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Energy Harvesting from Footsteps with Real-Time Output Visualization

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Abstract: *Urban energy demands continue to rise, with much of daily human movement going untapped as a resource. To explore alternative energy sources, this project introduces an "Electricity Generation from Footsteps with Real-Time Output Display" system utilizing piezoelectric plates and Arduino UNO, offering an innovative and eco-friendly way to capture and visualize energy generation from human steps. This system aims to convert mechanical pressure into usable electric power and display the output in real time, ultimately enhancing energy awareness and micro-power harvesting potential.*
For energy generation, piezoelectric sensors are embedded beneath a footstep platform to capture mechanical stress and convert it into electrical signals. The output from these sensors is rectified, regulated, and sent to the Arduino, which calculates the voltage produced and displays it on an LCD screen. This allows real-time tracking of energy output with every footfall, helping to educate users about renewable energy. The display system is powered by the same harvested energy stored in a rechargeable battery, ensuring smooth and independent operation. This project presents a cost-effective and modular approach to sustainable power generation in public or high-footfall zones.By integrating low-cost hardware and simple interfacing algorithms, the system provides a practical method for converting physical activity into usable energy. It highlights the potential of piezoelectric energy harvesting as a reliable source in compact and crowded environments. The inclusion of a real-time display not only measures output effectively but also encourages user interaction and awareness of sustainable energy literac..

Keywords: Footstep Energy, Piezoelectric Sensor, Arduino Uno, LCD Display, Energy Harvesting

I. INTRODUCTION

The Electricity Generation from Footsteps with Real-Time Output Display is an innovative energy harvesting technique designed to utilize the pressure exerted by human footfalls to generate electricity. This project leverages the piezoelectric effect, where mechanical stress on certain materials produces electric charge, and integrates it with an Arduino-based system to display real-time output. The pressure generated during walking or stepping is captured by piezoelectric sensors embedded beneath a flooring surface. The raw electrical energy is then rectified and regulated before being monitored and displayed on an LCD screen. This interactive setup allows users to observe the energy generated by each footstep, offering immediate feedback and enhancing public awareness about renewable energy applications. Simultaneously, the stored energy can be used for small-scale electrical applications like lighting LEDs or charging small batteries. It operates independently using harvested energy, eliminating the need for external power sources. This approach is highly scalable and can be deployed in locations with high pedestrian traffic such as footpaths, railway stations, or school corridors. By turning everyday human motion into a usable energy source, the project aims to promote green energy practices.

II. LITERATURE SURVEY

Electricity generation from footsteps has attracted considerable research interest due to the rising demand for renewable energy solutions and sustainable infrastructure. Traditional energy systems primarily rely on non-renewable resources,

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which are not only finite but also contribute significantly to environmental degradation. Footstep-based energy harvesting offers a clean, human-powered alternative by converting the mechanical energy generated during walking into usable electrical energy. Research in the field of energy harvesting has seen significant advancements, particularly in capturing ambient energy from human activity. Various studies have explored piezoelectric materials as a source of clean and sustainable power. Early systems focused on wearable technology that used body motion to charge low-power devices, but their efficiency was limited due to surface area constraints. To address this, more recent developments introduced floor-based piezoelectric energy harvesters, which are better suited for environments with high pedestrian movement, such as airports and railway stations.

In a study conducted by Gupta et al., piezoelectric plates embedded in footpaths demonstrated the ability to generate small voltages sufficient to power LED lights. However, their system lacked real-time output visibility, reducing user engagement. Another work by Sharma and Rao implemented a similar mechanism with multiple piezo tiles in parallel to increase voltage levels, but without any digital display interface or storage optimization. The addition of microcontrollers like Arduino has improved the usability of such systems, allowing integration with display modules and energy regulation circuits for enhanced user interaction. Moreover, advances in low-power electronics and microcontroller programming have made it feasible to build compact systems that can both measure and display energy in real time. Some recent designs also incorporated wireless modules for data transmission, although cost and complexity increased significantly.

III. EMBEDDED SYSTEMS

Embedded systems play a crucial role in enabling efficient real-time monitoring and control in renewable energy applications. In this project, the embedded system is built around the Arduino Uno microcontroller, which processes electrical signals generated by piezoelectric sensors placed beneath a walking surface. These sensors produce small AC voltages when pressure is applied. The generated signals are first rectified using a bridge rectifier, then regulated to provide a stable DC output, which is fed to the Arduino for analysis and output display. This localized data processing ensures immediate feedback without the need for external computation or communication modules.

The Arduino Uno is programmed to continuously read the voltage produced by foot pressure and convert it into readable output for display. The results are shown in real-time on a 16x2 LCD module, which is also controlled by the microcontroller. This embedded setup eliminates the need for complex external systems, making it compact and energy-efficient. The system's responsiveness enables users to visualize the amount of energy generated with every step, enhancing the learning and interactive aspect of the project. Moreover, the stored energy can be used to power small loads such as LED indicators, demonstrating how embedded platforms can bridge sensing, processing, and energy utilization in a single framework. This integration makes the solution practical, self-contained, and ideal for public or educational installations.

IV. ENERGY HARVESTING

Energy harvesting refers to the process of capturing and converting ambient energy from the environment into usable electrical energy. In the context of this project, energy is derived from human footsteps using piezoelectric sensors, which generate electrical voltage when subjected to mechanical pressure. This concept is particularly effective in areas with high pedestrian activity, where consistent foot traffic provides a reliable source of mechanical input. By converting this normally wasted kinetic energy into usable power, the system supports sustainable energy practices and offers a clean alternative to conventional electricity sources.

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V. EXISTING SYSTEM

Existing systems for electricity generation from footsteps primarily utilize piezoelectric technology to convert mechanical energy into electrical energy. These setups are often implemented in flooring tiles placed in high-footfall areas like railway stations, shopping malls, or pedestrian walkways. Most of these systems focus on lighting low-power devices such as LEDs or storing energy in small batteries for later use. However, many of them are limited in terms of user interaction and do not provide real-time feedback or monitoring of the energy generated.

Some existing models incorporate piezo plates connected directly to rectifiers and basic charging circuits but lack intelligent processing or display mechanisms. This makes it difficult for users to assess the effectiveness or contribution of each footstep. In addition, the systems are generally not modular or portable, reducing their adaptability across different environments. While they prove that piezoelectric harvesting is feasible, the absence of microcontroller integration restrictstheir functionality. Therefore, there is a need for more advanced, educational, and user-engaging models that demonstrate both energy harvesting and real-time output in a cost-effective and scalable manner.

VI. PROPOSED METHOD

The proposed system is designed to convert the mechanical energy generated by human footsteps into electrical energy using piezoelectric sensors. These sensors are placed under a pressure platform, where they detect the force exerted by a person's footsteps. The piezoelectric effect causes the sensors to generate an alternating current (AC) voltage when subjected to pressure. This generated AC voltage is then passed through a bridge rectifier circuit, which is responsible for converting the AC signal into a pulsating direct current (DC) voltage. Although this DC signal is usable, it still fluctuates, so capacitors are employed to smooth out the ripples and provide a steady DC output, ensuring the voltage is stable for further processing.

Once the voltage is smoothed, it is fed into a voltage regulator, which ensures the output voltage remains within a safe range for all the connected components. The regulated voltage is typically around 5V, which is ideal for powering the microcontroller and the display. The core of the system is the Arduino Uno, which functions as the central controller. The Arduino receives the analog input from the piezoelectric sensors and processes it using its internal analog-to-digital converter (ADC). The processed voltage data is then displayed in real-time on a 16x2 LCD display, providing immediate feedback about the energy generated with each step. This live data display not only visualizes the voltage but also serves to engage users, increasing awareness of the potential for sustainable energy generation. Additionally, the generated energy is stored in a rechargeable battery. This feature allows the system to accumulate excess energy during periods of activity, enabling it to be used later for powering small devices, such as LEDs or sensors. The inclusion of the battery storage system makes the energy harvesting process more efficient, ensuring the energy generated is put to good use, even when footsteps are not being actively detected

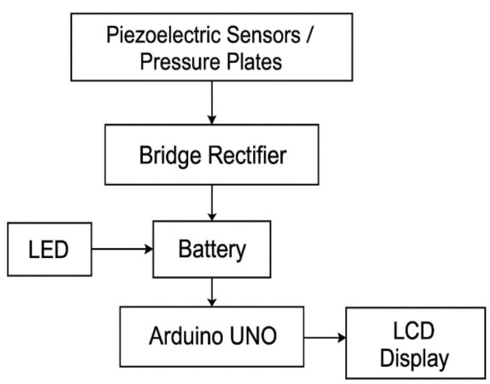

Figure 1 : Block Diagram

This Overall, the proposed system is not only an innovative approach to energy harvesting but also a demonstration of sustainable energy generation in real-time. The system is designed to be cost-effective, compact, and suitable for deployment in various public spaces, such as shopping malls or airports, where human movement is constant. It effectively showcases how everyday human activity can be transformed into valuable electrical energy, promoting the importance of renewable energy sources and energy conservation.

VII. SOFTWARE EMPLOYED

Thesoftware component of the proposed system is developed using the Arduino IDE, which is an open-source integrated development environment widely used for programming Arduino microcontrollers. The IDE provides a user-friendly interface for writing and uploading code to the Arduino Uno, allowing for efficient control of the entire system.The Arduino code is designed to perform several key functions. Firstly, it reads the analog signals from the piezoelectric sensors, which are proportional to the force applied by a person's footsteps. The analog values are then processed to calculate the corresponding voltage generated by each step. The calculated values are displayed in real-time on the 16x2 LCD module, providing an immediate visual representation of the generated energy.

The software also handles the voltage regulation process, ensuring that the output remains within safe limits for both the Arduino and connected peripherals. The system is designed to dynamically adjust based on input voltage fluctuations, ensuring stable operation throughout different scenarios.

Additionally, the code is written to manage the battery charging process, allowing the system to store excess energy for later use. The Arduino ensures that the rechargeable battery is properly charged and prevents overcharging, thus prolonging its lifespan and ensuring efficient energy storage.The entire system is programmed to be highly responsive and efficient, with minimal power consumption, making it ideal for real-time energy generation and monitoring applications

VIII. RESULTS

The proposed systemfor electricity generation from footsteps was successfully implemented and tested under real-time conditions. The piezoelectric sensors embedded beneath the pressure platform responded effectively to human footsteps, producing a measurable alternating voltage. During testing, it was observed that each footstep could generate an AC voltage ranging between 2V to 9V depending on the intensity and weight of the foot impact. This AC voltage was efficiently converted into DC using the bridge rectifier and further stabilized using filter capacitors and a voltage regulator.

The regulated voltage was fed into the Arduino Uno, which accurately read the analog values and displayed the corresponding real-time voltage output on the 16x2 LCD screen. The display provided immediate feedback, indicating the voltage generated with each step, which helped in analyzing the energy production efficiency. It was noted that repeated footsteps over a short duration led to continuous power generation, which could be effectively stored in a rechargeable battery.

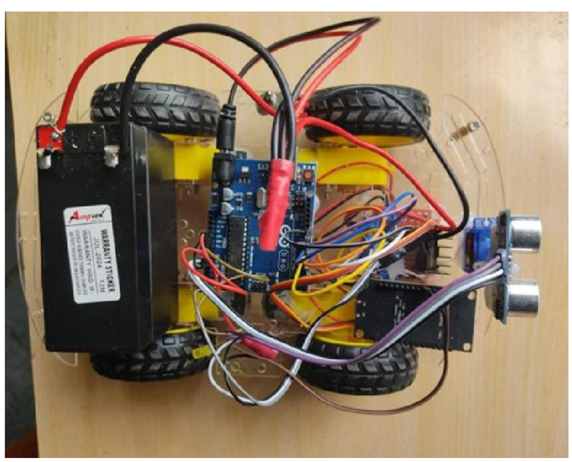

Figure3:Project Prototype

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Furthermore, the stored energy was successfully used to power small loads like LEDs, proving that the harvested energy could be utilized practically. The system performed consistently and demonstrated its potential for deployment in crowded areas such as railway stations, malls, or corridors, where frequent human movement occurs.

Result:The project achieved its goal of converting mechanical energy from footsteps into electrical energy and providing real-time monitoring, validating the concept of sustainable energy harvesting through piezoelectric technology.

Output:

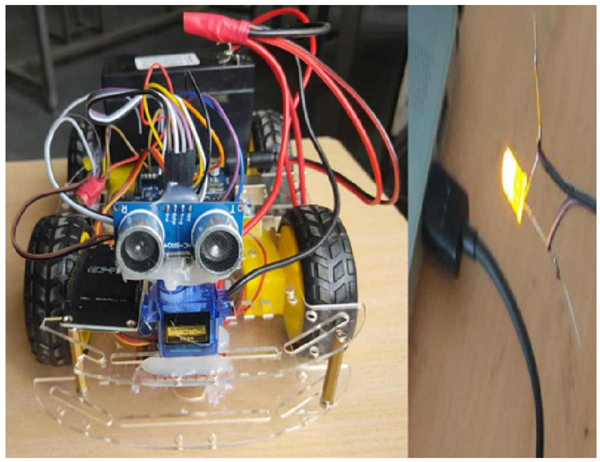

Figure4: When Drowsiness & Obstacles Detected

IX. CONCLUSION

The project successfully demonstrates the practical implementation of energy harvesting using piezoelectric technology. By converting mechanical energy from human footsteps into electrical energy, the system provides a sustainable and eco-friendly solution for low-power applications. The integration of components such as the bridge rectifier, voltage regulator, Arduino Uno, and LCD display ensures accurate voltage conversion, stable output, and real-time monitoring. The ability to store generated energy in a rechargeable battery and use it to power small electronic loads highlights the system's utility in real-world scenarios. This project not only supports the concept of renewable energy generation but also encourages public awareness about energy conservation. Its compact, cost-effective design makes it suitable for deployment in high-footfall areas, offering a promising approach to clean energy generation for future smart infrastructure.

X. FUTURE SCOPE

The concept of electricity generation from footsteps using piezoelectric sensors presents vast opportunities for enhancement and real-world application. As urban areas continue to grow and the need for sustainable energy solutions becomes more critical, this system can be scaled up to cover larger surfaces in high-traffic zones such as railway platforms, shopping malls, airports, metro stations, school corridors, and stadiums. By deploying a greater number of piezoelectric modules across these surfaces, a considerable amount of electrical energy can be harvested from daily human movement.

In future iterations, the system can be upgraded to include advanced power management units and high-capacity rechargeable batteries to store larger volumes of energy for longer periods. The integration of IoT (Internet of Things) technology can further enhance the system's functionality by enabling remote monitoring, data logging, and performance analysis. This would allow for real-time tracking of energy generation, foot traffic density, and battery status, making the system more intelligent and responsive to usage patterns.

Furthermore, with advancements in material science, more efficient and durable piezoelectric materials can be used to improve the system's output and lifespan. The platform could also be combined with other renewable energy

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technologies, such as solar panels or wind turbines, to create a hybrid energy system capable of supporting public lighting, information displays, or mobile charging points in smart city environments.

Educational institutions can adopt the system as a practical demonstration of renewable energy principles, while commercial spaces can use it to promote energy awareness and sustainability among the public. With proper support from government bodies and stakeholders, this project can contribute to the development of green infrastructure, reduce dependence on non-renewable sources, and pave the way for smart, self-powered urban spaces.

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