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Improved Energy Harvesting Conditioning Circuit using an Inductor

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Abstract - *There are two techniques to increase the energy taken out from the piezoelectric transducer. One is based on the improvement of the piezoelectric transducer itself, and the other is based on an improvement of the circuit connected to the piezoelectric transducer. This paper uses the latter technique to propose a distinct method in order to reduce the ripples in energy conditioning circuit and to improve the efficiency and performance of the harvesting circuit.*

***Key Words*: Energy, Harvester, MEMS, Piezoelectric harvester.**

I. INTRODUCTION

Devices are getting smaller and smaller, whereas the technologies are becoming better and better. One relevant example is Energy harvesting technique. This technology came into light when the devices reached micro-level as devices such as batteries are given less space on a circuit. The limited space of the battery makes it to store very less energy, which does not provide adequate energy to run a given circuit, for example, wrist watches, sensors, etc. The energy harvesting conditioning circuit is used to manipulate the harvested signal which is discontinuous and irregular as this irregular signals are not tolerated by the peripherals such as microprocessors, accelerometers, etc. The current researchers are focusing on improving the performance of the harvester by improving the efficiency of the individual components of the harvesting circuit. Many of the papers published on the harvester are not focusing on reducing ripples of the circuits. In fact this is what plays an imperative role in making the harvester work at high performance as the ripples affect all the components in the circuits. If the ripple performance is improved then the components' performance improves naturally, which in turn enhances the efficiency level of the entire device considerably. This paper, therefore, is proposing a method that reduces the ripples of the energy harvesting circuit, particularly on piezoelectric energy harvester, by using an inductor, that has improved the performance andefficiency of the circuit considerably.

II. BASIC ENERGY HARVESTING CIRCUIT

Energy harvesting circuit, shown in Fig-1, basically consists of five main components: transducer, AC-to-DC converter, DC-to-DC converter, power manager and battery. A transducer converts energy from other forms of energy such as vibrations, electric field, to name a few, to electrical energy. Ac-to-Dc converter converts alternating current to direct current by reducing ripples in the ac current, which can be usually achieved by half wave and full wave rectifiers. Following Dc-to-Dc converter helps in changing the voltage level to the desired level, which can be step-up, step-down. Power manager, on the other hand, stores the energy in the energy storage element—battery.

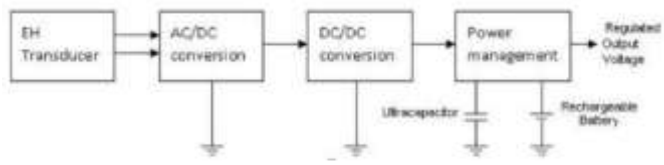

Fig-1: Energy harvesting circuit.

III. MICROSCALE ENERGY HARVESTERS

Generally there are two types of energy harvesting circuits: AC transducer and DC transducer. The AC transducer converts energy into AC current, whereas the DC transducer converts energy into DC current. Photovoltaic, seebeck, etc. fall under DC transducer. Coming to the AC transducer, piezoelectric, electrostatic, electromagnetic, electromagnetic (mechanical) are AC output transducers. For Dc output seebeck is preferred over other existing DC transducers, while piezoelectric is preferred over other AC transducers. The piezoelectric transducers are well known than any other transducer because of its simplicity in architectural design and high energy density in the materials such as PZT, PDVF, etc.

IV. CIRCUITS FOR PIEZOELECTRIC HARVESTING

The key objective of the power conditioning circuit is to have highly energy efficient transfer to the electric load as the output of MEMS energy harvester is typically in microwatts range. Therefore the minimization of energy dissipation is to be achieved as much as possible. Fig-2 is a block diagram for the piezoelectric energy harvesting conditioning circuit. The sources for vibration energy are walking (1Hz), refrigerator (240Hz), small microwave oven (121Hz) and more. There are two types of piezoelectric transducers: cantilever beam and circular disc. The major difference between the two is in pressure-mode-operating. However cantilever beam transducer is used for most of the applications because of its structural design. The output of piezoelectric transducer ranges from 1V to 10V. In the cantilever transducer beam with its mass proof oscillates up and down when kinetic energy is applied on it. The upward movement of the beam generates positive cycle, whereas the downward negative cycle. The AC signal is fed into Ac-to-Dc converter such as full wave and half wave rectifier, which converts to DC signal. Usually full wave is preferred over half wave because full wave has less ripples when compared to half wave. But the disadvantage with the full wave rectifier is that it utilizes 3 extra diodes, more space consumption in addition to more power dissipation (typically about .7V). The best way to overcome all these full wave rectifier problems is by improving the half wave rectifier itself and utilizing the half wave rectifier itself. This not only saves space, power, but also increases the speed of the harvester. A capacitor is used at the output of the rectifier to smoothen the AC ripples in the DC signal. Zener diode is used as DC-to-Dc converter, which is a step up converter that regulates the voltage and the voltage level can be changed to any desired higher level. The output of the stepped-up regulator is now connected to the power manager to store the energy in the battery.

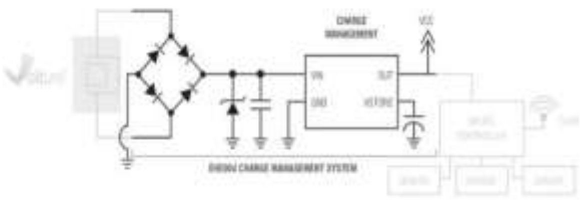

Fig-2: Piezoelectric energy harvesting conditioning circuit.

V. PROPOSED MODEL

In the proposed model, inductor is introduced in between the output of the rectifier and the capacitor. There are two main reasons that prompted to introduce the inductor in between them: first, inductor is a non-dissipative circuit; secondly, inductor opposes AC, which is the main principle on which the circuit is designed. The non-dissipative nature of the inductor makes it a good choice for the circuits like energy harvester. It is also important to note that in designing the inductor value it is to be chosen in milli henries as the higher values reduce the voltage level by back emf. The induced back emf becomes significant at the higher inductor value. This model is deployed for both full wave and half wave rectifier to understand the performance of the circuit for different environments. While Fig-3(a) shows for a full wave rectifier, Fig-3(b) for a half wave rectifier.

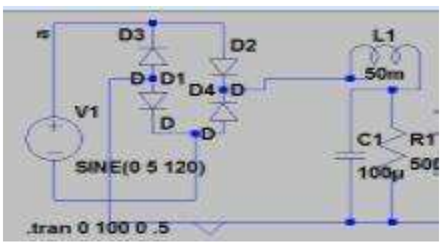

Fig-3(a): The proposed model (full wave rectifier).

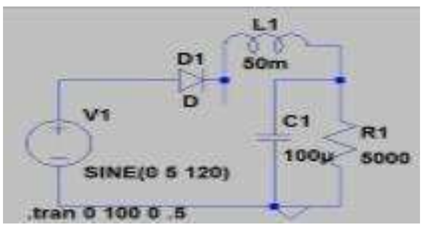

Fig-3(b): The proposed model (half wave rectifier).

VI. RESULTS

The ripple can be defined as the difference between the two opposite peaks. The full wave rectifier without inductor has voltage ripple of about .02167, while the full wave rectifier with inductor has voltage ripple of .019. The ripple percentage is decreased by 12.32% in this case. On the other hand, half wave rectifer's ripple percentage is decreased by 17%. This shows that for 50mH inductor value the half wave performs 29% better than the full wave rectifier in reducing the ripple in the circuit. These simulation results were further confirmed by testing the device on half wave rectifier , which is shown in Fig-4. Its waveform and readings are shown in Fig-4 and Table 1 respectively. The testing gave the ripple percentage value of around 13%. Table 1 shows the peak-peak voltage level for different inductor values. While the inductor is 0mH the peak to peak voltage ripple value is 2.31 Vp-p, for 50mH the value is 2 Vp-p. This confirms that inductor reduces the ripples of the circuit. Interestingly, the performance of the Dc-to-Dc converter improved by 5% because of the reduction of the ripples. Consequently, by reducing the ripples the performance and the efficiency of the circuit can be improved.

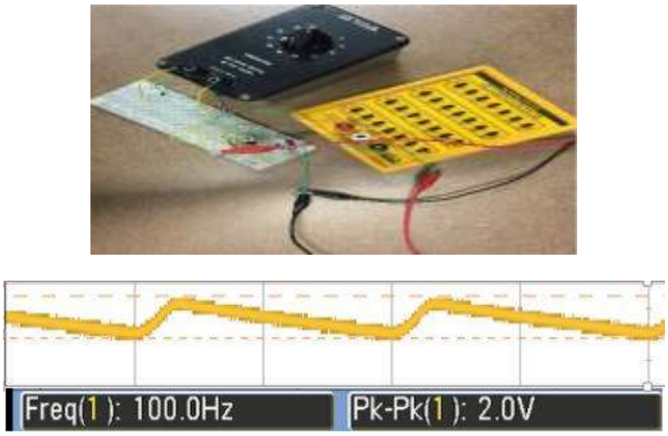

Fig-4: A prototype model for the proposed circuit.

Table -1: variation of the peak to peak voltage w.r.t inductor.

Sl.No.	Inductor(mH)	V(p-p)
1	0	2.31
2	50	2
3	100	1.4

VII. CONCLUSION

It is clear that by using an inductor in between the rectifiers and the capacitor the ripple percentage in the half wave and full wave circuit can be reduced by 17% and 12%. Furthermore it improves the performance of other devices such as DC-Dc converter (5% improved). Therefore inductor is to be used to reduce the ripples of the circuit and improve the performance of the circuit simultaneously.

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