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ARM based 3-Axis Seismic Data Acquisition System using Accelerometer Sensor

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Abstract: ***Seismology is the scientific study of earthquakes and the propagation of seismic waves through the earth. The large improvement has been seen in seismology from around hundreds of years. The seismic data plays an important role in the seismic data acquisition. The recorded seismic data is used by seismologists for analysis purpose. This analysis includes mapping of Earths interior, locating an earthquake properly, and measuring magnitude of an earthquake. The more efficient systems are used now a day to locate the earthquakes as large improvements has been done in this field. In older days analog systems are used for data acquisition. The analog systems record seismic signals in a permanent way. These systems are large in size, costly and are incompatible with computer. Due to these drawbacks these analog systems are replaced by digital systems so that data can be recorded digitally. In this paper, a recent development in seismic data acquisition has been focused. A cost-effective, small size seismic data acquisition system is implemented successfully based on ARM. The system consists of an Accelerometer sensor for sensing seismic signal along 3-axis corresponding to accelerations and can save the respective data in the memory which can be used for further analysis. The software routines written in MATLAB give graphical representation of seismic data along X, Y, and Z axis. An ARM processor compares the input signal with reference signal which is already set into the ARM processor. If the value of input signal exceeds reference signal then an alarm about possibility of an earthquake rang in PC.***

Keywords: Seismic Data Acquisition, Earthquake, Arm, Accelerom Eter, Adc, Linux Minicom Gui

1. Introduction

An earthquake is a natural disaster which can cause damage and loss of lives. It is the result of a sudden release of energy in the Earths crust that creates seismic waves. During earthquake, degree of the damage caused is depends on the magnitude that indicates the amount of energy released from Earths crust [1]. The magnitude of earthquake which is less than 5 is measured using local magnitude scale called as Richter magnitude scale. However earthquakes having magnitude greater than 5 are reported for world. The Richter Scale is used to measure magnitude of the earthquake by observing the amplitude on a seismogram. The Richter Scale is used because it is capable to measure decreased wave amplitude as the distance from the epicenter is increased. Richters scale is also a logarithmic scale [12].

In recent years, a standard magnitude scale is used which represents energy released at the time of earthquake more pre- cisely including large magnitude events. The earthquakes can be measured using a recording device such as seismometers in the form of seismograph. Seismometers are sensors that sense and record the seismic waves. The seismic waves are captured by using Seismometer, Hydrophone (in water), Geophone, or Accelerometer. A seismogram is written by seismograph in a response to vibrations produced by earthquake, or explosion. The seismograms are recorded for finding the location and magnitude of the earthquakes. In older days, seismograms were recorded on the paper in a permanent manner while now seismograms are recorded in a digital format [14].

In seismological experiments, each component of acceler- ation that is along x, y, and z axes is important, however in seismological calculations only one component has been taken into account. The surface waves, primary waves (p-waves) and secondary waves (s-waves) are among the important types of seismic waves which are consider mainly in earthquake detection. Pwaves arrive first at seismograph stations as they travel faster than other waves. P-waves are longitudinal and are also called as compression waves. S-waves arrive after p-waves at seismograph station therefore called as secondary waves and are transverse in nature. S-waves are also called as shear waves. The surface waves are most disastrous waves because of their long duration and large amplitude. The surface waves travel along Earths surface. Figure 1 shows structure of p-wave and s-wave [15].

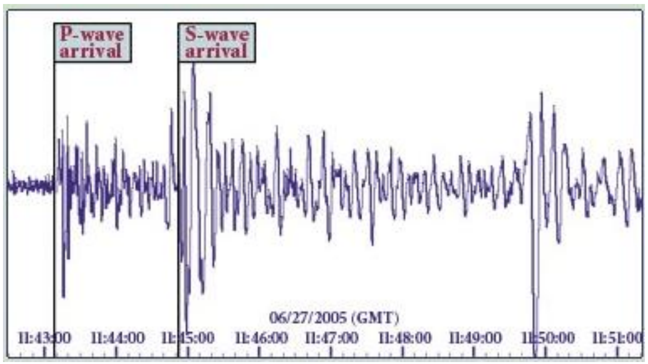

Figure 1: p-wave and s-wave from seismograph

The seismic data is useful in detection of earthquakes and in studying effects of the earthquake. The same seismic methods can be used for exploration of oil and natural gas. The seismic methods are based upon seismic wave measurement. This measurement can be done when any seismic source start generating seismic waves. 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.

2. Seismic Data Acquisition System

In recent years significant improvement and wide-spread use of digital embedded computers in seismology have been increased. This includes embedded computers consisting of 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 modifi- cation 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. Here, a cost-effective seismic acquisition system based on ARM, without compromising its performance is developed. Figure 2 indicates the block diagram of the system. The first block is an accelerometer sensor which converts nonelectrical signal into electrical quantity which is in the range of (0-1.76V).Here; we are using an accelerometer sensor ADXL 335 to measure accelerations. It is a 3-axis small, thin, low power accelerometer with signal conditioned voltage outputs. When any seismic like activity happens vibrations are generated at that time accelerometer sensor senses seismic data along X, Y, and Z axis corresponding to accelerations. 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. The LPF output is then passed to the ADC of an ARM 9 microprocessor. ADC converts the analog signal in to the digital form. Then the signal is given to ARM processor.

ADXL335 is 3 axis accelerometer with on board voltage regulator IC and signal conditioned Analog voltage output. The module is made up of ADXL335 from Analog Devices. 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 axis, and a range of 0.5 Hz to 550 Hz for the Z axis.This is the latest in a long, proven line of analog sensors the holy grail of accelerometers. Accelerometers are generally low-power devices. The required current typically falls in the micro () or milli-amp range The ADXL335 is a triple axis accelerometer with extremely low noise and power consumption only 320uA! The sensor has a full sensing range of +/-3g.

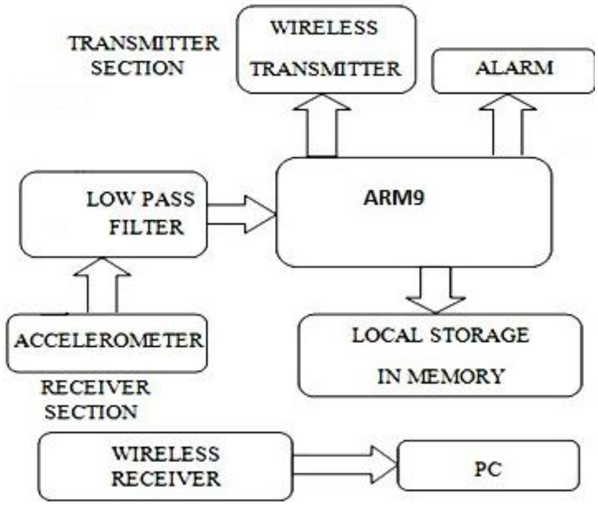

Figure 2: Block diagram of proposed seismic data acquisition system

The output of ADC is transmitted via wireless transmitter Xbee S1 module. On receiver side another wireless XBee S1 module is used which receives signal from transmitter. 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. The received data is then transferred to computer and cab be saved using excel sheet which can be used later for analysis by seismologists at seismological station. PC will contain Linux 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.ARM processor compares 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 an alarm blows in computer about possibility of arrival of an earthquake.

3. System Design

a. The Hardware design

The general hardware structure of the remote data acquisi- tion and control system based on ARM processor is shown in Fig 2. S3C2440 processor is used as core of the hardware.

The main frequency of Samsung S3C2440 is 400MHz and can up to of a peek frequency of 533MHz . JTAG (Joint Test Action Group) is an international test protocol standard, soft- ware simulation, single-step debug and vivi-boot download can be carried out through the JTAG port, it's a simple and efficient means of developing and debugging embedded systems. The SDRAM capacity in the system is 64MB, working voltage is 3.3V, data bus is 32bit, and SDRAM clock frequency can reach up to 100MHz.Flash memory is divided into 64M NAND flash and 2M NOR flash The S3C2440 CPU chip supports two kinds of boot modes: booting at the NAND flash and booting at the NOR flash. The allocation of the storage space of the chip selections is different in the two boot modes. For supporting boot loader in the NAND Flash a buffer named Steppingstone is present in SDRAM. When the system get started, the first 4Kbyte content in NAND Flash is loaded to the Steppingstone and be executed. When Start up code, the contents of the NAND

Flash are copied to the SDRAM. Main program will be executed from the SDRAM based on the completion of copy.

4. The Software Design

Software development process based OS includes: the establishment of cross-compiler, the creation of root file system, the transplant of Boot loader, the porting of embedded Linux, and the development embedded Web server. ARM Linux gcc is the cross compiler used. Boot loader vivi is used here. The function of Boot loader is to initialize the hardware devices, establish memory mapping tables, thus establish appropriate hardware and software environment, provides interface to send commands to target board and prepare for the final call to the operating system kernel. Linux is used as operating system because Linux system is having a hierarchical structure and completely opens its kernel source. Linux can port to a wide range of hardware platforms, and can run in most of the architecture. Linux has a comprehensive set of editing, debugging and other development tools, graphical interface, a powerful network supporting and rich applications. In addition, the kernel can be reduced by configuring it.

5. Results and Discussion

Figure 3 shows complete hardware seismic data acquisition system. The circuit operates on 5V power supply voltage. The experimental setup for data acquisition is as shown in Fig.4.An experimental setup consists of whole circuitry require for seismic data acquisition and ARM9. The accelerometer sensor ADXL 335 is placed at one end of the sheet. When accelerometer sensor senses vibrations it produces correspond- ing analog output voltage. The voltage converted by ADC is transmitted using one wireless XBee module to another XBee module present at receiver side and finally transferred to ARM9. His Accelerometer module is based on the popular ADXL335 three-axis analog accelerometer IC, which reads off the X, Y and Z acceleration as analog voltages. By measuring the amount of acceleration due to gravity, an accelerometer can figure out the angle it is tilted at with respect to the earth. Then open the serial monitor of ARM9, ADXL335 will output the acceleration values on x, y and z axis as shown in ARM9
Serial Monitor.

6. Conclusion

This paper has presented a development of a seismic data acquisition system based on embedded Linux. An ARM-9 hardware platform and a high-resolution ADC have been used with some device drivers to implement the system to deal with

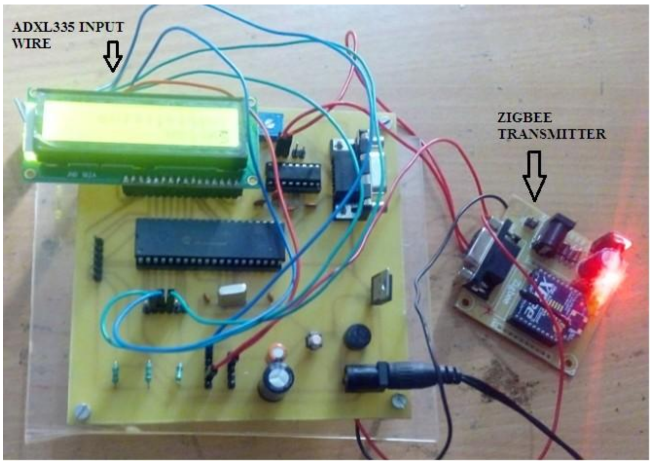

Figure 3: XBee Transmitter With PIC16F877A

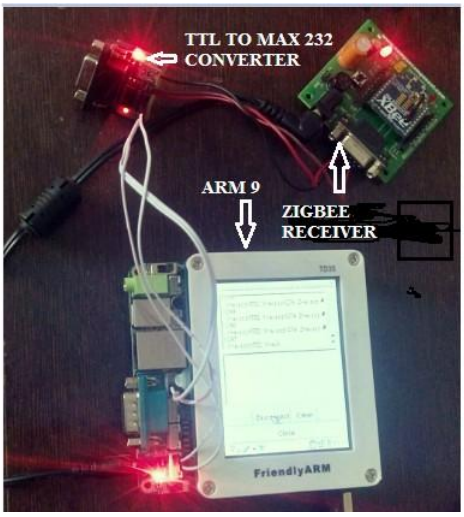

Figure 4: XBee Receiver With ARM9

The wide dynamic range of the concerned seismic signals. How the DMA feature contributes to better system performance has also been discussed. This platform is cost-effective and can also be developed further in any other applications.

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