Footstep Power Generation Using Piezoelectric Disks

Harnessing Footstep Energy for Mobile Phone Charging

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Abstract: This report details the design, implementation, and performance of a piezoelectric-based footstep power generation system for mobile phone charging. Eight 35 mm PZT disks convert mechanical energy from footsteps into electrical energy, which is rectified, regulated, and stored in 18650 Li-ion batteries to supply a stable 5 V USB output. Comprehensive cost analysis in Indian Rupees (), efficiency evaluations, and deployment strategies are provided.

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1 Introduction

1.1 Background

The piezoelectric effect enables certain materials to create electrical charge under mechanical stress. Harnessing energy from footsteps offers a sustainable energy source for charging low-power devices like mobile phones.

1.2 Scope

This report covers system design, circuit schematics, microcontroller integration, detailed cost analysis in , efficiency and performance metrics, supported by charts and tables, and real-world application possibilities.

2 Piezoelectric Effect and Materials

The direct piezoelectric effect is mathematically expressed as:

$$D = d \cdot T + \varepsilon^T \cdot E$$

where D is electric displacement, d the piezoelectric coefficient, T mechanical stress, ε^T the permittivity, and E the electric field intensity.

Lead Zirconate Titanate (PZT) disks of 35mm diameter are utilized for their high piezoelectric coefficients (200-600 pC/N), enabling efficient mechanical-to-electrical energy conversion.

3 System Architecture

3.1 Power Generation Stage

Eight piezoelectric disks connected in parallel produce approximately 3.2 V AC at 160 mA under a 50 kg footstep load.

3.2 Power Conditioning Circuit

A full-wave bridge rectifier made from four 1N4007 diodes converts AC voltage to DC, followed by a smoothing capacitor and a DC-DC boost converter that increases voltage to 5 V for mobile charging.

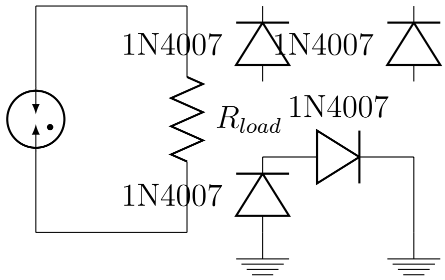

Figure 1: Simplified Power Conditioning Circuit

4 Component Specifications and Cost Analysis

4.1 Component Details and Pricing

Table 1: Key Component Specifications and Costs (Indian Rupees)

	Component	Specification	Cost ()
	Arduino Uno R3	ATmega328P, 5V operation	1,860
	Piezoelectric Disks (835mm)	PZT ceramic	240
	18650 Li-ion Batteries (2 pcs)	3.7V, 2500mAh capacity	240
	I2C LCD Module	162 Display	250
2LightGray	1N4007 Diodes (4 pcs)	1000V, 1A rectifier	60
	Capacitors and Resistors	Various values	200
	Breadboard and Wires	Prototyping kit	200
	Cell Holder	218650 battery holder	100
	Miscellaneous	Connectors, LEDs, transistor	234.5
	Total		**3,384.50**

4.2 Component Cost Breakdown

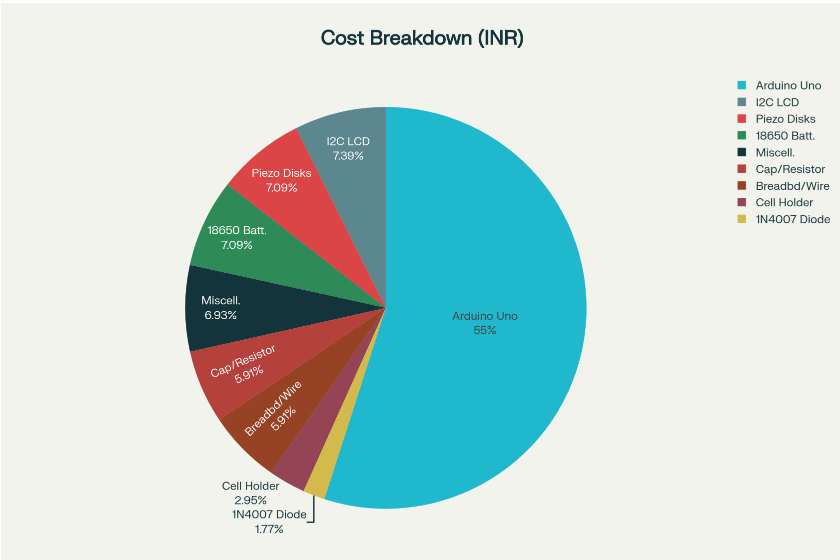

Figure 2: Component Cost Breakdown in Indian Rupees ()

5 Performance Analysis

5.1 Electrical Output

- AC Voltage from piezo disks: 3.2 V
- DC Voltage after rectification: 1.8 V
- Output Current: 160 mA
- Generated Power: $3.2 \times 0.160 = 512\,\text{mW}$
- Usable Power after system losses: 244.8 mW (47.8% efficiency)

5.2 Charging Time for Smartphone Battery

For a battery capacity of 3000 mAh at 3.7 V (11.1 Wh), charging time is estimated as:

$$t_{\text{charge}} = \frac{11.1\,\text{Wh}}{0.245\,\text{W}} \approx 45.3\,\text{hours}$$

5.3 Power Conversion Efficiency Stages

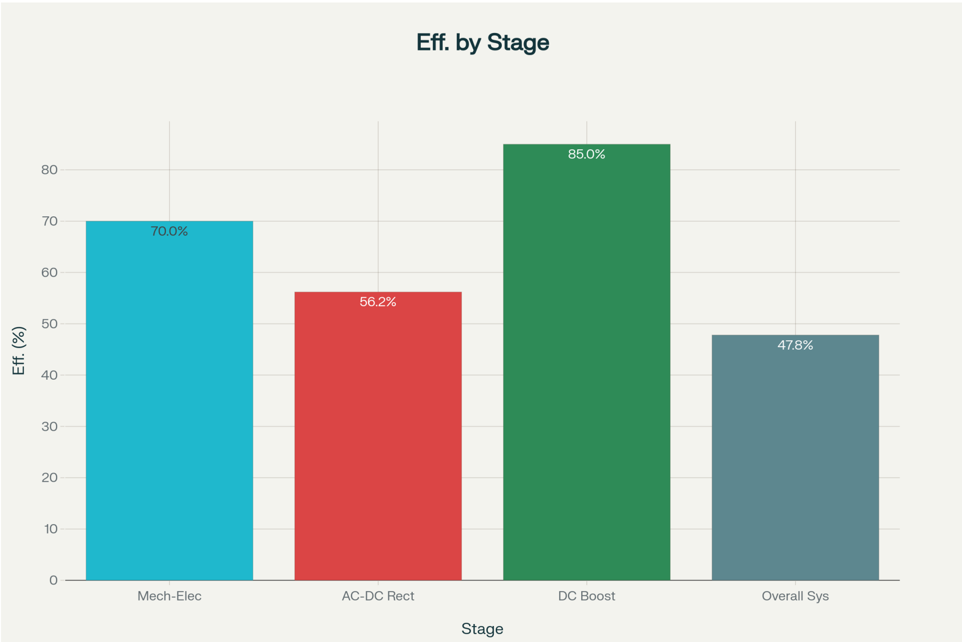

Figure 3: Power Conversion Efficiency Breakdown

Table 2: Power Conversion Efficiency Stages

	Stage	Efficiency (%)
	Mechanical to Electrical (Piezo)	70
2LightGray	AC to DC Rectification	56.2
	DC-DC Boost Conversion	85
	Overall System Efficiency	47.8

6 Arduino Programming Overview

The Arduino Uno microcontroller reads the piezo voltage via the analog input, processes power metrics, controls the I2C LCD for user feedback, and logs data via serial communication.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27,16,2);
const int piezoPin = A0;
float voltage = 0.0;

void setup() {
  lcd.init();
  lcd.backlight();
  Serial.begin(9600);
}

void loop() {
  int sensorValue = analogRead(piezoPin);
  voltage = sensorValue * (5.0 / 1023.0);
  lcd.setCursor(0,0);
  lcd.print("Voltage:␣");
  lcd.print(voltage);
  lcd.print("␣V␣␣␣");
  Serial.println(voltage);
  delay(500);
}
```

Listing 1: Simplified Arduino Code Example

7 Applications and Implementation

7.1 Deployment Scenarios

This system is ideal in locations with high pedestrian traffic, including:

- Railway stations — platforms, ticket counters
- Shopping malls and commercial building lobbies
- Educational institution campuses and libraries
- Public transport hubs such as bus and metro stations
- Entertainment venues like clubs and concert stages
- Bank entrances and ATM areas

7.2 Scalability

Multiple modules can be connected in parallel to increase power capacity. Future work includes integration with IoT devices and smart grid systems.

8 Conclusion and Future Work

This project effectively demonstrates sustainable footstep energy harvesting with piezoelectric disks, achieving approximately 244.8 mW usable power. While insufficient for fast charging, it supports trickle charging and emergency power supply.

Future research directions include:

- Development of advanced piezoelectric materials to enhance conversion efficiency.
- Implementation of Maximum Power Point Tracking (MPPT) algorithms for adaptive power extraction.
- Exploration of wireless power transfer methods.
- Deployment and field testing at high-traffic Indian locations.