Earthquake Early Warning System (EEWS)

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Abstract- **Natural disasters cause thousands of deaths and property worth millions of rupees is lost every year throughout the world. Earthquakes and tsunamis resulting from large earthquakes under the sea are of particular concern because they generally occur with very little or no advance warning. Almost all earthquakes are preceded by physical processes which are commonly known as earthquake precursors. An instrumentation system is presented here for the detection of the variations of these precursors which change well before the event. It consists of a sensor coupled to an embedded system to enable precise detection of variation in physical parameters. This helps us to interface it with the microcontroller through the related software and send an alarm in the audio and visual form when the parameters exceed beyond certain critical threshold. The measurements of the dynamic variations of the parameters indicate a departure from the routine values. The instrumentation system allows a comparative monitoring of such parameters with previously set standards along with an alarm system to trigger off during exceptional variations. This alarm enables us to put in place the preventive safety measures. The instrumentation includes the vibration sensor geophone as the predominant sensor for detecting the relative parameters from the simulations of the earthquake.**

Keywords: Earthquake, microcontroller, Piezoelectric Accelerometer, Embedded System.

I. INTRODUCTION

Because of the extreme complexity involved in the earthquake processes, reliable earthquake prediction is not currently possible. Present technological advances in seismic instrumentation and in digital communication and processing permit the implementation of a real-time earthquake monitoring system. From the point of view of seismic hazards mitigation, earthquake early warning (EEW) is becoming a practical tool to reduce the loss caused by a damaging earthquake.

The idea of an earthquake early warning system was proposed more than one hundred years ago by Cooper (1868) for San Francisco, California. About a hundred years later, Japan Railways Company designed an EEW system in 1965 and started operation in the following year (Nakamura, 1988). In the past decade, progress has been made towards implementation of earthquake early warning in Japan, Taiwan, Mexico, Southern California, Italy, and Romania. In particular, the systems developed at the National Research Institute for Earth Science and Disaster Prevention (NIED) and the Japan Meteorological Agency (JMA) were

integrated in June, 2005. The system was successfully activated during the 2007 Noto Hanto (Peninsula) and the 2007 Niigata Chuetsu-Oki earthquakes, and provided accurate information regarding the source location, magnitude and intensity at about 3.8 s after the arrival of *P* wave at nearby stations. Thus, it provided early warning before arrival of strong shaking. Currently, there are many seismic networks using real-time strong motion signals for earthquake monitoring. In this paper, we describe a method of generating an alarm on the arrival of P – waves before the destructive S – waves and surface waves arrives.

II. PHYSICAL CHARACTERISTIC OF EARTHQUAKE

Earthquakes are generated by different types of movement within the lithosphere. The center of the primary event happens in a depth from zero to a few hundreds kilometers. The depth depends on the geological situation, as a rule of thumb; most earthquakes are generated within 200 km. beneath the surface. If an earthquake happens, different types of waves are generated. The p-waves are pressure waves and have the characteristic, that they have the highest speed. This type of wave is the first signal, that reaches the surface and this waves are usually not destructive. The reason is, the movement is orthogonal to the surface and buildings are well prepared to this type of force.

Seismic waves are also known as elastic waves because they cause a temporary distortion of the solid material. Body waves travel through the inside of the Earth: P-waves cause the rocks to expand and contract as the wave moves through the material. They are really nothing more than sound waves; every time you speak, your voice produces P-waves in air. S waves are shear waves which cannot travel through a fluid like air but can travel through solid rocks. We know that the outer core of the earth is fluid because S-waves do not pass through it. In addition to body waves, we also have two types of surface waves, a transverse shearing along a boundary (Love wave) and a rolling motion (Rayleigh wave). The first wave to arrive at a station is the P-wave, followed by the S-wave and then the surface waves. Because these waves travel at different velocities, we can tell how far away the earthquake is by the difference in arrival time between the P- and S-waves. Surface waves, which travel the slowest, produce the damage to buildings and roads.

Primary and secondary waves are body waves that travel within the Earth. The motion and behavior of both *P*-type

and *S*-type in the Earth are monitored to probe the interior structure of the Earth. Differences in arrival times of waves originating in a seismic event like an earthquake as a result of waves taking different paths allow mapping of the Earth's inner structure. Almost all the information available on the structure of the Earth's deep interior is derived from observations of the travel times, reflections, refractions and phase transitions of seismic body waves, or normal modes. Body waves travel through the fluid layers of the Earth's interior, but P-waves are refracted slightly when they pass through the transition between the semisolid mantle and the liquid outer core. As a result, there occurs a P-wave "shadow zone".

Earthquake advance warning is possible by detecting the non-destructive primary waves that travel more quickly through the Earth's crust than do the destructive secondary and Rayleigh waves, in the same way that lightning flashes reach our eyes before we hear the thunder during a storm. The amount of advance warning depends on the delay between the arrival of the P-wave and other destructive waves, generally on the order of seconds up to about 60–90 seconds for deep, distant, large quakes such as Tokyo would have received before the 2011 Tohoku earthquake and tsunami. The effectiveness of advance warning depends on accurate detection of the P-waves and rejection of ground vibrations caused by local activity (such as trucks or construction) as otherwise false-positive warnings will result. Earthquake Early Warning systems can be automated to allow for immediate safety actions such as issuing alerts, stopping elevators at the nearest floors or switching gas utilities off.

Table 1: Seismic Waves

| Wave Type	Particle Motion	Typical Velocity	Other Characteristics
P, **Compressional**, Primary, Longitudinal	Alternating compressions ("pushes") and dilations ("pulls") which are directed in the same direction as the wave is propagating (along the ray path); and therefore, perpendicular to the wavefront.	V_P ~ 5 – 7 km/s in typical Earth's crust; >~ 8 km/s in Earth's mantle and core; ~1.5 km/s in water; ~0.3 km/s in air.	P motion travels fastest in materials, so the P-wave is the first-arriving energy on a seismogram. Generally smaller and higher frequency than the S and Surface-waves. P waves in a liquid or gas are pressure waves, including sound waves.
S, **Shear**, Secondary, Transverse	Alternating transverse motions (perpendicular to the direction of propagation, and the ray path); commonly approximately polarized such that particle motion is in vertical or horizontal planes.	V_S ~ 3 – 4 km/s in typical Earth's crust; >~ 4.5 km/s in Earth's mantle; ~ 2.5-3.0 km/s in (solid) inner core.	S-waves do not travel through fluids, so do not exist in Earth's outer core (inferred to be primarily liquid iron) or in air or water or molten rock (magma). S waves travel slower than P waves in a solid and, therefore, arrive after the P wave.
L, **Love**, Surface waves, Long waves	Transverse horizontal motion, perpendicular to the direction of propagation and generally parallel to the Earth's surface.	V_L ~ 2.0 - 4.4 km/s in the Earth depending on frequency of the propagating wave, and therefore the depth of penetration of the waves. In general, the Love waves travel slightly faster than the Rayleigh waves.	Love waves exist because of the Earth's surface. They are largest at the surface and decrease in amplitude with depth. Love waves are dispersive, that is, the wave velocity is dependent on frequency, generally with low frequencies propagating at higher velocity. Depth of penetration of the Love waves is also dependent on frequency, with lower frequencies penetrating to greater depth.
R, **Rayleigh**, Surface waves, Long waves, Ground roll	Motion is both in the direction of propagation and perpendicular (in a vertical plane), and "phased" so that the motion is generally elliptical – either prograde or retrograde.	V_R ~ 2.0 - 4.2 km/s in the Earth depending on frequency of the propagating wave, and therefore the depth of penetration of the waves.	Rayleigh waves are also dispersive and the amplitudes generally decrease with depth in the Earth. Appearance and particle motion are similar to water waves. Depth of penetration of the Rayleigh waves is also dependent on frequency, with lower frequencies penetrating to greater depth.

III. DESIGN CONCEPT OF PROPOSED SYSTEM
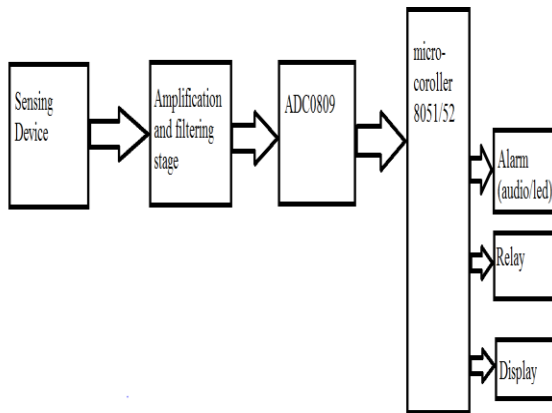
Fig: Block Diagram of EEWS

The EEWS is divided into 2 main modules, namely:
(1) Earthquake detection　　(2) Earthquake warning.

A. Module 1: Earthquake detection

The Earthquake is detected on a simple principle of piezoelectric excitation. The sensing device is piezo type, generates output on vibration. This output is analog in nature and contains noise, so this analog signal is applied to a filter (band pass), which filters frequency 0.075Hz to 20Hz, the frequency range of Earthquake waves, P – waves have frequency of 1 – 10Hz. This filtered signal digitalized by an ADC which is connected with an 8051 microcontroller.

P – waves have specific characteristic as it passes through 2 different media - ferromagnetic rod and high temperature medium. The changes induced in the P wave waveform marks the essence of the entire early warning mechanism. P-wave velocity in earthquakes is in the range 5 to 8 km/s. The precise speed varies according to the region of the Earth's interior, from less than 6 km/s in the Earth's crust to 13 km/s through the core.

B. Module 2: earthquake warning

The program is loaded in controller, so whenever a P – wave is detected it will generate an alarm with an on/off relay gets operational. Also on detection of P – wave it will display a message "Earthquake is on way" on LCD. The alarm will give an early warning of some seconds.

IV. HARDWARE & SOFTWARE DESCRIPTION

A. Accelerometer

An accelerometer measures the real time, instantaneous acceleration of the object on which the accelerometer is mounted. It transduces the acceleration, which results from some shock or vibration, onto a proportional analogue signal. Although there exist numerous types of accelerometers, the piezoelectric type is the most widely used. We are using a piezo plate as a sensing element, it senses the vibration and gives corresponding output.

B. AT89C51 Microcontroller

The 8051 family of microcontrollers is based on an architecture which is highly optimized for embedded control systems. It is used in a wide variety of applications from military equipment to automobiles to the keyboard. Second only to the Motorola 68HC11 in eight bit processors sales, the 8051 family of microcontrollers is available in a wide array of variations from manufacturers such as Intel, Philips, and Siemens. These manufacturers have added numerous features and peripherals to the 8051 such as I2C interfaces, analog to digital converters, watchdog timers, and pulse width modulated outputs. Variations of the 8051 with clock speeds up to 40MHz and voltage requirements down to 1.5 volts are available. This wide range of parts based on one core makes the 8051 family an excellent choice as the base architecture for a company's entire line of products since it can perform many functions and developers will only have to learn this one platform.

C. The ADC 808

The ADC0808, ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals.

The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL TRI-STATE outputs.

V. RESULTS AND DISCUSSIONS

The project focuses on generating an alarm when ever earthquake occurs, which is achieved through acceleration data under comparable working condition. The data obtained will be analyzed and use to judge severity.

The purpose of this project is to provide means of early through monitoring and analysis of ground motions at site. Faults could occur unintentionally by human or animal, resulting into severe damage to machine. With early fault finding it will not prove to be a threat and faults will be fixed early with the proper drawn condition based maintenance schedules. Our expected scope are as follows:

1) Early Alarm will be generated for earthquake above threshold value
2) A well documented method for condition monitoring and analysis of earthquake
3) The quality of P wave detection and attenuation of false alarm

Well the project is under construction we hope that we will able to complete it with required outcomes.

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CONCLUSION

It is feasible to build a global earthquake warning system based on a peer to peer network. The distribution of the software will be fast, if the participants of the system receive the warning first. After the implementation of the first generation of this system, a lot will be learned how the signals appear and when a real alert should be given and hopefully, a lot of lives could be saved.

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