

Energy Harvesting for Piezoelectric using multi-device architecture with Parallel Charge Accumulation

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Abstract: *In present era vibrational energy is a promising nonconventional energy source for portable and wireless electronic devices with extended lifespan, where less energy is required as energy source. Batteries are frequently used in these devices but charging is required to power the batteries just because limited lifespan of batteries, so replacement to be done in this field by researchers and piezoelectricity to be introduced as a promising source. The use of Piezoelectric materials to harvest power has already become popular. Piezoelectric materials have the ability to transform mechanical strain energy into electrical charge. This paper focuses on Piezoelectric devices as possible energy source and to research on multi-device connection and look for maximum energy generation. The scope of work will include, working for various configurations, connectivity etc to extract maximum energy from source. The research would consider 'human walking' as energy source, hence a shoe mounted Piezo generator would be developed as energy source. The paper also considers to design an electronic circuit which can store the energy generated and even deliver the energy as a power Source. The emphasis would be on parallel charge accumulation which can enhance the charge generation. The paper will approach on the above postulates and will look for maximum power extraction from Piezo devices.*

Keywords: energy harvesting ,piezoelectricity, impact of series and parallel combination, multi device architecture.

1. Introduction

Energy harvesting is the process where external energy presented in our surroundings is converted in to useful energy. There are conventional and nonconventional energy sources, the renewable energy sources are categorized as conventional energy source but geothermal, tidal and vibrational energy is categorized as nonconventional energy source, devices are designed to capture the ambient energy from surrounding and convert it into usable electrical energy. The concept of piezoelectric harvesting works towards developing self-powered devices that do not require replaceable power supplies. A number of sources of harvestable ambient energy exist, including waste heat, vibrations, electromagnetic waves etc. While each of these sources of energy can be effectively used to power remote sensors, the structural and biological communities have placed an emphasis on scavenging vibrational energy with piezoelectric materials[1].The ambient vibrational energy present in mechanical and biological systems is lost but this loss is converted in to electrical energy by using a phenomenon of piezoelectricity ,according to this the pressure and strain has to be converted in to electric charge by using piezoelectric crystal .In the highly populated areas like walkways, highly traffic areas , malls, railway stations etc where lots of mechanical energy has to be present due to foot pressure can be converted in to electrical energy to be consume. This article emphasizes the field of power harvesting and its drive to create completely self-powered device. In this paper first we introduced the basic working principle of piezoelectric crystal and later we describe how to extract the maximum energy by using single and multiple discs of piezoelectric material. The placement and series and

parallel combination of discs in circuitry to be always cited and then how the charge to be accumulate and stored for further use is also describe.

2. Working Principle

A. Piezo Principle

Crystalline materials produce small amounts of electricity when a force is applied that changes their shape in some way. These are called piezoelectric materials. Quartz, Rochelle salt, topaz, tourmaline, cane sugar ,Berlinite titanate(BaTiO₃),Dent -in silk, Lead Titanate(PbTiO₃), lithium niobate(LiNbO₃),Potassium niobate(KNbO₃) such are examples of crystalline structure[3]. When small amounts of pressure are applied to these crystal structures, a small voltage is produced from the changing charge created by the moving electrons. Phonographs, Microphones and barbecue lighters also use this principle. The output voltage obtained from a single piezoelectric crystal is in millivolts range, which is different for different crystals. And the wattage is in microwatt range. So in order to achieve higher voltages, the piezoelectric crystals can be arranged in cascading manner, that is, in series. The energy thus obtained is stored in lithium batteries or capacitors. This is the working principle behind piezoelectric energy harvesting system. Now the extreme engineering lies in optimization of piezoelectric energy. [4]



B. Principle of Operation

Depending on how a piezoelectric material is cut, three main modes of operation can be distinguished: transverse, longitudinal, and shear.

Transverse effect

A force is applied along a neutral axis (y) and the charges are generated along the (x) direction, perpendicular to the line of force. The amount of charge (C_x) depends on the geometrical dimensions of the respective piezoelectric element. When dimensions apply,

$$C_x = d_{xy} F_y b/a$$

Where (a) is the dimension in line with the neutral axis, is in line with the charge generating axis and is the corresponding piezoelectric coefficient.

Longitudinal effect

The amount of charge produced is strictly proportional to the applied force and is independent of size and shape of the piezoelectric element. Using several elements that are mechanically in series and electrically in parallel is the only way to increase the charge output. The resulting charge is

$$C_x = d_{xx} F_x n,$$

where n is the piezoelectric coefficient for a charge in x-direction released by forces applied along x-direction (in pC/N). is the applied Force in x-direction [N] and corresponds to the number of stacked elements.

Shear effect

The charges produced are strictly proportional to the applied forces and are independent of the element's size and shape. For elements mechanically in series and electrically in parallel the charge is

$$C_x = 2d_{xx} F_x n$$

In contrast to the longitudinal and shear effects, the transverse effect opens the possibility to fine-tune sensitivity on the force applied and the element dimension

According to above description and lot of studies are being carried out to obtain the maximum output voltage and wattage. In next paragraph we have mentioned the past work which have done in this field of research and most promising vibrational sources.

3. Previous Work and Sources of Vibration

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files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

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a) Energy Generation by Automobiles

Noticing that a bicycle in movement is vibrating permanently, and these vibrations are vectors of mechanical energy, we can recover and convert the mechanical energy contained in these vibrations into electrical energy by using electromechanical transducers such as piezoelectric materials. The electrical energy thus produced can be used to power devices aboard the bike, or other portable devices that the cyclist uses.[13]. A concept tyre introduced at the recently concluded Geneva Auto Show is capable of generating electricity that could power the very electric car it is fitted into. Goodyear Tire & Rubber Co. introduced the concept tyre, BHO3, which offers the possibility to help recharge the batteries of electric cars by transforming heat from a rolling tyre into electrical energy. Material used in these BH03 concept tyres captures the heat generated when the tyres flex under normal driving conditions and transforms it into electrical energy

b) Energy Generation in Walkways, Gyms and Traffic Areas

Researchers are also working on the idea of utilizing the mechanical vibration caused by machines in the gym.[4] In walkways means densely populated areas like stations, bus stands and public areas where lots of mechanical energy is present which can be converted in to electrical energy by laying piezoelectric crystals. Innowattech energy harvesting systems in Israel introduced energy generators for road applications in heavy traffic areas and for railway application. The conversion is based on the compressed piezo-mechanical effect

INNOWATTECH'S SOLUTION = PIEZOELECTRIC GENERATOR (IPEG) + ELECTRICAL SYSTEMS (HARVESTING MODULE AND STORAGE DEVICES)

c) Power Generation in dance floors and clubs

In Europe certain nightclubs have already begun to power their night clubs, strobes and stereos by use of piezoelectric crystals, the crystals are laid underneath the dance floor when bulk of people use this dance floor enormous amount of voltage is generated which can be used to power equipments of club. [11]

d) POWER GENERATION BY FOOT STEPS

In united states defence advance research project agency(DARPA) initiated a innovative project on energy harvesting which attempts to power battlefield equipment by piezoelectric generators embedded in soldier's boots[1].while these harvesting technique left an impact on the soldier's body and create a discomfort while walking due to shoes design ,but this approach of innovation has been used by the most researchers for future scope .In another section of this paper we have also used this innovating idea

of harvesting from the additional energy expended by the person wearing a shoes.

4. Our Work on Piezoelectric Generator

In order to achieve a particular amount of energy for potable and low energy consuming devices we briefly studied the further research work, researchers have successfully built and tested vibration based generators using three types of electromagnetic transducers: Electromagnetic, electrostatic and piezoelectric all of them are based on the same principle.[6] In further section we have described how to cross sectional area and mechanical force is responsible for charge generation .Here we proposed our work on piezoelectric generation which is categorized in three stages : first the type of piezoelectric material is used , in second stage the placement and connection of piezoelectric materials , and the last stage is electronic circuit design for charge amplification .

A: here we describe the structure of piezoelectric component which is used in work for energy harvesting. The illustration shows below describes the complete phenomenon.

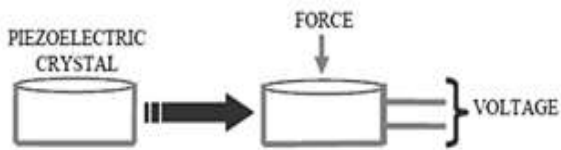


Fig 1. Principle of direct piezoelectric effect

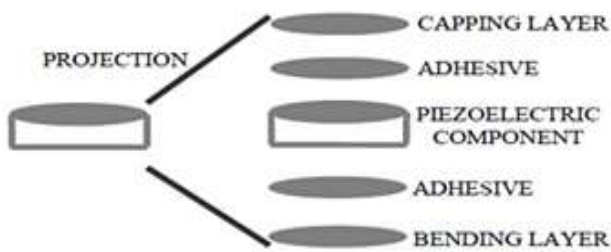


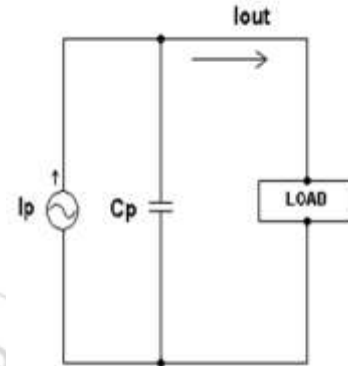
Fig 2. Structure of a piezoelectric component

The above structure is architecture of piezo disc which is used as energy generator in our work.

B ; multiple disc architecture :for further work first we tested the single disc for charge generation and found the voltage generated by a single disc is in millivolts and wattage is in microwatt range which is not sufficient for charging of portable devices. so in order to achieve the required amount of voltage ,we connect the disc in cascade manner and found the obtained results are good enough but not satisfactory due to longitudinal effect of force. Another manner of connection of discs is the parallel combination of discs in which we placed the discs in form of stacks means one above another with a insulating layer between them and then test the signal. Now we found the strength of signal is increased as compare to cascade manner, So the principle of transverse and longitudinal effect we used here means mechanically in series and electrically in parallel connection in our work. But optimization is necessary for obtained output for further use, which is done by electronic circuit design means a harvesting module with storage capacitor.

C : electronic circuit design : the equivalent circuit of proposed architecture illustrate below

In the circuit the vibrating piezoelectric element is placed as a alternating (sinusoidal) current source I_p which is in parallel with the capacitor, which is the internal electrode capacitance C_p . The magnitude of the polarization current varies with the mechanical excitation level of the piezoelectric element, but is assumed to be relatively constant .The resonant frequency depends on the piezoelectric material , Fig.1 shows the equivalent circuit of a piezoelectric device which is driving a load.



The voltage achieve from the circuit is an ac voltage but in MEMS and portable devices digital signal is needed and electro chemical batteries are also required a dc voltage for charging , so it is necessary to first convert it the signal in DC form which is done by using the ac to dc converter as shown in figure 4 . This ac-dc converter is often simply composed of a diode rectifier bridge and an output filtering capacitor.

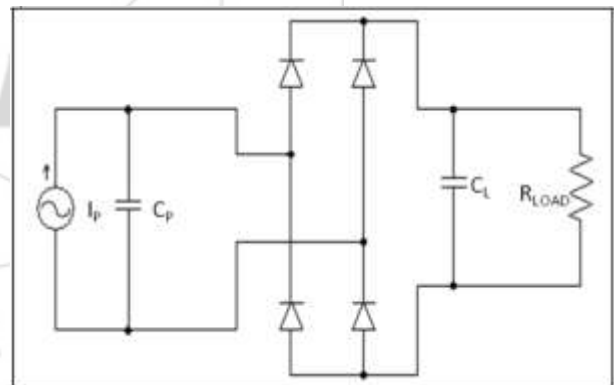


Figure 4: circuit diagram for capacitive load

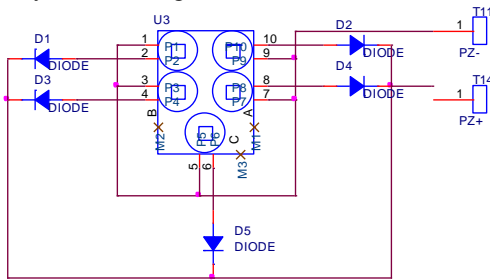
5. Results

The circuit experiment has been done and the result shown below, it has to be performed also on light emitting diode (LED) which had given the satisfactory result it blows with full



intensity, the output voltage is more then 5 volts and current rating is 150 milliamps come out from the generating device. We used two discs in parallel with each other and

individually connected with diode rectifier circuit ,this concept is using behind this assembly .For assembling a device in shoe sole we have designed the assembly in a particular manner described above . The schematic diagram of assembly shown in figure below.



6. Future Scope

Vibrational energy is abundant source of energy and has promising field of applications in automotive, aviation, roads, railways, public joints, etc. Our future work would involve in making harvester units which can be easily installed at such areas. Researchers are also working on a project to maximize energy harvesting on a spacecraft of the future. The research will look at how mechanical energy generated by the vibration of the aircraft's wings can be transferred, stored, and used to support the communications systems. The inventiveness seeks to discover energy-saving and – maximizing solutions to allow eco-friendly solutions for different areas of work. Additional work will be conducted into categorizing the long term effects of charge amendment techniques in the lead, the uniqueness of piezoelectric energy harvesters as well as further developing an ultra-low-power FRTZ circuit configuration.

7. Conclusion

Vibrational energy source have less energy but change in future piezo material technology can harvest more energy. This amount of energy can be critical in powering various sensors and small electronics to work for longer durations but the idea of integrating piezo device in shoe sole will be promising for microcells, portable devices and wireless technology. We hope the idea of technology will help in future progress and researches.

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