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Energy Harvesting on Footsteps Using Piezoelectric based on Circuit LCT3588 and Boost up Converter

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ABSTRACT

Piezoelectric utilization as a generator is an effort to obtain electrical energy that refers to the concept of energy harvesting referring the development of piezoelectric as a generator that converts the pressure or vibration generated from steps into electrical energy that can be used on low-power electronic devices. Because the use of piezoelectric as a generator allows the use in charging low voltage, a larger resource is required in different series. Based on the problem, an energy harvesting device and a voltage amplifier are created to increase the voltage of the pizoelectric output. An arduino microcontroller is used to control the energy harvesting device and voltage booster. It is required approximately 10 steps to charge four AA 1.2 Volt batteries and 80 steps to charge two 12 volt batteries respectively.

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1. INTRODUCTION

The current energy crisis is a problem that greatly affects the survival of human life, especially the problem of electrical energy. The development of technology makes most of human activities are supported by various equipment and technologies that use electrical energy as a source of energy. This certainly makes the electrical energy as an inseparable part in all human activities. The main source of power today is fossil fuel, but fossil fuel is non-renewable natural resource and the availability is limited because it has a certain amount of mass and if used continuously without any restriction it will considerably decrease and run out. The production and use of fossil fuel has a detrimental effect on the environment, and fossil fuels are carbon dioxide producers that produce greenhouse gases. Along with the increasing energy demand and the unbalanced condition between the demand and supply due to the decrease of the fossil fuel supply, the development of alternative energy sources is needed to meet current energy needs.

A renewable energy is needed to reduce the use of fossil fuels as a major source of energy for power generation. It is a source of sustainable energy that is available in nature and can be used in a relatively long time so that there is no need to worry about the lack of the resources. Reflecting to the last few years, many studies have been conducted in developing renewable energy sources both in large and small scale. One of the research developments of renewable energy is energy harvest design. Some previous researchers have conducted energy harvesting research such as Kymissis et al. conducting a research on energy harvesting on shoe-use by using micro-generator [1]. When the shoe stepped on, the micro-generator rotates to produce voltage. Energy harvesting in sea and river using small generators is conducted by Taylor et al. [2].

The generator is driven by the flow of river water and ocean currents to produce very low energy. Controls and modifiers for energy harvesters using micro power are examined by Shengwen Xu et al. [3]. Pizoelectric transducer is used to generate micro power and digital control is used to increase the dc power of micro power.

The mechanical analysis of vibrate energy harvesters on pizoelectric is carried out by Blažević et al. [4]. In an experiment to analyze the mechanics of energy harvesters, a Caterpillar is used to create vibrations against the pizoelectric. The energy harvester of the pizoelectric transducers is applied to shoes by Rocha et al. [5]. When the shoes are used for walking, they will produce energy from pizoelectric transducers applied to the shoes' pedestal.

Designing a circuit using pizoelectric transducers and capacitors has been conducted by Pisharody [6]. The circuit is arranged in parallel to which the output voltage is rectified with the diode bridge circuit. The harvesting of vibrational energy by using pizoelectric transducers has been performed by Wang et al. [7]. Four pizoelectrics are coupled in parallel to the diode, and then the output voltage is measured and tested by several forces. The greater the force applied, the greater the voltage resulted.

The dropped energy harvesting using pizoelectric and its model has been conducted by Alkhaddeim et al. [8]. The pizoelectric circuit is modeled and tested with water droplets such as rain. In the test it is seen that the voltage generated by the pizoelectric closes to 0.5 volts with a 10Kohm output. Energy harvesting from low airflow velocity using pizoelectric has been investigated by [9]. Pizoelectric energy harvesters are installed on the windmill so that when the windmill is rotated, the pizoelectric produces energy. A research on rectifiers for energy harvesters has been examined by Do et al [10]. The rectifier circuit is examined and applied to the energy harvester using a Triac component which gate is controlled by a digital block.

The research on inverter design for stand-alone piezoelectric energy harvesting has been conducted by Stein & Hofmann [11]. The inverters are designed using a new resonant inverter topology that applies dynamic energy harvesting techniques. The research on super capacitors applied to pizoelectric energy harvesting has been investigated by Shahriat et al.[12]. This paper presents the application of energy harvesting on foot steps using pizoelectric transducer. This study is different from the studies previously mentioned. This research modifies the pizoelectric energy harvesting circuit so that the output voltage from energy harvesters can be stored at large energy sources such as battery.

2. RESEARCH METHOD

2.1. Hardware Design

This paper presents a renewable energy by using a transducer to convert pressure energy into electrical energy designed as shown in Figure 1. It shows that the transducer used is piezoelectric which has the capability as some crystals and other materials in that they can generate electrical voltage if getting pressure or strain treatments. Piezoelectric has the ability to generate electrical voltage when given a mechanical pressure. In this study, the pizoelectric is assembled using a parallel circuit as shown in Figure 2. The picture shows that in one footstep there are 40 pizoelectrics arranged in parallel. The parallel circuit serves to raise the pizoelectric output current.

The voltage and current generated from the pizoelectric is so small that an energy harvesting circuit is required. The energy harvesting circuit used is LTC3588 IC circuit. The output voltage generated from this circuit is very small that is 1 volt so that the output voltage is not able to charge 12 volt energy source. Based on these problems, this paper explains the idea of how to calibrate a 12-volt battery using energy harvesting components.

Figure 1 shows that the output from the energy harvester is used to charge two AA batteries. After the batteries are full, they are connected to the boost step up circuit so that the voltage goes up to 12 volts. This boost step circuit uses XL6009 IC as shown in Figure 3. It is seen in the picture that the circuit uses 33uH inductor that serves as a current folder. The output of this circuit is used to charge the 12-volt battery. As shown in Figure 1, the study uses a microcontroller to control the flow of power flowing from the pizoelectric to the 12 volt battery. The voltage sensor is used to determine the voltage stored in two AA batteries. This sensor is connected to the Arduino microcontroller and this microcontroller is used to control the relay. The algorithm to control the relay is fuzzy cell decomposition algorithm [13]. Fuzzy algorithms has been frequently used by former researchers to control algorithms such as in guadrotor control.

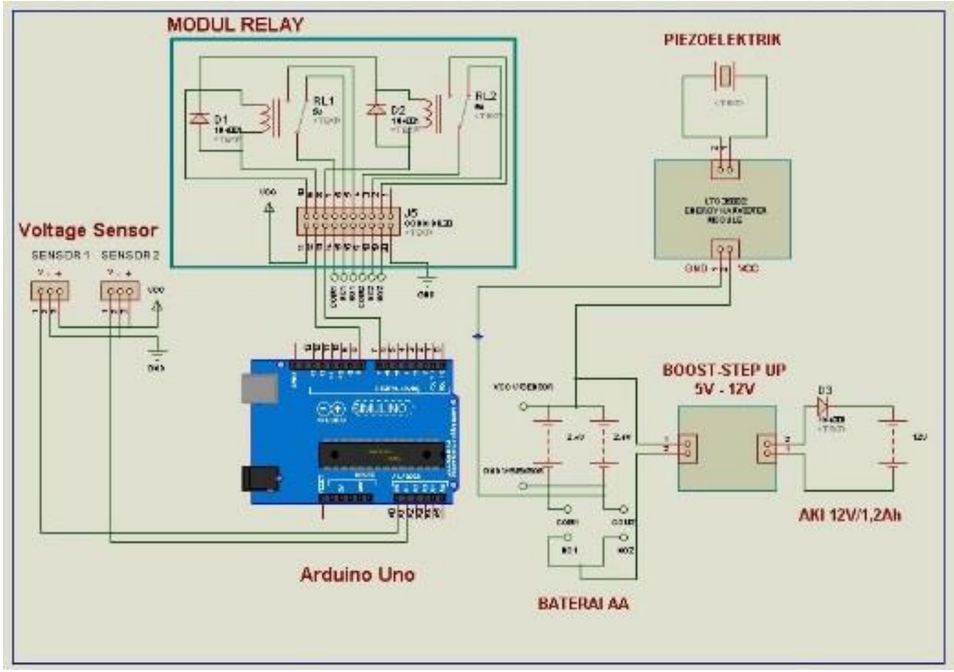

Figure 1. Design of pizoelectric energy harvester to charge 12 Volt battery

Figure 2. The 40 piezoelectric circuit is coupled by using a parallel circuit

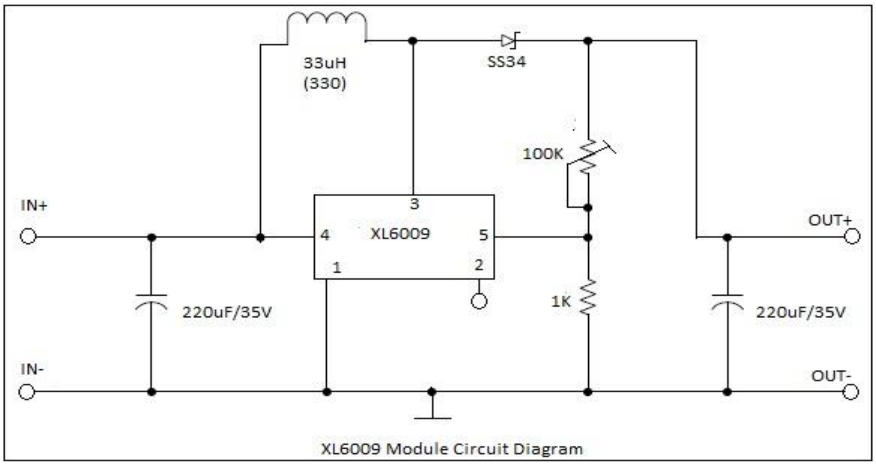

Figure 3. Boost up converter circuit

2.2. Software Design

The function of the microcontroller in the energy harvesting circuit is to do a simple control that is to control the ignition time on the relay circuit so as to make the channeling of the AA battery voltage to the 12 Volts battery voltage, read the input from the voltage level detector, and give action on each input given by a voltage level detector circuit,as shown by the flowchart in Figure 4. Figure 4 shows that the initial step of the program is to initialize the pin and memory usage of the microcontroller that is followed by the ADC initialization which will be used to read the voltage level [14]-[16].

The program will then read from the signal given by the voltage level detector circuit. When the voltage is sufficient, the microcontroller will do the ignition control on the relay circuit and turn on the light indication of the safe input voltage level. When the input voltage indicates the descending level, the microcontroller stops the control on the relay which is then continued by turning on the LED indicated in red and the Buzzer sounds. The control algorithm uses fuzzy algorithm control found by zadeh that have been used in multi-quadrotor path planning [13], closest path planning for motorcycle safety [16], path planning of robot trash [17] and quadrotor control [18].

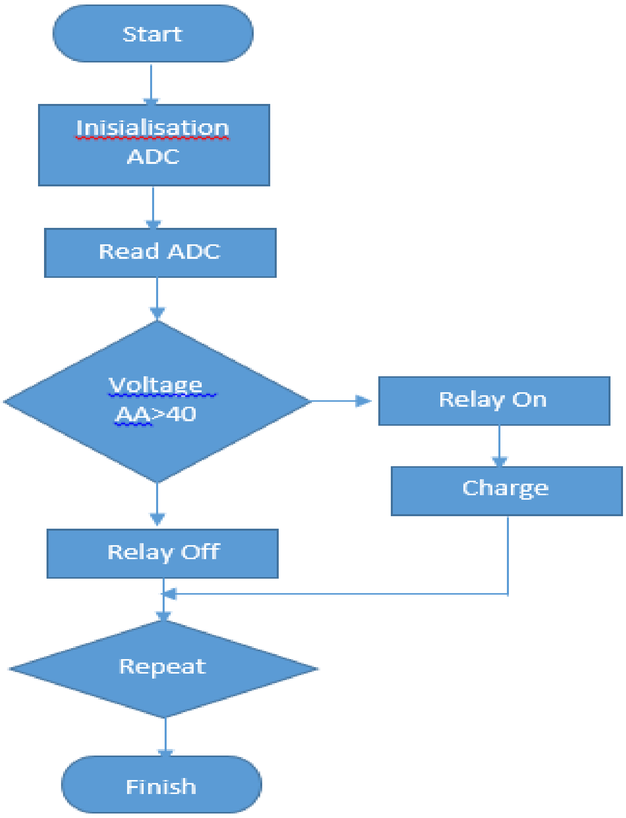

Figure 4. Flowchart energy harvesters

3. RESULTS AND ANALYSIS

The system testing and analysis include piezoelectric system test and current reader circuit test previously made. In piezoelectric system test, forty piezoelectrics were arranged in parallel, then, in the last stage, there was a test for charging the battery.

3.1. The test on 40 Piezoelectrics in Parallel

The test of the output voltage on the forty piezoelectris in the parallel circuit is shown in Figure 5. The figure shows that the forty piezoelectris were tested by applying an average weight of people 70 Kg. In the graph, it can be seen that from fifty tests using heavy pressure of 70 Kg weight of people, the piezoelectric output voltage varies from 35 Volts to 50 Volts. Although they have the same weight, different pressures generate different piezoelectric voltages.

The current test of forty piezoelectrics arranged in a parallel circuit is shown in Figure 6. The figure shows that the forty piezoelectrics are tested by applying an average weight of 70 Kg. From the graph, it can be seen that from fifty tests using pressure of people of 70 Kg showed that the piezoelectric output current varies from 22 milli-ampere to 33 milli-ampere. Although people have the same weight, but different pressures generate different piezoelectric currents.

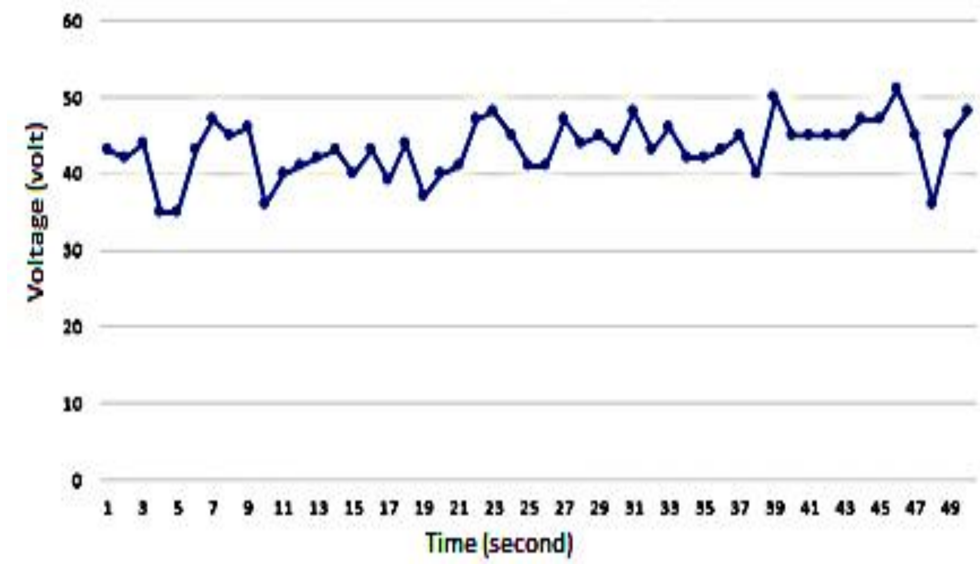

Figure 5. Voltages generated by 40 piezoelectrics in parallel

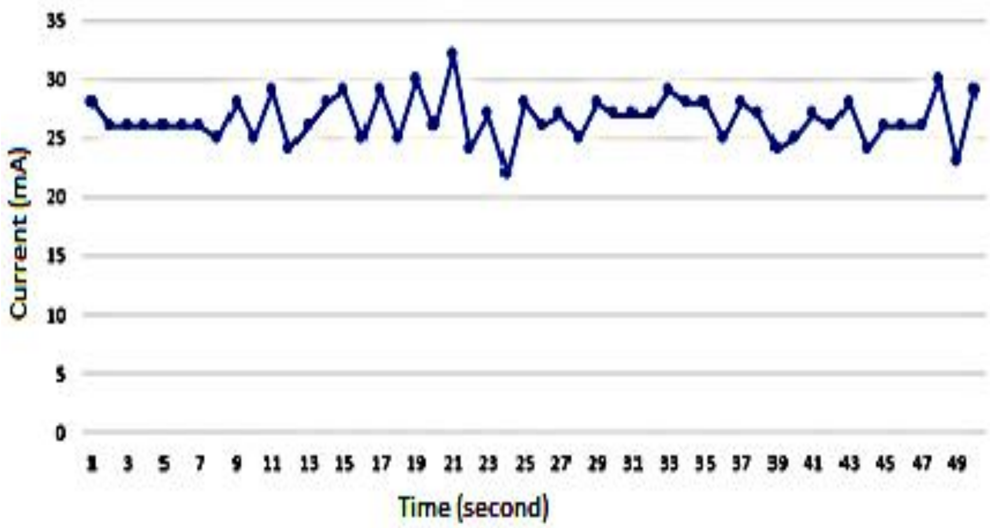

Figure 6. Current generated by 40 piezoelectrics in parallel

3.2. Battery Charging Test

AA battery charging current test using forty piezoelectrics in parallel circuits is shown in Figure 7. The picture shows that the forty piezoelectrics are tested by gving a pressure of 70 Kg weight. From the graph, it can be seen that from fifty tests using pressure of people of 70 Kg showed that the piezoelectric output current varies from 1.2 milli-ampere to 1.6 milli-ampere. Although people have the same weight, but different pressures generate different piezoelectric currents.

AA battery charging current test using forty piezoelectrics in parallel circuits is shown in Figure 8. The picture shows that the forty piezoelectrics are tested by giving a pressure of 70 Kg weight. From the graph, it can be seen that from fifty tests using pressure of people of 70 Kg showed that the piezoelectric output current varies from 9 volts to 20 volts. Although people have the same weight, but different pressures generate different piezoelectric currents.

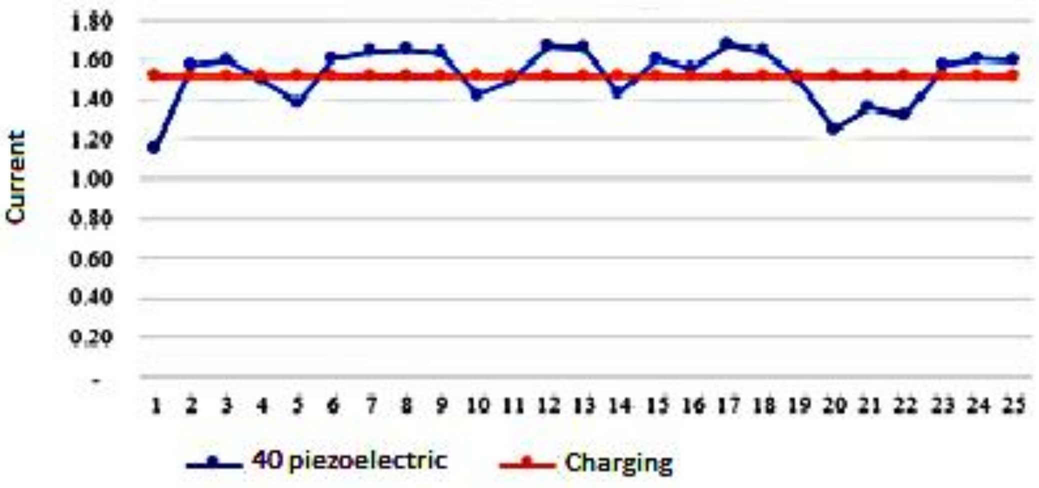

Figure 7. AA battery test using 40 piezoelectrics in parallel

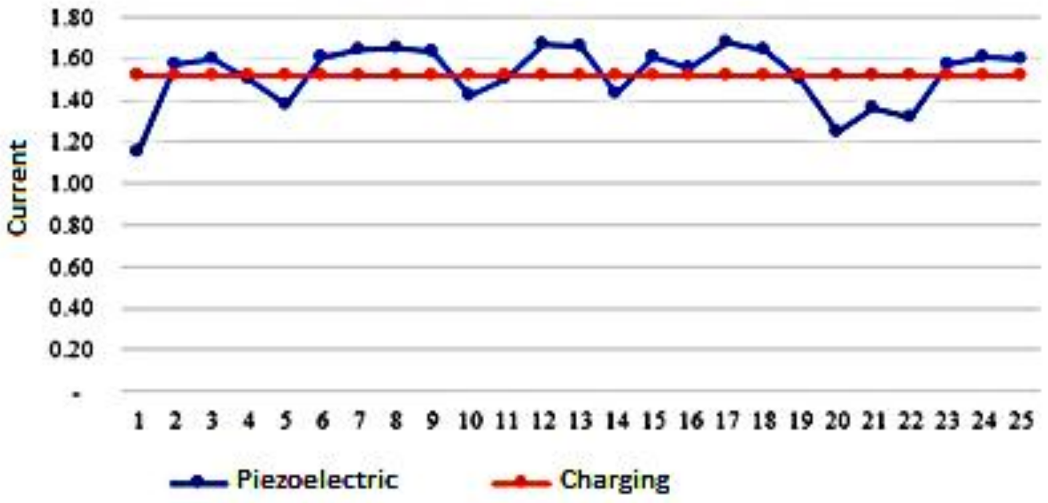

Figure 8. AA battery test using 40 piezoelectrics in parallel

4. CONCLUSION

Based on the discussion and the analysis of the data that has been obtained, it can be concluded that the current and voltage generated by piezoelectric is proportional to the size of the given force. The highest current obtained is 938 micro amperes and the lowest is 641 micro amperes. While the highest voltage obtained is 80 volts and the lowest is 67 volts. The utilization of electric current and voltage from the piezoelectric with small current and large voltage for charging the battery can be carried out by limiting piezoelectric output voltage using voltage regulator in accordance with the capacity of the battery used. This results in a long time consumed in battery charging due to the small current cut by the regulator. The greater the cutting voltage, the greater the discharged current. In addition, the frequency of stepping on the piezoelectric floor affects on the battery charging. The higher the frequency, the more stable the current, and the faster the battery charged. Piezoelectric current and voltage monitoring can be performed, but for monitoring the battery capacity takes a considerably long time due to the very small battery capacity, whereas microcontroller can only process with a minimum change of 4 mV.

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