etc. Lower end embedded systems - Generally 8,16 Bit Controllers used with a minimal operating systems and hardware layout designed for the specific purpose.

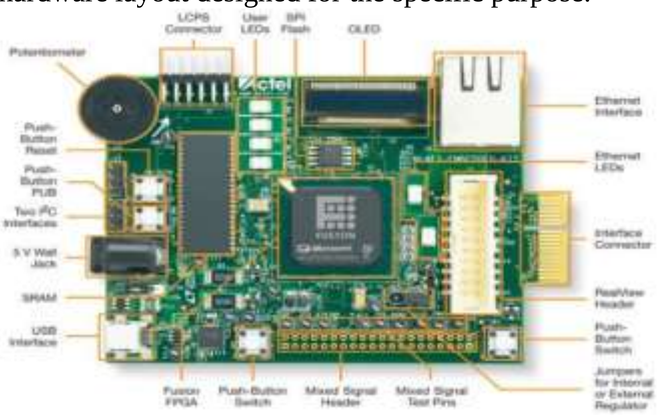

Fig 3.1 Basic Embedded System

3.2Embedded System Design Cycle:

The embedded system design cycle refers to the step-by-step process involved in designing an embedded system, which is a computer system with a dedicated function embedded within a larger device. This cycle covers everything from initial concept and specification to design, testing, and deployment. It is crucial to ensure the system meets the specific requirements of performance, reliability, and cost.

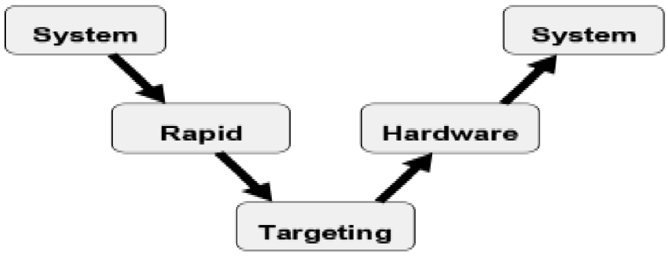

Fig 3.2. V Diagram

3.3 Characteristics of Embedded System:

An embedded system is any computer system hidden inside a product other than a computer. They will encounter a number of difficulties when writing embedded system software in addition to of data in a short period of time. Response–Our system may need to react to events quickly. Testability–Setting up equipment to test embedded software can be difficult. Debugability–Without a screen or a keyboard, finding out what the software is doing wrong (other than not working) is a troublesome problem. Reliability – embedded systems must be able to handle any situation without human intervention.

Memory space – Memory is limited on embedded systems, and you must make the software and the data fit into whatever memory exists. Program installation – you will need special tools to get your software into embedded systems. Power consumption – Portable systems must run on battery power, and the software in these systems must conserve power. Processor hogs – computing that requires large amounts of CPU time can complicate the response problem. Cost – Reducing the cost of the hardware is a concern in many embedded system projects; software often operates on hardware that is barely adequate for the job. Embedded systems have a microprocessor/

microcontroller and a memory. Some have a serial port or a network connection. They usually do not have keyboards, screens or disk drives.

4. Experimental Methodology:

4.1 Introduction

4.1.1 Proposed System: -

The proposed system is a warning and alert system to monitor efficiently earthquake areas in real time basis. The system even detects an earthquake by using a vibration sensor and provide alert to authorities through GSM. A siren is used in this system to alert surrounding people when earth quake detected.

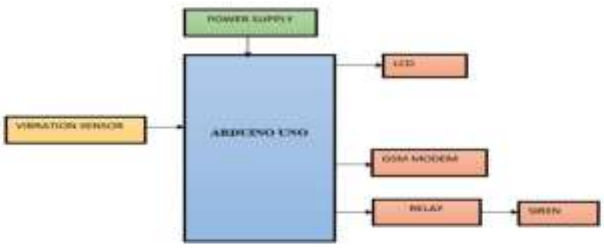

Fig 4.1 Block Diagram

4.2 Hardware Requirements: -

- ARDUINO UNO
- POWER SUPPLY
- GPS MODULE
- GSM MODEM
- BUZZER
- LCD

4.3 Software Requirements: -

- LANGUAGE: EMBEDDED C
- SOFTWARE: ARDUINO IDE

4.4 Working Principle: -

The system works by continuously monitoring vibrations through an accelerometer. When movement exceeds a predefined threshold, the Arduino triggers an alarm, displays an alert, and (if included) sends a notification.

4.5 Methodology: -

4.5.1 Sensor Selection & Calibration:

Use an accelerometer (such as MPU6050) to measure changes in X, Y, and Z axes. Calibrate the sensor to ensure it accurately detects normal vibrations versus earthquake-induced tremors.

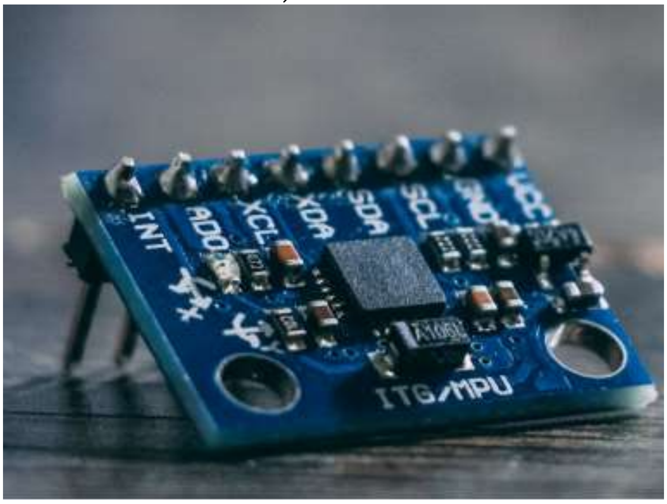

Fig 4.2 ARDUINO UNO

4.5.2 Writing and Uploading the Arduino Code:

- Read accelerometer values using Arduino code.
- Set a threshold value for earthquake detection based on sensor readings.

If the threshold is exceeded:

- Activate buzzer and LED.
- Display intensity on the LCD.
- Send an alert (if GSM module is used).
- Upload the code using the Arduino IDE and test.

4.5.3 Testing and Validation:

- Simulate different vibration levels to verify system accuracy.
- Adjust the sensitivity by modifying the threshold value.
- Cross-check readings with actual seismic data if available.

5. Hardware Description

5.1 Arduino Uno Board:

Arduino is a single-board microcontroller meant to make the application more accessible which are interactive objects and its surroundings. The hardware features with an open-source hardware board designed around an 8-bit Atmel AVR microcontroller or a 32-bit Atmel ARM. Current models consists a USB interface, 6 analog input pins and 14 digital I/O pins that allows the user to attach various extension boards.

The Arduino Uno board is a microcontroller based on the ATmega328. It has 14 digital input/output pins in which 6 can be used as PWM outputs, a 16 MHz ceramic resonator, an ICSP header, a USB connection, 6 analog inputs, a power jack and a reset button. This contains all the required support needed for microcontroller. In order to get started, they are simply connected to a computer with a USB cable or with a AC-to-DC adapter or battery. Arduino Uno Board varies from all other boards and they will not use the FTDI USB-to-serial driver chip in them. It is featured by the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

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Fig 5.1 ARDUINO UNO BOARD

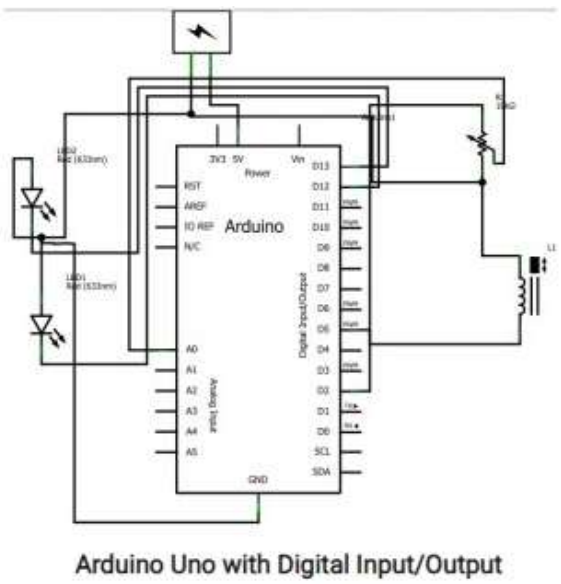

Fig 5.2 Arduino Uno Digital Input/Output

There are various types of Arduino boards in which many of them were third-party compatible versions. The most official versions available are the Arduino Uno R3 and the Arduino Nano V3. Both of these run a 16MHz Atmel ATmega328P 8-bit microcontroller with 32KB of flash RAM 14 digital I/O and six analogue I/O and the 32KB will not sound like as if running Windows. Arduino projects can be stand-alone or they can communicate with software on running on a computer. For e.g. Flash, Processing, Max/MSP). The board is clocked by a 16 MHz ceramic resonator and has a USB connection for power and communication. You can easily add micro-SD/SD card storage for bigger tasks.

5.1.2 Features of the Arduino Uno Board:

- It is an easy USB interface. This allows interface with USB as this is like a serial device.
- The chip on the board plugs straight into your USB port and supports on your computer as a virtual serial port. The benefit of this setup is that serial communication is an extremely easy protocol which is time-tested and USB makes connection with modern computers and makes it comfortable.

5.2 Power Supply:

5.2.1 Power Supply block Diagram:

Many electronic circuits need a direct current (DC) voltage source, but what we commonly find are voltage sources of alternating current (AC). In order to achieve a direct current voltage source, the alternating current input must follow a conversion process like the one shown in the power supply block diagram below the image shows the main components of a basic power supply diagram and the waveforms at the beginning (AC input), at the end (DC output) and between blocks.

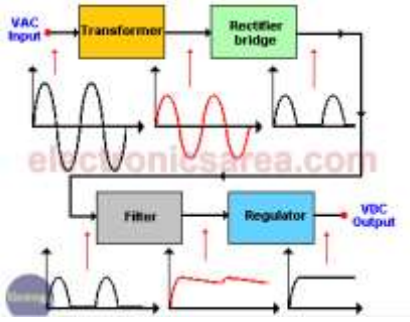

Fig 5.3 Power Supply Circuit Diagram

5.3 GSM Module – SIM900:

This is a GSM/GPRS-compatible Quad-band cell phone, which works on a frequency of 850/900/1800/1900MHz and which can be used not only to access the Internet, but also for oral communication (provided that it is connected to a microphone and a small loud speaker) and for SMSs. Externally, it looks like a big package (0.94 inches x 0.94 inches x 0.12 inches) with L-shaped contacts on four sides so that they can be soldered both on the side and at the bottom. Internally, the module is managed by an AMR926EJ-S processor, which controls phone communication, data communication (through an integrated TCP/IP stack), and (through an UART and a TTL serial interface) the communication with the circuit interfaced with the cell phone itself.

The processor is also in charge of a SIM card (3 or 1,8 V) which needs to be attached to the outer wall of the module.

In addition, the GSM900 device integrates an analog interface, an A/D converter, an RTC, an SPI bus, an I²C, and a PWM module. The radio section is GSM phase 2/2+ compatible and is either class 4 (2 W) at 850/ 900 MHz or class 1 (1 W) at 1800/1900 MHz. The TTL serial interface is in charge not only ofcommunicating all the data relative to the SMSalreadyreceived and those that come in during TCP/IP sessions in GPRS (the data-rate is determined by GPRS class 10: max. 85,6 kbps), but also of receiving the circuit commands (in our case, coming from the PIC governing the remote control) that can be either AT standard or AT-enhancedSIMComtype.The module is supplied with continuous energy (between 3.4 and 4.5 V) and absorbs a maximum of 0.8 A during transmission.

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Fig 5.18 GSM

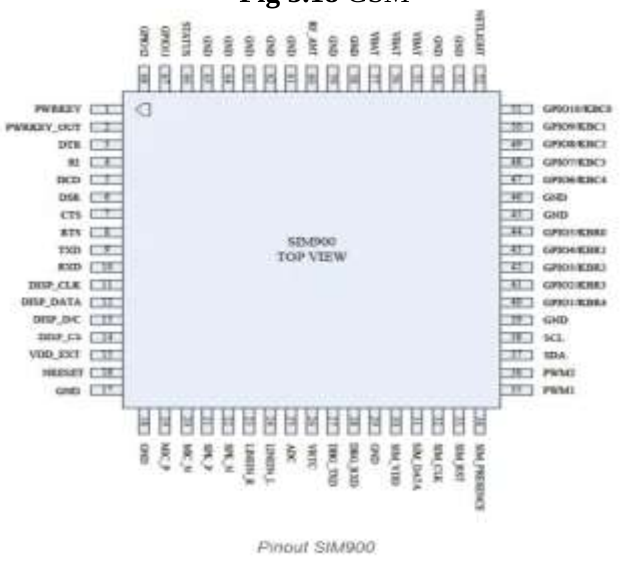


Fig 5.19 GSM PINOUT SIM 900

6. Software Description

1. Download and install Arduino IDE (https://www.arduino.cc/en/Main/Software)
2. Plug in your Arduino Board
3. Select the proper board in the IDE (Tools>Boards>Arduino Uno)
4. Select the proper COM port (Tools>Port>COMx (Arduino Uno))
5. Open the "Blink" sketch (File>Examples>Basics>01.Blink)
6. Press the Upload button to upload the program to the board
7. Confirm that your board is working as expected by observing LED

6.1 Troubleshooting Uploading Errors:

Arduino has lots of community support and documentation. Your best bet when running into unexpected problems is to search online for help. You should be able to find a forum where someone had the same problem you are having, and someone helped them fix it. If you don't find results, try modifying your search, or post on the Arduino forums.

● My board isn't listed under devices and is not recognized by IDE:

○ Most likely, this means that the ATMega328p chip is not programmed with the Arduino firmware. If you have a separate working Uno available, you can program the unprogrammed chip using this guide and a few jumper cables: https://www.arduino.cc/en/Tutorial/ArduinoISP

○ If you don't have a separate Arduino available, let me know and I can use an Atmel Programmer to upload the firmware.

○ There may be hardware damage if you had the board plugged into USB and external power at the same time. You may have to replace the chip if this is the case.

● Error Message: avrdude: stk500_recv (): programmer is not responding

○ Double-check that you are using the correct COM port.

○ Make sure that your Arduino Board is plugged into the computer.

● The IDE says "Uploading…" after pressing the upload button, but nothing is happening.

○ Double-check that you have the correct board selected in the Tools menu.

○ Depending on the size of your program, it may take a few seconds to upload. If you feel like it is taking too long, it may be encountering an error and you can try unplugging and plugging in the Arduino board.

7. Results:

7.1 Results from the Earthquake Detector Project:

1. Detection of Ground Movements: The sensor will pick up small vibrations or movements in the ground. For low-intensity movements, such as nearby traffic or walking, the sensor might show minor fluctuations, which can be filtered out by setting a threshold value in the code.
2. Threshold Breach: When an earthquake (or significant ground shaking) occurs, the sensor will detect a sharp spike in the acceleration data. If the measured value crosses the predefined threshold, the system triggers an alert. This threshold is calibrated based on the expected seismic activity level that you're testing for.
3. Alert Mechanism: The Arduino may activate a buzzer or LED to signal an earthquake. The buzzer will make noise, or the LED will blink to indicate that a significant seismic event has been detected.
4. Data Logging (Optional): Depending on the project design, the Arduino can send the seismic data to a computer or server for logging and analysis. This could help in understanding the intensity and frequency of vibrations over time.
5. Testing and Calibration: During the testing phase, the system will be subjected to various types of ground vibrations to ensure it responds only to real seismic events and ignores false positives (like wind or human-induced vibrations). You might calibrate the system to differentiate between different levels of vibrations based on intensity.
6. User Interface: If an LCD or serial monitor is used, the intensity of the detected movement can be displayed in real-time, showing data such as:
    - Acceleration in X, Y, and Z axes
    - Earthquake detection status
    - Seismic event strength

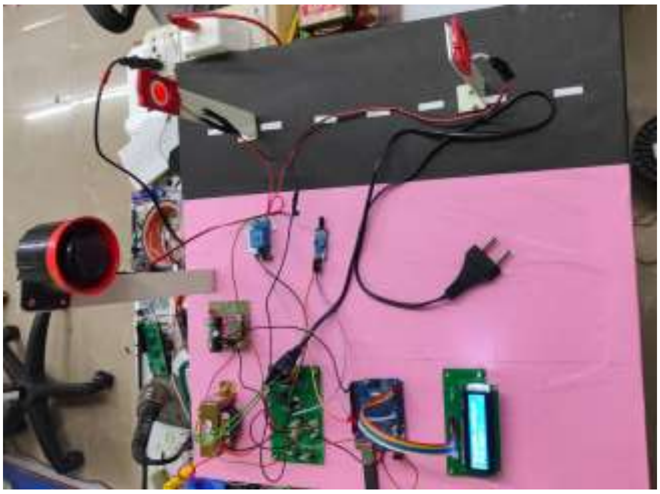
7. Power and Efficiency: The Arduino system can be powered via USB or batteries, and power consumption will depend on the setup. For portability, a low-power design would be ideal, especially if used for long periods or in remote locations.

7.2 Observations:

- Seismic Movement Detection: The system should show significant changes when real earthquakes or vibrations occur. Minor movements from objects (like walking) should not trigger false alarms if the threshold is set appropriately.
- Alert Activation: The buzzer or LED should activate when the system detects a vibration that exceeds the threshold, indicating an earthquake or strong ground movement.
- Real-Time Feedback: You will see data displayed in real-time, which can help you evaluate the system's sensitivity to different levels of ground movement.
- Threshold Calibration: You may need to adjust the threshold for sensitivity based on testing in different environments to avoid false positives or missed detections.

This type of project provides a basic, entry-level approach to earthquake detection, and it's a good way to learn about sensors, Arduino programming, and data processing. However, keep in mind that real-world earthquake detection requires much more sophisticated equipment, algorithms, and large-scale sensor networks.

8. Conclusion



Early detection can ensure easy evacuation. Creating awareness can lead to make possible preventive measures so that a huge disaster can be avoided. Optimal size makes the system easier to handle. The future work involves improving our system's sensor accuracy and better scaling calculation, also improving our device portability, and therefore system can be attached to various suitable places inside the building.

In conclusion, the earthquake detection system using Arduino proves to be an effective and accessible solution for early earthquake detection. By utilizing simple yet reliable components such as accelerometers, sensors, and Arduino boards, the system can detect seismic movements in real time. The project provides a cost-effective way to monitor ground motion, offering early warning alerts to mitigate potential damage and enhance safety.

This system is particularly beneficial in regions prone to earthquakes, where early detection can save lives, reduce property damage, and assist in emergency response efforts. With the growing importance of disaster preparedness, this Arduino-based earthquake detection project serves as a valuable prototype for more advanced systems.

Future improvements could include enhancing the system's accuracy by integrating more sophisticated sensors, adding communication features like SMS or Wi-Fi for real-time alerts, and expanding the system's range and sensitivity. Additionally, integrating machine learning algorithms to distinguish between earthquake-induced vibrations and other sources of ground movement could further improve the system's performance.

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