Seismometer Candidate for Globe Project

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Tuesday, December 03, 2002

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Executive Summary

We have come to understand that the goal of this project is to design and build a functional, inexpensive seismometer that can be attached to a PC. If the seismometer is inexpensive enough, then it would be possible for schools to purchase it and it could possibly be a candidate for the Globe Project. If there were a functional seismometer in the classroom, it would allow students to observe seismic activity around the world. The Globe Project is a planned worldwide network of seismometers linked to each other via computers.

We realize that the seismometer must meet several specifications. The specific technical aspects are a period range of 15-30 seconds, a signal to noise ratio of 1-20 seconds, capable of detecting a magnitude 6 or greater earthquake anywhere on earth, and able to attach to a PC to record data.

The seismometer we have chosen to modify is based on the original Lehman design. The design consists of a structure, a pendulum, a dampener, a sensor, and the electronics. The hurdle that our team most needed to overcome was the costs. Most seismometers cost upwards from about $200. The Lehman design was picked because we as a group believed that this design could be most easily manipulated into our desired price range.

The structure of our seismometer will be primarily composed of PVC pipe. The PVC pipe is very inexpensive, durable, and extremely light. The use of the PVC pipe will allow our seismometer to weigh less then 30 pounds. The structure has dimensions of about two feet long by one foot wide by one and a half feet tall. The structure is held together by PVC glue.

The pendulum is a horizontal 21¼-inch threaded steel rod. The pendulum is then attached to a 1¼-inch flat head screw with the use of a nut. The pendulum rests against a knife-edge placed horizontally within the post of the structure. For safety reasons, we used a sharpened compact disc section rather than a knife-edge. The pendulum is also attached to a string that has two springs attached to each end. The springs absorb the seismic waves of the earthquake to keep the pendulum from moving.

The dampener is used to keep the pendulum from moving due to energy waves outside our target frequency. We used an eyehole screw and put our steel rod through it. We placed the screw in the center of the pendulum. We used two washers and the center of a compact disc to on the bottom of the eyehole screw to slow down the movement of the pendulum. We used vegetable oil as our dampening fluid.

The sensor is composed of eight circular magnets and a tightly wrapped spool of copper wire. The magnets will be attached to the end of the pendulum, and during seismic activity, the pendulum will remain motionless, but the base will move up and down causing a current.

We found that we could save money with the electronics by purchasing the electronic devices from another source. Through research, we found that we could save a substantial amount of money in this fashion that we could then use in other areas of the project.

If you have any questions whatsoever please feel free to contact us.
Phone 303-215-6318 email mfarnik@mines.edu. We believe you will find that our design meets all our your criteria and does so in an exceptional manner. We thank you for this opportunity, and we hope that you are pleased with what you see.

Introduction

The goal of the project is to develop a seismometer that could be purchased for $150 or less that attaches to a PC. The development of such an inexpensive seismometer could lead to a nationwide, and even worldwide, seismic detection network, as well as put the purchase of a seismometer within bounds of a typical educational budget. The program AmaSeis will monitor the data coming into the PC so that it can be easily recorded and viewed graphically.

This seismometer would be for use in educational institutions as well as a candidate for the Globe program. The Globe program is a project with the goal of developing a worldwide seismic network. With the placement of thousands of identical, standardized seismic stations around the world, and the corroboration of the data recorded from these stations, scientists could reinforce current theories about seismic activity and even form new theories. Such information could be used in both pure science fields as well as in application, such as structural design. The amount of data that would be collected by a worldwide seismic network would prove invaluable in the scientific community, and the usability of a seismometer meeting these design specifications would prove a most valuable learning tool in the classroom.

By having a functional seismometer in the classroom, students would have the opportunity to explore with a hands-on learning approach and participate in the collection of a vast amount of scientific data. In order to be a useful learning tool in the classroom, our seismometer needs to fulfill several addition requirements, constraints, and concerns. First, the dimensions and weight of the seismometer need to be conducive of a classroom environment. Too large or heavy seismometer would be an inconvenience. The seismometer should be visually pleasing and a design such that it renders itself easily to classroom demonstrations of the functionality of the seismometer. It would also be a good idea to include an option on the seismometer that would give notification of when an earthquake has been detected. The design needs to be durable so that it supplies the most functionality for the longest time with the least maintenance. When maintenance is necessary, the design needs to simple enough to maintain easily. The inclusion of an instruction booklet for proper use and maintenance of the device is a necessity. The safety of the operator should be a concern during the design process.

Specifications

The technical requirements for the seismometer are as follows:

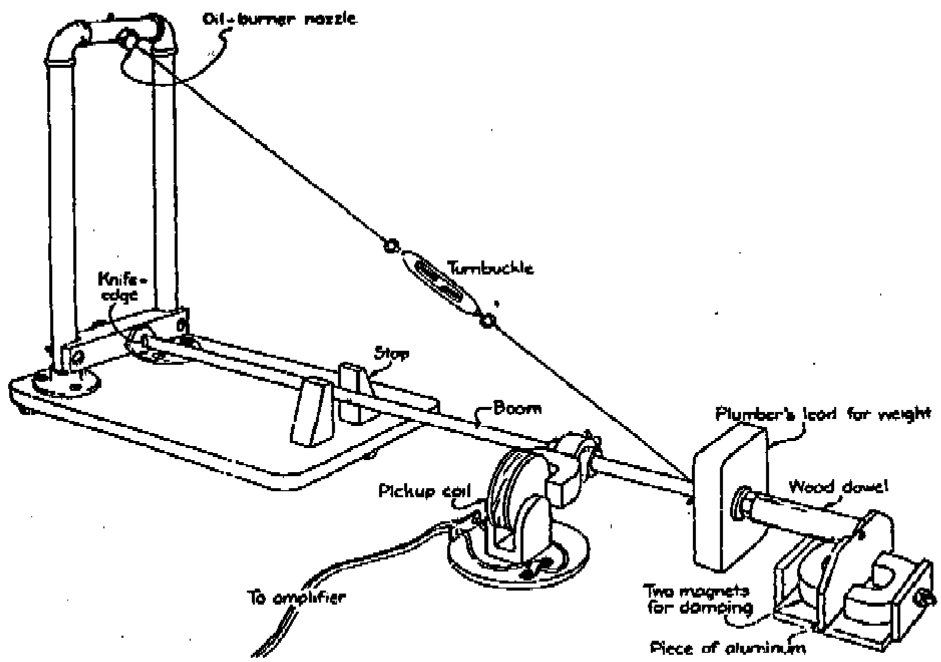
- A period range of 15-30 seconds
- A signal to noise ratio of 1-20 seconds
- Capable of detecting a magnitude 6 or greater earthquake anywhere on earth
- Able to attach to a PC to record the data

The sensor will be connected to an amplifier, filter circuit, analog-to-digital converter, then to the PC via the serial port. Another connection option is to add an AD with serial output to the amplifier/filter circuit, which would allow a direct connection to the serial port. We understand that the seismometer needs to be relatively durable with dimensions suitable to a classroom environment.

Subsystems Breakdown

During the research and brainstorming processes, we found and thought of numerous designs for a seismometer. These designs were thrown out after time constraints, cost, and/or knowledge required hindered further pursuit of these designs. Our team has made modifications to the Lehman design in order to meet the criteria outlined by this project. We feel that this time-proven design lends itself easily to modification, and that we can make the necessary modifications to this design to meet your specifications. The primary hurdle for this approach is cutting costs in the design without compromising effectiveness of the design. With five members in our design team, it worked out well, both in a systems breakdown and in manpower, to divide the subsystems into the frame, pendulum, dampener, sensor, and electronics.

Modified Lehman Design



[1]

Overview

We have completed the construction of a vertical modified Lehman seismometer at a cost of $55.14 including the electronics and excluding tax. The first concern when choosing the materials after functionality was cost. We attempted to find the least expensive materials that would function properly.

The structure is made of 1 inch PVC. (Please see page 5.3 in Graphics Portfolio) The pendulum is made of a threaded steel rod. At one end, it is connected to a flat-head bolt with a nut. The flat-head bolt rests against a compact disc that has been cut in half and filed to an edge. Please see (6.1) The blunt edge of the cd has been glued into a horizontal slot that has been cut into the vertical pole of PVC pipe. (See page 10.2) Half of the dampener, consisting of several washers, the center of a cd cut to three inches in diameter, four nuts, and an eyehole bolt (See 7.3) is held in place between two nuts threaded on the boom. The magnet is attached near the outside end of the pendulum with PVC glue. (See 10.1) A spring is attached to the opposite end of the pendulum. (See 10.1) The spring is attached to wire that runs to another spring that is attached to the top of the vertical piece of PVC pipe. The other half of the dampener, the cup filled with vegetable oil, is glued with PVC glue to sections of acrylic. The acrylic is glued with PVC blue and attaches to the frame. Two six-inch pieces of one inch PVC are glued vertically to the acrylic to serve as stops for the pendulum. The coils of the sensor are attached to another section of acrylic attached to the base. Wire runs from the coils and attach to the amplifier that attaches to the analog-to-digital converter, which attaches to a computer.

Structure

The purpose of the structure is to hold the other components of the seismometer in place. The material needs to be rigid enough as not to lose energy to the elasticity of the structure.

The dimensions of the frame are 2 feet long by 1 foot wide by 1.5 feet tall. Our entire seismograph weighs less than thirty pounds. This would allow the seismometer to be a useful and dynamic tool in the classroom. We used approximately 10 feet of 1" PVC pipe at a cost of about $.24 per foot. One 1" PVC tee was needed at a cost of about $.48. Four 1" PVC 90 elbows were needed at a cost of $.39 each. One female 1" PVC cap can be purchased for $.29. The use of four screws in the bottom of the PVC can be used to properly level the structure. One tube of epoxy can be purchased for about $3.00.

PVC is lightweight, durable, and easy to work with. The other subsystems will be able to attach their components to the frame by the use of screws and glues. Two eye-whole fastener screws can be used to attach the pendulum to the frame at a cost of $.86 each. One 12X3 inch piece of acrylic is attached with PVC glue to the frame directly below the dampener. The cup containing the vegetable oil is glued to this piece of acrylic. Another 12X3 inch piece of acrylic is attached to the frame below the sensor. The wire coil for the sensor is attached to this piece of acrylic. A third piece of 12X3 inch piece of acrylic has been cut into equal pieces to raise the height of the cup for the dampener and to act as vertical stops for the pendulum. (Please see 5.1-5.3) The estimated material cost for the structure is approximately $10.92. The expenses are broken down as follows:

Structure Cost Chart

Part Description	Quantity	Units	Unit Cost	Total Cost
1" PVC pipe	10	ft	$0.24	$2.40
1" PVC tee	1		$0.48	$0.48
1" PVC 90 deg. Elbows	4		$0.39	$1.56
1" PVC female cap	1		$0.29	$0.29
PVC glue	1		$2.99	$2.99
Eye-hole fasteners	2		$0.86	$1.72
Screws	4		$0.10	$0.40
Acrylic	108	in^2	$0.01	$1.08
			Total Structure Cost	**$10.92**

*Prices obtained from homedepot.com and do not include tax. [2]

Pendulum

The pendulum is usually made of steel or a strong plastic. Flexible materials cause the pendulum to oscillate for a longer, more noticeable period of time, making the seismometer less accurate. The horizontal pendulum starts with the arm. The movement of the arm is actually what gives the reading. [8] The arm comes to a point and it rests against a knife-edge that is placed on the support beams [3] (Please see 10.2). As you move down the pendulum, depending on design, you will come to a dampener. The dampener can be in the middle of the pendulum or on the end. Next comes the sensor, and the placement of this depends on the placement of the dampener. The sensor consists of a coil of wire and a magnet. One half of the sensor, either the coil or the magnet, is attached to the boom, and the other half is attached to the base. During an earthquake, the pendulum remains stationary and the base of the seismometer moves with the motion of the ground. As the magnet moves through the coils, it generates current that is sent to the electronics that are attached to a computer generating a graphic display of the seismic activity. [8]

The pendulum is attached to the frame at two locations. The connection on one end of the pendulum nearest the frame consists of a flat surface with a lip and a knife-edge. (See 10.2) The pendulum slopes slightly down to this point, allowing the knife-edge to rest on the lip. The opposite end of the pendulum is held up by a spring attached to about a 30-degree angle to the frame. (See 10.1)

The pendulum is most often made of steel, aluminum, or very hard plastic. After looking at availability, cost, and functionality of each material, we decided on using a threaded steel pendulum that can be purchased for $1.98. The pendulum is made of a threaded steel rod. At one end, it is connected to a flat-head bolt with a nut. The flat-head bolt rests against a compact disc that has been cut in half and filed to an edge. The blunt edge of the cd has been glued into a horizontal slot that has been cut into the vertical pole of PVC pipe. Half of the dampener, consisting of several washers, the center of a cd cut to three inches in diameter, four nuts, and an eyehole bolt is held in place between two nuts threaded on the boom. (See 6.1) The magnet is attached near the outside end of the pendulum with PVC glue. A spring is attached to the opposite end of the pendulum. The spring is attached to wire that runs to another spring that is attached to the top of the vertical piece of PVC pipe.

Dampener

The word "damp" is to attenuate the amplitude of repetitive motion and dampening is generally expressed in relation to what is needed for "critical" dampening. The dampener is the part that makes the seismometer sensitive. [3]

The dampening is very important to make the seismometer sensitive as a well dampened seismometer will reveal the various phases of seismic motion. If there is no dampening, the boom will be sensitive to seismic waves that have the same period as the natural pendulum period of the boom. With dampening, it will be most sensitive to waves with periods about half the length of the boom's natural oscillation period. An instrument built to respond to a seismic wave period of about a second is called a short-period seismometer. One that responds to periods of from 10 to 20 seconds is a long-period seismometer. Lehman adjusts his boom for a natural period from 12 to 18 seconds. As this is a long-period instrument, we decided to use an oil, instead of a magnetic, dampener. [4]

This dampener consists of a paddle connection to the boom and is suspended in a peanut butter jar full of olive oil. (See 7.3) This dampener cost about $2.25. Without this dampening system, the boom would continue to swing for a long time after initially set in motion.

Here is a picture of what the dampener will look like.

[6]

Sensor

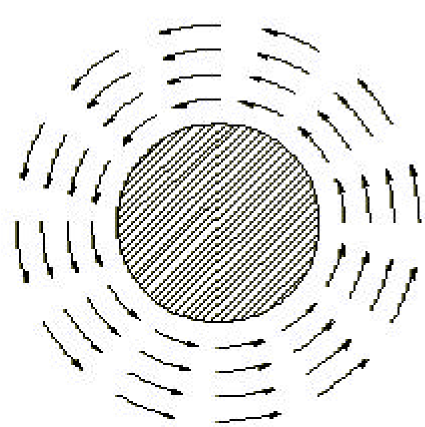
The sensor consists of a magnet and a coil. (See 8.4) The magnet is a cylindrical magnet and will be connected to the boom. The coil is a determined number of wire coils and will be connected to the base. The sensor's function is to detect the movement of the earth.

The signal is generated by the sensor in response to seismic activity. We will use the generation of current in a coil to make a signal. The information contained in the signal will be representative of the movement of the earth from seismic activity. Signal is created by movement of a concentric magnet inside a coil. The magnet creates a magnetic field, as does current flowing through a wire. Current is the movement of electrons through a wire. Movement of a magnetic field near a coil of wire will generate current. Using this concept, a wire coil and a magnet create the sensor of our seismometer. When an earthquake takes place, the base moves with the motion of the ground and the magnet on the boom stays stationary, causing the coil to move around the magnet generating current. The signal has both an amplitude and frequency.

Amplitude:
The amplitude indicates the strength of the waves. The amplitude of our signal will be related to the movement of the earth. Maximum amplitude is when the earth's distance displaced by an earthquake is high.

Frequency:
The frequency comes from the fact that the system oscillates due to the spring and is dampened using the dampening solution. The dampening filters high frequencies out of the movement of the arm. The resonance of the signal is between 15 and 30 seconds. This is a very low frequency signal. This is obtained using a spring that has a small spring constant, thus, further filtering out high frequency "noise". Noise is any waves outside the target frequency.

Movement of current through wire coil around magnet



[7]

We are using a cylindrical shaped magnet that can be purchased from Home Depot for $2.45. One wire coil can be purchased from Radio Shack for $1.36. The magnet is attached near the end of the pendulum using PVC glue. (See 10.1) The wire coil is glued to a rectangular piece of acrylic that is attached to the frame. The magnet moves vertically through the coil generating current that is sent to the electronics.

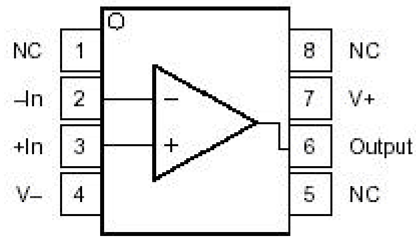
Electronics

Originally we were not going to research the electronics, we were going to simply use the option stated in our original letter from the client. However, a little research sparked an interest, and we were able to save money for the project. The function of the electronics in the overall system is very major as it is to take the signal and allow it to be read by a computer in a low level computer language and turned, using a high level computer language, into a signal that will contain information for the computer user to determine the magnitude of movement in the earth's crust.

In doing research for this system, I have found that there will be several components that will comprise the entire electronics subsystem. These components include an amplifier, an AD converter, and connections for both the computer and the sensor. While I have checked many different places for these products, I have found that the least expensive is through a catalog called Newark electronics. They offer several amplifiers for less than $20, several AD converters for less than $10, and a serial port connection for less than $10. These are the maximum prices for these components. This will drop the cost of this subsystem significantly and will free up some money for the other subsystems if necessary. The construction of the components will be very simple, all it will take is wiring. This is due to the fact that the amplifier has been built and so has the converter, it is simply about picking the right ones out. Some safety precautions will be to not touch any of the live wires, to wear safety goggles if soldering is involved, and to keep the wires insulated in the final product. The wires must be insulated because this will be in a classroom atmosphere where small children may have the ability to come in contact with this equipment, and even though this will not be a high voltage unit, it could still do damage. It is important to talk about each of these components and what the significance of them to the overall subsystem, and in the entire project.

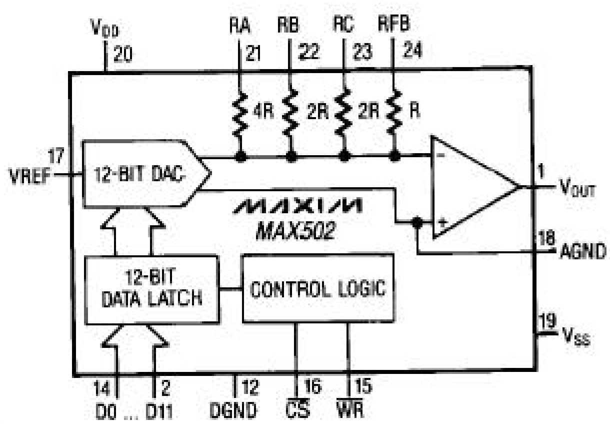
I will start from where the signal is developed and work through the entire subsystem. I will try to explain, as best I can, the physical aspects of each component. We have decided that, with the sensor we are using, the easiest connection between that system and the electronics is simply with a small gauge copper wire. This is true because the only way to get a significant signal out of the sensor is to use small gauge wire and have a coil with as many loops in as little space as possible. This wire will be a copper and will connect to the amplifier in two places. The amplifier will be an operational amplifier (see figure 1) with a gain of 100. This means that whatever signal comes in, it will be amplified 100 times.

operational amplifier



The signal we will be working with will be in the millivolt range, and we will want to convert that to a range of 1-5 volts. The signal coming in will also be that which is proportional to the velocity of the magnet in the coil. We want it proportional to the displacement of the magnet. This will give us a direct correlation between the movement of the earth and the voltage out of the amplifier. Therefore, we must us an amplifier that has an integrator. An integrator is an amplifier that integrates the signal, in our case one that is proportional to velocity, and integrates it to a signal proportional to displacement. This is done using a capacitor in the feedback of the signal inside the amplifier. From the amplifier, we have to change this new signal into something that the computer can read. This is done using the analogue to digital converter (see figure 2). An AD converter takes an analogue signal containing sines and cosines and samples it. It then converts the signal to a digital signal (0's and 1's). This digital signal can then be read by the computer and regenerated using the sampled points.

A-D converter



There are a couple of different choices for this converter that we could use. We could use a 10-bit converter or a 12-bit converter. This means simply what kind of resolution do you need. A sample of the signal is taken and it is changed into a binary representation, and the extent of the value taken from the signal is dependent on the bits in the converter. A 12 bit converter has a resolution of 2^12-1, which is 4095. This means that if we have a signal with a range of 1-5 volts we will have an accuracy of 2.5 -12.2 millivolts, which is very accurate! Finally the connection to the computer is the final step of our project. I will use the serial port to go from the AD converter into the computer. I think that this is a more widely used method and will be more compatible with any computer

By researching the electronics as a subsystem of our seismometer, we were able to cut total costs to build our unit.

Conclusion

Thank you for the opportunity to work with you. We appreciate all of your time and effort on our behalf in order to give us this opportunity. Thank you for taking time out of your schedule in order to view our project. If you have any questions or comments, please contact Mitchell Farnik at 303-215-6318 or mfarnik@mines.edu. We hope you find our design exceeds your expectations and thanks again.

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