Performance Analysis of Commercially Available Piezoelectric Based Energy Harvester

Naveed Sheikh, Muhammad Waseem Ashraf, Nitin Afzulpurkar, Muhammad Sohail and Shahzadi Tayyaba

Abstract- In this paper we focused on the performance and analysis of commercially available piezo generator, which converts mechanical vibration to electrical power. The relationship between the dynamic response of piezo generator and its power output is realized. The efficient energy transfer of mechanical structure and high electromechanical transformation of piezoelectric material make the piezoelectric generator a extraordinary performance. The piezoelectric generator produces maximum output voltage of 4.3 V which is 0.012 µW per centimeter square.

Index Terms: MEMS, Energy harvester, Piezo generator.

I. INTRODUCTION

In the past few years, flexibility, miniaturization and multi-functionality have become the development trend of electronic devices [1]. Currently, research is focused on energy source, which is light weight, small size, environmentally friendly, and power efficient [2]. Harvesting energy from the environment to power micro devices is feasible to self-powered nano/micro systems. There are plenty of possible sources of ambient energy include thermal energy, light energy, vibration, ultra sonic waves, pressure, small friction, light energy, and body movement that can be used to operate an energy harvester [3].

In many applications, micro-electromechanical systems (MEMS) need to be self-powered, and therefore efficient energy harvesting becomes critical. The transformation of mechanical vibration to electrical energy is considered one the most suitable methods of powering wireless sensor, deprived of hazardous byproducts associated to conventional power generation systems [4]. A piezoelectric material can be suitable candidate for such harvester. They utilize the mechanical-electrical coupling effects. They are the prominent candidates of converting mechanical energy into electrical energy. Piezoelectric harvester proposed by White et al. [5] that was made on 100 µm thick steel substrate with lead zirconate titanate (PZT) film having thickness of 7 µm. The generator produced an output of 2.1 µW from vibrations. The output from piezoelectric generator depends on geometry of harvester. Roundy et al. [6] enhanced the geometry of the harvester's piezoelectric bimorph. Trapezoidal geometry can produced more than twice the energy than the rectangular geometry. Minazara et al. [7] developed a unimorph piezoelectric membrane transducer which is excited mechanically. At the resonance frequency 1.71 KHz across a (5.6 KΩ) optimal resistor a power of 0.65 mW was produced. On the basis of two energy densities Dutoit et al. [8] compared three generators. The electrostatic transducers have the lowest conversion efficiency and energy storage among these three mechanisms.

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In this study, we present a simple and reliable system to explore performance analysis of a commercially available piezoelectric energy harvester (Model and Name of Device). After the short literature presented in section I, the section II presents the system for the measurement of parameters, particularly Open Circuit Voltage (OCV) and Closed Circuit Voltage (CCV) at different vibrating frequencies. A circuit used to store energy from piezoelectric device is also presented in Section II. Section III deals with the results obtained from the experimental setup demonstrated in section II. Finally we conclude our discussion in Section IV.

II. SYSTEM DESIGN FOR MEASUREMENT

The system used for measurement is schematically shown in Fig. 1. The complete system consists of a functional generator, a piezoelectric energy harvester, a linear electro-mechanical vibrator and an oscilloscope. The piezoelectric power generator was clamped on an electro-mechanical vibrator.

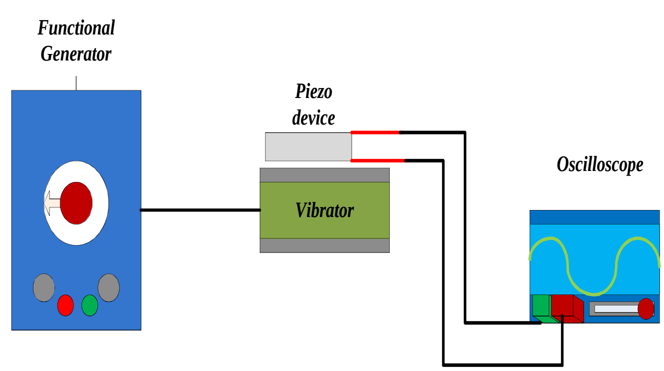

Fig.1. Schematic of the measurement of power generating.

The vibrator consists of a linear motor (speaker) and depicted in Fig. 2. This was connected to functional generator for control purpose.

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Fig. 2. Electro-mechanical vibrator.

The vibrating frequency can be controlled by the function generator. The induced voltage output voltage and the resonant frequency from the generator are measured using the oscilloscope as shown in Fig. 3.

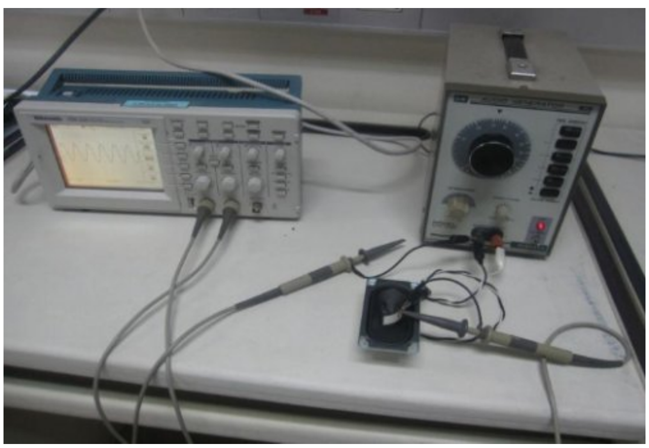

Fig. 3. System for measurement of power.

A. Resonance response and output power measurement

In order to find out the resonant frequency node and output voltage, the applied signal frequency is varied from 150 Hz to 400 Hz, with a step size of 10 Hz. Measurements are taken under OCV. For output power measurements, energy harvester is used with a load resistor R. The value of R is changed to 100 Ω to 6.2 MΩ. The CCV is measured as a function of load resistance at the input frequency which is set at first mode resonance. The resonant frequency totally depends upon the internal impedance, the stiffness and on mass so, effective bandwidth of resonance is different for different type of piezoelectric energy harvester.

B. Circuit for storing electrical energy from piezoelectric energy harvester

The output current from the piezoelectric energy harvester, which is based on piezoelectric effect is an alternating (both positive and negative cycle are produced by this source). In order to store electrical energy from such source we need to convert it into unidirectional current. Schematic illustration of the entire system to convert AC to unidirectional current is shown in Fig. 4.

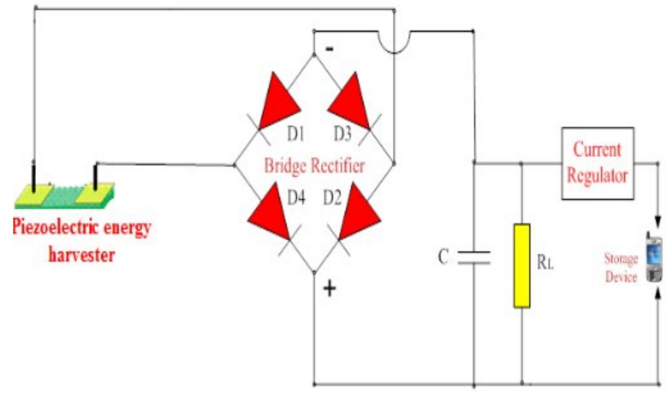

Fig .4. Schematic diagram of converting electrical energy to unidirectional current.

A simple diode can be used as a half wave rectifier to obtain the DC current. The disadvantage of such rectifier is that it only converts half of the cycle and the energy for the next half is not utilized at the output. On the other hand a bridge rectifier can completely convert the AC cycle in to DC and gives good energy efficiency. The output from the bridge rectifier charges the capacitor every time when a pulse arrives across its ends. The capacitor stores energy and delivers it to the output circuit. The output circuit consists of current regulator, which supplies a constant current to storage device as shown in Fig. 5.

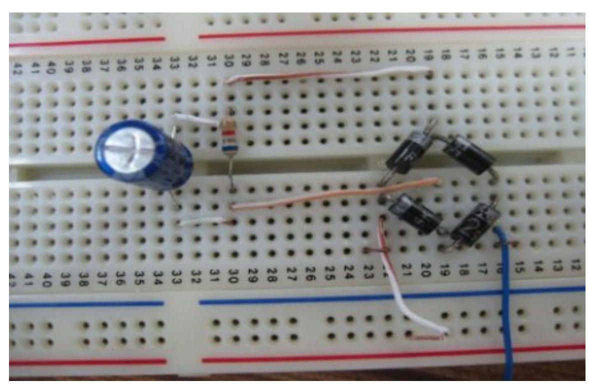

Fig .5. Circuit to convert electrical energy of piezoelectric harvester to unidirectional current.

III. EXPERIMENTAL RESULTS

The output waveform from piezoelectric harvester is shown in Fig. 6. The Fig. 4 illustrates that the output is a linear function of input mechanical vibration at the vibrating frequency of 238 Hz. The output follows the input sine wave

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pattern with a voltage output of 2.8 V. To obtain the resonance frequency (ωn) for the piezoelectric harvester under investigation, vibrating frequency is varied from 150 Hz to 400Hz. we take measurements of output voltage across the terminals for each value of input frequency. The input vibrating frequencies (ω) and output voltages are than used to plot the Fig. 7.

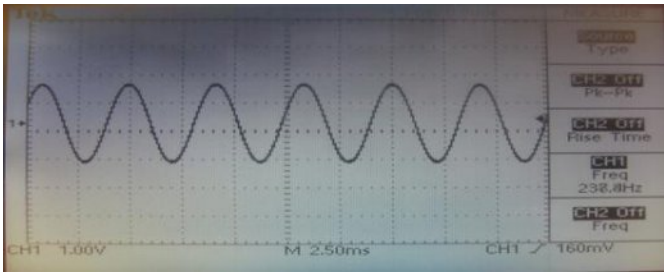

Fig. 6. Output voltage of piezoelectric device at 238 Hz vibrating frequency.

The OCV gradually increases from 2.3 V to 4.3 V as frequency is changed from 150 Hz to 280 Hz. The resonance occurs at ωn = 280 Hz. After 280 Hz, the output voltage gradually decreases and at 400 Hz it becomes 2.2 V. The bandwidth of this device is taken by using Full Width Half Maximum (FWHM), which is 200 Hz for the piezoelectric harvester used.

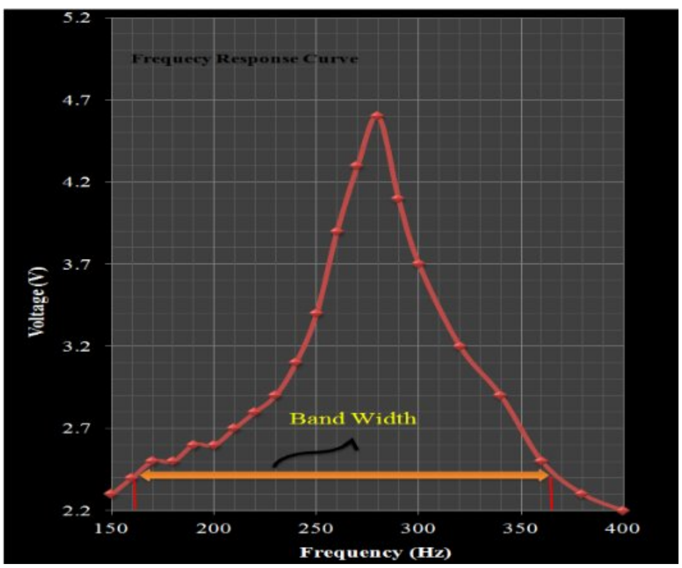

Fig. 7. Output voltage as a function of vibrating frequency.

For the output power measurement we use CCV, which is the potential drop across the external load resistance R. The graph depicted in Figure. 6 reveal that CCV greatly depends upon the value of R. For small values less than 2 MΩ, the CCV increases linearly with R. and above 2 MΩ the CCV attains a contestant voltage of 4.3 V.

Optimum output power and input impedance of peizo-electric device are obtained by using Figure. 7

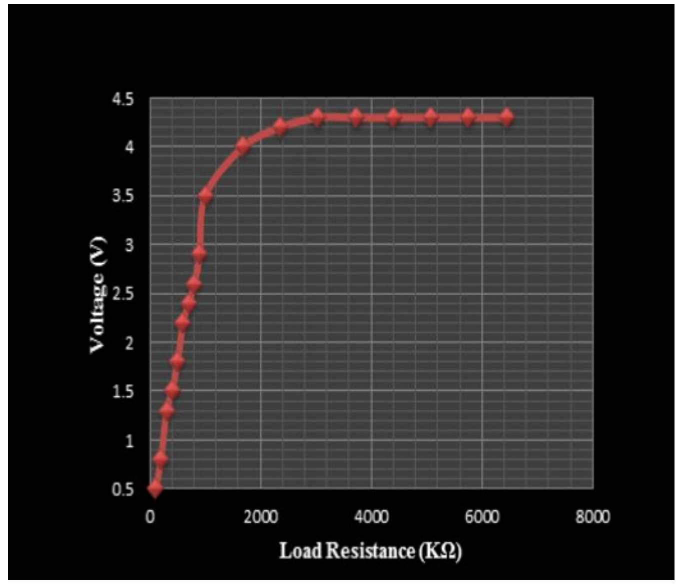

Fig.8. Load voltage vs load resistance at first mode resonance.

As indicated in Figure.7 the output power has a maximum value of 0.012 μW when a load resistance of 1 MΩ is used. It means that the internal resistance of piezoelectric generator is equal to external load resistance R. After this value, the output power decreases with the increased load resistance.

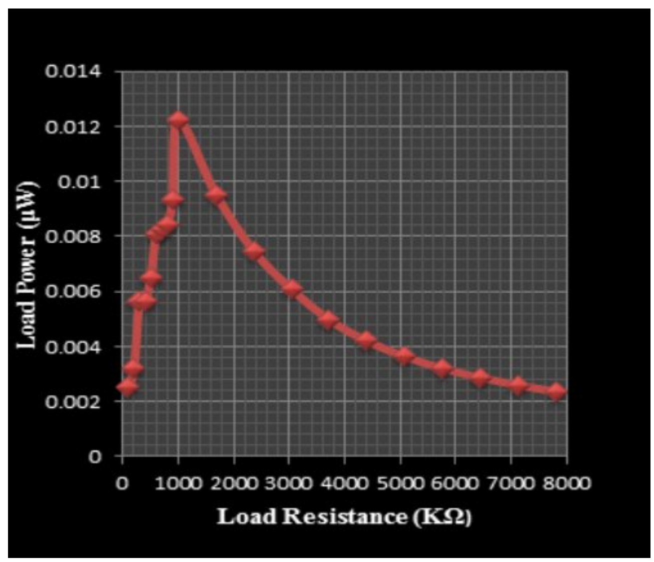

Fig. 9. Load power vs load resistance at first mode resonance.

In Fig. 10 the output obtained from the circuit is shown in Fig. 9. The circuit effectively converts AC output from piezoelectric harvester into unidirectional current and gives good energy efficiency.

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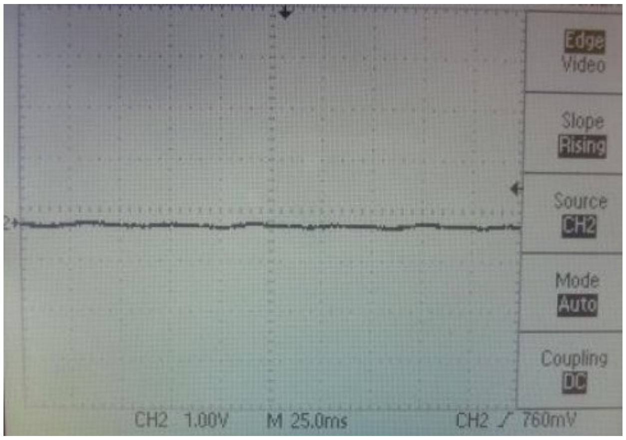

Fig.10. Oscilloscope result of converting AC signal to DC signal.

IV. Conclusion

We have analyzed the performance of a commercially available piezoelectric energy harvester. Parameters such as resonance vibrating frequency, OCV, CCV, Output power and Output impedance are measured using a simple linear motor. The measuring system is very simple and easy to operate. The results revealed that the commercially available piezoelectric energy harvester has a bandwidth of 200 Hz. The optimum voltage of 4.3 is achieved at 280 Hz. The maximum power recorded for said device was 0.012 μW when an output load resistance of 1 MΩ is used.

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