RANCANG BANGUN PROTOTIPE ALAT PEMANEN ENERGI LISTRIK BERBASIS PIEZOELEKTRIK DARI TEKANAN PADA ANAK TANGGA

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Design of a Piezoelectric-Based Electric Energy Harvester Prototype from Pressure on Stairs

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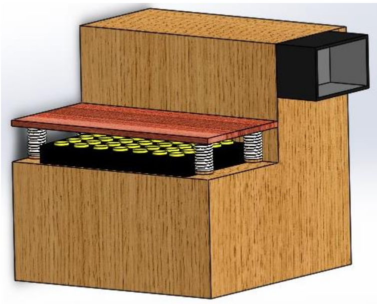
ABSTRACT



Electrical energy is one of the energy that is needed by people throughout the world, to support human and industrial activities. The large demand for electrical energy can be caused by running out of resources such as the use of fossil energy as an energy source and the resulting effects such as environmental pollution, so there is a need for innovation to overcome this. One of the innovations in this research is by utilizing a human footing on a piezoelectric ladder as an alternative energy. Piezoelectric is a sensor that can react when given vibration or pressure. Energy harvesting steps are made using piezoelectric circuits arranged in series of 30 pieces. This harvester is assisted by a DC voltage rectifier using 4 diodes and a digital multimeter. The output power of one piezoelectric when going up the stairs is 0.13 mW and when going down the stairs is 4.32 mW, the output can be influenced by how to climb and descend the stairs, both slowly and quickly. Piezoelectric scheme with 4 piezoelectric and 4 rectifiers and then in series the power produced is more effective than 4 piezoelectric in series and then rectified using 1 rectifier. The power that can be harvested in 1 day with a total of 30 piezoelectric and 500 steps going up and down the stairs is 30.975 Watts/day. When going up and down the stairs it generates a different force which is superior when going down the stairs.

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1. INTRODUCTION

Electrical energy is one of the energy that is needed by humans and industry throughout the world. Excessive and continuous use of natural energy sources can gradually run out and can also cause damage to nature [1]. Therefore, there is a need for a solution to prevent this by obtaining electrical energy from energies that we do not realize are all around us and are wasted for free, one of which is in our daily activities and the energy contained in our appliances [2]. which is created when walking on stairs which is used as a low-power alternative energy harvester that can be utilized.

The source of electrical energy is obtained by converting the kinetic energy generated by human movement into electrical energy [3]. This is achieved by using electronic components, namely piezoelectric, piezoelectric energy harvesting systems. This system, together with an efficient energy management suite, can be used to charge batteries and save electrical energy with just simple everyday activities.

Piezoelectricity is the ability to work on components of quartz and certain other materials. The production of piezoelectric electrical energy by mechanical stress is called the piezoelectric effect [4]. The piezoelectric effect can be divided into two areas: the direct piezoelectric effect, which converts mechanical energy to electrical energy, and the direct piezoelectric effect, which converts mechanical energy to electrical energy, and the inverse piezoelectric effect [5].

Heart Foam and Rubber Sheet are used as a base and also as a protector for piezoelectric components that are subjected to excessive pressure loads. Heart foam and rubber were chosen because they are soft or not too hard, have spring-like properties that can return to their original shape when pressed and also have high elasticity [6]. AC-DC rectifier circuit which converts alternating current (AC) voltage to direct current (DC), the output of the rectifier has ripple, adds a filter or regulator to reduce ripple and produce a smoother and more consistent waveform at certain values [7].

2. METHODS

The method used in this research is the design of a piezoelectric-based electrical energy harvester prototype from the pressure on the stairs. The system design uses an experimental method that aims to compare the results of electrical energy from piezoelectric schemes.

2.1. Hardware Design

This research was conducted by making a system block diagram that serves to see the relationship between components so as to form a system to achieve research objectives. The system block diagram will be an overview of the system to be made [8] shown in Figure 1. The input from the block diagram process is the human footrest, which will enter the conversion process stage by the piezoelectric sensor so that mechanical energy in the form of footing pressure is converted into electrical energy in the form of VAC, the converted energy enters the rectifier circuit, which aims to convert AC electricity into DC which will then be supplied to the LED as a load [9].

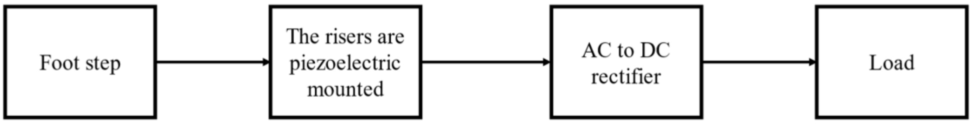

Figure 1. System Block Diagram

2.2. Software Design

The design of the software is described as a flowchart that functions to understand the flow of the system starting from input and data retrieval shown in Figure 2 [10] . The flow diagram of the system starts with permanent energy which contains a piezoelectric circuit connected in series, will respond to mechanical energy from human pressure when climbing and descending stairs and will be converted into AC electrical energy, then the piezoelectric output energy will be turned over to DC so that energy can be stored in a capacitor. then the output voltage will be measured using a digital multimeter [11].

2.3. Piezoelectric Design

Making a prototype using a series circuit, the series circuit will be divided into 2, namely the first series circuit installed 1 piezoelectric rectifier has 1 DC rectifier using 4 diodes and so on, and the second is a series circuit directly from the piezoelectric with 1 DC rectifier, then the output results are connected to the load is an LED [12]. Shown in Figure 3.

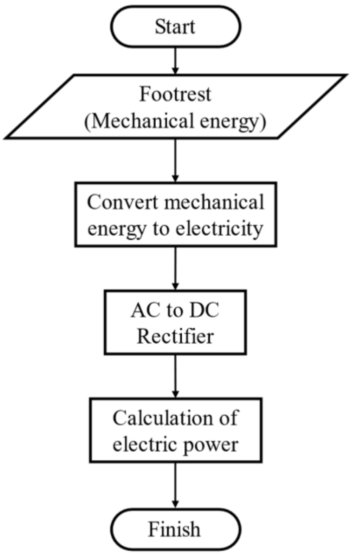

Figure 2. System Flow Chart

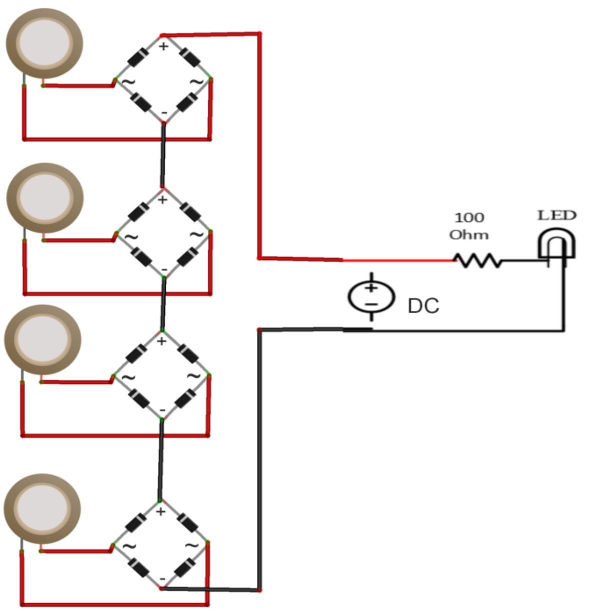

Figure 3. Circuit Scheme of 4 Piezoelectric Series, 4 Rectifiers

The series circuit can be explained in that the output from the positive part of the first rectifier is connected to the negative part of the second rectifier, and the positive part of the second rectifier is connected to the negative part of the third rectifier. The piezoelectric circuit is in series with 4 piezoelectric 1 DC rectifiers, where the negative side of the piezoelectric is connected to the negative side of the other piezoelectric and so on [13] – [15]. Shown in Figure 4.

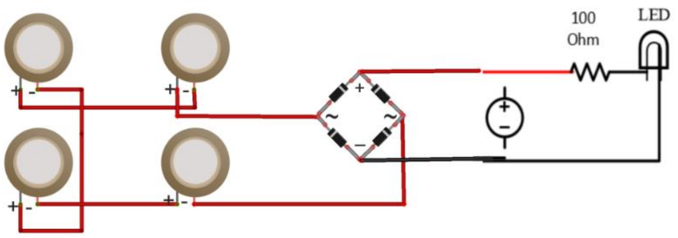

Figure 4. Circuit Scheme of 4 Piezoelectric Series, 1 Rectifier

3. RESULT AND MATERIALS

The results and discussion of the study consisted of testing prototypes, piezoelectric feature testing, piezoelectric circuit schematic testing.

3.1. Prototype Testing

Prototype testing aims to determine the piezoelectric characteristics, and compare the output voltage, current and calculation of the power value, generated by the good prototype piezoelectric series 4 circuit scheme, 4 rectifiers and series 4 piezoelectric circuit schemes 1 rectifier [16], [17], by going up and down the stairs that have been made, and the tester's weight is 75 kg.

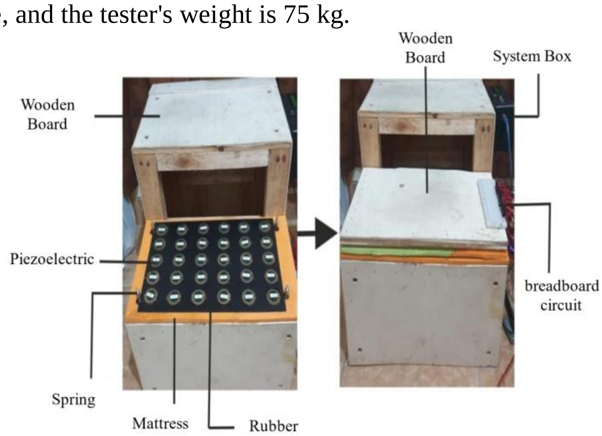

Figure 5. System Build Framework

The frame of the permanent risers has a height of 15 cm between the steps, footing 45 cm long and 27 cm wide footing, with 30 pieces of piezoelectric piezoelectric installed [18].

3.2. Piezoelectric Characteristic Testing

Feature testing is carried out in order to find out the features of 1 piece of piezoelectricity, with a variety of pressure techniques, when going up and down stairs, and find out how much output is produced by the piezoelectric which has been rectified using 4 diodes into a DC voltage, and given a load of LEDs [19]. Shown in Table 1.

Table 1. Piezoelectric Test Results 1 Module

No	Piezoelektrik	Voltage (mV)DC	Current (mA)	Power (mW)	Explanation
1	1 Piezo	1.93	0.07	0.13	Piezoelectric Test Results 1 Module
2	1 Piezo	4.2	1.03	4.32	Pressed when going down the stairs slowly
3	1 Piezo	2.33	0.08	0.18	Pressed when climbing stairs quickly
4	1 Piezo	6.13	1.08	6.62	Pressed while going down the stairs quickly

The results of testing 1 piezoelectric module which can be interpreted that when going up and down the stairs the output value differs more when going down the stairs, as well as the way the footrests are, when going up and down stairs, this can be the effect of the piezoelectric output voltage becoming unstable.

3.3. Piezoelectric Circuit Scheme Testing

Testing of this piezoelectric circuit scheme is carried out in order to determine the efficiency of the piezoelectric output energy in the form of voltage, current and power, measured using a digital multimeter, of two types of circuit schemes namely testing of 4 piezoelectric 4 rectifier circuit schemes and testing of 4 piezoelectric 1 rectifier circuit schemes. This test is carried out up and down the stairs by assembling them in series [20].

The test was carried out 5 times to try going up and down the stairs and recording the output for one step, this is done because of the way the pressure is different when going up and down the stairs, so that it will affect the pressure given even though the weight or load is the same, so that an average of 5 times the stamping will be taken.

3.3.1. Schematic Testing of Series 4 Piezoelectric Series 4 rectifiers

The test results of the 4 series piezoelectric circuit scheme, 4 direction rectifier, produce an average power value of 75.42 mW when going down stairs and 21.29 mW when going up stairs. This experiment is by stepping in general when going up and down the stairs, the resulting power output when going up and down the stairs is different, here because the pressure energy when going down the stairs is greater than the compressive energy when climbing the stairs. Shown in Table 2.

Table 2. Schematic Test Results for Series 4 Piezoelectric Series, 4 Rectifiers

No	Voltage (mV)		Current (mA)		Power (mW)	
	Climbing up the stairs	Down the stairs	Climbing up the stairs	Down the stairs	Climbing up the stairs	Down the stairs
1	5.54	11.5	0.47	0.48	2.603	5.52
2	2.42	13.12	0.19	3.04	0.459	39.88
3	4.22	7.79	0.27	0.29	1.139	2.259
4	2.71	7.37	1.75	3.2	4.742	23.58
5	6.4	12.29	1.93	0.34	12.35	4.178
Average	21.29	52.07	4.61	7.35	21.29	75.42

3.3.2. Schematic Testing of 4 Series Piezoelectric Circuits, 1 Rectifier

Test results of the 4 series piezoelectric circuit scheme, 1 rectifier produces an average power value of 9.02 mW when going down stairs and 2.69 mW when going up stairs. This experiment is by stepping in general when going up and down the stairs, the resulting power output when going up and down the stairs is different, here because the pressure energy when descending the stairs is greater than the pressure when climbing the stairs. Shown in Table 3.

Table 1 Schematic Test Results for 4 Series Piezoelectric Circuits, 1 Rectifier

No	Voltage (mV)		Current (mA)		Power (mW)	
	Climbing up the stairs	Down the stairs	Climbing up the stairs	Down the stairs	Climbing up the stairs	Down the stairs
1	4.95	11.48	0.71	0.25	3.51	2.87
2	2.59	7.36	0.1	3.78	0.25	27.82
3	4.8	8.63	1.85	0.19	8.88	1.63
4	4.97	8.98	0.07	1.28	0.34	11.49
5	2.66	9.98	0.17	0.13	0.45	1.29
Average	3.99	9.28	0.58	1.12	2.69	9.02

Comparison of the power generated from the use of a piezoelectric scheme in the experiments that have been carried out produces a series of 4 piezoelectric circuit schemes, 4 rectifiers and 4 piezoelectric circuit schematics, 1 rectifier, which can be seen the power gain by going up and down the stairs and 5 trials, circuit scheme of 4 piezoelectric series 4 rectifiers, producing the greatest power, namely the average power when up and down reaches 21.29 mW and 75.42 mW.

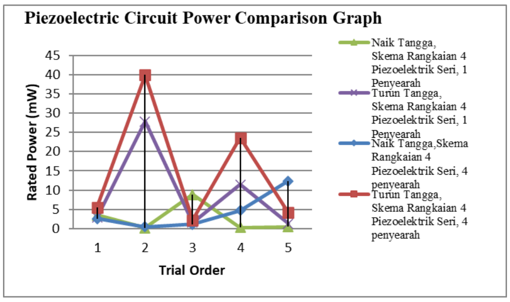

Figure 6. Piezoelectric Circuit Power Comparison Graph

3.4. Estimation of Piezoelectric Energy Harvester Rung Potential

Many studies have utilized piezoelectricity as a generator of electricity, based on previous research studies in chapter 2, this time the analysis is carried out how much potential output power is generated by the prototype as an alternative electrical energy in a day by the specifications of the steps that have been made, based on the results of piezoelectric characteristic testing data. the average value of the power generated when going up and down the stairs as follows in Table 4.

Table 2 Power Generated By 1 Piezoelectric

No	Piezoelectric	Power (mW)	Explanation
1	1 Piezo	0.13	Pressed when going up the stairs slowly
2	1 Piezo	4.32	Pressed when going down the stairs slowly
3	1 Piezo	0.18	Pressed when climbing stairs quickly
4	1 Piezo	6.62	Pressed while going down the stairs quickly

a. The Piezo type is Piezoelectric PZT with a size of 35 mm totaling 30 pieces
b. The height of the steps is 15 cm between the steps, the length of the steps is 45 cm and the width of the steps is 27 cm
c. Assuming the number of human steps up and down the stairs as much as 500 times per day.

Assuming the size of the prototype that has been made can be installed as many as 30 piezoelectric pieces and can produce power with the calculation Piezo Generating Power = Power 1 piezo going up the stairs x the number of piezoelectrics assembled Piezo Generating Power = 0.13mW x 30 = 3.9mW = 0.0039 Watt/foot climbing up the stairs. Or Piezo Generating Power = Power of 1 piezo going down the stairs x the number of piezoelectrics assembled Piezo Generating Power = 4.32mW x 30 = 129.6mW = 0.12 Watt/ step down stairs. If the efficient assumption of a piezoelectric generator is stepped on 250 times when going up stairs and 250 times when going down stairs per day, then the output power is 0.0039 Watt x 250 steps = 0.975 Watt/day when going up stairs or 0.12 Watt x 250 steps = 30 Watt / day when going down the stairs if you add up and down the stairs, it becomes 500 steps producing a power of 0.975 Watt + 30 Watt = 30.975 Watt/day so to get a power of 30.975 Watt/day, it requires 500 steps of stepping.

4. CONCLUSIONS

Based on the results of the tests carried out, it can be concluded that the output power of one piezoelectric when going up the stairs is 0.13 mW and when going down the stairs is 4.32 mW, the output can be influenced by how to climb and descend the stairs both slowly and quickly. Piezoelectric scheme with 4 piezoelectrics and 4 rectifiers and then in series the resulting power is more effective than 4 piezoelectrics in series and then rectified using 1 rectifier. The power that can be harvested in 1 day with a total of 30 piezoelectrics arranged in series and in a number of steps 500 times going up and down the stairs is 30.975 Watts/day.

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