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Piezoelectric Footstep Power Generation RFID Based Mobile Charging

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Abstract
The increasing global demand for sustainable and renewable energy sources has encouraged the development of innovative energy harvesting techniques. This work presents a Piezoelectric Footstep Power Generation system integrated with RFID-based Mobile Charging, designed to convert mechanical energy from human movement into usable electrical power. Piezoelectric sensors embedded beneath walking surfaces such as tiles or flooring generate electrical energy when subjected to pressure caused by footsteps. The generated alternating signal is subsequently rectified, conditioned, and stored using appropriate power management circuitry for later utilization.To enhance system efficiency and provide controlled access, Radio Frequency Identification (RFID) technology is incorporated into the design. Each user is assigned an RFID tag that enables authenticated access to a mobile charging unit powered by harvested energy. This approach ensures fair usage, reduces unnecessary energy consumption, and enables monitoring of individual utilization patterns. The automated authentication process improves convenience while supporting intelligent energy distribution.The proposed system is particularly suitable for deployment in locations with heavy pedestrian traffic such as railway stations, shopping complexes, educational institutions, and sports venues. Although the energy produced from a single step is minimal, continuous foot traffic leads to significant cumulative energy generation. Furthermore, the system encourages environmental awareness and demonstrates the feasibility of integrating smart electronics with renewable energy harvesting technologies.This project provides a practical and eco-friendly solution addressing both power generation and mobile charging needs. By combining piezoelectric energy harvesting with RFID-based authentication, the proposed system represents a step toward intelligent energy management and sustainable infrastructure development.

Keywords: *Piezoelectric sensor, Energy harvesting, RFID, Footstep power generation, Renewable energy, Mobile charging, Smart energy system*

INTRODUCTION

Energy plays a vital role in modern society, supporting residential, commercial, and industrial activities. However, the rapid growth in population and technological development has significantly increased electricity demand. Conventional energy sources such as coal, petroleum, and natural gas are limited and contribute to environmental issues including air pollution and climate change. These concerns have motivated researchers to explore alternative energy solutions that are sustainable, environmentally friendly, and locally available.

One promising but underutilized source of renewable energy is mechanical energy generated from human movement. Large numbers of people pass through public spaces such as railway stations, airports, shopping malls, and educational institutions every day. Each step produces mechanical force that is usually dissipated without being utilized. Converting this mechanical energy into electrical energy offers a practical approach to distributed power generation. This concept forms the basis of the Piezoelectric Footstep Power Generation with RFID-Based Mobile Charging system.The proposed system employs piezoelectric sensors embedded beneath a walking platform. Piezoelectric materials generate electrical charge when mechanical stress is applied, a phenomenon known as the piezoelectric effect. When a person steps on the platform, the applied pressure compresses the sensors and produces electrical energy. The generated output is then rectified, regulated, and stored using appropriate power conditioning circuits. The stored energy can subsequently be used for low-power applications such as charging mobile devices.To improve functionality and ensure controlled utilization, Radio Frequency Identification (RFID) technology is integrated into the system. Each user is assigned an RFID tag that enables authenticated access to the charging unit. When a valid tag is scanned, the system activates the charging mechanism. This approach enhances security, prevents misuse, and allows monitored distribution of harvested energy.The proposed system demonstrates how everyday human activity can be transformed into a useful power source. Unlike solar or wind systems, piezoelectric energy harvesting does not depend on weather conditions and requires minimal installation space. Although the energy generated from a single footstep is small, cumulative energy from continuous pedestrian movement can provide meaningful output. The integration of piezoelectric technology with RFID-based access control contributes to sustainable energy utilization and promotes smart infrastructure development.

Aim of the Project

The primary aim of this project is to design and develop a system that converts mechanical energy generated from human footsteps into electrical energy using piezoelectric sensors and utilizes the harvested energy for RFID-controlled mobile charging. The project addresses the growing demand for renewable energy sources while providing convenient charging facilities for portable electronic devices.

The system captures pressure applied during walking and converts it into electrical energy through piezoelectric materials embedded beneath the floor surface. The generated energy is conditioned and stored using suitable electronic circuitry. RFID technology is incorporated to authenticate users before allowing access to the charging facility. This ensures controlled usage, prevents unauthorized access, and promotes efficient energy management.

The overall aim is to demonstrate a cost-effective, scalable, and environmentally friendly solution that combines energy harvesting with intelligent access control for practical public applications.

Objectives

The major objectives of the proposed project are:

1. To design a footstep power generation system using piezoelectric sensors.
2. To convert mechanical energy from walking into electrical energy.
3. To implement rectification and voltage regulation for stable output.
4. To store generated energy using batteries or capacitors.
5. To develop an RFID-based authentication system for user access.
6. To design a mobile charging unit powered by harvested energy.
7. To promote efficient energy management and controlled usage.
8. To provide an eco-friendly solution suitable for public installations.
9. To demonstrate integration of energy harvesting with embedded systems.
10. To create awareness about renewable energy technologies.

Hardware Requirements

Power Supply

The power supply unit provides regulated DC voltage required for the operation of electronic components. A step-down transformer converts the high-voltage AC input into low-voltage AC. This voltage is then rectified using a diode bridge to obtain pulsating DC. A filter capacitor reduces ripple components, and a voltage regulator IC such as LM7805 produces a constant +5V output.

The regulated supply ensures stable operation of the microcontroller, RFID module, LCD display, and other peripheral devices. Proper regulation is essential because fluctuations in voltage can affect system performance and reliability.

Transformer

A transformer is used to step down the mains AC voltage to a safer and lower level suitable for electronic circuits. It operates on the principle of electromagnetic induction, where an alternating magnetic field transfers energy between primary and secondary windings.

In this system, a step-down transformer reduces the input voltage from 230V AC to approximately 6V AC. The secondary output is then supplied to the rectifier circuit for conversion into DC voltage. Transformers provide isolation and improve safety while maintaining efficient power transfer.

Rectifier

Rectifiers convert alternating current (AC) into direct current (DC). Diodes are arranged in specific configurations to achieve this conversion. Depending on circuit design, rectification can be half-wave or full-wave.

For efficient energy conversion, a full-wave rectifier is preferred, as it utilizes both halves of the AC cycle, resulting in improved DC output.

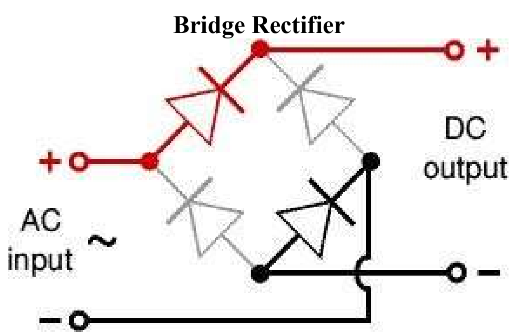

Fig. 1 Bridge Rectifier

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A bridge rectifier consists of four diodes connected in a bridge configuration. It converts AC input into pulsating DC output. During each half cycle of the AC signal, two diodes conduct and allow current to flow through the load in the same direction.
The major advantages of using a bridge rectifier include:

- No requirement for a center-tapped transformer
- Higher efficiency compared to half-wave rectifiers
- Improved DC output with reduced ripple frequency

This configuration is widely used in power supply circuits due to its reliability and simplicity.

Voltage Regulator

Voltage regulators provide a constant DC output regardless of input variations or load changes. Integrated circuits from the 78xx series are commonly used for fixed voltage regulation.
The LM7805 regulator provides a stable +5V output, which is suitable for powering microcontrollers and digital components. These regulators also include built-in protection features such as thermal shutdown and current limiting, ensuring safe operation.

Arduino Uno Board

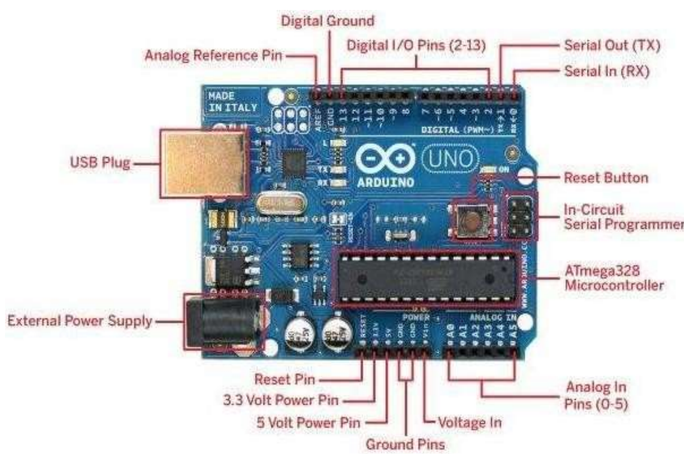

Fig 2: Arduino Board

The Arduino Uno is based on the ATmega328P microcontroller and provides an easy-to-use development platform. It features 14 digital I/O pins, 6 analog inputs, and operates at a clock frequency of 16 MHz. The board includes USB connectivity for programming and power supply options.
The Arduino Uno is selected due to its:

- Ease of programming
- Wide library support
- Built-in communication interfaces
- Reliability and low cost

It controls RFID detection, monitors energy availability, and manages charging operations.

Liquid Crystal Display (LCD)

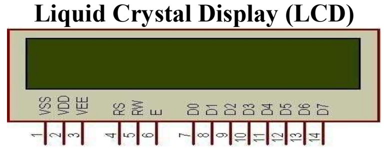

Fig. 3 16x2 LCD

A 16×2 LCD module is used to display system information such as user authentication status, charging availability, and system messages. LCDs are preferred because they are economical, easy to interface, and capable of displaying alphanumeric characters.
The display improves user interaction and provides real-time feedback.

Battery

A rechargeable battery is used to store the energy generated by piezoelectric sensors. The stored energy is later used for mobile charging. Secondary batteries are preferred because they allow repeated charging and discharging cycles.
Energy storage improves system reliability and ensures power availability even when footstep activity is low.

Software Requirements

The Arduino Integrated Development Environment (IDE) is used for programming the microcontroller. The IDE allows users to write code, compile it, and upload it to the Arduino board. It also provides serial monitoring for debugging and testing.
In this project, the Arduino IDE is used to:

- Read data from the RFID module
- Authenticate users
- Control power delivery
- Display messages on LCD
- Monitor system operation

The availability of libraries simplifies integration of hardware modules such as RFID readers and displays. The software ensures proper coordination between energy harvesting, storage, and charging operations.

PIEZOELECTRIC FOOTSTEP POWER GENERATION WITH RFID-BASED MOBILE CHARGING

Piezoelectric footstep power generation combined with RFID-based mobile charging represents an innovative approach to sustainable energy utilization. The system converts mechanical pressure produced by human footsteps into electrical energy using piezoelectric sensors. The generated energy is conditioned, stored, and later used for charging mobile devices. To ensure secure and controlled access, RFID authentication is incorporated into the charging unit. This integrated solution is particularly suitable for public locations with high pedestrian traffic, offering an environmentally friendly and self-sustaining power source..

Proposed System

The proposed system introduces a smart and sustainable approach to energy generation by harvesting mechanical energy from human footsteps. Piezoelectric sensors are embedded beneath a walking surface, and when pressure is applied, they generate electrical voltage due to the piezoelectric effect. Although the output from a single step is small, continuous pedestrian movement results in cumulative energy generation.The generated alternating voltage is passed through a rectifier circuit to convert it into DC. Each user is assigned an RFID tag containing unique identification data. When a user scans the tag, the system verifies authentication and allows charging for a predefined duration or energy quota. This prevents unauthorized access and ensures fair distribution of harvested energy.An Arduino-based microcontroller manages the entire operation. It processes RFID input, controls switching circuits, and regulates power delivery to the charging port. The microcontroller also enables additional features such as timing control, user identification, and energy management. An LCD display may be included to provide real-time information such as authentication status, charging time, and system messages.Unlike conventional charging stations, the proposed system operates independently of grid electricity. It utilizes energy generated from human movement, making it eco-friendly and cost-effective. The modular design allows installation in locations such as railway stations, shopping malls, educational institutions, and public walkways. Additional piezoelectric units can be added to increase energy output depending on foot traffic.This system promotes sustainable energy usage while incorporating intelligent access control. The integration of RFID technology also enables future expansion such as usage monitoring, IoT connectivity, and smart energy analytics.

Block Diagram

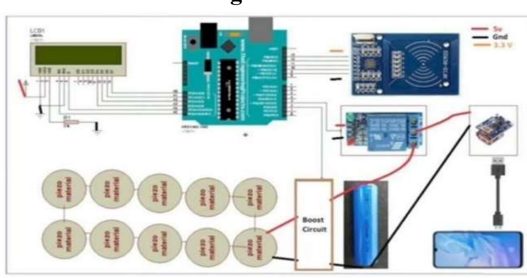

Fig. 4 Block Diagram of piezoelectic footstep power generation rfid based mobile charging

The block diagram of the system consists of piezoelectric sensors, rectifier circuit, voltage regulator, energy storage unit, microcontroller, RFID module, relay driver, and mobile charging output.When a person steps on the platform, piezoelectric sensors generate electrical energy. This energy is rectified and regulated before being stored in a battery. The Arduino microcontroller continuously monitors RFID input. When an authorized RFID card is detected, the controller activates the relay and connects the stored energy to the USB charging module. The LCD display provides system status messages.The system allows multiple users to register RFID cards. Each authorized user is allocated a limited charging duration. If the card is scanned again, charging stops and the remaining time is displayed. Recharge functionality allows additional time allocation through system control buttons.

Methodology

The methodology begins with installation of piezoelectric sensors beneath a walking platform.

Mechanical pressure applied during walking produces small AC voltage signals. These signals are converted into DC using a bridge rectifier.Since the output voltage is low, a boost converter increases the voltage to a suitable level. The regulated DC output is stored in a rechargeable battery to ensure continuous power availability.

An Arduino Uno microcontroller interfaces with an RFID reader module to authenticate users. When a valid RFID tag is detected, the microcontroller activates a relay switch. The relay connects the battery output to a USB charging module, allowing mobile devices to charge.

The LCD display shows system messages such as authentication status and charging information. If an invalid card is scanned, the system denies access. This ensures secure and efficient energy utilization.

The modular architecture allows scaling of the system by adding additional sensors. This improves energy generation in high-footfall locations. The design operates without dependency on grid electricity, making it environmentally friendly and sustainable.

ADVANTAGES

The proposed piezoelectric footstep power generation system integrated with RFID-based mobile charging offers several technical and practical benefits. These advantages make it suitable for sustainable energy harvesting in public environments.

- **Utilization of Human Motion:** The system converts mechanical pressure generated by daily pedestrian movement into usable electrical energy without requiring additional effort from users.
- **Environmentally Friendly:** Energy is generated without combustion, emissions, or dependence on fossil fuels, making the system eco-friendly.
- **Low Maintenance Requirement:** Piezoelectric sensors have long operational life and require minimal maintenance after installation.
- **Space Efficient Installation:** Sensors are embedded beneath floors or tiles, eliminating the need for additional space.
- **Scalability:** The system can be deployed in small locations such as staircases or expanded to large areas including stadiums and airports.
- **Support for Smart Infrastructure:** The generated energy can power low-power devices such as LED lighting, sensors, and charging units, contributing to smart city development.
- **Weather Independence:** Unlike solar and wind energy systems, the proposed design operates regardless of environmental conditions and depends only on foot traffic.
- **Promotes Environmental Awareness:** The concept encourages public participation in renewable energy generation through everyday activities.
- **Suitable for High Footfall Locations:** Areas with continuous pedestrian movement can produce cumulative energy for useful applications.
- **Instantaneous Energy Generation:** Electrical output is produced immediately when pressure is applied, enabling real-time operation of low-power devices.
- **Off-Grid Capability:** The system can function independently of the electrical grid, making it useful in remote or rural areas.

Disadvantages

Despite its advantages, the proposed system also has certain limitations that must be considered during implementation.

- **Low Power Output:** The energy generated from a single footstep is relatively small, limiting its use to low-power applications unless deployed over large areas.
- **High Initial Installation Cost:** The cost of piezoelectric sensors, circuitry, and structural integration may be significant during setup.
- **Dependence on Foot Traffic:** Energy generation depends directly on pedestrian movement, resulting in reduced output in low-traffic areas.
- **Material Fatigue:** Continuous mechanical stress may cause wear and degradation of sensors over extended periods.
- **Requirement of Energy Storage:** Since energy is generated intermittently, batteries or capacitors are required for storage and stable output.
- **Complex Integration:** Installing piezoelectric tiles within existing infrastructure may require structural modifications and careful planning.

4.3 Applications

The piezoelectric footstep power generation system with RFID-based charging can be implemented in various real-world scenarios where pedestrian movement is frequent.

- **Street Lighting Systems:** Energy generated from pedestrian pathways can power nearby LED street lights.
- **Railway Stations:** Installation on platforms can provide energy for lighting, display boards, and information systems.
- **Shopping Malls and Airports:** High-footfall areas can generate power for digital signage, indicator lights, and charging units.
- **Educational Institutions:** Corridors and walkways in schools and colleges can utilize footstep energy for lighting and monitoring systems.
- **Sports Stadiums and Event Venues:** Crowd movement can be converted into power for emergency lighting and display systems.
- **Remote and Rural Areas:** Off-grid locations can use the system for small-scale lighting and mobile charging.
- **Public Mobile Charging Stations:** Parks, bus stops, and campuses can provide eco-friendly charging facilities.

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- **Security and Surveillance Systems:** The generated energy can support motion sensors and low-power monitoring equipment.
- **Interactive Exhibitions and Museums:** Footstep energy can activate interactive displays and audio systems.
- **Smart City Infrastructure:** Integration with IoT-based systems can enhance sustainable urban development.

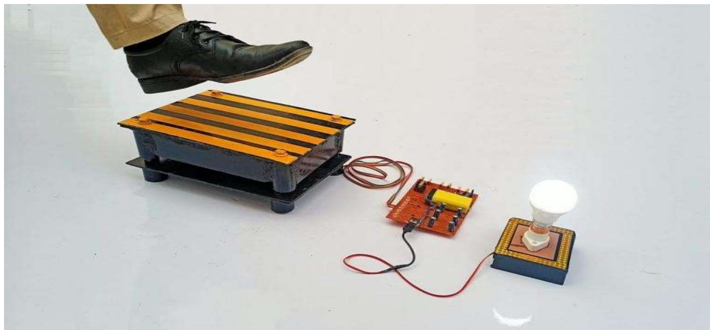

Fig 5: Smart Step: Lighting with Every Footfall

RESULTS

The experimental setup demonstrates the feasibility of generating electrical energy using piezoelectric sensors installed beneath a walking surface. When mechanical pressure is applied through human footsteps, the piezoelectric elements convert the applied force into electrical energy based on the piezoelectric effect. The generated voltage is rectified and regulated before being stored in an energy storage unit. The stored energy is subsequently utilized to operate low-power loads such as LED indicators and mobile charging circuits Observations from the prototype indicate that energy generation increases with the number of footsteps and the intensity of applied pressure. In areas with continuous pedestrian movement, the cumulative energy produced is sufficient to support small electronic devices. The integration of RFID technology enables controlled access to the stored energy, ensuring efficient distribution among users. These results confirm that footstep-based energy harvesting can serve as a supplementary renewable power source in high-footfall environments.

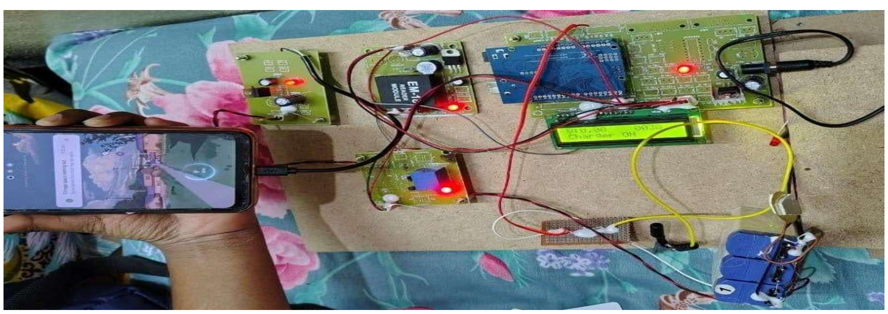

Fig 6: Piezoelectric footstep power generation using RFID for mobile charging

Prototype Result

The developed prototype of the proposed system consists of a wooden platform embedded with piezoelectric sensors that generate electrical energy when subjected to foot pressure. The generated energy is routed through a rectifier circuit and voltage regulation stage before being stored in a rechargeable battery. The stored energy is then used to provide mobile charging capability.The system also incorporates an RFID module that enables user authentication and controlled access to the charging unit. When a valid RFID tag is scanned, the system activates the charging circuit. An LCD display is included to show authentication messages and system status information, improving user interaction. Additional components such as voltage regulators, relay modules, and a microcontroller coordinate power management and control operations.The prototype successfully demonstrates energy harvesting from human movement and its utilization for mobile charging. The compact design validates the practicality of deploying such systems in public locations with heavy pedestrian traffic.

Discussion

The proposed piezoelectric footstep power generation system integrated with RFID-based mobile charging demonstrates an effective combination of renewable energy harvesting and intelligent access control. The piezoelectric sensors convert mechanical stress generated by footsteps into electrical energy, which is then processed through rectification and regulation stages. The stored energy is made available for charging mobile devices, providing a practical low-power application.The inclusion of RFID technology enhances system usability by allowing authenticated access to the charging facility. This prevents unauthorized usage and ensures fair energy distribution in shared environments. The prototype also integrates essential electronic components such as rectifiers, voltage regulators, energy storage units, and a control unit, which together improve overall efficiency and stability.Although the energy generated from a single step is limited, the cumulative output increases significantly when multiple sensors are used in high-footfall locations. This makes the system suitable for deployment in areas such as railway stations, shopping malls, and educational institutions. The study demonstrates that combining piezoelectric energy harvesting with smart identification techniques can contribute to sustainable and intelligent energy management solutions.

CONCLUSION

Piezoelectric footstep power generation presents an innovative approach to harvesting renewable energy from human movement. The system converts mechanical stress generated by footsteps into electrical energy using piezoelectric sensors embedded beneath walking surfaces. This method provides a clean and sustainable alternative to conventional energy sources, particularly in locations with heavy pedestrian traffic such as shopping malls, railway stations, and educational campuses.Although the electrical output from a single step is relatively small, the accumulated energy from continuous movement is sufficient for powering low-energy devices including LED lighting, sensors, and small electronic loads. The integration of RFID-based authentication enhances the efficiency of the system by ensuring controlled access to the generated energy. Furthermore, the proposed design requires minimal maintenance and can be deployed without occupying additional space.With improvements in piezoelectric materials and optimized power conditioning circuits, the performance of the system can be further enhanced. The proposed solution demonstrates a practical step toward sustainable energy harvesting and supports the development of smart infrastructure. Overall, piezoelectric footstep power generation offers a promising pathway for reducing reliance on conventional power sources while promoting environmentally friendly technology.

Future Scope

The proposed system offers considerable opportunities for enhancement and large-scale deployment in the future. Advancements in piezoelectric materials with higher sensitivity and durability can significantly improve energy conversion efficiency. Enhanced circuit design and energy storage techniques may allow the system to support a broader range of electronic devices.In future implementations, the technology can be integrated into smart city infrastructure to power street lighting, sensor networks, and digital display systems in public spaces. The system can also be deployed in rural or off-grid locations to provide basic lighting and mobile charging facilities where conventional electricity supply is limited.Additionally, integration with Internet of Things (IoT) platforms can enable real-time monitoring of energy generation, consumption, and system performance. This data-driven approach can improve maintenance planning and optimize energy utilization. Research into flexible and lightweight piezoelectric materials may also simplify installation and reduce overall cost.Overall, piezoelectric footstep power generation combined with intelligent control technologies has strong potential to become a sustainable energy solution for future urban infrastructure and environmentally conscious development.

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