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Powerstride: A Smart Piezoelectric Energy Harvesting Flooring Monitoring

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ABSTRACT

This paper presents PowerStride, an innovative energy harvesting system designed to capture mechanical energy from human footsteps and convert it into usable electrical power. The system utilizes piezoelectric sensors embedded in floor tiles to generate voltage through pressure. To address the lack of data transparency in traditional harvesting methods, we integrated an ESP32 microcontroller and a monitoring module programmed in C++. This module facilitates real-time tracking of voltage generation and battery storage levels. The captured energy is stored in a power battery and utilized for low-power applications, such as mobile phone charging and lighting LED bulbs. Our results demonstrate that the system provides an efficient, automated, and sustainable solution for energy generation in high-traffic public areas

1.INTRODUCTION

Energy is one of the most essential resources for modern society. With the rapid growth of population, industrialization, and technological advancements, the demand for electricity has increased significantly. Conventional energy sources such as coal, petroleum, and natural gas are widely used for electricity generation. However, these sources are limited in availability and contribute to environmental pollution and global warming. Due to these challenges, researchers and engineers are increasingly focusing on renewable and sustainable energy sources.

Renewable energy sources such as solar energy, wind energy, and hydroelectric power are commonly used alternatives to conventional power generation. Although these sources are effective, they also have certain limitations such as dependency on weather conditions and high installation costs. Therefore, it is important to explore other innovative methods of generating energy that can complement existing renewable technologies.

One promising approach is energy harvesting from human movement. Every day, millions of people walk in public places such as railway stations, shopping malls, airports, sidewalks, and educational institutions. During walking, mechanical energy is generated due to the pressure exerted by human footsteps on the ground. Normally, this mechanical energy is wasted. However, with the help of piezoelectric technology, this mechanical energy can be converted into electrical energy.

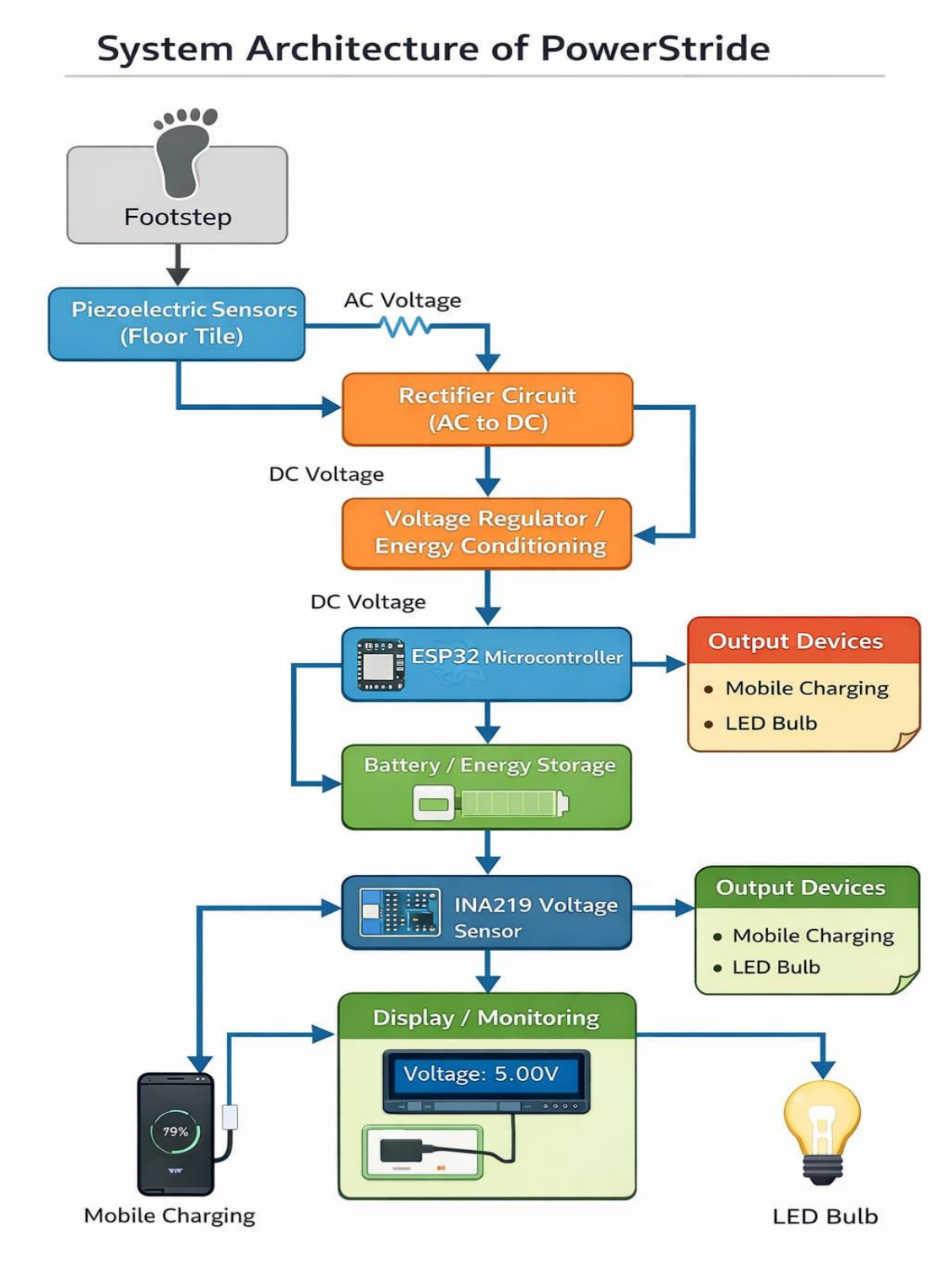
Piezoelectric materials have the unique property of generating electrical voltage when mechanical stress or pressure is applied to them. This phenomenon is known as the piezoelectric effect. When a piezoelectric sensor is compressed or vibrated, it produces a small electrical charge that can be collected and utilized. By placing piezoelectric sensors beneath a tile or floor surface, it is possible to capture the pressure generated by footsteps and convert it into usable electrical energy.

The proposed system, PowerStride, is designed to demonstrate this concept of footstep energy generation using piezoelectric sensors. In this system, multiple piezoelectric sensors are installed beneath a tile platform. When a person steps on the tile, the applied pressure causes the sensors to generate electrical voltage. This generated voltage is then processed through a rectifier circuit to convert the output into usable direct current. The electrical energy is stored in a rechargeable battery, which can later be used to power small electrical devices such as LED bulbs or mobile charging modules.

The PowerStride system highlights the potential of utilizing human activity as a renewable energy source. Although the power generated from a single footstep is relatively small, large amounts of energy can be produced in areas with heavy foot traffic. This concept can contribute to the development of smart cities and sustainable infrastructure by utilizing otherwise wasted mechanical energy.

The main objective of this project is to design and develop a prototype system that demonstrates the conversion of mechanical energy from human footsteps into electrical energy using piezoelectric sensors. The system also aims to promote awareness about renewable energy technologies and innovative methods of energy harvesting.

2. SYSTEM ARCHITECTURE



The PowerStride system is designed to generate electrical energy from human footsteps using piezoelectric sensors. The system consists of several modules that work together to convert mechanical pressure into usable electrical power. The overall architecture includes piezoelectric sensors, an energy conversion circuit, a storage unit, and output devices.

When a person steps on the tile surface, mechanical pressure is applied to the piezoelectric sensors installed beneath the tile. These sensors convert the applied pressure into electrical voltage using the piezoelectric effect. The generated voltage is usually in alternating form and unstable, so it is passed through a rectifier circuit to convert it into direct current (DC).

After the rectification process, the generated electrical energy is stored in a rechargeable battery. The battery acts as an energy storage unit that collects the generated electricity from multiple footsteps. This stored energy can then be used to power small electrical devices.

The output module of the system demonstrates the practical usage of the generated energy. The stored electricity can be used to power LED lights or charge mobile devices through a charging module. The architecture of the system ensures efficient conversion, storage, and utilization of the generated energy.

The overall working flow of the system can be represented as:

Footstep Pressure → Piezoelectric Sensors → Rectifier Circuit → Battery Storage → Output Devices (LED / Mobile Charging).

3.PROPOSED METHODOLOGY

1. Energy Generation

The first stage of the system involves generating electrical energy using piezoelectric sensors. These sensors are placed beneath a tile surface where mechanical pressure is applied when a person steps on it. Piezoelectric materials have the property of producing electrical voltage when mechanical stress or pressure is applied. When a person walks on the tile, the pressure exerted causes the sensors to deform slightly, which generates an electrical charge. Multiple sensors are used to increase the amount of generated voltage.

2. Energy Conversion

The electrical output produced by the piezoelectric sensors is usually alternating and unstable. Therefore, the generated voltage is passed through a rectifier circuit. The rectifier converts the alternating current (AC) generated by the sensors into direct current (DC). This step is important because most storage devices and electronic components require stable DC power for operation.

3. Energy Storage

After the conversion process, the generated DC voltage is stored in a rechargeable battery. The battery acts as an energy storage unit that collects electricity generated from multiple footsteps over time. Since the power produced from a single step is relatively small, storing the energy helps accumulate sufficient power to operate small electronic devices.

4. Energy Monitoring and Control

To monitor the generated electrical energy, a microcontroller such as ESP32 can be used along with a voltage sensor. The sensor measures the generated voltage and sends the data to the microcontroller. The microcontroller processes the data and can display the voltage information on a display module or through serial communication. This helps analyze the performance and efficiency of the system.

5. Energy Utilization

The stored energy in the battery can be used to power small electrical devices. In the PowerStride prototype, the stored electricity is used to power LED lights and demonstrate mobile phone charging. This shows that mechanical energy from footsteps can be converted into useful electrical power for low-energy applications.

The overall methodology demonstrates a simple and effective approach to energy harvesting using human movement. By installing such systems in crowded public areas, the continuous movement of people can generate usable electricity and contribute to renewable energy solutions.

4. IMPLEMENTATION

4.1 Technologies Used

The implementation of PowerStride is divided into hardware and software layers to ensure modularity and scalability.

Hardware Layer:

Microcontroller: ESP32. This dual-core processor was selected for its high processing speed and integrated Wi-Fi capabilities, allowing for future IoT-based monitoring.

Sensors: Piezoelectric transducers are utilized for energy harvesting. An INA219 or a similar voltage sensor is used to provide real-time data to the microcontroller.

Storage and Output: A rechargeable battery stores the rectified DC power, which is then used to power LED loads or charge mobile devices via a 5V regulator.

Software Layer:

Language: C++. The system uses C++ for efficient memory management and real-time execution.

Environment: Arduino IDE.

Libraries: The implementation relies on specialized libraries for I2C communication and sensor interfacing.

4.2 Software Logic

The software follows a structured flow to ensure data accuracy. The C++ code initializes the system, polls the analog pins for sensor data, applies a mathematical calibration to determine voltage, and updates the display interface.

5. SCOPE FOR FUTURE WORK

The PowerStride system demonstrates the basic concept of generating electrical energy from human footsteps using piezoelectric sensors. Although the prototype successfully shows energy generation and storage, there are several opportunities for further improvement and development.

In future work, the efficiency of the system can be increased by using a larger number of piezoelectric sensors and improving the mechanical design of the tile structure. This can help generate more electrical energy from each footstep. Advanced energy storage systems such as high-capacity rechargeable batteries or supercapacitors can also be integrated to store the generated power more efficiently.

The system can be further enhanced by integrating smart monitoring technologies using microcontrollers and Internet of Things (IoT) platforms. This would allow real-time monitoring of energy generation and performance analysis through mobile or web applications.

In addition, the PowerStride system can be implemented on a larger scale in high-traffic areas such as railway stations, shopping malls, airports, and public walkways. Large installations in such locations could generate significant amounts of renewable energy and contribute to sustainable urban infrastructure.

Future research can also focus on improving the durability, efficiency, and cost-effectiveness of piezoelectric materials to make footstep energy generation systems more practical for real-world applications.

6. CONCLUSION

The PowerStride system demonstrates an innovative method of generating electrical energy from human footsteps using piezoelectric sensors. The project focuses on converting mechanical pressure produced during walking into electrical energy through the piezoelectric effect. The generated voltage is processed through a rectifier circuit and stored in a rechargeable battery for later use.

The prototype successfully shows that mechanical energy from footsteps can be harvested and utilized for low-power applications such as lighting LED bulbs and charging small electronic devices. Although the amount of energy generated from a single step is small, continuous foot traffic in crowded areas can produce a significant amount of usable electrical energy.

This project highlights the potential of footstep energy generation as a renewable and eco-friendly

energy source. The PowerStride system demonstrates how simple technology can be used to utilize wasted mechanical energy and contribute to sustainable energy solutions.

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