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DEVELOPMENT OF STEP-UP TRANSFORMER FOR LOW CURRENT AND LOW POWER SOUND ENERGY HARVESTING SYSTEM

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ABSTRACT

In this paper, an enhanced low power (2.29 mW) and low current (0.588 mA) step-up transformer energy harvester circuit for powering low consumption electrical devices were designed and verified. The objective of this research is to presents a novel method for battery-less circuit start-up from ultra-low voltage energy harvesting sources. The approach proposed for the first time by using a transformer and bridge rectifier as the key component for the step-up harvesting device. The proposed transformer circuit is first modeled and then experimentally verified with a sound energy harvesting system. Based on several experiments carried out in laboratory and results presented show that the proposed step-up transformer topology begins to operate at 3.89 V and achieves a 5.0 V output voltage at low frequency that is 68 Hz. This work transformer design construction needs no inductive component, not have SMT microelectronics technology. It is also have benefits of simple and achieves self-starting operation with a smaller input voltage, simple circuits and save cost. The measured results agree well or comparable with the theoretical results. From the result, it shows that the vibration of sound energy generates from speaker strike impact produce mechanical energy convert into electrical energy. The PZT-5A harvest energy effectively through transformer and provide energy to utilize low power devices such as wireless sensor network or ultra-low power sensor.

Keywords: *Development, Transformer, Current, Low Power, Sound Energy, Harvesting System*

INTRODUCTION

Nowadays, renewable energy sources have become popular in attempt to reduce global warming. These energies are an alternative form of energy resources which reduce the consumption of traditional energy resources like fossil fuels [1]. Typical renewable energy resources are wind, tidal waves, geothermal solar [2], water [3] and heat [4], Wind [5], tidal waves, and geothermal energies required large spaces, specific location, and high construction costs [6]. On the other hand, solar power might be a good alternative to capture energy as it is easier to install and has a low maintenance cost, but low solar radiances during raining days cause low energy production. However, the energy harvester systems from other sources such as wind and solar are much dependent on the availability of the source that is not constantly available and will directly affect the efficiency of the energy conversion [7]. Therefore, the energy harvested from the sound waves is unlike the other sources, where it is always available all the time and becomes a great advantage of this system [8].

This improved technique would help in placing the energy harvester as one of the best source to low power portable electronic devices. Much work has been done on studying the optimal AC power output, while little has considered the AC-DC output. However, the power produced by piezoelectric materials is far too small and is lower than the power of most electronics applications. It usually requires energy harvesting circuit to modulate the output power of harvesting system [9]. This research investigates the optimal AC-DC power generation for a rectified piezoelectric device. It shows that the harvested power depends on the input vibration characteristics (frequency and acceleration), the mass of the generator, the electrical load, the natural frequency, the mechanical damping ratio and the electromechanical coupling coefficient of the system. An effective power AC-DC converter scheme is provided to compare the relative performance and efficiency of devices. A step-up transformer is a device that transfers electrical energy from one circuit to another by electromagnetic induction (transformer action) [10]. The electrical energy is always transferred without a change in frequency, but involves changes in magnitudes of voltage and current. It is due to a transformer works on the principle of electromagnetic induction, so in this experiment, must be used with an input source voltage set as that varies in amplitude (sound level dB). Many types of transformer topology, used in the AC-DC converter devices, are introduced in the literature for harvesting different forms of ambient energies [11, 12].

The purpose of designing the medium frequency low power transformer is to explore some techniques to step-up the AC voltage produced by the piezoelectric transducer which is basically very low [13, 14]. Previously the method of designing transformer is complicated and emphasizes on high frequency circuit, but on this paper focus on develop an simple, save cost and ambient frequency range (< 100Hz) transformer which specifically to harvest low voltage and low current produced by sound wave energy.

METHODOLOGY

In this experiment, a transducer model Q220-A4-503YB is used to harvest and convert the sound waves into a useful electrical energy. The sound wave energy system was accumulated from a loudspeaker. Piezoelectric, which used as an energy transducer, placed at various distance from the speaker and then connected to the harvesting circuitry. The piezoelectric transducer model Q220-A4-503YB was operated at 68 Hz and accomplished a maximum power response of 33.133 dBuW, V_{ac} is 3.89 V and I_{ac} is 0.588 mA at sound level of 95 dB. This level is in the range of the sound level for ambience environment; which is between 50-100 dB.

Figure 1 shows the experimental setup used for the characterization of sound energy harvesting. The loud speaker is installed in a wooden box and connected to a function generator. During in-lab testing, instead of energy harvester, a function generator is used to provide input voltage waveforms with various amplitudes and frequencies. Meanwhile, oscilloscope is used to observe the input and output voltage signals for different frequencies and amplitudes. Sinusoidal waveform was supplied as an input throughout the in-lab characterization.

Piezoelectric (PE) transducer is used to convert kinetic energy from motions and vibrations to electrical energy. The output of the PE transducer is an AC quantity. The AC signal obtained from loudspeaker is extracted by the piezoelectric transducer and then fed into step-up transformer. The step-up transformer is used to increase the voltage before supply to the load. Voltage produced from piezoelectric transducer through transformer will have some ripples which should be rectified and converted before store it in a storage device. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a linear DC voltage. The proficiency of a piezoelectric transducer energy harvesting system depends on the extraction power and conversion efficiencies of rectifier, and step-up transformer. Figure 2 shows experimental setup diagram for low power step-up transformer and full wave bridge in energy harvesting system.

In this research, the rectangular shape of transformer core is selected. These shapes are ease to assemble and winding, low cost and commercially available in market. In this work, the rectangular core shape names as E-I types core transformer is used. The E-I type transformer is constructed from the shell-type and typically both windings are wound directly to the bobbin and inserted at the centre of the core leg. This type of wound is called „bobbin wound transformer‟. The bobbin insulating material which made from ABS plastic built of combination copolymer of Acrylonitrile, Butadiene, and Styrene, and generally possesses medium strength and performance at medium cost.

CONCLUSIONS

The presented direct ac-to-dc low voltage and low current step-up transformer converter using the conventional bridge rectification and achieves higher efficiency energy-harvesting system. The step-up transformer can be replaced as buck–boost converter to boost the voltage input signal 3.89 V of the piezoelectric transducer to high positive dc output voltage of 5.0 V. Based on the analysis, a simplified control scheme is proposed for high-voltage step-up application. Experimental result is presented for selecting values of the key components and control parameters of the converter. Based on the analysis and the design guidelines, a prototype of the converter with full wave and capacitor 4.7 uF is developed. The proposed control scheme with the self-start up circuit is implemented and the converter is successfully operated to directly step-up the low AC voltage to a high DC voltage 5.0 V. Future work will be concentrated on the efficiency of the current technique utilizing E-I core transformer can be improved by investigating the usage of coreless PCB transformer. These coreless PCB transformer where the latter has the potential in increasing the effectiveness, low cost and high power density through its attribute of no frequency limitation, no magnetic saturation, eliminate the manual winding process and since it does not have magnetic cores, therefore, there is no core losses.

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