ECE 4901
Fall 2010

Seismic Monitoring of Rivers & Streams

Fall 2010 Final Report

Senior Design Group 142

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Summary:

In this project, Seismic Monitoring of Rivers and Streams, The USGS has identified the need to develop a device which can be placed near rivers to monitor the flow levels of water for flood and agricultural forecasting. USGS expressed their requirement of the data storing device to support future studies: simple and inexpensive, its primary function is the acquisition of data from geophones. Our goal is to generate a solution to obtain data from existing geophone sensors and backup the data into memory. Data is transferrable by communicating through a USB port and storing that data into a portable storage device such as a flash drive. Our device is designed with a programmed microcontroller to accomplish all the anticipative functions. The ultimate goal is to deploy these devices remotely, but for the purposes of the phase one design, attention should focus on the design of a low-cost data acquisition and storage device.

Background:

USGS has focused recently on adapting new communications and sampling methods to develop more efficient methods for collecting and distributing data. The use of seismic monitoring in geological applications is becoming widespread in many research projects. However, measuring the flow of water continuously in streams and rivers is a major unanswered problem. There are some techniques to solve this issue: If starting the data monitoring procedure by using a large number of simple low-priced geophones in various locations; the labor cost is too high to be practical of taking the step; otherwise, if using high-tech advanced geophones, the cost of equipment is unacceptable. The purpose of our project is to enhance the usability of the existing equipment and make it practical to use geophone sensors in fieldwork widely.

Theory:

The geophone sensor collects data from the surface wave, which concentrates most energy at a relative low frequency range. As a result we will use a low pass filter to get useful information by converting the signal from analog to digital and then amplifying it. Our project links tightly to signal processing and microcontroller. The relative theories that will be used in our project are signal sampling, filtering and amplifying, analog-digital converting, serial connections and some basic concepts of microcontroller.

Approach:

First of all, we will find a way to collect data. The amplitude of the seismic wave obtained by geophone sensor is too small to be processed by further procedures; therefore, we need to build a preamplifier to magnify the signal. Then, the signal needs to be passed through a filter to obtain the useful bandwidth. Next, the signal will be converted to a digital signal by ADC calculated and saved by microcontroller. Secondly, we will make the data transferrable through a USB interface. The most important thing is to set up the USART communication method to transfer data from memory to a flash drive; and because both steps require the microcontroller to perform certain functions, programing is an essential factor in our project.

Phases:

We divide our project into three phases. First phase is the most crucial phase. The main objective of it is to develop an inexpensive data acquisition-storage device which incorporates the use of an existing geophone. The second phase is an improvement of the first phase. If possible, we plan to involve developing a sustainable energy power source (solar energy) for the device. Clean energy can reduce use of battery and maintain cost and protect environment at the same time. The third phase is a further exploration of our design. We will try to create a method to access stored data remotely via satellite or using mobile devices.

Milestones:

- Research and Measurement
- Building Hardware Circuit
- Software Programming
- Testing and Debugging

Experimental Setup:

To determine that the geophone was working accordingly, we created a controlled scenario where we were able to produce a desired frequency in which we tested if the geophone would detect and indicate that exact frequency (or relatively close to it) onto the oscilloscope. By attaching a speaker (sub-woofer) unto a plastic container filled with water, we placed the geophone first into a paper cup full of gravel to stabilize its movement, and then placed it into the water-filled container. By attaching both the geophone and speaker to their own separate oscilloscope, we were able to carefully adjust the frequency that was being generated by the speaker and that very same frequency measurement was being produced by the oscilloscope that was connected to the geophone. Data was collected at different frequencies which are displayed below.

Data:

Because of the output of geophone is quite insignificant, the oscilloscope cannot read the exactly frequency of the output signal somehow. Therefore, we derived the frequency directly from the oscilloscope graphs. It is noticeable that the output signal is periodic on the screen. Therefore, we used two time cursors to help us determine the time of one period and derive the frequency from the period. The waveforms below the cutoff frequency are a little ambiguous: there is more than one peak in a period; however we still can affirm a complete cycle by their shapes. For the frequency higher than 10 Hz, the waveform of a whole period is clear to tell. This situation could be caused by the range cutoff frequency.

In the following graphs, all the speaker frequency equals to the corresponding geophone output frequency. Note that at certain frequencies, the geophone was able to accurately calculate and read the exact frequencies at the bottom right of geophone reading screen. However, at the frequencies range lower than 12 Hz, the oscilloscope cannot calculate the correct signal frequency which could also be expected due to the fact that the specific geophone of use has a cutoff frequency of about 10 Hz. The amplitude of the geophone's output is not high enough for the oscilloscope to get the correct value. Figure 4, figure 5 and figure 6 are showing that the oscilloscope got the correct frequency while their signals have amplitude around 20 mV. The amplitude of the output signal from the function generator also can affect the geophone's output amplitude. We also repeated the experiment for several times to determine the relationship between the geophone's frequency and output voltage. The output amplitude of function generator is 200 mV. As we can see from figure 7, the amplitude is quite low below 10 Hz, and there are jumps at certain frequency which we think are errors caused by our equipment. We added a three order correlation trend line to our result which has a similar trend to the geophones frequency response diagram.

Speaker Frequency #1 **Geophone Reading #1**

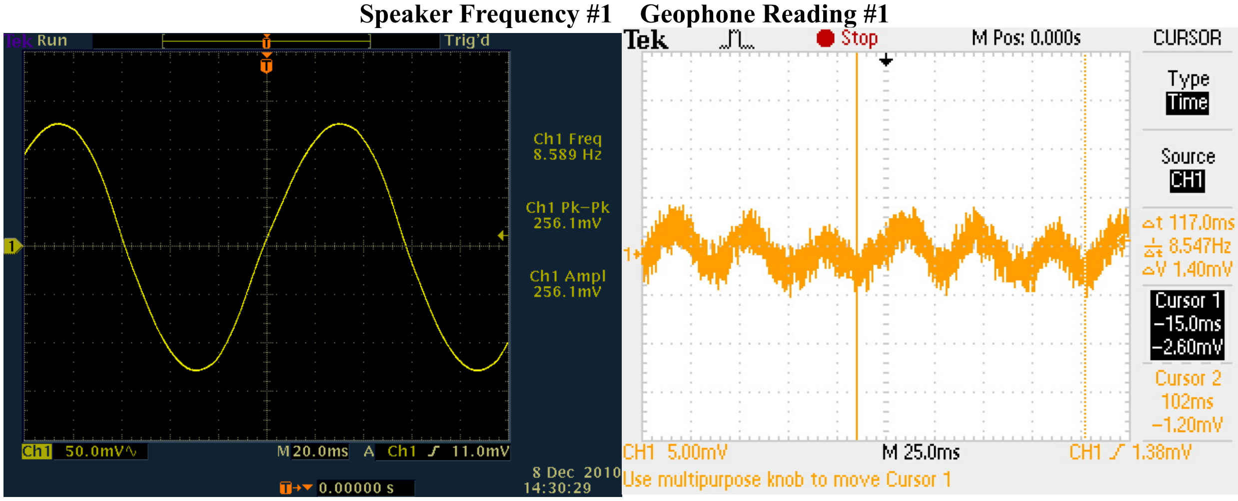


Figure 1: Frequency set ≈ 8.5 Hz

Speaker Frequency #2 **Geophone Reading #2**

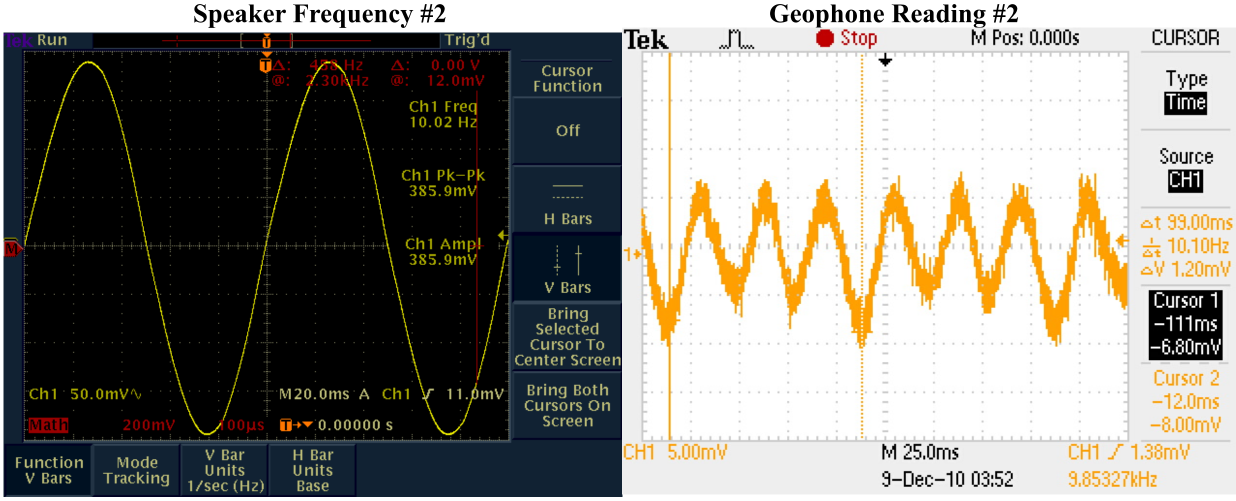


Figure 2: Frequency set ≈ 10 Hz

Speaker Frequency #3 Geophone Reading #3

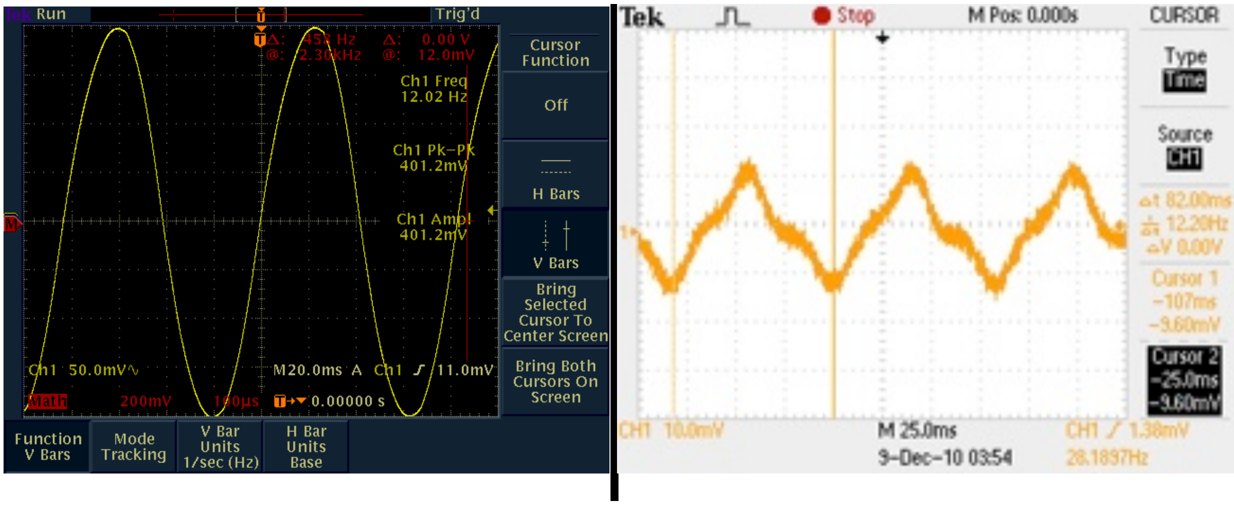


Figure 3: Frequency set ≈ 12 Hz

Speaker Frequency #4 Geophone Reading #4

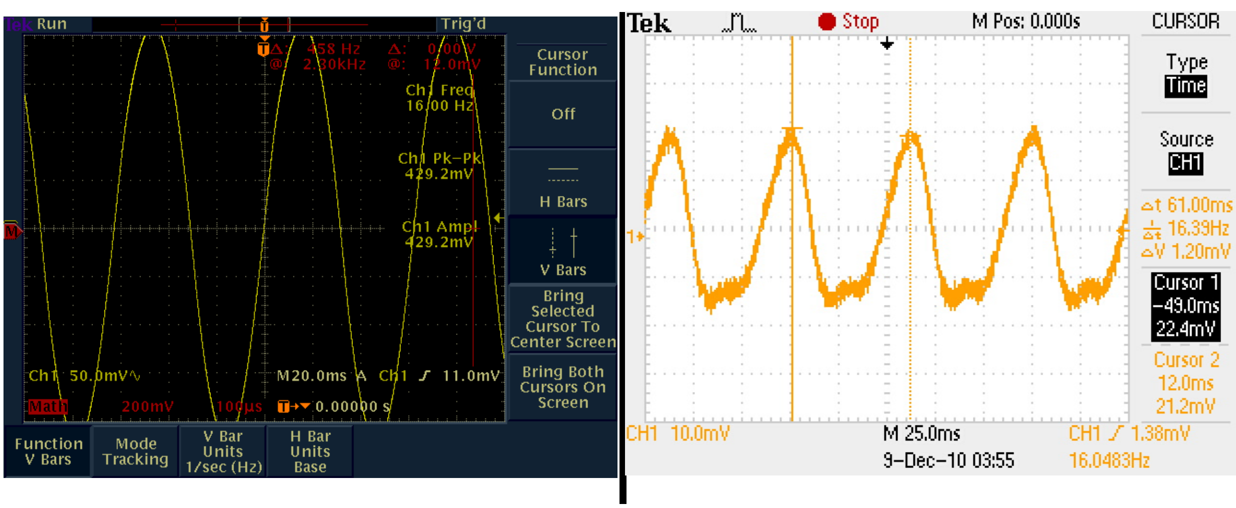


Figure 4: Frequency set ≈ 16 Hz

Speaker Frequency #5 Geophone Reading #5

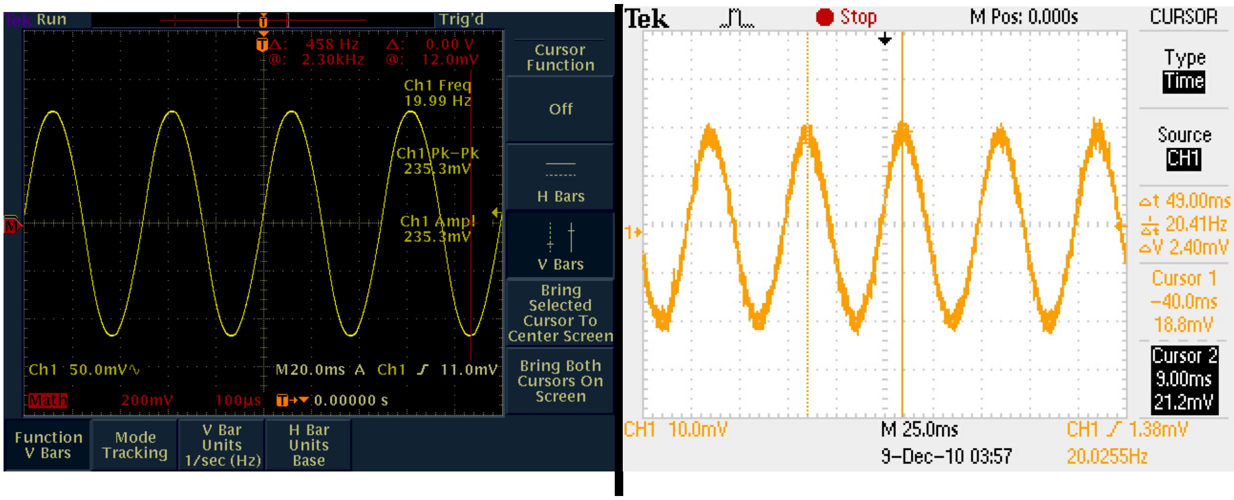


Figure 5: Frequency set ≈ 20 Hz

Speaker Frequency #6 Geophone Reading #6

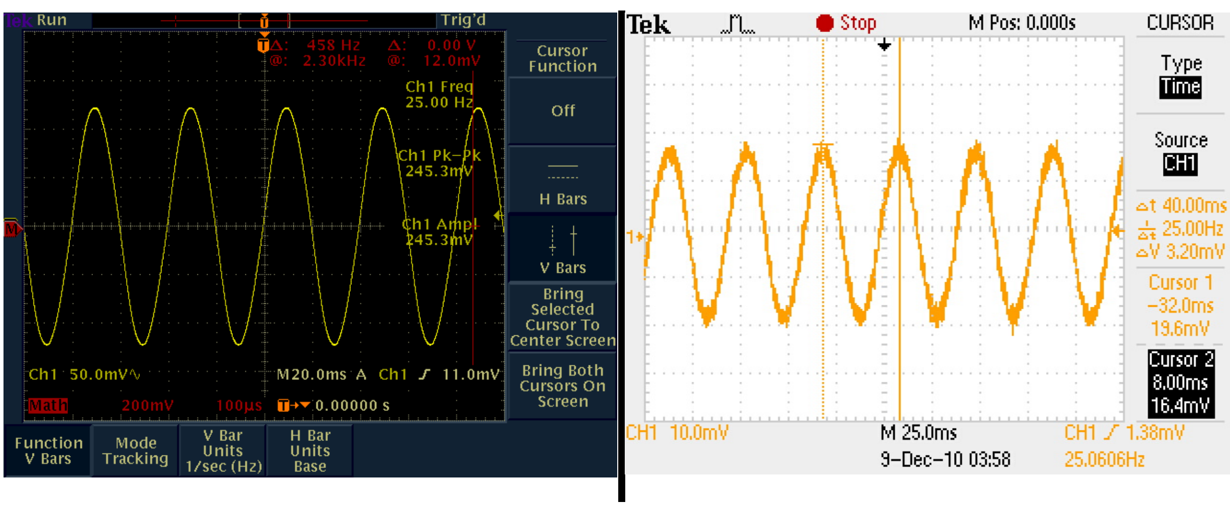


Figure 6: Frequency set ≈ 25 Hz

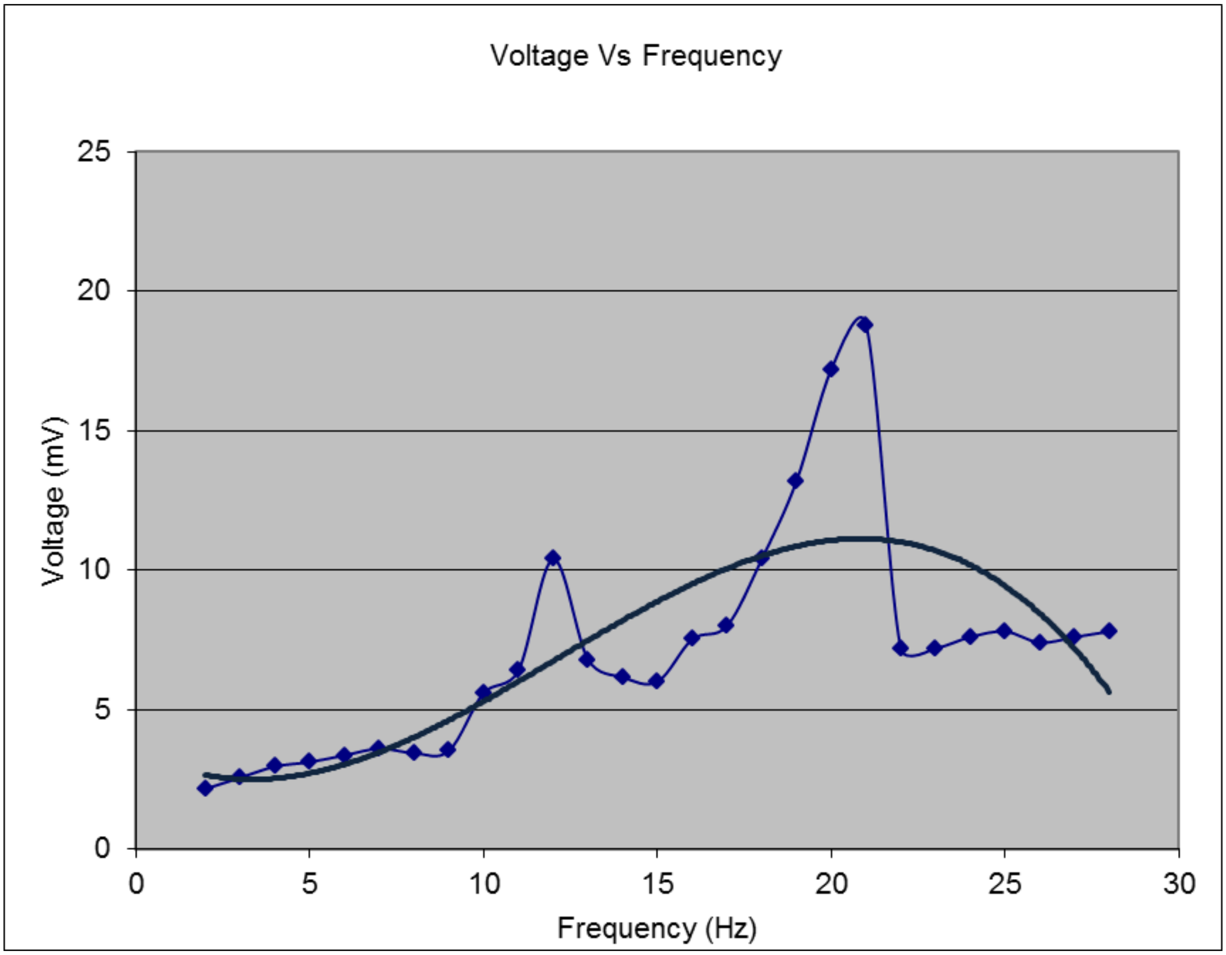


Figure 7: Frequency Vs. Geophone output

Circuit Schematics:

The schematic is designed for three sections. First part is the preamplifier which is set up as a differential amplifier. The component we are choosing is an instrumentation amplifier which provides great accuracy and stability for the circuit. The second part is a 2nd order Butterworth low pass filter. The third part is the connection to the microcontroller.

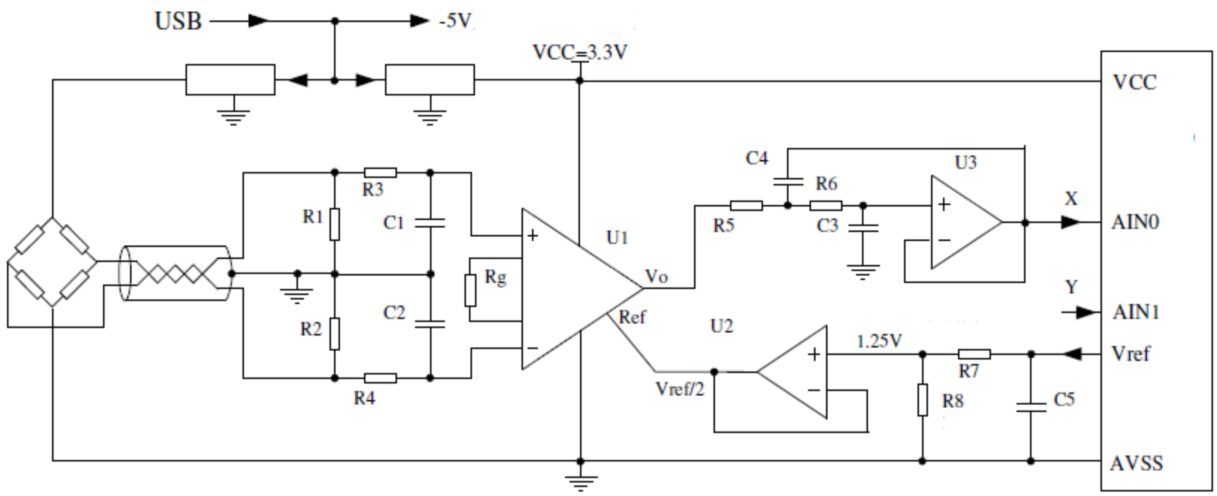


Figure 8: Circuit Schematic

Following is the schematic for USART connection. This is a rough draft of our circuit, further modification might be required. The basic outline of the serial connection is to build a USB port by a bridging chip.

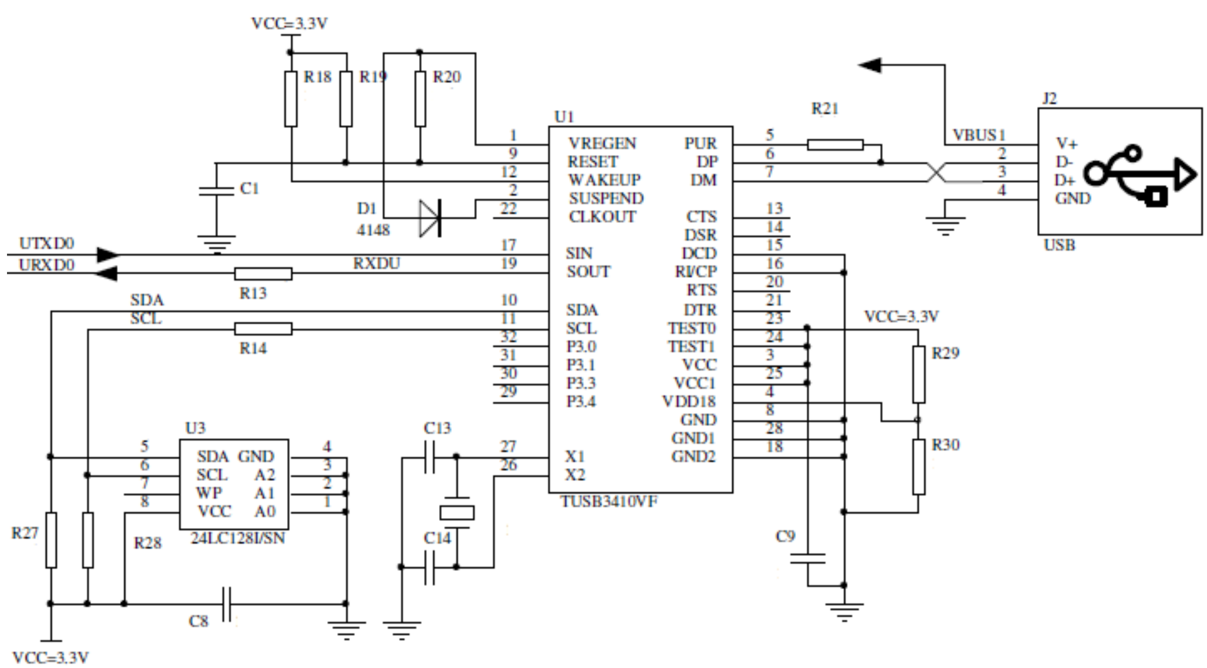


Figure 9: Serial Communications Schematic

Specifications:

Electrical Parameters	
Battery Life	Last at least one month
Operating Voltage Levels	5V or less
Current Capabilities	N/A
Input and Output Impedances	N/A
Gains	N/A
Input/output Power	Low power
Power Consumption	Minimum power consumption
Precision	±5%
Mechanical Parameters	
Size	4×8×2 in
Weight	0.5-1.5 lb.
Durability	Resilience to harsh natural conditions
Environmental Parameters	
Weatherproof	Yes

Table 1: Specification

Alternative Testing Setups

The initial step of our project was to verify the proper working of the geophone. To do this we setup many different methods, but eventually only one of the setups was able to give us a conclusive result. Many of the experimental setups we designed or thought of are listed below.

1. Linear motion via an electric car

   In this experiment we placed one of the geophones on top of an electric car and ran the car via remote control over a specified distance. We measured the distance covered over time (with stopwatch) and obtained readings on an oscilloscope which was attached to the geophone with wires. This gave us an undesirable result because the wires were very long and exhibiting drag on the car. Also the length of the wires was allowing for electric noise as well as some other radio signals to be picked up which were distorting the reading on the oscilloscope.

2. Using an electric motor to create desired frequency

   In this testing method we thought of using a motor with propellers which would be submerged in a tank of water containing the geophone. The motor would be powered with a signal generator and thus create a steady frequency flow in the water which would be picked up by the geophone and displayed on an oscilloscope. We decided this method would not work because the working of the motor would be unreliable with the fact that there could be slipping as well as finding a motor which could generate the desired range of frequency would be difficult to find. Another fact would be that we would lose a lot of accuracy because of friction between the propellers and the water since we are using a very low range of frequencies.

3. Using an actuator to produce a constant frequency

   An actuator typically is a mechanical device that takes energy, usually created by air, electricity, or liquid, and converts that into some kind of motion. That motion can be anything from blocking to clamping to ejecting. We were going to use the actuator to create a frequency by letting its needle strike a tank of water containing the geophone at a constant rate. This method was not used because of mainly lack of knowledge on detail working of an actuator as well as how it would be linked to the signal generator. Also we explained this method to our professors who explained that most mechanical methods of creating frequency this way would contain many errors.

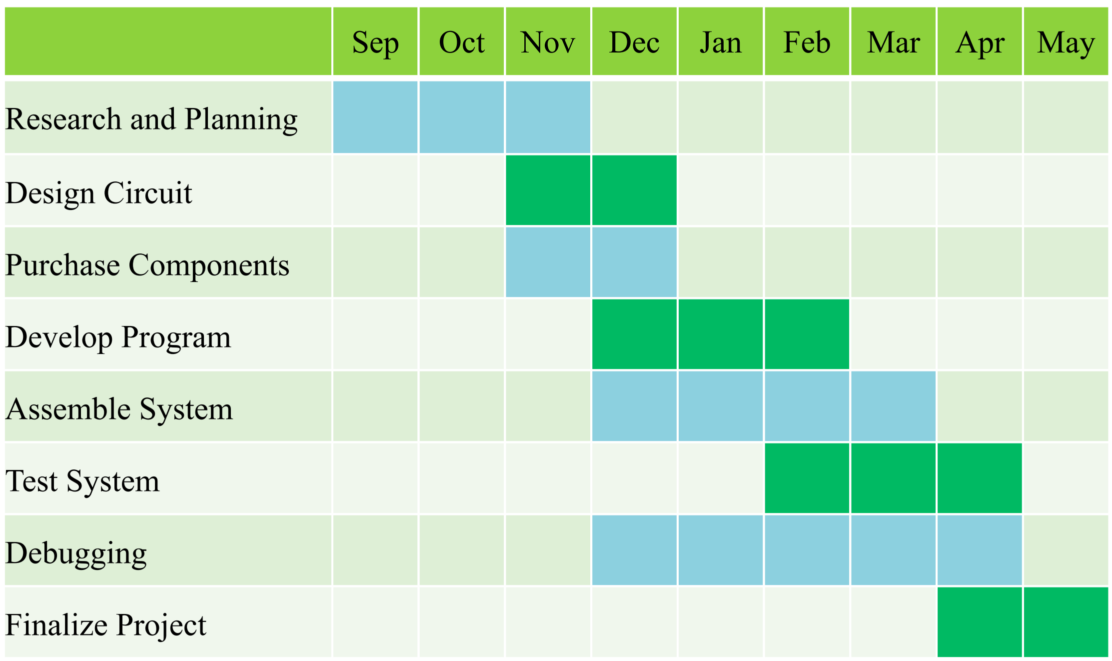
4. Using a diaphragm to transmit the signal from a speaker

   In this method we were going to use a speaker and attach it to a diaphragm which would than me immersed in the water and act as a transmission line for the frequency. We decided that we would lose some frequency or it might get absorbed in the diaphragm, so we decided against this method.

Results and Discussions:

The controlled experiment proved to be a success. The geophone was working accordingly, despite previous assumptions that it may have been damaged. Phase 1 of our project is well underway and we are right on schedule according to our project timeline. Other ideas we intended on using that either failed or were not necessary helped us to learn the problems we may encounter in our setup in the future.

Project Timeline:



Budget:

- Test equipment $100
- Microcontroller $50
- Instrumental Amplifier $50
- USB interface $5
- Programming interface $150
- Board fabrication $200-$300
- Portable power source $100
- Other components $100

Appendix

Data for each figure is attached electronically attached to the report.

- Table 1 includes the data for figure 1
- Table 2 includes the data for figure 2
- Table 3 includes the data for figure 3
- Table 4 includes the data for figure 4
- Table 5 includes the data for figure 5
- Table 6 includes the data for figure 6
- Table 7 includes the data for figure 7