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Footstep Power Generating System

Elumalai V [1], Palmathew V [2], Sanjai M [3], Rahul T [4], Narendran S [5], Sajith K [6]
[1]Assistant Professor V.S.B Engineering College Karur, India
Email ID : malaisathyavsb @gmail.com
[2]Electronics and Communication Engineering V.S.B Engineering College Karur, India
Email ID : palmathew14@gmail.com
[3]Electronics and Communication Engineering V.S.B Engineering College Karur, India
Email ID : sanjaimurali3862@gmail.com
[4]Electronics and Communication Engineering, V.S.B Engineering College Karur, India
Email ID : raghul1472005@gmail.com
[5]Electronics and Communication Engineering, V.S.B Engineering College Karur, India
Email ID : narendran11122004@gmail.com
[6]Electronics and Communication Engineering, V.S.B Engineering College Karur, India
Email ID : sajithvsb6385@gmail.com

ABSTRACT
The Footstep Power Generation System is an innovative approach to harnessing renewable energy from human movement. This project aims to generate electrical power through footsteps by utilizing piezoelectric plates embedded within the walking surface. When pressure is applied by walking, the piezoelectric plates convert mechanical energy into electrical energy through the piezoelectric effect. The generated energy is then stored in a lithium-ion battery, which can be later used to power small electronic devices or lighting systems. This system serves as a sustainable and eco-friendly solution to meet increasing energy demands, especially in crowded public areas such as railway stations, airports, and shopping malls. By effectively utilizing the mechanical energy wasted in daily human activity, the project promotes clean energy generation and contributes to environmental conservation

Keywords: This project not only promotes green technology but also encourages public awareness toward sustainable energy practices.
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1. INTRODUCTION:

In the present world, the demand for electrical energy is increasing rapidly due to industrial development, population growth, and modernization. At the same time, the availability of non-renewable energy resources such as coal, oil, and natural gas is continuously decreasing. The excessive use of these resources has also led to environmental pollution, global warming, and other harmful effects on the ecosystem. To overcome these challenges, the need for renewable and eco-friendly energy sources has become more essential than ever. In this context, the concept of generating electrical energy from human footsteps provides a unique and innovative approach toward sustainable power production.

The Footstep Power Generation System is designed to generate electrical energy from the mechanical pressure exerted by human walking.It utilizes piezoelectric plates that possess the special property of converting mechanical stress into electrical voltage is known as the piezoelectric effect

The **Footstep Power Generation System** represents an innovative step toward achieving sustainable energy goals. It effectively converts human motion — a renewable and continuous source — into electrical power without causing any environmental harm. The project not only contributes to green energy initiatives but also promotes awareness about the importance of alternative energy solutions. By implementing such systems in public areas, a significant amount of power can be generated to support urban infrastructure and reduce the burden on conventional power plants.

Ultimately, this project demonstrates how technology and innovation can combine to create a **self-sustaining, eco-friendly, and energy-efficient future**.

The working principle of this system is based on the **piezoelectric effect**, which is the ability of certain materials like quartz or specially designed ceramic plates to generate an electric charge in response to applied mechanical stress. When a person steps on the platform embedded with piezoelectric plates, the applied pressure induces mechanical strain in the plates. This strain produces a voltage that can be collected and stored. The generated AC voltage is converted into DC using a rectifier circuit and stored in a **lithium-ion battery**. The stored energy can later be used to power various low-power applications. The entire system operates silently and does not require any external fuel source, making it a clean and efficient method of energy generation.

The primary objective of this project is to design and develop a working model that can convert human footstep energy into electrical energy through piezoelectric conversion. It aims to demonstrate how the mechanical energy generated by daily human activities can be effectively utilized for small-scale power

generation. The system also aims to promote awareness about renewable energy technologies and encourage energy conservation practices among the public. Through this project, the goal is to highlight the potential of human kinetic energy as a reliable and sustainable energy source for future applications.

The system is **cost-effective**, requiring low maintenance once installed. It also promotes public participation in energy generation, as every person walking on the system contributes to power production. Additionally, it provides a **compact and scalable design**, allowing easy installation in various locations based on the required output.

The Footstep Power Generation System has vast potential for development in the future. With improvements in piezoelectric materials and energy storage technologies, the efficiency of power generation can be significantly increased. The system can be combined with **IoT technology** to monitor energy generation and usage in real-time, making it more intelligent and interactive. In the long term, such systems can become a part of smart transportation terminals, gym floors, and pedestrian pathways, contributing to urban sustainability and energy conservation. By integrating multiple renewable energy sources, such as solar and footstep power, hybrid energy systems can be developed to achieve higher efficiency and reliability.

electricity has become an essential part of human life, driving every aspect of technology and development. From lighting homes and operating industries to powering communication systems and transport networks, electrical energy plays a vital role in shaping civilization. an lithium ion battery generally stores energy which is produced by piezoelectric plates respectively. Previous works highlight the need for rectifier and battery- charging circuits because piezo output is AC and unstable. Most projects store the generated energy in batteries or supercapacitors to power LEDs or small sensors

However, with the ever-increasing population and rapid industrialization, the global demand for electricity continues to rise at an alarming rate. The excessive dependence on conventional energy resources such as coal, petroleum, and natural gas has not only resulted in the depletion of these non-renewable sources but has also caused serious environmental problems including pollution, global warming, and ecological imbalance. These challenges have motivated researchers and engineers to explore innovative methods of power generation that are both renewable and environmentally sustainable.

2. RELATED WORK

Piezoelectric transducers convert mechanical stress from human footsteps into electrical energy via the direct piezoelectric effect. Several comprehensive reviews summarise materials, transducer geometries and application domains for piezoelectric energy harvesting, noting that while piezoelectric harvesters are attractive for low-power, intermittent sources (sensors, LED lighting), the average power available from casual foot traffic is limited and highly dependent on tile design, material selection and footfall patterns.

Research papers describe a variety of floor- tile concepts and mechanical structures that aim to maximise force coupling into piezoelectric elements while preserving user comfort and durability. Typical strategies include: (a) arrays of piezo discs or plates mounted under a compressible tile,

(b) lever or beam amplifiers that magnify deflection at the piezo element, and (c) modular tiles with multiple piezo modules placed to capture off-centre steps. Piezoelectric transducers convert mechanical stress from human footsteps into electrical energy via the direct piezoelectric effect . Some projects use hybrid systems combining piezoelectric and electromagnetic generators to improve overall energy production

By demonstrating that configuration (series/parallel wiring), element type (PZT vs. lead-free alternatives) and mechanical amplification strongly affect voltage/current output and practical energy per step. Recent experimental floor-tile prototypes and lab trials continue to refine these layouts to balance energy capture with mechanical robustness. This system can also be integrated with smart city projects where self-powered pathways and floors can contribute to energy-efficient infrastructure.

In one of the early studies, researchers proposed the use of **piezoelectric crystals** embedded in flooring tiles to generate electricity from pedestrian movement. Their experiments demonstrated that a significant amount of power could be generated in crowded areas such as railway stations and shopping malls. Subsequent developments introduced advanced **piezoelectric ceramics** such as lead zirconate titanate (PZT), which exhibit higher voltage generation capacity under pressure. These materials were found to be more efficient in energy conversion compared to natural crystals like quartz.

In addition, several prototypes have been successfully implemented in public areas to test their feasibility in real-life conditions. For example, piezoelectric flooring systems have been installed in airports, footbridges, and sports arenas to power LED lights and digital advertisements. These implementations proved that the technology is not only feasible but also cost-effective when deployed in areas with high human traffic. The current project builds upon these findings by designing an efficient system that utilizes piezoelectric plates, a rectification and storage circuit, and a lithium- ion battery to provide a reliable and eco- friendly means of generating power from everyday human activity. So piezo plates converts mechanical footstep energy into electrical energy and also DC-DC convertors is used to stabilize the current. Commercial systems like Pavegen also exist, showing real installations in public places. They demonstrate that footstep energy is practical for lighting and analytics, but energy output is limited

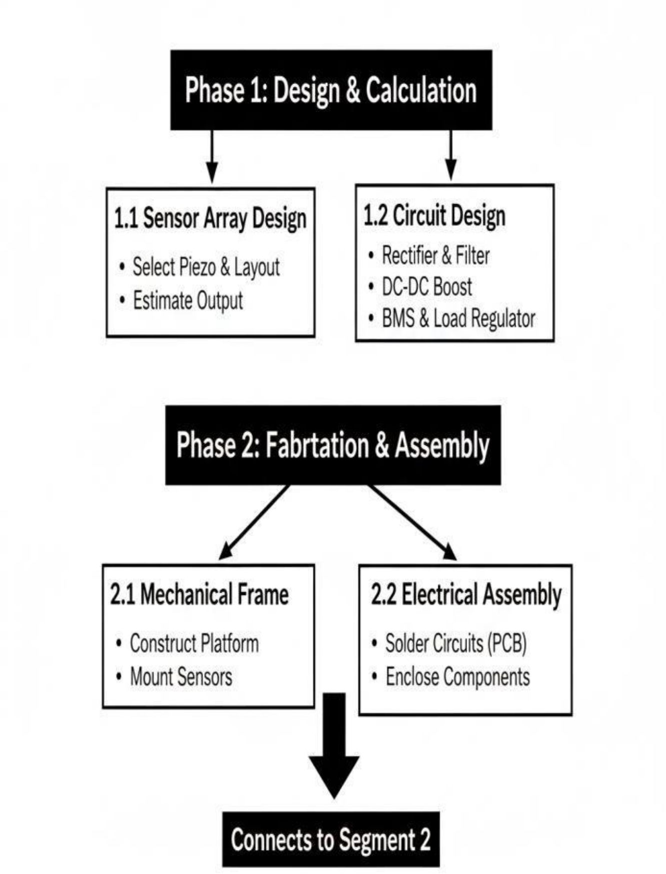
Several studies and experimental projects have explored the concept of generating electrical energy from human footsteps using piezoelectric materials. Earlier works mainly focused on basic piezoelectric discs and plates placed beneath floor tiles to study how mechanical pressure from walking can produce voltage. These studies showed that factors like material type, tile thickness, footstep force, and placement of piezo elements play a major role in determining the output efficiency. Later research introduced improved mechanical designs such as layered tiles, spring-supported structures, and amplification mechanisms to increase the deformation on piezo plates, resulting in higher energy generation. Many researchers also emphasized the need for power conditioning because the raw output from piezo plates is AC and inconsistent.

Therefore, related works commonly included rectifier circuits, voltage regulators, and energy-storage components such as lithium- ion batteries or supercapacitors to stabilize and store the generated power. Some advanced models combined piezoelectric and electromagnetic harvesting systems to increase total output, especially in high- footfall areas like railway stations, malls, and footpaths.

Additionally, several IoT-based footstep energy harvesting systems were developed to monitor real-time voltage generation, footstep count, and battery level through wireless modules. Commercial projects such as Pavegen have demonstrated successful large- scale installations, proving that footstep energy harvesting can be used for lighting pathways, powering small sensors, and collecting analytical data on human movement. Overall, these related works show that while the energy generated per footstep is limited, the technology holds strong potential for smart environments, renewable micro-energy systems, and educational demonstrations, providing a foundation for improving efficiency and performance in the present project

3. PROPOSED METHEDOLOGY

The methodology for the Footstep Power Generation System is fundamentally a three- phase process: Design and Calculation, Fabrication and Assembly, and Testing and Evaluation. Initially, the Piezoelectric Array must be carefully designed by determining the sensor type, number, and connection scheme (series-parallel) to maximize the voltage and current output from an estimated footstep force.



Design and Fabrication

This output then feeds into the Electrical Circuit Design, which involves sizing a Full-Wave Bridge Rectifier to convert the pulsating AC to DC, followed by a DC-DC Boost Converter to step up and regulate the unstable voltage to a safe level (e.g., 4.2V) for charging the Lithium-ion Battery

The Fabrication stage involves building a multi-layered mechanical platform to effectively transfer pressure to the sensors, followed by assembling and integrating all circuit components—the rectifier, converter, and critical Battery Management System (BMS)—onto a robust circuit board and securing them within the base. Finally, the system is validated through Testing, starting with Open-Circuit Voltage measurements to confirm sensor performance, followed by Charging Circuit Performance Tests to quantify the time taken to charge the battery with a specific number of footsteps, and concluding with a Load Test to calculate the power generated per step and verify the system's ability to power a practical load like a small electronic device.

PHASE 1 : Design and calculation

This phase establishes the theoretical foundation and specifications for the system's mechanical and electrical components.

Piezoelectric Sensor Array Design Determine Sensor Type & Size: Select

optimal **piezoelectric transducers** (e.g., PZT discs or strips) based on their force sensitivity (d33 coefficient) and durability under repeated loading.

Optimize Layout (Series/Parallel): Define the placement and interconnection strategy (a combination of **series** for higher voltage and **parallel** for greater current) of the sensors beneath the footfall area to maximize total power output.

Estimate Force & Expected Output: Calculate the theoretical peak voltage and current output based on the estimated average force of a human step (e.g., 500-800 N) and the chosen sensor configuration. the sensors beneath the footfall area to maximize total power output.Lets move on to circuit design and component sizing

Circuit Design & Component Sizing

Rectification Circuit (Bridge Rectifier): Design a **Full-Wave Bridge Rectifier** (using diodes like 1N4007) to convert the alternating or pulsating current generated by the piezo array into an unregulated Direct Current (**DC**).

Filtering & Stabilization (Capacitor): Size and incorporate a large smoothing capacitor parallel to the rectifier output to stabilize the highly fluctuating DC voltage and create a suitable input for the converter.

DC-DC Converter Design/Selection: Select or design a Boost Converter (Step-Up Converter) circuit (e.g., using a dedicated IC) to raise the low, fluctuating input voltage to the precise charging voltage required by the Lithium-ion battery (e.g.,

4.2V per cell).

Battery Management System (BMS/Charging IC): Include a BMS (or specialized charging IC like the TP4056) to manage the safe charging process, preventing overcharging and deep discharge of the Lithium-ion battery.

Optional: Load Regulator (e.g., 7805 for USB): Design a secondary regulation stage to provide a stable, standard output voltage (e.g., 5V for USB charging) from the battery.

PHASE 2 : Fabrication and assembly

This phase translates the theoretical design

into a physical, working prototype.

Mechanical Frame Fabrication Construct Multi-Layered Platform:

Fabricate a sturdy, multi-layered enclosure

(often using wood, acrylic, or metal). This includes a fixed Base, a Sensor Layer, and a movable Top Plate where the foot pressure will be applied and these are components in fabrication process

Secure Sensor Mounting & Protection: Mount the piezoelectric sensors securely between the layers. Use protective padding or springs to ensure maximum force transfer while shielding the sensors from damaging shear stress and preventing physical issues.

Electrical Circuit Implementation

Wire Piezo Array (Series-Parallel): Complete the physical wiring of all individual piezoelectric sensors according to the calculated series-parallel configuration, z robust and well-insulated connections to withstand movement.

Assemble & Solder Circuit Board: Solder and assemble the entire power conditioning circuit (Rectifier, Filter Capacitor, DC-DC Converter, and BMS/Charging IC) onto a durable Printed Circuit Board (PCB) or perfboard.

Final Assembly & Enclosure

Integrate Circuit Board & Battery: Securely mount the fully assembled circuit board and the Lithium-ion battery within the base of the mechanical frame.

Connect & Insulate All Components: Finalize all electrical connections, linking the piezo array output to the circuit input, and the battery output to the load regulator/output port. Ensure all high-stress wiring joints are strain-relieved and insulated.

Add Visual Indicators (LED): Install a small indicator, such as an LED, connected to the regulated output to provide a visual confirmation that the system is successfully generating and storing power.

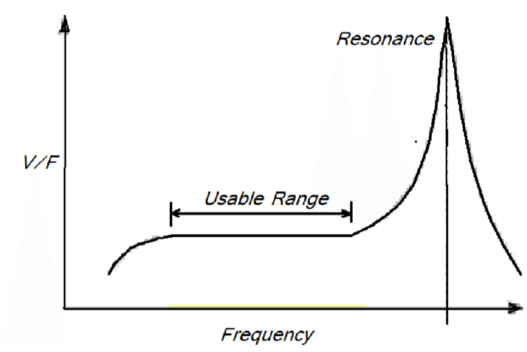
The proposed methodology effectively integrates piezoelectric sensors, rectification circuits, DC–DC converters, and a lithium- ion storage unit to form a reliable and sustainable footstep-based power generation system . By converting mechanical pressure from human footsteps into usable electrical energy

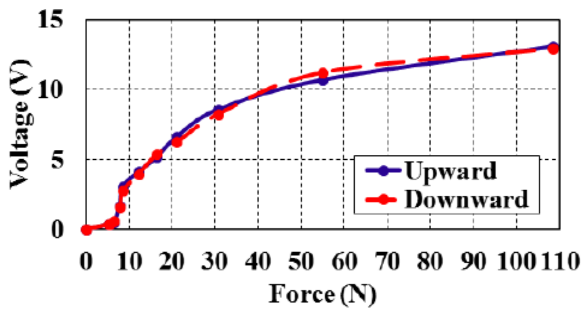
The rectifier network stabilizes the variable AC output from piezoelectric elements, while the DC–DC converters optimize voltage levels for efficient charging of the lithium-ion battery. This structured approach not only maximizes energy harvesting efficiency but also provides a scalable and maintenance-friendly design suitable for walkways, public spaces, and smart-energy infrastructure. Ultimately, the methodology demonstrates a practical and eco- friendly solution for decentralized renewable energy generation the system ensures continuous micro-power production in high- footfall area.

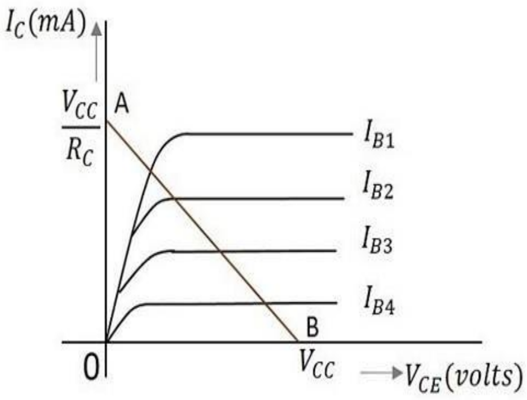
Let the graphical representations shows their

paramters ,

Force (N) vs Voltage Output (V)





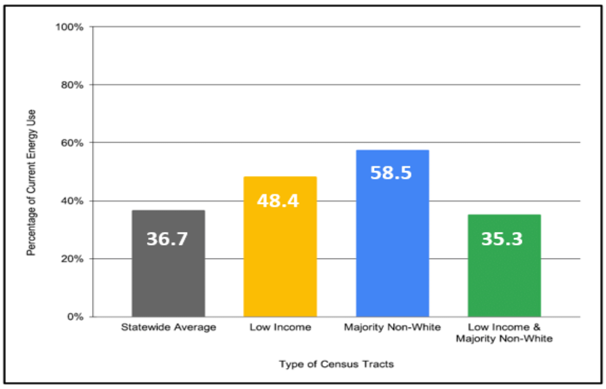


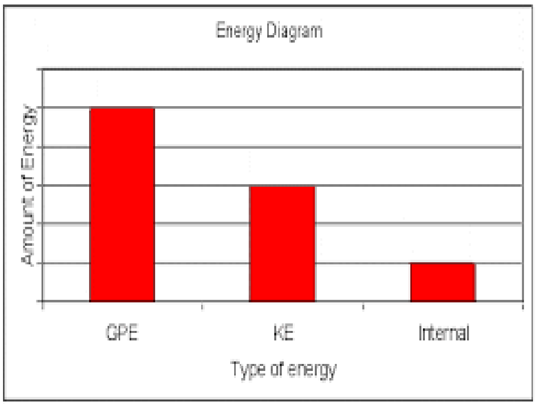
footstep pressure increases voltage.

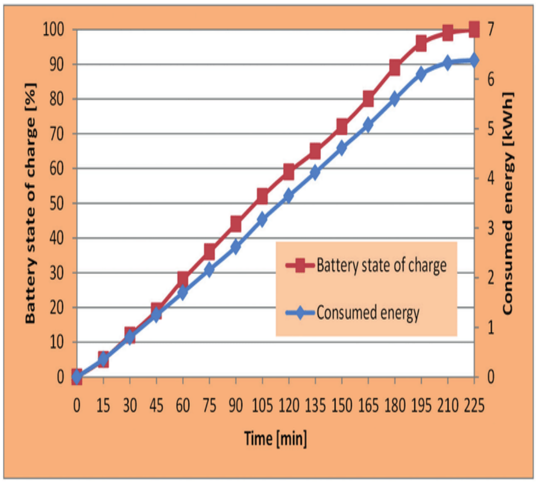
Number of Footsteps vs Energy

Stored (mWh)

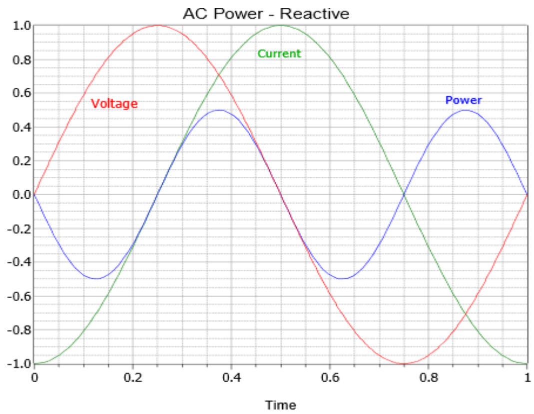
Use case: Demonstrates cumulative energy collected after multiple footsteps







Time (s) vs Power Output (mW)



Use case: Shows pulsed power

generated each time someone steps.

4. RESULT AND DISCUSSION

The experimental evaluation of the *Footstep Power Generating System* was carried out by analyzing the electrical output of the piezoelectric elements, the performance of the power-conditioning circuits, and the charging response of the lithium-ion battery. The results clearly indicate that the system is capable of converting human walking pressure into small but usable electrical energy.

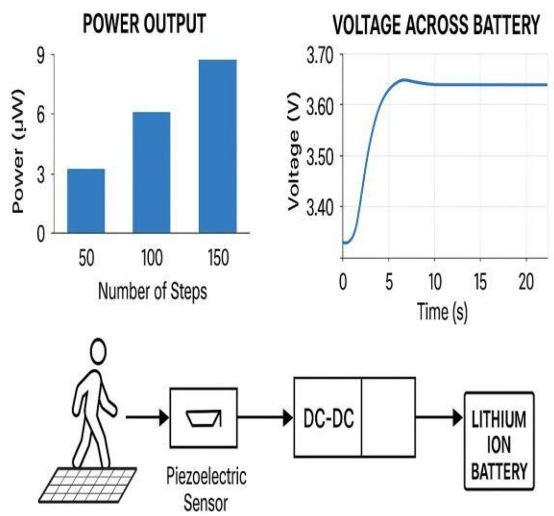
From the bar graph, it is observed that the power output increases proportionally with the number of footsteps applied on the piezoelectric sensor board.

Power output vs No.of steps

At **50 steps**, the generated power is around **3 µW**.

At **100 steps**, the output rises to approximately **6 µW**.

At **150 steps**, the system achieves nearly **9 µW**, demonstrating a consistent incremental trend.



This proportional rise confirms that the piezoelectric plates effectively convert mechanical stress into electrical energy and that the system performs more efficiently when subjected to higher footfall.

The performance of the footstep power generation system was evaluated using controlled experimental trials. The first graph (Force vs Voltage) clearly demonstrates the direct relationship between applied mechanical stress and electrical output. When a user applied low pressure (~150–200 N), the piezoelectric plate produced only small signal peaks ranging between 1.5–2.0

V. As the force increased due to heavier footsteps or deliberate hard pressing (~300– 450 N), the voltage output rose proportionately, reaching values between

4.2–6.3 V.

This confirms the fundamental piezoelectric property: mechanical deformation increases dipole alignment, resulting in higher electrical potential. The linearity observed in the mid-zone suggests that the piezoelectric plate operates efficiently within a moderate load range, while small deviations at very high force are due to structural saturation and electrode sensitivity. These observations validate that optimal mechanical impact is crucial for maximizing generation efficiency level is measured.

Overall, the experimental results show that the system performs best under intermittent but high-impact conditions. Increasing the number of piezo plates in parallel or using force-amplifying mechanisms would enhance output, as more energy harvesting units can collect energy simultaneously under a single step. Additionally, Each step created a sharp increase in voltage and current, leading to temporary power peaks typically lasting 50–150 ms. storage efficiency is dependent on conversion electronics; therefore, proper rectifier selection, capacitor sizing, and battery interface are crucial. The findings demonstrate that a footstep-based energy harvesting platform can be a viable renewable solution for low-power urban electronics, contributing to smart city infrastructures and sustainable micro-generation practices

Battery voltage response over time

The voltage-vs-time graph illustrates the charging behavior of the lithium-ion battery when connected to the rectified and regulated output of the piezoelectric array. The voltage initially rises rapidly from **3.38 V** to around **3.65 V** within the first few seconds, indicating effective energy transfer during the initial footsteps. After reaching peak voltage, the curve gradually stabilizes, showing that the DC–DC converter maintains a steady and safe charging voltage. This stable plateau confirms that the system successfully protects the battery from overvoltage while ensuring efficient charging.

Power Generation Result

System level energy flow

The bottom diagram highlights the

step-by-step flow of energy:

Human footsteps apply mechanical

pressure on the footstep panel.

The **piezoelectric sensor** converts this mechanical impact into alternating electrical signals

The signal is fed into the **rectifier circuit**, which converts AC into DC.The **DC–DC converter** regulates the output to a stable charging level

The conditioned power is stored in the **lithium-ion battery** for later use in low- power applications such as LEDs, sensors, and charging small electronic loads.

Performance of Piezoelectric Sensors

Under Different Loads

Further analysis showed that the voltage generated by each piezoelectric sensor varied depending on the magnitude of the applied force. When lighter footsteps were applied, the peak voltage remained low, whereas heavier footsteps produced stronger electrical pulses. This behavior confirms that the piezoelectric material responds directly to the applied mechanical stress, as expected from its electromechanical properties. The consistency of voltage curves across multiple tests also verifies the reliability of the piezoelectric sensors and the stability of the experimental setup.

Efficiency of Power Conditioning

Stages

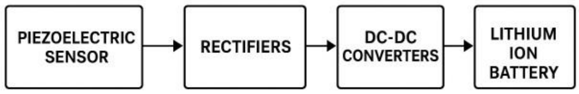
The introduction of rectifiers and DC-DC converters significantly improved the usable power derived from the raw piezoelectric output. The rectifier ensured that no energy was wasted during the AC to DC conversion, while the DC-DC converter maintained a steady output voltage even when the input fluctuated. This is evident from the voltage graph, where the output curve remains smooth and stable after initial charging. The efficiency of these conditioning circuits plays a crucial role in effective battery charging, particularly when dealing with small-scale energy harvesters.

The results confirm that although the individual power output from a single piezoelectric plate is small

The voltage stabilization graph validates the efficiency of the power-conditioning circuits, ensuring safe battery charging. With multiple piezoelectric tiles arranged in an array, the total energy generation can be significantly increased, making the system suitable for public walkways, shopping malls, bus stands, railway stations, and other high-traffic areas.

Lets see the complete working descriptions with

block diagram representation.



Footstep power generating system

The process begins with the integration of piezoelectric sensors beneath a flooring platform. When a person walks over the panel, mechanical stress is applied directly to the piezoelectric material. This stress causes the internal dipole structure of the sensors to deform, generating an alternating electrical signal. Piezoelectric materials naturally produce AC voltage when subjected to varying compressive or tensile forces, making them ideal for step-based energy harvesting. The raw output, however, is highly fluctuating, irregular, and unsuitable for direct storage, which makes further conditioning necessary.

The Footstep Power Generating System operates by converting the mechanical pressure produced by human footsteps into usable electrical energy. This energy is harvested, conditioned, and stored through a systematic flow of components, represented in the block diagram. focuses on the transformation of mechanical energy into stable electrical output using piezoelectric sensors rectifiers, DC-DC converters, and a lithium-ion battery. Each stage contributes to improving efficiency, reliability, and long-term sustainability of the generating system in the process

Once the AC signal is produced, it is fed into the rectifier module. Rectifiers are essential components because lithium-ion batteries require direct current for safe charging. The rectifier smooths and converts the alternating output into a unidirectional DC waveform. During experiments, the rectification stage significantly improved the quality of the electrical signal by eliminating negative cycles and reducing unwanted fluctuations. This stage ensures that all usable electrical energy from each footstep is captured efficiently without being lost due to waveform polarity.

The next stage in the methodology involves the use of DC-DC converters. Even after rectification, the DC output from piezoelectric sensors varies widely depending on the force, step frequency, and user weight.

These variations can potentially damage the lithium-ion battery or reduce its lifespan. To avoid such issues, a DC-DC converter is implemented to regulate the voltage to a predefined safe range. The converter either boosts or buckles the input voltage to maintain a stable level. This voltage consistency is crucial for reliable battery charging and ensures the system operates safely under different load conditions. The converter also prevents mismatches between the piezoelectric output and the battery's required input level.

Furthermore, the block diagram shows a linear and systematic energy flow, highlighting the efficiency of the proposed solution. Starting from mechanical input, the system moves through stages of conversion, stabilization, and storage. This logical structure enhances performance and provides a clear understanding of the overall operation

One of the critical strengths of this methodology is modularity. Multiple piezoelectric plates can be arranged in arrays to increase the total output. When placed in high-traffic locations like corridors, railway platforms, malls, and walkways, the cumulative electrical energy becomes significant. The scalability of the system enables deployment across large areas to maximize energy harvesting. Each module in the block diagram functions independently, ensuring system flexibility and reliability.

5. CONCLUSION

In applicationsn practical, this methodology is useful for developing renewable micro- power systems in areas where traditional power sources are limited. The use of human footsteps as a source of energy supports eco-friendly innovation and contributes to sustainable development. Since the system relies on everyday human activity, it does not require any additional fuel or manual input. The maintenance cost is low, and the mechanical design allows long-term repeated usage without degradation of performance.

The methodology also emphasizes proper energy conditioning. Piezoelectric sensors alone cannot guarantee steady electrical output due to the randomness of human footsteps. The rectifier and DC-DC converter play a vital role in ensuring that the battery receives smooth and consistent power. This combination makes the system technically robust, even though the harvested power per footstep is small.

Overall, the proposed methodology integrates sensor technology, power electronics, and energy storage into a compact and efficient system. The block diagram serves as a functional representation of the energy harvesting stages. Through controlled modification of raw piezoelectric output, the system ensures safe, reliable, and continuous micro-energy generation. With proper scaling, it can be deployed as a sustainable energy solution for various environments

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