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Design and Developmnet of A Piezoelectric Insole

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ABSTRACT

This study evaluates the performance of piezoelectric materials in converting kinetic energy from footsteps into electrical energy and examines the resulting current and voltage for powering an LED. Test results indicate that body weight influences the output current and voltage of the piezoelectric circuit integrated into a shoe insole. Using a capacitor, the highest recorded current was 0.48 mA at a body weight of 80 kg. In tests with an LED, the peak current was 0.28 mA, with a voltage drop to 2.99 V at the same weight. The highest voltage output with a capacitor reached 15.50 V at 80 kg. Although the generated current and voltage were relatively small, parallel circuit configurations improved performance. Capacitors proved essential for storing energy and maintaining consistent LED illumination during walking, highlighting the potential of piezoelectric shoe insoles as practical alternative power sources.

Keywords*: piezoelectric, kinetic energy, body weight, shoe insole, current, voltage.*

1. INTRODUCTION

The demand for environmentally friendly alternative energy sources is increasing in line with technological advancements and awareness of the limitations of conventional energy resources. These limitations motivate innovations to develop practical solutions that can support daily life while reducing dependence on fossil energy (Pramudiyanto & Suedy, 2020). One potential alternative energy source is kinetic energy generated from human physical activities, such as walking or running.

Piezoelectric technology offers opportunities to convert pressure or vibration into electrical energy. The term piezoelectric comes from the Greek word "piezo," meaning "pressure," allowing electronic devices to convert pressure into electrical flow through special crystals. This technology is increasingly attractive for development, as several studies have preceded research on utilizing piezoelectricity as an energy generator. Notable examples include the design of piezoelectric systems in speed bumps with a cantilever system (Putra et al., 2016) and studies generating electricity from human footsteps using parallel-connected piezoelectric devices (Stiawan & Taufiq, 2020). The problem statement of this research is how to design footwear that can generate electrical energy from human footsteps using piezoelectric

materials. The focus is on how much and how to optimize the electrical energy produced to charge small devices like LED lights.
In this context, the research will focus on analyzing the performance of piezoelectric materials in generating sufficient voltage and current to consistently power LEDs during walking activities. Additionally, this technology has significant potential for further development on a larger scale, opening up opportunities for environmentally friendly energy accessible anywhere (Pramudiyanto & Suedy, 2020).

2. LITERATURE REVIEW

2.1. *Piezoelectric*

Piezoelectric in Figure 1 is electronic components capable of generating electrical energy when mechanical pressure is applied to their surfaces. These materials consist of crystalline, ceramic, or polymer molecules that produce electrical energy under pressure, which will be harnessed for electricity generation.
There are two distinct effects in piezoelectric materials: the direct and inverse piezoelectric effects. When mechanical pressure is applied, the direct piezoelectric effect generates an electric potential. Conversely, when an electric voltage is applied, the piezoelectric effect produces mechanical pressure. Positive and negative charges are often separated within piezoelectric crystals but can be symmetrically distributed, rendering the crystal neutral (Stiawan & Taufiq, 2020).

Figure 1. Piezoelectric

Parallel Piezoelectric Circuit

A parallel circuit configuration connects two or more components to the same voltage source. In a piezoelectric parallel circuit, each positive and negative component is connected to a single point, completing the parallel piezoelectric circuit. The principle of a parallel circuit states that current flowing through each branch varies based on resistance in each branch and the potential difference across them.

Systematically, the series circuit can be seen in the following equation.

$$Itotal \ = I1 + I2 + I3 + IN \quad (3)$$

$$Vtotal = V1 = V2 = V3 = VN \quad (4)$$

dimana,
$Itotal$ = Total current of circuit in Ampere (A)
$Vtotal$ = Total voltage of circuit in Voltage (V)

Rectifier Circuit

The output of piezoelectric devices is typically in the form of AC voltage or impulse signals, which cannot be directly utilized. Therefore, an energy harvesting system is required to convert and stabilize the output. A full-wave rectifier is employed to transform both the positive and negative cycles of the AC signal into DC voltage. This system comprises components such as energy storage media, voltage regulators, and rectifiers to ensure stable and usable power output.

In electrical circuits, rectifiers and wave regulators are combined to integrate voltage regulation and bridge rectification into a single unit. The waveform produced by a full-wave rectifier does not undergo phase shifting. Instead, the inversion of the opposite-phase waveform transforms troughs into peaks, resulting in a consistent DC output.
A basic bridge rectifier system in Figure 2 utilizes four diodes arranged in a bridge configuration. Diodes D1 and D3 rectify the positive half-cycle of the AC signal, while Diodes D2 and D4 handle the negative half-cycle, effectively converting the AC signal into a smooth DC output suitable for storage or direct use.

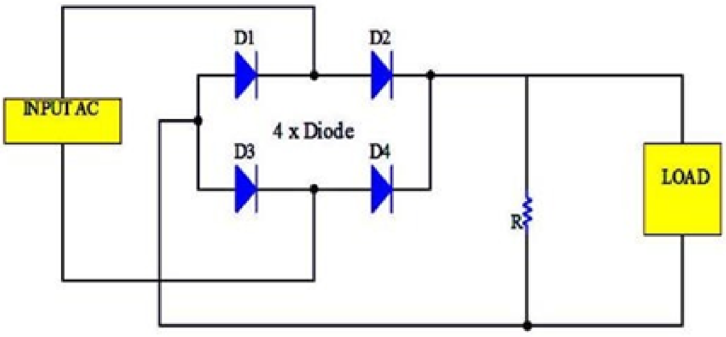

Figure 2. Bridge Rectifier Circuit

2.2. Dioda IN5819

The IN5819 diode in Figure 3 is a Schottky diode designed for DC and low-voltage AC rectification. With a low forward voltage drop, it efficiently converts current and minimizes energy loss. It is widely used in power supplies, battery charging circuits, and solar panel systems due to its high-current capacity and optimal performance at low voltages.

Figure 3. Dioda IN5819

2.3. Capasitor

A capacitor in Figure 4 behaves as a filter in piezoelectric circuits to stabilize the generated voltage. The voltage output from piezoelectric devices is often unstable due to fluctuations; thus, the capacitor filters high-frequency components, producing a smoother voltage. As a low-pass filter, the capacitor stores and releases energy, reduces noise, and maintains signal stability and circuit performance.

Figure 4. Capasitor

2.4. LED

An LED (Light Emitting Diode) in Figure 5 is a semiconductor component that emits light when an electric current flows through it, based on the principle of electroluminescence. LEDs are highly efficient, consume low power, have a long lifespan, and are compact in size. These characteristics make LEDs widely used for indicators, lighting, and displays. With their bright and energy-efficient output, LEDs have become a popular solution for various modern electronic and lighting applications (Hariyono & Nasution, 2023).

Figure 5. LED

3. RESEARCH METHODOLOGY

The research begins with planning and conceptualizing the study, conducting literature reviews from books and journals, writing proposals, assembling tools, collecting data, analyzing results, and drawing conclusions.

A. Research Flow Diagram

Research flow diagram is seen by Figure 6.

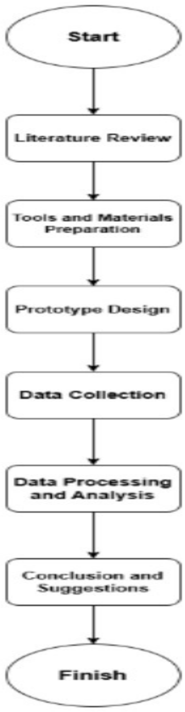

Figure 6. Research Flow Diagram

B. Research Tool Cicuit

Research tools is given by Figure 7.

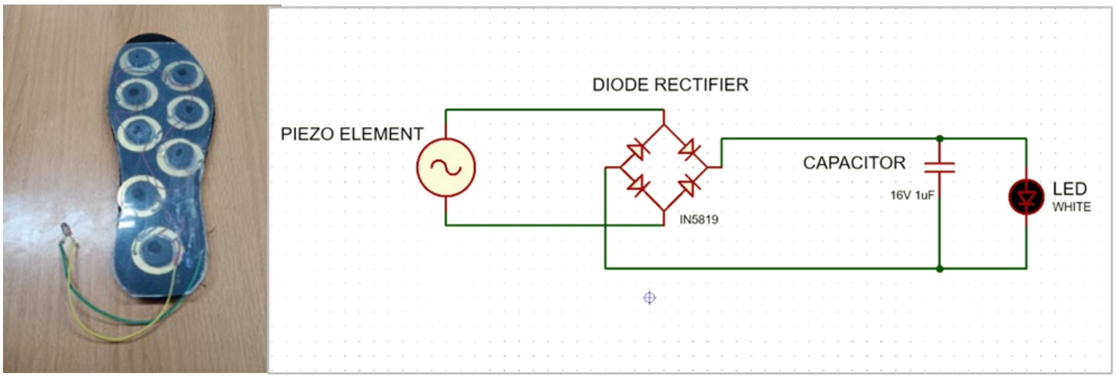

Figure 7. Research Tools

C. Testing Tool Circuit

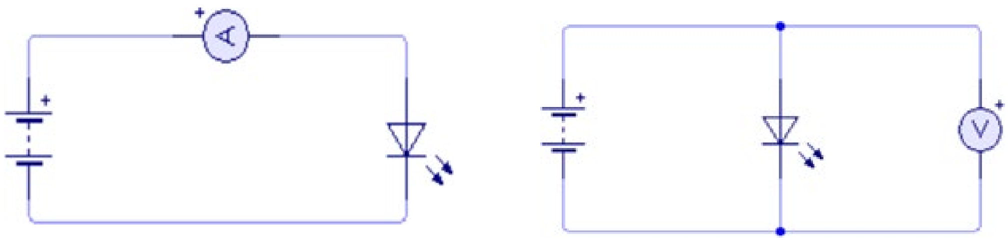

Figure 8. Current and Voltage Output Test Circuit

Figure 8(a) is a schematic diagram of the output current testing circuit. In this study, output current testing will be conducted using a parallel circuit configuration. Figure 8(b) shows the schematic diagram of the output voltage testing circuit, where voltage testing will be performed using both series and parallel circuit configurations.

4. RESULT AND DISCUSSION

In its implementation, the trials focused on loads of 80 kg and 50 kg with the number of human footsteps. The main parameters of this research involve output voltage and current. Meanwhile, the calculation process remains a point of attention. The prototype was subjected to specific loads and a certain number of steps, and its voltage and current were measured for data collection. Voltage measurements were conducted using a multimeter connected in parallel with a capacitor in the rectifier circuit. Current measurements were taken with a multimeter connected in series with the capacitor in the rectifier circuit and the load being an LED.

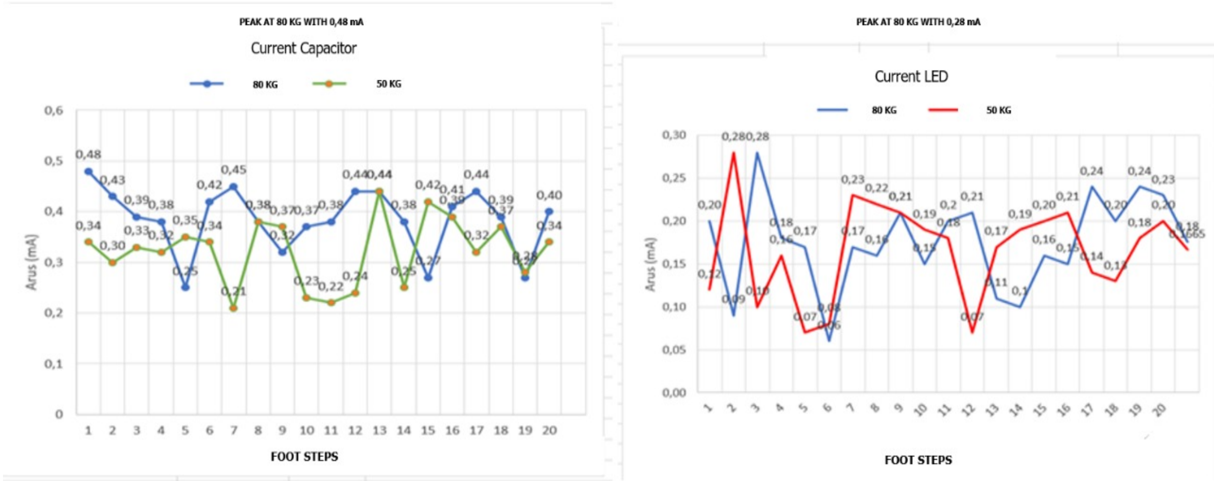

Figure 9. Graph of the relationship between the number of footsteps and body weight on output current with capacitors and using LEDs.

Figure 9 shows that different body weights, namely 80 kg and 50 kg, can affect the output current of each circuit, whether it uses only capacitors or uses LEDs as the load. It can be seen that the current graph with capacitors has the highest current value at 0.48 mA at a body weight of 80 kg. Meanwhile, the current graph with LEDs shows similar peak current characteristics between body weights of 80 kg and 50 kg, both valued at 0.28 mA.

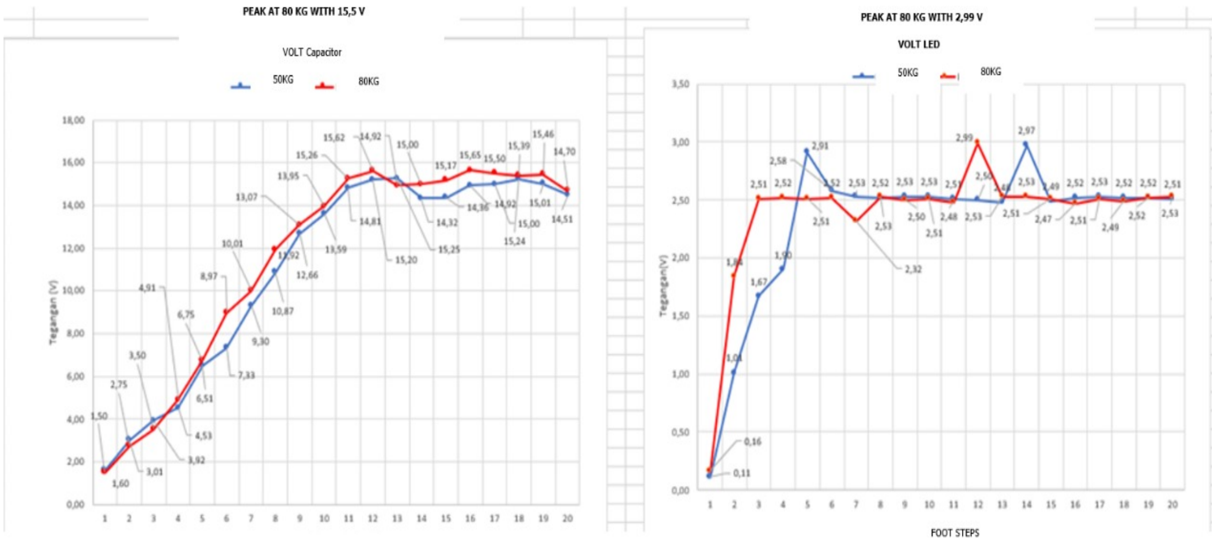

Figure 10. Graph of the relationship between the number of footsteps and body weight on output voltage with capacitors and using LEDs.

Figure 10 indicates that different body weights, namely 80 kg and 50 kg, can influence the output voltage of each circuit, whether it uses only capacitors or uses LEDs as the load. It can be seen that the voltage graph with capacitors has the highest voltage value at 15.50 V at a body weight of 80 kg. Meanwhile, the current graph with LEDs shows a peak voltage characteristic that decreases to 2.99 V at a body weight during testing with 80 kg. This occurs because the system focuses on supplying a constant voltage to power the LED with an operating voltage of 3V.

5. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

Based on the research conducted, it can be concluded that piezoelectric materials are capable of converting kinetic energy from footsteps into electrical energy. Testing with varying pressure showed that piezoelectric devices can generate voltage and current, although the amounts are relatively small. The piezoelectric circuit connected in parallel proved to enhance output voltage and current. Performance analysis indicates that the voltage and current produced are sufficient to power an LED as a visual indicator, although the LED's illumination depends on the stability of the pressure received by the piezoelectric material. Therefore, the use of capacitors as temporary energy storage is necessary to ensure that the LED can consistently light up during walking activities.

B. Recommendations

To improve energy conversion efficiency, it is recommended to explore more sensitive piezoelectric materials and optimal circuit configurations. The use of capacitors should be optimized with more efficient storage circuits, such as supercapacitors, so that the generated energy is sufficient for long-term applications. Additionally, trials with variations in activity intensity, such as running or brisk walking, should be conducted to measure their impact on the amount of energy produced. Integration with other technologies, such as sensors or IoT, can also be developed to monitor and optimize energy usage in daily applications.

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