

Acoustic Energy Harvesting System

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ABSTRACT

The continuous growth in energy consumption and the depletion of conventional energy resources have created a strong demand for alternative and renewable energy sources. Acoustic energy, also referred to as sound or vibrational energy, is an abundant yet underutilized form of energy present in everyday life, especially in noisy environments such as highways, industrial zones, railway stations, and public areas. This paper presents the design and implementation of an acoustic energy harvesting system that converts sound vibrations into usable electrical energy. In the proposed system, a loudspeaker diaphragm is used as an acoustic transducer. When sound waves strike the diaphragm, the voice coil moves within a magnetic field, generating a low-level alternating voltage. Since this voltage is very small, a step-up transformer is used to increase the voltage level, followed by a bridge rectifier circuit to convert AC into DC. A blocking diode is used to prevent the flow of reverse current. The harvested energy is stored in a 12V lithium-ion battery pack with an inbuilt battery management system to ensure safe operation. The stored DC energy is converted into AC using an inverter circuit and a center-tapped transformer to power a 3W LED bulb. Additionally, a buck converter supplies a regulated 5V DC to an STM32 microcontroller for system monitoring. A 16×2 LCD display is used to show voltage levels and system status. The experimental results confirm that acoustic energy can be harvested and effectively utilized for low-power applications. The proposed system demonstrates a practical approach toward sustainable and eco-friendly energy solutions.

Keywords: - Acoustic Energy Harvesting, Sound Energy Conversion, Speaker Generator, Inverter Circuit, STM32 Microcontroller, and Renewable Energy System.

1. INTRODUCTION

The increasing demand for electrical energy and the limited availability of fossil fuels have made renewable energy sources an important area of research. Conventional power generation methods cause environmental pollution and contribute to climate change. Therefore, researchers are exploring new and unconventional energy sources that are clean and sustainable. Sound energy is one such source that is continuously generated due to human activities, transportation systems, and industrial operations. Most of this sound energy is wasted and dissipates into the environment. By harvesting this energy, it is possible to generate small amounts of electrical power suitable for low-power devices. This project focuses on converting sound vibrations into electrical energy using simple and economical components. ^{[2] [4]}

1.1 Importance of Acoustic Energy Harvesting

Acoustic energy harvesting uses unwanted sound from noisy surroundings and converts it into electrical energy. Sound is produced continuously in places like traffic areas, industries, railway stations, and markets. Because of this, sound energy is available both day and night, making it more reliable than solar and wind energy. Special devices convert sound vibrations into small electrical power. This power is suitable for low-energy electronics like sensors, wireless devices, and monitoring systems. It helps reduce battery use and supports clean and sustainable energy solutions. ^[4]

1.2 Objective of the Project

The main goal of this project is to design a system that converts sound vibrations into electrical energy. The generated electrical energy is then safely stored using suitable storage components like batteries or capacitors. An inverter circuit is used to convert this stored energy into usable power to operate a 3W LED bulb. The system also uses an STM32 microcontroller to monitor important parameters such as voltage and current. These values are displayed on an LCD, which helps in easy observation and system monitoring.

2. SYSTEM ARCHITECTURE

The acoustic energy harvesting system shown in fig. 1 is divided into four main sections, each having an important role. The first section is acoustic energy generation, where sound waves are captured and converted

into small electrical signals. The second section is energy conditioning and storage, which improves the quality of the generated power and safely stores it for later use. The third section is power conversion, where the stored energy is converted into a usable form to drive electrical loads. The final section is monitoring and control, which checks system performance and displays important parameters. Together, these blocks work to ensure efficient use of sound energy. ^{[2] [4]}

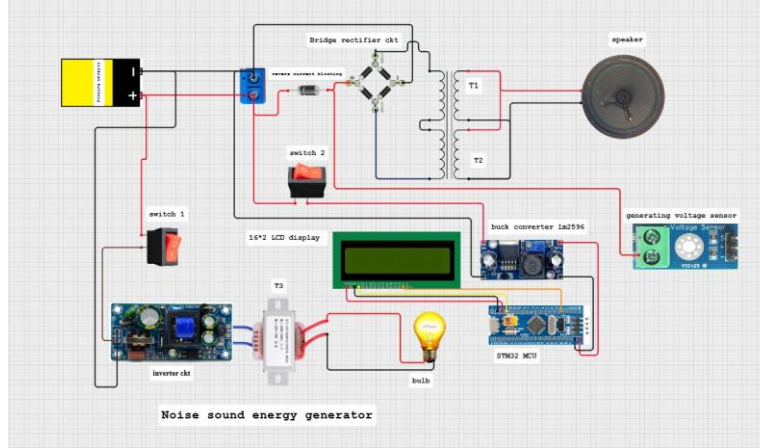


Fig -1: Acoustic Energy Harvesting System Circuit Diagram

2.1 Acoustic Energy Generation

In this system, in our project, we used a loudspeaker to convert sound energy into electrical energy. During our testing, we observed that higher sound intensity produced higher output voltage. When sound waves hit the speaker diaphragm, it starts vibrating. These vibrations move the voice coil inside a magnetic field. Due to this movement, a small AC voltage is produced at the speaker terminals. The amount of generated voltage depends on how loud the sound is and how strong the vibrations are. ^[2]

2.2 Energy Conditioning and Storage

The AC voltage produced is very small, so it cannot be used directly. A step-up transformer is used to increase the voltage to a higher level. This increased AC voltage is then changed into DC using a bridge rectifier. A blocking diode is added to stop reverse current from flowing back to the battery. The final DC output is stored in a 12V lithium-ion battery pack, which has an inbuilt battery management system for safe charging and protection. ^{[1] [4]}

Step Up Transformer – 1, Bridge Rectifier – 2, Battery - 3

2.3 Power Conversion (Inverter Stage)

The energy stored in the 12V lithium-ion battery is in DC form, but many electrical loads require AC supply. Therefore, in our system, we used an inverter circuit to convert 12V DC into 220V AC. The inverter uses switching devices to generate AC output, which is stepped up using a center-tapped transformer. This AC output is used to power a 3W LED bulb. During testing, we observed stable illumination of the LED, confirming proper inverter operation. This stage makes the harvested acoustic energy usable for practical applications. ^[4]

3. MONITORING AND CONTROL SYSTEM

An embedded monitoring system is added to continuously observe the system performance. It helps in checking important values like voltage and overall operation of the circuit. We used a buck converter to step down the 12V battery voltage to a stable 5V. We selected a buck converter because it provides higher efficiency and less heat loss compared to linear regulators. This regulated 5V supply is required for the safe operation of the microcontroller and the display unit. Using a buck converter improves efficiency and protects the components from overvoltage. ^[3]

3.1 SMT32 Microcontroller and LCD Interference

In our project, the STM32 microcontroller acts as the main monitoring unit. We used it to measure battery voltage and system output voltage through voltage sensors. The measured values are processed by the microcontroller and displayed on a 16x2 LCD. We selected I2C communication because it reduces the number of connecting wires and improves system reliability. During testing, this setup helped us quickly identify voltage variations and system performance.

3.2 Calculation

Speaker output voltage ≈ 0.2 to $0.5V$ AC. After step-up transformer, voltage $\approx 12V$ AC. Rectifier output voltage ≈ 10 to $12V$ DC. Battery voltage = $12V$. Power rating of LED bulb = $3W$. Current required by LED bulb: $I = P/V = 3/220 \approx 0.013A$.

Table-1: Experimental Results

Sr. No	Parameter	Measured Value	Remarks
1	Speaker Output Voltage	0.2- 0.5V AC	Low-Level Generation
2	Rectifier Output voltage	10-12V DC	Stable Output
3	Battery Voltage	12V	Energy Stored
4	Inverter Output Voltage	220V AC	Suitable
5	Load	3W LED Bulb	Successfully Illuminated

4. CONCLUSIONS

The acoustic energy harvesting system successfully demonstrates the conversion of sound energy into electrical energy. It shows that wasted sound from noisy environments can be captured and used for useful purposes. The system works well for low-power applications, proving that sound energy can act as a supplementary energy source. This is especially useful in places where noise is always present, such as industries and traffic areas. Although the system works successfully, the power generated from acoustic energy is very small. High sound intensity is required to obtain better output. This limits its use for high-power applications. Through this project, we learned the importance of energy conditioning and efficient power conversion in energy harvesting systems. Although the power generated is limited, the project highlights strong future potential. By improving the efficiency of the acoustic transducer and using better power electronics, the output power can be increased. With further development, this type of system can support more low-energy devices and help in building sustainable and eco-friendly energy solutions. ^[4]

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6. REFERENCES

- [1]. S. Priya and D. J. Inman, Energy Harvesting Technologies, Springer, 2009.
- [2]. S. P. Beeby et al., "Energy harvesting vibration sources," Measurement Science and Technology, vol. 17, no. 12, 2006.
- [3]. STMicroelectronics, STM32 Reference Manual.
- [4]. IEEE Journals on Acoustic Energy Harvesting Systems.