

# Design of Vibration Energy Harvester using Piezoelectric Sensor

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## Keywords

Piezoelectric sensor, Vibration energy, Electrical energy.

## Abstract

This project explores the development of a vibration-based energy harvester utilizing piezoelectric sensors to convert mechanical energy into electrical energy for powering low-energy devices such as LED lighting. The primary aim is to design and evaluate a sustainable, compact system capable of capturing energy from environmental vibrations stimulated through a vibration motor and storing it efficiently. The methodology involved integrating piezoelectric sensors with electronic components including Arduino UNO, LM7812 voltage regulator, bridge rectifier, relay module, and a 12V battery. The system was tested at various motor speeds (1000–6000 RPM), revealing a direct correlation between vibration intensity and electrical output. An array of eight piezoelectric sensors connected in parallel generated voltages up to 6V and currents up to 320  $\mu$ A at peak conditions, successfully reaching the threshold to trigger energy storage and lighting. Results demonstrated improved charging rates and system efficiency with increased motor speeds and sensor counts. The project concludes that piezoelectric-based energy harvesting systems, when carefully designed and safeguarded, offer promising solutions for smart, low-power urban applications. The findings support further development toward scalable, environmentally friendly energy sources integrated within public infrastructure.

## 1. Introduction

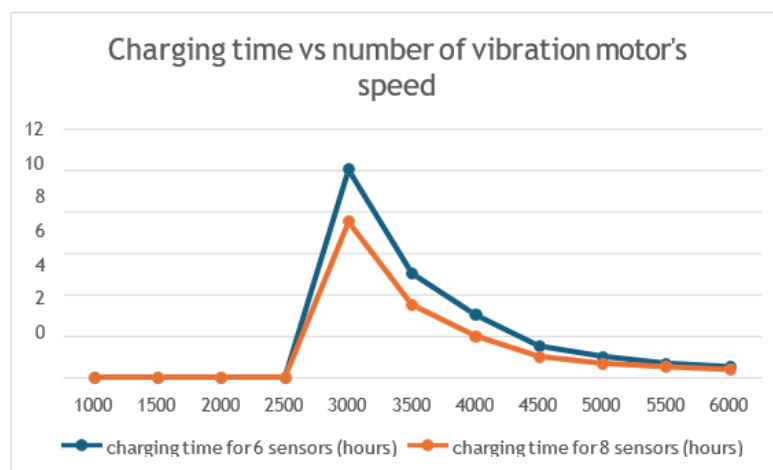
This project explores the development of a vibration energy harvester using piezoelectric sensors to convert mechanical energy—particularly from human footsteps or vibrations—into electrical energy. The goal is to create a compact, efficient system capable of powering low-energy devices like LED lights in urban environments. While piezoelectric systems offer promising sustainability benefits, challenges such as low energy conversion efficiency and integration complexity hinder wide adoption. The study aims to address these limitations through optimized material selection, system design, and circuit integration.

## 2. Research Methodology

The project involves both hardware and software development. Hardware includes a 12V vibration motor as the vibration source, piezoelectric sensors for energy conversion, a bridge rectifier, LM7812 voltage regulator, Arduino UNO, relay module, and a 12V battery for storage. Eight piezo sensors are connected in parallel to boost current output. The system also includes safety features like a relay that disconnects charging once voltage exceeds 4.5V. Software tools such as Arduino IDE, Fritzing, and SketchUp were used for circuit design, prototyping, and simulation. Testing was done across different motor speeds (1000–6000 RPM) to evaluate system performance.

## 3. Results and Discussion

Testing showed that increasing motor speed and sensor count significantly improves energy output. At 6000 RPM, the system achieved up to 6V and 320  $\mu$ A current using eight sensors. Charging time to reach 4.5V was reduced from over 10 hours (at low RPM) to just 22 minutes at maximum speed. While the system isn't sufficient for fully charging a 12V battery, it demonstrates potential for powering low-energy devices or trickle charging. Key challenges included sensor fragility and voltage drop issues, which were addressed using voltage dividers and protective physical reinforcements.



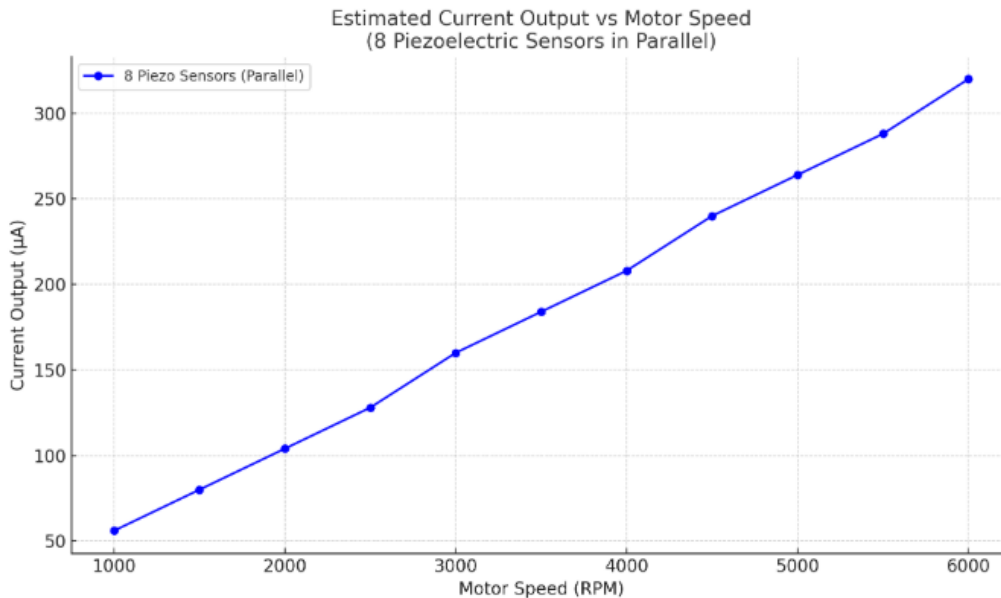
**Fig 1** Charging time from speed of vibration motor's speed.

**Table 1** Comparison number of Piezo and RPM of vibration of motor to reach 4.5V

| RPM  | Voltage per Sensor (V) | Voltage Output (Parallel) | Est. Charging Time to 4.5V (6 sensors) | Est. Charging Time to 4.5V (8 sensors) |
|------|------------------------|---------------------------|----------------------------------------|----------------------------------------|
| 1000 | 0.8                    | 0.8                       | Not achievable                         | Not achievable                         |
| 1500 | 1.3                    | 1.3                       | Not achievable                         | Not achievable                         |
| 2000 | 1.8                    | 1.8                       | Not achievable                         | Not achievable                         |
| 2500 | 2.3                    | 2.3                       | Not achievable                         | Not achievable                         |
| 3000 | 3.0                    | 3.0                       | >10 hours                              | ~7.5 hours                             |
| 3500 | 3.5                    | 3.5                       | ~5 hours                               | ~3.5 hours                             |
| 4000 | 4.0                    | 4.0                       | ~3 hours                               | ~2 hours                               |
| 4500 | 4.5                    | 4.5                       | ~1.5 hours                             | ~1 hour                                |
| 5000 | 5.0                    | 5.0                       | ~1 hour                                | ~45 minutes                            |
| 5500 | 5.5                    | 5.5                       | ~40 minutes                            | ~30 minutes                            |
| 6000 | 6.0                    | 6.0                       | ~30 minutes                            | ~22 minutes                            |

**Table 2** Current output for Piezo Sensor

| RPM  | Est. Current (1 Sensor) | Est. Current (8 Sensors) |
|------|-------------------------|--------------------------|
| 1000 | ~7 $\mu$ A              | ~56 $\mu$ A              |
| 1500 | ~10 $\mu$ A             | ~80 $\mu$ A              |
| 2000 | ~13 $\mu$ A             | ~104 $\mu$ A             |
| 2500 | ~16 $\mu$ A             | ~128 $\mu$ A             |
| 3000 | ~20 $\mu$ A             | ~160 $\mu$ A             |
| 3500 | ~23 $\mu$ A             | ~184 $\mu$ A             |
| 4000 | ~26 $\mu$ A             | ~208 $\mu$ A             |
| 4500 | ~30 $\mu$ A             | ~240 $\mu$ A             |
| 5000 | ~33 $\mu$ A             | ~264 $\mu$ A             |
| 5500 | ~36 $\mu$ A             | ~288 $\mu$ A             |
| 6000 | ~40 $\mu$ A             | ~320 $\mu$ A             |



**Fig 2** Current output vs Motor Vibration Speed

#### 4. Conclusion

The project successfully developed a vibration energy harvesting system capable of converting mechanical vibrations into electrical energy using piezoelectric sensors. The system was designed to store the harvested energy in a battery and supply it to low-power devices such as an Arduino UNO and a 220 VAC lamp through an inverter. The inclusion of a relay module ensured the battery was protected by cutting off the power supply when the voltage exceeded 4.5 V. Despite the small amount of energy generated, the system demonstrated that even a compact piezoelectric setup could effectively charge a storage battery. All project objectives were achieved, including energy conversion, voltage regulation, and energy storage. The report also provides recommendations for future improvements, such as increasing the number of piezoelectric sensors to enhance energy output, using various vibration sources for better performance, and incorporating an Op-Amp to prevent voltage drops. Overall, the project showcases a promising and sustainable approach for powering low-energy devices using renewable vibration energy.

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