Prediction of Earthquake Using 3 Axis Accelerometer Sensor (ADXL335) and ARDUINO UNO

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Abstract: ***Seismology is that branch of Science that deals with the study of Earthquake and Seismic wave through the body and Surface of Earth. Today, Detection of Earthquake is carried out everywhere but a need to predict it is urgent to prevent deterioration to both life and property! In this paper, we have given brief information about what is earthquake and designed a model to predict it. A brief introduction has been given to different types of seismic waves with their respective frequencies. The Accelerometer ADLX335 has been used in combination with Arduino Uno (ATMega 328) at the earthquake prone areas which are connected with the Data Centers by a wireless network. ADLX335 is capable of sensing vibrations from all the directions X, Y as well as Z.The ADXL335 is a low power, complete 3-axis accelerometer with signal conditioned voltage outputs and can measure static and dynamic accelerations. Programming for the controller is carried out using the software Arduino 1.8.3 By which we obtain the graphical data of seismic waves in X, Y, Z directions.***

Keywords: Earthquake, Seismic Waves, Seismic data Acquisition, ATMega 328, Accelerometer, ADC, XBee S1, Minicom GUI

1. Introduction

An earthquake is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. An *earthquake* is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the *fault* or *fault plane*. The location below the earth's surface where the earthquake starts is called the *hypocenter*, and the location directly above it on the surface of the earth is called the *epicenter*[1].

During earthquake, degree of the damage caused is depends on the magnitude that indicates the amount of energy released from Earths crust. The magnitude of earthquake which is less than 5 is measured using local magnitude scale called as Richter magnitude scale. Itmeasures the magnitude of earthquake by observing the amplitude on a seismogram.In recent years, a standard magnitude scale is used which represents energy released at the time of earthquake more precisely including large magnitude events. This technique makes use of devices like either seismometer, geophone, accelerometer. Meanwhile before selecting any seismic sensor we need to know that the seismic sensor should provide signals which are unaffected by the sensors inherent characteristics and as closely as possible reflect the true soil response to the seismic source wave traveling through it. In terms of frequency response of the receiver, its output should be constant for all input frequencies. In addition, the phase of the input frequency should be unaffected so that the wave's shape does not change. In general terms, it is desirable to have a seismic sensor with a fast response time and a small settling time [2].When it comes to the selection of a seismic sensor though Geophones have larger peak time and settling time compared to accelerometer but the accelerometer are selected for the seismic activities because of their low noise, fast response times, and high bandwidths compared to geophones.

2. Seismic Waves

As these Tectonic Plates are moving the energy that would normally cause the blocks to slide past one another is being stored up. When this force overcomes the friction of the Fault edges, allthe stored energy is released.

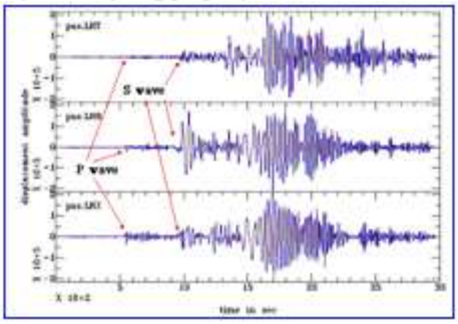

Figure 1: P waves and S waves

This energy is radiated outward s from the focus in all directions in form of *Seismic waves*. These Seismic waves produced tend to shake the earth surface as it moves through it. When we talk about Seismic wave , these are further of two types , Body waves and Surface waves .We focus more on body waves rather than surface waves because the source regions can be constrained in both azimuth and distance using conventional array technique . Also, the velocity of Surface wave is even less than 2 mi. per sec as compared to velocity of Body wave. Body waves are classified into Primary waves (P waves) and Secondary Waves (S waves) . P waves are the longitudinal waves and travel with a velocity of 6.4 km per sec while S waves are the transverse waves and travel at 3.2 km per sec [3]. Therefore, P waves being the fastest among all the Seismic waves are the first to be detected on the seismograph and help predicting it. Frequency range for P waves varies from 1Hz to 10 Hz with wavelength of range 600 m to 6km. While the Frequency range of S waves is from 0.1 Hz to 0.2 Hz with a wavelength of 10 km .The seismic data collected for the earthquake prediction can also be used to detect vibrations due to heavy vehicle transport or heavy drilling.In seismological experiments, each component of acceleration that is along x, y, and z axes is important, however in seismological calculations only one component has been considered. This measurement can be done when any seismic source start generating seismic waves.

3. Seismic Data Acquisition Setup

The collection and recording of continuous seismic signals and use it for further analysis is known as *seismic data acquisition*. The analysis of these recorded signals to eliminate noise and create map of the subsurface is called *seismic data processing*. With the increasing importance of embedded systems and its ubiquitous connectivity , It provides a great deal of help in seismic data acquisition.However, some combination of cost pressure, long life-cycle, real-time requirements, reliability requirements, and design culture dysfunction can make it difficult to be successful applying traditional computer design methodologies and tools to embedded applications. Embedded systems in many cases must be optimized for life-cycle, cost sensitivity, withstanding harsh environments, small in size and other business-driven factors rather than for maximum computing throughput.

The most embedded computers consistof a powerful microprocessor unit (MPU), a high-resolution analog to digital converter (ADC) and storage memory. However, these commercial devices are costly and restricted to modification or upgrade as well as not compatible with the computer. The use of open-source software with common hardware platform has been increasing because of advantages like open platform, improved performance, and lower cost. The seismic signals have very large dynamic range and wide bandwidth; hence ADC resolution is a key factor of designing a digital acquisition system [4]. The Figure 2. Shown below represents the setup for seismic data acquisition where the Transmitter area is an earthquake prone zone while the Receiver is a Data Centre which collects Seismic data information from nearby Transmitters which vary from one to multiple.

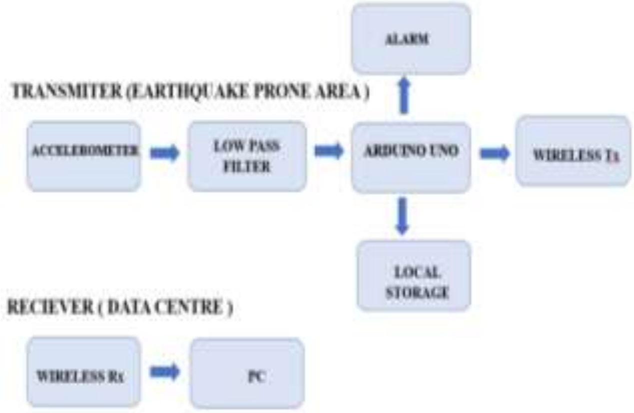

Figure 2: Set up for seismic data acquisition system

The first Block in the Transmitter section is of an Accelerometer, which is an electromechanical device used to measure different acceleration forces. Various accelerometers are available, we use ADLX335 accelerometer. The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g.It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis. It is a single supply device whose supply voltage varies from 1.8V to 3.6V and a low power consumption of 350 μA. It provides a sensitivity of 300±0.01 mV/g by responding to minute vibrations in all three directions [5].

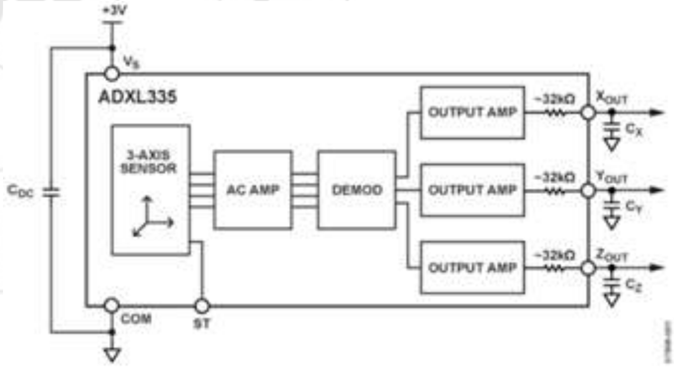

Figure 3: Block representation of ADLX335

The measured values appear as change in voltage at three output pins with respect to a common ground. The sensormeasures acceleration with the help of a layer of polysilicon suspended above silicon wafer with the help of polysilicon springs. The motion of this mass is translated into the motion of the plates of a differential capacitor and thereby providing an output proportional to acceleration.

Let mx, my, mzand dx, dy, dzare the values of the accelerometer when it placed in six perfect axial positions(m stands for the values when it placed 1g position and d stands for the values when it placed 1gposition). Again, let a = (ax, ay, az) is the acceleration vector in x, y and z plan.Therefore, the acceleration values can be written as:

$$ax = (x-mx)/ dx,$$
$$ay = (y-my) / dy,$$
$$az= (z-mz) / dz$$

Where, x, y, z are the three axialvalue at all the position.If the values are taken at zero noise condition sum of the square of all the above values
are equaled to 1.

$$ax2 + ay2+ az2= 1$$

But in presence of noise there might be some error. And these errors are nonlinear. It has been found that the nonlinear LeastSquare problem can be solved numerically using GaussNewton method [6].

To acquire the best sensor data the sensor must be rigidly affixed to the test article. By this means, maximum energy is transferred from the test article into the sensor. Rigid connection to the test article results in the highest frequency response possible within the limit of the sensor upper frequency response. Often a test person may loosely mount a sensor. Sometimes such an approach may result in off-axis orientation. To prevent this, a prerequisite to mounting the sensor is to “face” the mounting location. A flat (faced) surface is required to properly mount the accelerometer. Accelerometer mounting studs are used to secure the accelerometer to the test object. To ensure accurate measurements, always mount the accelerometer to the datasheets recommended mounting torque [7]. The Figure 4 above shows various accelerometer mounting techniques using studs and screws.

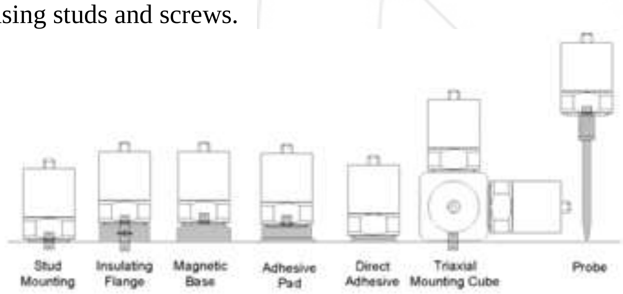

Figure 4: Accelerometer mounting using studs and screws

After sensing the vibrations, the sensor converts the vibrations in to some voltage levels then an accelerometer transfers the signal to the low pass filter which is inbuilt in an accelerometer. LPF is used to reduce the high frequency component from the received signal means it reduces the distortions present in the signal. Then the output from LPF is passed onto the ADC of Arduino Microcontroller which is responsible for converting the analog voltages into digital format.

The Microcontroller we are making use of is Arduino Uno based on ATMega328, which is a high performance 8-bit Microcontroller operating on 5V supply with a clock speed of 16MHz.It has a built in 6 channeled 10 bit ADC in PDIP package and an on chip analog comparator . Programmable Serial USART present on chip, helps in receiving and transferring of data [8].

As the Arduino now converts the analog data into digital, Now the data must be transferred to the data center through wireless networks with are more cost effective, secure, expandable compared to the wired network. To solve this purpose of ours we make use of Wireless Transmitter and ReceiverXBee S1 Module which provides simple, out of the box RF communication with no extra configuration needed. XBee S1 operates at 2.4GHz for worldwide deployment enabling point-to-multipoint topology. XBee 802.15.4 modules seamlessly interface with compatible gateways, device adapters and range extenders [9]. The Xbee S1 wireless module is based on 802.15.4 protocol 1mW with wire antenna and it allows communication between microcontrollers, computers, systems, etc. with a serial port. For communicating XBee, they must be configured using X-Ctu Software where the transmitter is configured as the Coordinator and the receiving part is configured as a Router.

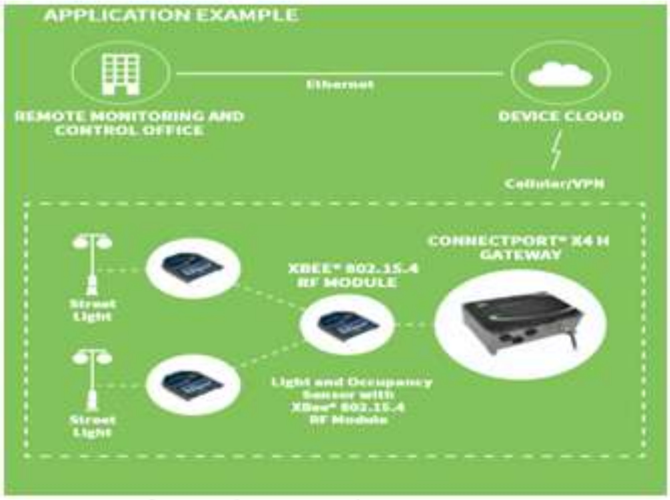

Figure 5: Connectivity with XBee S1

Now the received data is transferred to the PC or Laptop which will contain Linux OS with minicom GUI which will have routines for serial communication and graph plotting. It will show real time display of graph of received data verses time.Minicom GUI is aimed mainly at hardware developers or other people who need a terminal to talk to their devices. It features line oriented interface instead of character-oriented, Arduino will compare the input seismic signal and referenced signal which is already set in to the processor. If input signal is greater than the referenced signal then the people at the data center are informed about a higher magnitude earthquake which is predicted to come and an alarm present also starts ringing.

4. Result and Conclusion

Nowadays, It has become a necessity to predict Earthquake and send its Early Warning to the places nearby in order to prevent massive destruction caused by it . The whole procedure and the technique studied above in the paper can be summarized by the flow diagram .It provides a jist of the steps to be carried out for earthquake prediction , including from how the analog information has to be transferred by the accelerometer which is further converted into digital using microcontroller and then data is sent to the data center through wireless medium . If no earthquake is predicted the system is said to be in the loop itself and repeat the steps.After action has to be taken if the earthquake is predicted to hit the area to prevent loss.

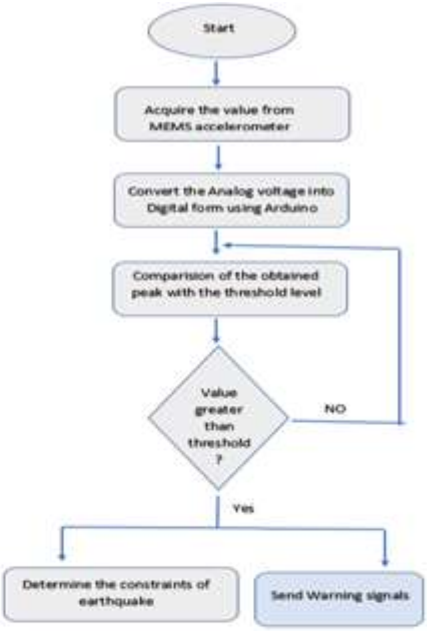

Figure 6: Flow Chart for Earthquake Prediction steps

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