Analysing and Monitoring Earthquake Vibrations using Geophones, Interfaced with Microcontroller

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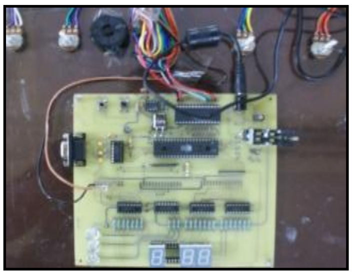
ABSTRACT

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 [1].Almost all earthquakes are preceded by physical processes which are commonly known as earthquake precursors [1]. 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

Geophone, Seismology, Transducers, Signal conditioner circuit& The Intelligence.



1. INTRODUCTION

Variations in the environmental energy parameters such as temperature, pressure, relative humidity, conductivity of ionosphere, earth’s magnetic field, gravitational field etc either natural or man-made has led to calamities such as tsunamis and earthquakes [2].

Several types of faults occur in the earth’s crust. Due to the accumulated stress, these faults break resulting in sudden release of energy which leads to earthquakes. Earthquakes occur along the plate boundaries [2]. The energy is released as seismic waves which travel away from the epicentre of the earthquake.Seismology is the study of earthquakes. The principal tool to measure earthquakes is a seismometer which measures the intensity of the arrival of the earthquake, after sudden displacement along a fault will generate different types of waves that travel through the earth and along it’s surface [1].Geophone is an instrument for measuring ground motion. It is designed for earthquakes, machine vibrations, oil exploration, mining etc [4].

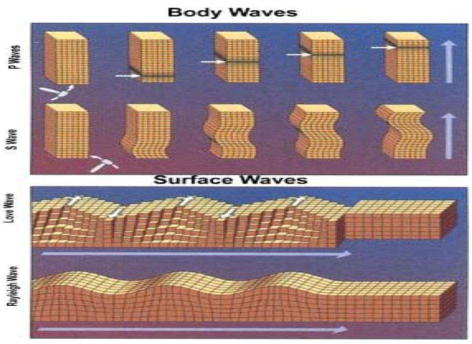
A signal conditioner can vary in complexity from a simple resistance network or impedance matching network to a complex multistage amplifier with or without detectors, demodulators and filters [5]. Alternately they are termed as signal modifiers or signal processors. The output is usually analog but can be converted into digital using the analog to digital converter.The output of signal conditioning circuit which is interfaced to an analog to digital converter is given as input to the microcontroller 8051. The microcontroller on the other hand monitors and sends warning signal when the parameter exceeds the predefined critical value [6].

Almost all natural calamities send their signature well before they do the destruction. Our Aim is to pick up these signatures as and when they occur, analyze them and if the value exceeds a certain predetermined threshold; send an appropriate warning signal to the people so that a lot of lives can be saved. However it is observed that variation in few physical parameters is common to many natural calamities. So it is necessary to study which 3 – 4 parameters changes predominantly and in case; any three of them exceeds a certain threshold then the alarm should be activated. Monitoring many parameters at a time would avoid false alarming, for example the nature of wave in the earth’s interior during earth quake and nuclear explosion is same, the sensor should not alarm for earthquake when there is nuclear explosion.The variation in the content of ions in the ionosphere as well as the variation in humidity takes place before earthquake as well as during thunder, again the false alarm of earthquake should not be send when it simply thunders. To summarize, if four dominating parameters are finalised and if any three of them cross the threshold; there should be a strong alarm. The occurrence of earthquake sends its signature well in advance through the Lithosphere, Atmosphere and Ionosphere [1].

- Emanation of Radon gas takes place in the lithosphere,
- Infrared radiations are emitted in the atmosphere,
- Change of E-flux takes place in the ionosphere and
- Variation of Humidity is experienced in the atmosphere.

2. SEISMOLOGY

Seismology is the study of earthquakes. The principal tool to measure earthquakes is a seismometer which measures the arrival of earthquake waves. Sudden displacement along a fault will generate different types of waves that travel through the earth and along its surface [1].There are of two types of seismic waves i.e. body waves and surface waves. Body waves consist of Primary waves (P-waves) and Secondary waves (S-waves), and Surface waves consist of Love waves and Rayleigh waves [2].The velocity of P and S waves generally increases with depth in the earth which causes the waves to bend. The waves also reflect and refract off abrupt discontinuities such as the crust/mantle boundary. Fluid layers in the earth block S waves and create "shadow zones". P waves (or "longitudinal waves") travel through fluids, and solids.



They are compression waves and rely on the compression strength and elasticity of the materials to propagate. They are known as body waves because they travel though the body of a material in all directions and not just at the surface, as water waves do. For P waves, the motion of the material particles that transmit the energy move parallel to the direction of propagation. P waves travel the same way as sound waves in air. P waves are the fastest seismic waves and travel at roughly 6.0 km/s in the crust (much more than the speed of sound). S waves depend on the shear strength of the material. S waves do not travel as fast as P waves and have a velocity of about 3.5 km/s in the crust. Surface waves are of two types, i.e. Love waves and Rayleigh waves. The velocity of the surface waves varies with their wavelength but always travel slower than P and S wave [2]. An earthquake will generate all of these waves and they will propagate over the surface of the earth and through the body of the earth.

2.1 LOCATING EARTHQUAKES

Earthquakes produce all three types of seismic waves: P waves, S waves, and Surface waves. Because the different waves travel at different velocities, the time it takes each wave to arrive depends on the distance to the earthquake (just like thunder and lightning; the farther away the lightning is, the longer it takes the thunder to arrive) [1].If we have a recording of the seismic waves made by a seismometer, we can measure the time between the P and S waves. From that time we can calculate the distance to the earthquake. It has been observed that before the actual occurrence of an earthquake, anomalous change in various environmental parameters of the Earth take place [2].These variations effect the thermosphere, ionosphere, atmosphere and lithosphere in space and time. It is due to the geo-physical parameter E-flux (electron flux) which changes after the coronal mass ejection from the outer periphery of the sunspots. When the E-flux (electron flux) changes suddenly it affects the environment of the earth. This phenomenon changes the thermosphere, ionosphere atmosphere and lithosphere locally as well as globally [1]. The response of the magnetosphere to interplanetary shocks or pressure pulses can result in sudden injections of energetic particles into the inner magnetosphere. It has been recorded that 36 hours before the occurrence of the earthquake; the E-flux increases drastically.

3. INSTRUMENTATION

The experimentation system comprises of the following elements:

- The transducer/sensor which converts the physical parameter into usable electrical output [4].
- The signal conditioner which converts the transducer output into an electrical quantity suitable for control, recording and display[5].
- The display or read out devices which display the required information about the physical parameter in certain units [5].
- The power supply which provides the required excitation to the transducer and the necessary power to the signal conditioners and display devices [7].

3.1 TRANSDUCERS/SENSORS

In order to study control and monitor of any physical parameter through an electronic instrumentation, we need a device called transducer/sensor. This device converts the variation in the physical parameter to a variable electrical signal. A transducer is defined as a device which when actuated by one form of energy is capable of converting it into another more useful form of energy.Transducers usually generate output signals in the mV range (spans of 10mV to 250mV), often amplified to the voltage level (1 to 5V) and converted to current loops, usually 4-20mA dc [4].Quartz based Electrostatic Pressure Sensors are the most preferred sensors because these transducers are small and rugged. The force can be applied to the crystal longitudinally or in the transverse direction. In either case this will cause a high voltage output proportional to the force applied. The crystal's self-generated voltage signal is useful because providing power to the sensor is impractical or impossible. These sensors also provide high speed responses (30 kHz to 100 kHz), which makes them ideal for measuring transient phenomena.

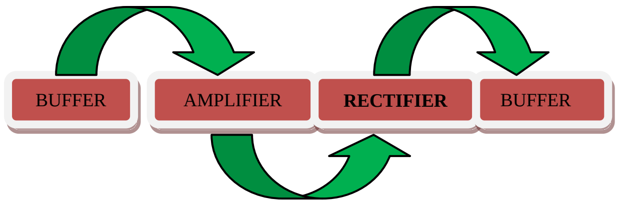
3.2 AMPLIFIERS

The output voltage of almost all active sensors corresponding to the variation in a physical parameter is very small. Amplifier with very high input impedance and sufficient gainareused to pick up very small signals (approximately inpico to millivolts) is necessary [5]. Along with this, the

CMMR of the amplifier should be very high. So an amplifier with appropriate input/output impedance, sufficient gain and high CMMR is an important part of the signal conditioning circuit [5].The amplifier CA3140 are integrated circuit operational amplifiers that combine the advantages of gate protected MOSFET (PMOS) transistors with bipolar transistors on a single monolithic chip. BiMOS operational amplifiers have PMOS transistors in the input circuit which provides very high input impedance, very low input current and high speed performance.

3.3 SIGNAL CONDITIONER CIRCUIT

The signal conditioner circuit consists of a buffer (Op-amp as voltage follower), an amplifier (Op-amp in non-inverting mode) with adjustable gain (maximum up to 500), a rectifier followed by a filter (to get smooth dc) and a buffer (Op-amp as voltage follower) for impedance matching between the signal conditioner circuit and the ADC [5].



3.4 ANALOG TO DIGITAL CONVERTER

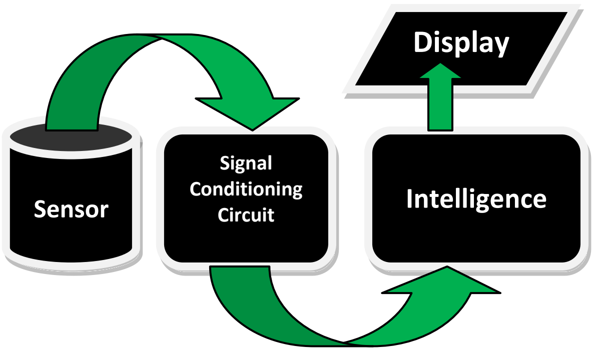
ADC's are among the most widely used devices for data acquisition. A physical quantity is converted into electrical signals using transducer. Digital computers use binary numbers while temperature, pressure, humidity etc are analog in nature. Therefore we need an ADC's to translate the analog signals to digital numbers so that the microcontrollers can read and process them.

3.5 INTELLIGENCE

The output of the sensor is interfaced to signal conditioning circuit which in turn is interfaced to an analog to digital converter and further the output of the ADC converter is given as an input to a microcontroller [3].The Microcontroller 89C51monitors and sends warning signal when the parameter exceeds the predefined critical value.

4. EXPERIMENTAL SET UP

The Experimental setup consists of the following Components:
The sensor Quartz dyne/Geophone [4], the output of the sensor is interfaced to the signal conditioner consists which in turn consists of a buffer (Op-amp as voltage follower), an amplifier (Op-amp in non-inverting mode) with adjustable gain (maximum up to 500)[5], a rectifier followed by a filter (to get smooth dc) and again a buffer (Op-amp as voltage follower) for impedance matching between the signal conditioner circuit and the next stage i.e. the ADC[5].

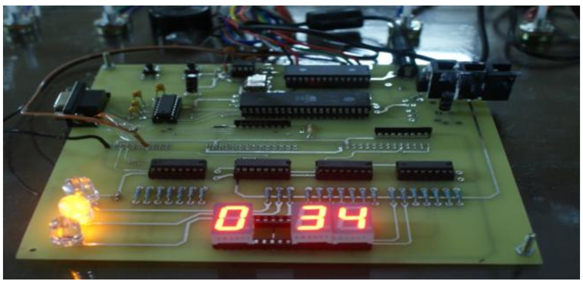


Further the output of ADC 0809 is controlled and monitored by microcontroller 89C51 [6]. The display used is a seven segment display and is coupled to a buzzer [8].

4.1 MICROCONTROLLER BASED INSTRUMENTATION

Microcontroller 89C51 based instrumentation involving interfacing hardware with software to connect the Sensor for parametric measurement of the precursors to the earthquakes [7]. The instrumentation can monitor four channels (Sensors) at a time [3].An arrangement is made to display the channel (Sensor) number and the equivalent number corresponding to the voltage available at the channel. Maximum display of 99 is divided into three parts i.e. 33, 66 and 99. The GREEN LED glows till the voltage at the sensor does not exceed the voltage corresponding to the value of 33 on the display. While the display is between 33 and 66 the ORANGE LED glows and the RED LED comes ON and glows when the voltage exceeds the value corresponding to 66 and reaches that corresponding to 99.

Glowing of Red LED indicates that the physical parameter has exceeded certain predefined critical value and is basically connected to a warning system. This monitoring is possible for all the four channels. The channel selection is made possible with the help of a push button switch.This software helps us to monitorall the four signals continuously (channels) and the moment any three of the four signals exceed the value corresponding to the display of 66 (i.e three signals exceed the critical threshold simultaneously) the sound alarm is activated. The sounding of alarm is an indication of the gravity of the real dangerous situation so that the preventive measures can be taken and people can be advised to evacuate the place to save their life and prevent loss of movable property.



5. CONCLUSION

The instrumentation setup was intended to work on the basic principles of Physics and Electronics [5]. This is the first time that such an instrumentationis set up using systems based on Microcontroller and interfaced with the circuitry developed for monitoring the output parameters of the Geophone [4]. Incidentally these are the very parameters which are understood to develop weeks before the advent of the actual earthquake.

6. FUTURE SCOPE

No part of the world is immune from earthquakes. Developing countries, in particular, are the most affected because response services may not be available even in less stressful times. Earthquake prediction research in the country should be taken seriously, of course, along with other necessary measures aimed at reducing damage and minimizing human suffering. Almost all earthquakes are preceded by physical processes which are commonly known as earthquake precursors [1]. The whole idea is to detect even the most feeble information fast enough to process, analyze and generate an appropriate warning signal [2].HOBOnode wireless sensor applications could perhaps be useful along with the associated instrumentation [9]. HOBOnode wireless sensors monitor temperatureand soilmoisture conditions and transmit the data back to thecomputer. They enableus to view currentconditions through a remote sensor,receive alarm notifications,and logdataon to the PCwithouthaving to runcablesthrough the field.The HOBOnode Outdoor Wireless Sensorsare easy todeploy and move. Thereare no cablesto run throughcrops or walls, we arenot limited by physical cable lengthlimits,andthere is less chancefor losing measurements from cable damage.The system can wirelessly transmit parametric readings to a PC, and provide audible and visual alarm notifications via cell phone text messaging and email when frost conditions occur.

7. ACKNOWLEDGEMENT:

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8. REFERENCES:

[1] Fundamentals of earthquake prediction: CinnaLomnitz, John Wiley & Sons Ltd.

[2] Earthquake Instrumentation: Sixth world conference on earthquake engineering Preprints.

[3] Designing Embedded Systems with PIC Microcontrollersby Tim Wilmshurst

[4] Handbook of Modern Sensors: Physics, Design and Applications. Jacob Fraden, 3rd edition, Springer International Edition.

[5] Digital principles and applications D.P.Leach, A.P.Malvino and G. Saha. 6thedition, the McGraw-Hill.

[6] Microcontroller and Embedded Systems Muhammad Ali Mazidi

[7] Serial Communications by David Benson

[8] ‘ICWET 2012’ - International conference & workshop on emerging trends in technology 2012, ‘Inter Integrated circuits’, Pg. No. 820 – 824.

[9] ‘ZENITH – 2011’ – National conference on Advances in Engineering, Technology & Management, ‘Managing a wireless HOBOnode network’, Pg. No. 30 – 31.