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Development of Seismic Data Acquisition Based on MEMS Accelerometer MMA7361L

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Abstract

MEMS Accelerometer MMA7361L is an accelerometer-based sensor has been to develop for seismic acquisition system. The MMA7361L sensor has a linear frequency response to acceleration from 0Hz to 800Hz and works in three components. The signal response test has been done by the MMA7361L sensor compared with the L4C and SM-24 geophone-based sensors in the Laboratory of Volcanology and Geothermal, Cangar, Batu with providing vibrations at varying distances to get a signal response and frequency range of MMA7361L. The test results obtained MMA7361L sensor frequency range from 20Hz until 60Hz in three components work. Therefore, the MMA7361L sensor on this seismic data acquisition system has very low sensitivity.

Keywords : MEMS Accelerometer MMA7361L, seismic data acquisition, frequency, sensitivity.

INTRODUCTION

Coil-based geophone is a technology that has been to develop and its quality is proven in the exploration industry [1]. Geophone is a simple sensor which consists of wire coil covered the permanent magnet and it has a length of 3 cm and weight ~75g. Principle work of geophone based on velocity. The sensor has excellent linearity and able for detecting from very low frequency to very high frequency and it has a low ground noise relatively [2]. Geophone sensor is often used to detect seismic signal for exploration or hazard mitigation purposes. The advantages of geophone such as it could work without power supply and it is able for detecting very small ground displacement [3]. However exploration industry currently need a lot of seismic data and fast acquisition then they required some a lighter sensor, low noise and calibration process easier. Field data collection requires a lot of geophones which they need more wires to connect one another. Moreover it is difficult to install and resolve the errors obtained when measuring [1].

Currently, there is a great interest in Micro Electro Mechanical System (MEMS) Accelerometer sensor for exploration industry and earthquake monitoring. MEMS Accelerometer sensor work based on acceleration with it form like microchip shape where inside it has embedded digitizer and filter elements but power supply need to operate them [3]. MEMS Accelerometer has been to develop for the exploration and seismic activity monitoring [4]. The MEMS accelerometer amplitudes are larger than geophone and it has greater sensitivity than the geophone [5]. MEMS Accelerometer has a linear frequency response to acceleration from DC (0Hz) until several hundred hertz [3]. The frequencies response range from 0 Hz to 800 Hz for and provide lower noise up to -10dB [6]. Moreover, the sensor has a very small size with the length ~1 cm, weight less than 1 gram, work in three components (x, y, and z), and its price also has a cheaper than geophone sensor [7],[8]. Therefore in this research will be developed a data acquisition of seismic sensor based on sensor MEMS Accelerometer type MMA7361L.

METHODS

MEMS Accelerometer sensor MMA7361L (Fig.1) used has the sensitivity i.e 800mV/g 1.5g and 206mV/g at 6g which it works in three components (x, y, and z)[9]. The sensor voltage required to work at between 3.3 V and 5V but when the sensor is not affected by the acceleration output voltage is half of the power supply voltage. Pin at g-select should be filled by high or low logic to set the sensitivity of the MEMS sensor. If the low logic value is given then the sensitivity is equal to 800mV/g and if the logic is high then the sensitivity is equal to 206 mV/g [10].

Figure 1: MEMS Accelerometer MMA7361L

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Design of Seismic Data Acquisition

The block diagram (Fig. 2) designed for seismic data acquisition system that MEMS Accelerometer MMA7361L used to detect the ground vibration. Then the output signal is forwarded to the signal conditioning circuit. In the signal conditioning circuit, the output signal will be filtered and buffered to reduce the noise so it is expected that the output signal has a frequency corresponding to its original frequency. Then the output signal amplified and shifted at a voltage of 2.5V in order to fluctuate between 0 - 5V.

Figure 2: Block diagram of seismic data acquisition system

The signal conditioning circuit (Fig. 3) is the implementation of the acquisition system block design (Fig. 2). Based on Fig. 3 the circuit used IC LM324 which it is a low power quad Op-Amp IC that works on single supply [11]. The signal conditioning circuit consists of several stages such as noise filtering, buffer, frequency filtering, and signal amplify. The value of the signal conditioning circuit is determined by Eq. 1 as the cut-off frequency value. Moreover, the filtered signal to reduce noise is buffered in order to keep the output voltage more stable. The buffered signal processed in the frequency filter circuit. LPF (Low Pass Filter) and HPF (High Pass Filter) circuits used in this circuit are given by Fig. 3. Both circuits match to define the signal frequency value that it could be passed from the signal conditioning circuit so the rejected signal can be attenuated. The value of resistors and capacitors in the circuit could be calculated using Eq. (2) and Eq. (3). LM324 used in the signal conditioning circuit as a signal conditioning. The output signal passed through the frequency filter circuit is amplified using instrument amplifier AD620. The AD620 amplification required a resistor as a variable amplifier value (Eq. 4) [12].

$$f_{-filter} = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} Hz \quad (1)$$

$$f_{c-LPF} = \frac{1}{2\pi\sqrt{R_5 R_6 C_3 C_4}} Hz \quad (2)$$

$$f_{c-HPF} = \frac{1}{2\pi\sqrt{R_7 R_8 C_5 C_6}} Hz \quad (3)$$

$$A_v = \frac{49.4k\Omega}{R_G} + 1 \quad (4)$$

Where,

R = Resistors

C = Capacitors

$f_{-filter}$ = Frequency of filter

f_{c-LPF} = Cut-off Frequency of Low Pass Filter (LPF)

f_{c-HPF} = Cut-off Frequency of High Pass Filter (HPF)

A_v = Amplifying

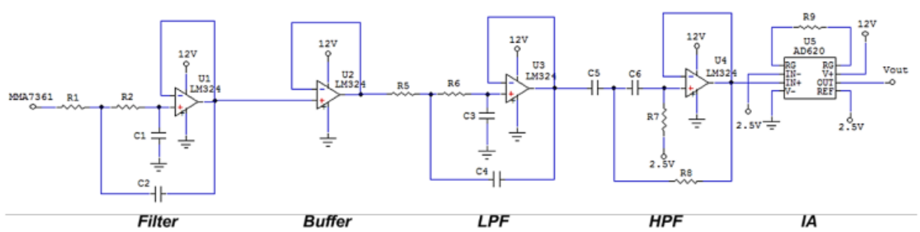

Figure 3: Signal conditioning circuit

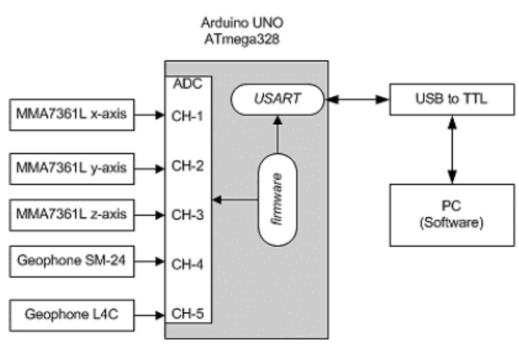

Figure 4: Design Hardware Data Acquisition

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The microcontroller used as the main component of acquisition hardware design (Fig.4). The advantage of using the microcontroller for data acquisition is it has a small size, cheaper, simple and easy to program. Another advantage is to facilitate communication with PC [13]. ATmega 328 is used as a microcontroller which is an Arduino Uno module with ADC resolution of 10bit (8 channels) [14]. The output signal from the signal conditioning circuit must have an analog output voltage within 0 - 5V according to ADC reference. Eventually, the ADC channels are used as sensors interface. Channel 1, 2, and 3 sequentially used for MMA7361L x-axis, y-axis and z-axis. Communication between data acquisition module and PC arranged by the already installed program both in PC and microcontroller.

Data acquisition and sensor test conducted in the Volcanology and Geothermal Laboratory, Cangar, Batu. MEMS Accelerometer MMA7361L tested with geophone-based sensors are L4C and SM-24. Both sensors are always used as the seismic sensor and they have been sold commercially. Acquisition design for sensor test is designed on Fig. 5. Sensors are tested by providing them some vibration source of the human leap at varying distances. The distance of sensor to source used are 5m, 10m, and 15m. The testing process focused on the seismic response provided by the vibration source. Then obtained seismic response data for each sensor is processed using FFT analysis to determine the frequencies response of MEMS Accelerometer MMA7361L and they are compared to each other.

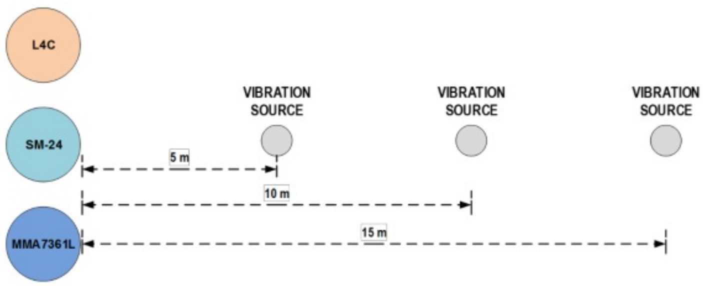
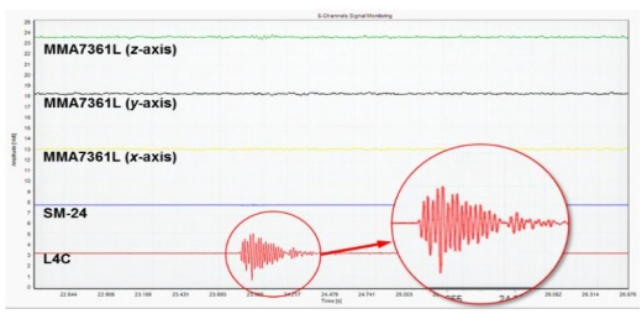
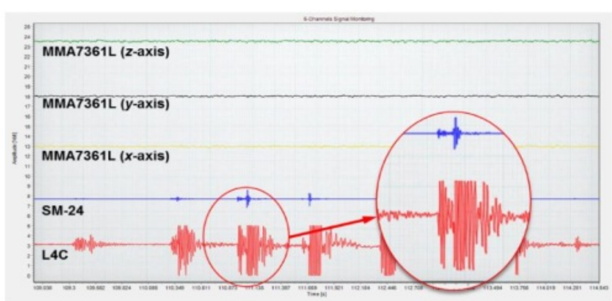


Figure 5: Acquisition design to obtain signal responses given by vibration sources in different distances



(a)



(b)

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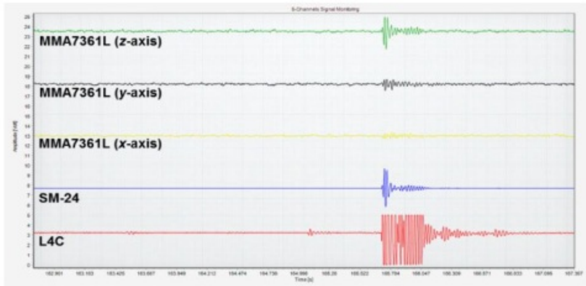
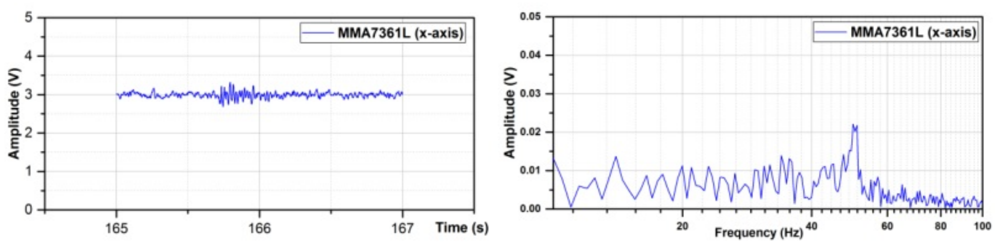


(c)

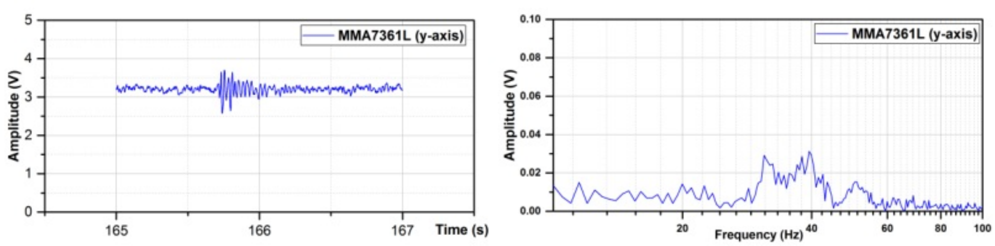
Figure 6: Display of recorded signal at distance (a) 15m, (b) 10m and (c) 5m

RESULT AND DISCUSSION

The test result has shown the MMA7361L sensor is less sensitive than L4C and SM-24 geophone-based sensors although MMA7361L sensor has a sensitivity of 800mV/g (1g = 9.8m/s^2). It is assumed that the MMA7361L sensor base is too wide and solid so that it only records the vibration below the sensor. For the L4C sensor has a sensitivity of 284.64 V/m/s [15] and the SM-24 sensor has a sensitivity of 28.8 V/m/s with the frequency bandwidth from 10Hz to 240Hz [16]. This had proved by response test of vibration source with varying distance from 15m to 5m (Fig.6).



(a)



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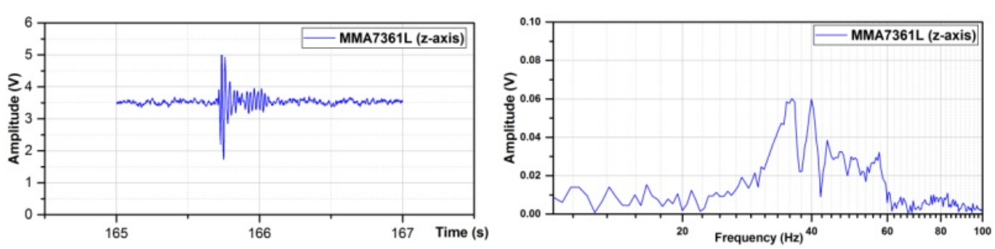

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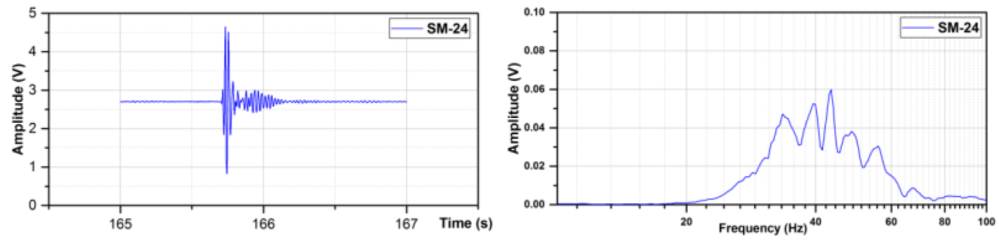

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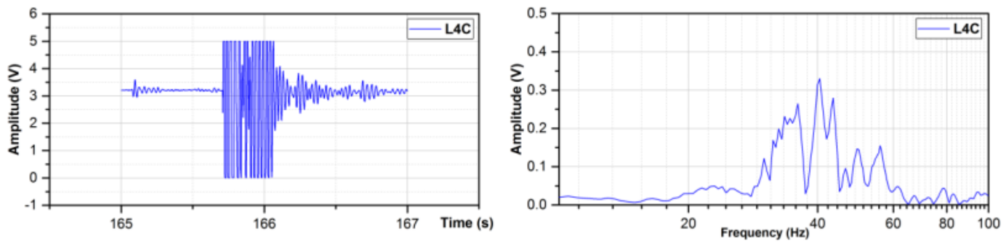

(e)

Figure 7: Fast Fourier Transform Analysis Result: (a) MMA7361L x-axis, (b) MMA7361L y-axis, (c) MMA7361L z-axis, (d) Geophone SM-24, and (e) Geophone L4C

After obtained the signal response from each sensor then performed Fast Fourier Transform (FFT) analysis to determine the frequency value of each signal. Fig.13 is the result of signal and frequency response had analyzed from each sensor. Especially for MMA7361L the signal shown in Fig. 6a, 6b, and 6c were the signal capture of their every component of components x, y, and z. The signal shown was a signal response test result with the distance of 5m because only at this distance the array sensor can be detected the presence of vibration. FFT analysis results showed the sensor array has a frequency range of 20 Hz to 60Hz. The MMA7361L sensor x-axis has a dominant frequency of 50Hz (Fig.7a), for the 40Hz y-axis (Fig.7b) while for the z-axis has a dominant frequency of 37Hz (Fig. 7c). Whereas the L4C and SM-24 sensors also have the same frequency range from 20Hz to 60Hz with 40Hz dominant frequency L4C (Fig.7d) and for SM-24 by 45Hz (Fig.7e).

Based on the results of the dominant frequency analysis of MEMS Accelerometer MMA7361L indicated that the signal obtained *x*-axis and *y*-axis have not so strong because the resulting vibration source is dominant to the vertical. So the recorded signal was only on the z-axis. While the *x*-axis and *y*-axis only record the surface noise that propagates horizontally.

CONCLUSIONS

MEMS Accelerometer MMA7361L has been to develop for seismic data acquisition system. The test was performed by comparing MEMS Accelerometer MMA7361L with L4C and SM-24 geophones in Volcanology and geothermal laboratory, Cangar, Batu. This test was conducted to get a signal response and analyze the response signal to get the MEMS Accelerometer MMA7361L frequency value. The MMA7361L sensor can detect signal with the range frequency from 20Hz to 60Hz in three components. However, the MEMS Accelerometer MMA7361L in this research has very low sensitivity. Its proven MMA7361L is only able to detect the signal at 5m to the sensor. In addition, MEMS Accelerometer MMA7361L has a lot of noise, because MEMS Accelerometer MMA7361L at silent period can record vibration caused by itself. Furthermore, research was recommended to develop a seismic data acquisition based on MEMS Accelerometer MMA7361L which can reduce noise and can develop the sensor base so the sensitivity can be used maximally.

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