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Piezoelectric Energy Harvesting Using Car Tyres

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Abstract: The aim of this project is to insert piezo electrical materials in tyres and extract electrical energy by using buck and boost converters for extra backup, thus reducing the fossil fuel consumption.
Energy source when not connected to the electric grid. One solution is to build a better battery. Another solution is energy scavenging from the ambient environment.

I. INTRODUCTION

Electricity has become a basic necessity for humans. But the fact is that, electricity is not available naturally and it can't be contained. It has to be converted from other source of energy which may be renewable (solar, wind, piezoelectric, fuel cell) or non-renewable (fossil fuel). World's 79% energy consumption is coming from the fossil fuel and India's electricity generation of 88.4% are consuming non-renewable source for generation. The World Energy Forum has predicted that fossil based oil, coal and gas reserves will be exhausted in less than another 10 decades which create the shortage of the world's energy along with environmental pollution problems.

Due to the present environmental concerns, the need remains for a cleaner power-generation technique that allows maximum range extension with minimal environmental impact through the use of renewable energy sources and critical part of the solution will lie in promoting renewable energy technologies.

Hence we have to envision a transition from non renewable resources to renewable resources. Also we have to aim at generating energy locally to reduce the load on grid and also to decrease transmission losses.

Recent advances in low power electronics have provided new opportunities for the use of piezoelectric materials to power consumer electronic devices; either without the need for batteries, or in conjunction with rechargeable batteries. Typical applications include wireless sensors, wireless networks, wearable computers, cell phones, MP3 players, and other portable electronic devices. All of these systems or devices require power from batteries or some other

II.PRINCIPLE

Piezoelectric materials generate electrical energy when subjected to mechanical strain. Power-generation devices based on such materials have surfaced in recent years in the context of vibrational-energy harvesting. The piezoelectric effect is reversible and convertible. When piezoelectric material is placed under mechanical stress, a shifting of the positive and negative charge centers in the material takes place, which then results in an external electrical field.

As a piezoelectric material undergoes an alternating compression/tension cycle it produces a near-sinusoidal voltage across its electrodes due to direct piezoelectric effect. The piezoelectric effect is the transfer of kinetic/mechanical energy to electrical energy.

The piezoelectric material behaves like a parallel plate capacitor having a total electrostatic capacitance expressed by equation (4).

$$C = \varepsilon_{o}.\ \varepsilon_{r}.\ \frac{A}{D} \qquad (4)$$

In Equation (4) ε_o is the permittivity of free space, ε_r is the relative permittivity of piezoelectric material, 'A' is the electrode area, and 'd' is the thickness

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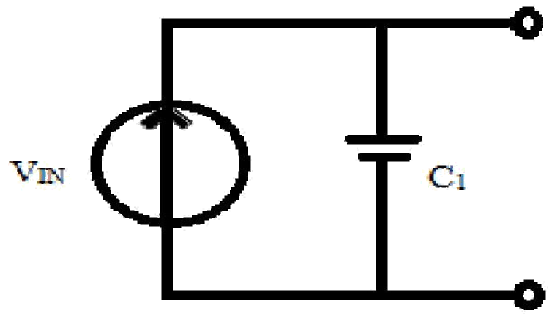

piezoelectric element

A. Electrical representation ofpiezoelectric material

The output voltage of the piezoelectric is directly proportional to the strain across the piezoelectric. Output power is proportional to the square of the voltage. Therefore, it is extremely advantageous to maximize the peak strain of the piezo-element.

The harvested energy would most likely be used to power wireless sensor networks and other low power applications where batteries would normally be used. Replacing batteries is inconvenient for the users of wireless sensor networks and consumers of other low power electronics. Recharging batteries with power extracted directly from the ambient eliminates the need for frequent battery replacement.

Before going further, let’s just understand basic DC-DC Converters. In order to utilize the DC power directly available from the renewable sources, there is need to step down or step up as various applications work at different

The average output voltage Va is always greater than the input voltage Vs of converter, its voltage equation is written as under.

$$Va = Vs\,(1/k) \qquad (2)$$

B. Buck-Boost Converter-

The average output voltage Va is less than or greater than the input voltage Vs of converter, it will be decided by value of k and its voltage equation is written as under. Output voltage of this converter is having opposite polarity than the input voltage hence it also known as Inverting converter.

$$V_a = V_s.(k/1-k) \qquad (3)$$

When 0<K<0.5-Converter operate in Buck Mode.

0.5<K<1- Converter operate in Boost mode.

0.5=k- Converter operate in Ideal mode.

III. MODEL

The idea here is to extract electrical energy by placing piezoelectric dial shaped material in the car’s tire.

A car tire has to hold up tons of weight on a cushion of air, stay in good contact with road surfaces, give excellent grip and flex when those tons of weight go around a corner and spring back exactly to its original shape. The car tire is made up of Plies, Steel Belts, Cap Plies, Bead and Chaffer. The steel belts run longitudinally around the circle of the tire. Steel belts are made up of thin steel wires that are woven together into thicker cords, and then woven again to form large sheets of braided steel. The steel belts run longitudinally around the circle of the tire. Steel belts are made up of thin steel wires that are woven together into thicker cords, and then woven again to form large sheets of braided steel.

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voltage levels. There is absence of a device like transformer incase of DC power, a buck boost converter serves the purpose. Here the voltages can be stepped up or stepped down depending on the requirement by varying the gate pulse to power devices (MOSFET/IGBT).

Basically there are three types of the dc-dc converter which are:

A. Buck Converter-

The average output voltage V_a is always less than the input voltage of converter its voltage equation is written as under.

$$V_a = K.Vs$$

Where K=Duty cycle of chopper 0<k<1

B. Boost Converter

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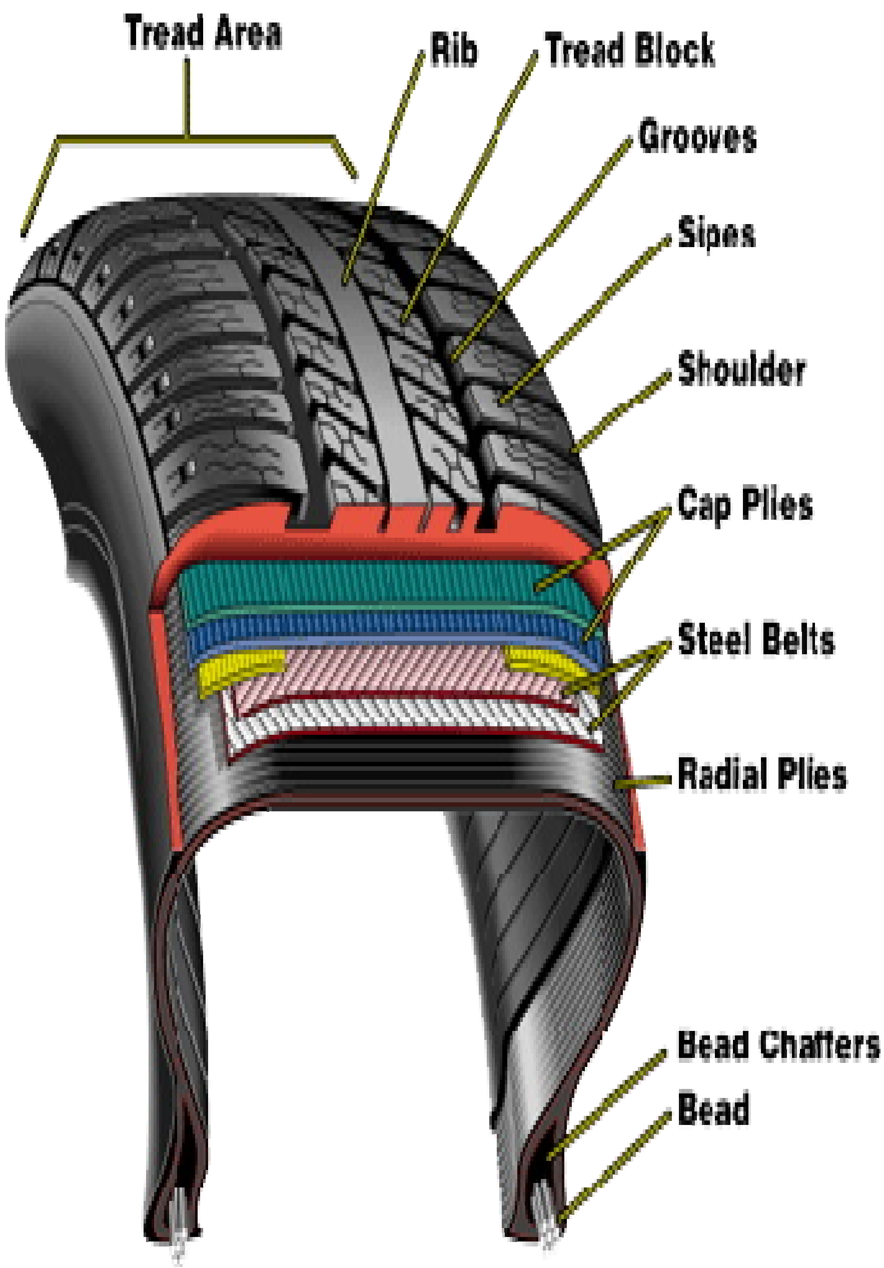
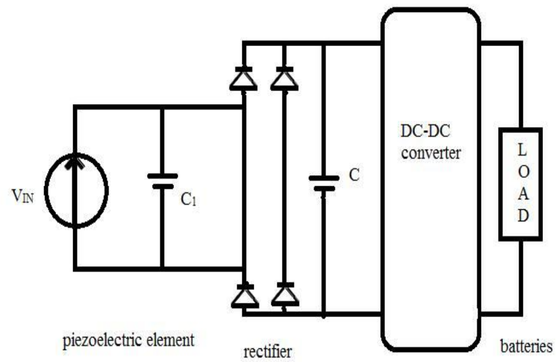
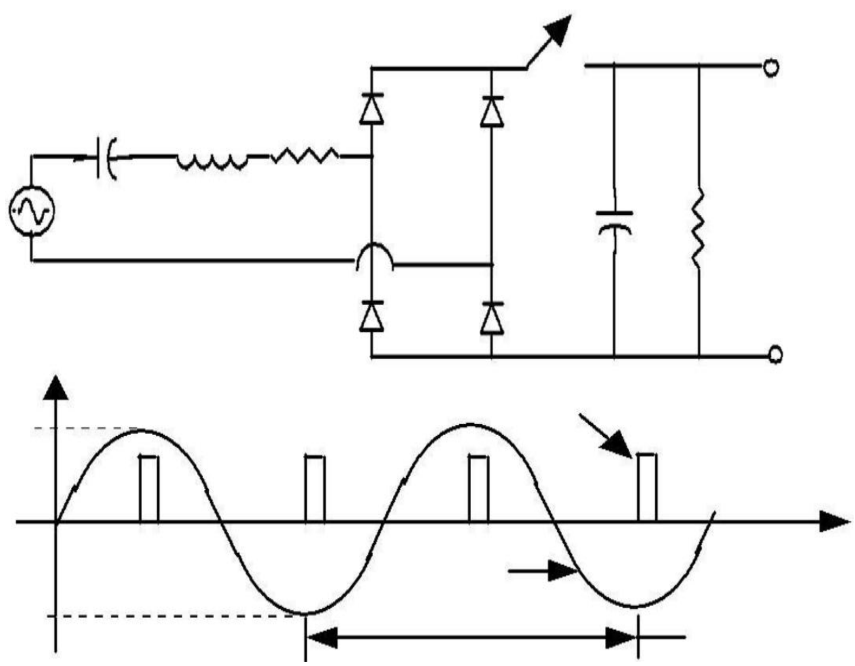


Now we introduce small dials of piezoelectric materials in between two rubber sheets in the tire which are enclosed in turn by the steel belts, all along the tire material. All the piezo-dials are connected through wires. These are taken out of the tire and are connected to a rectifier for rectification. Because the piezoelectric devices can't produce high voltages an energy harvesting module is connected to the output of rectifier to accumulate the produced energy and to regulate the output power.
The output of the harvest module is connected to the buck-boost converter to either increase or decrease the output voltage, depending on the input voltage ,the piezoelectric material generated .The output of inverter is connected to the batteries.
When the car is at rest, the piezoelectric material at the bottom points are subjected to stress and potential difference is created. But as the system is static we can't utilise this effectively because of the charge leaking property.
When the car is in motion, the bottom material is under pressure and as it goes up it relaxes and the cycle continues. Thus we obtain continuous energy.



BLOCK DIAGRAM

V
(DC)
C
o
R L



IV. IMPROVEMENT TECHNIQUES

Piezoelectric materials are intrinsically capacitive. Therefore at low excitation frequencies very low currents are realizable due to their high output impedance. Higher output current and hence more power can be achieved via resonating an inductor with the intrinsic capacitance of the piezoelectric. Due to the fact that the piezo-element frequency of oscillation is 5-10Hz and the capacitance of commercially available piezo-electrics is in the

nano/microfarad range, it is physically unrealistic to design an inductor with enough inductance to resonate with the piezoelectric capacitance at the frequency of oscillation. Hence, a quasi-resonant rectifier switching circuit is employed to reduce the source impedance.

An energy harvesting circuit termed ‘Series Synchronized Switch Harvesting on Inductor’ (SSSHI) is implemented in order to maximize AC to DC power flow from a piezo-element to a storage capacitor. The circuit comprises of a peak-triggering circuit, inductor, switch, and regulated micro-power step-down converter powered directly from the piezo-element. An SSSHI circuit has been found to lower the optimum load resistance by a significant amount (factor of four has been demonstrated). Thus, the SSSHI circuit can source several times more power than that of a conventional full-wave rectifier. The performance of the SSSHI circuit is highly dependent on the Q value of the magnetic components and the switch characteristics.

The SSSHI circuit is to be powered directly from the piezo-element itself. No batteries are needed for initial start-up or to provide a supply voltage to the switching circuit. A

micro-power regulated step-down converter is implemented to provide a 3Vdc supply voltage to the SSSHI switching circuit. The step-down converter is optimized to have extremely low power dissipation (less than 1% of additional energy harvested via SSSHI); therefore, switching frequency is minimized in the DC/DC converter design. The Q value of the inductor has a significant impact on the efficiency of the SSSHI circuit. Therefore, a custom high-Q inductor is designed to maximize SSSHI performance.

The two-switch buck-boost converter can function in buck-boost, buck or boost modes of operation. Various combinations of operating modes can be used to accomplish both a step-up and step-down function. Appropriate control circuitry is required to ensure the desired modes of operation

fig. diagram of SSSHI circuit

The combination of buck, buck-boost and boost modes has the potential to achieve high efficiency over the VIN range. However, its control is very complicated due to multiple modes of operation and the resulting transitions between different modes. In the above application, the input voltage

V_s Trigger switch

t

V(t)

$-V_s$

T_s

(c)

usually rises above the output for only a short period of time. hence the efficiency of step-down conversion is not as critical as step-up conversion. As such, the combination of boost and buck-boost modes is a good trade-off between control complexity and efficiency.

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Table1. Comparison of operating modes

OPERATION MODES CONTROL	COMPLEXITY	EFFICIENCY (VIN > VOUT	EFFICIENCY (VIN < VOUT)
Buck-boost	simple	low	low
Buck and buck-boost	Moderate	high	low
Buck-boost and boost	Moderate	low	high
Buck, buck-boost, and boost	complicated	high	high

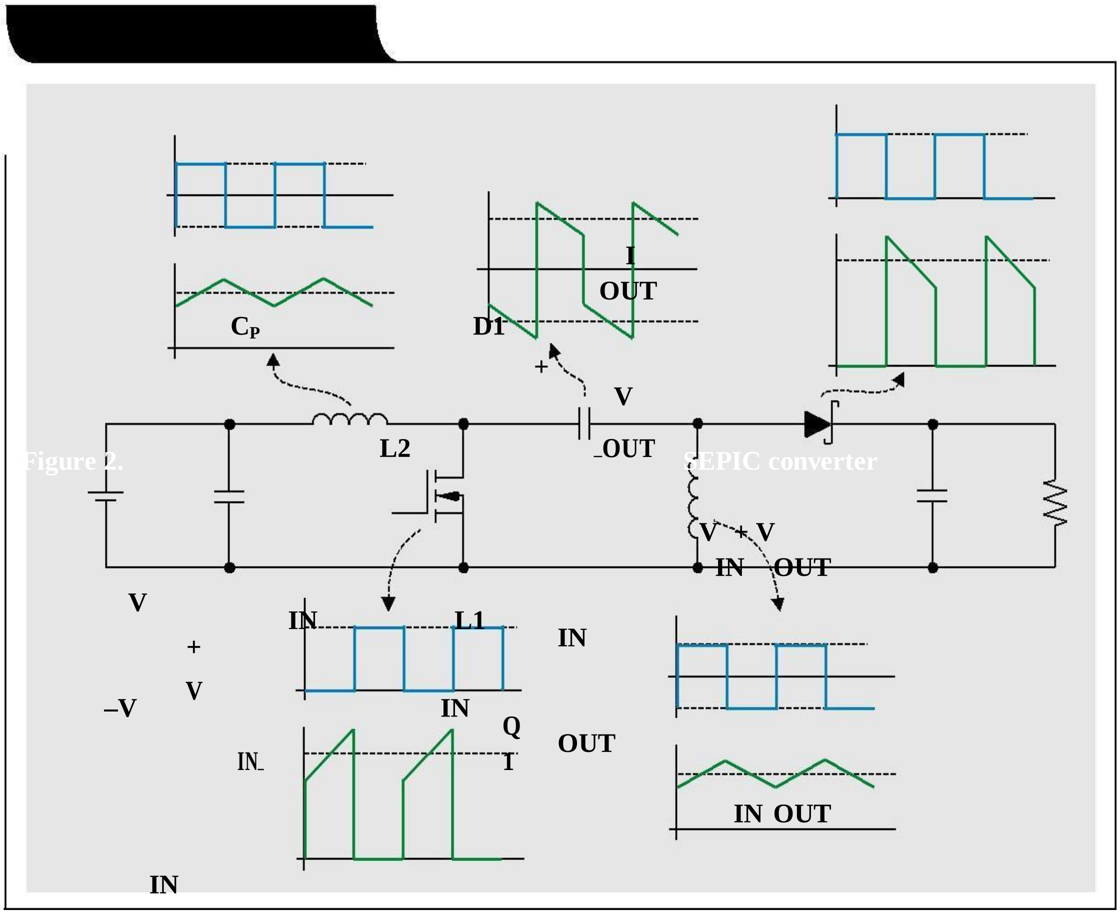
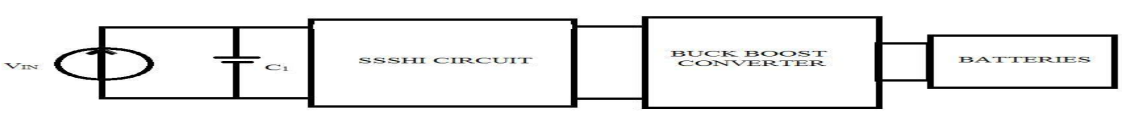


Figure 2. SEPIC converter

After implementing the above mention edimprovement techniques, the proposed model develops into the system as represented below.



A. Improved Model

To increase the overall efficiency of the system we can replace relatively inefficient and harmful lead acid batteries with super capacitors which have higher efficiency and good longitivity.

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