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A Review of Energy Harvesting From Vibration using Piezoelectric Material

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***Abstract*— The process of acquiring the energy surrounding a system and converting it into usable electrical energy is termed as energy harvesting. In the last few years, there have been many researches in the area of energy harvesting. This increase in research has been brought on by the modern advances in wireless technology and low power electronics such as micro electromechanical systems. The advances have allowed numerous doors to open for energy harvesting systems in practical real world applications. The use of piezoelectric materials to capitalize on the ambient vibrations surrounding a system is one method that has seen a dramatic rise in use for energy harvesting. Piezoelectric materials have a crystalline structure that provides them with the ability to transform mechanical strain energy into electrical charge and, vice versa, to convert an applied electrical potential into mechanical strain. The piezoelectric can be modelled as an AC current source with a resistive load. The model was tested in Pspice. While piezoelectric materials are the major methods of harvesting energy, other methods do exist; for example, one of the conventional methods is the use of induction charging. Inductive charging is an age old technology. The most used inductive charging is the transformers. However, who to transfer large amount of power in between two coils from far away has never been considered until recently. A Multisim model is also tested in comparison with the experimental data. In this paper we discuss the research that has been performed in the area of power harvesting and the future goals that must be achieved for power harvesting systems to find their way into everyday use.**

Keywords*— *Energy harvesting; Piezoelectric; Pspice; Induction charging; Multisim.

I. INTRODUCTION

With the recent advances in wireless and micro electro-mechanical systems (MEMS) technology, the demand for portable electronics and wireless sensors is growing rapidly. Because these devices are portable, it is necessary that they carry their own power supply. In most cases this power supply is the conventional battery; however, problems can occur when using batteries because of their finite lifespan. For portable electronics, it is problematic to replace the battery because the electronics could die at any time and replacement of the battery can become a tedious task. If ambient energy in the surrounding medium could be obtained, then it could be used to replace or charge the battery. One method is to use piezoelectric materials to obtain energy which is lost due to vibrations of the host structure. This captured energy could then be used to prolong the life of the power supply or in ideal case provide endless energy for the electronic devices lifespan. For these reasons, the interest in research of power harvesting has been rapidly increasing. Harvesting waste mechanical energy is an attractive alternative to depend on traditional batteries with limited lifetimes. Low-power wireless sensors are used in hundreds of commercial and military applications, where battery replacement is often impractical for a number of reasons (e.g., cost, inaccessible locations, etc.) In few years, piezoelectric harvesters moved on from harvesting power of the order of μW to mW.

The piezoelectric energy harvesting method was tested by acquiring a piezoelectric element. Since the voltage generated by the element is in AC domain, a full-wave bridge rectifier was built to convert the signal to DC power that can be transferred to the battery. Piezoelectricity can be generated by applying stress to an element, which in turn creates an electric potential. The cause of vibration may be an electromagnetic or mechanical imbalance, loose components, rubbing parts, bearing failure, or resonance.

Device class	Linear size	Power Requirements
Server, workstation	50cm-90cm	above 100 W
Desktop PC	20-50cm	200-300 W
Notebook PC	20-35cm	20-50 W
Handled	1-10cm 80m	80m W-10 W
Wireless Sensor Node	0.1-1cm	100 µW-100 mW
Nano devices Nano robots	0.01-1µm	0.1-100 µW

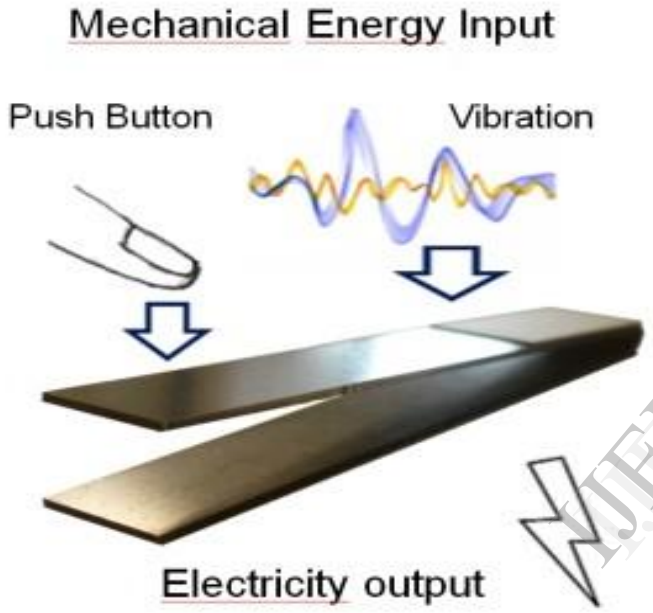

Fig 1: Basic input-output principle of piezoelectric energy generators.

A. Take Advantage of Vibration

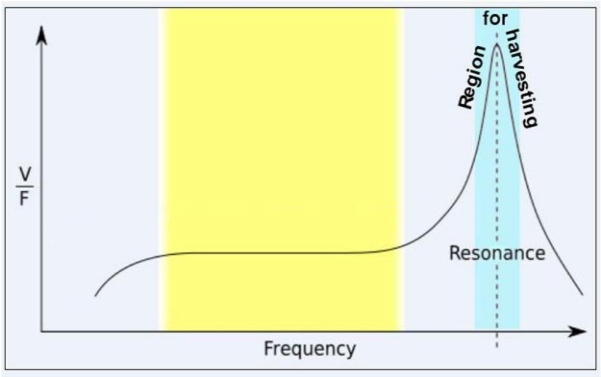

Fig 2: V is the output voltage, F is the input force.

B. Comparison of power demand of electronics devices

TABLE I
Power table

C. Advantages of piezoelectric energy harvesting method

- Long lasting life
- No chemical disposal
- Cost saving
- Safety
- Maintenance free
- No charging points
- Flexibility

D. Powering of portable electronics

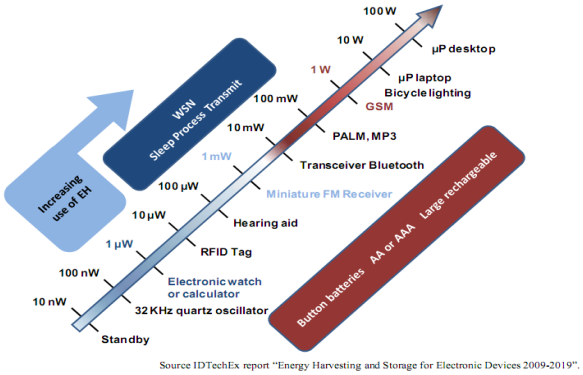

Fig 3: Power requirement for portable electronic devices.

The outcome of the piezoelectric circuit is widely applicable in portable electronic devices. The power requirement for portable electronic devices is shown in above figure. We can implement these circuits to power miniature FM Receiver, hearing aid, palm Mp3 players and many more.

II. METHODOLOGY

The principle of operation of the energy scavenger is based on the movement of the mass in the vertical direction that results in stretching of the piezoelectric layer and a voltage being generated.

A. *Piezoelectric Method*

The effect known as piezoelectricity was discovered by brothers Pierre and Jacques Curie, when they were 21 and 24 years old in 1880. Piezoelectricity is the ability of certain materials to produce a voltage when subjected to mechanical stress. Piezoelectric materials also show the opposite effect, where application of an electrical field creates mechanical stress (size modification) in the crystal. Piezoelectric materials, such as the lead zirconate titanate (PZT), are good examples for energy harvesting using vibrations from the surrounding environment. Fig 4 represents the experimental setup that was carried out.

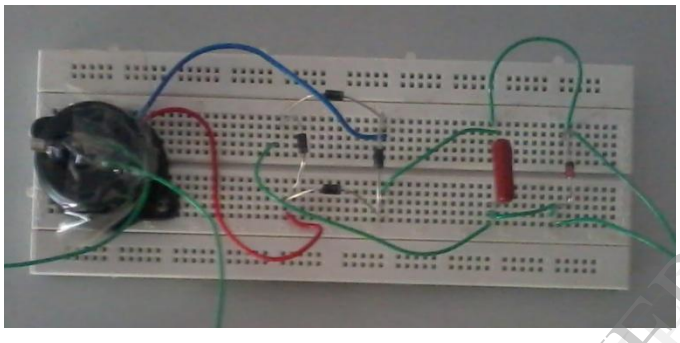

Fig 4: Experimental set up

Here we used small vibrating motor from which we are harvesting energy in order to supply the portable electronic devices shown in fig 3.

B. *Simulation*

The above hardware circuit was simulated using Multisim software and the results were analyzed. Simulated circuit using Multisim software is shown below in fig 5.

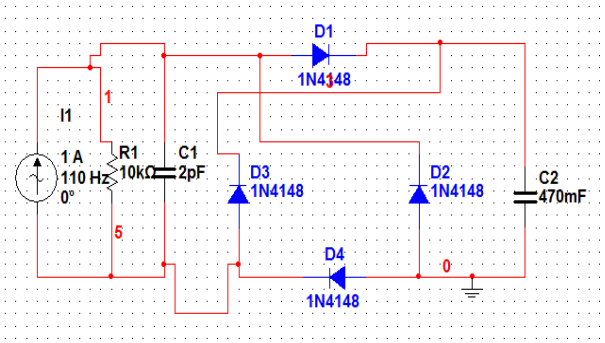

Fig 5: Simulated circuit using Multisim

III. RESULTS

A. *Hardware Results*

Hardware result of piezoelectric circuit is a plot of time vs. voltage and time vs. power. For every 5min the voltage and current readings are noted down at the output capacitor. The power is calculated from the readings. The tabular column of voltage and power is shown below for every 2 min.

TABLE III
Voltage and Power w.r.t time

Time min	Voltage in volts	Current in µa	power in µw
2	0.9	2	1.8
4	1.03	4.2	4.326
6	1.75	6.2	10.85
8	2	7.2	14.4
10	2.25	8.1	18.225
12	2.64	11.8	31.152
14	3.01	14.8	44.548
16	3.07	19.2	58.944
18	3.25	22.5	73.125
20	3.45	27.3	94.185
22	3.72	29.5	109.74
24	4.3	41.3	177.59

B. *Simulated Results*

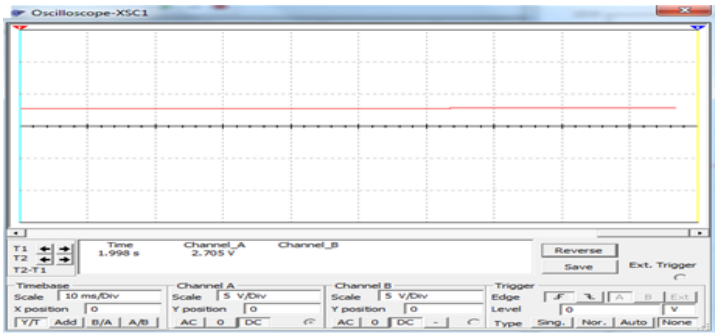

Fig 6: Total Voltage measured at Capacitor Output using oscilloscope

The simulated result of piezoelectric circuit is shown above. The result is taken across capacitor using oscilloscope. For 1.998s, 2.705v is measured using the oscilloscope and voltage is measured using voltmeter as shown in below fig.7

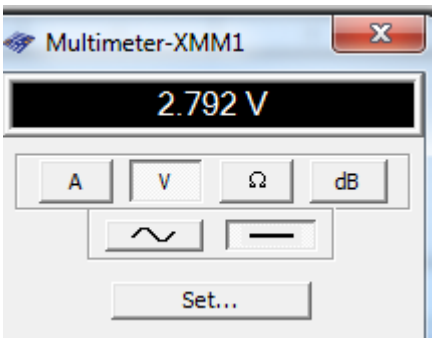

Fig 7: Voltmeter output

IV. CONCLUSION

Vibrations represent one of the most promising renewable and reliable solutions for mobile electronics powering. Most of vibrational energy sources are inconsistent and have relative low frequency. Scaling from millimetre down to micrometre size is important as well as further improvement of conversion efficiency. There are possible ways for efficiency improvements of Vibration Energy Harvesting technologies:

- Efficient nonlinear dynamics,
- Material properties,
- Miniaturization procedures,
- Efficient power harvesting electronics.
- A precise metrics for efficiency.

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