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Wireless Earthquake Alarm Design based on MEMS Accelerometer

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Abstract: This paper mainly used to monitoring the Wireless Earthquake alarm design using MEMS accelerometer. Earthquake is a vibration transmitted in the earth crust .Most of the naturally occurring earthquake are caused by Earth plate movement. In 1997, The idea gave rise to numerous argument and researches. Perhaps it is because earthquake breaks out in the inner part of the earth. It is impossible to the directly obtain the observational data and together with other complex factor. The process of research is very slow .but it still attracted a lot of scientists and scholars to study. Conventional earthquake detection device And system utilize a vibrometer in a magnetic-electric sensor, or pick-up unit. These device and system may involve complicated circuitry and it may be expensive. some experts have put forwards a design method for the Earthquakes Warming system. The model could theoretically simulate and be used to predict the probability of strong earthquake that could occur anywhere at any time. In order to mitigate earthquake disaster caused by the structure of building, the strong motion observation is the most important means to scientific understanding of above problem. Earthquake alarm researched in this paper was based on the strong motion observation theory adopted MEMS accelerometer and wireless transmission technology, was more advanced and practical device.

Keywords: Earthquake, EEW, ADXL335, ATmega328p, XBeeS2.

I. INTRODUCTION

Earthquake is one of the most damaging natural activities which offer serious threat to areas near major active faults on land. Earthquake happens due to the sudden release of large amount of energy from the earth crust Because of this energy earth create some destructive waves known as seismic wave. It has been found that the seismic waves include shear- wave, longitudinal wave and surface wave. The longitudinal wave and shear wave is also known as P-wave and S-wave respectively. Out of all waves surface wave is the most destructive in nature, the speed of the surface wave is slower than other waves. The P-wave's vibration direction and the forward motion are found to be same, which is the fastest in nature among the all waves. However, the destructive force of P-wave is found to be low.S-wave's vibration is perpendicular to the forward direction, whose speed is lower than P-wave but the destructive force is high .Due to urbanization, earthquake offer serious threat to human lives. According to Geller R.J.The prediction of earthquake are impossible. In many research paper work are still going on the predictions of earthquake. Early Earthquakes Warning systems is one of its useful development to save human lives. EEW detects the P-waves and generates warning as the most destructive S-wave follow the P-wave. It has been reported that some countries have already implemented EEW to rectifying earthquake hazard. In many countries don't have EEW. The cost of implementations is high. For these countries there must be some amout of low cost earthquakes alarm system to save human lives. This paper show the designs of low cost earthquakes alarm system which can be used by the people in their home to save their lives at the time of earthquakes. The acceleration of the seismics wave is greater than the predefined value. The system blows the alarm. This systems can be used in the multistoried buildings as the alarm was connected wireless.

II. LITERATURE REVIEW

According to survey we know that seismic data acquisition was very important factor in detection of the earthquakes before arrival of it. In previous days Seismometers are used at seismological stations for data acquisition. In 2003 Chungetal was developed by MEMS-type accelerometer which can be monitors of large scales structures. In addition to that of the same authors used MEMS Accelerometer for the real time seismics monitoring of the bridges [8]. This system was been installed at the pedestrian bridge in the Peltason Street on the University of California, Irvine campus. Again for seismic data acquisition C.P. Singh uses MEMS Digital Geophone. This geophone was based on the MEMS Accelerometer and onboard sigma delta modulator which was very useful for the exploration in the oil fields [7]. Further Takao Aizawaetal. [9] performed some field experiment using MEMS Accelerometer for seismic survey. In this survey the authors use of conventionals geophone. It was been reported that the property of MEMS Accelerometers which were used in the experiment were similar and they are found to be more sensitive than conventionals geophone for the seismic surveys. Adam Pascale in 2009 explained some advantages of MEMS Accelerometer for the earthquakes monitoring [10]. Recently, the Quake-Catcher Network (QCN) is used to the minimize the gap between the traditional seismic stations. MEMS Accelerometer sensors was been used in Quake-Catcher Network (QCN) to detect vibration of local seismic waves (0.1-25 Hz). In addition to that of distributed computing plays vital role in the QCN [11].

The use of QCN for recording earthquake also explains in the behavior of P- and S-wave [12]. Huayin Zengetal. [13] recently designed the wireless earthquake alarms systems using MEMS Accelerometer. The MEMS Accelerometer used in system detects the longitudinal wave which travels faster than the other waves. If the acceleration was higher than the threshold value then the systems alert the people by playing the alarm to leave the building as soon as possible, since the destructive share wave is followed by the longitudinal wave. MMA7260Q MEMS Accelerometer of the Freescale was used in this designd. This is a 3-axis accelerometers with very low power consumptions. Besides, CC1100 and C8051F330 used for the wireless transmissions and signal processing respectively. According to the authors, this systems will play very important role in near futures since its cost will be low. Tuetal also do some field experiments using MEMS Accelerometers with the Single frequency GPS for the monitoring ground motion generated due to the earthquake, landslides and volcanic activity in 2013 [14].

Conventionals Seismometers arethe use chart or drum recorder to records seismics signals. These signals were recorded by permanently. In oils exploration, The area for the explorations was large and the number of channel, sampling rates is used for the data acquisitions is less. This decreases the efficiency of oil exploration. The multi-channel seismic data acquisitions system was developes to improve the efficiency of oil exploration by means of increasings number of channels. This system is based on the wireless sensor network. In olders systems cables is used to carry seismics signals from geophones to recorders. In these seismic systems numbers of the cables and plugs used there larges this causes many problems.The accelerometers available includes both the dual axis as well as 3-axis accelerometers sensors. The dual axis accelerometer was capables to measures dynamic and static accelerations. The 3-axis accelerometers sensors senses the vibrations, shocks and gravity. This accelerometers was measures accelerations along x, y, and z axes. This selection of MEMS accelerometers sensor which was to be used depends upons the requirements of the systems and the parameter which is to be measured. In 2008, Agoston Katalin developed microcontroller based system for vibration analysis. The system was based on Lab Windows/CVI which gives data representation and analysis .Micro Electro Mechanical System (MEMS) accelerometer acquires both low and high-frequency data as their frequency response was linear. MEMS accelerometer is a low cost and small size. 3-Axis acceleration sensor that gives acceleration value of X, Y, and Z axis. An inexpensive seismic networks that was Quake-Catcher Network (QCN) was constructed by using distributing computing technique and MEMS accelerometers. The QCN combines MEMS technologys with computings and allow volunteers to collect seismic data and compute results. The QCN gives better earthquakes recognition and helps in study of the earthquakes. In recent years, the use of GPS technology is increased and is is helpful in examination of accelerations and motions. In 2013, a new system is proposed which gives measurements from a GPS as well as a MEMS accelerometer.

In the recent years the use of embedded computers along with software platform in seismology has been increasing This feature helps processor to read large amount of data from ADC. This reduces processor workload up to 25%. The earthquake alarm system using ATmega328p, ADXL335 and XBee S2 is a low cost system which can be used at home as a consumer product to save their lives. This system also consumes less power and can be used in sleep mode too The data collected by MEMS sensors is stored in a memory and via wireless module transmitted to computer. This system offers advantage of reduced size and power consumption .To analyze proper working of machines, engines, in earthquake detection, or in many scientific researches vibration measurement and its visual presentation is of important tconcern. A system based on accelerometer.

III. STRUCTURE OF THE SYSTEM

The structure of wireless Earthquake Alarm System includes one transmitting part and one or more than one receiving parts.

A Transmitting part

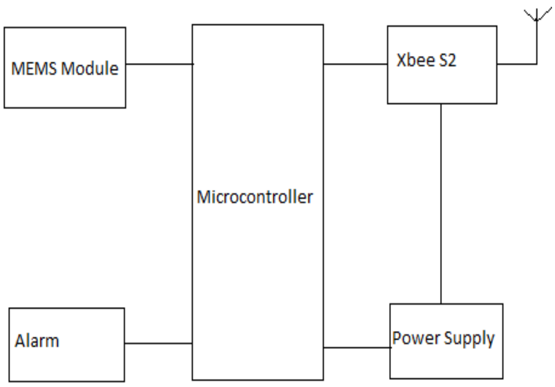

fig.3.1.Transmitting part of wireless earthquake alarm system

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B. Receiving part

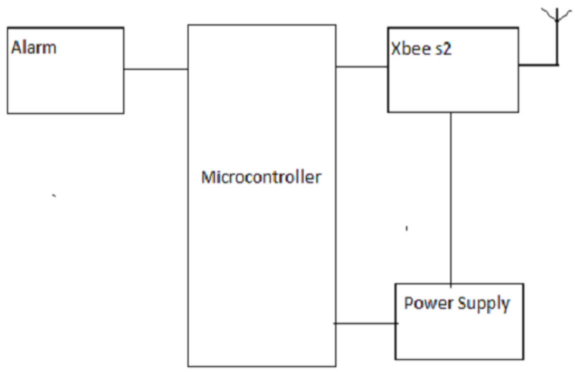

Fig. 3 .2 Receiving Part of wireless earthquake alarm system

IV. WORKING

The transmitting part include the ADXL335 MEMS accelerometers made by the Analog Devices. Which can be detect the vibration (Peak Ground Acceleration) produces due to earthquakes. This parts also to be includes a microcontrollers (ATmega328p) to process the value getting from ADXL335 and generate a signals when the ground acceleration was greater than the threshold values. The signal generated by the microcontroller was send by the receiving parts wirelessly using XBee S2. Figure 3.1 and 3.2 shows the block diagram of the transmitting parts and receivings parts.

A ADXL335

As per reported earlier ADXL335 it was a MEMS accelerometer made by the Analog Device. MEMS Accelerometer is devices which can detects gravity, vibrations or shocks . It has been found that MEMS Accelerometeris various applications such as for gamings applications in mobile phones, image rotation or stabilization in digital camera, automotive air bags .

B. ADXL335

It is thin, low powers, 3-axis accelerometer with a minimum full scale range of±3g. Figure 4.2.1 shows the functional block diagram of ADXL335.

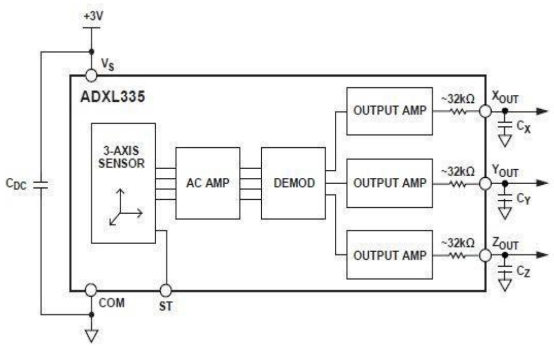

Figure 4.2.1 : Internal Block Diagram

ADXL335 connected to ADC pins of ATmega328p. It sends voltage levels to the microcontroller. As the datasheet says, ADXL335 is a small, thin, low power, complete 3-**axis accelerometer** with signal conditioned voltage outputs. The products measures acceleration with the minimum full-scale range of ±3 g. It can be measure static accelerations of the gravity in tilt-sensing application as well as dynamic accelerations resulting from motions, shock, or vibrations. ADXL335 is 3v compatibles devices; it is powered by 3.3v sources and also generates 3.3v peak output. It has three output for each axis X, Y & Z. These are analog output and thus require an ADC in a micro-controllers. Arduino solves this problems. We are using the analog functions of Arduino. The ADXL335 is the small, thin, low power or complete 3-axi s accelerometers with signals conditioning voltage outputs. The products measures accelerations with the minimum full-scale range of ±3 g. It can be measure the static accelerations of gravity in tilt-sensing applications, as well as dynamic accelerations resulting from motions, shocks or vibrations. The user select the band widths of the accelerometerx using the CX, CY and CZ capacitors at the XOUT, YOUT and ZOUT pins.Band widths can be selected to the suit of the applications, with a range of 0.6Hz to 1600 Hz for the X and Y axes, and a range of 0.6 Hz to 550 Hz for the Z axis. The ADXL335 is available in a small & low profile, 4 mm ×4 mm × 1.45 mm, 16-lead and plastic lead frame chip scale package.

C. ATmega328p

ATmega328p is a high performances, low power AVR 8-bit Microcontroller. It is 23 programmable pins and operating voltage is low (1.8- 5.5v).The main function of this module was processing the acceleration signals and comparings with the predetermined threshold values. ATmega328p has 10- bit successive approximations ADC. The ADC is connected to an 8-channel Analog Multiplexer which allows the eight single-ended voltage inputs constructed K8 from pins of the Port A. The single-ended voltage input refer to 0V. In these systems, 3 pins of Port C are connected to the ADXL335 and the USART (Universal Synchronous and Asynchronous serial Receiver and Transmitter) is connected to XBee S2 and send the signal to the receivers. The microcontrollers calibrates the values (voltage levels) getting from ADXL335 and calculates the peak ground accelerations. As per reported earlier that if calculated value is greater than the threshold value then it can be generates alarms and sends a signal to the receivers.

Fig. **4.3.1** ATMEGA328

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The Atmega328 is very popular microcontrollers chip produced by the Atmel. It is an 8-bits microcontroller that has 32K of the flash memory, 1K of EEPROM, and 2K of the internal SRAM. The Atmega328 is the one of the microcontroller chips that are used with the popular Arduino Duemilanove boards. The Arduino Duemilanove board comes with a either 1 of 2 microcontroller chips, the Atmega168 and the Atmega328.

Of these 2, the Atmega328 is the upgraded, more advanced chips.Unlike the Atmega168 which is 16K of a flash program memory and 512 bytes of internal SRAM, the Atmega328 has a 32K of the flash program memory and 2K of Internals SRAM. The Atmega328 has 28 pins. It has a 14 digital I/O pins, 6 can be used as PWM outputs and 6 analog inputs pi4.4.

XBeeS2 XBee S2 is a one of the powerful modules to communicate wirelessly. It has a in urban/indoor ranges and 120m outdoor line of sight ranges. It has been found that point-to-points, point-to-multipoints and peer-to-peers topologies are were supported by XBee S2. X-ctu software is a used for configuring XBee S2.In this system XBee S2 is a connected to the USART of the microcontrollers. XBee S2 Dout pin are connected to the Rx pin of ATmega328p. Din pin are connected to the Tx pin of ATmega328p.

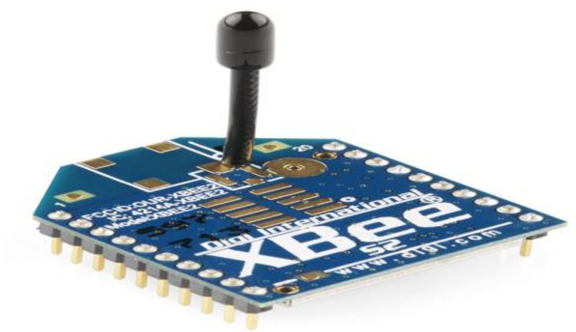

Fig. 4.4.1 XBee S2

This is a XBee XB24-Z7WIT-004 modules from Digi. Series 2 improves on the power of output and data protocol. Series 2 modules allows you to create complex mesh networks based on the XBee ZB ZigBee mesh firmwares.

These modules allow a very reliable and the simple communication between microcontrollers, computers the systems, really anything with a serial port, Point to point and multi-point networks is supported.

V. SYSTEM FLOW CHART

A workflow of a system is the stepwise representation of the operation of the system. Figure 5.1 shows the workflow of the transmitting part and Figure 5.2 shows a workflow of receiving parts.

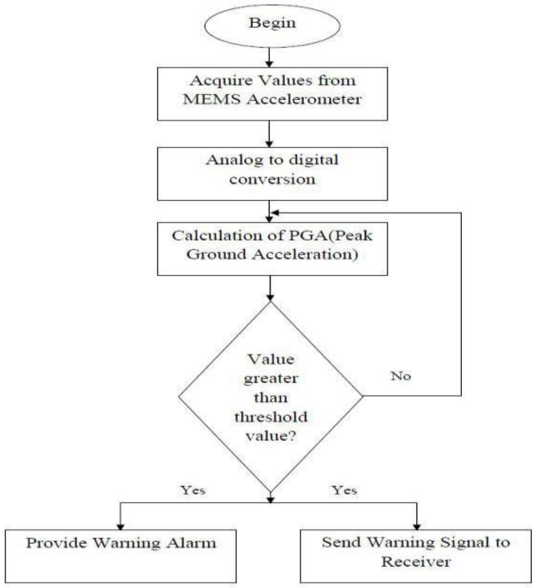

Fig. 5.1 Transmitting part work flow

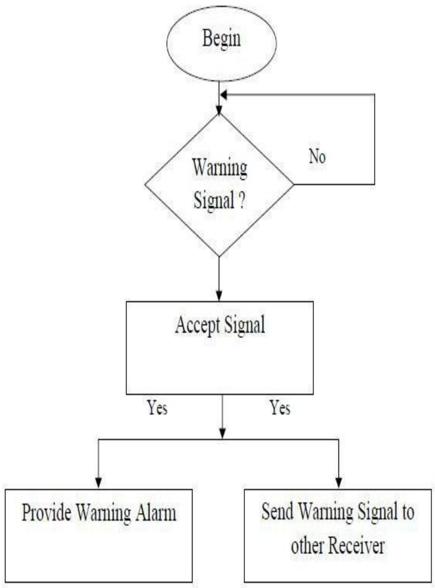

Fig. 5.2: Receiving part work flow

VI. ADXL335 CALIBRATIONS

As per reported earlier that ADXL335 sends voltage levels to the ADC of microcontroller. The values from the ADC from the microcontrollers when ADXL was placed at the top position are shown in below.

```
x = 339 y = 331 z = 407
x = 339 y = 331 z = 407
x = 340 y = 330 z = 407
x = 340 y = 331 z = 407
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Of the Peaks Ground Acceleration ADXL335 must be calibrated. It has been found that there are the many ways to the calibrate accelerometer. One of the calibration methods was Least-squares and Gauss-Newton methods

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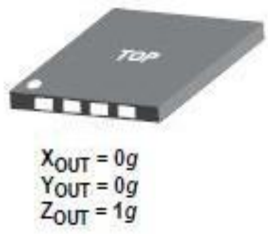

Fig 6.1 Values of Z= 1gposition for measuring

In this method, the accelerometer is placed in six perfect axial positions and collect the values .Let us mx, my, mz and dx, dy, dz are the values of the accelerometers. When it placed in the six perfect axial position (m stands for a values when it is placed 1g positions and d stands for a values when it placed - 1g positions). Again let the, a = (ax, ay, az) is a accelerations vector in x, y and z plan .Therefore the acceleration values can be written as

$$ax = (p-mx) / dx ,$$
$$ay = (q-my) / dy ,$$
$$az = (r-mz) / dz ,$$

Where p, q, r are the three axial value 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.

$$ap \ + aq + ar \ = 1$$

But in presence of noise there might be some error. And these errors are nonlinear. It has been found that the nonlinear Least-Square problem can be solved numerically using Gauss-Newton method.

VIII. CONCLUSION

This system has many advantages such as low cost, low power consumption and small in sizes. As mentioned it can be used in building with many receiving part with single transmitting part

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