IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 10, October 2026

DESIGN AND DEVELOPMENT OF A FOOTSTEP-BASED POWER GENERATION SYSTEM USING PIEZOELECTRIC SENSORS

Tejas Uddhav Jadhav[1], Ashish Kondekar[2]

Department of Civil Engineering, PCCOER, Pune[1,2]

Abstract: This paper proposes a compact footstep-based energy-harvesting system that uses piezoelectric sensors to convert a portion of mechanical energy from human footsteps into electrical energy. The proposed prototype consists of a mechanically supported tile, piezoelectric elements, a bridge-rectifier stage, a smoothing/storage capacitor, and a low-power output indicator. When pressure is applied to the tile, the piezoelectric elements generate an electrical signal. The rectifier converts the alternating or pulsating output into direct current, while the capacitor reduces voltage fluctuation and temporarily stores charge. The study is planned to examine the effect of sensor arrangement, repeated footstep loading, and electrical conditioning on the measured output. As the prototype has not yet been constructed and tested, this manuscript presents the proposed design and experimental procedure rather than claiming measured performance. After fabrication, open-circuit voltage, loaded voltage, current, and estimated output power will be recorded under repeatable test conditions. The work is intended as a small-scale demonstration of energy harvesting for low-power sensing or indication, not as a replacement for conventional electricity generation.

Keywords: Piezoelectric sensor, footstep energy harvesting, bridge rectifier, energy conversion, low-power application, prototype design

I. INTRODUCTION

Growing demand for electrical energy has increased interest in recovering small amounts of energy that would otherwise be dissipated in everyday activities. Human walking produces mechanical forces at the point of contact between a foot and a floor. A piezoelectric element can convert part of the mechanical stress applied to it into an electrical charge. This principle makes a footstep-operated tile a useful educational prototype for studying energy conversion and low-power electronics.

A piezoelectric footstep system generally includes a load-bearing surface, piezoelectric elements, an electrical conditioning circuit, and a storage or demonstration load. The output depends on the type and number of elements, their mechanical mounting, the force and duration of loading, the electrical connection, and the connected load. A high open-circuit voltage alone does not establish that useful power is available; voltage and current must be measured together under a defined load.

The aim of this work is to develop a proposed low-cost prototype and define a repeatable method for evaluating its electrical output. The objectives are: (i) to outline a mechanically supported footstep tile; (ii) to describe the rectification and storage circuit; (iii) to plan measurements of voltage, current, and output power; and (iv) to identify limitations that shou ld be considered before practical deployment.

The scope is limited to a small prototype and a low-power demonstration. The proposed device is not intended to supply household loads or to provide a continuous, guaranteed energy source. Its practical value will depend on the measured energy per step, durability, installation cost, and the number of steps available at the selected location.

II. LITERATURE REVIEW

Published work has investigated the use of piezoelectric elements in floor tiles, walkways, and other structures exposed to repeated mechanical loading. Asry et al. studied a piezoelectric tile and reported tests involving different participants and repeated foot pressing. Their work considered the relationship between applied loading duration and generated voltage, illustrating the importance of documenting test conditions when comparing output [1].

A 2022 paper by Asha T. and co-authors describes a footstep power-generation arrangement using piezoelectric sensors and a full-wave bridge rectifier. It explains that the sensor output requires rectification and filtering before it can be connected to a storage element or a direct-current load [2]. This supports the use of an electrical conditioning stage in the proposed design.

Earlier studies have also considered series, parallel, and series-parallel sensor arrangements. A series connection can increase voltage, while a parallel arrangement can increase the available current under suitable conditions; however, actual performance depends on the sensors and load. Therefore, the arrangement should be selected through testing rather than assuming that a particular connection will always provide the best result [1], [2].

© IARJSET This work is licensed under a Creative Commons Attribution 4.0 International License

Research gap and motivation: many student prototypes demonstrate voltage generation, but a useful evaluation should distinguish open-circuit voltage from loaded output and should state the test method clearly. This proposed study will use repeatable footstep trials, record the connected load, and calculate power only from measured voltage and current. The specific performance gap will be assessed after the prototype is built and the experimental data are collected.

III. PROPOSED SYSTEM AND METHODOLOGY

A. Proposed components

The planned prototype will use the following components, subject to availability and final circuit design: (1) piezoelectric discs or transducers; (2) a rigid top plate and supporting base; (3) a compliant layer or mechanical support to distribute force and limit excessive deflection; (4) a full-wave bridge rectifier, preferably using suitable low-forward-voltage diodes where appropriate; (5) a smoothing capacitor; (6) a storage capacitor or other suitable low-voltage storage element; (7) connecting wires and a protective enclosure; (8) a digital multimeter; and (9) an LED with a suitable current-limiting resistor for a simple demonstration. A battery should not be connected directly without an appropriate charging and protection circuit.

B. Working principle

When a person presses the tile, mechanical stress is transferred to the piezoelectric elements. The elements generate an electrical response due to the direct piezoelectric effect. The output is transient and may vary from step to step. The bridg e rectifier is intended to convert the alternating polarity into a unidirectional output. A capacitor can smooth some of the fluctuation and retain charge between steps. The conditioned output may then be measured across a defined load or used for a low-power indicator if the available voltage and current are sufficient.

C. System sequence

Footstep force → supported tile and piezoelectric elements → bridge rectifier → smoothing capacitor → measurement point and optional storage/load.

D. Mechanical design considerations

The top plate must distribute foot pressure without allowing direct crushing or sharp bending of the piezoelectric discs. The base should remain stable, edges should be secured, and wiring should be insulated and protected from moisture. The tile should not create a trip hazard or an unstable walking surface. Initial tests should be carried out with controlled loading before any person steps on the prototype. The device should not be used as a public walkway until its structural safety and durability have been checked.

E. Electrical measurements

The following quantities will be recorded: (i) open-circuit voltage before rectification, if the instrument and measurement method are suitable; (ii) rectified voltage across the capacitor; (iii) loaded DC voltage; (iv) load current; and (v) the number and duration of loading cycles. Measurements should be taken with the same circuit configuration and stated load resistance. The capacitor voltage should be measured at a consistent time after a specified number of steps.

IV. EXPERIMENTAL PLAN AND DATA ANALYSIS

The prototype has not yet been fabricated or tested. Therefore, this section defines the planned procedure and the data table to be completed after testing; it does not report experimental results.

A. Planned procedure

1) Inspect the mechanical assembly and check that the sensors and wiring are secure. 2) Test the rectifier and capacitor connections without applying foot pressure. 3) Apply a controlled, repeatable load to the tile and observe the output. 4) Record rectified voltage after a fixed number of steps, using the same measurement timing for each trial. 5) Connect a known load and measure the voltage across it and the current through it. 6) Repeat each condition at least three times where practical and calculate the mean and variation. 7) Inspect the tile and sensors after testing for loosening, cracking, or other damage.

B. Planned observation table

Trial	No. of steps	Load (Ω)	Loaded voltage (V)	Current (mA)	Power (mW)
1	To be measured	To be recorded	To be measured	To be measured	To be calculated
2	To be measured	To be recorded	To be measured	To be measured	To be calculated
3	To be measured	To be recorded	To be measured	To be measured	To be calculated

Power delivered to a resistive load can be estimated using $P = V \times I$, where P is power in watts, V is the measured voltage across the load in volts, and I is the measured current in amperes. For a known resistive load R, power may also be calculated as $P = V^2/R$. Units must be converted consistently. For example, current recorded in milliamperes must be

 This work is licensed under a Creative Commons Attribution 4.0 International License

divided by 1000 before calculating power in watts.

Open-circuit voltage should not be used by itself to calculate useful output power because current is not being delivered to a load in that condition. If stored energy is evaluated using a capacitor, the energy stored at voltage V can be estimated as $E = \frac{1}{2}CV^2$, where C is capacitance in farads. This calculation estimates energy stored in the capacitor and does not represent the total mechanical energy applied or the overall efficiency of the system.

V. EXPECTED OBSERVATIONS AND DISCUSSION FRAMEWORK

The experiment is expected to produce a transient electrical response when the tile is loaded, but the magnitude and repeatability cannot be stated before measurements are taken. The actual result will depend on the piezoelectric elements, mounting arrangement, force distribution, rectifier losses, capacitor value, measurement instrument, and load.

After testing, the results should be discussed in terms of the mean loaded voltage, current, calculated power, and variation between repeated trials. If different sensor arrangements are tested, the comparison should use the same loading procedure and load conditions. Any increase in open-circuit voltage should be distinguished from an increase in delivered power. The discussion should also state whether the output was sufficient to operate the selected indicator or whether additional conditioning was required.

Important limitations include the intermittent nature of footsteps, low available energy, losses in the rectifier and storage circuit, mechanical fatigue, variation between users, and possible damage caused by concentrated loading. A prototype may be appropriate for demonstrating energy conversion or intermittently powering a low-power indicator, but suitability for a real installation requires measured energy output, lifecycle testing, safety assessment, and an economic evaluation.

VI. CONCLUSION AND FUTURE SCOPE

This paper presents the proposed design and evaluation method for a footstep-based power-generation prototype using piezoelectric sensors. The system is planned around a supported tile, piezoelectric elements, a bridge rectifier, a smoothing or storage capacitor, and a low-power measurement or demonstration load. The proposed methodology emphasizes repeatable loading, measurement under a defined electrical load, and calculation of power from measured voltage and current.

Because the prototype has not yet been completed, no claim is made regarding its measured voltage, current, power, efficiency, or ability to operate a particular device. These findings will be added after the experimental work is completed. Future work may compare sensor connection arrangements, evaluate alternative rectifier components, improve mechanical force distribution, measure energy stored per set of footsteps, and assess durability under repeated loading.

ACKNOWLEDGMENT

The author would like to acknowledge the guidance of the project supervisor and the support provided by the Department of Civil Engineering. This acknowledgment should be revised to reflect the actual contributions and permissions before submission.

REFERENCES

[1] A. M. M. Asry, “Study on footstep power generation using piezoelectric tile,” Indonesian Journal of Electrical Engineering and Computer Science, vol. 15, no. 2, pp. 593–599, Aug. 2019.

[2] A. T., B. Priya, A. M., M. G. K. and M. T. M., “Foot Step Based Power Generation,” International Journal of Current Engineering and Scientific Research, vol. 9, no. 7, 2022. (Please verify the full author names, article pages, and DOI from the original paper before submission.)

[3] M. Nitashree et al., “Foot Step Power Generation Using Piezoelectric Material,” International Journal of Advanced Research in Electronics and Communication Engineering, vol. 4, pp. 2503–2506, Oct. 2015. (Bibliographic details reproduced from the reference list in [1]; verify against the original publication.)

[4] D. Marshiana et al., “Footstep Power production using Piezoelectric Sensors,” Research Journal of Pharmacy and Technology, vol. 9, pp. 831–834, Jul. 2016. (Bibliographic details reproduced from the reference list in [1]; verify against the original publication.)

BIOGRAPHY

Tejas Uddhav Jadhav is a Civil Engineering student at Government College of Engineering and Research, Awasari Khurd, Pune, India. His academic interests include sustainable engineering, energy-conscious infrastructure, and practical project development. This biography should be checked and edited by the author before submission.

 This work is licensed under a Creative Commons Attribution 4.0 International License