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Piezoelectric Energy Harvesting Tile With Complete Power Chain

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Abstract

Piezoelectric energy harvesting materials convert mechanical energy into electrical energy [1].This study presents the design and development of a piezoelectric floor tile integrated with a complete power conditioning system including rectification, voltage regulation, and energy storage. The generated electrical energy is stored in a lithium-ion battery and can be used to power low-power devices such as sensors or small electronic systems. Experimental results show that the prototype can generate voltage peaks of several tens of volts and power in the milliwatt range under normal walking conditions. The system demonstrates the potential of piezoelectric tiles as a sustainable micro-energy solution for high-traffic public areas.

Keywords: Piezoelectric energy harvesting, floor tiles, footsteps energy conversion, sustainable micro-energy, prototype development.

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I. INTRODUCTION

The growing demand for renewable and sustainable energy sources has encouraged the exploration of alternative energy harvesting methods. One promising approach is converting mechanical energy generated from human activities, such as walking, into electrical energy. Piezoelectric materials are well suited for this purpose because they produce electrical charge when mechanical stress is applied.

In crowded urban locations such as railway stations, shopping malls, and pedestrian walkways, large numbers of footsteps generate mechanical energy that can be harvested using piezoelectric floor tiles. These tiles can convert footstep pressure into small amounts of electrical energy without requiring major changes to existing infrastructure.

Although the power produced by a single tile is relatively small, combining multiple tiles can increase the overall energy output. This work focuses on the design and development of a piezoelectric energy harvesting tile integrated with a power conditioning system for efficient energy conversion and storage.

II. MATERIALS

A. Piezoelectric Sensor Array

- **Material**: Lead zirconate titanate (PZT) ceramic discs (27–35 mm diameter, 0.4–0.8 mm thick).
- **Configuration**: 4–8 discs in series-parallel arrangement to optimize voltage (1–20 V AC peak) and current (µA–mA range).
- **Function**: Converts footstep-induced mechanical stress into electrical potential via piezoelectric effect.

B. Bridge Rectifier

- **Components**: Four 1N4007 silicon diodes (1000 V PRV, 1 A forward current).
- **Topology**: Full-wave bridge configuration.
- **Function**: Converts AC piezo output to pulsating DC, utilizing both half-cycles for >80% efficiency

C. Filter Capacitor

- **Type**: Electrolytic capacitor (100–2200 µF, 16–25 V rating).
- **Placement**: Connected across bridge rectifier output.
- **Function**: Stores charge during voltage peaks and discharges during troughs, reducing ripple for stable DC.

D. Li-ion Battery (Energy Storage)

- **Type**: 18650 rechargeable lithium-ion cell.
- **Specifications**: 3.7 V nominal, 2000 mAh capacity.
- **Function**: Stores harvested energy from footsteps for continuous USB/Arduino supply.

E. LM2596 DC-DC Buck Converter Module

- **Specifications**: 7–40 V input, 1.25–35 V adjustable output, 3 A max current.
- **Efficiency**: 75–90% switching regulation.
- **Function**: Converts variable rectified DC to stable 5 V for battery charging and system supply.

F. TP4056 Li-ion Charging Module

- **Input**: 5 V DC.
- **Output**: CC-CV charging for 3.7 V single-cell Li-ion (up to 1 A).
- **Features**: Overcharge/over-discharge/short-circuit protection.
- **Function**: Safely charges 18650 battery from 5 V regulated bus.

G. MT3608 Boost Converter

- **Specifications**: 2–24 V input, 5 V adjustable output, 2 A max current, 93% efficiency[5].
- **Function**: Steps up 3.7 V battery voltage to stable 5 V USB supply using switching regulation.

H. USB Type-A Female Connector

- **Type**: Standard 5 V/2 A charging port (pin 1: +5V, pin 4: GND).
- **Function**: Provides compatible interface for smartphones and portable devices

I. Arduino Uno R3

- **Microcontroller**: ATmega328P, 5 V operation, 14 digital I/O, 6 analog inputs.
- **Function**: Monitors voltages, counts steps, controls outputs, logs data via serial

J. 16×2 LCD Display (I2C)

- **Interface**: I2C (SDA/SCL lines only).
- **Function**: Real-time display of piezo voltage, step count, power, battery status.

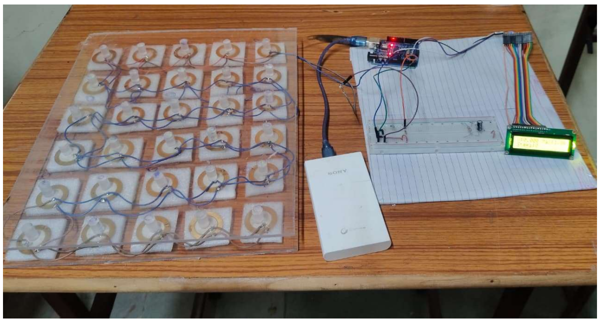

Fig1. Experiment setup of the piezoelectric tile

III. METHODOLOGY

The proposed system was developed to convert mechanical energy from human footsteps into electrical energy using piezoelectric sensors. The system consists of energy generation, power conditioning, energy storage, and monitoring stages[7].

Piezoelectric discs were mounted on a rigid base structure and arranged in a series–parallel configuration to obtain an optimal combination of voltage and current. When pressure is applied to the tile during walking, the sensors produce an alternating electrical signal[2].

The generated AC voltage is converted into DC using a bridge rectifier and then smoothed with a capacitor. A DC–DC buck converter regulates the voltage to a stable level suitable for charging a lithium-ion battery through a charging module.

The stored energy in the battery is later boosted to a constant 5 V output using a boost converter, allowing the system to power external devices. An Arduino microcontroller monitors system parameters such as voltage generation and step count, and the results are displayed on an LCD module.

The prototype was tested under different walking conditions to measure voltage generation, energy output, and overall system performance.

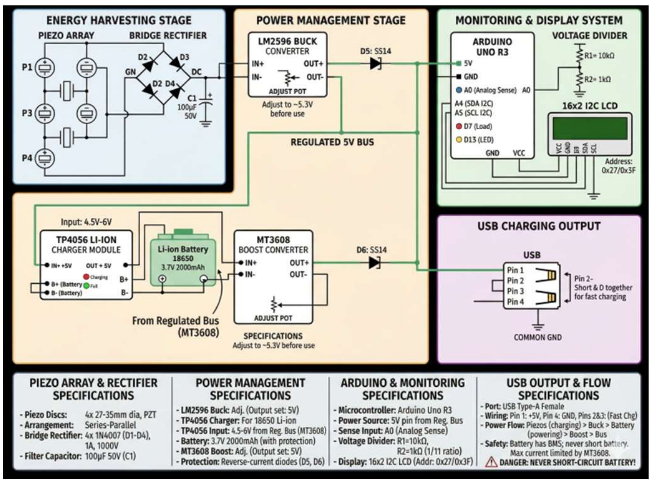

Fig2. Circuit design for the piezoelectric tile system

IV. WORKING PRINCIPLE

- Energy Generation

When a person steps on the tile, mechanical force is applied to the embedded piezoelectric discs. This mechanical deformation produces an alternating electrical signal due to the direct piezoelectric effect.

- Signal Rectification

The generated AC signal is converted into DC using a full-wave bridge rectifier circuit. This ensures that both positive and negative portions of the signal are utilized for power generation. Rectification and regulation improve energy harvesting efficiency[3].

- Voltage Stabilization

The DC output from the rectifier may fluctuate depending on the applied force. A smoothing capacitor reduces voltage variations, providing a more stable electrical signal for further processing.

- Voltage Regulation

The stabilized voltage is regulated using a buck converter, which maintains a consistent output voltage suitable for charging the battery and powering control electronics.

- Energy Storage

The regulated electrical energy is stored in a rechargeable lithium-ion battery using a dedicated charging module that controls the charging process and provides safety protections.

- Output Supply

When required, the battery voltage is increased using a boost converter to supply a stable output voltage to external devices such as mobile phones or low-power electronic systems.

- Monitoring and Display

An Arduino microcontroller continuously monitors the electrical parameters of the system. Information such as generated voltage, step count, and battery status is displayed on an LCD screen to provide real-time feedback

V. APPLICATIONS

- Smart Urban Infrastructure

Piezoelectric tiles can be installed in busy pedestrian areas to generate electricity from daily human movement. Installing energy harvesting tiles in these areas can contribute to powering local monitoring systems and information displays. The harvested energy can power small

devices such as LED pathway lights, sensors, or display indicators.

- Smart Infrastructure

- Transportation Facilities

Locations such as railway stations, airports, and metro stations experience large numbers of pedestrians.

In modern intelligent buildings, piezoelectric floor systems can be integrated to generate energy from occupants' movement. The collected energy can assist in operating automation systems or environmental monitoring devices[4].

- Educational Demonstration Systems

Energy harvesting tiles serve as effective teaching tools in engineering laboratories. They demonstrate principles of renewable energy, sensor technology, and embedded system integration.

- Distributed Micro-Energy Systems

Although the energy produced by individual tiles is small, deploying many tiles across large areas can create distributed micro-energy systems capable of supporting low-power electronics

VI. ADVANTAGES

i. Renewable Energy Source:

The system converts human motion into electrical energy, utilizing a naturally available energy source[8].

ii. Environmentally Friendly:

The technology generates electricity without producing pollution or harmful emissions.

iii. Utilization of Wasted Energy:

Mechanical energy produced by footsteps is normally wasted, but piezoelectric tiles convert it into useful electrical power.

iv. Easy Integration:

The tiles can be installed in existing infrastructure without significant structural modifications.

v. Suitable for Crowded Locations:

High-traffic areas such as stadiums, malls, and transportation hubs can generate substantial energy through continuous pedestrian movement

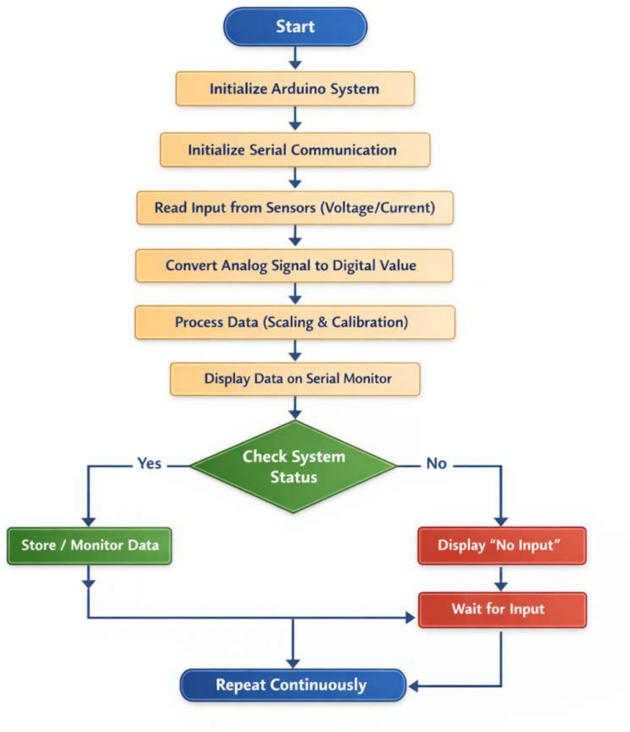

Fig 3. Software Working Flowchart

CONCLUSION:

This study presents the design and implementation of a piezoelectric floor tile system that converts mechanical energy from human footsteps into electrical energy. The developed prototype integrates piezoelectric sensors, power conditioning circuits, energy storage, and a monitoring system.

Experimental results show that the system can generate electrical power in the milliwatt range under normal walking conditions and store it in a rechargeable battery. The stored energy can be used to power small electronic devices and sensors. Although improvements in efficiency and durability are still required, the proposed system demonstrates the potential of piezoelectric tiles as a sustainable micro-energy solution for smart infrastructure and high-traffic public area.

REFERENCES:

[1] S. Priya and D. J. Inman, Energy Harvesting Technologies, Springer, 2009.

[2] A. Kumar and R. Singh, "Electrical Energy Harvester from Piezoelectric Tiles," *International Journal of Scientific Development and Research*, 2022

[3] E. Lefeuvre et al.,"A comparison between several vibration-powered piezoelectric generators," *Smart Materials and Structures*, 2006.

[4] P. D. Mitcheson,"Energy harvesting for human wearable and implantable bio-sensors," *IEEE*, 2010.

[5] S. R. Anton and H. A. Sodano, "A review of power harvesting using piezoelectric materials (2003–2006)," *Smart Materials and Structures*, vol. 16, 2007.

[6] P. D. Mitcheson, "Energy harvesting for human wearable and implantable bio-sensors," *IEEE*, 2010

[7] M. S. S. Sarip et al., "Design of Piezoelectric Tile for Energy Harvesting," *Journal of Mechanical Advancements*, 2023

[8] A. Khaligh and O. C. Onar,"Energy harvesting: Solar, wind, and ocean energy conversion systems," CRC Press, 2010

