Footstep Power Generation using Piezo Ceramic

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***Abstract*—** People move all the time. Wouldn't it be great to harness that movement and help to power our cities with the movement of people living in them? Piezoelectric harvesting is one of the most reliable and energy efficient method. The crystalline structure of piezoelectric material provides the ability to transform mechanical strain energy into electrical energy. The power generated by piezo is D.C signal with A.C ripples, which is not used directly for battery charging so hence we use rectifier and filter to get pure D.C signal. Further boost converter circuit is used to step up the D.C signal and through battery charger circuit, battery is charged. This charge can be used to drive the a.c loads by converting D.C signal to A.C with help of inverter circuit.

***Keywords*—** *piezo , piezoelectricity ,inverter, PZT 2N3055*

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I. INTRODUCTION

Rapidly increasing demand and improper use of electricity has made important to search for energy harvesting methods even lot of energy resources have been exhausted and wasted. Modern technologies need a huge amount of electrical power for its various operations. So ultimate solution to deal with this sort of problem is energy harvesting from wasted energy of foot power with the human locomotion. This technology is based on the principle called 'piezoelectric effect' in which certain materials have ability to build up electric charge from pressure and strain applied to them. The piezo electric crystals convert the mechanical vibrations into electrical energy.

II. BLOCK DIAGRAM

This project will focus on the concept of providing sufficient electricity to people living in rural areas by using quick and efficient source. Basically our aim is to make a cost effective product which can be easily used in various application.

2.1 Block diagram of footstep generation

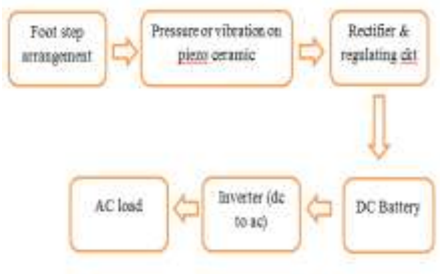

Fig.2.1 B.D of Footstep generation

2.2 Explanation:

In footstep arrangement section, Piezo electric ceramic are connected in series-parallel manner. As the step is pressed, pressure is applied on the Piezo ceramic and an electrical charge (Piezo electric charge) is generated, this electric charge is in dc with ac ripples, so to get pure dc voltage an electric charge generated by ceramic is applied to bridge rectifier. Then this dc is applied to 7805 IC, o/p of 7805 is 5V which is applied to 12vdc battery.

The voltage stored in dc battery is then applied to inverter section. So now by using inverter dc voltage is inverted to ac voltage and by using step-up transformer 12v DC is then amplified to 220vAC. Hence, AC load can be driven.

III. DESIGN AND IMPLEMENTATION

This project will focus on the concept of providing sufficient electricity to people living in rural areas by using quick and efficient source. Our motivation is twofold. First is to attempt and design a functional circuit that also has practical applications to the consumer and secondly to make a cost effective product which can be easily used in various application.

3.1 Piezo Crystal

A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure ,vibration ,strain or force by converting them to an electrical charge ;The word 'Piezo' is Greek for 'Press' or 'Squeeze'. A piezoelectric crystal / sensor is an active sensor and it doesn't need help of an external power as it is self-generating.

Piezoelectric effect was in 1880. The charge produced can be called as piezoelectricity. Piezoelectricity can be defined as electrical polarization produced by mechanical strain or certain class of crystal. Examples of ceramic which exhibit the

Piezoelectric effect are lead-zirconate ,titanate(PZT), lead-titanate(PbtiO2),Lead-zirconate (PbZrO3) and barium-titanate (BaTiO3).To date the commonly used piezoelectric ceramic is PZT mainly because it has very high electromechanical coupling ability.[1]

Fig.3.1 Piezo ceramic

The piezoelectric crystal bends in different ways at different frequencies. This bending is called the vibration mode. The crystal can be made into various shapes to achieve different vibration modes. To realize small, cost effective, and high performance products, several modes have been developed to operate over several frequency ranges. These modes allow us to make products working in the low kHz range up to the MHz range. PZT is an extremely brittle material and hence this presents limitations to the strain that it can safely withstand without being damaged.[2]

3.1.1 Electrical Properties

A piezoelectric transducer has very high DC output impedance and can be modeled as a proportional voltage source and filter network.

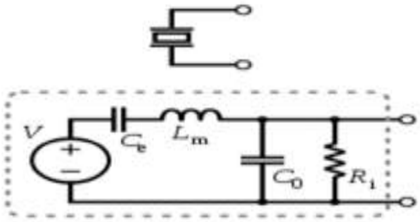

Fig.3.2 Schematic symbol and electronic model of a piezoelectric sensor

The voltage v at the source is directly proportional to the applied force, pressure or strain. The output signal is then related to this mechanical force as if it had passed through the equivalent circuit. We know from study that there are many energy sources such as vibration, wind power strain that it can safely withstand without being damaged and wave power. Also, there can be used to energy harvesting system using smart device like piezoelectric element.[4]

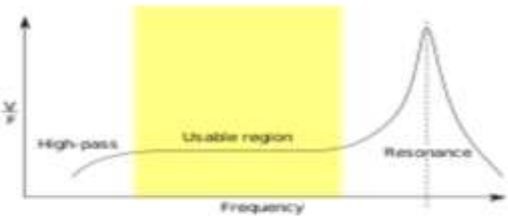

Fig. 3.3 Response Curve

3.1.2 Study Of Connections

Next to determine the kind of connection that gives appreciable voltage and current necessary, four PZT are connected in series. A force sensor and voltmeter is connected to this series combination. As varying forces are applied on this connection, corresponding voltages are noted. Also the voltage generated across the series connection and the current is measured. Similarly the connections are done for parallel and series-parallel connections are done and the graphs are shown in fig.3.4

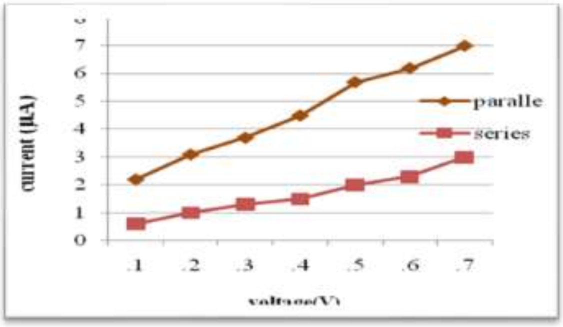

Fig.3.4 Series and Parallel connection

It can be seen from the graph that the voltage from a series connection is good but the current obtained is poor, whereas the current from a parallel connection is good but the voltage is poor. But this problem is rectified in a series- parallel connection where a good voltage as well as current can be obtained as the graph shown in fig.3.5[9]

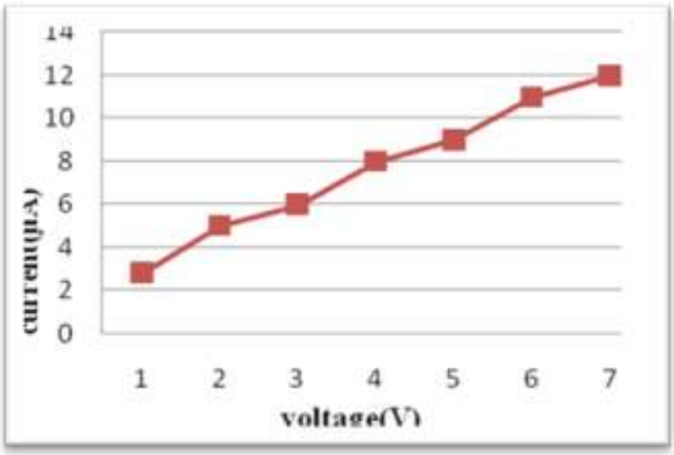

Fig.3.5 Combination of series parallel connection

III.2 Circuit Diagram

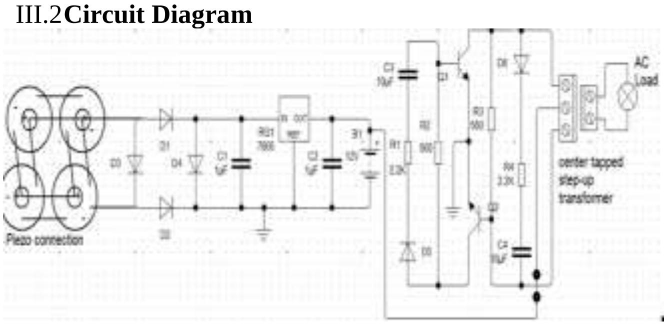

Fig.3.6 Circuit Diagram

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3.2.1 Working:

By applying vibration or pressure on a Piezo sensor, electricity is generated. The electricity generated by Piezo is then applied to a bridge rectifier to remove A.C. ripples and to pass D.C. signal. During this the capacitor C1 is charged and this stored charge is applied to voltage regulator IC, here IC 7805 is 5volt voltage regulator which is responsible to pass 5Vdc constant to further battery.

The DC voltage stored in the battery by Piezo electricity charge is then applied to the inverter section, Q1 will turn on more and some voltage will appear across transformer's primary winding. This in turn induces voltages in the base windings of such polarities that they drive Q1 further into saturation and Q2 into cut-off state. As current flows through Q1 and the half of the primary, magnetic flux in the core increases linearly with time. At some point it will approach saturation when the flux can no further increase. The voltages across all windings will drop to zero and then reverse polarities. This will cause Q2 to conduct and Q1 to be in cut-off condition. This self-oscillating process will continue and a bipolar rectangular voltage will be generated across the output. Its frequency depends on the time required for the core to saturate. The function of an inverter is to invert the D.C. charge to a A.C. this function is done by a push-pull inverter whose output is then applied to the center tapped step-up transformer. Here the transformer primary is supplied with a current from input section (battery) by the pairs of transistors in a push-pull circuit. The transistors are alternately switched on and off, periodically reversing the current in the transformer. Therefore, current is drawn from the line during both the halves of the switching cycle. The input current is supplied by both transistors which are switched on and off, so current is only drawn from the line during the half switching cycle. During the other half the output power is supplied by energy stored in the capacitors. Diodes are used for the protection of transistors.

3.3 Rectifier unit

Rectifier is a circuit which converts A.C into pulsating D.C. Generally semi-conducting diode is used as re citifying element due to its property of conducting current in one direct only. Generally there are two types of rectifier.

1. Half wave rectifier
2. Full wave rectifier

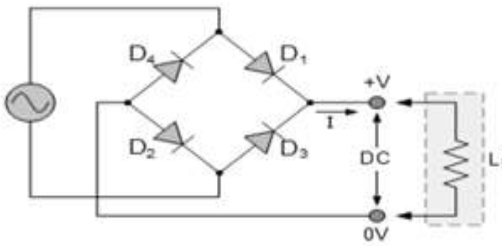

Fig. 3.7 Bridge Rectifier

In half wave rectifier only half cycle is rectified so its efficiency is very poor. So we use full wave bridge type rectifier, in which four diodes are used. In which each half cycle, two diodes conduct at a time and we get maximum efficiency at o/p. Following are the main advantages and disadvantages of a full-wave bridge rectifier.

Advantages:

• The need of center tapped transformer is eliminated.
• The o/p is twice that of center tap circuit for the same secondary voltage.
• The PIV rating of diodes is half of the center tap circuit.

Disadvantages:

• As during each half cycle, two diodes are conducting therefore voltage drop in internal resistance unit will be twice as compared to Center tap circuit.

3.4 Regulator IC 7805

The KA78XX/KA78XXA series of three-terminal positive regulator are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output Current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

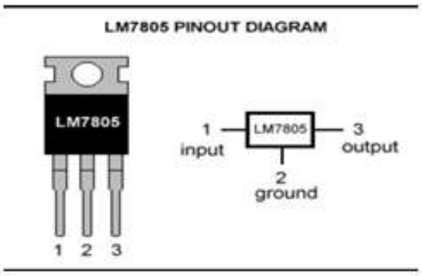

Fig 3.8 LM 7805

Features:

- Output Current up to 1A
- Output Voltages of 5V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

3.5 Battery

With the lack of centralized power grids, lead acid batteries have taken the place of one of the main energy sources available in developing countries. Lead-acid batteries are finding considerable use as both primary and backup power sources. The lead acid battery was invented in 1859 by French physicist Gastron Plante and is the oldest type of rechargeable battery. As they are inexpensive compared to newer technologies. Lead acid batteries are widely used even when surge current us not important and other design could provide higher energy densities. Large format lead-acid designs are widely used for storage in backup power supplies in cellphone towers, high availability settings like hospitals and stand-alone power system. Despite having a very low energy to weight ratio and a low energy to volume ratio, it ability to supply high surge current means that the cells have a relatively large power to weight ratio.

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Fig.3.9 Lead acid Battery

This features along with their low cost makes them attractive for use in motor vehicles to provide the high current required by automobiles starter motors. Replacement, recharging & disposal of batteries present costly challenges.[3]

Features:

- Manufactured/tested using CAD
- Electrolyte volume
- PE Separators
- Protection against leakage

3.6 Inverter

An inverter is an electrical power converter that changes direct current (DC) to alternating current (AC). The input voltage, output voltage, and frequency are dependent on design. Static inverters do not use moving parts in the conversion process. Some applications for inverters include converting high-voltage direct current electric utility line power to AC, and deriving AC from DC power sources such as batteries.

In this project the inverter used is a push-pull inverter. The distinguishing feature of a push-pull inverter is that the transformer primary is supplied with a current from input line by pairs of transistors in a symmetrical push-pull circuit. The transistors are alternately switched on and off, periodically reversing the current in the transformer.

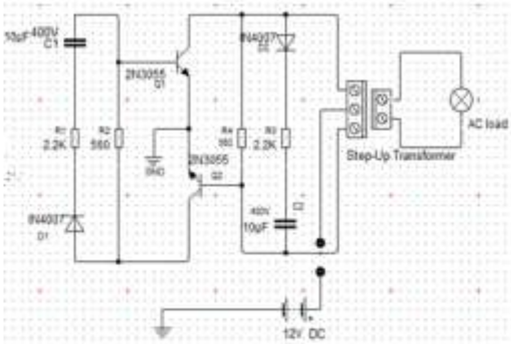

Fig. 3.10 Inverter Circuit

Therefore, current is drawn from the line during both the halves of the switching cycle. The input current is supplied by both transistors which are switched on and off, so current is only drawn from the line during the half switching cycle. During the other half the output power is supplied by energy stored in the capacitors. Diodes are used for the protection of transistors. Push-pull inverters has steadier input current, creates less noise on the input line, and are more efficient in higher power applications.

3.6.1 Transistor 2N3055

It is a silicon NPN power transistor intended for general purpose applications. It was introduced in the early 1960's by RCA. It is a15Amp, 100v, 115W power transistor with a β (forward current gain) of 20-70 at collector current of 4A. It has a transistor frequency of 3.0 MHz; at this frequency the calculated current gain (beta) drops to 1, indicating the transistor can no longer provide useful amplification in common emitter configuration.

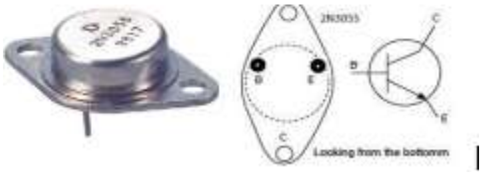

Fig.3.11 Transistor 2N3055

3.6.2 Transformer

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force cross a conductor which is exposed to time varying magnetic fields. Transformer change the voltage level of an A.C electrical supply.sometime transformer makes the o/p voltage bigger than the i/p voltage.

There are 2 types of transformer:
• Step-Up Transformer
• Step-Down Transformer

A. Step-Up Transformer:

A step up transformer act as a voltage increasing device. The amount by which it increases the i/p voltage depends on the ratio of the no. of turns in the primary coil to the no. of turns in the secondary coil.

If, for example, the secondary coil has double the amount of turns as the primary coil, the ratio will be 1:2 and the o/p voltage will be double the i/p voltage.

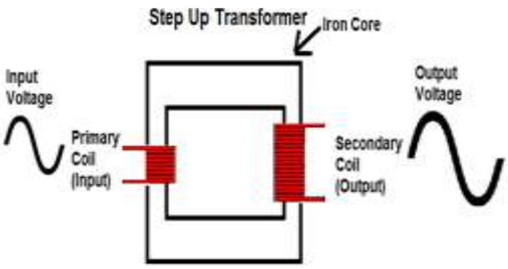

Fig. 3.12 Step-Up transformer

The step up transformers increase the voltage of the o/p voltage, it comes at a price. Transformers are simply conversion devices. They do not create voltage or power.so if a step up transformer increases voltage it decreases current, if it doubles the voltage o/p, the current o/p gets cut in half.so that the o/p signal now has half the current capability as the i/p signal. Step up transformers never create power; they only convert it into different forms.

3.7 AC loads

Anything that uses electricity is referred to as electrical load. There are many types of load: household appliances such as AC bulbs, electronic equipment like lighting and portable devices like cordless drills and cellphones.

A.C electricity is type provided by the local electrical company and is the type most people are familiar with. An electricity is what operates common household appliances and shop tools. To power AC loads in an alternating energy system, you will need either an engine generator or inverter. In our project we have driven 8W CFL Bulb as an AC load.

3.8 Analysis done on the footstep arrangement

People whose weight varied from 35kg to 75kg werw made to walk on the footstep arrangement and thus we got the results that maximum voltage is generated when maximum weight/force is applied.

IV. Advantages

- Easily affordable.
- Self-generating so no need of external source.
- Simple to use with small dimensions.
- Simple implementation.
- Compact
- Highly reliable

V. Applications:

A Piezo electric system can be constructed for virtual any application for which any other type of electromechanical transducer can be used.
They are categorized as-piezo generators, sensors, Piezo actuator and transducer.
Piezoelectric Generators: used as igniters in fuel lighters, gas stoves, welding equipment's.
Piezoelectric Transducer: Used to generate ultrasonic vibrations for cleaning, atomizing liquids, drilling or milling ceramics, medical diagnostic.
Other applications can be:

- Stair case
- Footpath
- Speed breaker
- Dancing floor
- Home application

VI. CONCLUSION

India is a developing country where energy management is a big challenge for huge population. This project power generation using foot step is successfully tested and it provides the affordable energy solution. By using this project we can drive A.C as well D.C load.

VII. FUTURE SCOPE

The research in the international community at this point is finding ways of introducing these materials into Nano scale devices, which would become able to power up cell phone, MP3 digital music players, and even biomedical implants.

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