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PROTOTYPE DESIGN OF GEOPHONE USING PIEZOELECTRIC SENSOR BASED ON ARDUINO UNO

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ABSTRACT

This study designed a geophone prototype using a piezoelectric sensor based on Arduino Uno. This research aims to create an alternative tool from the geophone that can measure vibrations on the ground. To find out if the geophone sensor that has been designed can work well, namely by knowing how far away the sensor can receive a given vibration source. Geophone design made using a piezoelectric sensor based on Arduino Uno R3. The components used to make the prototype will be connected to the Arduino, with the output as a byte value converted into a voltage. These results were obtained from testing by taking data using a vibration source, namely a dropped load. The testing process is carried out by dropping the vibration source from a height of 55 cm with variations in the distance as far as 20 cm, 30 cm, 50 cm and 60 cm. From the experiments carried out, the prototype made can function to read data from the dropped source. The farther the vibration source is dropped, the smaller the voltage generated. The results obtained from this study are the design of a geophone prototype made on a laboratory scale.

Keywords: Arduino Uno, Geophone, Vibration, Piezoelectric Sensor.

INTRODUCTION

Technology that continues to develop in the modern era must be used in various fields. One of which can be used in the field of geosciences. One of the technologies used in earth science is an instrument that can detect vibrations on the earth's surface and determine the layers below the ground surface. A geophone is a device that converts ground motion or vibration into a voltage that can be recorded with the result in the form of a wave graph. The geophone that will be designed as an alternative to this seismic method instrument is based on Arduino Uno and uses a piezoelectric sensor. Arduino Uno is a microcontroller-based electronic board with an IC (integrated circuit) chip that can be programmed with a computer via Arduino IDE software and has open-source properties (Rizki, Maulana and Kurniawan, 2018).

Previous research conducted by Wang Yao et al. (2019) is to make geophone instruments using a more complicated design because the series of tools used are extensive, the materials are complicated, and the costs are relatively expensive. Then (Sembiring, 2017) designed a vibration detector with an output that can be read on Organic Light Emitting Diodes (OLED); this tool is used as an alternative in vibration measurement. Finally, Kusmiran (2012) researched geophone design using a loudspeaker. The loudspeaker is a vibration sensor that can capture and get travel time data. So based on several previous

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studies, in this study, a prototype vibration detection device will be designed using a piezoelectric sensor based on Arduino Uno R3 (Potylitsyn *et al.*, 2019).

This tool consists of several components, namely, Arduino Uno as a microcontroller board that functions to facilitate the manufacture of prototypes (Li *et al.*, 2020). Then there is a piezoelectric sensor that functions as a vibration detector, where the vibration will then be converted into an electrical signal. So this research was carried out as an alternative tool that has the same function, namely displaying graphic data on the results of vibrations or seismic waves (Keyestudio, 2021). To determine the geophone that can function, a variation of the sensor distance with the source is used to determine the extent to which the sensor can receive a given source.

LITERATURE REVIEW

The geophone is a very important instrument in seismic exploration. This geophone is a tool that detects and records a vibration found on the earth (seismic waves) found on the ground surface (Li *et al.*, 2020). A sensor generally converts physical quantities into other physical quantities, especially electrical ones. The geophone will convert the ground motion or vibration obtained into a voltage (Song *et al.*, 2018). The working principle of the geophone in converting motion into electrical energy is to use the principle of electromagnetic induction. The geophone that will be designed uses a piezoelectric sensor to detect vibrations and uses Arduino Uno as a microcontroller (Rizki, Maulana and Kurniawan, 2018).

The sensor is a transducer that functions to process variations of a value in the form of light, motion or heat into a voltage or electric current. The word transducer means to change (Sujadi and Bastian, 2007). The form of change referred to in this case is the ability to convert one form of energy into another form of energy. A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure, acceleration, strain or force by converting it to an electric charge (Collette *et al.*, 2011). The working principle of this sensor is that when pressure is applied to the dielectric material, an electric field will be formed. When the electric field passes through the material part, the polarized molecules will immediately adjust to the electric field, then produce a molecular induced dipole and the crystal structure of the material (Preumont, 2018). Piezoelectric materials are materials that can produce an electric field when subjected to mechanical stress (Ardhi, 2018). And vice versa, when an electric field is applied, the piezoelectric material will experience mechanical strain or stress (Wang, Fu, Lu, *et al.*, 2019).

In piezoelectric elements there is piezoelectricity (piezoelectric effect) which is formed from the pressure on the piezoelectric which then creates an electric field. When the electric field passes through the material, the polarized molecules will adjust to the electric field, then an induced dipole is generated with the molecules or crystal structure of the material so that the molecular adjustment will cause the material to change dimensions (Xing, Liu and Wang, 2012). Arduino is an open-source single-board microcontroller whose main component is an AVR and Atmel microcontroller chip. The microcontroller is a chip or IC (integrated circuit) that can be programmed using a computer (Varadan *et al.*, 2000).

The purpose of entering the program in the microcontroller is so that the electronic circuit can read the input, process the input and then produce the desired output. The microcontroller functions as the 'brain' that controls the input, process, and output of an electronic circuit. Arduino generally consists of two parts: hardware in the form of an open-source input/output (I/O) board and software (Preumont, 2018). The main advantage of Arduino is that Arduino is a microcontroller platform that was created to simplify various kinds of complexities in microcontroller programming so that it becomes an easy-to-use unit (Wang, Fu, Fu, *et al.*, 2019)

METHODS

The design process is carried out in several stages. Starting from the study of literature, preparation of tools and materials, prototype design, electronics design, software design, and data retrieval processes. The selection of sensors is made by looking at the criteria of various vibration sensors and reading references from various journals. So the sensor used is a piezoelectric sensor. The piezoelectric sensor was chosen because it is more effective and affordable and can capture vibrations generated from the earth or a given vibration source. The last component chosen as a microcontroller is Arduino Uno because its use is relatively easy, effective and affordable. Next, the prototype design determines the shape and materials used in the geophone prototype. Use the form as shown in Fig. 1 because it considers the adequacy of the inside of the geophone to place components. Then form a good prototype to place piezoelectric sensors, Arduino and various connecting cables.

Furthermore, for selecting materials, namely using a breadboard, piezoelectric sensor, Arduino Uno and connecting cables to form a geophone. For geophone placement, Arduino and connecting cables will be placed on acrylic material because it has a strong enough strength so that it is not easily damaged when moved around. Acrylic material also has a glossy design, making the prototype look neat.

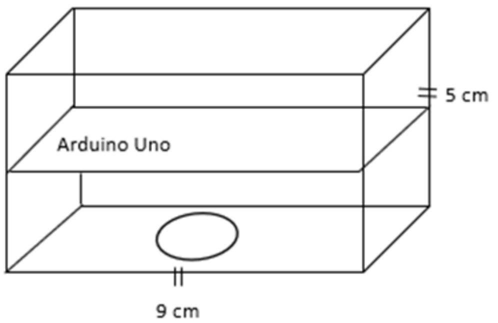

Figure 1. Geophone Prototype Design

Electronics design is done to design the wiring diagram between each component. Then the components will be connected to Arduino. The component that must be connected is a piezoelectric sensor with Arduino. All components that will be assembled will be connected by connecting cables or jumpers that have been provided.

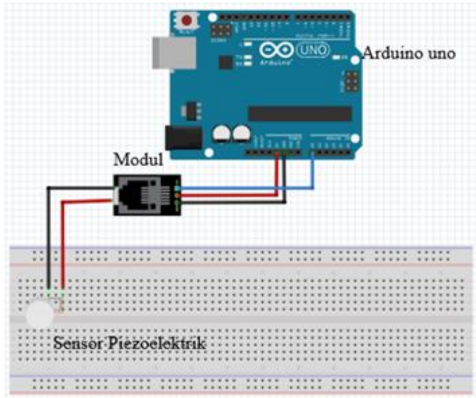

Figure 2. Sketch of electronic design with Arduino

Figure 2 is an Arduino circuit with a piezoelectric sensor. To connect the piezoelectric sensor to the Arduino, the piezoelectric sensor is connected to the available electronic components, and the red cable is connected to the input on the electronic component while the black cable is connected to the ground on the electronic component. Use jumper cables to connect the piezoelectric sensor module and electronic components to Arduino. The piezoelectric sensor module has three pins, where the negative (-) pin is connected to the ground pin (GND). The positive (+) pin is cone-

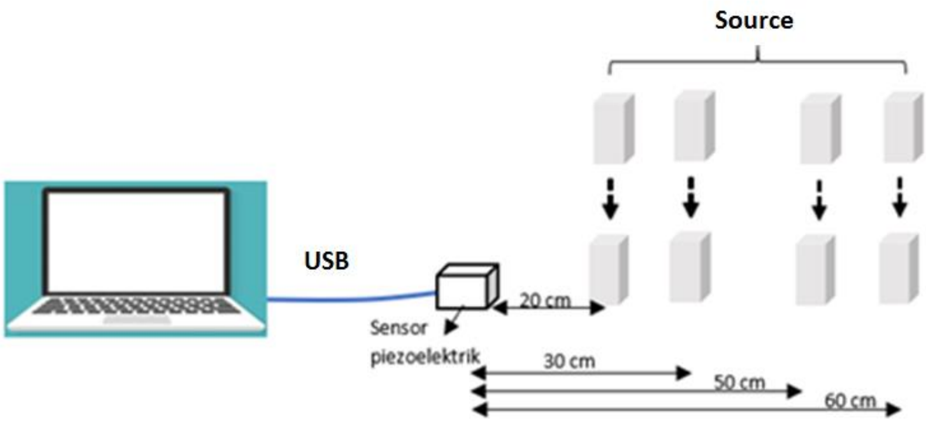

Figure 3. Sketch of the data collection process

-cted to the VCC pin (5V). And the S pin is connected to pin A0. Arduino has 14 digital input/output pins and 6 analog input pins. The data collection process is carried out using objects of the same weight.

Then the object is dropped at different distances near the piezoelectric sensor (detector), as shown in Figure 3. The dropped object will cause vibration, which will then be captured by the piezoelectric sensor. After receiving the piezoelectric sensor's feedback, the vibration will produce an output in the form of a wave graph listed on the Arduino software.

RESULTS AND DISCUSSION

A geophone design prototype has been made with a design size of length x width x height of each 9 cm x 8 cm x 5 cm. This prototype design uses Arduino Uno and a piezoelectric sensor module. In this prototype, the command made is intended for Arduino Uno, which will then be connected to the piezoelectric sensor and set the sensor so that it can run commands according to the Arduino Uno code. The piezoelectric sensor functions to measure pressure changes. The sensor will produce a voltage value when given a vibration source. The piezoelectric sensor module serves to regulate the input and output voltages generated. Arduino Uno serves to facilitate prototyping and programming microcontrollers. And the connecting cable is used to connect the electronic circuit.

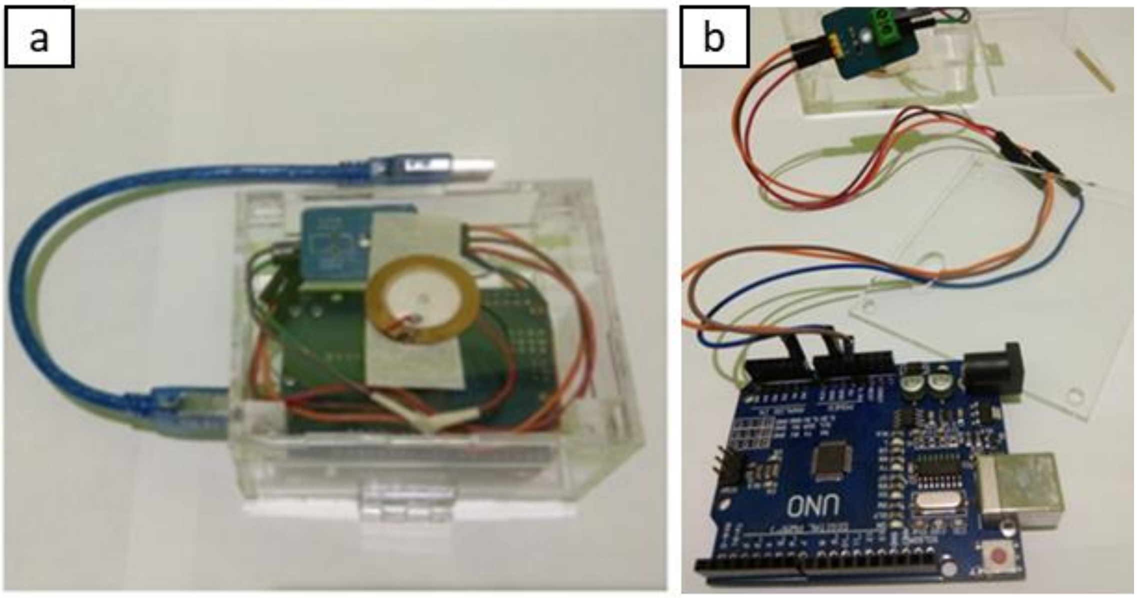

Figure 4. (a) Prototype Sequence and (b) Prototype Design

In Figure 4, the electronic circuit of the geophone design above is given the command so that the program runs. The commands are addressed to the Arduino Uno and will then be passed to the module and set up the piezoelectric sensor. The command made to the piezoelectric sensor is that if it is placed on the ground, it is given a source in the form of bricks that are dropped from a height of 55 cm with different distance variations. The sensor will read ground vibrations that hit the piezoelectric sensor. This piezoelectric sensor has high sensitivity, so the program code is given a filter to filter out noise. The working principle of this noise filter is that the signal passed is a signal with a frequency above the cut-off value, and a signal below that frequency will be attenuated. The speed of receiving vibration is set on the delay function in the program code. In this study, the delay value is set to 1000 milliseconds for fairly loud vibrations and 100 milliseconds for low vibrations. The delay value of 100 ms means that the voltage data received from the vibration received by the piezoelectric sensor will be printed on the monitor and read every 100 milliseconds. Using a delay value of 100 ms for low vibrations and 1000 ms for vibrations loud enough so that the data obtained can be printed on the Arduino IDE software, nothing is missed, or in other words, it can be read in its entirety. From the prototype design process that has been made, the testing process is carried out by taking data for the piezoelectric sensor. The programming algorithm used in Arduino Uno is pin configuration, variable declaration, initialization, the main program, and output. Pin configuration determines the pin to be used as input or output. Variable declarations are made for declaring the type of data to be worked on, such as analog data. Initialization is the program's initialization that is made to determine the status of the command, and the main program is used as a source of program control.

After testing the tool, experimental data can be collected using bricks dropped from a height of 55 cm, with several variations in distance, namely at a distance of 20 cm, 30, 50 cm and 60 cm. Experimental data is obtained by plotting a graph between the voltage value against time

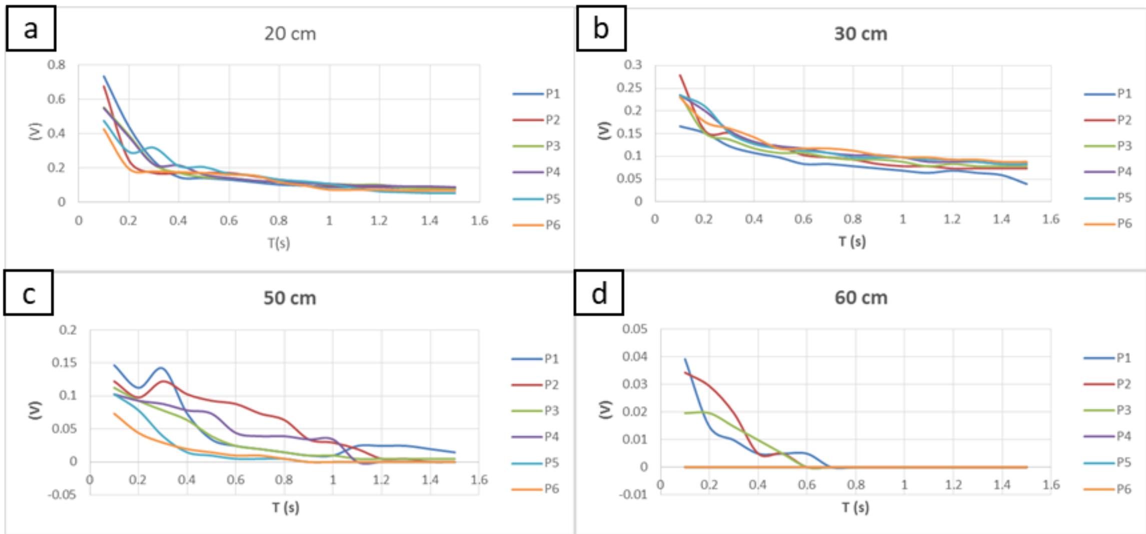

Figure 5. Graph of voltage and time values

Figure 5 is a graph of experimental data collection with different distance variations. Data retrieval was carried out using a repetition of 6 repetitions. The colorful lines P1, P2 to P6 on the chart show the 1st repetition, 2nd repetition to 6th repetition. The result of the voltage value obtained is that the farther the distance from the source is dropped from the sensor, the smaller the voltage value will be. This is because there is energy that propagates up to the sensor. If the distance of the source being dropped is further away from the sensor, the energy that reaches the sensor will be smaller because there is an attenuation factor until it reaches the sensor. Data retrieval at a distance of 20 cm from the sensor's resulting voltage value is still good because the damping factor is small.

The overall accuracy produced in data collection with 6 repetitions is 99.2068. The accuracy obtained is because there is a damping factor, so the accuracy value does not reach 100. Then for the accuracy of the first value obtained for each data collection on the four variations of the distance, namely at a distance of 20 cm, the accuracy value is 9.8118. At a distance of 30 cm, it is obtained the accuracy value is 99.8567. At a distance of 50 cm, the accuracy is 99.7983; at a distance of 60 cm, the accuracy is 98.9303. The results of the accuracy of the data that have been taken at a distance that is farther away, the value of accuracy is getting smaller because the soil is getting denser at the time of repetition so that the resulting attenuation is also getting bigger. According to (Suryolelono, 2010), attenuation can be described as a condition that causes the amplitude of the vibration to decrease with time until the energy runs out gradually. Then at the time of data collection, the soil conditions that can be used are dry and not wet, so if the soil conditions used for data collection are wet, the sensor cannot accept the propagation of energy generated from the given source.

The results of the data collection experiment, which can be seen in Figure 5, show that the designed tool can function and be used. However, this tool cannot be used with the same function as geophones because the resulting geophone data must be accurate and in the form of seismic data. Source of vibration in the form of sound waves from a given load. The distance for data retrieval can not be further, then the data generated from the Arduino itself is still in the form of bytes. So, compared with previous research conducted by Kurnadi (2009), the designed geophone can be used to record the movement of sensitive ground waves for certain survey purposes, such as geotechnical surveys for building a building or other infrastructure.

In addition, this study has similarities with previous research conducted by Sujadi et al. (2018), namely the implementation of testing a porous tree detection device using Arduino Uno and piezoelectric sensors. The result of this research is to detect the pressure in the tree, which then turns into a number in bytes listed on the Arduino serial monitor to determine how porous the tree is. If the resulting number is more than 100 bytes and less than 200 bytes, the tree is declared non-porous. Then, if the resulting number is more than 200 bytes and less than 300 bytes, the phone is porous. So in, this geophone design research is more similar to the research conducted by Sujadi et al. (2018); namely, if the vibration source given is close to the sensor, then the resulting number is greater, and if the distance of the given vibration source is getting further away, the resulting number is getting smaller.

CONCLUSION

From the research results, the geophone prototype design uses a piezoelectric sensor based on Arduino Uno, which is made in the form of a laboratory scale. And the results of the experimental data collected from the tools that have been made can function. Data collection experiments were carried out using variations in the distance of the vibration source from the piezoelectric sensor. Variations in the distance of the dropped vibration source are 20 cm and 30 cm. 50 cm, and 60 cm. at a distance of 60 cm, the received voltage gets smaller.

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