

Implementation of Piezoelectric Sensors for Generation of Power

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ABSTRACT: In this paper the energy from the running/walking motion of a human is captured and transformed to electricity using piezoelectric sensors and further utilized to charge the battery of a mobile phone. A shoe sole has been successfully designed with piezoelectric crystals which when subjected to mechanical deforming force develops potential difference which is then used to charge portable electronic devices.

KEYWORDS: Piezoelectric, Power Generation, Mobile Phone Charger, Overcharge Protection

I. INTRODUCTION

Man has used energy at an increasing rate for his sustenance and well-being ever since he came on the earth a few million years ago. Due to this a lot of energy resources have been exhausted. Non-conventional energy plays an important role in providing energy with sustainability to a vast population in developing countries who still do not have access to clean energy.

Non-conventional energy system is very essential at this time to the world. In this context, appears the energy harvesting concept. In this paper we are generating electrical power as a non-conventional method by simply walking or running. The mechanical force of the footsteps is converted to electrical energy using piezoelectric sensors. The stored energy in the rechargeable battery then can be used for charging mobile phones. Currently, all portable electronic devices are supplied energy only through batteries. However, the energy harvesting from human or environmental sources has proved to be an alternative which is highly effective.

II. PRINCIPLE OF PIEZOELECTRICITY

A. Law of Energy Conservation

The law of conservation of energy is a law of science that states that energy neither be created nor destroyed, but only changed from one form into another or transferred from one object to another. Here the mechanical energy of walking/running motion of a human is converted to electrical energy using the piezoelectric property of Lead Zirconate Titanate.

B. Piezoelectricity

Piezoelectricity (also called the piezoelectric effect) is the appearance of an electrical potential across the sides of a crystal when subjected to mechanical stress [7]. The necessary condition for the piezoelectric effect is the absence of a centre of symmetry in the crystal structure [5]. Piezoelectricity is phenomenon by which the electric charge accumulates in certain solid materials due to applied stress which is mechanical. The word piezoelectricity implies obtaining electricity from pressure. Energy harvesting from mechanical vibration is a potential power source which can be used for conversion to electrical energy through Micro electromechanical systems (MEMS) technology [2].

C. Mechanism

In a piezoelectric crystal, the positive and negative charges are separated from each other, but they are symmetrically distributed in order to keep the crystal electrically neutral. When a stress is applied, this symmetrical position is

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disturbed, and the asymmetrical charge generates a voltage. A 1 cm cube quartz crystal with 500 lb (2 kN) of correctly applied pressure upon it can produce 12,500 V of electricity [6].

III. BLOCK DIAGRAM AND COMPONENT DESCRIPTION

Block diagram for foot step power generation is shown in fig 1.

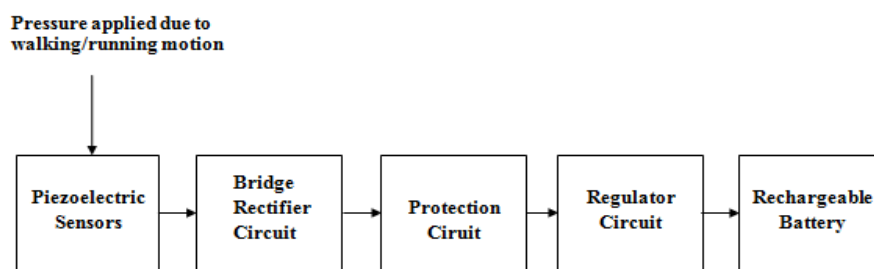


Figure 1: Block Diagram

A. PIEZOELECTRIC SENSORS

A piezoelectric sensor is a device which utilizes the piezoelectric effect to measure changes in pressure, acceleration, temperature, strain or force by converting it to an electrical charge. The strain, pressure, force, etc. applied causes the crystal to become electrically polarized creating a voltage [1]. And the current starts flowing through it. There are many crystals like Lead Zirconate Titanate that produces electric charges when pressure is applied on them or they vibrate when subjected to potential difference. The amount of charges generated depends upon the frequency of vibration. During simple lab test it was found that slight bending of a piezoelectric directly connected to one LED light produced enough current to light the LED. The design strategy is to find the optimum type of piezoelectric and positioning in the sole of a shoe for ideal power generation. The stiffer PZT is better suited to smaller, high impact areas so that the strain is high but the bending is limited.

B. BRIDGE RECTIFIER CIRCUIT

A diode bridge is an arrangement of four diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input[10]. In this application, it is used for conversion of an alternating current (AC) input into a direct current (DC) output, and filtered using a capacitor filter. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a centre-tapped secondary winding.

The smoothing capacitor converts the full-wave rippled output of the rectifier into a smooth DC output voltage. To remove the AC components or filter them out in a rectifier circuit, a filter circuit is used. In this filter a capacitor is connected across the load during the rise of voltage cycle it gets charge and this charge is supply to the load during the fall in the voltage cycle. This process is repeated for each cycle and thus the ripple is reduced across the load.

Bridge Rectifier Ripple Voltage

$$V_{(ripple)} = \frac{I_{(load)}}{f \times C}, \text{ Volts}$$

where I is the DC load current in amps, f is the frequency of the ripple or twice the input frequency in Hertz, and C is the capacitance in Farads.

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C. PROTECTION CIRCUIT

The Protection circuit is comprised of Reed Relay as the main component, along with 2 LEDs (Red and Green) for indication, and current limiting resistors. DIP reed relay by Elec-Trol part# RA30451051 is used in the circuit [9]. It is a Single Pole Double Throw Switch (SPDT) relay. When the relay is off i.e. the coil is unpowered the movable contact is in normally close position and powers the red LED in its path. When relay is on i.e. the coil is powered above certain voltage (5 V in this case) the movable contact shifts to normally open position and powers the green LED in its path [12]. An external switch is located along the path of green LED as a provision to check overcharging of the battery. They have fast operation and release time and when operated within their rated contact loads have very long life.

D. REGULATOR CIRCUIT

A regulated power supply is very important for charging of the mobile phones since the semiconductor material employed in them has a rate of current as well as voltage which is constant. The device gets damaged if there is any change from the constant rate. This circuit converts rippled DC power obtained from the rectifier circuit to a constant DC voltage of 5 V. Typically the controller of such a converter is designed to regulate the output voltage [3]. The circuit consists of voltage regulator which has the serial number 7805 along with capacitor and a current limiting resistor. IC 7805 is used as 5V regulator. It converts 12V into regulated +5V [8]. The maximum value of input to the voltage regulator is 35 V. Here the battery provides an input voltage of 7.5 V to the regulator which in turn gives a regulated 5 V DC supply. For the checking of large alterations in the input and in the output filter, capacitors are used.

IV. WORKING

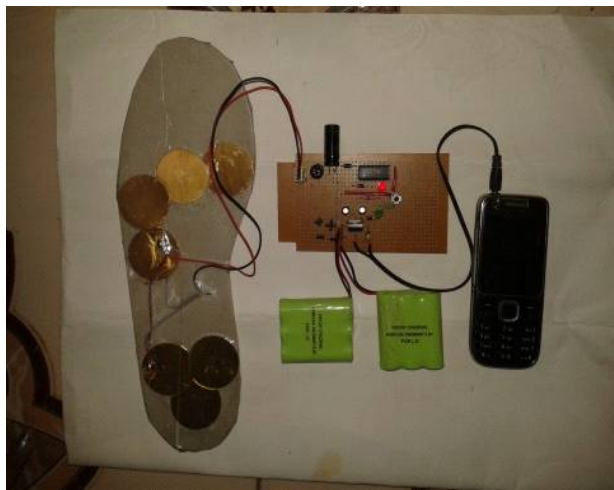


Figure 2: Main Circuit

When a person is in running or walking motion, the piezoelectric plates inside the shoe sole will be compressed under the weight of the walker. Presses will be used to ensure that all of the weight is directed to compressing the PZT. In case of bending, the amount of deflection must be limited so that the PZT does not fracture. Due to this alternating deformation caused by the movement of foot, an alternating voltage is generated proportional to the deforming force applied. Since an irregular pulsating voltage (Fig.1) is produced there is need for rectification. A full wave bridge rectifier with a capacitor filter is employed for the work of rectification. The 100 μ F smoothing capacitor filters the AC component of the output by charging and discharging momentarily. When the charge from the capacitor exceeds 0.7 V, the diode (1N4007) gets forward biased and conducts to supply the charge to the battery where it is stored [11]. Else when the diode becomes reverse biased and doesn't conduct.

The glowing of red LED indicates that the battery is connected to the circuit and that the capacitor is charging. At the same time, when the voltage across the capacitor exceeds 5.7 V the relay is energised. The movable contact moves from normally close (NC) position to normally open (NO) position and the circuit of Red LED gets disconnected and

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the movable contact switches to the green LED circuit. As the voltage across capacitor is more than 5 V the NiMH (Nickel Metal Hydride) rechargeable battery starts charging [13]. When the voltage drops below 5.7 V the relay gets de-energized and the movable contact of relay moves from normally open to normally close position and the green LED circuit connection is open. When switch S2 is pressed the Green LED indicates whether the battery is charged above 5.7 V or not. If the battery is less than 5 V and the switch S2 is pressed the green LED doesn't glow indicating the battery to be undercharged. If the battery voltage is more than 5.7 V and the switch is pressed the green LED glows indicating that the battery and charged and no need to supply energy from the piezoelectric plates. In this way overprotection is employed in the circuit. A fixed voltage regulator IC 7805 giving constant 5 V DC supply is connected across the rechargeable battery. A stabilized 5 V output of regulator is taken for the recharge pin of mobile phone through a 10 ohm resistor. The system is asynchronous, meaning that it does not require consistent or predictable force or vibration frequency to function efficiently [4]. Thus a stabilized voltage is available for charging the mobile phone.

V. CIRCUIT SIMULATION

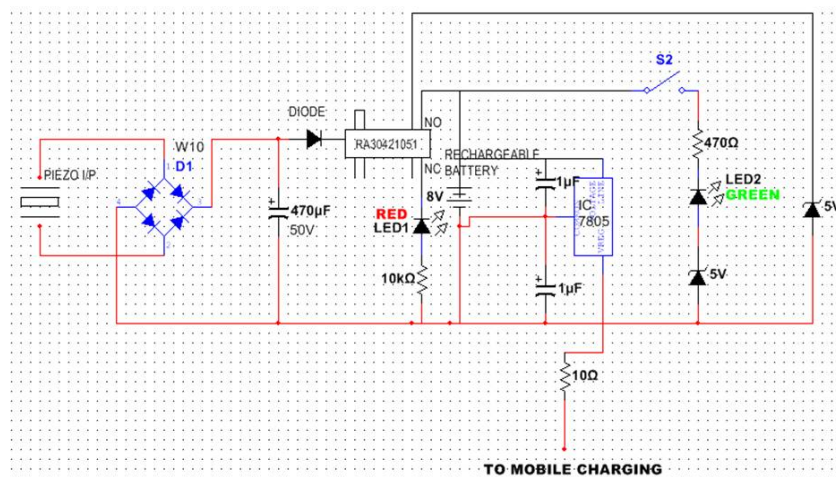


Figure 3: Circuit Diagram of the Footstep Power Generator

The Simulation tool that was used is Proteus design suite. The **Proteus Design Suite** is an EDA tool which includes schematic capture, simulation and PCB Layout. Here EDA stands for Electronic Design Automation. It is used because it has all the above tools together.



Figure 4: Pulsating Output Voltage of Piezo under pressure Charging circuitry

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VI. RESULT AND DISCUSSION

It has been observed that after walking 300 steps, the storage capacitor charges to approximately 4.975 V. In a single step the storage capacitor charges to 0.0165 V. Therefore in order to charge the battery completely a person has to walk for about 250 m. The NiMH rechargeable battery takes about 25 seconds to discharge by 0.01 V i.e. about 75 minutes are required to discharge the battery from full charged level to minimum level at which the IC 7805 can operate to give constant 5 V DC.

When a 50 kg man walks with the shoe it generated a voltage of 3.95 V on walking 200 steps, and 6 V on walking 400 steps which can be averaged to 4.975 V for 300 steps.

When the mobile phone is connected to the charging pin, it was found to be charging efficiently at the rate of 0.01 V per 25 sec. The design meets the design criteria and produces sufficient power. This rate is expected to continue to improve at higher excitation levels.

VII. FUTURE SCOPE

Among all the energy-harvesting techniques in use today piezoelectricity harvesting is able to generate electrical energy simply through vibration or external force. The scope of use of piezoelectricity is not just limited to mobile charging with a shoe but a completely efficient large scale energy harvesting allowing for a wide range of applications including flooring, bridges, and road. Such a concept is very much important for an overcrowded country like India where thousands of people move round the clock.

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