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Research paper

Earthquake Sensor Microcontroller Using Mma7361 Accelerometer

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Abstract

Vibrations propagate to the surface of the earth in two stages. The first stage is called the Primary wave-shaped longitudinal and the second stage is secondary wave, sinusoidal and destructive. The second wave did not come together so that there is a certain amount of time intervals. This time interval can be utilized to provide early warning from earthquake sensors microcontrollers. As registrar, earthquake seismograph always inform the level of earthquake damage in form of scales, but did not provide early warning. While the microcontroller and sensor technology developed and were able to catch the tremor.
This study aims to build earthquake microcontroller sensors to capture the primary seismic vibrations quickly. The study focused on the sensor design, calibration and data transmission, while the primary wave simulation given experimentally by treatment of vibration on the sensor that is connected to computer and displays the initial vibration data on computer. The results showed that interconnection MMA7361 accelerometer, EM411 GPS, ATmega328 on Arduino and data processing protocols have produced seismic sensor that captures digital data and data shakes position quickly. In the absence of vibration, the sensor does not provide the data and when vibration, there is transmitting data to computer database.

Keywords: *Early Warning, seismograph, Seismic Sensor, accelerometer*

1. Introduction

Earthquake sensor is a set of electronic components integrated hardware and software and can capture the movement of the tremor that propagate on the surface of the earth. Seismic vibrations propagate in two phases, namely the primary waves and secondary waves. Primary wave propagates longitudinally and secondary waves propagate sinusoidal. Sinusoidal wave is destructive and an actual earthquake (Rahman, Rahman, Mansoor, Deep, & Aashkaar, 2016), (ROSYIDI, JAMALUDDIN, Lim, & TAHA, 2011). Vibration earthquake waves can be measured and taken into account (Suzuki & Saruwatari, 2007), (Fabien-ouellet & Fortier, 2014). The primary and secondary wave propagation does not occur simultaneously so there is a time difference between the arrival of the primary vibration and secondary vibration. The time difference can be utilized to detect vibrations of primary earthquake and provide early warning to the public about the coming of actually earthquake through the processing of primary wave data vibrations (Rahman et al., 2016), (Biansoongnern, Plungkang, & Susuk, 2016).

Currently, Indonesia has earthquake seismographs sensor scattered throughout Indonesia. Seismograph has sensitive instruments that can be used to detect seismic waves generated by earthquakes. However seismograph only detects due to the earthquake that occurred, displayed in a certain scale and does not provide a warning system for the coming truth of eartquake. Seismic waves that occur during earthquakes depicted as wavy lines on a seismogram.

This study has designed a sensor system quake-based on microcontroller with 3 discussion, namely how to design earthquake sensors using MMA7361 MEMS accelerometer sensor (Vogl et al., 2009), how to perform the calibration of sensors and how to transmit data from sensors to a computer using an Ethernet media. The results of the study will contribute in the field of seismology to detect earthquakes, analyze the vibrations of an engine or the slope of an object and collision.

2. Method

Sensors seismic-based on microcontroller designed in two stages, namely interconnection microcontroller, accelerometer MMA7361 sensor and EM441 GPS into earthquake sensors and designing protocols transmission of data to computer. Process of interconnection microcontrollers and sensors, is done by connecting I/O pins on microcontroller ATmega328 contained in the Arduino UNO to I/O pins of MMA7361 accelerometer and EM411 GPS based on the characteristics of each component.

Figure 1 is a draft sensor made with ATmega328 on Arduino UNO is used as the central processing for all data from MMA7361 sensor and EM441 GPS.

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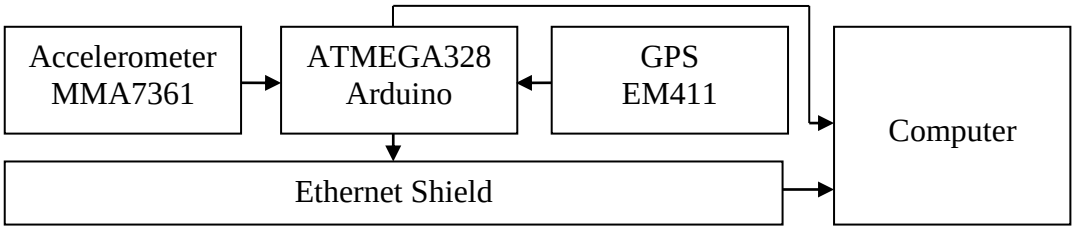


Fig 1: Draft Interconnection Sensor Earthquake

MMA7361 accelerometer acts as sensor to captures analog vibrations occur. Vibration in the form of analog voltage is converted to digital quantities and passed to the Arduino. EM411 GPS acts as a sensor that captures the seismic sensor position (latitude and longitude) from the satellite in digital value. The process of taking vibration and position data is done through a data collection protocol that are placed on the ATmega328 and sent to a computer using an Ethernet cable media.

The next step is design of protocol processing vibration data. The process is divided into three parts, namely the design of communication protocols to ATmega328 from MMA7361 accelerometer sensor, calibration protocol of MMA7361 vibrations data and transmitting protocol to send vibration data to computer. Communication data from sensor to ATmega328 is illustrated in Figure 2. The process is preceded by data retrieval position (latitude and longitude) of the satellite as much as 10 times and continued with data retrieval vibrations of the sensor shakes. Decision 10 times is that the data is read from the satellite position is really valid. In the data retrieval to eleven onwards, the data are drawn from the data sensor MMA7361 shakes. Vibrating Data will be stored temporarily in a buffer created at the location ATmega328 chip to wait for the calibration process, while the position data sent directly to the Ethernet port eth shield.

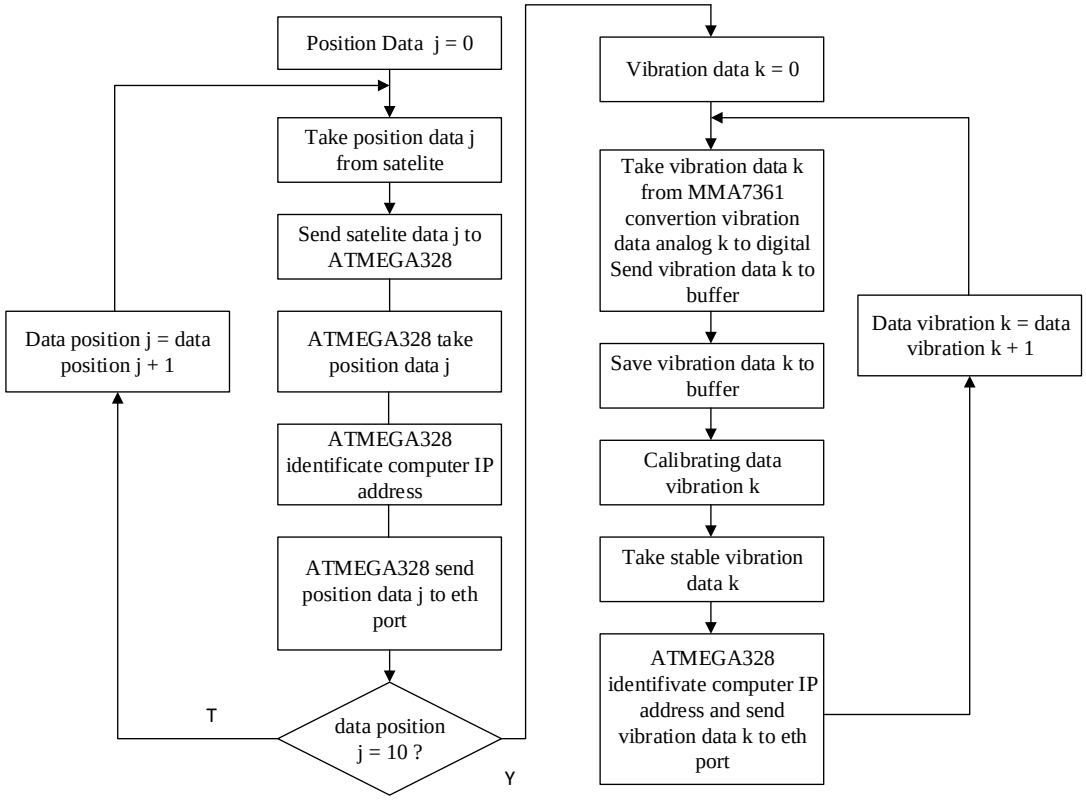


Fig 2: The Communication Process from Sensor to ATmega328

Calibration process is done by taking the digital value of x, y, z from the strengthening of accelerometer to ATmega328 and determine the zero_G value which is the axis value when the sensor in a stationary position without reversed and scale that is the average change in each value 3-axis. Both values are then processed by general equation that involves matrix multiplication P1 default parameters MMA7361 accelerometer to determine the value of x, y, z calibration. Conditions in this study stated calibration data conditions shakes x, y, z should be on the state is not worth (0,000) when no vibration detected.

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \frac{1}{\text{skala faktor x}} & 0 & 0 \\ 0 & \frac{1}{\text{skala faktor y}} & 0 \\ 0 & 0 & \frac{1}{\text{skala faktor z}} \end{bmatrix} x \begin{bmatrix} x_{read} - \text{sensit_x} \\ y_{read} - \text{sensit_y} \\ x_{read} - \text{sensit_z} \end{bmatrix} \quad [P1]$$

The calibration process is preceded by a vibration data capture digital x, y, z of the accelerometer and determine the value of zero. Zero value is the average value of the three axis when the sensor is in an inverted position, while the default scale in database accelerometer. All amounts are included in the equation of matrix multiplication [P1] to get V_axis (Vx, Vy, Vz) as a vibration output value calibration. This value is sent to the Ethernet port eth shield to wait for the next transmission process.

Figure 3 describes the process of transmitting data to a computer. The process is done by sending position data (latitude and longitude) and shakes calibration data (Vx, Vy, Vz) to a database on a computer set up. Transmissions are designed using rules of communication, namely:

1. Protocol mince C in ATmega328 that will initialize the IP address of the computer, make sure the Ethernet port ready, to communicate with the database and put the data on the port.

2. Other protocols in the computer that sends request to port Ethernet, took the position data and data vibrating calibration, parsing and querying and put into a database.

The data port is located in latitude and the longitude as well as data shakes Vx, Vy, Vz. Data collection was performed in two stages.

1. Computer request by sending 'a' and ATmega328 reciprocate by providing positioning data, the data was parsed and stored.

2. Computer request by sending a 'b' and ATmega328 reciprocate by sending data shakes calibration, in-parsing and stored.

The process of request and receipt of data is ongoing with the logic “request - receive the data - parsing-querying - save" until there is a stop command from the user. Only vibrate condition for which data was taken by the computer. If the sensor does not capture the vibration, the ATmega328 does not serve requests from the computer.

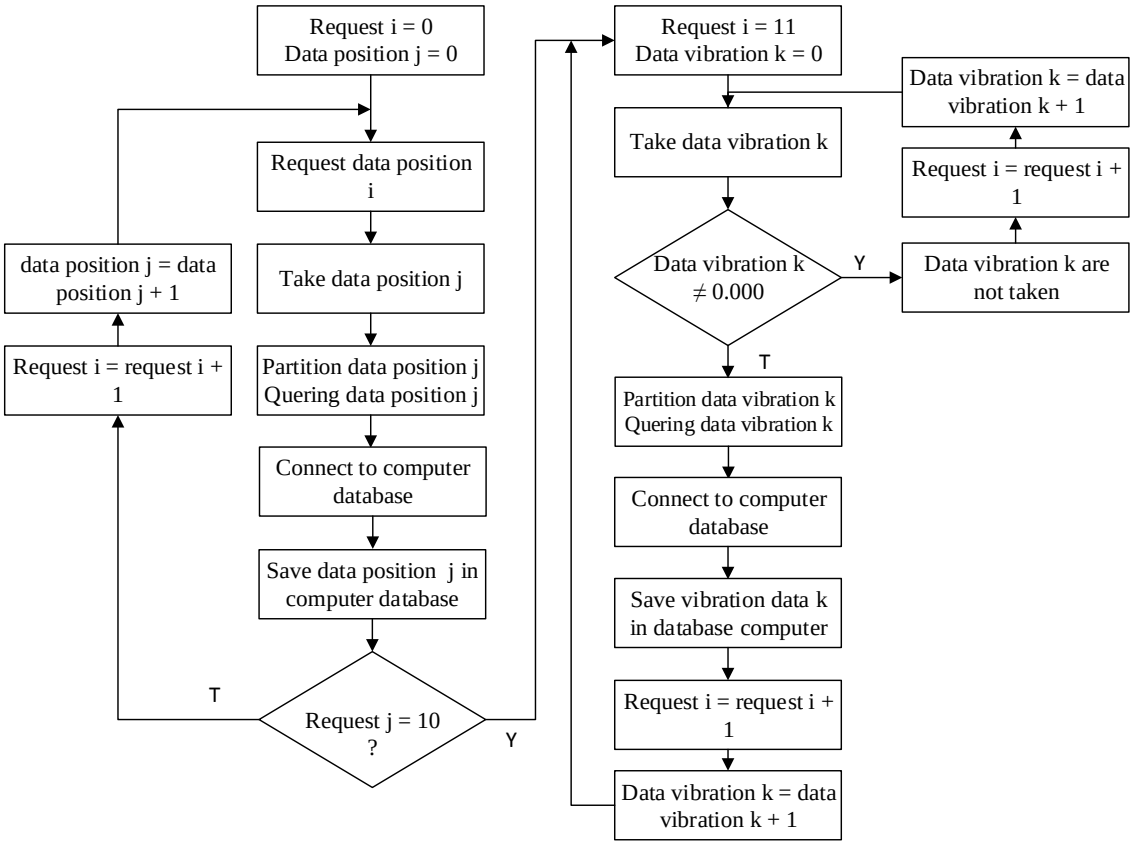


Fig 3: Transmission Data from Computer to ATmega328

3. Results and Discussion

Based on the phase of design manufacture earthquake sensors involving of ATmega328 microcontroller Arduino, MMA7361 Accelerometer, GPS EM411 and the Ethernet Shield, obtained Earthquake Sensor as Figure 4.

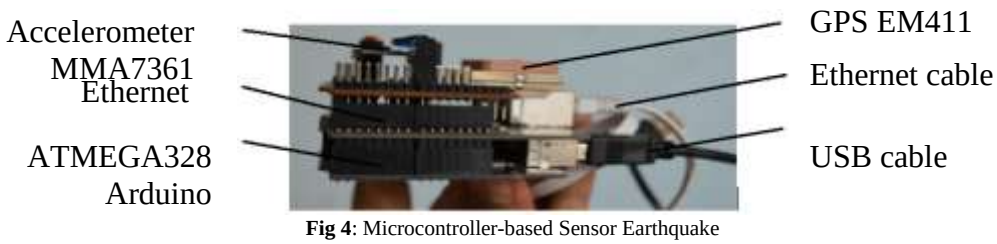


Fig 4: Microcontroller-based Sensor Earthquake

Specifically, earthquake sensors are produced using a 5 volt input voltage obtained from computer stations connected to it. While the Accelerometer and GPS respectively using the voltage 3.3 volt and 5 volt. I/O pins accelerometer function as data pins duty digital transmit vibrations that changed earlier into the ATmega328 on the Arduino. When testing, noise obtained by 0.02 g. Conditions initial vibration (P wave) is received, when there was a surge of acceleration greater than 0.02 g. The amount of data accelerations in the range of 25-40 times per second. This amount is enough to be referenced as Primary wave and further processed to provide early warning. The accuracy of GPS ranges between ± 8 m to ± 80 m. Table I is a table of testing and observation data is output from the earthquake sensor.

Table I: Results of Earthquake Observation and Testing ATmega328 Sensor

No	Observation and Testing	Result	Comment
1	Position of GPS data received at computer stations	Y	Only Latitude and Longitude
2	Data 3-axis vibrating accepted in Computer station	Y	
3	Data vibrating 3 received a fixed frequency	Y	Frekuensi of each data 25 Hz
4	the accuracy of the sensor data	Y	There is Noise of 0.02 g
5	accuracy of GPS position data	Y	Position data changes depending on the placement of earthquake sensors. Accuracy of position data between ± 8 m to ± 80 m

The process of receiving position data and data shakes, is shown in Table II.

Table II::Results of Testing Shakes and GPS Data Reading in Arduino.

No	**Treatment**	**Location data**		**Vibration**		
		Latitude	Longitude	x-axis (g)	y-axis (g)	z-axis (g)
1	Sensor not given interference	-10.169253….	123.635864….			
		-10.1692533484	123.6358642436			
		-10.1692533492	123.6358642576			
		-10.1692533493	123.6358642578			
		-10.1692533493	123.6358642578			
		-10.1692533493	123.6358642578			
		-10.1692533493	123.6358642578			
		-10.1692533493	123.6358642578			
		-10.1692533493	123.6358642578			
		-10.1692533493	123.6358642578			
				380	379	379
				380	379	379
				380	379	379
				380	379	379
				380	379	379
				380	379	379
				etc	etc	etc
2	Sensor by interference			385	357	379
				382	355	375
				386	360	380
				378	356	376
				etc	etc	etc

Table II shows the treatment given to earthquake sensors before calibration without treatment vibration/ shaken. The first data retrieval to the tenth, which is taken only position data from the GPS EM411. The accuracy of positioning data began to look at the data retrieval third to the tenth. While in the eleventh data retrieval and so on, only data from Accelerometer shakes are taken and sent to the ATmega328. When the sensor is given a vibration disturbance, visible changes in the value of each axis (x, y, z) accelerometer captured by ATmega328 changing.

Once the sensor is calibrated through programming based on the parameters zero_G and P1 matrix equation, the results obtained as Table III.

Table III: Testing Results Shakes Reading Data after Calibration.

No	Treatment	Vibration		
		x-axis (g)	y-axis (g)	z-axis (g)
1	Sensor not given disorder	0.00	0.01	0.00
		0.00	0.01	0.00
		0.00	0.01	0.00
		0.10	0.01	0.00
		0.00	0.01	-0.01
		0.01	0.01	0.01
		-0.01	0.01	0.00
2	Sensor by interference	0.01	0.34	0.23
		0.01	0.12	0.23
		0.11	0.01	-0.12
		-0.31	0.34	0.01
		0.22	0.04	0.28

Table III illustrates that when the sensor is not receiving vibration, then the output of each axis accelerometer provides values between 0.00 g and 0.01 g. Should have been the values shown is 0.00 g position for all axis, but non-compliance with the displayed results can be considered as noise and ignored. Figure 5 (a) and (b) to show the condition of the sensor data before calibration and after calibration. Display testing before and after calibration.

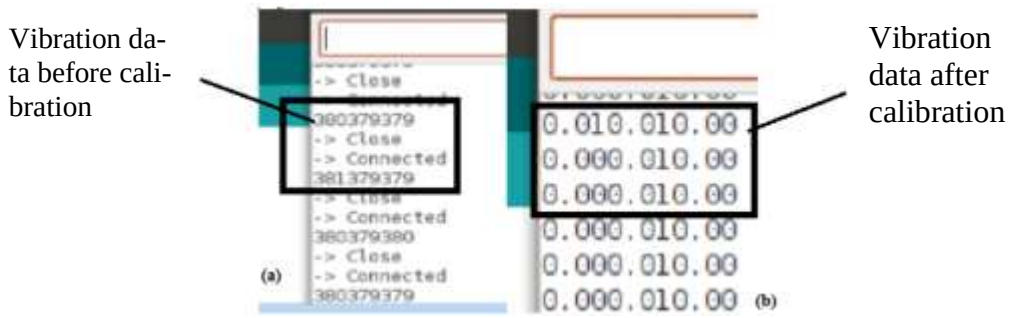


Fig 5: (a) and (b) Display Vibration Data before and after Calibration

Process of transmitting data from the sensors to Computer Base Stations do with media via an Ethernet cable to the Ethernet port module port eth computer stations. The process is preceded by identifying the IP Address station computer based network classes that have been identified on seismic sensors designed. Specifications IP address has been set as follows:

Earthquake Sensor IP Address: 192.168.43.115 / 255.255.255.0

IP Address Computer Stations: 192.168.43.116 / 255.255.255.0
Vibration data already in calibration packaged and sent to a computer database of the base station. Data packets sent a third value axis that is composed of 15 digits, which would then be in the partitions (cut) into 3 parts (x, y, z) respectively 5 digits and placed in a database available. The process of transmitting data from the sensors to the station computer databases are described in Table IV.

Table IV: Observation data transmission of vibration from the ATmega328 Arduino to Computer Database Station

No	Treatment	Data packets send are	Packet data received			LED
			x-axis (g)	y-axis (g)	z-axis (g)	
1.	Vibration not occurred	0.000.000.041	0.00	0.00	0.41	off
		0.00-0.000.041	0.00	-0.00	0.41	off
		0.000.000.041	0.00	0.00	0.41	off
		0.000.00-0.04	0.00	0.00	-0.04	off
		0.000.000.41	0.00	0.00	0.41	off
2	vibrations occur	0.100.010.50	0.10	0.01	0.50	on
		0.10-0.010.48	0.10	-0.01	0.48	on
		0.120.200.52	0.12	0.20	0.52	on
		-0.000.500.85	-0.00	0.50	0.85	on

Table IV illustrates that when vibrations are not given, data packets sent and received per unit time at a computer station in 5 digit form of partition. Led indicators do not abuse that means no vibrations. When the sensor by vibration, Led lights will be ON indicates vibration occurs and the received data packet also change according to the strength of the vibrations given.

Figure 6 displays output in Base Station Computer when no vibrations to vibration happen and captured by the earthquake sensor.

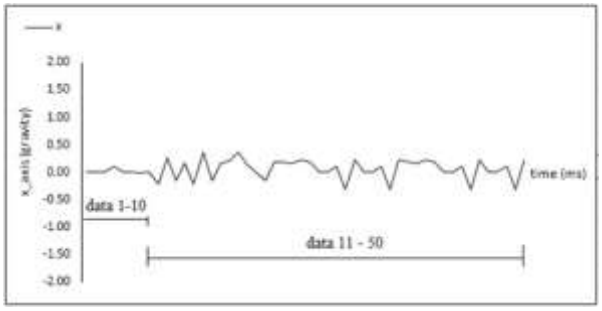


Fig 6: Outputs x_axis from sensors in Base Station Computer

Figure 7 displays a vibration in the x-axis (x_axis) of earthquake sensor with 50 sample data. At the beginning of vibration (± 10 x of data) value x_axis changed between -0.01 g to +0.01 g. But is regarded as noise and vibration does not occur. At the eleventh vibration data and so on, while the sensor is given a longitudinal and sinusoidal vibration waves, sensor starts capturing and propagating the vibration data between -0.25 to 0.45. X-axis data vibration tends to constant up to 50.

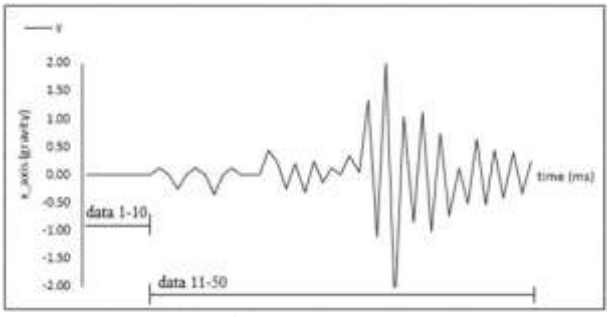


Fig 7: Outputs y_axis from Sensors in Base Station Computer.

Figure 8 displays the vibration on y_axis (y_axis) of earthquake sensors with 50 sample data collection. At the beginning of vibration (± 10 y of data) x_axis value changed between -0.01 g to +0.01 g. But is regarded as noise and vibration does not occur. At the eleventh vibration data and so on, while the sensor is given vibration as longitudinal wave, sensor has begun to catch the vibration. These vibrations initially remained constant, but underwent a significant change when vibration is given like a sine wave. Deviation of vibration experienced significant changes between -2.00 g to +2.00 g. This significant vibration changes that are secondary vibration or earthquake true.

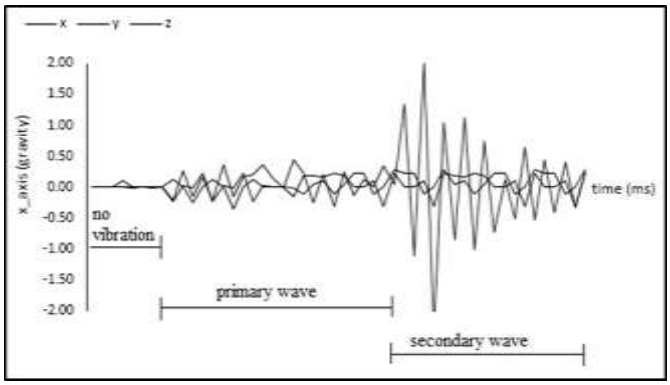


Fig 8: Outputs z_axis from sensors in Base Station Computer.

Figure 8 displays vibration in the z-axis (z_axis) of earthquake sensors with 50 sample of data. At the beginning of vibration (± 10 data z) value z_axis changed between -0.01 g to +0.01 g. But is regarded as noise and vibration does not occur. At the eleventh vibration data and so on, while the sensor is given vibration like longitudinal and sinusoidal waves, vibration sensor starts capturing and propagating the vibration data between -0.23 to +0.28. Z-axis vibration tends to constant vibration data up to 50.

If all axis are combined, the vibration captured from earthquake sensor is shown in Figure 9.

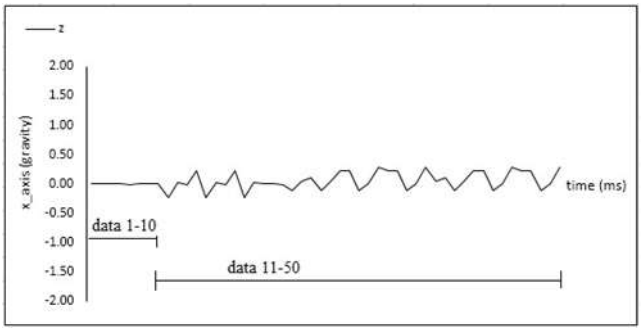


Fig 9: Outputs all axis in Base Station Computer

In the beginning of vibration data (± 10 data), there was noise of ± 0:02 g, but the noise is ignored and expressed no vibration. Vibration occurs when the sensor by wobble as longitudinal waves (primary waves) resulting in a change deviation exceeds ± 0:02 g, but the vibration is still constant (-0.35 g to +0.45 g). When wobble forwarded to resemble a sine wave, the deviation changed very significantly in y_axis, while two axiz did not have significant changes. The sudden change by y_axis between -2.00 to +2.00 is called secondary waves and that is actual earthquake vibrations.

4. Conclusion

MMA7361 MEMS Accelerometer have shaped vibrating digital data output is unstable in zero position. Calibration process specific required to stabilize vibration to zero (stable) when no vibration has been arrested, the calibration process is done by taking the 3-axis when condition sensor is silent, processed together with Zero-G variable in datasheet and processed using a matrix equation. When no vibration happen, noise occurs at ± 0.02 g. However, to facilitate data processing into early warning systems, noise is negligible. Sensor stated capture the vibration when LEDs indicate to ON position.

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