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Design of Low Frequency Vibration Generator As Seismic Sensor Calibrator with Optocoupler Counter

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Abstract

A sensor is an important component in measuring and controlling system. Several sensors use the high technology to fabricate such as a vibration sensor. Consequently, its make a vibration sensor have a high price and rarely in the market. Therefore, many researchers develop it to get a sensor with good a characteristic and low price. In order to get a good characteristic of vibration sensor, we required the low frequency vibration generator as sensor calibrator. This paper presents the design of a low frequency vibration generator instrument as a seismic sensor calibrator using an optocoupler counter sensor. The vibration generators consist of a mechanical and an electronic system with separate in two different boxes. A direct measurement was conducted to measure the sensor output and the time to count the frequency. The accuracy and precision were determinate based on the indirect measurement (statistical and graphical analysis). Testing result of the instrument shows that the sensor accuracy is about 94.2% with average of correctness 0.955. Accuracy average of vibration generator is 0.98 and the precision is about 0.976.

Keywords : *vibration generator, low-frequency, seismic sensor, calibrator, optocoupler counter*

1. Introduction

Sensor is a primary electronic component that used in the measurement system or control system. A sensor can be applied to built a system that works automatically and able to analyze the phenomena that occur in the nature. Sensors are used to construct a type of measurement or control system according to the physical quantity that can be sensed by a sensor such as the detection of vibration. Wirawan et al. (2012) develop an instrument based on the ultrasonic sensor to measure the vibration frequency of the object [1].

Vibration detection is able to provide vibration parameters that detected by sensor. Through this information can provide an early warning to prevent fatal damage due to the effect of vibration. This detection system is required to detect vibration and engine work analysis, vibration power bridge analysis, building strength vibration analysis, and earthquake. Especially for the natural vibration like an earthquake, it's requiring vibration measurement in the low frequency. For the purposes of developing a vibration detector, there are many varieties of sensors and other devices that response a vibration such as geophone sensors, piezoelectric, accelerometer, and etc. Generally the sensor material is semiconductor, optic materials, or metal and its need high technology to build a sensor. In 2011, we develop the vibration sensor based on the fluxgate [2]. In order to test the reliability and the characteristic of a vibration sensor system, especially for the low frequency vibration, we required the vibration measuring instruments especially for test equipment, calibrator, and vibration generator.

The low-frequency vibration generator produces low-frequency mechanical vibration wherein one of these vibrations is an earthquake vibration with the dominant frequency range from 1 to 5 Hz. In this paper, we present the design of a low frequency vibration generator instrument as seismic sensor calibrator. We were using a DC motor as an actuator and optocoupler sensor as counter sensor. DC (direct current) motors converts direct current electrical energy into mechanical energy [3]. DC motors are used because of its speed can be varied so that it can be used to regulate the frequency. In addition, DC motors also have high torque, linear performance, and simpler control system [4].

2. Materials and Methods

There are two types of work conducted in this research i.e. hardware and software design.

2.1 Hardware design

The design of Low Frequency Vibration Generator as Seismic Sensor Calibrator with Optocoupler Count can be seen in Figure 5. The main component that used in this the design are DC motor, optocoupler sensors, liquid crystal display (LCD), ATMega 8535 microcontroller. In order to produce an accurate data, its must complete a certain specification that give a description of the research product. There are two types of specifications, design specifications (Figure 1) and performance specifications. A performance specification is to identify the functions each of the components form the system, while design specifications also called the functional specification.

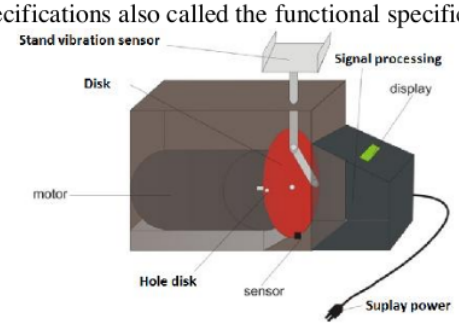

Figure 1 Design of low frequency vibration generator

The instrument has separate mechanical and electronic systems. Mechanical system and electronic system is connected by connecting cables. Both of these systems were deliberately separated so that the resulting vibration actuator does not interfere with the performance of the electronic components.

2.2. Software design

The controlling program that will be embedding to the microcontroller chip in order to control of the instrument work was written. The program was build using the CodeVision AVR program based on C programming language. Figure 2 shows the flowchart of the controlling program.

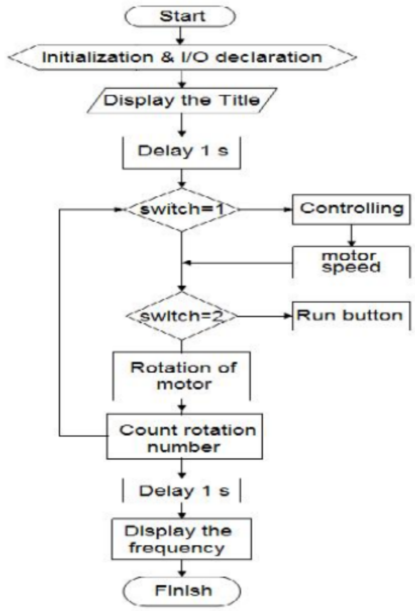

Figure 2 Flowchart of the controlling program

The measurement results can be expressed in a specified average value, standard deviation, and the relative and absolute error of measurement results. The accuracy and precision of the system was determined using the theory of errors. The percentage of error can be determined based on the equation:

$$\%\ \text{Percent error} = \frac{Yn - Xn}{Yn} \times 100\% \tag{1}$$

where *Yn* is an actually value and *Xn* is the value measurement.
For the relative accuracy (*A*) of a measurement system can be determined by the following equation [5].

$$A = 1 - \left| \frac{Yn - Xn}{Yn} \right| \tag{2}$$

and the precision of a measurement can be expressed in mathematical form as follows:

$$\text{Precision} = 1 - \left| \frac{Xn - \overline{X}n}{\overline{X}n} \right| \tag{3}$$

where *Xn* is the value of the n-th measurement and $\overline{X}n$ is the average of a set of n measurements.

3. Results and Discussion

The Figure 3 shows the low frequency vibration generator that has been made. The low-frequency vibration generating consists of two parts i.e. an electronic circuit system (Figure 3a) and a mechanical system (Figure 3b) that placed in two different boxes. The electronic circuit system of low-frequency vibration generator consists of a power supply circuit (1) as a current source, PWM (2) as a DC motor speed control, microcontroller minimum system (3) as the centre of controlling program of the systems, and optocoupler sensor circuits (4).

(a) (b)

Figure 3. Low-frequency vibration generators.

The mechanical system consists of several components i.e. a vibrating lever (1) that functions transform transformation circular motion into vertical motion, DC motor (2) function for the driving source (actuator), torque driver (3) serves to provide more big torque on vibrating sleeve, disc (5) and optocoupler sensor (4) for chopping round amount of low frequency vibration generator as shown in the inset of the Figure 3b. The number of vibration, time and the frequency will be displayed in the LCD module. In order to operate this generator, there is a button which serves to start the running system, to stop system and restore the original position readout. In addition to control the motor speed there is a rotary switch. When the DC motor rotates, it will rotate a disc and moving the arm to vibrate vertically.

Data analysis was performed on the low-frequency vibration generating system includes sensor characteristics, PWM output voltage relationship of the adjustments are, as well as the accuracy and precision of generating low-frequency vibration.

3.1. Accuracy and precision of optocoupler sensor

Optocoupler sensor emits infrared light from the transmitter to the receiver. When the transmitter and receiver blocked by obstacles, it will cause changes of the sensor output voltage. From the datasheet, the output voltage sensor is about 5 volts. The obtained measurement shows that the blocked voltage is 4.71 volts and the unblocked voltage is 0.0065 volts. According to this measurement result, the accuracy of the sensor is 94.2%. The discrepancy of the voltage due to the influence of the sensor cable is long enough so that the voltage drop occurs in the sensor. In addition, the repeated measurement of the sensor in case of blocked and unblocked was conducted to obtain the sensor precision. The unblocked optocoupler sensor precision is 0.999, whereas the blocked precision is 0.892.

3.2. Correlation between frequency and DC motor input voltage

The correlation between the input voltage DC motor with frequency is shown in Figure 4.

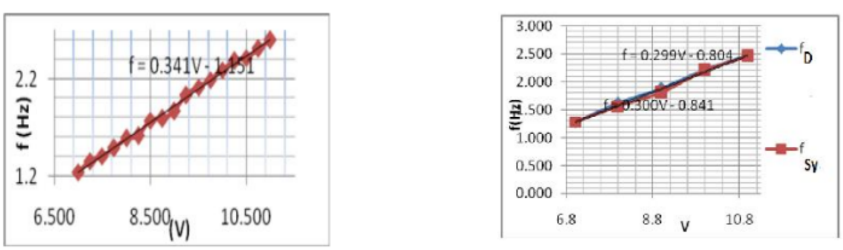

Figure 4 The correlation between the voltage and frequency.

Figure 5 Graphic of the frequency accuracy (f_D vs f_{Sy}).

From the graph it can be seen that increases of voltage make the frequency increase too. The correlation of frequency and the voltage can be depicted by the following regression line equation $f = 0.34V-1.151$ where the coefficient 0.34 is the sensitivity to changes in voltage DC motor speed and the 1.151 constant is the initial frequency.

3.3. Low-frequency vibration generating accuracy

The accuracy of a low-frequency vibration generator is determined by comparing the measured data (f_D) to a standard measuring system (f_{sy}). The precision of the low-frequency vibration generator can be seen in graphic of the Figure 5. The graphic shows the comparison between the measured frequency curves and the frequency count. Measurements and calculations results which represented by two line with the line equation $f = 0.299V-0,804$ for a measurement and $f = 0.3V-0,841$ for a calculation. The error percentage range is from 0% to 4.3289%. Meanwhile, the accuracy of the vibration generator systems ranged from 92% to 99%.

3.4. Absolute and relative error

For the 10 times of measurement, the average accuracy of low frequency vibration generating is 0.976, while the average error is 0.019. Absolute error of low frequency vibration generating system can be seen in Figure 6.

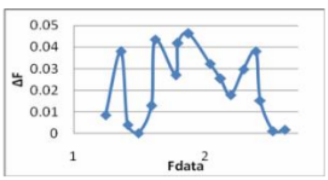

Figure 6. The graph of an absolute error

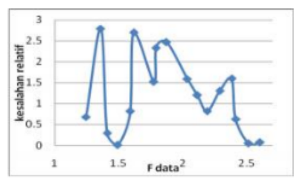

Figure 7. The graph of relative error

Based on sinusoidal shaped graph the Figure 6, the maximum of an absolute error values is 0.046. Meanwhile, the relative error of the system is ranged from 0% to 2.793% as shown in Figure 7.

4. Conclusion

Based on the analysis results of a Low Frequency Vibration Generator as Seismic Sensor Calibrator With Optocoupler Count that has been done, it can be drawn some conclusions that the accuracy of low frequency vibration is about 94.4%, the precision of the sensor is obstructed during 0.892 and 0.999 when there is unobstructed, with a relative error is 0.279. The generated voltage influences proportionally the vibration frequency. The average accuracy of the low-frequency vibration generator system is 0.98% with an average relative error 1.90%.

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