A Very Sensitive, Low-Cost, Portable Electronic System for Detecting Acoustic Earth Waves for Classroom Demonstration and Real Measurements

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Abstract— In modern times, interactive learning has received great intentions due to its beneficial impacts on the development of technology sense for geophysics, and geology, or even physics undergraduate students. In contrast with the last decades, it was extremely hard to gain these experiences because the lack of resources and limited funds. However, the development of electronics enables us to build inexpensive systems that can provide students with practical knowledge. For example, data acquisition is essential for undergraduates to support them through their further technical careers. In this paper, we are presenting, with a simple approach for constructing, a portable electronic system for measuring acoustic waves or motions using conventional seismic data acquisition technique. This approach can be suitable for detecting earth response inside classrooms, or even laboratories. Hopefully, this work provides instructors with a low-cost data acquisition system to be used in related foundation courses, especially in developing countries.

Keywords: Seismology; Data Acquisition; Acoustic waves

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1 Introduction

Nowadays, there is a growing concern for upgrading current teaching methodologies since the idea of sitting and listening to a scientific topic becomes not accepted anymore by students. Now, virtual courses are available everywhere which provide various types of teaching styles including online materials, videos, and supporting imitations. That leads students to finish courses without real learning outcomes. This phenomenon is considered as a direct result of the lack of creativity from lecturers and failing to raise the academic passion toward modules. To tackle this issue, there must be radical changes in the whole processes of education.

One of the most effective measures is to use interactive scientific tools during delivering the lecture. For instance, when it comes to talk about acoustic waves that propagates through the surface of earth, it would be very useful to demonstrate the acquisition system for students and give them the opportunity to hands-on the system.

These acquisition systems are extremely complex, expensive and always kept in black-boxes. It seems to be very challenging for developing countries to invest their limited funds in such devices, which can excess tens of thousand dollars per each [1], [2]. Not only the price problem, but also the limited experience during the acquisition process. However, the technology, with the assistance of computer science, has been developing several acquisition systems to provide the whole industry with low-cost equipment [3]. These systems find their utility in multi-discipline fields including seismology [4], mining [5], security systems [6], meteorology forecasting [7], [8], renewable energy, water quality monitoring [9], and biomedical purpose [10].

Despite these above-mentioned challenges, researchers have developed several applicable approaches for simplifying acquisition systems for detecting acoustic earth waves. At the present, scientists are hoping to use smartphones with embedded accelerometer sensors to replace the conventional seismic detectors [11]. Remote sensing technologies can also provide alternative measures to predict earth waves through complex analysis of GPS photos and videos [12]. Although these attempts might be promising to help in the development of detecting earth waves, their results could need time to be reliable and precise. Therefore, conventional measures still being used till now with several developments of the related algorithm with aim of increasing their responses [13].

At this work, we are presenting a simple solution to construct an electronic system for measuring acoustic waves through any medium, powered with a variable range amplifier and to provide with multi-channels acquisition data system that finds great utility inside seismic laboratories. We also claim that this system can offer geology and geophysics students a great knowledge about the electronics assembly.

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2 Detection Systam Description

Any acoustic acquisition system should have four primary components that are: (1) sensing unit (detector), (2) amplification unit that is used to maximize the weak measured acoustic waves to be sensible, (3) Analog-to-digital converter for digitizing these signals to be easy recorded and manipulated in digital format and (4) computer system to proceed and interpret information from recorded signals. These stages have been presented in Fig. 1.

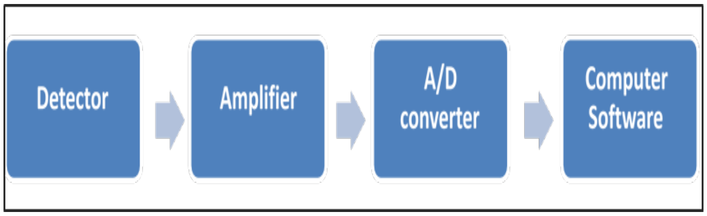

Fig. 1 A graphical diagram for the stages of acquisition system as following: (1) sensing unit (Detector), (2) Amplification unit (amplifier), (3) Analogue-to-Digital converter (interface), and (4) computer software.

First, the sensing unit involves, in this system, a cylindrical geometry with a hugging coil ended with mass oscillates between two halves cylindrical strong permanent magnets and another base magnet at the bottom. When acoustic energy propagates through the ground, the hugging mass starts to oscillate between the cylindrical magnets. As result of that, an electromotive force (e.m.f) is induced. In addition, the base magnet acts as a stabilizer to prevent coil to oscillate in the horizontal plane (for further technical details about the detector, see [14]). Detectors used in the system work with a natural frequency 10 Hz; each one costs around 6$ so a group of ten units could be around 60$.

The amplification unit is considered as the second necessary part of the detection system. A standard voltage amplifier has been used. It mainly consists of two operational amplifiers that are: (1) the inverting stage which responsible for the voltage gain, and (2) the buffering stage which derives an enough current to the next Analog-to-digital (A/D) converter unit as presented in Fig. 2. This amplifier works when the input signal is applied via input resistance, which can be (R1 or R2) to the inverting stage. This input resistance in conjunction with the feedback resistance (R3) gives a gain equals 300, or 1000 times of the original signal as the gain depends on the ratio between feedback and input resistances. Also, a variable resistor (VR1) may connect to the offset null pins which acts as a vital part because the AC output of the circuit needs to be shifted positively to match the next (A/D) converter. In addition, the combination of (R5) and the LED for giving an indication of power status (ON/OFF). This circuit is powered by (± 15) DC Volt that can supply by 16016 transformer. Finally, this amplifier unit could be repeated, to have more than one input channel. This unit nearly costs around 20$ to assemble it. Fig. 3 shows the assembly stage of the amplifier from basic design on pin broad to the standalone final product. This will encourage lecturers to ask their students to build their own prototypes to get familiar with assembling electrical circuits. Nowadays, many petroleum service companies deliver their fresh operators several training courses related to electronics and its safety before starting working on it directly.

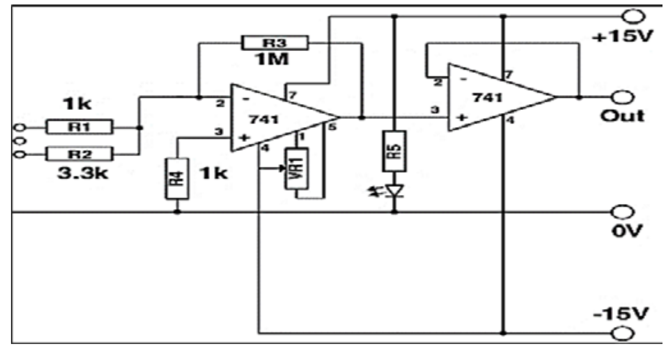

Fig. 2 The circuit of the standard voltage amplifier circuit that is mainly composed of two ICs (M741).

Fig. 3 Couple of digital images for the assembly process of the proposed amplifier: (a) initial design laid on electronic pinbroad for testing, (b) internal view of amplifier, and (c) stand-alone final product (amplifier)

Thirdly, Analogue-to-digital (A/D) converter, there are various types of data interfaces, may or may not match the acquired data so it is extremely crucial to examine their data sheet carefully. We chose the K8047 by Velleman Company because it gives students great opportunity to assemble it. This is not the only advantage, but also it can be used with various data logging. In addition, it can be plugged directly into a laptop through USB port and it is very compact and light too. It also provides a variable input range, with 10 (mV) sensitivity, and this interface provides a variable sampling rate between 1 and 1000 at each division on the software (for more technical information about this interface, see [15]). Almost all (A/D) interfaces provide the user with graphical views (oscilloscope format) with real-time data acquisition; it also displays the measured voltage verses against the recording time and it enables saving the data into "ASCII", or "TXT" formats for further data processing. The cost of this interface is around 100$.

Wire cables of copper (0.05 mm-diameter) with banana clips for each of detector, amplifier, and (A/D) interface are used to collect the whole system together, which costs around 10$ too. With regardless of the price of the laptop computer, the estimated cost for assembling whole parts for this electronic system would be less 200$ that can be affordable with low funds for schools' departments in developing countries.

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3 Results and Discussion

The proposed acoustic waves detection system is tested through the real surface of earth ground by synthesizing artificial low-frequency acoustic waves via striking the wooden plate supported on earth by a hammer, which is used to disturb the pressure waves (P-waves) that are created by hammer-shock. Unfortunately, we cannot control the frequency of the produced acoustic waves that will propagate through the ground via the hammer. A sinusoidal digital signal is synthesized on MATLAB platform, instead of the guided wave (Sweep signal) [16], with the aim of stimulating the idea of real seismic acquisition condition and get seismogram record that already extracted from the convolution of acoustic waves produced by any mechanical vibrator (Vibroseis) with earth response [17]. The sweep signal used in this experiment is called by Gibbs' oscillations, can express by eq. (1) [19].

$$q(t) = w(t)\sin[2\pi f(t)] \quad (1)$$

Where, w(t) is a "window" function of time, (t) is the length, usually around 250 (ms) and (f) is the frequency of sweep signal, this sweep signal is illustrated in the Fig. 4.

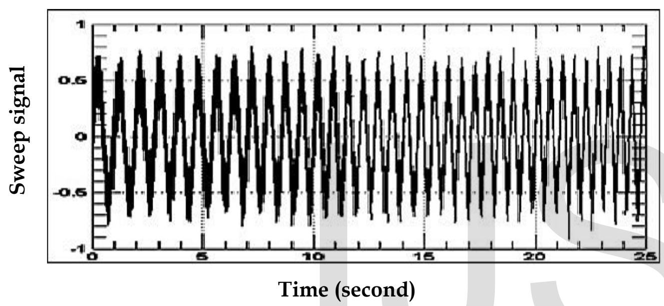

Fig. 4 The synthetic sweep signal (guided wave) with the same characterictics of real signal which it has 25-second length, 1-ms sampling rate and its frequency from 1 to 2 Hz

The next stage of detection process is to plant detectors vertically in the ground with a 1-meter offset from the wooden plate. Once the hammer struck the plate, the acoustic waves propagate through the ground to reach the array of detectors. After that, these acquired signals feed the amplifier and converted by the (A/D) interface. Following this, the digital signal displayed and recorded as data. The whole process is presented in Fig. 5.

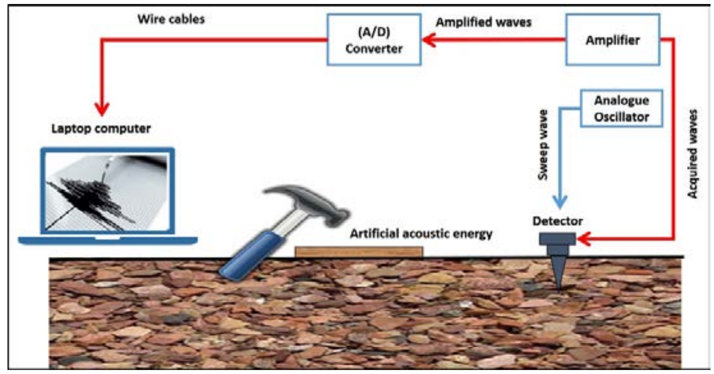

Fig. 5 A schematic diagram of the proposed design of system for acquiring acoustic waves, and motions. The system can be collected as following: (1) a source of mechanical waves, which is provided by Hammer, (2) sweep signal as guide from the analogue oscillator that is replaced in this work by digital version of with same characteristics, (3) amplifier, (4) the (A/D) interface and laptop computer.

Some scripts by Matlab program have been written to handle this data set. The seismogram record is obtained by convoluting the earth response with synthesized sweep signal.

Fig. 6 shows the graphical representation for the recorded acoustic wave from certain detector due to the multiple strikes from the hammer. While the acoustic earth response is obtained by deconvoluting the seismogram with the original sweep signal. It has shown several mechanical variations due to multiple hammer-shocks, which are measured in (mV) against the recording time in Fig. 7 .

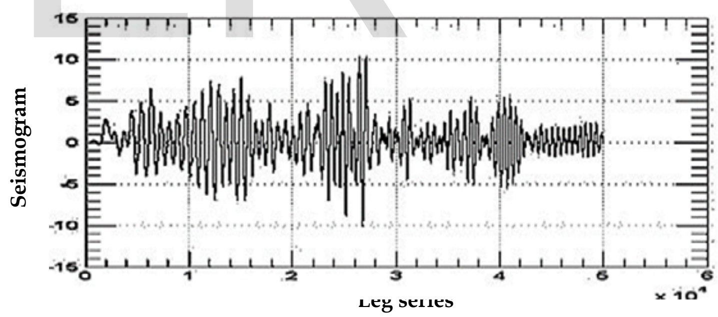

Fig. 6 seismogram view of recorded acoustic wave from certain detector planted into the ground

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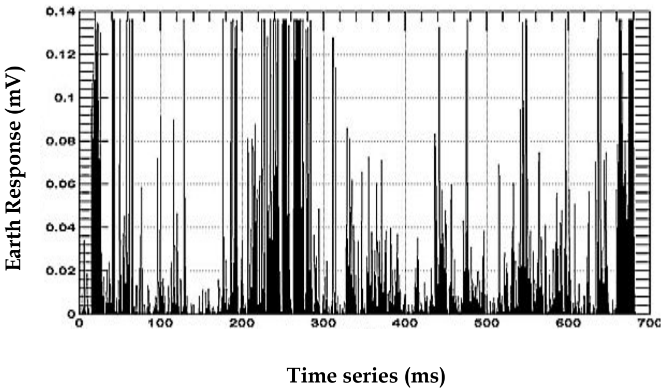

Fig. 7 the Earth response from certain detector is measured in (mV) that is represented many mechanical variations due to multiple acoustic waves.

4 Conslusion

Technology progressions have continuously provided us with advanced devices to improve our experience of the physics of Earth, geological events, seismology applications. The practical knowledge is extremely crucial to be delivered to students who will be involved in research centers, and companies related to geology, or geophysics fields. Here, we illustrated an inexpensive earth wave's detection system with high sensitivity, supported with a local design for multi-channels amplifier unit with a wide range of amplification factor from 300 to 1000 times. In addition to, an assembly version of multi-channels Analogue-to-Digital interface to digitize the acquired data. At the end, both of amplifier and interface provide students great experience in the electronic assembly. To conclude, this system could be affordable learning models in several developing countries, which can help academics to demonstrate real experiments in front of students with inexpensive systems.

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