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Green Floor Tiles Energy Harvesting Using Piezoelectric Disc

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Abstract: Energy harvesting using a piezoelectric material can save the energy consumption as it can be used to be one of the alternatives instead of fully using the conventional energy and the energy harvesting using the piezoelectric module is already practiced, but the energy harvesting is directly place under the floor tiles, and that kind of design has several drawbacks such as loose wiring problem, less efficient and less reliable design. The crucial objective of this research is to develop an embedded energy scavenging module using the piezoelectric concept in the floor tiles. In this research, 9 piezoelectric is used to develop the green floor tiles and the method used in this project were the piezoelectric had been embedded under the floor tiles. Then, a rectifier circuit was connected with the driver circuit in order to control the PWM signal from Arduino. The circuit was then connected to the DC-DC converter before being charged to the rechargeable battery. it can be concluded that piezoelectric discs can convert the mechanical energy from footsteps into electrical energy in AC voltage. Furthermore, the piezoelectric can be stored in an average total of 22.22 hours to charge a 12 V rechargeable battery. Thus, the green floor tiles succeed in harvesting energy using the piezoelectric and for the future work recommendation do increase the number of piezoelectric and add on a support element to the piezoelectric discs.

Keywords: Energy Harvesting, Piezoelectric, Floor Tiles, Boost Converter

1. Introduction

Energy harvesting or energy scavenging can be reviewed as capturing minute amounts of energy at surrounding energy sources from one another and accumulating them as well as storing them for future use[1]. From another point of view towards the energy conversion, humans have already succeeded in using the energy scavenging technology in the form of solar energy, geothermal and many more. Renewable energy is also called macro energy harvesting technology as it can generate a kilowatt or Megawatt's range of power [2]. Comparing the piezoelectric material with another electromagnetic method, it provides higher density and higher flexibility in being embedded into a system [3].

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In recent years, many innovative products especially the floor tiles where in almost all types of building have been developed. As far from that, an innovation of floor tiles with embedded energy harvesting component should be introduced. The energy harvesting using the piezoelectric module is being practiced, but the energy harvesting module is directly place under the floor tiles, and this kind of design has several drawbacks such as loose wiring problem, less efficient and less reliable design. The effectiveness is quite low as it is not directly to the force needed to generate the energy.

An innovative and creative product could attract the community awareness about new things such as the advantages of energy harvesting using the piezoelectric material. Besides, it also can help on reducing the energy consumption of the community and also help on reducing the need for burning fossil fuels. This means that the environment could be healthier than before and possible in reducing environmental issues. The crucial objective of this research and studies is to develop an embedded energy scavenging module using the piezoelectric concept in the floor tiles. Its measurable objectives are to design an effective piezoelectric generation circuit for floor tiles application, to integrate the piezoelectric generation circuit with the floor tile and to develop the appropriate energy storage circuit for the generation circuit. The expected outcome for this project is to succeed in developing the floor tiles that can generate voltage and be charged to the 12V rechargeable battery.

1.1 Scopes of study

This project proposed to use Piezoelectric transducer that will be embedded into a set of floor tile to developed an energy harvesting. The scopes represent the limitation of the project in order to predict the amount of energy harvest from it. The scopes of the research are Piezoelectric disc transducer produced more than 5 V, this product need to be applied only at crowded area to ensure its reliability, a 20 cm x 20 cm ceramic floor tile is used in this project and a 12 V, 2.2 AH battery is used as the storage element.

2. Methodology

This project can convey into several parts which were, the piezoelectric itself, rectifier circuit, boost converter and the storage element. Conversely, this project will use a vibration method for the Piezoelectric disc to start generating the energy before the energy being stored in an effective energy storage system. A rectifier is applied after the piezoelectric sensor received the mechanical motion (vibration) to convert the AC to DC. Furthermore, a boost converter is then applied after the rectifier to boost up the output voltage. The energy generate is stored in a 12 V, 2.2 AH where it can eventually withstand until 48 hours plus minus.

2.1 Methods

This project development will be divided into several stages in order to make the project flow becoming more systematic, manageable and much easier to troubleshoot to the problem accordingly based on the objectives stated above. Figure 1 illustrates the general project flowchart in order to fulfill the objectives stated and make the project run successfully. The project was begun with reviewing past research and project in order to figure out the limitation and improve it in this project. Next, the feasibility studies were conducted based on the data and information collected from the past research. Then, the circuit is designed for the whole system using Matlab Simulink and Proteus to simulate the circuit before proceed to hardware. Troubleshooting the possible problems until it is solved is vital before it can be proceeded with the analysis and discussion.

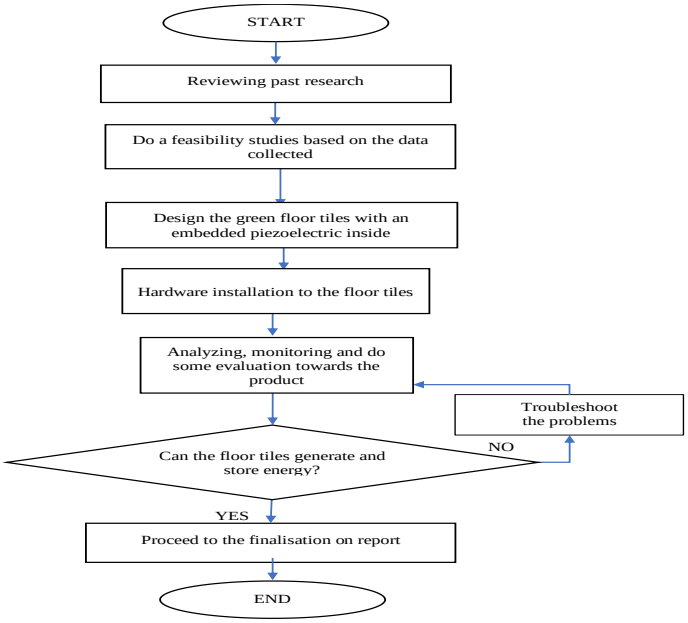


Figure 1: General flowchart of the project

The piezoelectric discs were connected in series-parallel connection. There were nine piezoelectric discs used for this project. The piezoelectric had been stick with a spring made up from galvanized wire. These wires act as a damper to piezoelectric from cracking Figure 2 illustrates the piezoelectric series-parallel connection in two different connections. Figure 2 shows six parallel connections with four series connection and four parallel connection and six series connection. As for Table 1, it illustrates the piezoelectric tiles development from scratch floor tiles.

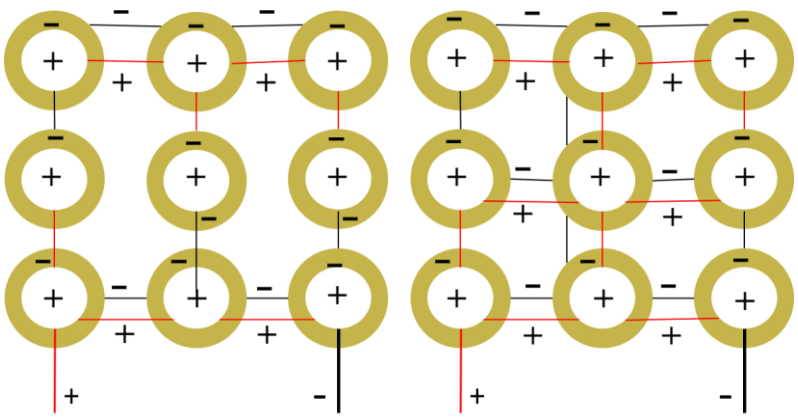
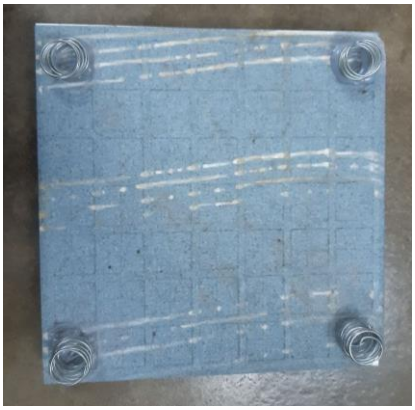
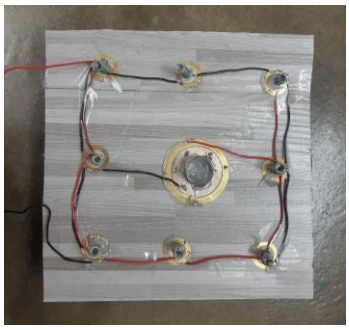
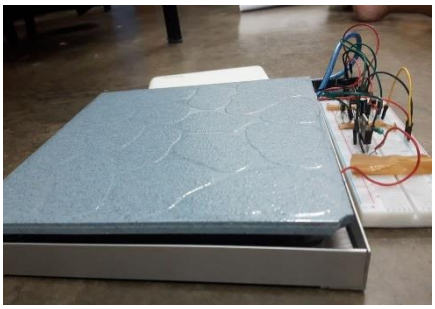


Figure 2: The connection of piezoelectric in two different connections

Table 1: Piezoelectric tiles development

Mosaic with Spring	Aluminum cut according mosaic size
	
Piezoelectric circuit	Complete prototype without battery
	

The rectifier, driver circuit with PWM control and boost converter circuit are combined to developed a full project main circuit that act as a good energy harvesting circuit to be transfer into a storage battery. Figure 3 consists of a combination of rectifier and boost circuit to developed an efficient energy harvesting circuit using Proteus Software. The PWM signal from Arduino is used to control the Pulse Width Modulation in the MOSFET (IRF540N) speed control that functions driving the switch with a series of ON-OFF pulses and varying the duty cycle according to the setting that have been set up in Arduino.

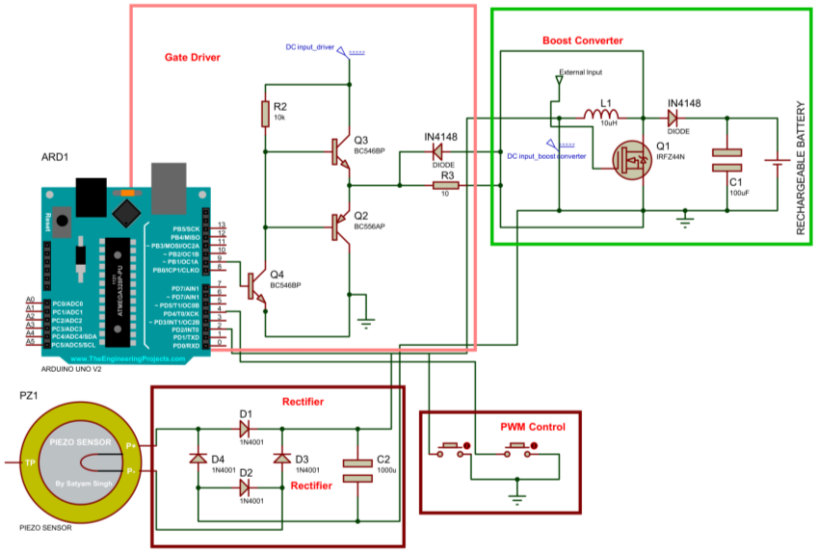


Figure 3: Piezoelectric energy harvesting circuit

3. Results and Discussion

The result of the simulated circuit will be shown. The simulation is developed using the Matlab Simulink with a stop time of 0.2 s. The input and output voltage for each circuit is measured using the scope to generate the waveform. Furthermore, the hardware outcome will also be discussed in this section.

3.1 Results

Figure 4 illustrates the result for series and parallel connection. For connection 1, it shows that the connection is not stable where the output voltage does not sustain and the result shown prove that it does not generate any voltage. For connection 2, it shows a better outcome where the voltage keeps increasing but not in a large range. These results shows that connection 2 is better than connection 1 in order to gain more voltage.

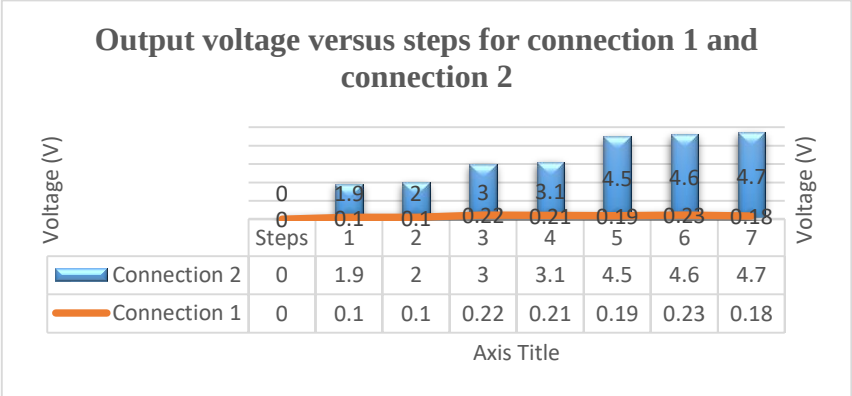


Figure 4: Output voltage versus steps for connection 1 and connection 2

This section shows the result for DC voltage output through the boost converter which it was brought from rectifier to PWM circuit and gate driver circuit. The schematic from Chapter 4 will be applied to get the result shown in Figure 5. As shown in the figure, the voltage output gain up until 7.43 V in square waveform. These happen because of PWM set up from Arduino coding and for the duty cycle for this is set up to 50%.

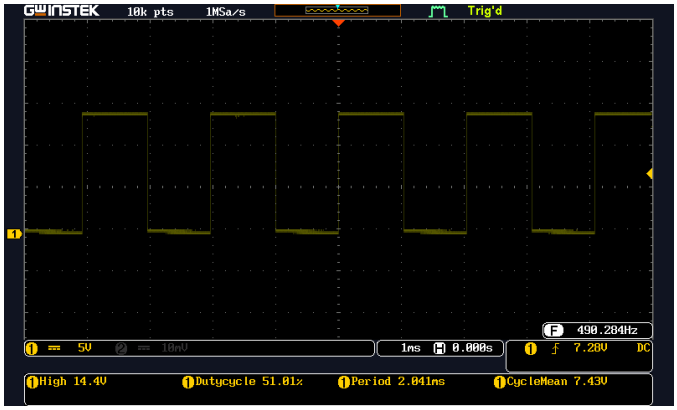


Figure 5: Waveform for 50% PWM DC-DC converter

Next, the result shown in Figure 6 is the voltage output gain after adjusting the PWM to 80% duty cycle. This duty cycle is controlled by the push button that is set up through Arduino. The voltage output gain from the boost converter is 10.2 V. As mentioned above, the DC waveform is in square waveform due to the effect of PWM function.

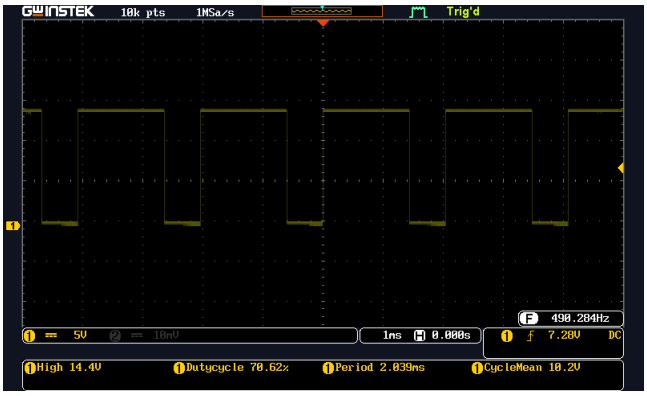


Figure 6: Waveform for 70% PWM DC-DC Converter

The storage element used for this project is the 12 V Li-ion rechargeable battery. The battery is then connected to the whole circuit in order to analyse the storage element. In this project, the circuit in a small range of tiles which is 20 cm x 20 cm. Table 2 illustrates the time taken for the battery to charged.

Table 2: Time taken for the battery to charge

Time Taken	Voltage Output (V)	Charged to the battery (V)
1 min	12	4.133
2 min	9.79	4.135
3 min	9.8	4.138
4 min	11.65	4.139
5 min	11.87	4.140
6 min	10.94	4.142
7 min	11.32	4.143

Assuming the battery can be charged in nearly average of 0.009 for every minutes. To charge fully 12 V will needed around 33 hours. The voltage output might vary due to different pressure (footsteps) applied onto the floor tiles. These can be proved with the following calculation:

Assuming that 1 min = 0.008V,

$1\ hour = 60\ min,$

$60\ \text{min} \times 0.008\ V = 0.54\ V$ (In 1 hour, 0.48 V will be produced)

In order to charge the battery with fully 12 V:

$\frac{12\ V}{0.54\ V} = 25\ hours$

For the conclusion, 25 hours is needed in order to charge the 12 V rechargeable battery. This assumption might be varied depending on the voltage produced for every footstep pressure applied onto the floor tiles.

4. Conclusion

The aim of this project is to design an effective piezoelectric generation circuit for floor tiles application, to integrate the piezoelectric generation with the floor tile and to develop the appropriate energy storage circuit for the generation circuit. Based on the activities carried out, all of the objectives above were achieved. The piezoelectric discs were embedded with the 20 cm x 20 cm floor tile which brought to a small range output voltage. The combinations of diodes and capacitor for the rectifier circuit had improve the peak value of the sinusoidal input voltage. The boost converter connected with the rectifier circuit succeeded in boosting up the voltage. Last but not least, the appropriate energy storage also succeeded in storing voltage in the rechargeable battery.

Acknowledgement

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