# Piezoelectric Energy Harvester using Voltage Doubling Rectifier

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*Abstract*— Now a days number of power sources is present, non-renewable & renewable, but still we can't overcome our power needs. Among these human population is one of the resources. In this paper we are utilizing the waste energy of foot power with human locomotion is important for highly populated countries like India. The electrical energy produced when the flooring is engineered with piezoelectric technology, by the pressure is captured by floor sensors and converted to an electrical charge by piezoelectric transducers, then stored and used as a power source. This paper describes the design of energy harvester prototype and the power conditioning circuit. The power delivered in this paper will not contaminate the surroundings and it is also will not rely upon the climate conditions. The output of piezoelectric energy harvester (PEH) is very low. In this paper we use voltage doubling rectifier type series synchronized switch harvesting on inductor(S-SSHI).

***Key words:*** Piezoelectricity; Piezogenerator; SSHI; Storage Device

## I. Introduction

Clean sources of energy utilizes renewable energy technologies that have a much lower environment impact than conventional energy technologies. These renewable energy include solar energy, Wind energy, Tidal energy and geothermal energy. However these sources are constrained to a specific region for e.g. The Solar energy can be utilized when the sun focus is entirely great and continuous.

We utilize a large part of our muscular energy for moving from one place to other. This energy i.e. muscular or mechanical strain on various Infrastructures like roads, railways gets wasted. But it is possible to convert this mechanical energy into electrical pulse form with the help of piezoelectric transducers. A piezoelectric transducers produce AC power which needs to be rectified and stored in battery.

The Power obtained from the piezoelectric transducer is very small and cannot be used by most electrical appliances. Therefore aimed at getting more electrical energy, this paper focuses on the selection of higher efficiency rectifier for increasing. The available output power of piezoelectric Generators. In the proposed circuit, a full-wave voltage doubling rectifier is chosen and the SSHI circuit is included in the rectifier circuit. Therefore, number of diodes and conduction losses of the diodes become smaller than the conventional circuit. Thereby, the maximum output power of the proposed circuit is larger than the conventional circuit, which has been confirmed in the simulation and in the experiment. In the experiment, the maximum output power with the PEH in the proposed circuit was 3.63 times larger than that in the conventional circuit.

## II. Piezo Generator

### A. Piezoelectric Transducers

When some load is applied on the sensor for generation of electrical energy either in the form of direct strain or vibration depends on various factors such as number of piezoelectric transducers, electromechanical coupling coefficient of piezoelectric sensor, amount of load applied, and also on the scheme of arrangement.

The output power obtained from piezoelectric generators depends on various factors like which piezoelectric sensor has been used it's packing density , type of strain applied to it, electronic circuitry to process the pulse generated, storage device and load connected to it.[Centimeter Scale piezoelectric elements are generating milliwatts range electric power using ambient vibrations for a frequency below 1kHZ.

For a piezoelectric material to induce maximum charge it must be strained between its self-resonant frequency (SRF) ranges.

$$f_0=c/(2\pi)\sqrt{(4a^2)/(d^2 h(t+ka))}$$

Where, c stands for Velocity of Energy wave, a stands for radius of ceramic diaphragm, d stands for diameter of the support, t stands for thickness of support, k stands for material constant.

Fig. 1: Piezoelectric Crystal.

### B. Electric Polarization

When mechanical compression or tension on a poled Lead zirconate titanate (PZT) transducer changes the dipole moment, creating a potential difference. Compression along the direction of polarization, or tension perpendicular to the direction of polarization, generates voltage of the same polarity as the poling voltage. Compression perpendicular to the direction of polarization or tension along the direction of polarization, generates a voltage with polarity opposite that of the poling voltage. These actions are generator actions i.e. the transducer converts the mechanical energy of compression or tension into electrical energy.

The standard gait of a human involves walking at a frequency of 2kHZ. i.e. 2steps per second.

The potential energy

$$(PE)=M*g*h$$

Where M stands for Mass of the body, g stands for Acceleration due to gravity, h stands for the vertical displacement of the foot while walking.

Available power P can be given by

$$P=PE*frequency$$

 

## III. Proposed Circuit

The Electric power available from the piezoelectric material is AC which needs to be rectified for storage purpose. Thus voltage available at the end of the piezoelectric will be pulsating in nature.

In the proposed circuit, a full-wave voltage doubling rectifier is chosen and the S-SSHI circuit is included in the rectifier circuit .To improve power factor, S-SSHI is proposed. This circuit has a switched inductor which resonates with a parasitic capacitance in the PEH. Applying the S-SSHI circuit to the Full Bridge circuit enables it to harvest more power from the PEH than the Full Bridge Circuit.

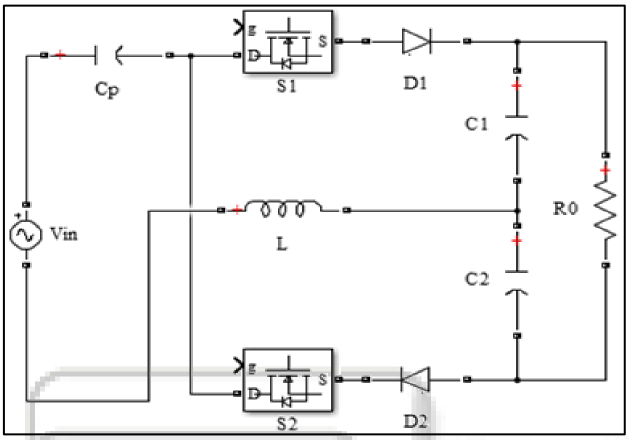


Fig. 2: PEH Circuit using FWVD Type S-SSHI Circuit

The switch S1, S2 are always open when an extremum of displacement occurs, one of the two switches is closed, and then the capacitance $C_0$ of the piezoelectric element and the Inductance L constitute an oscillator to reverse the voltage across the piezoelectric element fastly.

Voltage across the piezoelectric element is assumed to be reversed instantaneously at the extreme displacement, because the frequency of oscillator is much higher than the frequency of piezoelectric vibrator, Supposing that the charge on the up plate of piezoelectric element is positive, the bottom plate is negative, the charge on the plate is exchanged once at one oscillation, negative charge is pulled to the up plate, the positive charge is pulled to the down plate thus it avoids the charge reduction when the displacement reduces.

The voltage inversion is not perfect because a part of the energy stored on $C_0$ lost in the switching network. So after turning the voltage across the piezoelectric element decreases to $V_m$, with the increase of displacement the voltage across piezoelectric element is also increasing when $V>V_{DC}$ its works. At the same time only one conduction between S1 and S2.Because Oscillation period of the oscillator is far less than vibration period.

## IV. Circuit Operation

### A. STATE 1: (S1: OFF, S2: ON), in the Period $[t_o<t<t_1]$

The input current $I_{in}$ does not flow, though the nMOSFET S2 is in ON state, Because the diode D2 is in OFF state When the input voltage $V_{in}$ is larger than $-(V_0/2+V_D)$.Then input voltage $V_{in}$ increases in a positive direction and the filter capacitor $C_o$ discharges.

### B. STATE 2: (S1: ON, S2: OFF), in the Period $[t1 \leq t \leq t_2]$

When the Vp reaches the maximum value, the pMOSFET S1 turns ON, the diode $D_1$ turns ON, because the input voltage $V_{in}$ is larger than $V_0/2+V_D$. At this time, since Resonant occurs between $C_p$ and L, the filter capacitor $C_1$ & $C_2$ are charged.

### C. STATE 3: (S1: ON, S2: OFF), in the Period $[t_2<t<t_3]$

This state is symmetrical to the state 1. The diode $D_1$ is in OFF state. The filter capacitor $C_1$ and $C_2$ discharge.

### D. STATE 4: (S1: OFF, S2: ON), in the Period $[t_3 \leq t \leq t_4]$.

This state is symmetrical to the state 2. The nMOSFET $S_2$ turns ON and the pMOSFET $S_1$ turns OFF. The diode $D_2$ turns ON, then filter capacitor $C_1$ and $C_2$ are charged.

## V. Simulation Circuit

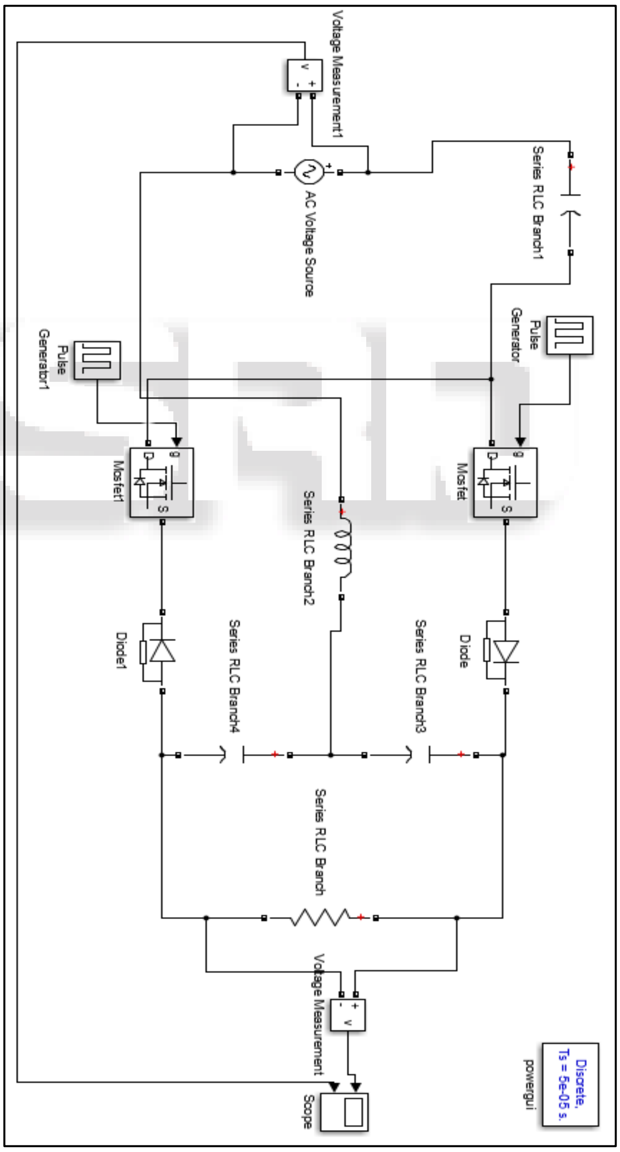


Fig. 3: Simulation Circuit

## VI. Output & Results

From the simulation below, it is evidently seen that there is a drastic variation in the output voltage of the voltage doubling rectifier from the conventional full bridge rectifier circuit.

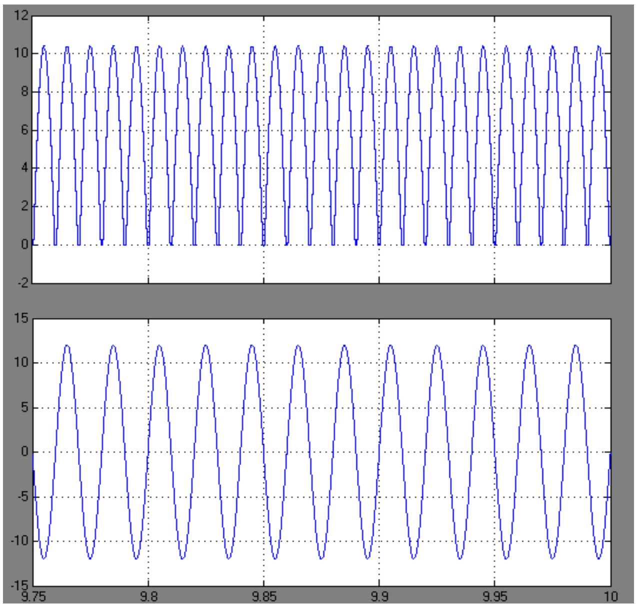


Fig. 4: Simulation Output of Full Bridge Rectifier Circuit.(Scale X-Axis-Seconds, Y-Axis-Volts)

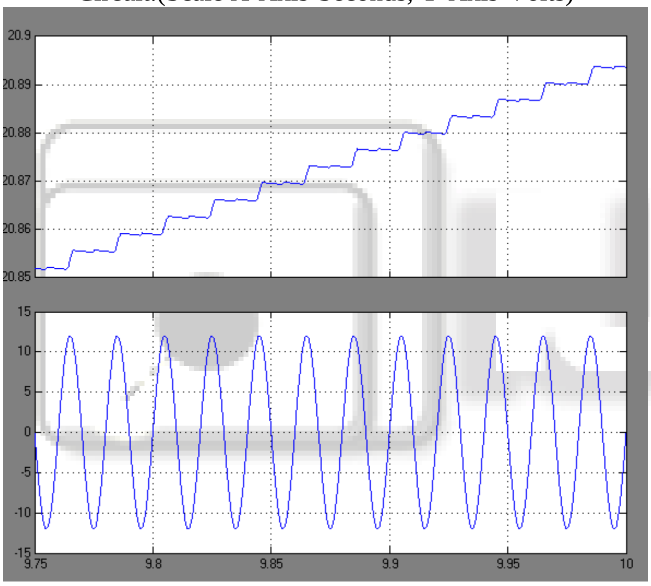


Fig. 5: Simulation Output of Voltage Doubling Rectifier Type SSHI (Scale X-Axis-Seconds, Y-Axis-Volts)

## VII. HARDWARE CONFIGURATION

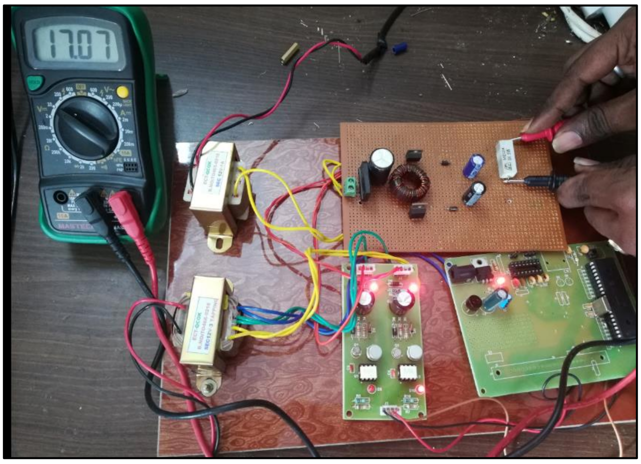

Fig. 6: Hardware Setup using SSHI.

## VIII. CONCLUSION

The synchronized switch harvesting circuit on inductor prevents the charge decreasing when the vibration displacement decreases, so it has a good application under the condition of small coupling coefficient.

Compare to full wave bridge rectifier circuit, the power harvested by the synchronized switch harvesting on inductor is more than four times.

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