

Advanced Footstep Power Generation System Using RFID for Charging

Prof. K. I. Mahale¹, Mr. Ghuge Kiran Dinkar², Mr. Ghuge Vishal Bhimraj³,
Mr. Phad Shubham Rajendra⁴, Prof. N. V. Bhoir⁵, Dr. Rahul M. Malujkar⁶

Department of Electronics and Telecommunications Engineering
Vidyaniketana College of Engineering, Bota, Sangamner

Abstract: *The Advanced Footstep Power Generation System Using RFID for Charging is an innovative renewable energy solution designed to generate electrical power from human footsteps and utilize it for charging applications. The system uses piezoelectric sensors to convert mechanical pressure produced during walking into electrical energy. The generated energy is conditioned through a rectifier and voltage regulation circuit before being stored in a rechargeable battery. An ESP32 microcontroller acts as the central control unit, monitoring energy generation, battery status, and overall system operation. To ensure secure and controlled access, an RFID-based authentication mechanism is incorporated, allowing only authorized users to utilize the stored energy for charging devices. A display module provides real-time information regarding battery level, charging status, and user authentication.*

Keywords: Footstep Power Generation, Piezoelectric Sensor, RFID Authentication, ESP32, Renewable Energy, Energy Harvesting, Battery Charging, Smart Energy System, Sustainable Technology, Green Energy.

I. INTRODUCTION

With the rapid increase in energy consumption and the depletion of conventional energy resources, there is a growing need for alternative and sustainable sources of power. Renewable energy technologies have gained significant attention due to their ability to generate clean energy while reducing environmental impacts. Among various renewable energy harvesting techniques, footstep power generation has emerged as an innovative method of converting human mechanical energy into electrical energy. Human movement in crowded public areas such as railway stations, shopping malls, airports, educational institutions, and pedestrian walkways represents a largely untapped source of energy that can be effectively utilized for power generation [1].

Footstep power generation systems primarily utilize piezoelectric sensors, which generate electrical voltage when mechanical pressure is applied. This technology offers an environmentally friendly and cost-effective approach to energy harvesting while reducing dependence on conventional electricity sources [2]. The generated energy can be stored in rechargeable batteries and later utilized for powering low-energy electronic devices, street lighting systems, sensors, and charging applications [3].

Recent advancements in microcontroller technology have further enhanced the efficiency and functionality of footstep power generation systems. Modern controllers such as the ESP32 provide real-time monitoring, data processing, wireless communication, and intelligent energy management capabilities. [4].

Security and controlled access are important considerations in public charging infrastructures. Radio Frequency Identification (RFID) technology provides a reliable solution for user authentication and access control. RFID systems enable contactless identification of authorized users through RFID cards or tags, ensuring secure utilization of the generated electrical energy.[5].

The Advanced Footstep Power Generation System Using RFID for Charging combines piezoelectric energy harvesting, battery storage, RFID authentication, and microcontroller-based monitoring into a single intelligent platform. The



system captures energy generated from human footsteps, stores it efficiently, and provides controlled access for charging electronic devices. [6].

Furthermore, the increasing adoption of smart infrastructure and Internet of Things (IoT) technologies has created opportunities for integrating energy harvesting systems into modern urban environments. Smart energy harvesting solutions can support self-powered devices, reduce operational costs, and contribute to energy conservation efforts. [7]. The proposed system demonstrates how wasted mechanical energy can be converted into useful electrical power through an eco-friendly process. By incorporating RFID-based authentication and intelligent monitoring, the system provides a secure, efficient, and practical solution for renewable energy generation and charging applications. [8].

II. PROBLEM STATEMENT

The increasing demand for electrical energy and the rapid depletion of conventional energy resources have created a need for alternative and sustainable energy generation methods. Large amounts of mechanical energy produced by human movement in crowded public places such as railway stations, shopping malls, airports, schools, and bus terminals are wasted every day. At the same time, the growing use of mobile devices and portable electronics has increased the demand for convenient charging facilities. Traditional charging systems rely entirely on grid electricity, leading to higher energy consumption and operational costs.

III. OBJECTIVES

- To generate electrical energy from human footsteps by using piezoelectric sensors that convert mechanical pressure into electrical power.
- To store the generated energy efficiently in a rechargeable battery for later use in charging and other low-power applications.
- To implement RFID-based user authentication for providing secure and controlled access to the stored electrical energy.
- To monitor and manage the system using an ESP32 microcontroller, enabling efficient control of power generation, storage, and utilization.
- To develop an eco-friendly and sustainable charging solution that reduces dependence on conventional energy sources and promotes renewable energy harvesting in public places.

IV. LITERATURE SURVEY

Paper 1: Energy Harvesting from Piezoelectric Materials for Low-Power Applications

Authors: Henry A. Sodano, Daniel J. Inman, and Gyuhae Park

Year: 2004

Journal: The Shock and Vibration Digest

Summary:

This paper presents a comprehensive review of piezoelectric energy harvesting technologies. The authors discuss how mechanical vibrations and pressure can be converted into electrical energy using piezoelectric materials. Various energy harvesting methods, design considerations, and practical applications are analyzed. The study highlights the potential of piezoelectric systems in powering low-energy electronic devices and wireless sensor networks. The findings demonstrate that piezoelectric energy harvesting is an efficient and sustainable method for renewable power generation.

Paper 2: Energy Scavenging for Mobile and Wireless Electronics

Authors: Joseph A. Paradiso and Thad Starner

Year: 2005

Journal: IEEE Pervasive Computing



Summary:

This research explores different techniques for harvesting ambient energy from human activities and environmental sources. The authors examine energy generation through walking, vibration, motion, and pressure-based systems. Special attention is given to footstep energy harvesting using piezoelectric sensors. The paper discusses the feasibility of utilizing harvested energy for powering portable electronic devices and wireless communication systems. The study concludes that human-powered energy generation can contribute significantly to sustainable energy solutions.

Paper 3: Piezoelectric Energy Harvesting for Self-Powered Wireless Sensor Systems

Authors: Shad Roundy, Paul K. Wright, and Jan Rabaey

Year: 2003

Publication: Energy Scavenging for Wireless Sensor Networks

Summary:

This paper investigates the use of piezoelectric transducers for generating electrical energy from mechanical movements. The authors developed energy harvesting circuits capable of storing and managing generated power efficiently. The research focuses on self-powered sensor systems and demonstrates how harvested energy can reduce dependence on conventional batteries. The results indicate that piezoelectric energy harvesting can provide a reliable source of renewable energy for low-power applications and smart systems.

Paper 4: Advances in Energy Harvesting Methods

Authors: Niell Elvin and Alper Erturk

Year: 2013

Publisher: Springer

Summary:

This work provides an extensive overview of modern energy harvesting techniques, including piezoelectric, electromagnetic, and electrostatic methods. The authors discuss the design, implementation, and performance of various energy harvesting systems. The book highlights the importance of converting wasted mechanical energy into useful electrical power for sustainable applications. It also examines future developments in smart energy harvesting technologies and their integration into public infrastructure, making it highly relevant for footstep power generation systems.

IV. WORKING OF SYSTEM

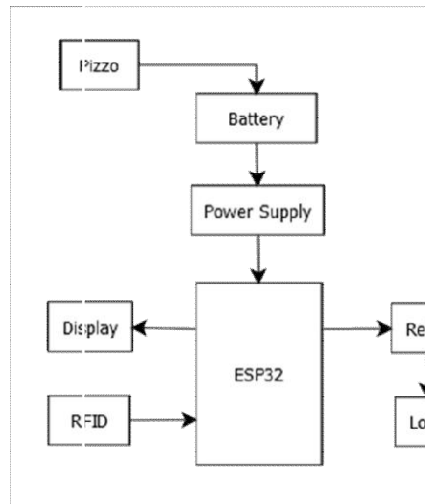


Fig 1: System architecture



A. Piezoelectric Sensor (Pizzo)

The piezoelectric sensor is the primary energy harvesting component of the system. When a person walks or applies pressure on the footstep platform, the piezoelectric sensor converts the mechanical energy generated by the footstep into electrical energy. This generated electrical energy serves as the input power source for the entire system.

B. Battery and Power Supply Unit

The electrical energy produced by the piezoelectric sensor is stored in a rechargeable battery. The battery acts as an energy storage device, ensuring that the generated power can be used whenever required. The power supply unit regulates and stabilizes the voltage from the battery and provides the required operating voltage to the ESP32 microcontroller and other electronic components.

C. ESP32 Microcontroller

The ESP32 acts as the central processing and control unit of the system. It receives information from the RFID module, monitors the battery status, controls the relay operation, and updates the display. The ESP32 manages the overall functioning of the system and ensures efficient utilization of the generated energy.

D. RFID Authentication Module

The RFID module provides secure user authentication. When a user scans an RFID card or tag, the module sends the card information to the ESP32. The microcontroller verifies the user's identity and determines whether access to the charging facility should be granted. This prevents unauthorized use of the stored energy.

E. Display Module

The display module is used to provide real-time information to users. It shows details such as battery level, charging status, power generation status, and RFID authentication messages. This helps users monitor the operation of the system easily.

F. Relay and Load (Charging Unit)

The relay functions as an electronically controlled switch. After successful RFID authentication, the ESP32 activates the relay, which connects the stored battery power to the load. The load represents the charging device, such as a mobile phone or other electronic equipment. Thus, the generated and stored energy is utilized for charging purposes in a secure and controlled manner.

V. SYSTEM DESIGN

A. ESP32 Controller Section

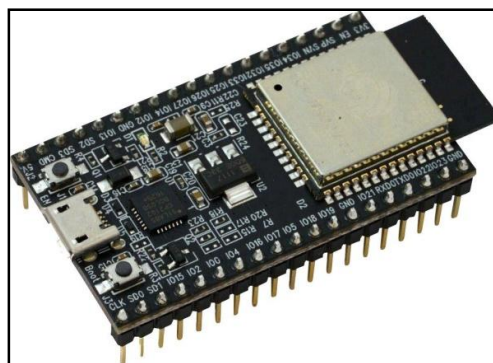


Fig 2: ESP32 microcontroller



The ESP32 microcontroller acts as the primary control unit of the robot. It manages sensor readings, motor movement, relay switching, and wireless communication. Its built-in Wi-Fi module enables IoT connectivity for remote monitoring and control.

B. Piezoelectric Sensor

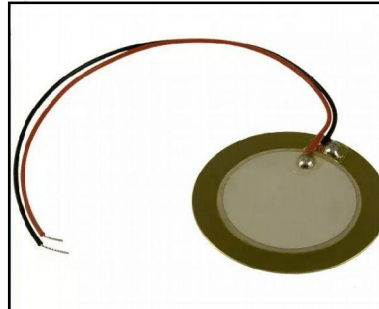


Fig 3: Piezoelectric Sensor

The Piezoelectric Sensor is the main energy harvesting component in this project. It converts mechanical pressure generated by human footsteps into electrical energy using the piezoelectric effect. When mechanical stress is applied to the piezo material, it produces an electric charge across its terminals. Multiple piezo sensors connected together increase the overall voltage and power generation.

C. RFID Module

The sensor section includes DHT11 and MQ6 sensors. The DHT11 measures temperature and humidity inside drainage channels. The MQ6 sensor detects toxic or flammable gases, helping to maintain safety during operation.

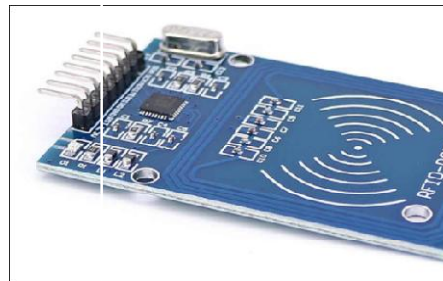


Fig 5: RFID Module

D. Battery



Fig 6: Battery



The Rechargeable Battery stores the electrical energy generated from footsteps. Since footstep-generated power is intermittent, battery storage ensures stable power availability for charging applications.

G. Relay Module

The Relay Module acts as an electrically controlled switch. It connects or disconnects charging output based on commands from ESP32. When RFID authentication is successful, ESP32 activates the relay.

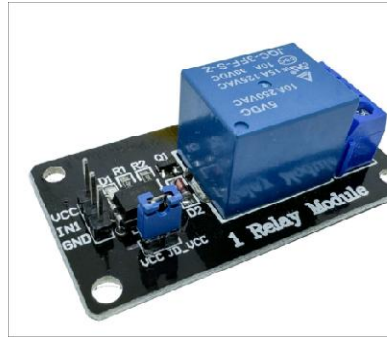


Fig 7: Relay Module

H. LCD / OLED Display

The figure shows a 16x2 Character LCD (Liquid Crystal Display) module used in the Advanced Footstep Power Generation System. This display is capable of showing 16 characters per line and 2 lines of text, making it suitable for displaying system information in real time..



Fig 8: LCD / OLED Display

I. Voltage Regulator

The figure shows the L7805CV Voltage Regulator IC, a three-terminal positive voltage regulator commonly used in electronic circuits. It is designed to provide a stable 5V DC output voltage from a higher input voltage source. In the Advanced Footstep Power Generation System, the L7805CV regulator is used to regulate the voltage obtained from the battery or power supply circuit. Since the voltage generated from the piezoelectric sensors and battery may vary, the regulator ensures a constant 5V output required for the proper operation of the ESP32 microcontroller, RFID module, LCD display, and other electronic components

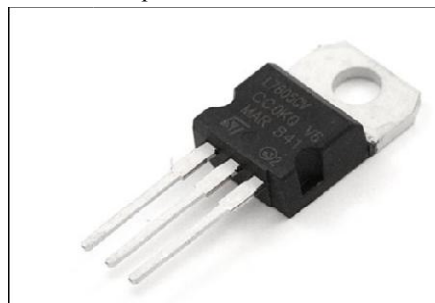


Fig 9: Voltage Regulator



VI. RESULTS

The Advanced Footstep Power Generation System Using RFID for Charging was successfully designed and tested to evaluate its performance in terms of energy generation, storage, authentication, and charging control. The experimental results show that the system effectively converts mechanical energy produced by human footsteps into usable electrical energy and stores it for later use.

During testing, the piezoelectric sensor array generated voltage whenever pressure was applied on the footstep platform. It was observed that the generated voltage depended on factors such as:

- Weight of the person
- Number of footsteps
- Force applied on the platform
- Sensor arrangement

A single footstep produced a small voltage, while multiple footsteps generated significantly higher output. By connecting multiple piezo sensors in a series-parallel configuration, the system achieved improved voltage and current output suitable for battery charging.

After power generation, the AC voltage from the sensors was passed through the bridge rectifier, filter capacitor, and voltage regulator. The output after rectification and filtering became stable enough for storage. The voltage regulator successfully maintained a constant output of 5V and 3.3V, ensuring safe operation of ESP32, RFID module, and display unit.

Sr. No	Parameter	Observation
1	Voltage generated per footstep	1V – 12V (approx.)
2	Rectifier Output	Stable DC output obtained
3	Regulated Voltage	3.3V / 5V
4	Battery Charging	Successful
5	RFID Detection	Accurate and fast
6	Relay Switching	Successful
7	Display Output	Real-time monitoring successful
8	Charging Output	Functional

Footsteps vs Generated Voltage

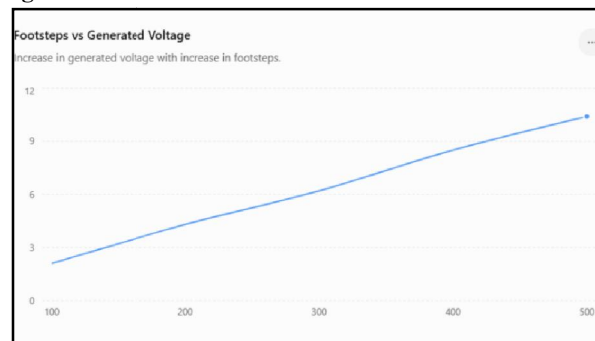


Fig 10: Graph 1

The graph illustrates the relationship between the number of footsteps and the voltage generated by the piezoelectric sensors. As the number of footsteps increases, the generated voltage also increases. At 100 footsteps, the system generates approximately 2.1V, while at 500 footsteps, the voltage reaches about 10.4V. This demonstrates that the



piezoelectric sensors effectively convert mechanical pressure into electrical energy. The results confirm that higher pedestrian movement leads to greater power generation, making the system suitable for installation in crowded public places.

Footsteps	Voltage (V)
100	2.1
200	4.3
300	6.2
400	8.5
500	10.4

Battery Charging Level Over Time

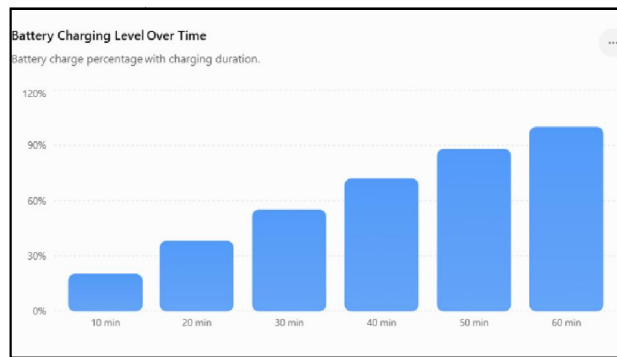


Fig 11: Graph 2

The graph shows the variation of battery charge percentage with charging time. As electrical energy is continuously generated from footsteps and stored in the battery, the charging level gradually increases. The battery charge rises from 20% at 10 minutes to 100% at 60 minutes. This indicates that the harvested energy can be effectively stored and utilized for charging applications. The graph demonstrates the capability of the proposed system to provide a reliable and sustainable power source through continuous footstep energy harvesting.

Time	Battery Charge (%)
10 min	20
20 min	38
30 min	55
40 min	72
50 min	88
60 min	100

VII. CONCLUSION

The Advanced Footstep Power Generation System Using RFID for Charging successfully demonstrates the conversion of mechanical energy generated from human footsteps into useful electrical energy using piezoelectric sensors. The generated energy is stored in a rechargeable battery and can be utilized for charging electronic devices. The integration of the ESP32 microcontroller enables efficient monitoring and control of the entire system, while the RFID module provides secure and authorized access to the stored energy.



The system offers an eco-friendly and cost-effective solution for renewable energy generation by utilizing energy that would otherwise be wasted. The experimental results show that the generated voltage increases with the number of footsteps and that the stored energy can effectively charge the battery over time.

VIII. FUTURE SCOPE

The proposed Advanced Footstep Power Generation System Using RFID for Charging has significant potential for future development and large-scale implementation. The system can be deployed in crowded public locations such as railway stations, airports, shopping malls, bus terminals, educational institutions, and pedestrian walkways where a large number of people pass daily. The increased foot traffic in such areas can generate more electrical energy, making the system more efficient and practical for real-world applications.

In the future, the system can be integrated with Internet of Things (IoT) technology to enable remote monitoring and management of energy generation, battery status, and charging activities. Through mobile applications or web-based platforms, administrators can monitor system performance in real time and optimize energy utilization

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