Energy Harvesting Circuits with Piezoceramic Material: Design, Integration and Optimization

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Abstract

Piezoelectric energy harvesters (PHE) have drawn significant interest as a method of harvesting environment energy to power because of its compatibility and high energy density. Piezoelectric energy harvesters can be integrated into other technologies such as wireless sensor networks, Internet of Things (IoT)) devices, and wearable electronics. This integration can be lead to the development of self-powered devices that can operate continuously without the need for external power sources. The main disadvantages of PEH are low level of harvested power and the need for rectification, maximum power extraction and output voltage regulation. So piezoelectric energy harvester or transducer cannot be used alone to harvest mechanical energy. To increase the output voltage and power it is necessary to choose a piezoelectric material, piezoelectric transducer as well as an electric circuit. In this paper, we discuss different circuits such as switch only rectifier circuit, voltage multiplier based energy harvesting circuit, synchronised switch harvesting on inductor (SSHI) and synchronous electrical charge extraction (SECE) to harvest piezoelectric energy. The design and optimization of the circuits were done by using multisim software. Physically, a stack transducer is developed by using PZT piezoceramic materials and integrated into the electrical circuit. The output voltage of 1.2 V to 1.9 V is recorded by using the human thumb impression to piezoelectric element and this voltage is sufficient to glow an LED bulb.

Introduction

Piezoelectric energy harvesters (PEH) have drawn significant interest as a method of harvesting environment energy to power because of its compatibility and high energy density. The main disadvantages of PEH are low level of harvested power and the need for rectification, maximum power extraction, and output voltage regulation. So piezoelectric transducers cannot be used alone to harvest mechanical energy. Efficiency of piezoelectric elements lies in optimization of piezoelectric energy, which can be done in various ways. In this paper, we discuss different circuits such as Switch only rectifier circuit, Voltage multiplier based energy harvesting circuit, Synchronized Switch Harvesting on Inductor (SSHI) .

Design/Other information

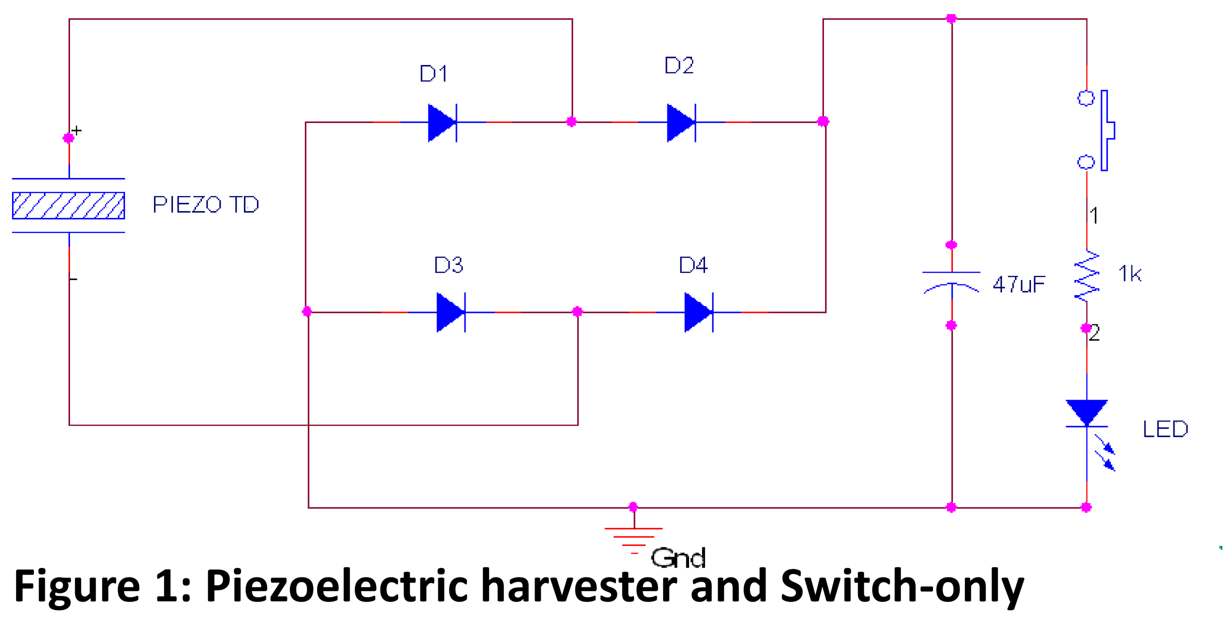

Figure 1: Piezoelectric harvester and Switch-only Rectifier

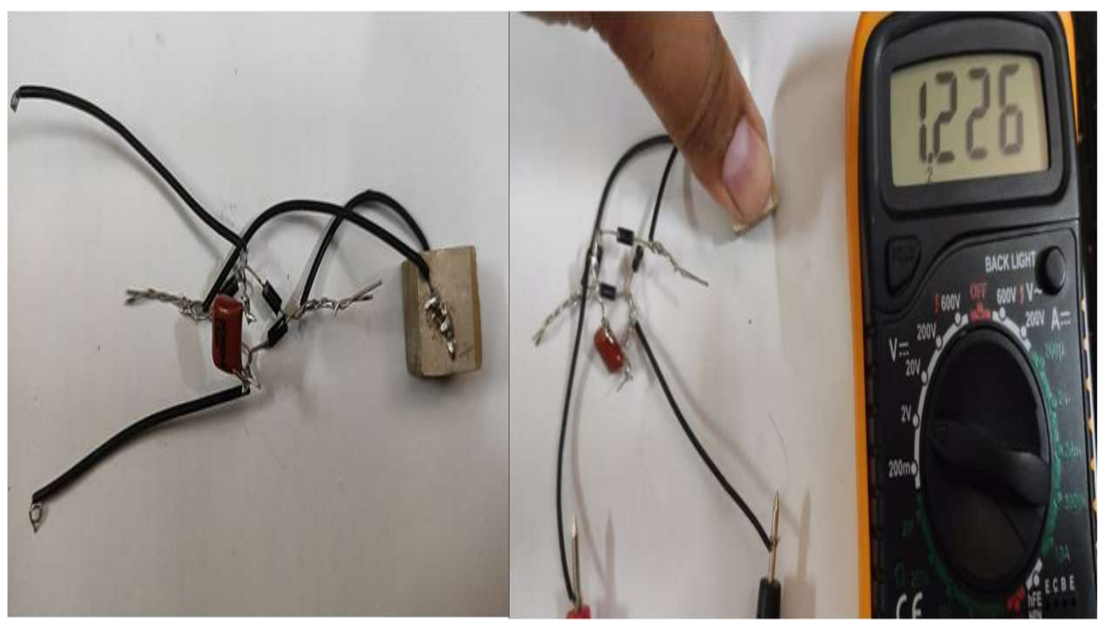

Figure 2: (a) (b)

Figure 2:(a) switch only rectifier circuit

Figure 2:(b) output voltage of switch only rectifier circuit

(We have designed the above circuit with 1N4007 diode, 50µF capacitor, 1K resister)

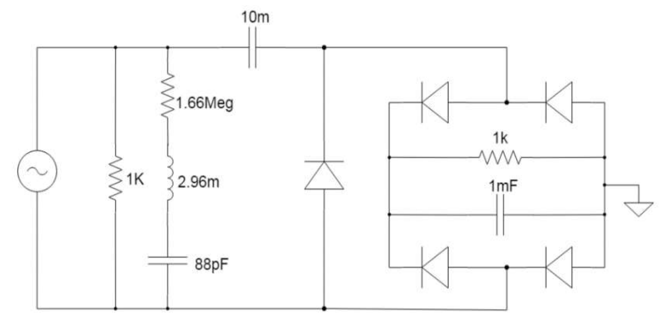

Figure 3: Voltage multiplier based energy harvesting circuit

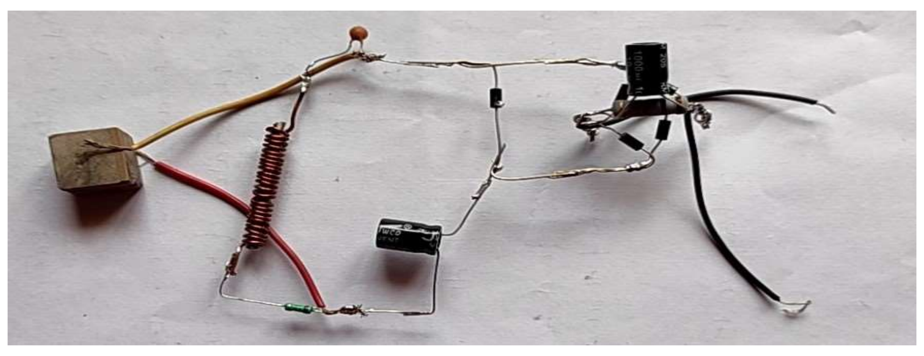

Figure 4: Physically developed Voltage multiplier based energy harvesting circuit

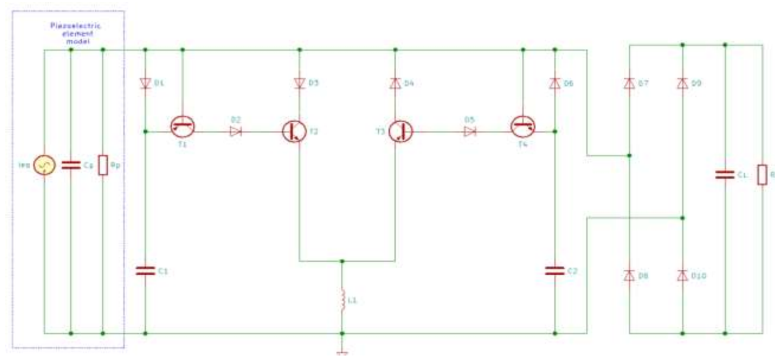

Figure 5: Self-powered parallel-SSHI energy harvesting circuit .

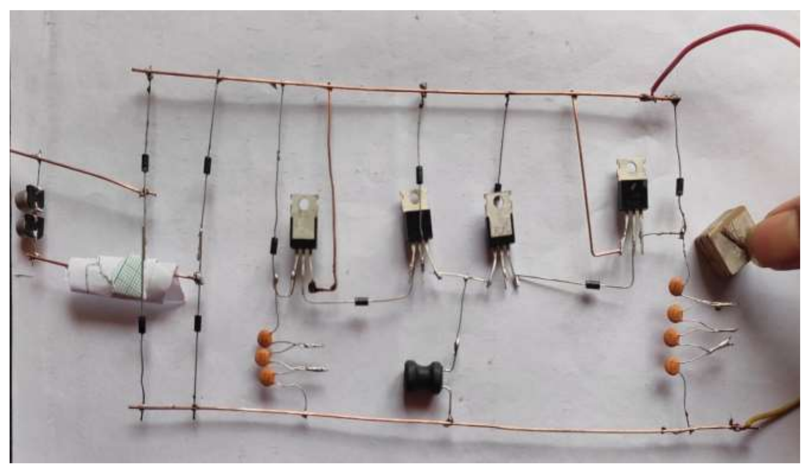

Figure 6: Self-powered parallel-SSHI energy harvesting circuit (physically developed)

Results

Piezoelectric Harvester and Switch-only Rectifier

The output of a piezoelectric crystal is alternating signal. In order to use this voltage for low power consuming electronic devices, it has to be first converted into digital signal. This is done with the help of AC to DC converter as shown in Fig. 1 and Fig.2. It shows a simple diode rectifier to convert AC to DC. This is followed by a capacitor, which gets charged by the rectifier up to a pre-decided voltage. After that the switch closes and the capacitor discharges through the device. In this way, the energy can be stored in the capacitor, and can be discharged when required.

Voltage Multiplier based Energy harvester

When there is higher voltage requirement we can use the voltage multiplier based energy harvesting circuit for generating a higher voltage across the output.

The piezoelectric element was represented electrically as a current source in parallel with a capacitor, inductor and resistor. The current source (represented by a voltage source in parallel with a resistor) provides current proportional to the input vibration amplitude. The output of the piezoelectric device needs to be rectified before it can be used to power circuits. Full-bridge rectifiers and voltage doublers are commonly used as rectifier circuits to convert the AC output of a piezoelectric harvester into a DC voltage.

Self-powered Parallel-SSHI Energy Harvesting Circuit

The self-powered parallel-SSHI energy harvesting circuit is a type of energy harvesting circuit that combines the benefits of parallel connection and synchronous switch harvesting on inductor (SSHI) to improve the overall performance of the system.

In this circuit, multiple piezoelectric transducers are connected in parallel, and each transducer is connected to its own SSHI circuit. The output of all the SSHI circuits is then combined in parallel to generate a higher output power.

We have tried to simulate the above circuit with multisim software and the results were obtained in following manner. When the output is observed across a load of 100 Ohm, potential drop across the resister was in the range 3.2 to 3.7 volts. The current across the load was in the range 32mA to 34mA. Output power was in between 105mW to 115mW.

Conclusions

The available vibrational energy can be converted in to electrical energy by different transduction mechanisms, out of which the piezoelectric energy harvesting mechanism can be used to harvest energy from micro-to-meso scale. These circuits can be designed using different topologies. In piezoelectric energy harvesting, the output power of the energy harvester will depends on frequency of the materials used. The output power will be maximum for low resonant frequency materials However, these circuits also have limitations such as frequency dependence and low voltage outputs, which need to be addressed for practical applications.

References

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