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Earthquake Detection and Warning System for Automatic Cut-Off of Electricity and Gas Supply Lines for Safety Measures

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Abstract*: The project aims at designing an earthquake monitoring and warning system that is capable of detecting earthquakes as well as warning people to take necessary precautions. The designed system will not only try to save human lives, but will also store the data for later use by professionals working at this sector. India is a country with a high frequency of earthquakes. Since the country lies at the junction of three tectonic plates, the intensity of earthquakes felt in this region is moderate. But surprisingly, the number of deaths and financial loss in this region by earthquakes is not due to building crashes or being crushed under homes. Rather, major reasons of losses are due to indirect effects such as induction of fear, as well as fire induced from a cracked gas line or faulty electrical transmission line damaged by earthquakes. Hence, a low cost automatic microcontroller based system has been designed and implemented using low cost locally sourced electronic components, which senses earthquakes and gas leaks through accelerometer and gas sensor respectively. The microcontroller operates a relay and a motor that cuts off electricity and gas supplies respectively during the event of an earthquake, helping to prevent associated potential disasters.

Keywords: Accelerometer, Gas sensor, Microcontroller, Relay, DC motor

I. INTRODUCTION

The earthquake is the vibration of the surface of the earth. It is caused by the movement of seismic waves. The seismic waves propagate through Earth's rocks or lithosphere. These seismic waves are generated because of sudden release of stored energy from underneath earth's surface. Generally, the seismic waves cause movement of the tectonic plates ,which we call as an earthquake. The earthquakes mainly occur in regions coinciding with the interjunctions of the tectonic plates. The modern seismicity maps show instrumentally determined epicenters of earthquakes. [14].

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Earthquakes can occur because of a variety of reasons. Some of the reasons are:-

- Natural Forces
- Tectonic Movement
- Volcanism
- Artificial Induction[14]

The Indian plate consists of most countries of the Indian subcontinent i.e., certain parts of Afghanistan, Pakistan, Sri Lanka, Myanmar, Bhutan, Nepal and certain parts of China[15]. It has three main objectives:-

1. Sensing and detection of the earthquake tremors at the earliest possible level.
2. Sounding the alarm and displaying the warning message for emergency evacuation.
3. Immediately shutting down the electricity and gas supply lines in the establishment.

The hardware circuitry of the designed system consists of the following parts:

1.Sensor Circuitry
2. Microcontroller
3. Alarm Circuitry
4. Actuation Circuitry
5. Power Supply Unit

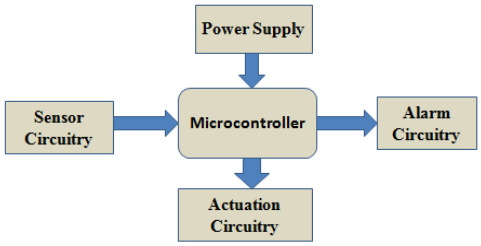

Figure 1: Basic framework of the system

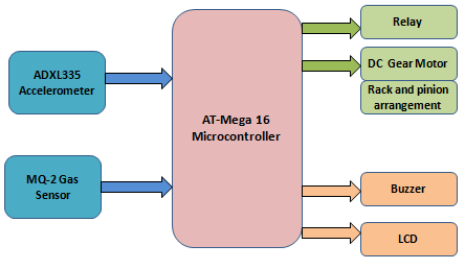

Figure 2: Basic overview of the system

A. Sensor Circuitry

There are primarily two sensors which are used in the earthquake detection and utility supply cut-off system ADXL335 Accelerometer and MQ-2 Gas Sensor. The accelerometer is used for detection of earthquake tremors and the gas sensor is used to detect leakage of gas.

B. ADXL335 Accelerometer

An accelerometer is a device which measures the acceleration which an object is subjected to and gives an equivalent electrical output. It is basically an electromechanical device. The device can measure both static and dynamic forces. It is fabricated using principle of MEMS. It is a Capacitive Accelerometric Sensor. It operates on the principle of operation of a parallel plate capacitor [18]. Here the ADXL335 accelerometer is a CAS (Capacitive Accelerometer Sensor), ADXL335. It measures acceleration due to force of gravity. It gives output in g unit[19].

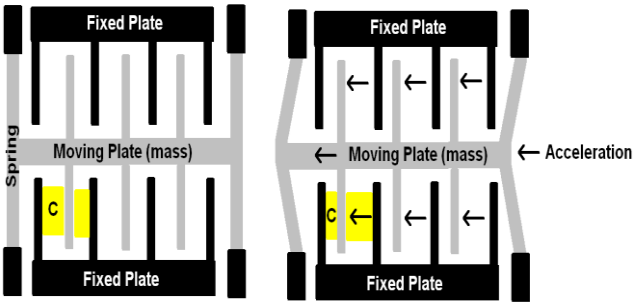

Figure 3: Mechanism of operation of ADXL335 accelerometer[18]

The change in capacitance is given by,

$$C \pm \Delta C = \varepsilon \frac{A}{d \pm \Delta d} \quad (1)$$

where, A & d are overlapping area and distance between plates respectively and ε is the permittivity of the medium. Δd is change in distance between plates.

The capacitance is then converted into voltage with the help of an inbuilt capacitance to voltage converter. Generlly, capacitance to voltage converter IC is used which is inbuilt in ADXL335 accelerometer[20].

The output voltage of the capacitance to voltage converter is given by,

$$V_{OUT} = V_{REF}\left(1 - \frac{C}{C_{max}}\right) \quad (2)$$

where,

V_{REF}= reference voltage =5V

C=capacitance of accelerometer

Cmax = maximum capacitance value of accelerometer.[18]

The ADXL335 module also has an inbuilt Analog to Digital Converter (ADC). It converts the analog voltage output of capacitance to voltage converter into suitable digital value.

The acceleration output in terms of 'g' is calculated

$$A_{out}(g) = \frac{\frac{ADC\ Value \times V_{max}}{2^{10}}(volt) - Voltage\ at\ 0g\ (volt)}{Sensitivity(^{mV}/_{g})} \quad (3)$$

where, voltage(0 'g')=1.65V

Vmax= 3.3V and sensitivity=550mV/g [19]

Table-I: Relationship between Richter scale And Acceleration

RICHTER SCALE MAGNITUDE	ACCELERATION (m/s^2)
1	<0.017
2-3	0.017-0.14
4	0.14-0.39
5	0.39-0.92
6	0.92-1.8
7	1.8-3.4
8	3.4-6.5
9	6.5-12.4
10	>12.4

II. MQ-2 GAS SENSOR

A gas sensor is an instrument which is used for the detection of various flammable and combustible gases such as hydrogen, methane, propane, butane, carbon monoxide, liquefied petroleum gas (LPG) etc. The gas sensor which we have used is the MQ-2 gas sensor. MQ is the acronym for 'Mingan Qi-Lai', which in Chinese means 'sensitive to gas' [21].

The output voltage of the MQ-2 gas sensor is given by,

$$V_{out} = V_{REF} \times \frac{R_L}{R_G + R_L} \quad (4)$$

where, R_L= load resistance

V_{REF}=supply/reference voltage

The MQ-2 gas sensor has an in built Analog to Digital Converter. The output of the MQ-2 gas sensor is given by,

$$V_{out} = V_{REF\,H} - ADC\ Value \times (V_{REF\,H} - V_{REF\,L})/(2^N) \quad (5)$$

where, $V_{REF\,H}$=higher reference voltage=5V

$V_{REF\,L}$ =lower reference voltage=0V

N=number of bits of ADC[22]

A. Sensitivity Curves Of Mq-2 Gas Sensor Atmega16 Microcontroller

The AT-Mega 16 microcontroller belongs to the AVR family of microcontrollers based on AVR architecture. It is a 8-bit high performance based device, which comes in as a 40 pin package. It has 40 pins in total out of which 32 act as I/O pins divided into four ports namely, Port A, Port B, Port C and Port D. It has a 16MHz operating clock frequency and 16KB flash memory which can be programmed. Along with that, it has 1KB static RAM and 512 bytes EEPROM[24].

B. Alarm Circuitry

The alarm circuitry consists of components which are used to indicate the occurrence of an earthquake and sounding the alarm. This helps for quick and effective emergency evacuation of people and implementation of other safety measures. It can also be used to alert the concerned authorities such as Fire and Safety Department, Disaster Management Department, Police and Casualty services etc. about the occurrence of the disaster.

In the designed earthquake detection and domestic utility supply cut off system,

the alarm circuitry consists of three components:

1. Buzzer
2. 16×2 Alphanumeic LCD
3.

III. WORKING OF A PIEZOCERAMIC BUZZER

The buzzer actually operates on the principle of DC to AC conversion. It consists of a resistor-inductor combination, which facilitates this conversion. When 5V DC is given to the buzzer, the resistor-inductor combination converts them into oscillating signal. These signals when applied to the piezomaterial disc produces the sound.
Commonly used piezo materials are Quartz, Rochelle salt, Tourmaline, Lead Zirconate Titanate etc[33].

IV. 16×2 ALPHANUMERIC LCD

The display module used here is 16x2 LCD. Here, the HD44780U standard is used. It has a controller chip. It receives data from microcontroller. It communicates with LCD. It has 3 control lines and 4 or 8 I/O lines for the data bus. We have 8-bit mode of LCD, i.e., using 8-bit data bus[31].
It has a matrix of LCD materials, a pair of electrodes, polarizing films and reflecting surface. When electric current is passed through LCD molecules they get deformed. When polarized light is passed through deformed LCD molecules, certain light rays undergo refraction and certain undergo reflection, thereby producing a visual sensation[31].

V. ACTUATION CIRCUITRY

The actuation circuitry consists of the following components:

1. RELAY
2. DC GEAR MOTOR
3. RACK AND PINION ARRANGEMENT

It is used to cut-off the electricity and gas supply lines in the event of occurrence of an earthquake or leakage of gas.

VI. RELAY

Here, we have used a 12V SPDT relay. It consists of a metallic coil, metallic moving contact which moves from one point to another. The relay is triggered indirectly with the help of a NPN BJT in order to protect the microcontroller from AC. When a signal is given from microcontroller to BJT, it behaves as a switch and gets closed. A current flows through the metallic coil magnetizing it. This pushes or pulls the metallic contact from one position to another. [26].

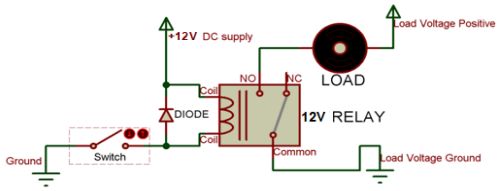

Figure 4: Operating mechanism of a 12V relay [25]

VII. CONNECTING GEARED DC MOTOR WITH MICROCONTROLLER-L293D BRIDGE

The outputs of Atmega 16 microcontroller cannot drive a dc motor directly. It is because our motors specification requires it to drive it on 12v dc but our microcontroller can give a max of 5v. So in order to drive our 12 V dc gear motor we require a driver circuit. The purpose is to amplify the 5v voltage to 12v.Nowadays, we have H-bridge motor driver. It is also called L293D BRIDGE. The driver H-bridge IS made up of transistors and MOSFETs etc. Here, the driver which we are using here to drive the motor is an IC L293D[29].

VIII. BASIC LAYOUT AND BLOCK DIAGRAM

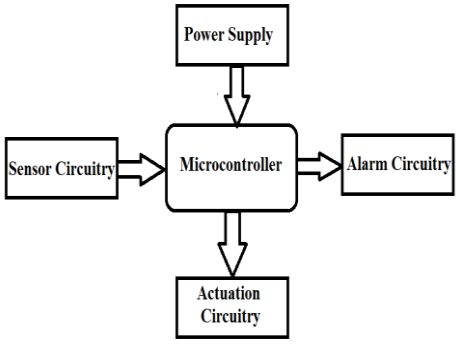

Fig-5: Basic layout of the system

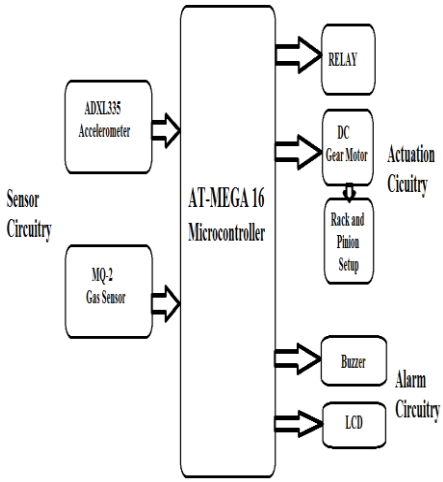

Fig-6: Block diagram of the system

A. Interfacing Of The Various components Interfacing Sensors With Microcontroller

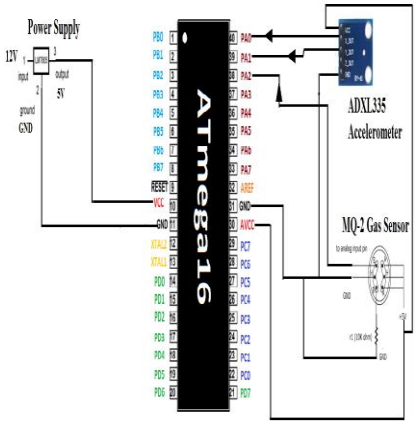

Figure-7

B. Interfacing Actuators With Microcontroller

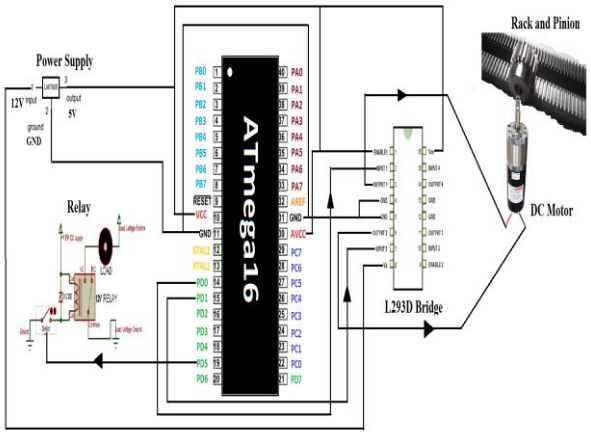

Figure-8

C. Interfacing Alarm Devices With Microcontroller

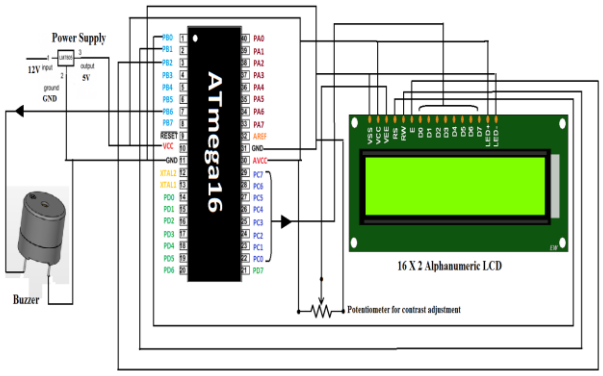

Figure-9

D. Working Principle

The entire setup is placed on a certain platform or location, where earthquake and gas leakage is to be monitored and detected.

- As soon as the ADXL335accelerometer is triggered due to ground movement, the LCD displays an emergency message and buzzer blows , indicating occurrence of earthquake tremors.
- The microcontroller then sends a signal to the relay. The relay gets triggered and cuts the electric supply off.
- The microcontroller then issues a signal to the motor driver IC.The driver rotates the dc motor connected to rack and pinion set up closing the gas supply line.

The electric supply and gas supply remains closed as long as the sensors are activated. As soon as the sensors return to the deactivated state, the electric supply resumes. But the gas supply has to be resumed manually.

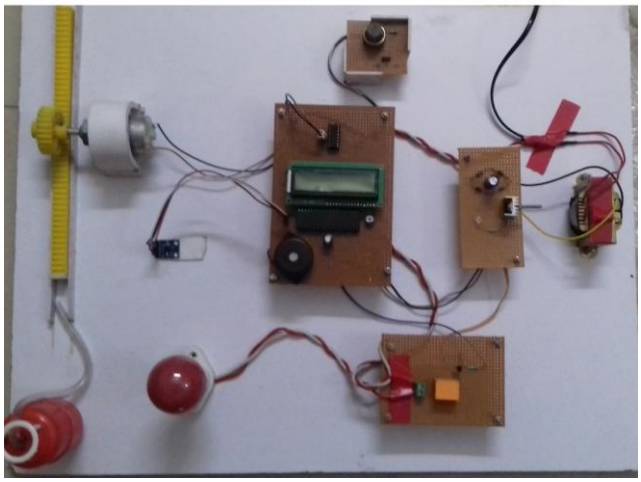

Fig-10 Working Model of earthquake detection and electricity/gas supply cut-off system

IX. OUTPUT RESULTS

During normal operating conditions i.e., before detection of earthquake tremors by ADXL335 accelerometer and leakage of gas by MQ-2 gas sensor, the electric and gas supply functions normally.

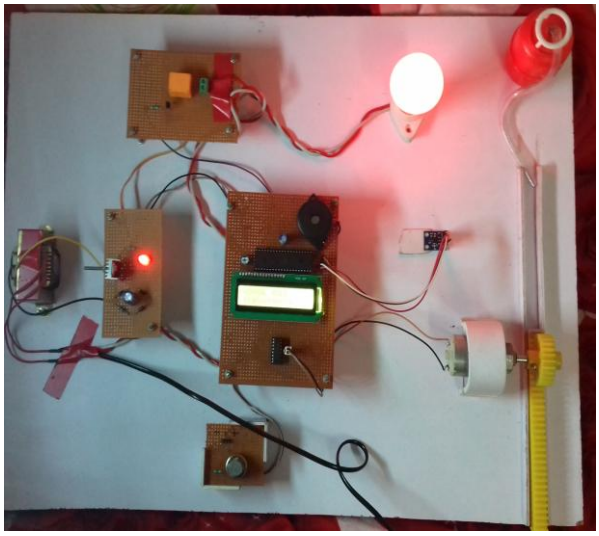

Fig-11: System functioning normally before triggering of sensors

When an earthquake tremor is detected by the accelerometer or gas leakage is detected by MQ-2 gas sensor, the system sounds the alarm through buzzer and displays warning message by LCD. Then, the electric and gas supplies are shut down immediately.

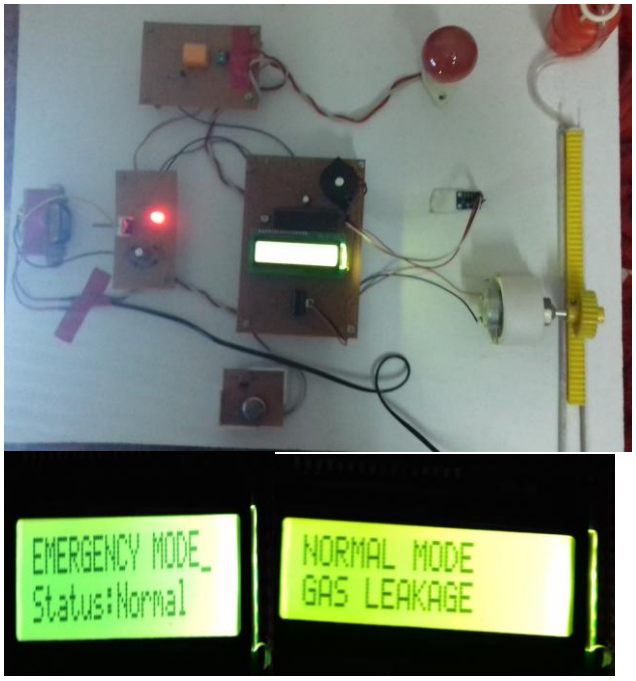

Fig-12: Utilities cut-off after triggering of sensors

Thus, we connected the various hardware components i.e., the sensors, the alarm devices and the actuators in the way as stated above so as to detect earthquake tremors and gas leakage at the earliest possible level. Then, after detection the alarm circuitry gets activated to sound the alarm and display the warning message and simultaneously, the actuation circuitry gets triggered to cut the electric and gas supply.

X. CONCLUSION

The earthquake detection and utility cut-off system provides us a means to detect earthquake tremors and immediately cuts off electricity and gas supply lines.

It has the following features:

- Senses and detects earthquake shockwaves at the earliest level possible.
- Provides automatic cutting off of electricity and gas supply lines.
- Sounds alarm to alert people to take the necessary precautionary measures.

XI. FUTURE SCOPE

- Establishing a correlation between earthquake intensity and acceleration output and displaying it.
- Tracking and pinpointing of the exact location of the domestic establishment where sensor is triggered using GPS technology.
- Automatic transmission of earthquake related data from the establishment where sensor gets activated to the nearest police station, fire department and hospital via wireless communication systems such as Bluetooth, Wi-Fi, Mobile communication, Li-Fi etc.

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