Factors About and a Proposed Method to Harvest Acoustic Energy

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Abstract:

Scientists have tested many different ways to generate electrical energy from other forms of energy, including nuclear, potential, kinetic, solar, and thermal energy. However, acoustic energy has not been as rigorously studied. We are constantly surrounded by sound to the point it may even be considered pollution. There are noises almost everywhere: in karaoke rooms, factories, airports, and highways, to name a few sources. These huge amounts of energy (for example, there is 1 megaWatts amount of power when the sound intensity is 60dB) can be used if we are able to find an effective way to convert acoustic energy to electrical energy, not only to reduce "noise pollution", but also to relieve the energy problem in our world. In this research we propose and partially test a potential method to harvest acoustic energy. A speaker/microphone can be used to convert pressure into electrical signals. The efficiency and cost of the system will be evaluated. In addition, future work could use resonance to create a vibration in a small piece of metal and induce electricity using a changing magnetic field. Throughout the research, it is found the proposed diode-capacitor rectifier could convert an AC input (representing an acoustic input) to a DC output (usable electrical energy). These results show a way to generate electricity from noise. Moreover, the proposed device could be used to measure or monitor the intensities of sounds using an LED as an power threshold indicator. Using resonance, which is highly frequency selective, frequency measurements could be obtained of various acoustic sources.

Introduction

Finding ways to generate energy has been an enduring issue throughout human history. From burning fossil fuels to utilizing solar energy, the evolution in energy sources influences human development. However, most energy comes at a cost: Burning fossil fuels releases carbon dioxide which adds to the greenhouse effect; solar and wind energy depend on the weather; nuclear fission has the potential to become unmanageable, leading to genetic alterations and even fatalities. It is important to find more efficient and cleaner ways to generate electrical energy, and acoustic energy, which many people have ignored, might be a good option.

Many metropolitan areas, where energy is required for life, have high levels of sound. As a result, finding an efficient way to convert acoustic energy into electrical energy may relieve the global energy crisis. Additionally, this technology can absorb the "annoying" noise and convert it to electrical energy which can be directly used.

Section 1: Definitions and Literature Review:

In order to convert acoustic energy into electrical energy, a microphone/speaker is needed as a transducer; the key difference between a microphone and a speaker is that a speaker converts electrical energy to acoustic energy, requiring some input electrical power, whereas a microphone converts acoustic energy to electrical energy. However, the construction of both devices is very similar. The main physical law governing the conversion of acoustic energy to electrical energy is Faraday's Law [1]: a magnetic field will interact with an electric circuit to produce an electromotive force. After collecting the acoustic energy, a transformer can be used to amplify either the current or voltage harvested from the acoustic input. A transformer can increase the voltage if it has more turns of wires on the secondary winding. Another technique to convert acoustic to electrical energy is to use resonance. To convert the AC output from the transformer to a DC value, which can be stored on a capacitor, a Schottky diode [2] is used. Additionally, a Schottky diode does not consume much power from the circuit so there will be enough voltage and energy across the capacitor.

To further increase the gain of the harvester (at the cost of acoustic bandwidth) resonance can be used. Resonance is the phenomenon of increased amplitude that occurs when the frequency of an applied periodic force/signal is equal or close to a natural frequency of the system on which it acts. Research has already identified the two main methods of converting acoustic energy to electrical energy. The first method uses piezoelectric materials to generate electricity. The amount of electrical energy that can be harvested is directly affected by the volume of the substance and the density of it.[3] All previous design on piezoelectric materials can output 30,000 uHz power at maximum, which is still a small number. Another method will use a Helmholtz resonator to harvest acoustic energy. Previous experiment found that the coil produces more power at 98 Hz when Sound Pressure Level (SPL) is less than 105 dB, but it outputs more power at 140 Hz when SPL is larger than 105 dB.[4]

Section 2: Overview/Methodology

The proposed harvester will use a microphone, a power transformer, wires, LED (as an indicator), a multimeter, a Schottky diode and a capacitor to create a method of converting acoustic energy into electrical energy. The output voltage of this harvester at different frequencies is investigated.

The microphone collects acoustic energy from the environment. A transformer with a high turn ratio is used to connect 2 circuits together and amplify the voltage output from the microphone. A Schottky diode limits current flow to one direction, acting as a rectifier. The capacitor serves to store the electrical energy harvested by the microphone. The multimeter is used to measure the amount of voltage and current in different components of the circuit. The breadboard connects the wires and components together. Finally, if desired, an LED can be used to indicate whether the capacitor voltage exceeds a certain threshold.

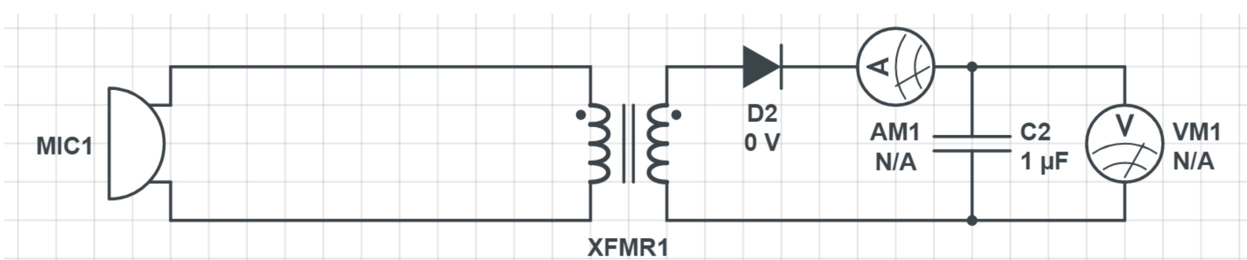
To test the system, a computer speaker will be used as a sound source and it can provide sound in the same frequency range, which keeps one variable fixed.

Table of components and proposed Schematic:

Table 1: Components

Component	Part Number (from digikey)	Unit Price
microphone	931-SPKM.50.8.A-ND	$2.88
LED	1080-1064-ND	$0.36
Power Transformer	237-1577-ND	$5.13
Jumper wires	1568-1511-ND	$2.10
Breadboard	1528-2143-ND	$5.95
Multimeter	1568-TOL-18340-ND	$18.25
Schottky diode	1655-1922-1-ND - Cut Tape (CT)	$0.60
Capacitor	732-8851-1-ND - Cut Tape (CT)	$0.10
Signal generator	1HZ-500KHZ DDS	$29.99

Diagram 1: the Circuit in Stimulation



Section 3: Simulation Results

The harvester was stimulated in Circuitlab [5] and different input voltages were applied to the circuit which correspond to the different amounts of acoustic energy the microphone receives. **For each diagram, the blue curve is the amount of input voltage; the orange one is the**

output voltage from the transformer; the yellow one is the voltage across the capacitor. The actual forward voltage of the Schottky diode used is 350mV. The transformer turns ratio used in simulation matches that of the transformer purchased, which is 1:19.

Diagram 2: (10mV input voltage with 20mV diode forward voltage)

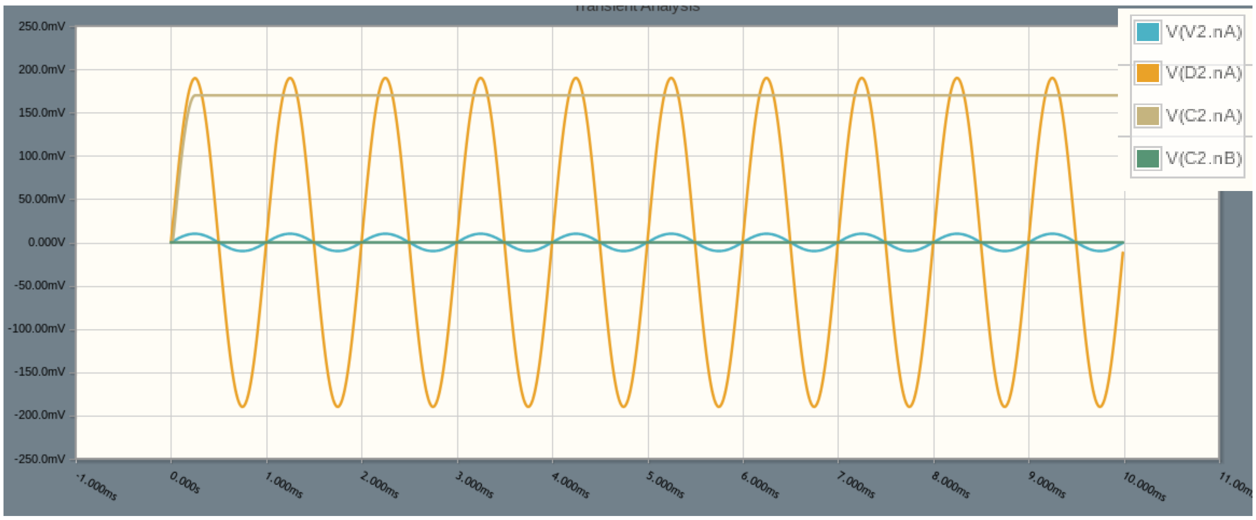


Diagram 3: (1V input voltage with 2V diode forward voltage)

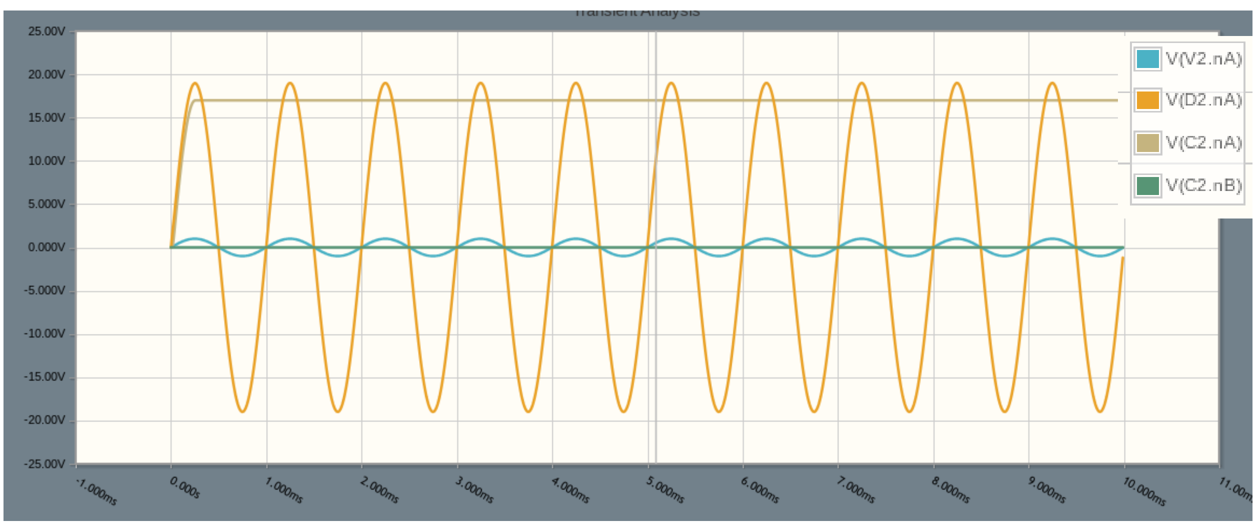
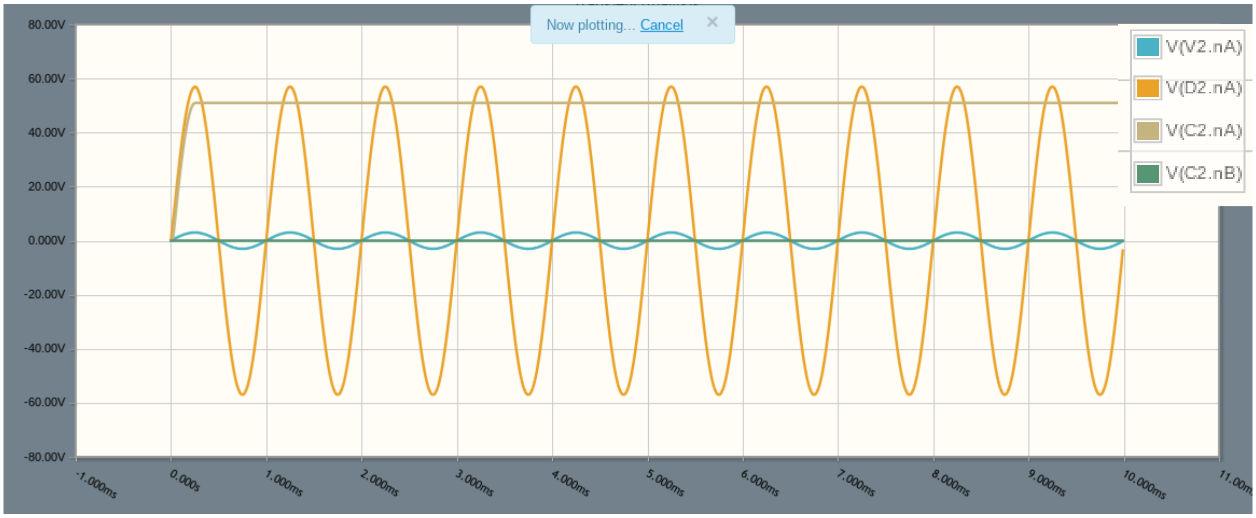
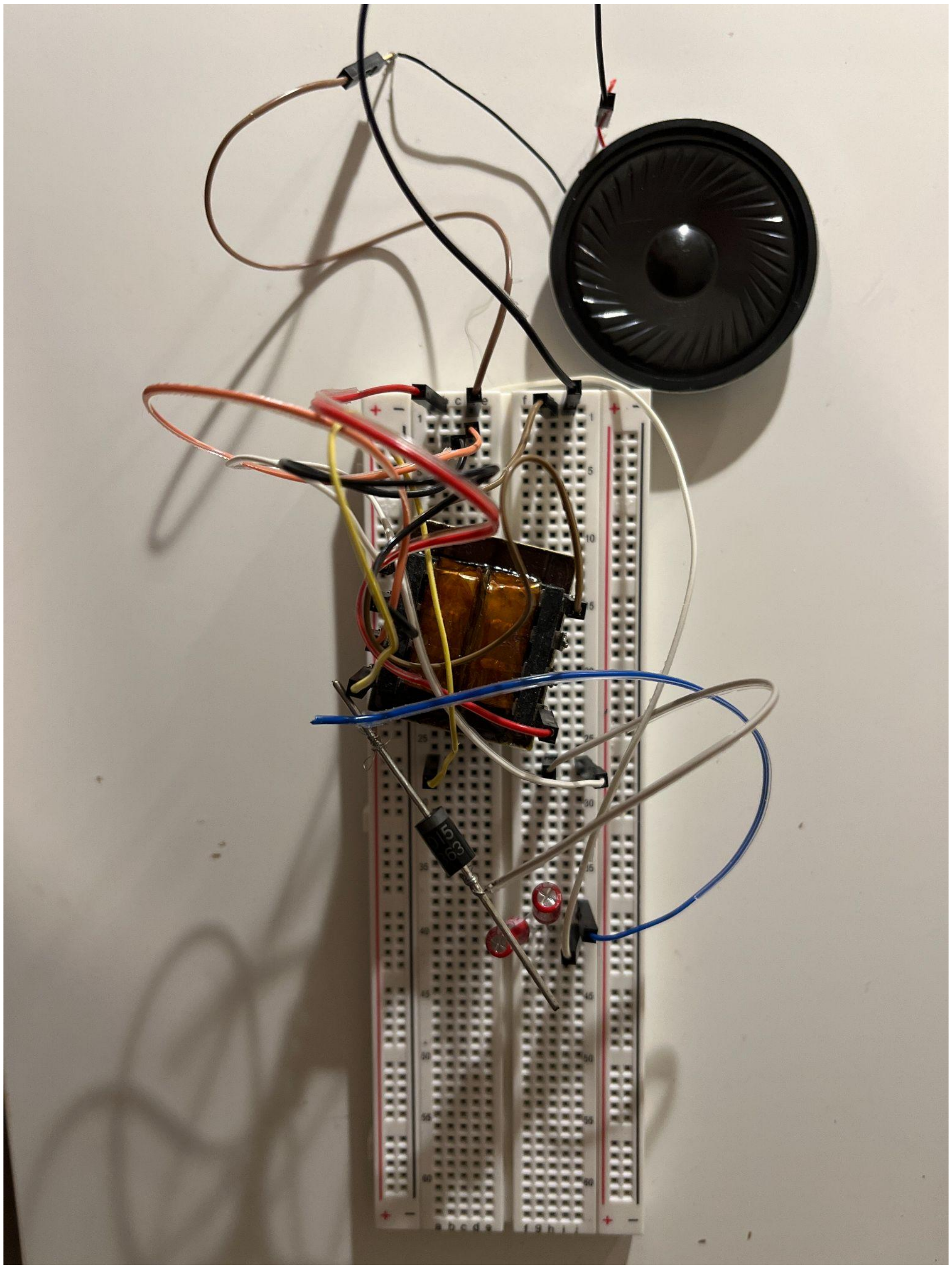


Diagram 4: (3V input voltage with 6V diode forward voltage)



Section 4: Measurement Results

Diagram 5:The diagram of the circuit which the experiment used



Due to limited acoustic energy produced by standard computer speakers, a signal generator [6] is used to emulate what would be the transformer output. The signal generator output is set to 10Vpp and the input frequency was swept from 20Hz to 20000Hz. This frequency range approximately matches the audible range [5]. The DC voltage across the capacitor(s) is measured using the multimeter.

Table 2: Frequency vs Voltage across Single 1uF Capacitor

	Frequency	Capacitor Voltage (DC)
1	20 Hz	0.045 V
2	100 Hz	0.045 V
3	500 Hz	1.99 V
4	1000 Hz	3.7 V
5	1500 Hz	4.63 V
6	2500 Hz	5.64 V
7	3500 Hz	6.19 V
8	7000 Hz	6.95 V
9	13000 Hz	7.28 V
10	20000 Hz	7.42 V

Diagram 6: Voltage over different frequencies

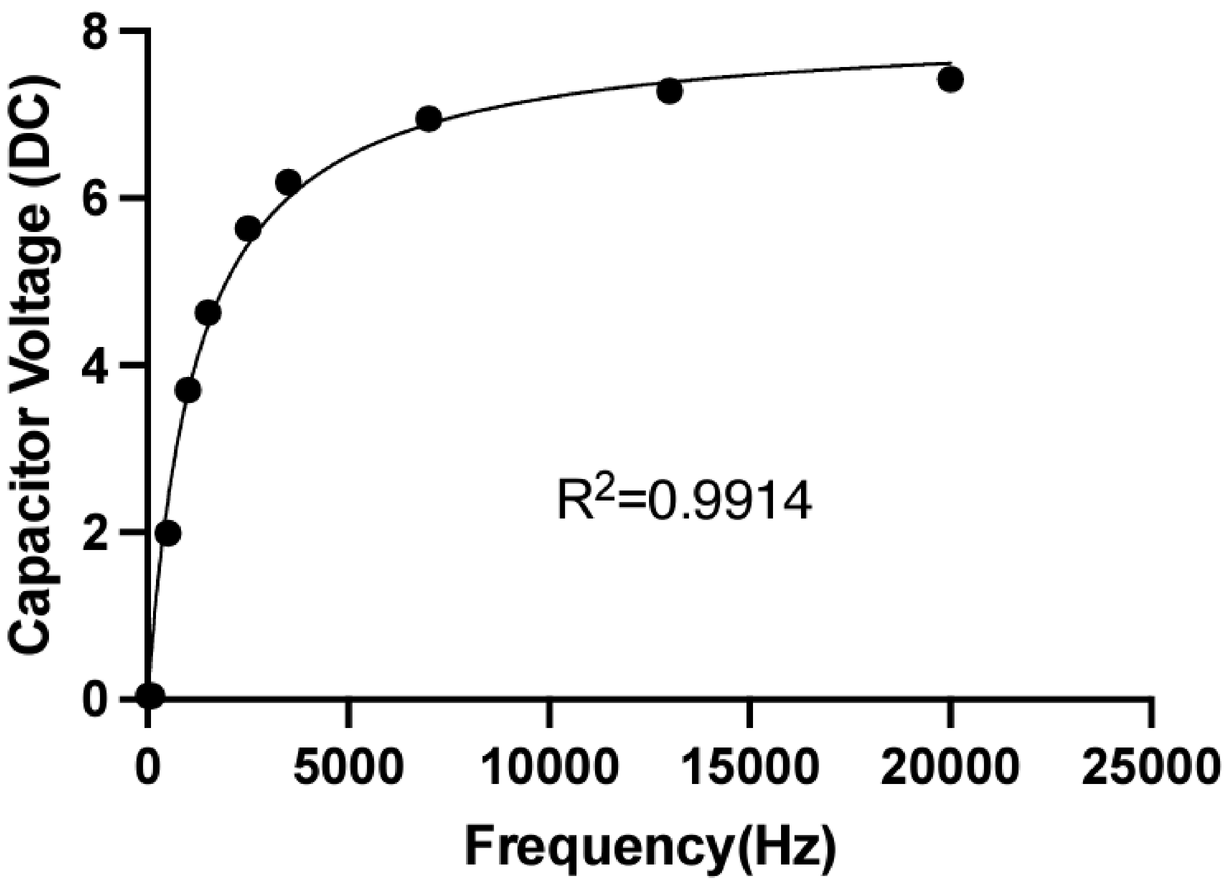
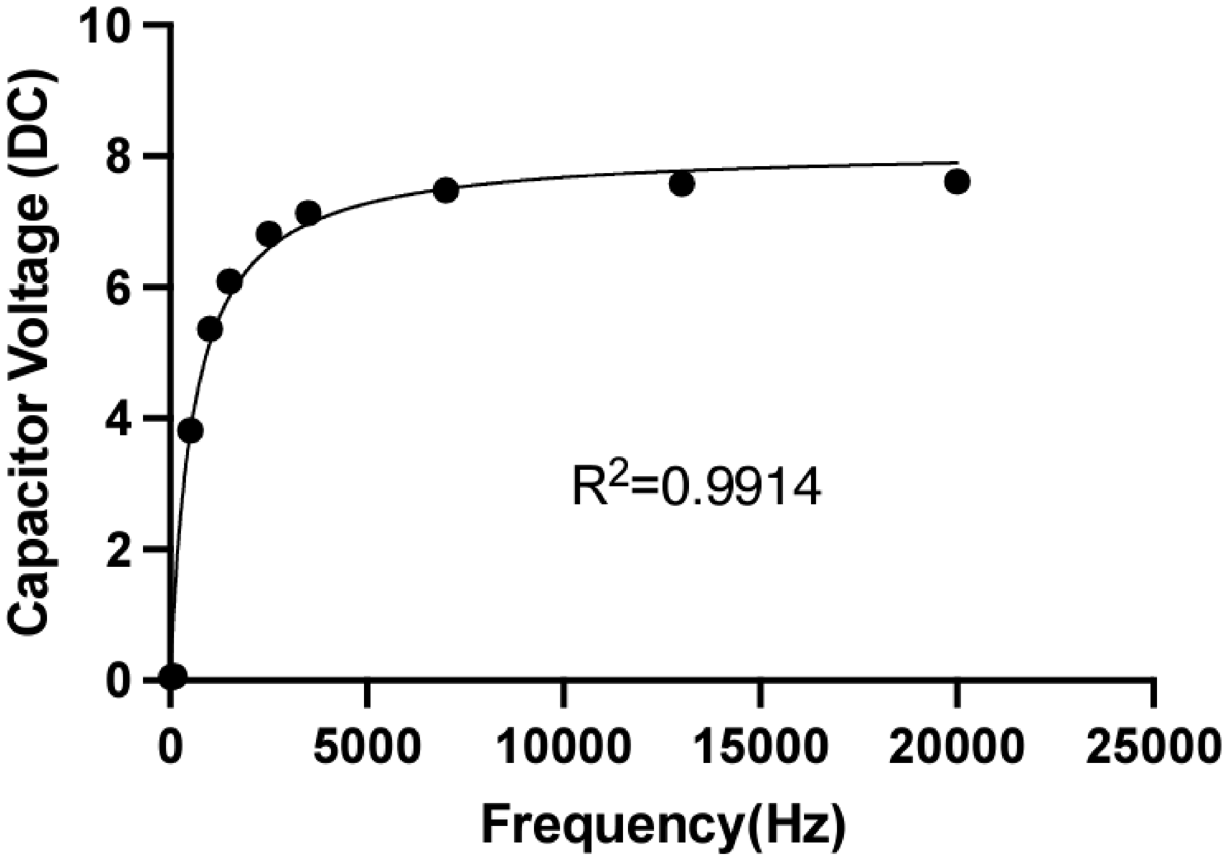


Table 3: Frequency vs Voltage across Two 1uF Capacitors

	Frequency	Capacitor Voltage (DC)
1	20 Hz	0.044 V
2	100 Hz	0.059 V
3	500 Hz	3.81 V
4	1000 Hz	5.36 V
5	1500 Hz	6.09 V
6	2500 Hz	6.81 V
7	3500 Hz	7.13 V
8	7000 Hz	7.48 V
9	13000 Hz	7.58 V
10	20000 Hz	7.61 V

Diagram 7: graph of data from Table B



Section 5: Discussion of Results

The result above shows that as the input frequency increases, the amount of voltage across the capacitor increases. Both curves are hyperbolic and has a horizontal asymptote. Every capacitor has an inherent leakage which causes the capacitor to discharge slowly. As the input frequency increases, the capacitor charges up more often, which leads to a higher average voltage. The highest voltage that can be harvested, in the frequency range tested, is around 7.5 V for single capacitor and 7.7 V for double capacitor. We find that as the input frequency increases, the output voltage monotonically increases. For both a 1uF and 2uF storage capacitor, the slope between from 100 to 500 Hz is the greatest. Adding capacitance leads to an increase of voltage across the capacitor, and increasing the input frequency has the same trend. The slope levels off at approximately 7 kHz for a 1uF storage capacitor and about 3.5kHz for a 2uF storage capacitor. At these frequencies the capacitors have more than 90% of their maximum voltage. While this input across all frequencies had the same input magnitude (10Vpp), it could be that the microphone shapes this frequency-voltage characteristic by its own frequency response. This should also be considered in the harvester design.

Section 6: Conclusion

We have proposed a method where acoustic energy can be harvested by the speaker and be stored in a circuit after being transformed. While limited sound levels prevented testing full systems, the rectifier circuit consisting of the diode and capacitor was characterized and shows promise of operating in an acoustic harvester. Based on the data, the DC voltage across the capacitor increases as frequency or the amount of storage capacitance increases. Although this is only a small amount of energy, it could come from otherwise un-utilized acoustic energy. Even these small amounts of energy can add up in the long run and prove to be useful as power for electronics. This circuit can be referenced in the future experiment on harvesting acoustic energy, which converts acoustic signal to electrical energy. In the future, this experiment can be implemented by adding the factor of a transformer and using a more sensitive speaker to collect the sound.

Acknowledgements:
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References:

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