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EECE 404 Senior Design II

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Team Graphone

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Summary

The condenser microphone is a device that converts sound waves into electrical signal. The way this is achieved is using capacitance between a backplate and a diaphragm when the diaphragm oscillates due to sound waves. However, the signal that is created is very miniscule, hence requiring the help of a preamplifier to convert it to a usable form. To power the preamplifier, an external voltage source is needed. It is noted that a condenser microphone generally offers a better sound quality than a dynamic microphone due to its lower mass diaphragm. In addition, condenser microphones have a wider range of frequency, a lower noise ratio, and a higher sensitivity. The “graphone” is an alternative design of a condenser microphone that uses graphene for its diaphragm. Due to its nature, graphene offers a more flexible component which can withstand more intense sound waves without tearing. As such, “graphone” can offer a smaller microphone but with the same sensitivity. A custom PCB is required to establish the foundation of the device and connect it to a preamplifier for use in other applications. Our project focuses on applications in audio signal location, utilizing the graphone to determine the location of an audio source through the rotation of a Servo motor.

Problem Statement

Today's microphones are limited in their material designs. Graphone provides a robust design that can tolerate sound waves more than its standard microphone counterpart. Graphene bolstered by polymer provides a flexible component that provides more elasticity as a diaphragm. In addition, the graphone is generally much smaller but still provides the same sensitivity. The project aims to enable the benefit of graphene-based microphone to be realized on a circuit board, and can be applied to audio signal location with comparison to the conventional electret counterpart. Our 2018-2019 year goal consisted of the construction of circuits used to implement the graphene microphone for use in audio signal location. Our long term goal is to integrate the graphone into the previously developed audio signal location circuit.

Design Requirements

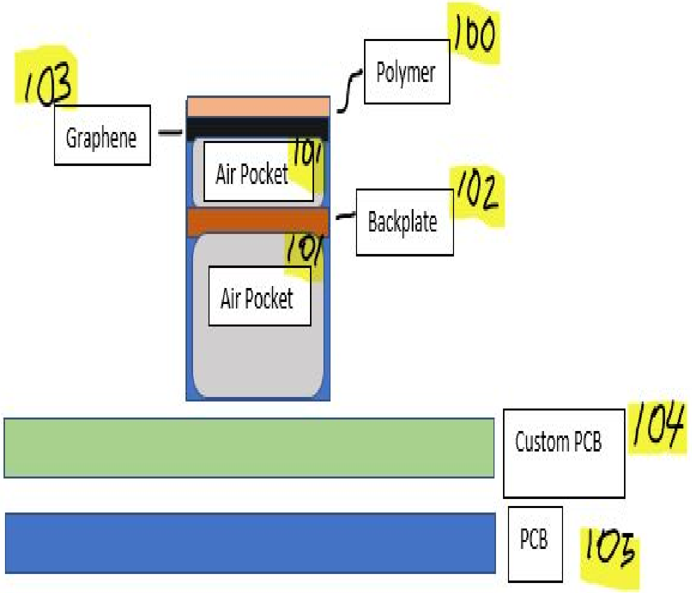
Performance: Graphene diaphragm must be more flexible and prone to sound waves

Specifications: The operating frequency is defined to be 100 Hz - 20 kHz. The typical operating voltage must be 2 V (DC). The max operating voltage must be 10 V (DC). The Max System Response Time must be 1 s. The minimum required Signal-to-Noise Ratio (SNR) must be 56 dBA. The weight requirement will be < .03 g. The cost of the entire system, including the MSP432 Arduino microcontroller, should be no more than $30.

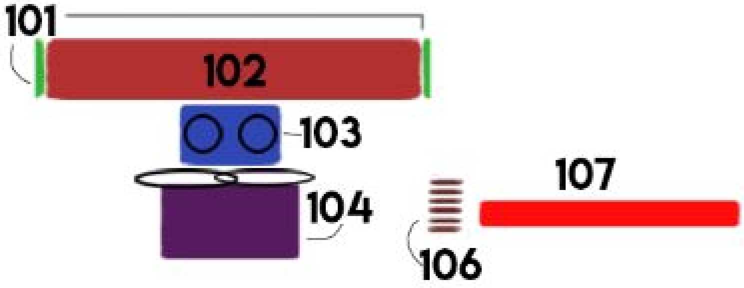
Constraints: Some studies suggest graphene particles may create respiratory inflammation (**environmental**). The graphone must comply to all FCC standards pertaining to microphones and applications. Spectrum interference must be considered with wireless service and broadcast TV applications. The available bands for unlicensed wireless microphones is 902-928 MHz, 1920-1930 MHz, 2.4 GHz. Some **economic** constraints are that graphene is more expensive to harvest and produce than counterparts. What must also be considered is the **ethical/legal** rules against recording using a microphone without consent. The **physical** constraints are comprised of powering the microphone and maintaining the functionality on a sub-nanoscale.

Interface: Graphone, Servo motor, and ultrasonic sensor must be connected through ADC GPIO pins on the MSP432 Arduino. A connection through the serial port must be established to validate data near real time. The Arduino must convert electrical signal into 10 bit ADC binary value.

Solution Design

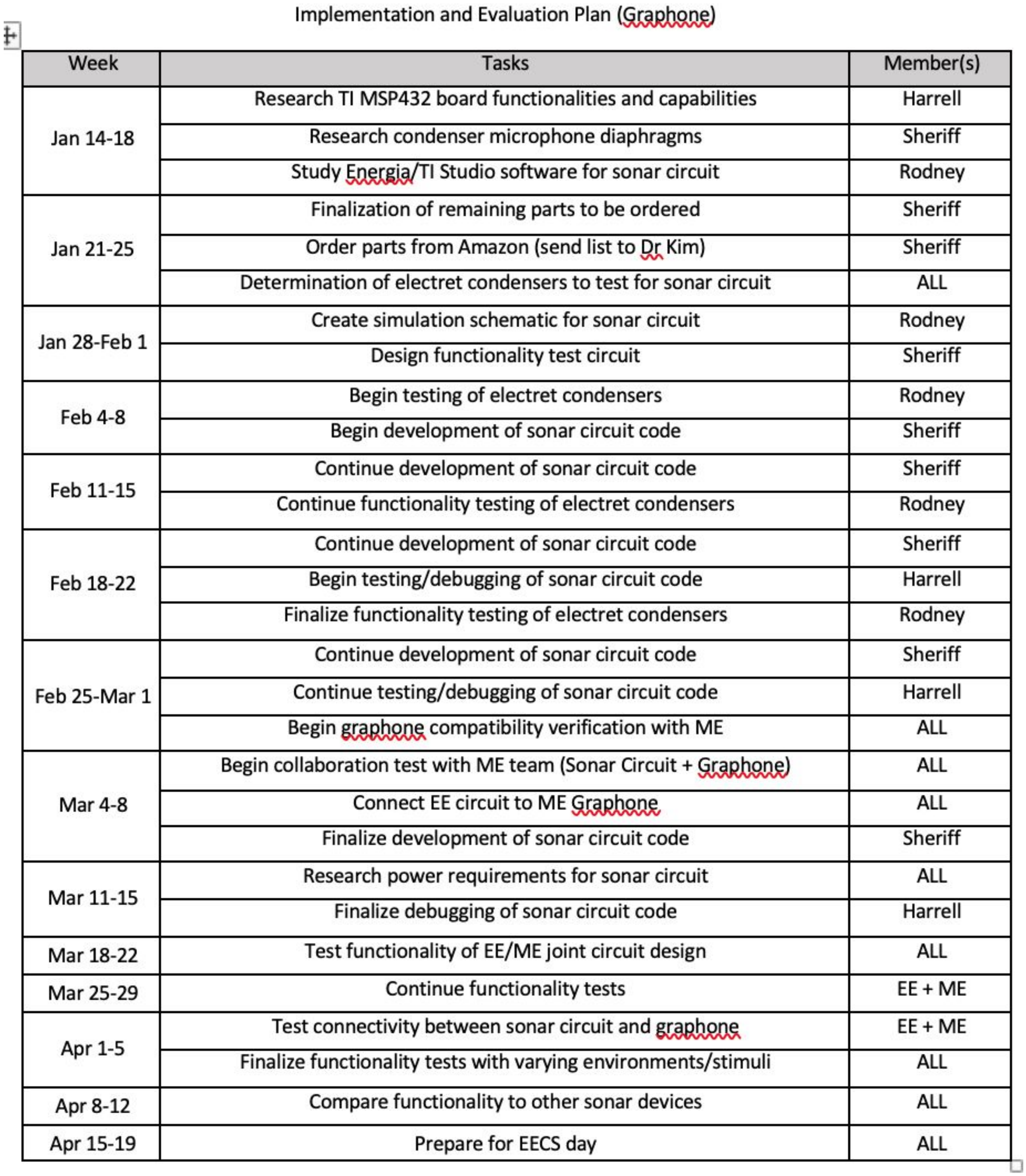


The diaphragm consists of a one-part polymer sheet **100** and one-part sheet of graphene **103**. The graphene provides a robust diaphragm that is more flexible than a standard diaphragm. The polymer provides further elasticity and durability to the graphene sheet. The backplate **102** is stationed to realize the capacitance. The spacing between the backplate and diaphragm is carefully measured in relation to commercially available condenser microphones. Furthermore, the air pocket **101** provides the final component for solving capacitance with the permittivity of 8.85×10^{12} . The custom PCB **104** is the bridge between the microphone itself and the PCB **105**. The PCB includes both the preamplifier and capacitance/voltage measurements.



101 Graphene based microphones with graphene as the diaphragm. **102** A platform to attach the microphone array; one microphone is facing the left and one facing the right. **103** Ultrasonic sound sensor that is attached on top of the servo motor and below the microphone platform; this will determine the distance of the object creating the sound. **104** A single servo motor that rotates the top platform according to the “difference” factor in the Energia software. **106** Wiring that connects the sensors to the MSP432 controller. **107** MSP432 controller is designated as the brain and bridge for the ADC input into the Energia software.

Project Implementation Plan

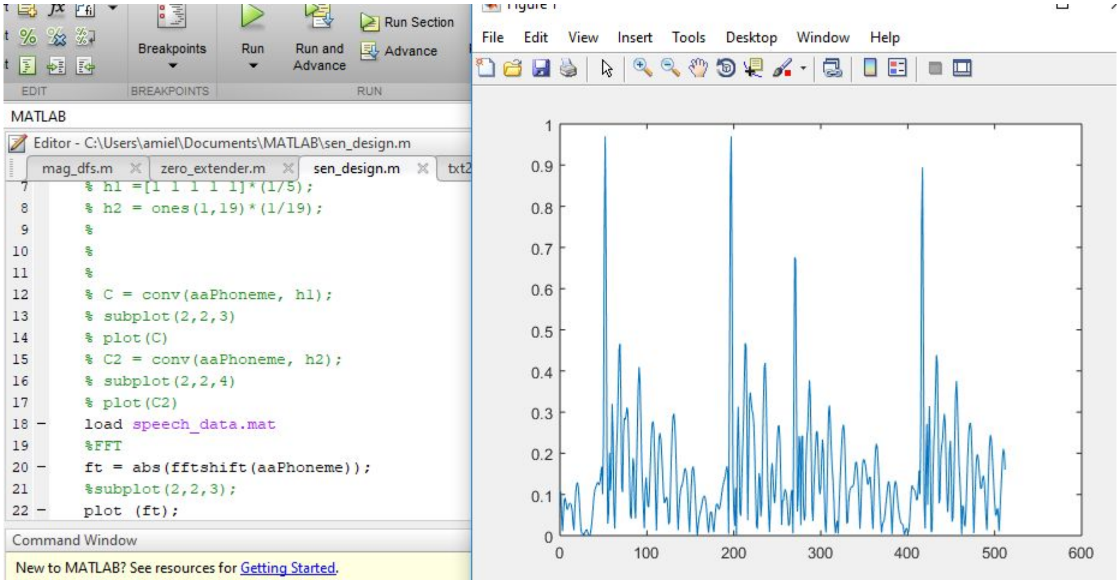


Implementation and Evaluation Plan (Graphone)

Week	Tasks	Member(s)
Jan 14-18	Research TI MSP432 board functionalities and capabilities	Harrell
	Research condenser microphone diaphragms	Sheriff
	Study Energia/TI Studio software for sonar circuit	Rodney
Jan 21-25	Finalization of remaining parts to be ordered	Sheriff
	Order parts from Amazon (send list to Dr Kim)	Sheriff
	Determination of electret condensers to test for sonar circuit	ALL
Jan 28-Feb 1	Create simulation schematic for sonar circuit	Rodney
	Design functionality test circuit	Sheriff
Feb 4-8	Begin testing of electret condensers	Rodney
	Begin development of sonar circuit code	Sheriff
Feb 11-15	Continue development of sonar circuit code	Sheriff
	Continue functionality testing of electret condensers	Rodney
Feb 18-22	Continue development of sonar circuit code	Sheriff
	Begin testing/debugging of sonar circuit code	Harrell
	Finalize functionality testing of electret condensers	Rodney
Feb 25-Mar 1	Continue development of sonar circuit code	Sheriff
	Continue testing/debugging of sonar circuit code	Harrell
	Begin graphone compatibility verification with ME	ALL
Mar 4-8	Begin collaboration test with ME team (Sonar Circuit + Graphone)	ALL
	Connect EE circuit to ME Graphone	ALL
	Finalize development of sonar circuit code	Sheriff
Mar 11-15	Research power requirements for sonar circuit	ALL
	Finalize debugging of sonar circuit code	Harrell
Mar 18-22	Test functionality of EE/ME joint circuit design	ALL
Mar 25-29	Continue functionality tests	EE + ME
Apr 1-5	Test connectivity between sonar circuit and graphone	EE + ME
	Finalize functionality tests with varying environments/stimuli	ALL
Apr 8-12	Compare functionality to other sonar devices	ALL
Apr 15-19	Prepare for EECS day	ALL

Project Implementation Process

Our goal is to distinguish where the sound is coming from. Upon research, one of the first thing we read is development of anechoic chambers for the sound sensor to reduce noise. However, upon implementation, we experienced higher sporadic behavior, hence dismissing the idea. Another idea we took keen of is using a whistle to remove noise completely by only focusing on a higher frequency sound source (whistle). In order to accomplish this, we tested a fast fourier transform (FFT) system in Matlab. As a test, we created a text file with data in the time domain as it would be captured in Energia. Afterwards, we transformed the signals into a matrix to be used in Matlab. Then, we used FFT to convert the data in to the frequency domain. However, along the way we realized it is not particularly useful to record data from Energia, transfer it into Matlab, then transfer it back into Energia to control the servo motor. As a result, we moved away from this idea.



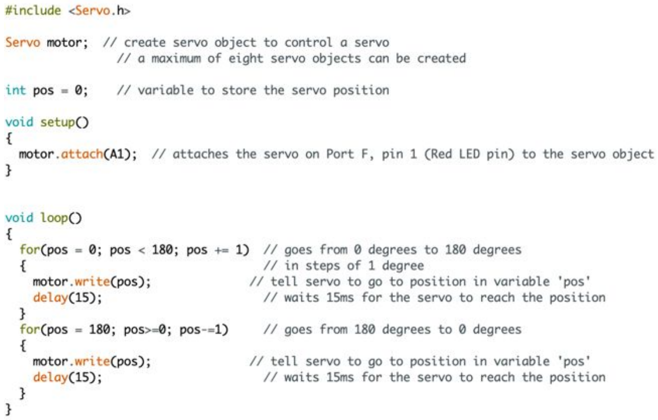
```
% h1 =[1 1 1 1 1]*(1/5);
% h2 = ones(1,19)*(1/19);
%
%
%
% C = conv(aaPhoneme, h1);
% subplot(2,2,3)
% plot(C)
% C2 = conv(aaPhoneme, h2);
% subplot(2,2,4)
% plot(C2)
load speech_data.mat
%FFT
ft = abs(fftshift(aaPhoneme));
%subplot(2,2,3);
plot (ft);
```

New to MATLAB? See resources for Getting Started.

The figure depicts a graph of a transformed signal into the frequency domain

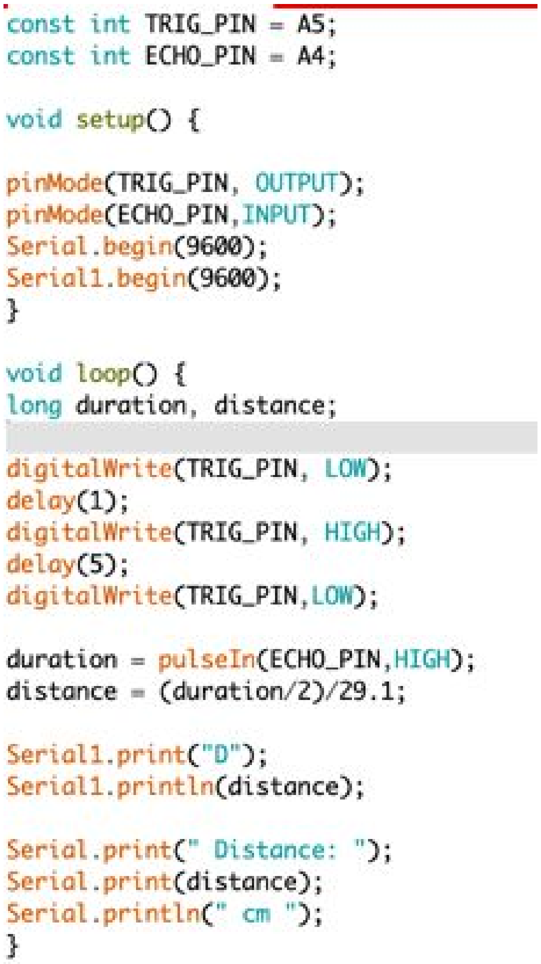
For our final implementation, we decided to create a difference algorithm between the two different microphones facing opposite sides. The microphone receiving the greater average signal over a specified sample amount will control the servo motor and move it either left or right. Since the environment varies in difference, we had to implement a threshold to eliminate possible noises that would interfere with the performance of the overall system.

Servo



```
#include <Servo.h>

Servo motor;  // create servo object to control a servo
                // a maximum of eight servo objects can be created

int pos = 0;    // variable to store the servo position

void setup()
{
  motor.attach(A1);  // attaches the servo on Port F, pin 1 (Red LED pin) to the servo object
}


void loop()
{
  for(pos = 0; pos < 180; pos += 1)  // goes from 0 degrees to 180 degrees
  {                                  // in steps of 1 degree
    motor.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
  for(pos = 180; pos>=0; pos-=1)     // goes from 180 degrees to 0 degrees
  {
    motor.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
}
```

Ultrasonic



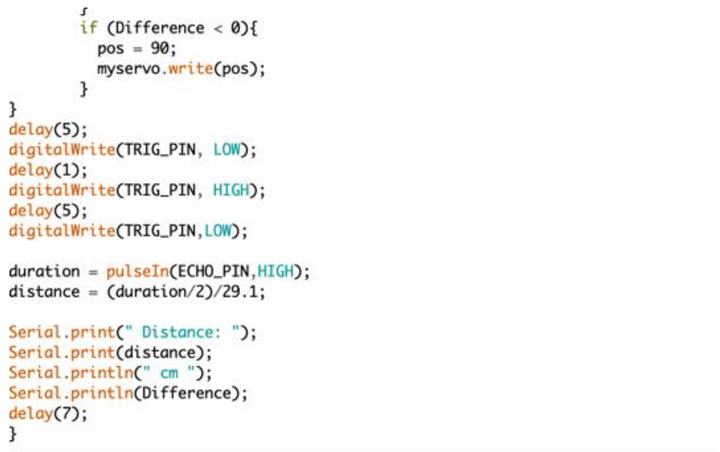
```
const int TRIG_PIN = A5;
const int ECHO_PIN = A4;

void setup() {

pinMode(TRIG_PIN, OUTPUT);
pinMode(ECHO_PIN,INPUT);
Serial.begin(9600);
Serial1.begin(9600);
}

void loop() {
long duration, distance;

digitalWrite(TRIG_PIN, LOW);
delay(1);
digitalWrite(TRIG_PIN, HIGH);
delay(5);
digitalWrite(TRIG_PIN,LOW);

duration = pulseIn(ECHO_PIN,HIGH);
distance = (duration/2)/29.1;

Serial1.print("D");
Serial1.println(distance);

Serial.print(" Distance: ");
Serial.print(distance);
Serial.println(" cm ");
}
```

Difference

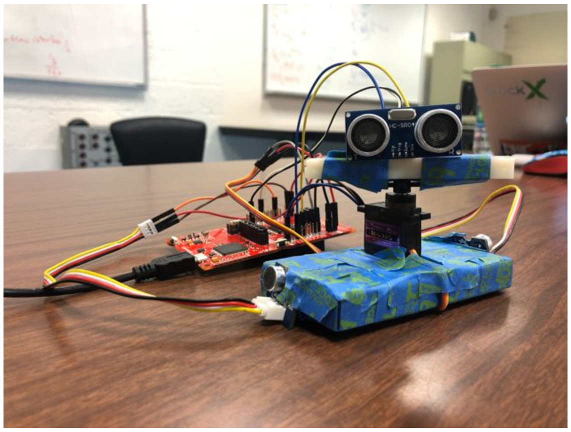
```
#include <Servo.h>
const int pinAdc = A0;
const int pinAdc2 = A3;
Servo myservo;
void setup()
{
    Serial.begin(115200);
    Serial.println("Grove - Sound Sensor Test...");
    myservo.attach(A1);
}
void loop()
{
    long Difference= 0;
    long pos = 90;
    for(int i=0; i<128; i++)
    {
        Difference += analogRead(pinAdc) - analogRead(pinAdc2);
        delay(10);
    }
    Difference >>= 7;
if (Difference > 20 || Difference < -20) {
        if (Difference > 0){
          pos = 45;
          myservo.write(pos);
        }
        if (Difference < 0){
          pos = 0;
          myservo.write(pos);
        }
}
    Serial.println(Difference);
    delay(10);
```

Integrated

```
#include <Servo.h>
const int pinAdc = A0;
const int pinAdc2 = A3;
const int TRIG_PIN = A11;
const int ECHO_PIN = A9;
Servo myservo;
void setup()
{
    pinMode(TRIG_PIN, OUTPUT);
    pinMode(ECHO_PIN,INPUT);
    Serial.begin(115200);
    Serial.println("Grove - Sound Sensor Test...");
    myservo.attach(A1);
}
void loop()
{
    long duration, distance;
    long Difference= 0;
    long pos = 135;
    for(int i=0; i<128; i++)
    {
        Difference += analogRead(pinAdc) - analogRead(pinAdc2);
        delay(10);
    }
    Difference >>= 7;
if (Difference > 20 || Difference < -20) {
        if (Difference > 0){
          pos = 270;
          myservo.write(pos);

        }
        if (Difference < 0){
```



```
    if (Difference < 0){
      pos = 90;
      myservo.write(pos);
    }
}
delay(5);
digitalWrite(TRIG_PIN, LOW);
delay(1);
digitalWrite(TRIG_PIN, HIGH);
delay(5);
digitalWrite(TRIG_PIN,LOW);

duration = pulseIn(ECHO_PIN,HIGH);
distance = (duration/2)/29.1;

Serial.print(" Distance: ");
Serial.print(distance);
Serial.println(" cm ");
Serial.println(Difference);
delay(7);
}
```



Conclusion

In conclusion, our academic year goal was a success. We were able to develop the sonar circuit that is able to distinguish the location of a sound from left to right. Although the focus of our project shifted in between semesters, we were still able to apply all the principles of our senior design class to our project and complete a deliverable that lined up with our 2018-2019 goal. As we realize the first step in this high potential project, some of the future plans we have for the Graphone project include the integration of the graphene microphone for use in signal audio location, implementation of frequency detection (i.e. human whistle) to aid in audio signal location, increased microphone array size and functionality, and the development of a toy car operated by graphone audio signal location. All of these are future plans are extended applications of our long term goal, which is to realize the implementation of the graphene microphone for audio signal location.

References

1. “An Adaptive Microphone Array Implemented on the Signal Processor TMS 32010.” *IFAC Proceedings Volumes*, Elsevier, 20 June 2017, www.sciencedirect.com/science/article/pii/S1474667017559881
2. Bill. “Grove - Sound Sensor.” *Seeedstudio*, wiki.seeedstudio.com/Grove-Sound_Sensor/.
3. “Experimenting with Sound Localization and Arduino.” *42 Bots Hobby Robotics and Electronics Blog*, 42bots.com/showcase/experimenting-with-sound-localization-and-arduino/
4. “Graphene Electrostatic Microphone and Ultrasonic Radio.” *Graphene Electrostatic Microphone and Ultrasonic Radio | College of Engineering | University of Nebraska–Lincoln*, engineering.unl.edu/graphene-electrostatic-microphone-and-ultrasonic-radio/.
5. “Grove - Sound Sensor User Manual.” *Manualzz.com*, manualzz.com/doc/6962626/grove---sound-sensor-user-manual
6. “Microphone Basics (2).” *Microphone Basics: What's a Condenser Microphone?*, www.neumann.com/homestudio/en/what-is-a-condenser-microphone
7. “X.” *Fast Fourier Transform - MATLAB*, www.mathworks.com/help/matlab/ref/fft.html.
8. “Fast Fourier Transform.” *Fast Fourier Transform - an Overview | ScienceDirect Topics*, www.sciencedirect.com/topics/engineering/fast-fourier-transform