Footstep Power Generator Using Piezoelectric Sensors and Arduino-based Monitoring System

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***Abstract*—This paper represents footstep power generating system using the piezoelectric sensors, which are designed for environments with the high foot step areas like malls,parks,railways and stadiums,This project integrates energy harvesting from footsteps with Ardunio-based voltage monitoring,we can store the energy using 18650 Li-ion cells, and real-time data visualization via Bluetooth and LCD modules and aslo on web interface through bluetooth.The system uses a combination of capacitors,rectifiers and a voltage regulation mechanism to ensure consistent and efficient power output.The prototype successfully demonstrates energy conversion,atorage and also the utilization with potential applications in smart cities and the renewable energy harvesting systems.**

***Index Terms*—Piezoelectric, Arduino UNO, Energy Harvesting, Voltage Regulation, Bluetooth, Smart Monitoring**

I. Introduction

Now -a-days the world is becoming more and more urbanized, which is driving up energy demand and necessitating creative, environmentally friendly energy solutions. The idea of turning the mechanical energy of human footsteps into electrical energy is one of the many exciting sustainable energy alternatives. Using piezoelectric discs ,which have the unusual ability to produce an electric charge when under mechanical stress ,this project go through it and applies that idea.The system is intended to capture the pressure generated by footsteps and transform it into alternating current (AC) electricity by embedding piezoelectric discs beneath a platform.This system is made up of the following 18650 lithium-ion cells, a transistor, and capacitors is then used to effectively rectify, regulate, and store the energy that has been generated from the piezoelectric disc's. The Arduino Uno has a crucial part in managing the energy data and keeping an eye on voltage levels is there any fluctuation on the voltage generated, which is the brain of the system.An LCD with an I2C interface shows the current system status, and a Bluetooth module is integrated to wirelessly transmit voltage data for improved usability and real-time monitoring. An example of a useful application of the harvested energy is the use of the stored energy to power low-power gadgets like LED strips. This strategy raises awareness of renewable energy generation in commonplace situations while also aiding in energy conservation.

II. System Design and Components

The proposed system is composed of the following core modules:

A. Piezoelectric Discs

Multiple 35mm piezoelectric discs are embedded beneath a transparent acrylic sheet which are connected in series and parallel. These discs which convert's the mechanical pressure from footsteps into alternating current(AC) voltage.

B. Rectifier and Filtering

A bridge rectifier made from using the four 1N4007 diodes converts AC voltage into DC voltage .A 10µF capacitor filters and also smooths the rectified output to reduce the voltage ripple.

C. Voltage Regulation

To maintain a safe and consistent voltage level for that a voltage regulator is used.It ensures that proper charging of 18650 Li-ion cells and protects the microcontroller from any highvotage .

D. Energy Storage

The generated and regulated power is stored in 18650 lithium-ion cells, chosen for their high energy density and also these cells are rechargable.

E. Control and Monitoring

An Arduino UNO serves as the central processing unit like a bran , which receives analog voltage input from the voltage divider circuit. It processes the data and also it displays on a 16x2 I2C LCD display. It also uses a BC547 transistor to control a connected LED strip that lights up when voltage

F. Bluetooth Communication

The HC-05 Bluetooth module sends the real-time data (voltage levels and activity logs) to a mobile device, allowing remote monitoring of the energy harvesting system.

III. Block Diagram

This is the Block Diagram of our respective system.

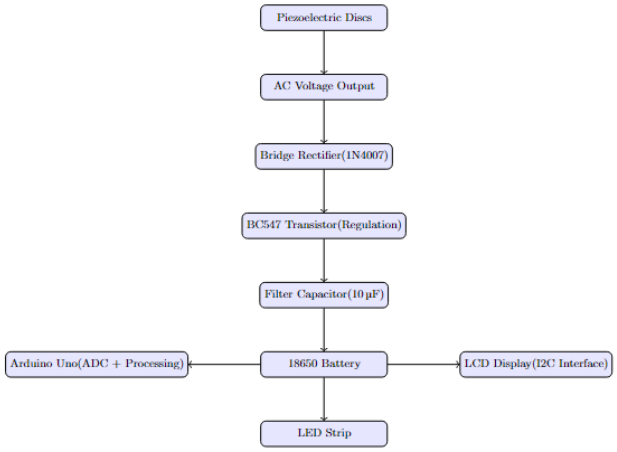

Fig. 1. Block diagram of the footstep power generator system.

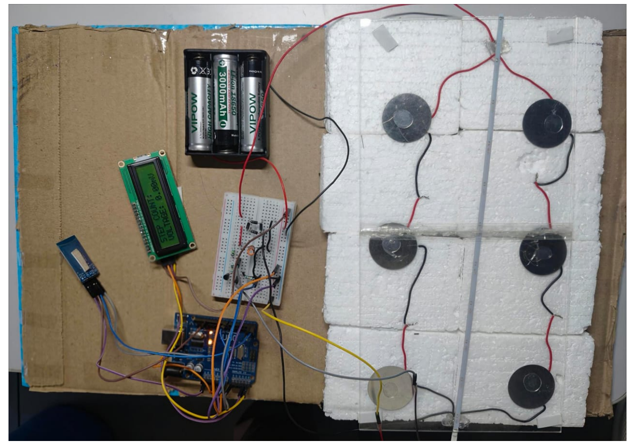

Fig. 2. Hardware view of footstep power generator system.

IV. Methodology

When a footstep or pressure is applied to the platform, piezoelectric discs beneath the surface undergoes some charge distribution which leads to generating an alternating current (AC) voltage due to the piezoelectric effect. However, the AC voltage is unsuitable for direct storage, so it is converted in to DC voltage.A bridge rectifier circuit composed of four 1N4007 diodes which is used to rectify the AC voltage, allowing current to flow in only one direction and converting the AC into pulsating DC.

The rectified voltage is then passed through a 10 µF filter capacitor that smooth down the voltage by filtering out any ripples in it, thereby this provides a stable DC output. To regulate the voltage and prevent overcharging of the battery,The BC547 NPN transistor is used for power regulation switch. It acts as a simple on/off switch, ensuring that only safe and also controlled voltage is supplied to the battery for storage which makes the system efficient.

The regulated DC voltage is stored in a 18650 lithium-ion battery which are rechargeable, providing a reliable source of energy for later use. An Arduino Uno microcontroller monitors the output voltage from the piezoelectric system through its analog-to-digital converter (ADC). The Arduino is programmed to process this data to calculate both the voltage levels and the number of footsteps of the system.

The processed data, including voltage levels and step count, is displayed on a 16x2 LCD screen equipped with an I2C interface, allowing for easy visualization of the system's performance. The stored energy in the lithium-ion battery and also while we applying pressure on the platform we can clearly visualize that some power is generated by seeing the glowing of LED, demonstrating the practical application of harvested footstep energy.

This system offers a sustainable and innovative approach to energy harvesting, effectively utilizing the energy generated by footstep vibrations to power low-energy devices in various environments.

V. Results and Discussion

A. Voltage Measurement Methodology

The voltage produced by the piezoelectric sensor is first received by the Arduino UNO's analog pin (A0), which provides a 10-bit ADC reading between the 0 and 1023. The raw ADC value is initially converted to voltage using the formula:

$$V_{\text{out}} = \frac{N \times V_{\text{ref}}}{1024} \tag{1}$$

where:

- V_{out} is the initial output voltage in the volts,
- N is the ADC reading,
- V_{ref} is the reference vvoltage of Arduino assumed to 5V.

To get more accurate accuracy for hardware-specific variations like losses in the voltage divider or how sensitive the sensor is,we are calculating a calibrated input voltage using a scaling factor.

$$V_{\text{in}} = \left(\frac{V_{\text{out}}}{0.040909}\right) \times 100 \tag{2}$$

Constant 0.040909 is an empirically determined calibration factor derived from experimental measurements, and the multiplication by 100 scales the result to millivolts or a display-friendly format. This calibrated voltage is then used for display, power calculations, and transmission to the Bluetooth module.

Working on this footstep power generation system has been enlightening and inspiring. The idea of taking something as excitement as walking and turning it into energy that can be used , with the idea of simple, everyday movements building a more sustainable world. Through the piezoelectric effect, we were able to convert mechanical pressure—generated by footsteps—into small signals of electrical energy. Although the output per step is minimal, the system begins to demonstrate real promise when put into places where large groups of people walk during the day.

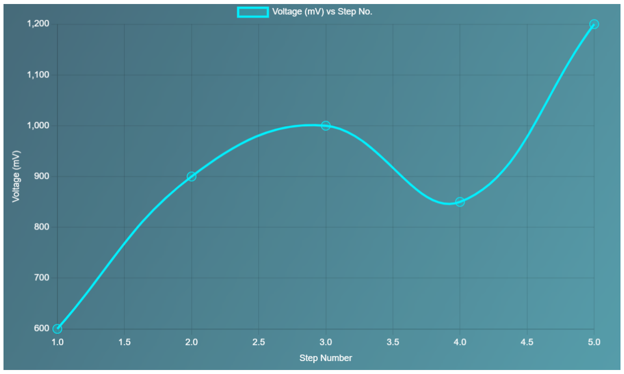

Fig. 3. Graph between steps v/s voltage

Through development and prototyping, we discovered that where and how we mount the piezoelectric sensors matters a lot. Surfaces that evenly distribute foot pressure will provide more consistent measurements. Materials that are too stiff lower the stress that makes it to the sensors, and materials that are too soft may impact durability.

Perhaps the most thrilling addition of our system was the addition of a Bluetooth module in the model. This enabled us to view data such as voltage output and step count in real time. In practical applications, this type of live feedback can be used to view performance and even allow users to interface with the system via mobile app or display unit. It's a little detail, but it's a huge difference in terms of interaction and usability.

Of course, there were some issues. The power output isn't all that high, and it also depends on how much the person weighs and how powerful each step is. That is to say that we can't directly use it to charge big devices, at least not without some form of storage or power control system. In order to convert the power into something that can be utilized, we had to deal with regulators, rectifiers, and storage elements, and that makes things more complicated.

Still, even with these limitations, the idea is extremely promising. The system is modular, which means that it can be scaled across larger areas like sidewalks or station platforms. The more it is amplified, the larger the energy produced. And since it is silent, discreet, and clean, it is highly in line with the smart city vision of the future.

This project showed us that real change isn't necessarily a matter of great infrastructure or high tech. Sometimes it takes a simple bright idea to activate the power already at our fingertips.

VI. Applications and Future Scope

Future Scope The applications for footstep power generation with piezoelectric technology are broad and fascinating. As technology continues to advance, the possibilities are enormous to further make the technology more efficient and practical for mass use. One of the most exciting paths may be coupling high-quality power management electronics with high-end energy storage devices like supercapacitors or lithium-ion batteries. This possibility can allow energy to be stored in greater capacities and reused for long periods of usage.

The addition of Internet of Things (IoT) capability and wireless communication modules would also introduce smart control capability, whereby generated and used energy is constantly tracked. Remote monitoring of performance would be feasible, with adjustments accordingly being made, especially for large-scale or public implementations.

In the future, integrating piezoelectric technology with other energy harvesting technologie e.g., solar,wind-mill based, triboelectric, or electromagnetic harvesting,would provide strong hybrid systems. Not only would it enhance the overall amount of energy supplied, but also system reliability over a variety of different environments and usage patterns.

There is also plenty of room for innovation in the physical design itself. With even more sophisticated structures of piezo material like PVDF or PZT, and with improved surfaces for sensing foot pressure, you can get much higher levels of energy conversion. And as we move toward smart cities, putting this technology into everyday architecture—like sidewalks, stairs, or public transit stops—can turn ordinary human activity into a source of substantial energy.

In the long run, the integration of artificial intelligence to monitor patterns of pedestrian flow can potentially optimize the location and placement of such systems to achieve maximum efficiency. With continuous research and interdisciplinary research in material science, electronics, and urban planning, footstep-generated energy can potentially be a common source of clean, dispersed energy in the future.

VII. Conclusion

The piezoelectricity-driven footstep power generator is an intelligent and sustainable method to utilize the straightforward motion of walking as source of renewable energy. By harvesting the kinetic energy created by the humans walk and translating that into electricity, this technology promotes energy efficiency and promotes the movement towards the exclusion of conventional, non-renewable sources of energy.

Installing piezoelectric sensors under walking surfaces such as public areas with heavy foot traffic like railway stations,stadiums,airports, and shopping malls—provides a constant, consistent means of harvesting energy from normal movement. This electricity can be stored and utilized to supply energy for small and vital devices such as LED lighting, electronic displays, sensors, or charging stations.

What makes this system especially attractive is the fact that it is easy to install and has minimal maintenance requirements which is cheap in cost , and operates silently, making it a ideal solution for the modern city setting. Ultimately, footstep-powered generation is an achievable step towards the creation of cleaner, smarter, and more sustainable cities—where even our footsteps contribute toward powering the future.

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