Portable Step Power Generation Using Piezoelectric Discs: Design, Implementation, and Application

G Pragnatej*, Marian Abhiroop Paul[1]

[1]*Science Department, Excellencia Infinitum School, Upparpally, Shamirpet, Telangana 500078*

*Author Email: marianpaul996@gmail.com

Abstract- **This paper presents a compact, portable system that harvests energy from mechanical pressure using piezoelectric disc. When a person steps on the prototype platform, piezoelectric discs convert mechanical energy into electrical voltage. The system incorporates a bridge rectifier and a capacitor to stabilize the signal before feeding it into an Arduino microcontroller. Voltage generated is displayed on a 4 Bit Digital Tube LED Display Module, and an LED lights up to indicate significant power generation. The setup demonstrates a clean, renewable energy concept suited for high-footfall environments such as schools, malls, and transit stations. The prototype uses nine piezo discs mounted on a wooden platform, generating up to 5V in optimal conditions.**

Keywords - Piezoelectric effect, energy harvesting, renewable energy, Arduino, step power generation, smart city technology

1. INTRODUCTION

Energy harvesting from ambient sources is an emerging area of research in sustainable technologies. Human locomotion, which involves repetitive mechanical motion, offers a practical and underutilized energy source. One promising method of capturing this energy is through the piezoelectric effect, where specific materials produce electrical charge under mechanical stress. This study describes the creation of a prototype designed by a high school student and mentor to demonstrate small-scale power generation from foot pressure. Using a piezoelectric platform and basic electronics, this system showcases how simple materials can generate real-time electrical feedback. Though this project is currently a small educational prototype, its concept has far-reaching implications for integration into public infrastructure, particularly in areas with dense pedestrian traffic.

1.1 Literature Review

Piezoelectric energy harvesting has been studied extensively in various formats, such as floor tiles, wearable devices, and sensors in transportation.

Gupta et al. (2018) demonstrated a piezoelectric footpath tile system capable of powering small streetlights.

Mishra and Singh (2020) designed a multi-layer piezo tile array for use in airports and found increased power output through parallel wiring configurations.

Arduino-based solutions like those discussed in Sharma et al. (2021) show how microcontrollers can be used to effectively display and log real-time data from piezo systems.

These studies align with and reinforce the objectives of our compact educational prototype.

2. MATERIALS AND METHODS

2.1 Components Used

Component	Quantity	Description
Piezoelectric discs	9	Convert foot pressure into electrical energy
Arduino Mega	1	Reads analogue voltage and controls display
4 Bit Digital Tube LED Display Module	1	Displays voltage readings in real-time
LED	1	Indicates when voltage exceeds threshold
Jumper Wires, Breadboard	—	Circuit connections
Wooden Board	1	Mounting surface for piezoelectric discs

2.2 Hardware Setup

- The nine piezo discs are connected in series and glued to a small wooden board to form a pressure-sensitive platform.
- When stepped on, these discs generate a small AC voltage due to internal stress and deformation.
- This AC voltage is passed through a full-bridge rectifier made of four 1N4007 diodes to convert it into DC voltage.
- A 103k capacitor smooths the output voltage.
- The resulting DC voltage is fed into Arduino Mega analogue pin A0 for real-time voltage monitoring.
- A 4 Bit Digital Tube LED Display Module shows the voltage value, and an LED provides instant visual feedback when the voltage exceeds 1V.

2.3 Working Principle

Piezoelectric materials generate an electric charge when subjected to mechanical stress. When force is applied on the piezo discs, they deform, producing an alternating voltage. This AC signal is rectified and stabilized to be readable by microcontroller systems like Arduino. The voltage generated is proportional to the pressure and frequency of steps.

2.4 Technical Specifications

- Maximum Measurable Voltage: 10.0 V
- Operating Range: 0.5–6 V
- Arduino ADC Resolution: 10-bit (0–1023 steps)
- Sampling Interval: 500 ms
- Display Refresh Rate: 2 Hz
- Piezo Output Type: AC (converted to DC)

3. CIRCUIT AND CODE

3.1 Block Diagram

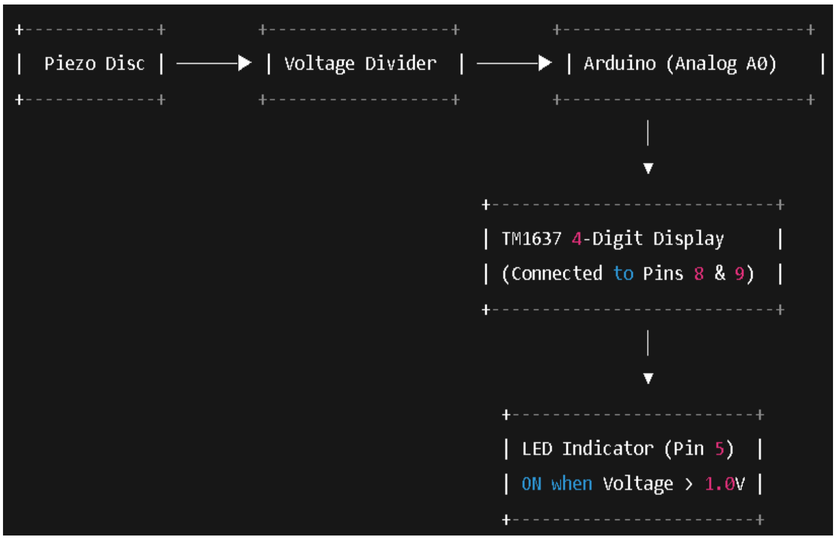


Fig 1: Block Diagram of Piezoelectric Step Power Generation and Monitoring System

3.2 Arduino Code

```
#include <TM1637Display.h>

const int CLK = 9;
const int DIO = 8;
TM1637Display display(CLK, DIO);

const int analogPin = A0;
const int ledPin = 5;

void setup() {
  pinMode(ledPin, OUTPUT);
  display.setBrightness(7);  // Max brightness
}

void loop() {
  int raw = analogRead(analogPin);
  float measured = raw * (5.0 / 1023.0); // Raw voltage at A0
  float voltage = measured * 2.0;        // Adjust for 8kΩ + 8kΩ voltage divider

  // If voltage is too low (floating or not connected), show 0.00 and turn off LED
  if (voltage < 0.3) {
    display.showNumberDec(0, true);       // Show 0.00V as 0
    digitalWrite(ledPin, LOW);            // LED OFF
  } else {
    // Convert 3.26V to 326 for display
    int displayVoltage = voltage * 100;

    // Show with decimal point: e.g., 3.26
    display.showNumberDecEx(displayVoltage, 0b01000000, true);

    // LED ON if voltage > 1.0V
    if (voltage > 1.0) {
      digitalWrite(ledPin, HIGH);
    } else {
      digitalWrite(ledPin, LOW);
    }
  }

  delay(200);
}
```

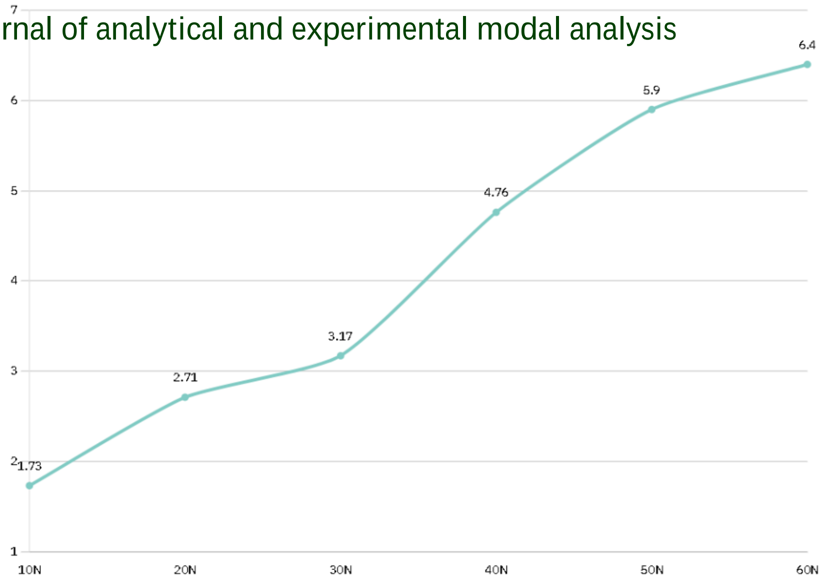
Fig 2: Arduino Code used in the Arduino Mega

4. RESULTS AND OBSERVATIONS

- Maximum Output Voltage: 10.0 V with a firm force applied.
- Average Output Voltage: ~2.5–3.5 V depending on force applied.
- Response Time: Real-time update every 500 ms on LCD.
- Power Source: USB for the 4 Bit Digital Tube LED Display Module
- Scalability: Adding parallel arrays of piezo elements may increase current capacity.

4.1 Data Collection

Step Force (N)	Voltage Output (V)
10N	1.73 V
20N	2.71 V
30N	3.17 V
40N	4.76 V
50N	5.9 V
60N	6.4 V



[Graph of Voltage vs Step Force]

5. APPLICATIONS AND FUTURE WORK

5.1 Practical Applications

- School corridors or staircases
- Subway/railway station walkways
- Pedestrian pathways in parks
- Shopping malls and sports arenas
- Temporary energy supply for remote locations

5.2 Planned Enhancements

- Battery integration: To store excess energy for lighting or charging USB devices.
- Supercapacitor addition: For rapid charge-discharge cycles.
- Wireless data logging: Using IoT modules (ESP8266/Bluetooth) for step tracking and analysis.
- Multi-piezo grid: Increase surface area and support multi-user stepping.
- Enclosure design: Protect electronics from external damage or moisture.

5.3 Challenges and Limitations

- Output voltage is inconsistent due to variation in foot pressure.
- Limited energy storage due to the absence of a dedicated power bank or rechargeable battery.
- Low current output limits practical usage beyond LED or small load indication.
- Environmental factors (e.g., moisture, dust) may affect longevity unless encased properly.

5.4 Safety and Maintenance

- The system should be enclosed in a water-resistant casing to avoid electrical damage in outdoor environments.
- Periodic testing of piezo discs and solder joints is essential to ensure long-term durability.
- Overvoltage protection should be added if battery storage is integrated in the future.
- Sharp edges and wiring must be insulated properly for safety in public spaces.

6. FUTURE SCOPE

- Integration with renewable energy monitoring systems.
- Deployment in public spaces with foot traffic analytics.
- Use in emergency floor lighting systems.
- Connecting to cloud-based IoT platforms for smart city dashboards.

7. CONCLUSION

This project successfully demonstrates a portable and scalable approach to harvesting kinetic energy from human footsteps. The prototype, while simple and educational, showcases the broader potential of piezoelectric energy generation in smart infrastructure. Future developments in storage, scaling, and data monitoring can turn such systems into viable components for sustainable urban energy networks. Beyond its technical demonstration, this project serves as an engaging educational tool for teaching students about renewable energy, basic electronics, and microcontroller programming. It promotes hands-on STEM learning aligned with NEP 2020 goals of experiential education.

ACKNOWLEDGMENT

The authors express their sincere gratitude to Mr. Marian A. Paul, Physics Teacher at Excellencia Infinitum School, for his guidance and mentorship throughout the course of this project. We also thank the Science Department and school management for providing all the necessary materials and resources that enabled the successful completion of this extracurricular initiative. This project originated from a keen interest in renewable energy and was made possible through the academic encouragement and infrastructure support provided by the institution.

REFERENCES

1. Gupta, R., Jain, A. (2018), *Piezoelectric Energy Harvesting Using Footstep: A Review*, *International Journal of Engineering Research & Technology (IJERT), Vol. 7, Issue 04*
2. Mishra, S., Singh, A. (2020), *Design and Testing of Piezoelectric Floor Tiles for Smart Buildings*, *Journal of Green Energy Technologies, Vol. 2, Issue 1*
3. Sharma, K., Chauhan, R. (2021), *Microcontroller-based Energy Monitoring using Piezoelectric Tiles*, *IEEE Conference on Smart Technologies for Energy, Environment and Sustainable Development (STEE)*
4. Priya, S., Inman, D.J. (Editors), *Energy Harvesting Technologies*, Springer, 2009. ISBN: 978-0-387-76463-4
5. Arduino Official Documentation: https://docs.arduino.cc
6. Electronics Tutorials – Piezoelectric Materials, https://www.electronics-tutorials.ws/articles/piezoelectric.html
7. Circuit Digest – Piezo Energy Harvester Project, https://circuitdigest.com/microcontroller-projects
8. Arduino Official Documentation: https://www.arduino.cc
9. NCERT Physics Class 12 – Chapter on Waves and Materials
10. Electronics Tutorials – Bridge Rectifier: https://www.electronics-tutorials.ws/diode/diode_6.html
11. Circuit Digest – LCD with Arduino: https://circuitdigest.com
12. Instructables – Piezo Energy Projects: https://www.instructables.com

APPENDIX

A. Circuit Diagram

Schematic showing the connection between the piezoelectric disc, voltage divider (R1 and R2), and Arduino analog pin A0. The diagram also includes connections to the 4Bit Digital Tube LED Display Module display and an LED indicator.

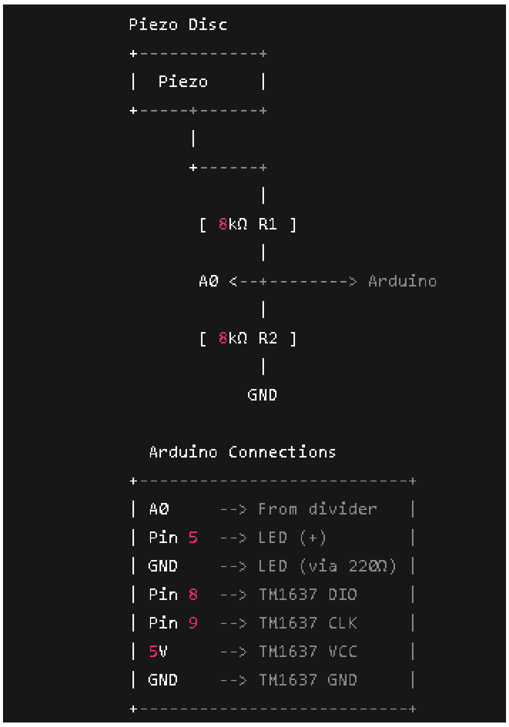


Fig 3: Circuit Diagram of the setup

B. Components Used:

- Piezoelectric Disc
- Resistors: 8kΩ (R1 and R2)
- Arduino Uno
- 4Bit Digital Tube LED Display Module
- LED with 220Ω resistor
- Jumper wires, breadboard

C. *Purpose:*

This diagram illustrates how voltage from the piezo disc is scaled using a voltage divider and read by the Arduino, which controls both a display and an LED indicator.