Acoustic Energy Harvesting

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Abstract ***In this paper an effort to generate power using the sound energy is presented. In this experimentation is carried out upon two sources through which energy can be generated on an experimental basis. In this electromagnetic induction concept is used for getting expected performance to generate voltage up to 280mV. As work targets the harvesting of energy through sound at an experimental basis, output such as mentioned above is primarily accepted.***

Keywords: Energy Harvesting, Pizo- electric, electromagnetic, sound, Electromagnetic transducers

1. Introduction

Energy harvesting through sound is one of the most interesting and new topics of discussion in this modern world. The world has many different sources to generate energy but still it is insufficient to power it completely. Also various different types of pollution is grasping this world. Hence, noise being one of the biggest reasons of pollution can be used as a source to generate energy [15]. This might solve the world's ever rising energy crisis. [3][4].Energy harvesting materials and systems have emerged as a prominent research area and continue to grow at rapid pace. There are numerous energy harvesting methods used Ambient-radiation sources [8][16], Biomechanical harvesting [9], Photovoltaic harvesting [10], Electrostatic (capacitive) energy harvesting [11], Magneto static energy harvesting [11]. Since, there have been no significant researches done on the harvesting of energy through sound; availability of noise making it pollution has been a great plague in the world we live in. This is what derived conducted research on this very new subject. Two experiments are conducted to get best solution through which significant amount of energy through sound could be generate.

2. Electromagnetic Induction

2.1. Working Principle

Electromagnetic Induction is the production of an electric current across a conductor moving through a magnetic field. It underlies the operation of generators, transformers, induction motors, electric motors, synchronous motors, and solenoids. Michael Faraday formulated that electromotive force (EMF) produced around a closed path is proportional to the rate of change of the magnetic flux through any surface bounded by that path. In practice, this means that an electric current will be induced in any closed circuit when the magnetic flux through a surface bounded by the conductor changes. This applies whether the field itself changes in strength or the conductor is moved through it.[2][7]

In mathematical form, Faraday's law states that

$$\varepsilon = -\frac{d\varphi_B}{dt} \quad (1)$$

Where, 'ε' is the electromotive force; 'Φ_B' is the magnetic flux. For coil of wire, composed of N loops with the same area, the equation becomes

$$\varepsilon = -N\frac{d\varphi_B}{dt} \quad (2)$$

A corollary of Faraday's Law, together with Ampere's law and Ohm's law is Lenz's law: The EMF induced in an electric circuit always acts in such a direction that the current it drives around the circuit opposes the change in magnetic flux which produces the EMF. Dynamic transducer filament depends on the principle that moving a wire within a magnetic field generates a current in the wire. In the case of moving-coil dynamic transducer, the wire is a coil of very fine diameter wire, situated within a magnetic field and attached to a diaphragm in contact with the air. [3][4].

As the pressure varies, the diaphragm moves in response to the changing force applied by the moving air. The coil produces a small voltage as it moves in the fixed magnetic field.[14] This voltage is fed, usually through a transformer, to an external amplifier optimized for low input impedance and high gain. While conceptually simple, the implementation of the dynamic transducer is not so straightforward. The mass of a coil of wire is not negligible, so the construction of the element requires special care to make sure the element can move easily enough to allow the small air pressure variations to produce a measurable voltage at all audible frequencies.[12] There are also acoustical considerations necessary to produce a consistent output level for sounds originating from different directions and of different frequencies.

This often leads to complicated acoustical labyrinths built into the housing of the transducer in order to control the frequency response and directional sensitivity. They can tolerate very high sound pressures and are also extremely durable and reliable, so are ideal for use in harsh environmental conditions.[6][9] In dynamic transducer the speed of the diaphragm movement causes the signal, not the current deflection.

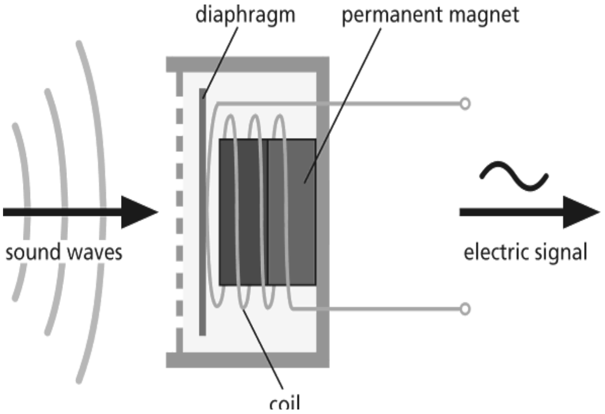

Figure 1: Operating principle [6]

3. Experimental Setup

3.1 Block Diagram

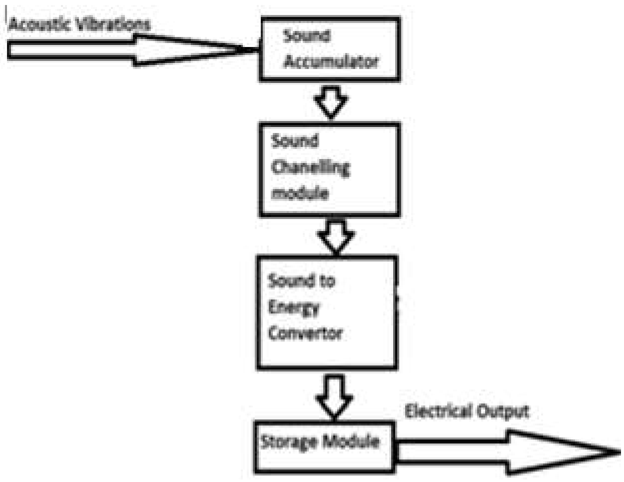

Figure 2: Operational block Diagram

The block diagram consists of four important modules which has its own important functions. But future research may give rise to the elimination of one or more modules. These modules were derived through careful experimentation and finally made.

3.2 Preliminary Design

Three EMI transducers made were mounted in between two thick rectangular PVC switch board plates screwed together. This assembly was connected to one end of a moderately long PVC pipe and the other end was left open.

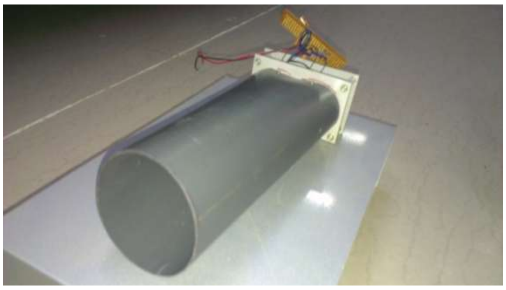

Figure 3: Setup front view showing PVC pipe position

Figure 4: setup side view showing mounting

The end of the PVC pipe connected to the Transducer assembly was squeezed according to the shape of the assembly, covering it. Hence PVC pipe formed a funnel design converging towards the transducer assembly.

Holes were drilled on to the PVC pipe at the end connected to the transducer assembly so as to let the air pass and the sound pressure is maintained. The sound entered the module through the open end of the PVC pipe and formed different interference patterns, some cancelling each other and others summing up. Overall amplitude was increased as all the sound wave converged towards the transducer assembly. There are various theories that come into picture when a sound travels in a hollow pipe.[9] Theories such as resonance of sound, reflectivity of sound, sound transmission losses etc.[3] The converged sound waves imparted pressure on the transducer assembly, thereby generating electricity as mentioned in its working. The length of the pipe was experimented upon to achieve the optimum length for maximum result. The final output is collected from the capacitor connected to all the three EMI transducer.

3.2.1 Reasons for Design Modification

Though the output available is 280mV and is acceptable, it could have been better.

- Squeezing of the PVC pipe to form the conical design produced non-uniform, unsymmetrical shape thereby generating more transmission loss.
- Perfect circular conical structure with perfect cylindrical pipe would have provided optimal results.
- In order that the transducers are in the affective area, the assembly had to be changed.
- PVC pipe absorbed considerable amount of sound pressure.

Hence to achieve optimal results highly sound reflective material like aluminum was to be used.

3.3 Final Design

In order that the transducers fall in the affective area, the assembly had to be changed. So as the EMI transducers fall perfectly in front of the cylindrical tube, which acts as the sound channeling module, the transducers were to be assembled in a manner that it is confined within the circumference of the cylindrical tube. EMI transducers were assembled in a manner in which it forms three vertexes of an equilateral triangle. The area surrounding the transducers is drilled to form air vents.

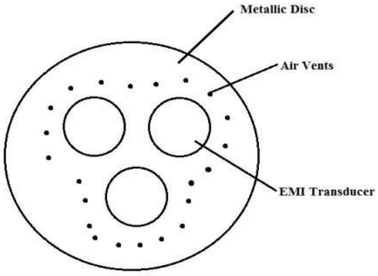

Figure 5: Transducer Mounting Base

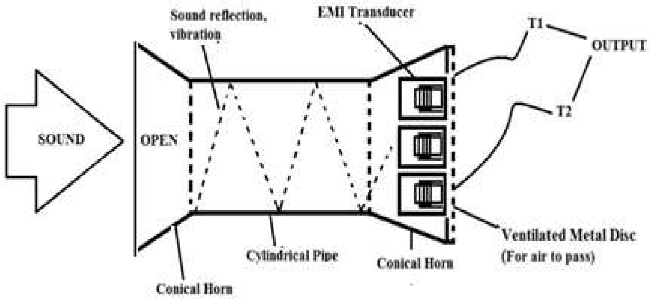

Figure 6*:* Final Design

The main model consistss of a metal cylindrical hollow tube with conical horn opening on both the sides. One of the openings in the module is left open for the sound to enter inside. On the other side the ventilated disc with mounted dynamic transducers(*Figure 5*) is attached with the circumference of the disc same as the circumference of the conical opening. The horn shapes having its top side like an open mouth which collects sound and its lower side like a semi closed mouth which channelizes sound in a unidirectional paththrough the tube towards the transducer. The sound waves accumulated, passing through the cylindrical tube form different interference patterns, some cancelling each other and others summing up. Overall amplitude is always increased. There are various theories that come into picture when a sound travels in a hollow pipe. Theories such as resonance of sound, reflectivity of sound, sound transmission losses etc. The reverse conical horn at the end of the cylindrical tube helps reflecting back the wave which did not impact upon the transducer, to the transducer. The air passing through the module would also contribute to vibrations. The output of the system is the summation of output of all the three EMI transducers. The output from the transducer can be calculated from the terminals T1 and T2.

3.3.1 Final Design Circuit Diagram

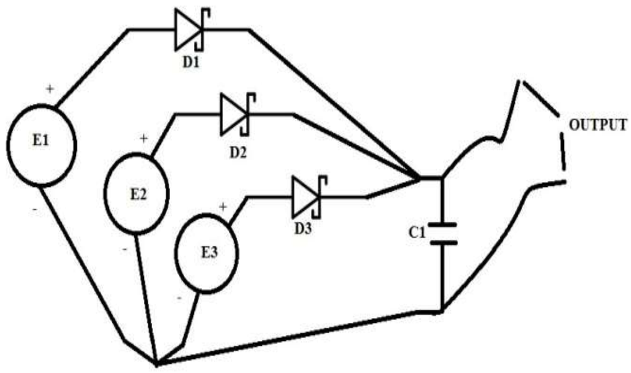

Figure 7: Circuit diagram

The circuit basically consists of 3 Schottky Diodes and 1 capacitor (1uf). The positive terminals of the EMI transducer are connected to anodes of respective Schottky Diode. Schottky Diodes are used because of their low forward voltage drop and very fast switching action. When current flows through the diode is a very small voltage drop across the diode terminals. The diode obstructs the charge from moving towards the transducer if the transducer's output is at a lower potential as compared to other two transducers. All the cathodes of Schotttky Diodes are connected to one terminal of the capacitor. All the Positive terminals of the Transducers are connected to the second terminal. Final output is collected from the capacitor.

3.3.2 Final Design Module – 1

This module serves as one of the most important part of the device. The acoustic vibrations or sound travels in numerous directions without any fixed path. So, the mechanics of the device had to be such that there could be a proper accumulation of sound. Hence, we thought of different shapes that could satisfy our purpose of acoustic vibrations accumulation. Therefore, we gave it a shape of a horn.

Figure 8: Horn shaped opening

A horn shapes having its top side like an open mouth which collects sound and its lower side like a semi closed mouth which channelizes sound in a unidirectional path.

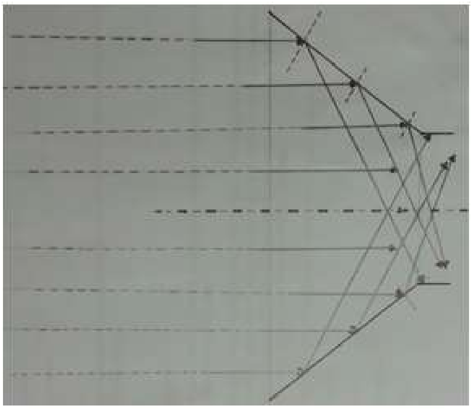

Figure 9: sound channelization concept

This serves as one of the most significant aspect of our project because of the aim that we have; collection of sound so as to generate maximum energy through our other modules. As per the above figure, sound enters into the hull of the horn accumulator; obviously sound travelling in straight line, reflects the hard surface, in turn accumulating in the next module, i.e., the sound channeling module.

3.3.3 Final Design Module – 2

The channeling module is initiated for the proper movement of the sound waves being accumulated inside by the horn shaped sound accumulator. The sound waves here form different interference patterns, some cancelling each other and others summing up. Overall amplitude is always increased. There are various theories that come into picture when a sound travels in a hollow pipe. Theories such as resonance of sound, reflectivity of sound, sound transmission losses etc

Figure 10: Guiding channel

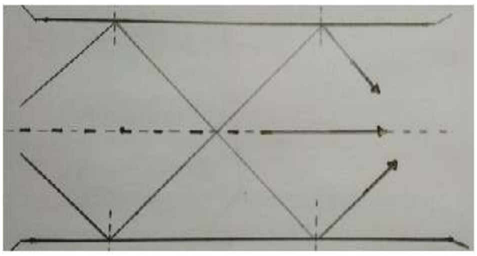

Figure 11: sound channelization through guide

According to our research, there are three major factors that play its role when we were deciding the entirety of the channeling module:

A. Material of the Hollow Pipe – The material of the hollow pipe so as to achieve maximum reflections and very low absorption. We have various different types of material available which achieves so:

- Aluminum
- Stainless Steel
- Iron
- Steel

According to the feasibility of the entire structure and its cost effectiveness, we chose to use aluminum. Aluminum is cheap, easily available and also does not portray magnetic properties. Steel and iron are eliminated because we cannot use a material which shows magnetic properties for obvious reasons. Stainless steel is a costly material; hence we do not use it.

B. Shape of the Hollow Pipe – The shape of the hollow pipe we selected is cylindrical so as to achieve maximum output. Since sound is going to travel in a hollow medium, we expect it to undergo a lot of reflections; producing a lot of interference patterns. Hence, the cylindrical pipe was an apt solution.

C. Length of the Cylindrical Pipe– We had to select the length of the pipe to be apt so as to achieve maximum output. Maximum output means minimum transmission losses, minimum interference and maximum sound vibration transfer.

D. Thickness of the Pipe –The pipe had to as thin as possible to as to achieve proper channelization. We made the pipe as thin as possible and not hampering the shape.

3.3.4 Final Design Module – 3

This is the most important aspect of our entire research module. This is the part which contains our sound energy to electrical energy convertor. As the sound vibrations enters into our system, accumulated through the Sound Accumulator, passes through the Sound channeling module, and finally falls onto our Electromagnetic Inducing Transducer (EMI Transducer). This module was what had specially constructed so as to achieve smart conversion of the same, acquiring lesser space and producing maximum output. Our device is made up of a magnet wrapped around by a coil which is connected to a diaphragm. This diaphragm vibrates when the sound vibrations are struck on the surface in turn vibrating the coil. As the coil vibrates under a constant magnetic field, current is induced in the coil. This coil is in turn connected to the wires which provides with the output. The output is a fluctuating current; voltage being alternating in nature. Hence a capacitor is connected to the output providing with a non-fluctuating constant alternating voltage. This voltage is summed up with the voltage outputs of the other two similar devices; as we have used only three of those due to cost effectiveness, and the output is given to the capacitor. This capacitor can be either used to provide the power directly or can be used to store the power in a battery.

Figure 11: Electromagnetic transducer Mechanism

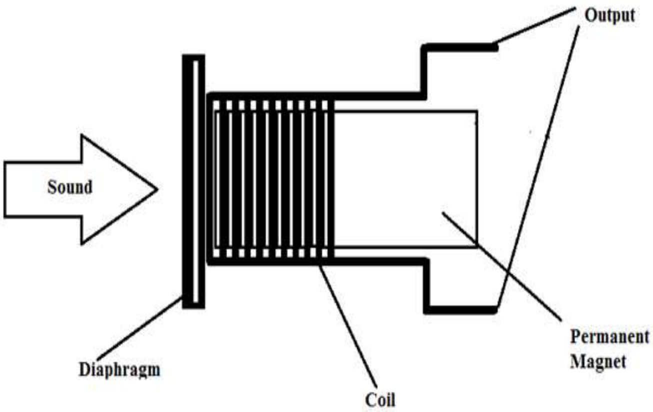

Figure 12: Electromagnetic transducer function

The system follows Faraday's law of magnetism as well as Lenz law of magnetism explanation to which we have mentioned earlier in the research section.

4. Technical Analysis

Table 1: output for different level of sound

Sr. No.	*Sound Source*	*V (mV)*	*I (uA)*	*P (x10^-6) uW*	*Sound Intensity (dB)*
1	Mess Kitchen	123	12	1.476	60
2	Child Shouting	230	20	4.600	76
3	Mechanical	280	26	7.280	88
4	Group of people	340	31	10.540	90
5	Lady Shouting	380	33	12.540	94
6	Motorbike	390	36	14.040	92
7	Tractor	500	46	23.000	102
8	Car Horn	620	58	35.960	109
9	Man Shouting	880	86	75.680	120
10	Truck Horn	1050	94	98.700	128

The above said analysis speaks of the different sound levels that are generated by each source and also the different values of power, voltage and current generated. One must note that while verifying these values, the sound levels may vary, so can the power levels. These sources are highly inconsistent and also depend upon different environmental variations. All that we need is fluctuating pressure on the diaphragm.

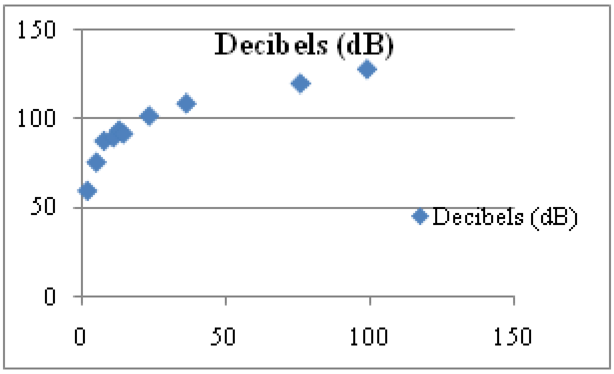

Figure 13: graphical representation of table 1

The graph that we have plotted shows the relation between the power generated vs. the sound pressure. It shows, according to our experiments conducted, a rising graph until it reaches its peak value. The above analysis that we conducted has yielded us all the results required to make our system a success. However, due to limitations of the magnetic induction of the magnet, there is a maximum value of sound intensity that our project can withhold. The maximum value of sound intensity or sound pressure which our system can withhold is 150 dB approximately above which the diaphragm may rupture. Correspondingly, a maximum value of energy can be generated. There is also a minimum value of sound intensity and sound pressure that is needed to actuate our system. That value varies from 20dB-40dB. Below these intensities, the devise may not work. Note that these are the analysis of our system. A better system with improved specs can be developed. All that we need is better resources to build it.

5. Conclusion

We conclude by saying that, through our experiments we were not able to generate enough power by using the phenomenon of piezoelectricity.[10][11] Also cost of significant generation of power would have been too high. We need a feasible and a sustainable solution.

Hence, through our experiments, by using the phenomenon of electromagnetic induction, a sustainable as well as feasible and yet significant quantity of power we have generated. Thereby, saying that we have successfully generated power from a source that is very raw in nature. All the noise generated in the world can now be converted into sustainable form of energy. Although our research is in preliminary stages of the revolution well said, but as we all know that all the technology in the world today came out of a box. If we are able to proceed further with our research, with sufficient funds and resources, we might be able to one day successfully mass generate power from sound.

There are some advantages The input fuel to some large scale generation of energy costs money and exhaustible fuels, the energy source for our energy harvesting module is present in the ambient background and is freely available.[17] Our module consists of no moving parts, hence eliminating the frictional hazards and results are typically rugged and durable. As it is not directly impacted upon by heavy pressure, wear and tear losses and minimized. The generation of electricity is not limited to a particular frequency or sound level but it can be actuated by and source of sound excluding ultrasonic noises. Wind pressure can also add to the vibration when passing through the chastity with the sound. The horn shaped pipe opening ensures that the sound is directed as a beam towards the transducer thereby increasing the overall amplitude. Metallic Pipe ensures that the vibrations are kept to maximum and thereby not inducing any kind of absorbing properties. Echoing of the sound inside the metallic chamber helps increase the overall vibration force. The sealed chamber ensures minimum potential energy losses. The allowance of freely moving air ensures minimum heat generation and hence minimizing power loss due to heat.

6. Application & Future Scope

- Inside or Outside Factories – Mechanical factories as well as factories of different origins produce a lot of noise pollution. Hence, noise pollution can be targeted by this device. Although using such would not decrease the noise pollution but would certainly be put some use enabling us to generate sufficient power for local use.
- Cinema Theaters – The sound generated by the speakers inside the cinema theatres is pretty much enough for thousands of such devices generating a sum total of 1000 volts of voltage. This much voltage can be easily used up by the theatres itself. Thus, terming this special theatre as the self-sustained theatre.
- Discotheque – Similar to the concept of the theatre, thousands of these devices actuated by the loud music in the discotheques would easily help in self-sustenance.
- Airports – Airports can generate a lot of power through these devices as the airports create lots of noise. Such a device can act as a failsafe power generator when the major power supply fails.
- Bus Depots– The bus depots can be fitted with such devices, therefore enabling it to generate a lot of power..
- Railway stations - Railway stations can be fitted with such devices which will in turn power the railway station itself. Such a device can act as a failsafe power generator when the major power supply fails.
- Roads(e.g. On Traffic signals)–Roads have been a constant area of noise pollution, Hence such a device can very well generate a lot of power from it
- Supermarkets – Areas such as supermarkets can act as a major supply of power if fed such a device to the noise generated.

In our world where energy is a crisis, our ever demanding need for sustainable and clean energy resource is nothing but a dream. In our attempt to curb this dream, to support technology and creating a better life, we have devised this module. Mobile phones, palmtops, tablets, pallets would not require any charging as there would be a feature, then known as Talk and Charge. Talking on the phone would not drain the battery, instead would initiate charge up of the battery. Laptops, having such a module would help the common user decrease the battery drain anywhere in the world. Be it in a car, on the streets, malls, offices, supermarkets, etc. Our Smart Homes would be ever smart as there will be minimum power consumption from the government. Our Smart Offices can then be a 24 hour functional enterprise where people will enjoy working in shifts. Everyone will have electricity at their disposal curbing the needs of all and ensuring smart development of all humans. Earth will be a cleaner and quieter place to live making all its inhabitants happy.

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