Conversion of Sound to Electric Energy Using Piezoelectric Sensor

Chandan Kumar[1], V. Srikanth[2]

[1]Master's Student, School of Science and Computer Studies, CMR University, Bengaluru, Karnataka
[2]Associate Professor, School of Science and Computer Studies, CMR University, Bengaluru, Karnataka

Abstract
With the increasing energy demands and environmental issues day by day, there is a need for sustainable alternatives. Noise pollution has always been a topic to worry about. So, we are utilizing noise or sound by converting it into electrical energy using piezoelectric sensor. The piezoelectric sensors use the piezoelectric effect to transform mechanical energy, for instance, sound waves into electrical energy. The potential applications of this technology are numerous, including energy harvesting from traffic noise, music, and even heartbeats. To the study in the field of piezoelectric energy collecting sensors Polyvinylidene fluoride (PVDF) and lead zirconate titanate (PZT) is used. The maximum power outputs achieved in these studies vary between 0.77 mW to 51.6 mW, depending on what is the outline of the energy harvester and the type of sound source used. Use of piezoelectric sensors for energy harvesting has great potential for generating renewable energy from ambient sound sources.

Keywords: Piezoelectric; polyvinylidene fluoride; lead zirconate titanate; renewable energy; ambient sound source.

INTRODUCTION

Piezoelectric materials have been known since the late 19th century for their ability to generate electricity when subjected to mechanical stress. In recent times, there has been an increasing level of attention towards using piezoelectric sensors to harvest energy from ambient mechanical vibrations, including sound waves. With the help of this technology there can be possibilities to provide a renewable and sustainable source of energy, particularly in urban environments where noise pollution is high. The fundamental concept behind a piezoelectric energy harvester is to convert mechanical energy, such as sound waves, into electrical energy by utilizing a material of piezoelectric. When you apply pressure, like the vibrations produced by sound waves, to a piezoelectric material, it generates an electric charge. This electric charge can be captured and utilized to power electronic devices. Recent studies have delved into the potential of using piezoelectric sensors to harvest energy from sound waves. These inquiries delved into diverse elements, such as the choice of piezoelectric material, the configuration of the energy harvester, and the characteristics of the sound waves, encompassing both frequency and amplitude. The objective of this research is to fine-tune the design of piezoelectric energy harvesters to suit specific applications, such as extracting energy from traffic noise, musical instruments, and even the movements of the human body. In essence, the aim is to optimize these devices for diverse environments. The broader goal is to establish piezoelectric sensors as a reliable method for harvesting energy from sound waves, offering a sustainable and renewable energy source. This holds significant promise, especially in urban settings where there is a constant influx of ambient sound. With ongoing research and development, this technology has the potential to play a vital role in the renewable energy landscape.

Literature Review

Piezoelectric sensors have a vital role in converting sound waves into electrical energy, which has a wide range of uses. Piezoelectricity is essential for gathering power from diverse sources, particularly sound waves. This ongoing research is focused on improving and optimizing piezoelectric energy harvesting systems to convert sound energy into useful electrical power.

S.no	Tittle	Author	Journal / Content	Objective	Methodology / Technical	Finding	Drawbacks
1	Investigating Piezoelectric as a Potential Sound Wave Energy Harvester (Liew Hui Fang, 2017)	Liew Hui Fang , Syed Idris Syed Hassan, Rosemizi Abd Rahim (L. H.Liew HuiFang, 2017)	The 8th International Conference on Applied Energy (Liew Hui Fang, 2017)	Address the challenge of low-level energy density available in the surroundings for energy generation by sound wave.	Researchers used the piezoelectric material (Q220- A4-503YB) as the energy transformer.	The piezoelectric transducer exhibited a peak power response measuring 33.133 dBuW when subjected to a sound level of 96 dB.	it's essential to consider practical limitations and challenges when implementing such energy harvesting systems
2	A Look at Using Piezoelectric Materials to Capture Sustainable Electrical Energy from Sound Hazards . (Nalla Mohamed Mohamed Ismail, 2024)	Nalla Mohamed, Mohamed Ismail ,Nitish Aadithya Loganathan (Norfarah Nadia Ismail, 2024)	Presented at the ICP (International Conference on Processing) & ICPPM 2023 (Performance of Materials) (Norfarah Nadia Ismail, 2024)	The objective of this research is to explore the use of piezoelectric materials for harvesting electrical energy from sound hazards	The piezoelectric material used in the experiments is cost-effective.	The amplitude of a 90 dB sound resulted in the generation of 2 volts using a single piezoelectric sensor	The study does not explicitly mention any drawbacks, but practical implementation challenges should be considered when deploying such energy harvesting systems.
3	piezoelectric material for transforming sound energy into electricity: a	Mr. Sankalp Shrivastava, Mr. Manish Gome ,Mr. Sanjay Purohit, Mr.	Submitted at IJMET (International Journal of Mechanical Engineering	The objective of this study is to explore the conversion	By converting sound energy to heat energy and further to electrical energy.	The paper provides a theoretical examination of power generation	The study does not explicitly mention any drawbacks, but practical implementation

	research	Chahat Mundra, Mr. Shashank Singh Pawar	& Technology)	of sound energy into electricity using piezoelect ric materials		through piezoelectric means utilizing sound vibrations.	challenges should be considered when deploying such energy harvesting systems.
4	Applications of piezoelectric transducers for capturing vibrational energy from sound: A case study of passing automobiles (Muhammd Nurhafizi Rosman, 2019)	Muhammad Nur Hafizi Rosman, Nurul Hanis Azhan (Muhammd Nurhafizi Rosman, 2019)	AIP Conference Proceedings (Muhammd Nurhafizi Rosman, 2019), Volume 2129, July 30, 2019	The objective of this study is to harvest the sound vibration available in our environment.	Designing and identifying the suitable piezoelectric material utilizing COMSOL Multiphysics 5.3.	Both simulation and experimental findings affirm that the piezoelectric transducer adeptly captures vibrations induced by passing road vehicles.	The study does not explicitly mention any drawbacks, but practical implementation challenges should be considered when deploying such energy harvesting systems.
5	Power Generation Using Sound by Piezo Electric Material (D. J.Chaithanya, 2021)	A P Aisiri, S Anitha Ramya, D J Chaithanya (D. J.Chaithanya, 2021)	Journal of Physics: Conference Series. (D. J.Chaithanya, 2021)	This study aims to know the process of converting sound energy into electricity by utilizing piezoelectric materials.	Concentrating on converting mechanical vibrations	The paper delineates a method to develop a piezo- electric energy generating system from noise, using piezo crystals.	The study does not mention practical implementation challenges should be considered when deploying such energy harvesting systems.
6	Piezoelectric Sensors for the	Arunesh Kumar Singh, Shahida	Presented at the International	The aim of this study is to investigate the	Utilizing piezoelectric sensors,	The paper examines the conversion of mechanical	The study does not explicitly mention any drawbacks, but

	Conversion of Noise Pollution into Electricity (Arunesh Kumar Singh, 2023)	Khatoon, Kriti (Arunesh Kumar Singh, 2023)	Conference on Processing and Performance of Materials (ICPPM 2023) (Arunesh Kumar Singh, 2023)	application of piezoelectric sensors for transforming noise pollution into electrical energy.	specifically PZT (lead zirconate titanate) and PVDF (polyvinylidene fluoride) thin film	vibrations (sound pressure) from 85 dB to 140 dB into electrical energy.	practical implementation challenges should be considered when deploying such energy harvesting systems.
7	Using noise as a strategy to cut down on energy use for street lighting (Yasser A. Farghaly, 2019)	Yasser A. Farghaly,Faten A. A. Hameeda, Shaimaa Salah (Yasser A. Farghaly, 2019)	PLOS ONE, Volume 14, Issue 7, July 2019	The objective of this study is to utilize noise pollution as a resource for producing electrical energy in urban areas.	Utilizing piezoele ctric materials to convert sound-induced vibrations into electrical energy.	The energy generated from a region equipped with 690 piezoelectric QB220-503YB transducers [6] at each station was approximately 0.024 watt-hour.	The study does not explicitly mention any drawbacks, but practical implementation challenges should be considered when deploying such energy harvesting systems.
8	Transmission of sound and electricity Using piezoelectric materials	Richard Li	Not specified in the provided link, but the paper is available on ResearchGate.	The objective of this proof-of- concept experiment is to demonstrate how piezoelectri c materials can be utilized to convert sound energy into measurable elec tric voltages.	Using a 256 Hz or 512 Hz tuning fork to produce sound. Comparing voltages generated by the piezoelectric disc in different resonator configurations.	By using an op-amp mode with a multimeter.	The study does not explicitly mention any drawbacks, but practical implementation challenges should be considered when deploying such energy harvesting systems.
9	India's Production of Piezoelectric	Hari Anand ,Binod Kumar Singh (Singh,	Energy Harvesting and Systems	The objective of this study is to explore the	Designing flooring with integrated	The study underscores the	The study does not explicitly mention any

	Energy: An Empirical Study (Singh, 2019)	2019)	(Singh, 2019)	utilization of piezoelectric materials for generating alternative sources of energy.(Singh, 2019)	piezoelectric technology to capture electrical energy generated by pressure using floor sensors	practicality of utilizing piezoelectric materials to capture energy from the vibrations produced by people's walking	drawbacks, but practical implementation challenges should be considered when deploying such energy harvesting systems.
10	Energy Harvesting using Piezoelectric Transducers: A Review (N.Nilimamay ee Samal, 2021)	Nilimamayee Samal,O. Jeba Shiney (N.Nilimamay ee Samal, 2021)	The Institute of Science of Banaras Hindu University, Varanasi, India publishes the Journal of Scientific Research. (N.Nilimamay ee Samal, 2021)	The paper's objective is to analyse and summarize the cutting edge developments in piezoelectric energy harvesting syste ms. (N.Nilimamay e e Samal, 2021)	Transducer configurations: Explores different shapes and arrangements of piezoelectric transducers.	The paper provides insights into the working principles of piezoelectric energy harvesting systems.	The study does not explicitly mention any drawbacks, but practical mplementation challenges should be considered when deploying such energy harvesting systems.

Identification of Problem

The use of piezoelectric sensors for generating electric energy from sound has great potential for providing a renewable and sustainable source of energy. However, there are a number of challenges which must be mitigated to fully realize the latent of this technology. One main problem is the low power output of piezoelectric energy harvesters. The power output of these devices is limited by different factors, that includes efficiency of the energy conversion process, sensitivity of the piezoelectric material to mechanical stress, and the frequency and amplitude of the sound waves. Increasing the power output of piezoelectric energy harvesters is essential for making this technology commercially viable. Another challenge is the design and fabrication of piezoelectric energy harvesters that are compact, lightweight, and durable. The design of these devices must be optimized for the specific administration, considering factors such as the frequency and amplitude of sound waves, size and shape of the energy harvester, along with the materials used in its construction. The fabrication process must also be scalable and cost- effective. Furthermore, the integration of piezoelectric energy harvesters into electronic systems presents additional challenges. The electrical output of these devices is typically low voltage and high impedance, which may require additional circuitry to convert the output to a usable form. The integration of piezoelectric energy harvesters into electronic systems must also take into account factors such as power management, signal conditioning, and noise reduction. Moreover, piezoelectric sensors only can detect pressure, vibration only.

In the foreseeable future, piezoelectric sensors are anticipated to extend their capabilities beyond detecting vibration and pressure, encompassing the detection of environmental factors like heat, humidity, noise, and light. Addressing these challenges is essential for realizing the full potential of piezoelectric energy harvesting from sound. By developing more efficient and durable energy harvesters, and integrating them into electronic systems, it may be possible to generate significant amounts of renewable energy from ambient sound sources. So in this paper we specifically did research onto the process of converting sound energy into electric energy and have proposed the methodology of this process.

Existing Methodology

There are very many ways that people can do to change sound into electricity using piezoelectric sensors. Ferro-ceramic piezoelectric material, a Breadboard Switch, a Multimeter, an LED bulb, 14K resistors, IN 4148 diodes, and a 25 V Capacitor are required which are found in local markets for experimentation. The Piezo element is inserted into the breadboard by placing the black lead in socket 5E and the red lead into socket 6E. The positive lead is connected to socket 11E while the negative lead is connected to 1E. To ascertain whether or not the circuit works well enough; an LED was attached to a breadboard and then the piezo element was softly knocked causing short illumination of the LED. This way it ensures that this circuit operates right. (N. Nilimamayee Samal, 2021)

In the second methodology, sound waves which are passing in a medium from time-to-time cause displacement. As waves of sound oscillate, they cause a back-and-forth displacement due to the K.E(Kinetic Energy) of the fluctuation and the P.E(potential Energy) of truncation. Firstly, sound energy is transformed into heat energy before converting into electrical energy. The use of piezoelectric material introduces an additional loss conversion. Unlike other methods, this process involves the conversion of mechanical deformation in piezo materials, crystals that can be changed into electric energy. In the methodology by Nilmamavee, a Piezoelectric Energy Harvesting (PEH) system was designed and connected to a 2 hp, two-pole, 3-phase AC induction motor. The horizontal vibration was measured at 80 mG at 60 Hz. The device demonstrated the capability to generate an output power of 726.2 microwatts under optimized conditions, targeting a resistance of 100 KΩ.

Methodology

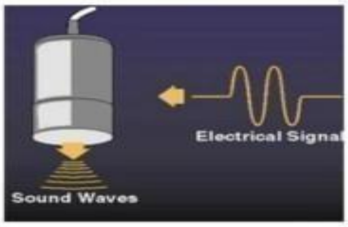
The conversion of sound waves into electrical energy using piezoelectric materials can be achieved through the following steps:

a) **Generation of sound waves**: The first step to generate sound waves which can be achieved through various methods, such as singing, playing musical instruments, or even through ambient noise in the environment.
b) **Detection of sound waves**: Next, the sound waves need to be detected. This can be done using a piezoelectric sensor, which is a device that converts mechanical stress or pressure into electrical charges.
c) **Conversion of sound waves into electrical charges**: When sound waves come into contact with a piezoelectric sensor, they generate mechanical stress on the surface of the sensor. This stress creates electrical charges within the sensor, which are proportional to the intensity of the sound waves.
d) **Collection of electrical charges:** The electrical charges generated by the piezoelectric sensor need to be collected in order to generate a usable electrical output. This can be done using an electrical circuit

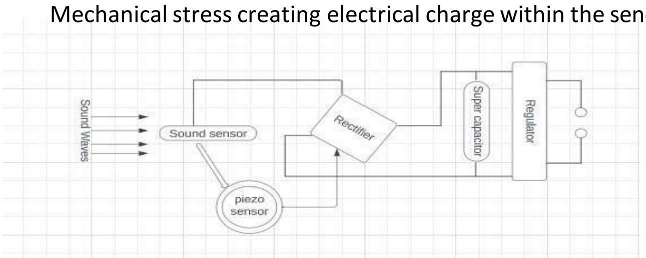
connected to the piezoelectric sensor.

e) **Conversion of electrical charges into electrical energy:** Finally, with piezoelectric sensor electrical charges is collected in order to convert into a usable form of electrical energy. This can be achieved through the use of an electrical converter, such as a rectifier or an inverter, which converts the electrical charges into a usable form of AC or DC electrical energy. This is a basic overview of the steps involved in converting electrical

Noise Coming from Environment



Mechanical stress creating electrical charge within the senor



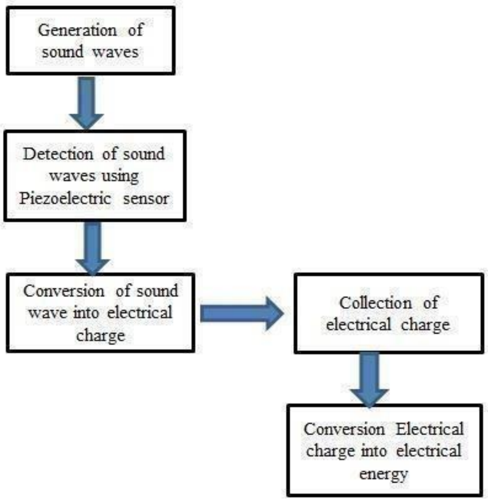


Fig. Flowchart of methodology

Use of regulator/rectifier to convert electric charges into electrical energy energy from sound energy using piezoelectric materials

Implementation

In this configuration, a speaker serves as the primary sound source, generating vibrations. To enhance the sensitivity of the quartz crystal with piezoelectric effect, a connection directly to the speaker is established.

Acknowledging the inherent sensitivity limitation attributed to the material's size, a network of interconnected sensors is utilized, with strategically placed springs between each sensor to introduce additional pressure. This unique configuration is intended to effectively convert sound vibrations into a measurable electrical signal. Given the initially low voltage and current output from the piezoelectric sensors, a solution is found in the LM2596S DC to DC buck power converter. This converter serves the crucial role of amplifying the signal, offering adjustable output voltage in the process. The strengthened signal is then directed towards charging a cost-efficient sealed lead-acid battery with a voltage rating of 12V. To validate the efficacy of the generated voltage and current, an initial test involves employing a DC motor. Upon successful completion of this testing phase, an inverter is introduced to transform the 12V DC output into a more substantial 220V AC. This increased voltage is subsequently utilized to power a 9W LED lamp for practical applications. While the system has the potential to accommodate additional loads, the choice is made to use an LED lamp for simplicity and demonstration purposes. The overarching energy conversion process encompasses capturing sound vibrations, enhancing the resulting electrical signal, storing it efficiently in a 12V lead-acid battery, and then utilizing this stored energy to power both a DC motor and an inverter for AC output, ultimately illuminating an LED lamp. This approach exemplifies a comprehensive utilization of sound energy, showcasing its transformation through various stages for practical applications.

Result

Piezoelectric sensors are capable of transforming physical movements or acoustic waves into electrical signals. When a type of piezoelectric material is subjected to mechanical stress or deformation, the material generates an electric charge across its surface. This phenomenon is known as the piezoelectric effect. Therefore, using piezoelectric sensors to capture sound energy is possible. When sound wave shits the sensor, they cause mechanical vibrations that are then converted into an electrical signal. The strength of the electrical signal generated by the sensor depends on the amplitude and frequency of the sound waves.

Level of sound(dB)	**Output voltage in AC (v)**	**Output Voltage of Rectifier DC**
40-45	0.4	0.3
50-55	0.8	0.7
60-65	1.1	1.0
65-70	1.6	1.5
70-75	2.1	2

Conclusion:

In conclusion, Piezoelectric sensors can convert mechanical vibrations or sound waves into electrical energy by generating an electric charge across their surface through the piezoelectric effect. While it is possible to harvest sound energy using piezoelectric sensors, the amount of electrical energy produced is relatively small and limited to low-power applications such as small electronic devices and sensors. The strength of the electrical signal generated by the sensor depends on the amplitude and frequency of the sound waves. Therefore, while piezoelectric sensors can be used to generate electricity from sound, their practical application is mainly suited for low- power devices and sensors.

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