PRESSURE-INDUCED FOOTSTEP POWER GENERATOR FOR BIOMETRIC SECURITY

A PRODUCT DEVELOPMENT REPORT

Submitted to

SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES

In partial fulfillment of the award of the degree of

BACHELOR OF ENGINEERING

By

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BONAFIDE CERTIFICATE

Certified that this product development report **"**Fire Extinguisher drone**"** is the Bonafide work of **" Katta Narasimha Prasad(192111091) and Kovi Sai Ganesh(192124028) "** who's Carried out the product development work under my supervision

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INTERNAL EXAMINER

EXTERNAL EXAMINER

DECLARATION BY THE CANDIDATE

I declare that the project entitled **" PRESSURE-INDUCED FOOTSTEP POWER GENERATOR FOR BIOMETRIC SECURITY "** submitted by us for the *SPIC708 PRODUCT DESIGN & DEVELOPMENT FOR COMPOSITE MATERIALS* is the work carried out by us during the period from **June 2024 to October 2024** under the guidance of **Dr. C.Clement Raj** and has been completed successfully.

Signature of the Candidates
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1. EXECUTIVE SUMMARY

The Pressure-Induced Footstep Power Generator is an innovative solution designed to address the increasing demand for sustainable power sources in biometric security systems. By harnessing pressure- induced energy, this device powers a biometric fingerprint sensor, eliminating the need for traditional batteries or wired power connections. This self-sustaining technology ensures seamless operation in remote or harsh environments, providing a robust and eco-friendly alternative to conventional energy solutions.

Overview of the Product:

The Pressure-Induced Footstep Power Generator operates by converting the mechanical energy of footsteps into electrical energy. This energy powers biometric fingerprint sensors, offering a reliable and uninterrupted power supply. Compact, lightweight, and easy to integrate, the product is tailored for a wide range of applications, from securing remote facilities to enhancing mobility in urban infrastructure.

Key Features:

- Self-Sustaining Power: Completely eliminates the need for external energy sources.
- Durability: Designed to withstand heavy usage and extreme environmental conditions.
- Eco-Friendly: Reduces reliance on batteries, minimizing environmental impact.
- Easy Installation: Integrates seamlessly with existing biometric systems.

Market Relevance:

The global push toward sustainability and renewable energy solutions has created a demand for innovative power systems in security technologies. Traditional biometric systems often face challenges in remote or off-grid locations, where power reliability is a critical issue.

Market analysis reveals:

- **Growing Biometric Security Market:** Expected to surpass $80 billion by 2030, driven by increasing demand for secure and contactless authentication systems.
- **Gap in Sustainable Power Solutions:** Existing biometric technologies often rely on finite energy sources, creating operational inefficiencies in remote areas.
- **Rising Focus on Green Energy:** Governments and enterprises are increasingly investing in sustainable technologies, creating opportunities for innovative products like the Pressure-Induced Footstep Power Generator.

Environmental Impact:

The Pressure-Induced Footstep Power Generator aligns with global sustainability goals by:

- Reducing e-waste through battery elimination.
- Utilizing clean, renewable energy from human movement.
- Supporting eco-friendly development in the tech and security sectors.

2. INTRODUCTION

Problem Statement:

Biometric security systems are becoming increasingly popular due to their ability to provide enhanced security through unique user identification. However, many of these systems face significant limitations in terms of their power supply. Most rely on disposable or rechargeable batteries, which not only require frequent replacement or recharging but also contribute to environmental waste. Wired connections, while providing consistent power, restrict the placement of these systems and make them less suitable for remote or inaccessible locations. Furthermore, these limitations make it challenging to deploy biometric security solutions in areas where infrastructure is limited, such as remote villages, disaster-affected zones, or industrial sites with hazardous environments. The need for a more sustainable, flexible, and cost-effective power solution for biometric security systems is evident.

Purpose:

The primary aim of this project is to design and implement a biometric security system that is entirely self- powered through footstep-induced pressure. This approach leverages piezoelectric technology or other pressure-based mechanisms to convert mechanical energy from footsteps into electrical energy, which is used to power a biometric fingerprint sensor. By eliminating reliance on external power sources, this system provides an eco-friendly and sustainable solution that addresses the challenges faced by traditional systems. Additionally, the system's on-demand power generation capability ensures its operational efficiency and reliability, even in remote or environmentally challenging settings. This innovation holds the potential to revolutionize the deployment of biometric systems, making them more accessible and adaptable to diverse environments.

Scope:

This project focuses on developing a self-sustaining biometric security system with the following key features:

1. **Pressure-Induced Power Mechanism**: A system that utilizes energy generated from footsteps to power the biometric fingerprint sensor. This ensures the system remains operational without external energy input.
2. **Standalone Biometric Security System**: The project aims to design an integrated unit that combines the power-generation mechanism with a reliable fingerprint recognition system for user authentication.
3. **Adaptability to Various Environments**: The system is designed to function effectively in diverse environments, including indoor settings and areas with low light or harsh weather conditions, where alternative solutions like solar power may not be viable.
4. **Sustainability and Eco-Friendliness**: By eliminating the need for disposable batteries and minimizing maintenance requirements, the system reduces environmental impact and operational costs.

3. GPCU(Gap Analysis, Product Description, Comparison, Uniqueness)

Gap Analysis:

Market Gap or Lacuna: The growing reliance on biometric security systems highlights a pressing need for innovation in power efficiency and sustainability. Despite a 35% increase in biometric system usage over recent years—particularly in security-sensitive areas such as government offices, industrial plants, and disaster zones—most available solutions still rely on conventional power sources. Current systems are predominantly powered by disposable or rechargeable batteries, which require frequent maintenance, leading to increased operational costs and environmental impact. Alternatively, wired systems limit placement flexibility and are impractical in remote or infrastructure-deficient areas.

Additionally, in off-grid or environmentally challenging locations, the lack of power-efficient and sustainable solutions creates a significant deployment barrier. While renewable energy sources like solar panels have been explored, they are often unreliable in indoor or low-light environments. This market gap highlights the absence of reliable, self-sustained biometric security systems designed to operate independently of traditional power sources. Addressing this gap can pave the way for deploying secure and eco-friendly biometric solutions in previously inaccessible areas, fulfilling a critical need in both urban and rural applications.

Product Description:

The Pressure-Induced Footstep Power Generator is a revolutionary biometric security solution that combines self-sustained energy generation with advanced fingerprint recognition technology. Designed to operate without external power sources, the system is powered entirely by footstep pressure, making it ideal for applications in remote or environmentally challenging settings.

This system operates through a spring-based stand equipped with piezoelectric cells that convert mechanical energy from footstep pressure into electrical energy. The generated energy is stored in a compact, rechargeable battery, which powers an integrated fingerprint sensor for secure user authentication. The seamless integration of power generation and biometric recognition offers a highly reliable, eco-friendly security solution with minimal maintenance requirements.

Key features include:

- Self-Sustaining Power Generation: Utilizes the mechanical energy from footsteps to generate and store electrical energy, eliminating reliance on batteries or wired connections.

- Adaptability: Designed to function efficiently in both indoor and outdoor environments, accommodating various conditions such as low-light settings and different types of footwear.

- Low Environmental Impact: Reduces dependency on disposable batteries, contributing to waste reduction and promoting the use of renewable energy sources.

Core Technologies:

- Piezoelectric Cells: These cells convert the mechanical energy of footstep pressure into electrical energy through a simple and efficient mechanism.
- Spring-Based Stand: Enhances the energy conversion process by amplifying footstep pressure, ensuring sufficient power output for continuous operation.
- Arduino Uno Microcontroller: Serves as the central processing unit for integrating the energy-generation system with the biometric fingerprint sensor.
- Fingerprint Board: Provides robust biometric recognition capabilities, ensuring accurate and secure identification of authorized users.

Technical and Functional Highlights

1. Power Output and Storage: The system generates a sufficient amount of energy to power the fingerprint sensor for multiple scans with each footstep, storing surplus energy for later use in an onboard rechargeable battery.

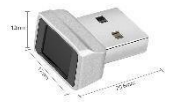
2. Compact and Durable Design: The system is lightweight yet durable, withstanding varying foot traffic levels and environmental conditions while maintaining consistent performance.

3. Ease of Installation: The standalone unit requires no wiring or additional infrastructure, allowing for flexible deployment in remote locations or temporary setups, such as event venues or construction sites.

4. Security Features: The fingerprint board supports multiple user profiles with high accuracy, ensuring only authorized individuals gain access.

5. Scalability: The design can be scaled to larger surfaces, such as entrance mats or pathways, to accommodate higher foot traffic and generate more energy.

Comparison of Alternative Products:

Features	Battery-Powered Biometric Sensors	Wired Biometric Systems	Solar-Powered Biometric Sensors
Images			
Cost	INR 2,900	INR 3,301	INR 11,500
Power Source	Disposable/rechargeable batteries	Wired connection to a power source	Solar panels
Sustainability	Limited battery life and frequent replacements	Dependent on consistent electricity	Effective only in sunny conditions
Deployment Flexibility	Limited by battery locations	Fixed installations	Dependent on sunlight and location
Environmental Impact	Generates electronic waste from batteries	Minimal impact if infrastructure is already in place	Utilizes renewable energy, but can impact land use
Maintenance	Requires regular battery replacement	Needs wiring maintenance	Solar panel cleaning and maintenance

Uniqueness of the Product:
The Pressure-Induced Footstep Power Generator stands apart due to its unique, renewable energy approach. Unlike battery-operated models that require constant maintenance or solar-powered systems that are light- dependent, this product guarantees on-demand energy by converting footstep pressure into power. This self-sustaining feature addresses a critical market gap, providing a maintenance-free, renewable power source ideal for high-traffic and remote locations.

4.STANDARDS

Standards followed in the development of this prototype ensure that it meets safety, performance, and sustainability criteria:

1. IEC 61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Systems)

- Ensures the system incorporates fail-safe mechanisms to prevent unauthorized access or malfunction during operation.
- Verifies that all electrical components meet safety-critical requirements for reliable performance in security applications.

2. ISO 9001 (Quality Management Systems)

- Requires adherence to established procedures during design, testing, and production to ensure consistent quality.
- Promotes continuous improvement to enhance reliability and customer satisfaction.

3. IEEE 754 (Floating-Point Arithmetic)

- Ensures accurate calculations for energy output and biometric recognition processes.
- Prevents rounding errors, improving the precision of digital computations.

4. ASTM D638 (Standard for Tensile Properties of Plastics)

- Confirms that plastic components, like casings, can withstand repeated mechanical pressure from footsteps.
- Ensures durability under normal operating conditions, minimizing the risk of damage.

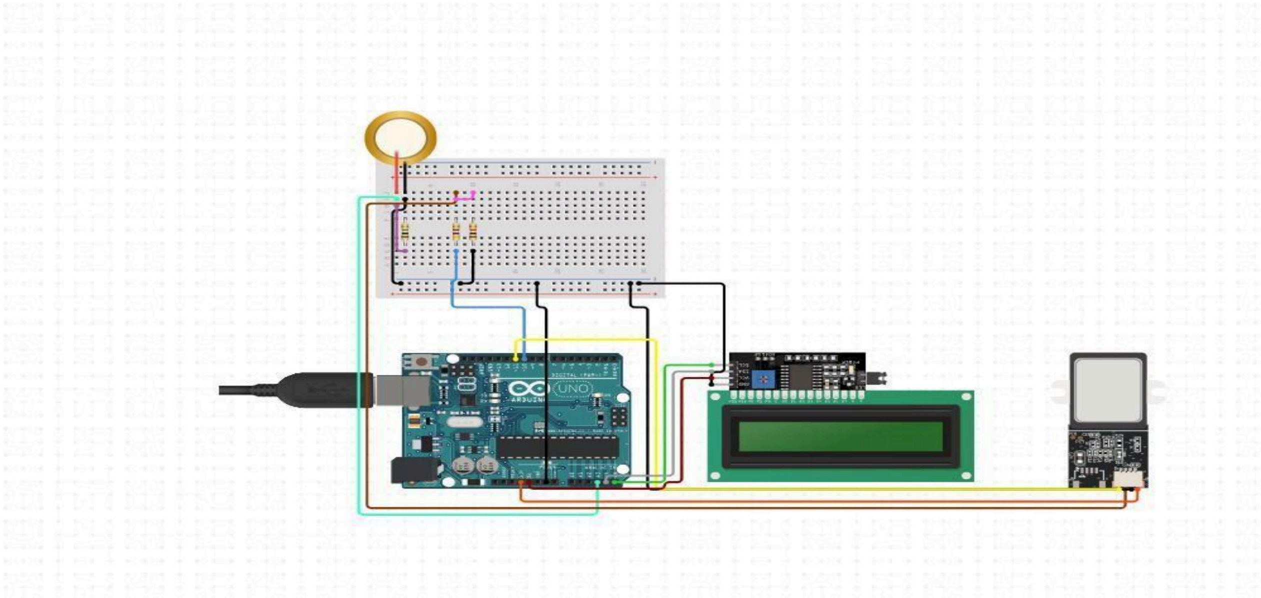
5. ISO 14001 (Environmental Management Systems)

- Promotes environmentally responsible practices during production and operation by minimizing waste.
- Ensures compliance with global sustainability goals, aligning with the eco-friendly design of the device.

6. IEC 60601 (Medical Electrical Equipment Safety)

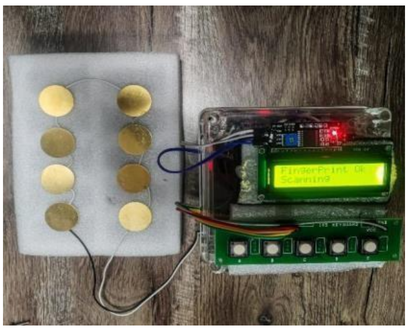
- Ensures that the system is safe for human interaction, especially for the pressure applied during power generation.
- Mandates rigorous testing for electrical safety to prevent harm to users.

5. DESIGN AND IMPLEMENTATION

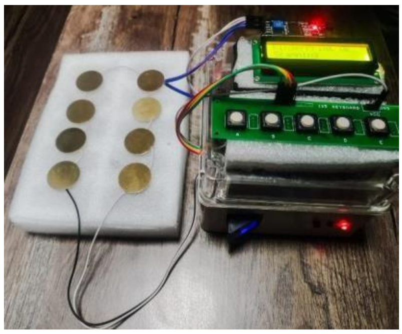


2.1. 2D Design

5.2 3D DESIGN



5.2. TOP VIEW



5.4. SIDE VIEW

6. FUNCTIONAL PROTOTYPE

Prototype Description: The functional prototype of the "Pressure-Induced Footstep Power Generator for Biometric Security" was built using both mechanical and electronic components to capture footstep energy and convert it into electrical power for the biometric fingerprint sensor. The key materials included a pressure plate with piezoelectric cells, an Arduino Uno microcontroller, a fingerprint sensor, an LCD display for user feedback, batteries, and essential wiring.

The assembly followed a modular approach:

1. **Piezoelectric Plate Integration**: The piezo cells were mounted on a spring-supported platform, allowing them to compress under foot pressure and generate electricity through mechanical stress.

2. **Arduino and Sensor Connection**: The Arduino Uno served as the control hub, managing input from the piezo cells and controlling the fingerprint sensor's activation.

3. **Power Storage**: A rechargeable battery was connected to store the generated electricity, providing consistent power to the sensor and other components when activated

7.TESTING

Testing focused on validating both the power generation efficiency and the reliable activation of the fingerprint sensor under various conditions to ensure the system's functionality across different environments.

1. Energy Output Verification

- Each piezoelectric cell was rigorously tested to evaluate its voltage and current generation capacity under different footstep pressures, simulating both light and heavy steps. On average, each step generated 0.2V, with sufficient energy accumulated in a 12V rechargeable battery.
- Energy output remained consistent even with varying step intensities, step frequencies, and user weights, proving the system's robustness and reliability across a diverse range of user profiles.
- The energy storage system was also tested for efficiency, ensuring that stored energy could be accessed and used without significant loss, even after extended periods of non-use.

2. Fingerprint Sensor Activation

- The system was rigorously tested to ensure that a single footstep generated enough energy to fully activate the fingerprint sensor and power the authentication process. In all tests, the system consistently delivered sufficient power for biometric scans.
- The response time of the fingerprint sensor was also tested under various footstep pressures, ensuring the system reliably registered and processed fingerprints in real-time.

3. Environmental Testing

- The prototype was subjected to both indoor and outdoor testing environments to evaluate its performance under different lighting and temperature conditions.
- The system successfully operated in low-light indoor scenarios, proving that it is not dependent on sunlight and could function effectively in areas such as hallways, entrances, and remote locations with minimal lighting.
- **Outdoor Performance**: The device was exposed to both sunny and cloudy weather to determine the system's resilience to environmental variables.

8. DEPLOYMENT DESCRIPTION

The deployment of the footstep-powered biometric security system is designed to be both flexible and scalable, ensuring its suitability for a variety of environments. The system can be easily integrated into existing security infrastructure, such as doors, gates, and entry points, where the pressure of footsteps is naturally generated. Its modular design allows for quick installation, with minimal disruption to existing structures. The pressure sensors can be installed under floors, walkways, or pathways, making it adaptable for both indoor and outdoor settings. Once installed, the system requires little maintenance, with energy generated from footstep pressure stored in rechargeable batteries for on-demand use. The system is particularly advantageous in remote locations, where conventional power sources are unavailable, as it can operate independently without reliance on electricity grids. By utilizing ambient energy, it offers a sustainable, eco-friendly solution for various security applications.

9. CONCLUSION AND FUTURE WORK

Summary of Key Points

- The footstep power generator effectively addresses the demand for sustainable, low-maintenance power in biometric security systems, eliminating dependency on batteries or wired connections.
- It introduces an innovative approach by harnessing human footstep energy, contributing to the adoption of green energy solutions in everyday environments.
- The system's adaptability for both indoor and outdoor applications makes it suitable for deployment in diverse settings, including remote or infrastructure-deficient areas.

Challenges Faced

- Ensuring consistent and stable power output from footsteps, especially in low-traffic areas, posed a significant challenge.
- Optimizing the energy storage mechanism to retain power for extended periods without waste required considerable refinement.
- Balancing durability and cost-effectiveness, especially in selecting materials and components, was a critical factor during development.
- Designing the system to operate efficiently under varying environmental and user conditions, such as different footwear and step intensities, required iterative testing.

Future Improvements

- **Enhanced Energy Storage:** Increase the capacity and efficiency of energy storage to prolong operational reliability and support additional features.
- **Smart Traffic Monitoring:** Incorporate sensors to monitor foot traffic and optimize energy generation in real-time based on usage patterns.
- **Integration with IoT:** Enable remote monitoring and control of the system through IoT-based platforms for better system management.
- **Broader Applications:** Expand the design for larger-scale deployment, such as in public pathways, stadiums, or high-traffic zones, to maximize energy generation.
- **Material Innovation:** Explore advanced, eco-friendly materials to further reduce environmental impact while enhancing durability.

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