Energy Harvesting for Sustaining Smart Devices

the Use of Pressure Initiators in Piezoelectric Generators

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Abstract

The paper explores the use of novel pressure initiators in the form of small masses within piezoelectric generators to enhance to enhance the efficiency of piezoelectric energy harvesters[1] for sustaining smart devices. The best arrangement of piezoelectric generators and the type of motion producing the greatest voltage were shown by the results as well. With this, piezoelectric energy harvesters will be made available to assist energy harvesting in constrained space[2] or as add-ons to other energy harvesting devices.

Keywords: energy harvesting, piezoelectric generator, ball, motion, arrangement, pressure initiator

I. Introduction

The growth of smart devices has resulted in higher power consumption and a frequent need to recharge batteries[1]. It compromised the convenience they were designed for. Recent research on small-scale energy harvesting[3] has promised potential to replace batteries altogether[1]. Vibrational energy is the closest source of energy to our daily life. A ball was chosen as popular ball sports produce readily observed vibrations[4].

A. *Assumption*

Based on previous research and the Gauss's theory, it was expected the generators in a stack would yield more energy than the generators unattached randomly. A pressure initiator would increase the energy harvested as more pressure was introduced. Hence, the question investigated was which arrangements (stacks or the unattached), motions and with or without the inner ball mass will allow the piezoelectric generators to produce the highest voltage in the simulation of a ball game.

II. Methodology

A. *Testing*

It was done with pressure applied on the piezoelectric plate at a constant frequency of 1.5Hz. A flash of light was observed on the LED bulb connected in series with Capacitor C2, reinforcing the viability of the circuit in generating a current, as recorded by the multimeter which registered a steadily increasing voltage up to 6.5 V after the generators were being tapped by hand for about one minute. Having been removed from the circuit for one day, the charged capacitor was still able to register a reading of around 5V on the multimeter and light up the LED bulb on the next day. This shows that the energy was successfully harvested from the piezoelectric plate and stored in the capacitors. (Figure 1)

- Experiment 2 with was done with two piezoelectric ceramic transducers connected in series. The number of piezoelectric transducers was increased to investigate the feasibility of increasing the surface area from which piezoelectricity can be harvested from.
- When the two piezoelectric transducers were tapped on simultaneously, the capacitor was charged at a faster rate than that in experiment 1, but the capacitor was easily overloaded.
- When the two piezoelectric transducers were tapped on separately, the capacitor could accumulate charges whenever tapping on either generator continued.

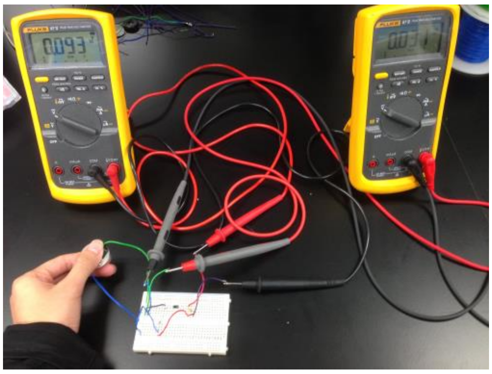

Figure 1. Testing setup

- Conclusions: It was plausible to connect the piezoelectric generators in series in the circuit to generate more energy and to harvest the energy in all directions at all times when the ball moves.

B. *Prototyping*

The circuit was reconstructed on a 4.00cm x 5.00cm new PCB by soldering and inserting the electric components, forming the energy harvesting and storage unit. The unit was inserted into a plastic ball cut half-open with a pen knife. Its edge of 1.5cm still connects the two halves rigidly to prevent the prototype from falling apart while maintaining a certain degree of flexibility.

- For easier measurement of the voltage produced by the harvester, an improved version of the prototype was constructed. The wires and the PBC were left outside the plastic ball for measurement and monitoring (Figure 2). The use of a stress ball within the plastic ball was introduced to induce more pressure on the transducers.

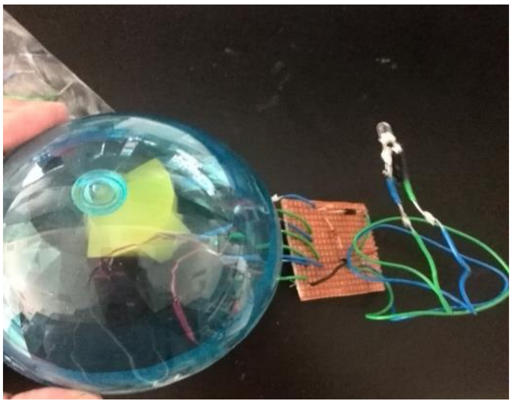

Figure 2. Improved prototype

III. Data Collection

A. For the original prototype, shaking the ball resulted in the lighting up of the LED bulb.

B. For the improved prototype, a multimeter was connected across the LED bulb to measure the voltage produced by the harvesters.

C. A series of motions were used in the simulation of a typical ball game. The ball was shaken with and without the stress ball inside. Under the same conditions, modes of motion were varied. The ball was also dropped from different heights onto the piezoelectric ceramic transducer to show any relationship of the amplitude of movement and voltage produced. Mean values of voltage were calculated and presented in the results section. The generators were stacked (Figure 3) or randomly lined up in all directions (Figure 4) to vary the arrangement.

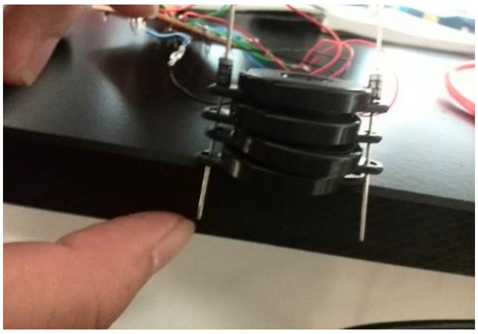

Figure 3. Stacked arrangement

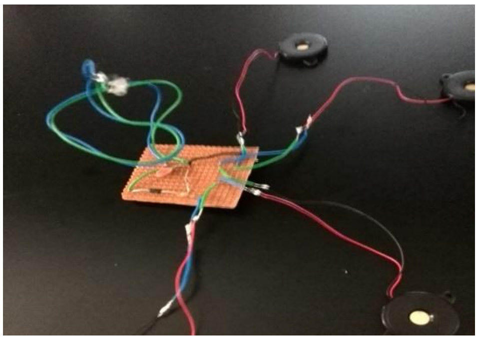

Figure 4. Random arrangement

IV. Results and Discussion

A. Investigation of the efficiency of stacked and random arrangements under controlled condition

One transducer tapped by stress ball released from 10 cm above the table surface produces an average of 1.298V, fluctuating according to hitting position : 0.5V at the side, 1.3V in the middle. Stacking the transducers in series improves the efficiency of energy harvesting as one impact is exerted on four generators simultaneously (See Table 1).

TABLE 1: Comparison between the efficiency of two arrangements under tapping

Arrangement of 4 transducers	**Observation**
Randomly lined-up	5 taps for above 1V
Stacked together	1 tap for above 1V

B. Investigation of the performance the energy generator in various ball motions

Circular and rolling motions tend to generate more voltage as pressure on more parts of the ball was felt by the generators. Moreover, higher frequency of the motion results in higher voltage produced . Also, the stress ball inside the plastic ball increased the voltage produced by various motions by an average of 1.7% (See Table 2).

TABLE 2: Voltage produced in various ball motions (Note: Voltage produced without the stress ball were inconsistent, sustaining for 20%of the time - crude estimate)

Frequency/ Hz	**Duration/s**	**Mode of motion**	**Voltage produced with the stress ball/ V**	**Voltage produced without the stress ball/ V**
2	4	Linear 10cm	1.341	1.300
2	4	In a circle of diameter 10cm	1.454	1.402
2	4	Rolling for 10cm	1.311	1.323
4	2	Linear 10cm	1.436	1.433

4	2	In a circle of diameter 10cm	1.483	1.478

C. Investigation of the influence of the amplitude of motion on the amount of energy harvested and the effect of the novel pressure initiator

The height from which the ball was released had no significant influence on the voltage produced by the piezoelectric generators (See Figures 5 and 6). The random, unattached arrangement resulted in higher voltage generated , by average about 56.5% than that of the stacked generators. This may be due to a greater flexibility allowed for vibrations in such arrangement as opposed to the stacking arrangement whereby the piezoelectric disks were bundled together and restricted from individual movements. Once again, the stress ball inserted inside the plastic ball shell enhanced the voltage produced by the generators to a significant degree, by an average of 8.8%. The unattached randomly-arranged generators might not have experienced the impact of the ball simultaneously, thus introducing in randomness and uncontrolled errors.

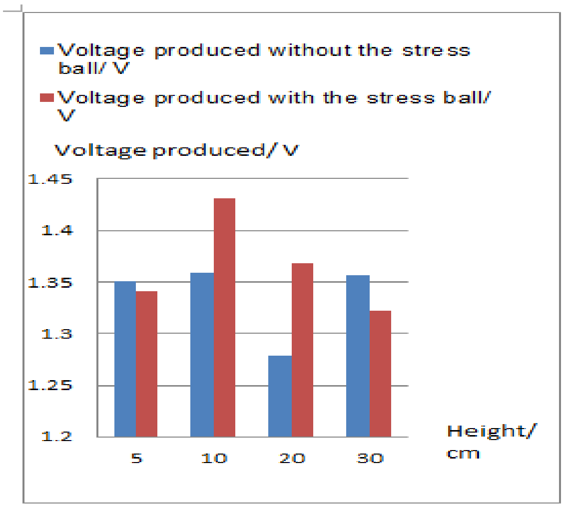

Figure 5: Voltage produced when the ball is dropped from a height (Random arrangement)

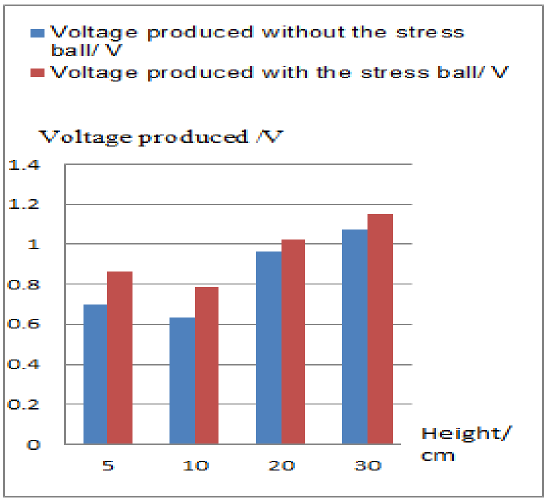

Figure 6: Voltage produced when the ball is dropped from a height (Stacked arrangement)

V. Conclusion

The results collected and analysed confirmed the feasibility of the suggestion of a pressure initiator such as a ball within a ball to enhance the efficiency of energy harvesting in ball-shaped piezoelectric generators. This method is able to increase the voltage produced by up to 8.8%. In addition, arrangements of piezoelectric generators are significant factors for considerations in improving energy harvesting efficiency. Random and unattached piezoelectric generators produce more energy in a normal ball game where dropping and circular motions are prevalent, creating ample opportunities for the generators to harvest energy by vibrating with greater frequency and flexibility than which were allowed by the stacking method. Moreover, the results have shown that while the height from which the ball was released is not related with the magnitude of voltage produced, different modes of motions do yield different results of voltage produced. Circular and rolling motions promise more energy to be generated while higher frequency allows a higher voltage to be produced by the piezoelectric generators. Future research could investigate a greater variety of possible arrangements of the piezoelectric generators such as spirals along different axes. Supercapacitors and batteries could be used to store the energy produced. Investigation could thus focus on how to best store the electric energy from the optimised energy harvester ball for use in smart devices such as charging a smartphone and other personal gadgets with low power requirement to bring the convenience and dynamic of this digital age back to life.

VI. References

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