

## Piezoelectric Battery Charger

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### Abstract

Piezoelectric Battery Charger is an alternative rechargeable battery that uses mechanical vibrations to apply strain energy to the piezoelectric material. This hallmark meets the standard of environmental responsibility as it creates less waste. This project aims to design and fabricate a free energy battery charger that inspects the voltage output based on the number and arrangements of piezoelectric plates used and the effects on the shape and material of the pusher up and pusher down. The product development includes inserting dimensions for machine components in SolidWorks, material selection, fabrication, 3D printing, assembly and testing for results and discussions. The performance of alternating current voltage output was between 0.5 V to 3.9 V from the test implemented by using a washing machine. By using the concept of electricity accumulation, the battery can store unused energy for later needs.

## 1. Introduction

The demand for batteries is increasing daily. Therefore, an innovative battery charger is proposed to meet the growing needs of various electronic devices. As humans increasingly rely on grid power [1-6], it's important to recognise that this resource is finite and may not be available indefinitely. The depletion of such resources could have significant consequences for future generations if demand remains high. Moreover, conventional power sources also significantly contribute to global climate change [7-10]. Hence, investing in alternative energy sources, such as vibration, is crucial, as they can be converted into more usable forms, including storing potential energy [11-13]. Piezoelectric mechanisms offer a promising avenue for harvesting this energy. If this situation continues, the demand for fossil fuels will increase and contribute to the increase in carbon emissions. This project aims to develop a free-energy battery charger utilising piezoelectric effects, which leverage a material's capacity to generate an electric charge in response to mechanical stress or vibration. As a result, the Piezoelectric Battery Charger has been created to produce an energy generator that can charge the battery by utilising vibration induced by the washing machine. This innovation would help reduce the use of fuels in energy generation and reduce waste generation. However, rechargeable batteries lack alerts when they are depleted. If the power goes out, it becomes unusable [14]. Therefore, this research aimed to design and fabricate a free-energy battery charger. Furthermore, the goal was to test and analyse the performance of a free-energy battery charger using different arrangements and materials for piezoelectric, pusher and varying numbers of piezoelectric plates, which will result in different voltage outputs.

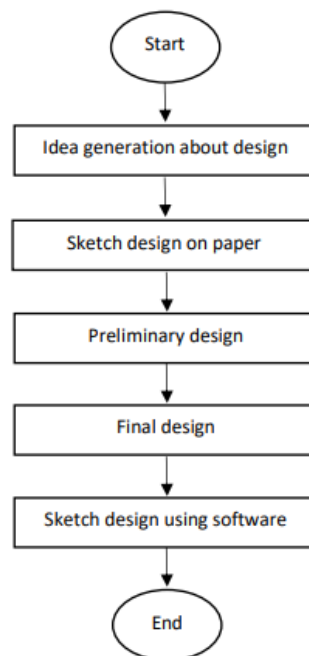
## 2. Materials and Methods

### 2.1 Materials

The selection of the right material for the project is paramount to ensure that our battery charger is lightweight, highly durable, and cost-effective. Wood is the most suitable material selection option for the charger body, offering numerous advantages [4]. The wood exhibits exceptional resistance, making it capable of withstanding heavy loading imposed on the charger. Depending on the model, it will be placed under a washing machine weighing approximately 50 kg to 70 kg. The wood is also notably lightweight, facilitating easy transport and handling. Additionally, the cost of procuring wood is economical compared to other materials, and it is readily available at local wood stores. Due to these advantages, the machine case/body structure and pusher up are made of plywood, whilst the pusher down is made of Polylactic Acid (PLA) and the piezoelectric cover is made of Polyvinyl chloride (PVC). This material is evaluated using a suitable rating method based on criteria sets.

### 2.2 Methods

A manufacturing process must be organised and systematic to create a high-quality product design. Fig. 1 shows this project flowchart. In the initial phase, several designs are generated by each potential individual to gather ideas for the project's design formulation. These designs are sketched on paper to facilitate the selection of the final design to be used for the project. The preliminary design is chosen from the designs contributed by each group member. This selection process aims to identify the best design, considering the elements of each previous design. The design idea is selected using the weight-scoring method to identify the best design for the next stage.

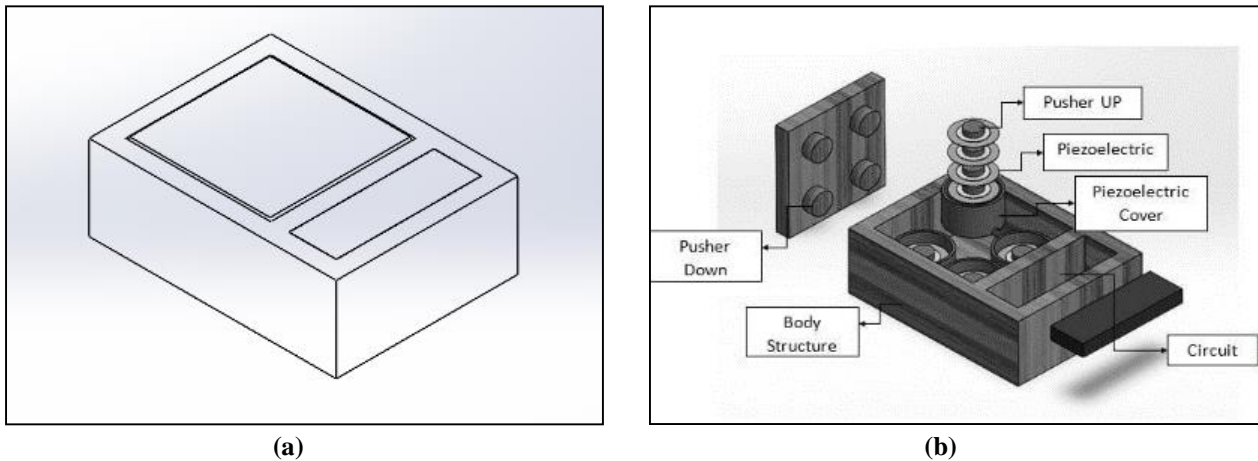


**Fig. 1** Design flowchart

The next step involves creating a detailed design using the CAD software SolidWorks (Dassault Systèmes 2018), resulting in the final design depicted in Fig. 2. Fig. 2 shows the 3D view of the piezoelectric battery charger. The charger comprises several components: body structure, cover, pusher up and down, piezoelectric, piezoelectric covers and electric circuit. The optimal method for completing the final project design, which will serve as the prototype, employs two circuits connected in series and parallel configurations. A breadboard and other electronic components are used as a medium to ensure a successful circuit.

Creating the final 3D model design involves incorporating all necessary information, including dimensions, materials, and perspective views. The selection of materials, which includes plywood, PVC pipe, and PLA, is prioritised based on their respective characteristics to ensure the success of the test run.

This project encompasses two phases in developing a piezoelectric battery charger. Phase 1 comprises the cap body and the main body, a foundation for Phase 2 – the structural phase. Similarly, within Phase 2, the construction of additional components includes the pusher, consisting of pusher up and pusher down components, a piezoelectric cover, and a circuit featuring piezoelectric and electrical elements.



**Fig. 2** 3D view of the Piezoelectric Battery Charger (a)Main case (b)explode view of the main case

## 2.3 Equations

In this project, the analytical method relies on formulas from physics, mathematics, and engineering science to forecast the performance of product designs. Equation 1 calculated the pressure imposed on the machine when it is located under the washing machine leg, ensuring the machine was not damaged [15]. This equation determined the amount of pressure reaching the project.

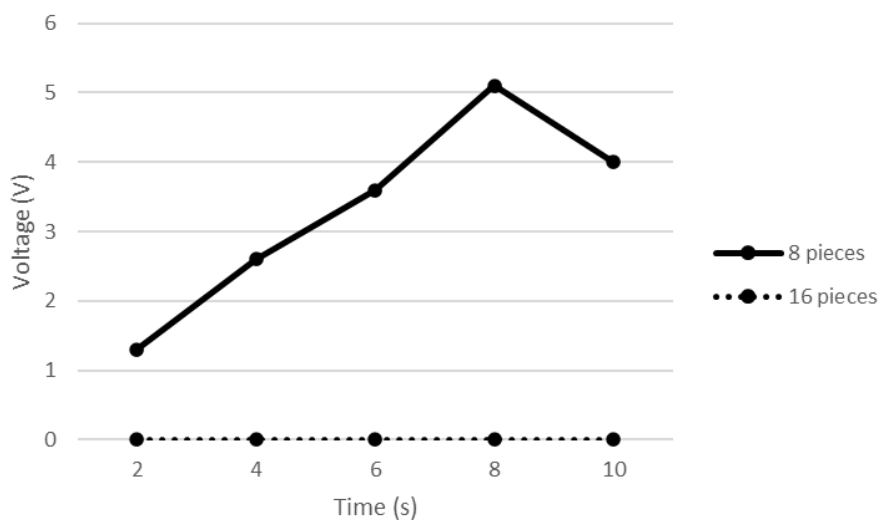
$$p = \frac{F}{A} \quad (1)$$

## 3. Results and Discussion

The machines are tested with several parameter evaluations, and the data collected are presented and discussed in this section. Among the parameters that are considered in the evaluation include the number and arrangements of piezoelectric plates used and the effects on the shape and material of the pusher up and down.

### 3.1 Number of Piezoelectric

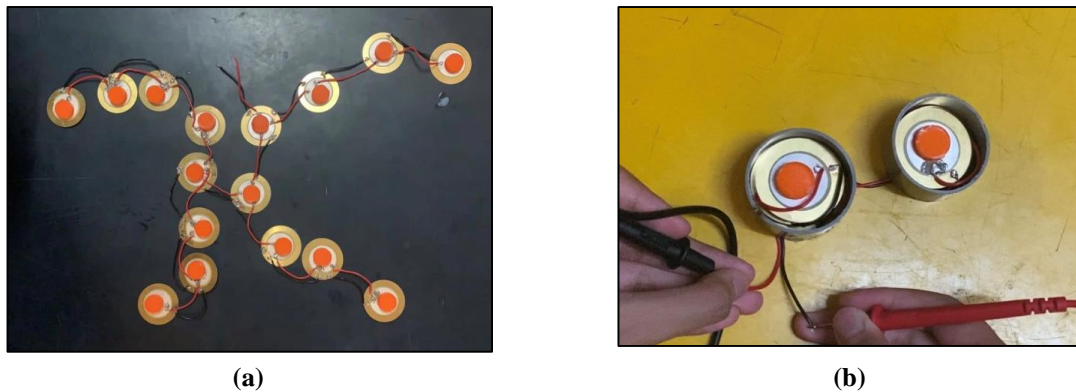
At this stage, the value of voltage and current values produced by the machine are measured using a multimeter. The testing results are depicted in Fig. 3. The piezoelectric plates were connected in parallel, showing that 8 numbers of piezoelectric plates can generate an output voltage compared to 16 numbers of piezoelectric in the same connection method. This indicated that adding twice the number of piezo plates is not fully functional for the current machine design dimension. The voltage output started at 1.3VDC and gradually increased to approximately 5.1VDC. However, there was a subsequent voltage drop to 4VDC after 8 seconds of the machine test.



**Fig. 3** Voltage vs Number of Piezoelectric

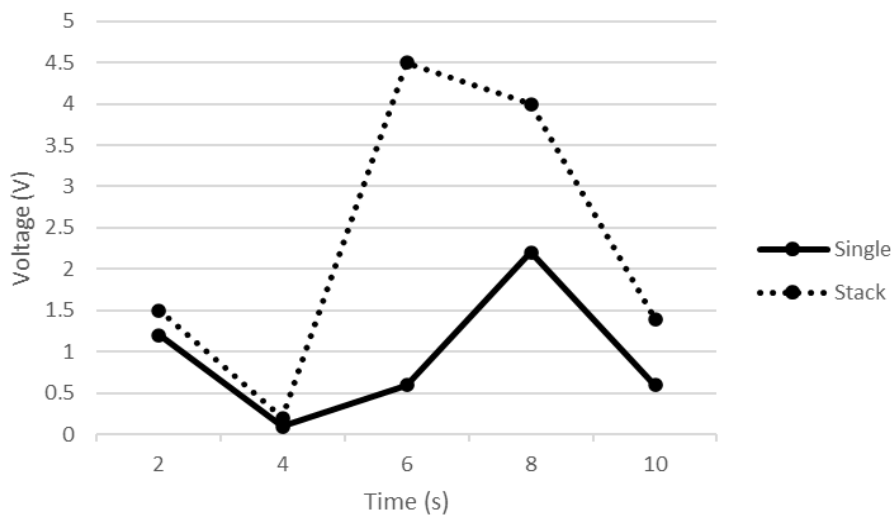
### 3.2 Arrangements of Piezoelectric

Referring to the previous test implemented, 8 number of piezoelectric plates were then tested in single and stack arrangements. Fig. 4 shows the two types of piezoelectric arrangements used in evaluating the machine's performance.



**Fig. 4** Piezoelectric arrangement (a) Single (b) Stack

During the testing, both arrangements produced a voltage output. Fig. 5 illustrates that piezoelectric plates arranged in a stack within a PVC pipe generated a higher voltage than a single arrangement. In the case of stack arrangements, during the first two seconds, the voltage decreased from 1.5 VDC to 0.2 VDC, then rose to 4.5 DCV, followed by fluctuations to 4 DCV and 1.4 DCV in the subsequent seconds. Referring to the single arrangements, the trend of voltage generations is almost identical; however, the difference in the amount of voltage generated ranges from 0.8 VDC to 3.9 VDC for the same period of the test.



**Fig. 5** Voltage vs Piezoelectric Arrangements

### 3.3 Pusher-up and Pusher-down Material

The stack arrangement was chosen based on previous test results as it produced a higher voltage output. In this testing, two different pusher materials and shapes were tested to evaluate the machine's performance. Both pushers were installed at their locations during the testing stage to achieve higher voltage values. In the test, the material and shape of the 'pusher up' component, the circular PLA pusher, remained unchanged. However, the 'pusher down' material is fabricated using wood, rubber, and PLA and tested accordingly.

Fig. 6 shows that the machine generates a higher voltage output when piezoelectric plates are in contact with a wooden pusher than when in contact with rubber and PLA pushers. From the figure, the voltage output can reach up to 2.4 VDC for the wooden pusher compared to the other two types that can produce less than 1 VDC. This is due to the wooden pusher's higher density, rigidity, durability, and ability to withstand heavy loads. It's suggested that the substantial contact surface between the piezoelectric material and the wooden pusher is crucial in achieving a significant voltage output.

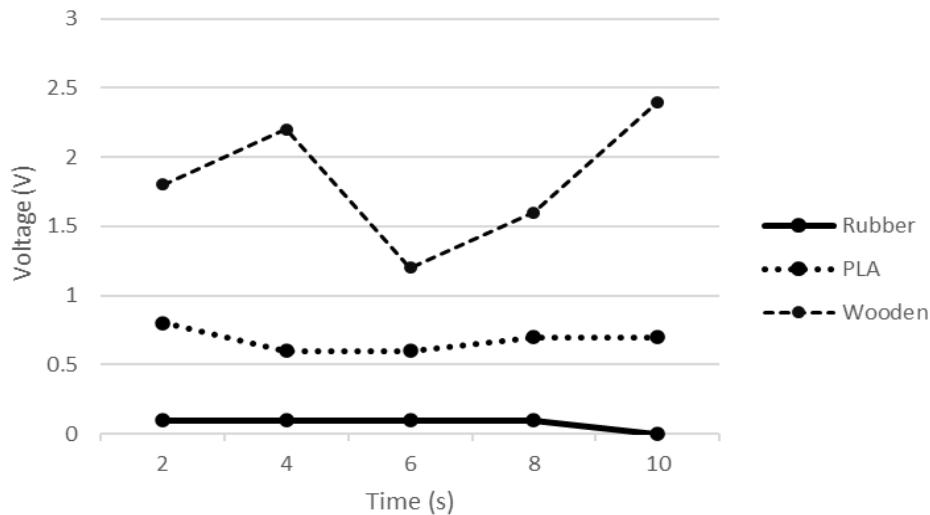


Fig. 6 Voltage vs Material of Pusher Down

### 3.4 Vibration test

The Piezoelectric Battery Charger is designed as a rectangular wooden box with two sets of eight piezoelectric plates stacked within a PVC pipe. PLA pushers were inserted between each piezoelectric plate to act as the 'pusher up,' contacting wooden circles attached to the rectangular 'pusher down.'

The machine is tested using a vibration produced by a top loading washing machine during the laundry activities. The machine is positioned under the washing machine's leg pad. To ensure stability, bricks of the same height were placed on each side of the leg pad during the testing. The machine is tested consecutively using both the front and back leg pads of the washing machine. The washing machine was run through three cycles, and the position of the battery charger was adjusted for each cycle. Fig. 7 shows that the front leg pad of the washing machine generates a higher voltage output than the back leg, and higher voltage fluctuation can be observed. The back leg pad generates lower voltage, with low voltage fluctuations. This indicates the vibration onto the piezoelectric plate is smaller at the back section. This is due to most of the weight of the washing machine being transferred to the back section preventing the piezoelectric plates to vibrate.

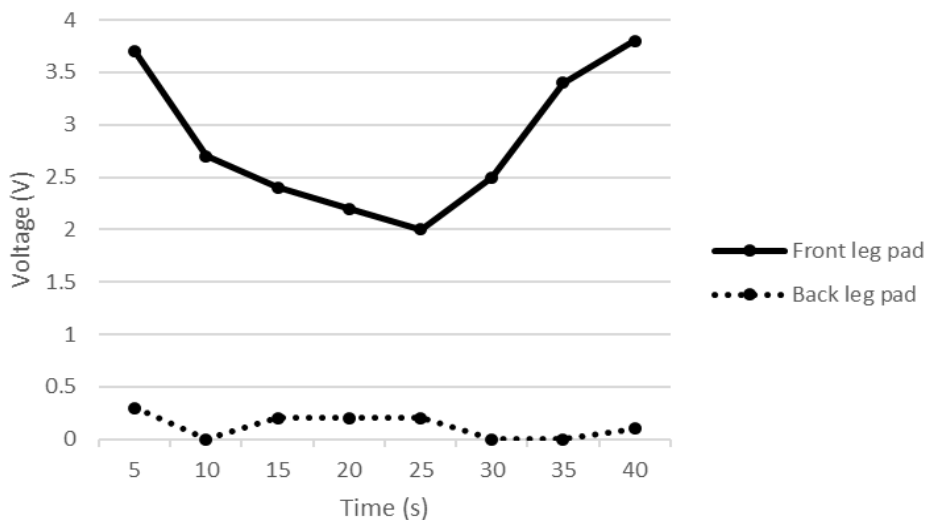


Fig. 7 Voltage vs Positions of Piezoelectric Battery Charger

## 4. Conclusion

In conclusion, a prototype of a free energy battery charger was successfully developed, the Piezoelectric Battery Charger. This machine's primary source of voltage generation is the piezoelectric plates arrangement within a PVC pipe located in the battery charger box. The piezoelectric battery charger demonstrated the capability of generating voltage output ranging from 0.5 V to 3.9 V. However, at this stage of development, it's important to note that the machine needs regular and consistent inspections to keep it functioning well. Despite their relatively low voltages and lightweight, piezoelectric remains applicable to various applications. This effect is harnessed by

utilising a material's ability to generate an alternating current voltage in response to mechanical stress or vibration, such as that produced by a washing machine. The built-in circuit subsequently converts This alternating current into direct current voltage. In conclusion, the piezoelectric battery charger can be a viable alternative for emergency charging in critical situations.

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## Conflict of Interest

The authors declare no conflict of interest regarding the paper's publication.

## Author Contribution

The authors confirm their contribution to the paper as follows: **study conception and design:** Zin, A.F.M., Mantari, M.H.A.R, Roslan, M.S., Azahan, A.D.M., Aziz, N.I.N.A., Daud, N.L.M; **data collection:** Zin, A.F.M., Azahan, A.D.M., Aziz, N.I.N.A., Daud, N.L.M.; **analysis and interpretation of results:** Zin, A.F.M., Azahan, A.D.M., Aziz, N.I.N.A., Daud, N.L.M.; **draft manuscript preparation:** Zin, A.F.M., Azahan, A.D.M., Aziz, N.I.N.A., Daud, N.L.M. All authors reviewed the results and approved the final version of the manuscript.

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