

Experimental Comparison of Piezoelectric Rectifying Circuits for Energy Harvesting

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Abstract- Piezoelectric energy harvester transforms mechanical energy into electrical energy. However, the electrical output purely from the energy harvester needed to be conditioning before being use to power up small electronic devices. Output voltage in AC form will need to be rectified followed by stepping down using DC-DC converter to voltage level suit to any desired application. In this paper, an experimental was carried out to compare two different integrated circuit based rectifiers one of which is constructed using low voltage drop Schottky diodes, BAT754L and the other one is glass passivated single-phase bridge rectifier, W08G. It has been verified with experiment that Schottky diode outperformed normal diode type rectifying circuit.

I. INTRODUCTION

Energy harvesting using piezoelectric is one of the popular approaches to generate electrical energy from the conversion of low level ambient energy sources such as vibrations and human activities [1]. Due to its limited output power in the range of a few hundreds milliwatts, therefore it is applicable for small microelectronic system, which requires no battery and operates in a big number such as those deploy in wireless sensor network.

Piezoelectric energy harvesting is commonly associated to green technology as it can replace battery, that work toward the trend of small electronic device which is standalone and with greater mobility and less maintenance. Piezoelectric is well known in harvesting energy from ambient vibration sources. This is due to the fact that vibration is abundant around us as long as there is mechanical movement generated naturally or artificially, such as moving automobile as well as those generated from home appliances and industrial machineries [2]. However, one of the major concerns for piezoelectric based energy harvesting system is the power conditioning circuit.

When vibration is excited on piezoelectric material usually constructed in the form of a cantilever [3], it will transform kinetic energy into AC output voltage. This AC output voltage need to be rectified, DC-to-DC step down and stored before supplying to external electric load as shown in Fig.1. Beside that a more complex interfacing circuit involving inductor was reported to be able to improve the efficient of piezoelectric energy harvesting [4]. However, in this paper, we focus on the comparison on the performance of rectifying circuits

constructed with low voltage drop Schottky diodes, and conventional diodes.

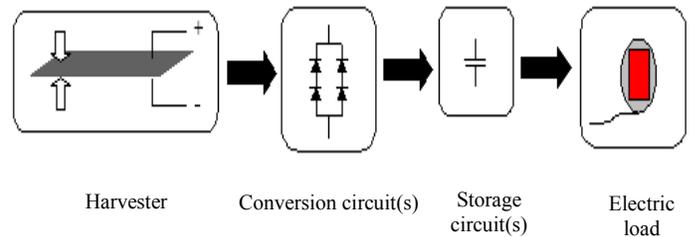


Fig. 1 The schematic for the concept of a piezoelectric energy harvesting system

II. RECTIFIER AND INTERFACING CIRCUIT FOR PIEZOELECTRIC ENERGY HARVESTER

The demand of low loss electronic circuit and high efficiency have been always the basic requirement for piezoelectric energy harvesting circuit due to its low level electrical output generation with output voltage in the range of a few volt while output current in the range of a few μA .

There is a series of stages that involve in extracting electrical energy from vibration source as shown in Fig. 2. AC output voltage generated by piezoelectric when excited by vibration source, is rectified and followed by DC-DC step down and regulated before going either into storage circuit or powering small electronic device.

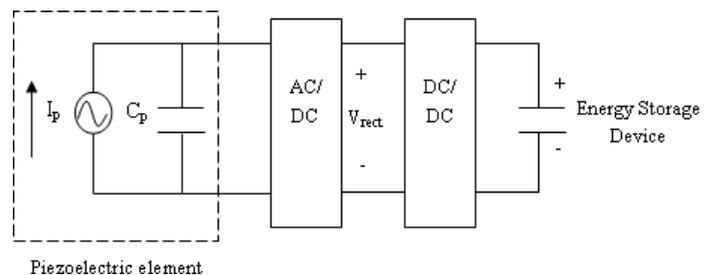


Fig. 2. Stages of piezoelectric energy harvesting circuit.

In this paper, we investigate the performance of rectifying circuits constructed with low voltage drop Schottky diodes, BAT754L from NXP Semiconductors and normal diodes, W08G from Vishay Intertechnology, Inc. BAT754L series Schottky barrier (double) diode is chosen because it has very low forward voltage and also low diode capacitance [5]. The normal diode has voltage drop about 0.6 to 1.7 volts [6]. However, Schottky diode has much lower voltage drop between 0.15 to 0.45 volts. As a result, it enhances the system efficiency and also has an advantage for its higher switching speed. Common semiconductor type has PN junction. However, Schottky diode junction is made of metal contact (anode) and semiconductor (cathode). This characteristic can protect the circuit from any damage or defect. Fig. 3 and 4 illustrate the simplified outline and graphic symbol for BAT754L and W08G respectively. Fig. 5 illustrates an application of rectifying circuit before feeding into DC-DC step-down stage.

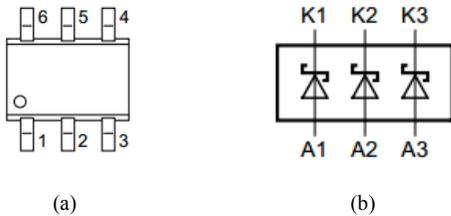


Fig. 3. BAT754L Schottky diode (a) simplified outline and, (b) graphic symbol.



Fig. 4. Glass passivated single-phase bridge rectifier, W08G (a) photo illustration and, (b) graphic symbol.

III. EXPERIMENT SETUP

The experimental set-up for the piezoelectric cantilever beam energy harvester tested under base excitation is shown in Fig. 6. The piezoelectric is clamped to the Labworks ET-126 electrodynamic transducer shaker. The input from the shaker is connected to the function generator ED-4770 in order to drive the shaker at desired input frequency. As the output power from the function generator is low, therefore Labworks PA-138 linear power amplifier is used to amplify the signal so that enough of output power can be supplied to drive the electrodynamic shaker to higher level of excitation.

In this article, piezoelectric beam bender, PSI-5A4E from Piezo Systems, Inc. [7] with size of 0.51mm x 31.8mm x 63.5mm is being used. This piezoelectric is made from vacuum sputtered nickel electrodes, is able to generate intensely low current leakage and has the advantage of low magnetic permeability.

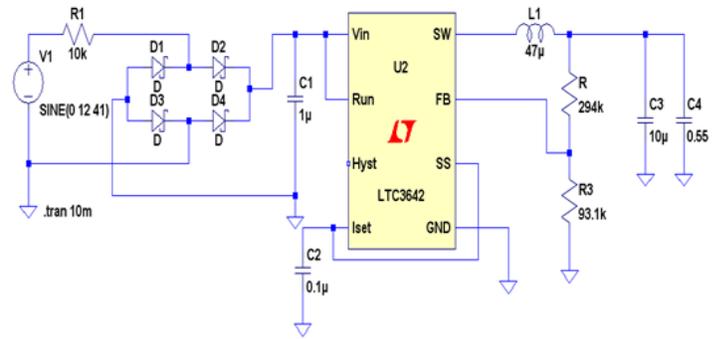


Fig. 5. Schematic diagram of a bridge rectifier using Schottky diode.

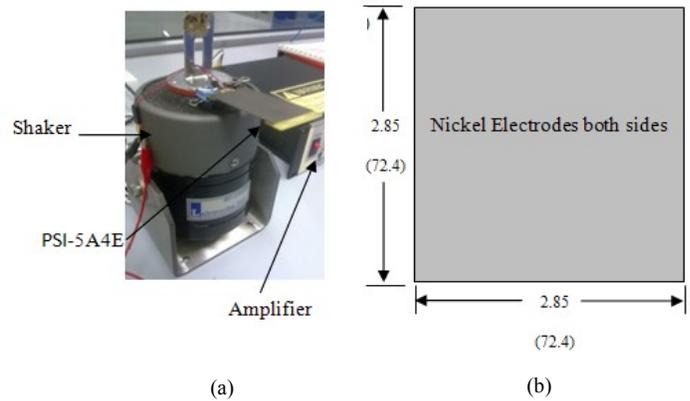


Fig. 6. Experimental set-up consists of (a) Electrodynamic shaker and (b) piezoelectric beam bender (PSI-5A4E)

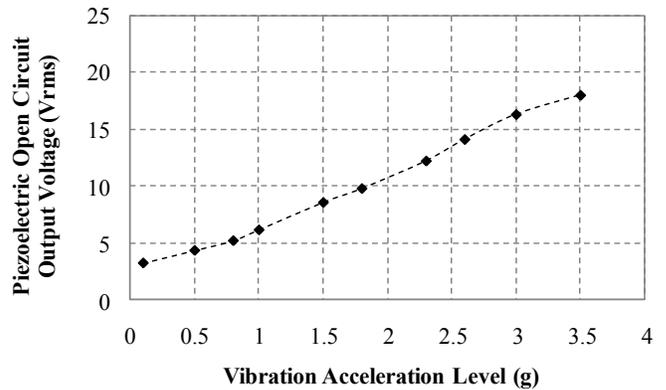


Fig. 7. Piezoelectric energy harvester open circuit voltage output as a function of vibration acceleration level (1 g = 9.81 m/s²), at resonant frequency 68 Hz.

In order to maximize the output power from the piezoelectric generator, the cantilever based structure needs to be excited to its resonant frequency. From the experimental result, it was found that the resonance frequency for the piezoelectric device is at 68 Hz and the output power from the piezoelectric energy harvester is proportional to the acceleration level of the electrodynamic shaker as can be seen in Fig. 7. In the following experiment, a constant level of

acceleration at 3-g (about 30 m/s²) will be used to investigate the performance of rectifying circuits. At this level of acceleration, the rms value of piezoelectric open circuit output voltage is around 15 V. This output voltage will be fed into the rectifying circuits.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The performance of the rectifying circuits is determined by comparing the instantaneous output power by connecting directly the output terminal of the piezoelectric energy harvester with a varying external resistive load from 10Ω up to 500kΩ.

Fig. 8 shows the experimental results of output power from the same source of piezoelectric output but with two different rectifying circuits. It is clearly seen that rectifying circuit constructed with Schottky diode, BAT754L performed better than rectifying circuit constructed with normal diode, W08G. The maximum output power for BAT754L circuit is about 27uW when driven external load of 20kΩ, whereas the maximum output power generated by W08G circuit is reduced to half at a lower optimum external load at around 10kΩ.

Fig. 9 shows the output voltage of the piezoelectric energy harvester circuits. After going through rectifying circuit of BAT754L, an output voltage of around 15V was measured at very high value of resistive load near to open circuit, while rectifying circuit of W08G reduced to around 7V, which is as expected because the voltage drop across the normal diode is around two times compare to the Schottky diodes. This verified that rectifying circuit using Schottky diodes is outperformed normal diodes.

V. CONCLUSION

This paper has presented the performance comparison of rectifying circuits for piezoelectric energy harvesting application. The experimental results have verified that Schottky diodes with low voltage drop performed better compared to normal diodes. An instantaneous output voltage of about 15V generated when excited at resonant frequency of 68 Hz with acceleration level of 3-g, is able to be rectified and delivered an output power of 27uW by BAT754L Schottky, whereas normal diodes using W08G is only delivered half of the output power due to higher voltage drop.

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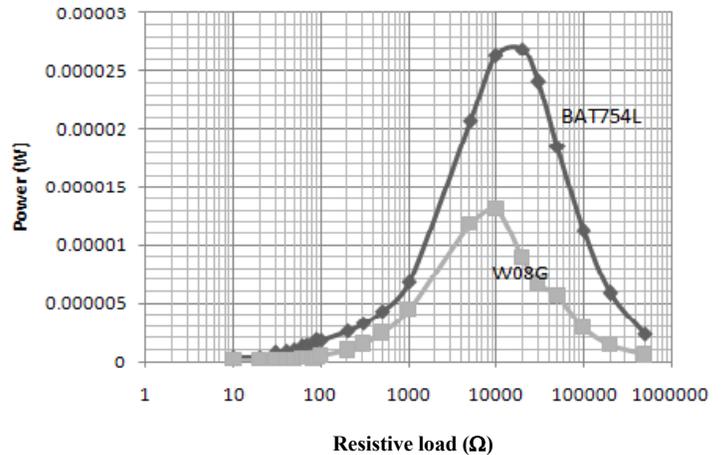


Fig. 8. Output power for BAT754L rectifier and W08G rectifier

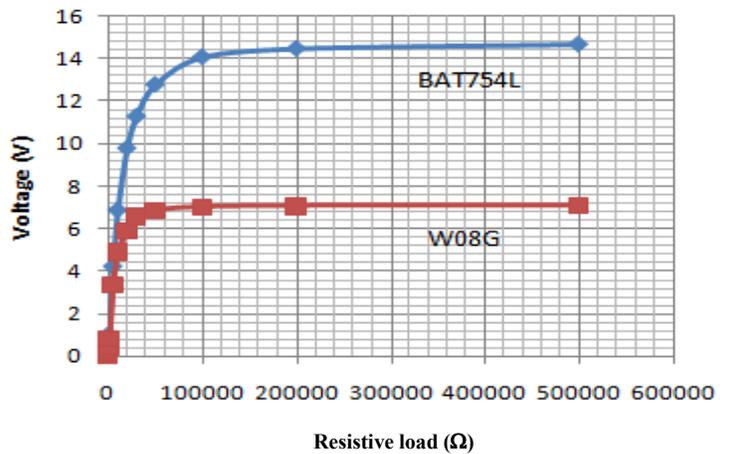


Fig. 9. Output voltage from buck boost converter

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