Micro Energy Harvesting Using Piezoelectric Material

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Abstract - *The increase in energy consumption of portable electronic devices and the concept of harvesting renewable energy in human surrounding arouses a renewed interest. This project focuses on one such advanced method of energy harvesting using piezoelectric material. The process of acquiring the energy surrounding a system and converting it into usable electrical energy is termed POWER HARVESTING. Mechanical energy is one of the most ubiquitous energies that can be reused in our surroundings. Mechanical waste energies usually can be harvested by using vibration-to-electricity conversion. This project describes the use of PIEZOELECTRIC MATERIAL in order to harvest energy from mechanical vibration, mechanical stress and strain energy, human body which can generate milliwatt or microwatt level power. Piezoelectric material are excellent power generation devices in which, when a piezoelectric material is strained it produces an electric field; therefore, piezoelectric material can convert ambient vibration into electrical power. Piezoelectric materials have a vast application in real fields.*

Keywords – Piezoelectric, Power generation, Vibration, Mechanical stress, Human body motion.

1. INTRODUCTION

In last few years low power electronic devices have been increased rapidly. With the increase in energy consumption of these portable electronic devices, the concept of harvesting alternative renewable energy arises a new interest among us. Thus new power generation techniques are required for the next generation devices because of their ability to couple mechanical and electrical properties [1].

This project describes the use of piezoelectric material in order to harvest energy from mechanical vibration, mechanical stress and strain energy, human body motion which can generate milliwatt or microwatt level power. The concept of capturing the lost energy surrounding a system from vibrating sources in the environment is pervasive and accessible, found in places such as automobile engines, rotating equipment, and the human body, in all instances translating vibration into electrical energy via the deformation of a piezoelectric material. Harvesting this energy is one of the most promising techniques owing to the high energy density. Piezoelectric materials have a crystalline structure that provides a unique ability to convert an applied strain into an electrical current and vice versa [2]. Piezoelectric material are excellent power generation devices in which, when a piezo is strained it produces an electric field; therefore, piezoelectric material can convert ambient vibration into electrical power. Piezoelectric materials have a vast application in real fields. Some of the latest applications are mentioned below. Currently, there is a need to utilize alternative forms of energy at passenger terminals like airports and railways across the world. Cleaner, more sustainable forms of electrical power are needed in order to keep costs lower, to maintain positive and productive relationships with neighbours and to insure a healthier environment for future generations [1]. The use of piezoelectric devices installed in terminals will enable the capturing of kinetic energy from foot traffic. This energy can then be used to offset some of the power coming from the main grid. Such a source of power can then be used to operate lighting systems.

2. PIEZOELECTRIC EFFECT

An unique property of the material which has the ability to convert mechanical energy to electrical energy i.e vibration to electricity.This effect is naturally found in Quartz but compared to this the energy harvesting is more advantageous in Lead Zirconate Titanate(PZT). This effect makes them excellent power generators.

This mechanism of producing electricity from these piezoelectric material is called Piezoelectric Effect.

There are two Piezoelectric Effects:
1.Direct Effect
2.Converse Effect.

1.DIRECT EFFECT - The direct effect (designated as a generator) is identified with the phenomenon whereby electrical charge (polarization) is generated from a mechanical stress. It is the property of the material to develop electric charge on the material when mechanical stress is applied on it.

Ex: found in gas lighters, PE sensors like acceleration sensors, pressure sensors.

2. CONVERSE EFFECT – The converse effect (designated as a motor) is associated with the mechanical movement generated by the application of an electrical field. It is the property of the material to develop mechanical stress when an electric charge is induced.

Ex: Buzzers, PE actuators used for micro positioning also rely on inverse piezoelectric effect.

Therefore, piezoelectric energy harvesting is to use the direct effect (generator)[3-4].

3. BLOCK DIAGRAM

A Piezoelectric material when strained produces electricity i.e the mechanical vibration, pressure applied on the material is converted into electricity. Therefore these crystals are connected in series in order to increase the voltage and connected in parallel to increase the current so as to meet the required generation of electricity.

The output of Piezo is AC which is converted into DC using a Bridge rectifier, and then this is stored in a Storage capacitor. Storage capacitor is connected to battery via Charge switching relay. The charge controller prevents over-charging and also protects against over voltages. The controller stops charging the battery when it exceeds a set high voltage limit i.e 14.2V and re-enable charging when the battery voltage drops back to 11.2V. To avoid the battery from over-charging, battery high cut off relay is used. Similarly to avoid the battery from deep-discharge low cut off relay is used. For this relay to operate, a Relay driver circuit is used (ULN2003), which acts as a current amplifier.

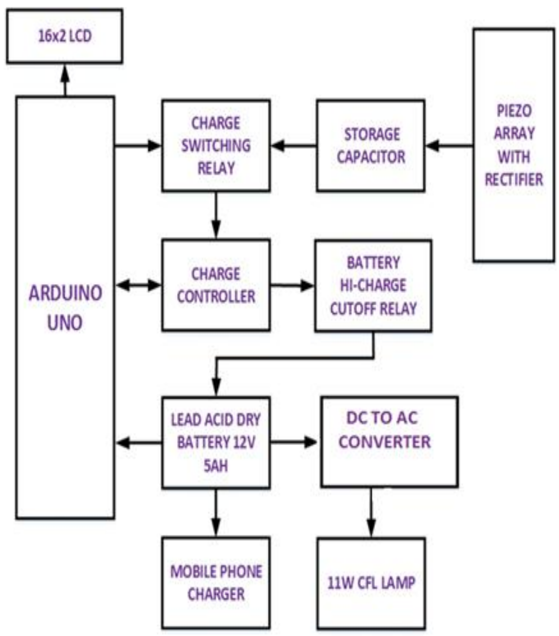

Fig-1: Block Diagram

From the Relay Driver circuit the output voltage is stored in a two Lead acid battery of 6V, 5Ah connected in series. This is used because it's cheaper, easily disposable, long life it doesn't require maintenance. The stored voltage in the battery is used to power both AC and DC load. The DC load used here is mobile charger.

For powering an AC load of 3-13W bulb, the DC voltage of 12V is converted to 12V AC by generating a frequency of 50Hz using RLC network. Now this 12V AC is stepped up to 220V AC using Step-Up Transformer and the ripples are filtered.

The power supply to the Arduino board is the power generated by the Piezo array itself and this input voltage to the Arduino board is of 5V. To supply this 5V, a Voltage Divider circuit is used, which is designed to a ratio of 1:10 which supplies a voltage of 5V to Arduino. Similarly the Voltage Regulator 7805 supplies a constant voltage of 5V to LCD.

For monitoring the voltage level of Piezo array and the battery status, a program is written using the language Sketch in which the LCD displays the voltage levels of battery and Piezo array. Switches are used to turn ON and OFF the Loads.

4. COMPONENTS USED

1. Piezo material-PZT
2. Arduino Uno
3. LCD – 16x2
4. Voltage Divider
5. Battery – Lead acid, 2-6V, 6Ah
6. Voltage Regulator – IC 7805
7. Relay Driver-ULN2003
8. Relay – SPDT
9. Load – 13W Bulb, 5V Mobile charger

5. PIEZO CONFIGURATION

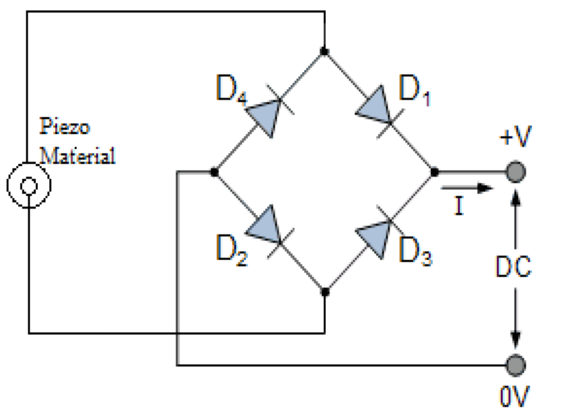

Fig-2: Circuit Diagram of Each Piezo

Fig-3: Bridge rectifier connection to Piezo

The output of Piezo is AC which is converted into DC using a Bridge rectifier, [5] here we have used four 1n4148 diodes of each 100mA capacity to make bridge rectifier. The voltage obtained from this one piezo connection is around 1.1-2.8V .

Since one piezo generates a voltage of 2.5volts, five such piezo's are connected in series as shown in Fig-4 to increase the voltage upto 12.5volts and 20milliA of current. Further in order to increase the current three such series connected piezo array is connected in parallel to form a bank of piezo array as shown in Fig-5 which generates a current of 60milliA.

Fig-4: Series connection of Piezo

Two such banks of piezo array are made and connected in parallel which generates a voltage of 12.5volts and 120milliA of current as shown in Fig-6 across these two parallely connected banks a capacitor of capacitance 22microF is connected for temporary storage purpose and later from this the battery is charged.

Fig-5: Bank 1 of piezo array

Fig-6: Parallel connection of two banks

6. CALCULATION FOR NUMBER OF PIEZO REQUIRED

- One Piezo generates 2.8V and 20mA.
- If 5 such Piezo's are connected in series then voltage developed is =2.8*5 =14V(20mA)
- To increase the current value, 5 series connected Piezo's has to be connected in parallel.
- Therefore 6 such parallel connections has to be done

I=6*20m
=120Ma

Total number of Piezo material required is 6*5=30 crystals

7. TESTED RESULTS AND OUTPUT

In a 370mm*200mm mat we used 30 Piezo's. As the voltage developed by Piezo varies with the pressure applied, minimum and maximum voltages obtained are as follows.
generate a voltage of 13.56V in time span Minimum voltage developed = 1.1V per Step.
Maximum voltage developed = 2.8V per Step.
We took an average weight of 60Kg's pressure from a single person, the output voltage developed are as shown in the calculation below
Calculation:

Voltage developed = Voltage per Step * No. of Steps
= 1.13 * 12
= 13.56V

Therefore it took 12 Steps to of 10.46 seconds. The above procedure was repeated for different load values and the readings are as shown in the table below,

Table-1: Tested results for different load values

Load	11KΩ	22KΩ	44KΩ
Voltage in V	13.6	13.6	13.6
Charging time in sec	10.46	9.42	13
Discharging time in sec	4.88	7.95	13.95
No of steps	12	12	15

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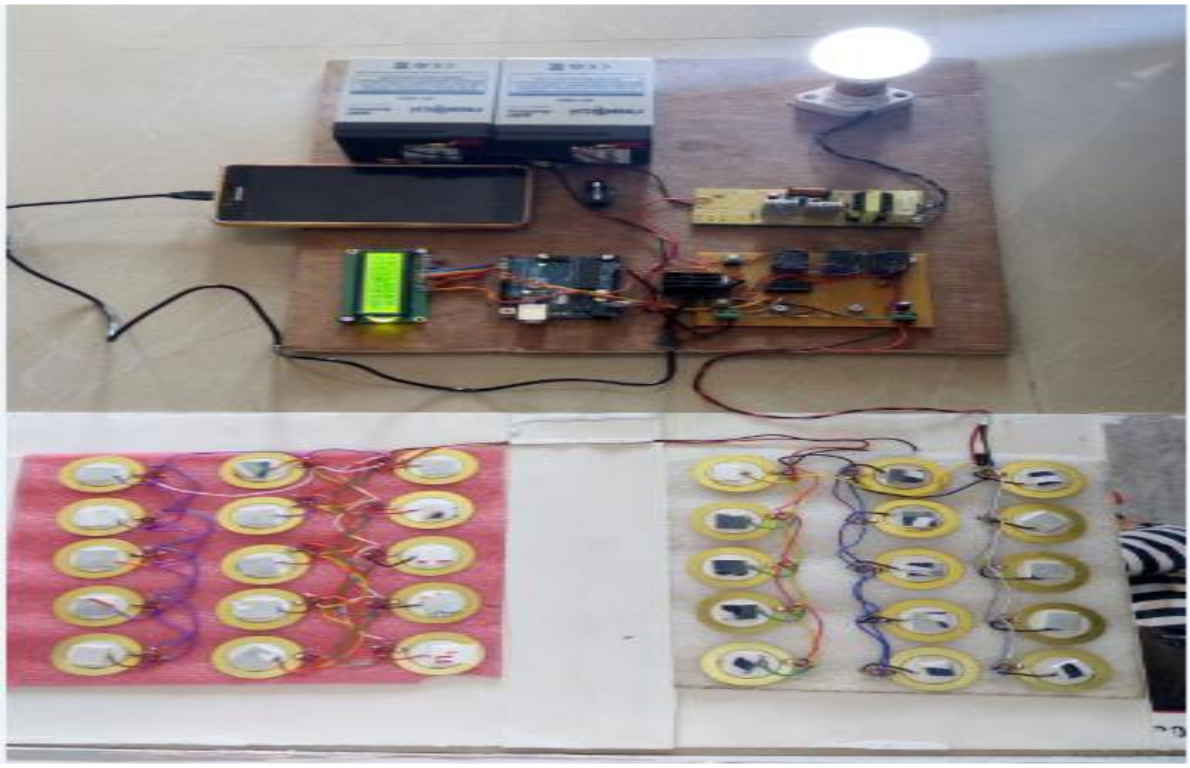

Fig-7 : Complete setup of Project

8. ADVANTAGES

1. This is a green solution for power generation.
2. Piezoelectric material can be made in any desired shape and form.
3. It has no moving parts, hence long service life.
4. Ultra low noise.
5. Easy replacement of equipment.
6. Cost efficient.

9. DISADVANTAGES

1. Piezoelectric crystal is prone to crack if overstressed.
2. Change in Humidity affects the output power generated.
3. May get affected by long use at high temperature.

10. CONCLUSION

In this paper a model for energy harvesting system using Piezoelectric materials have been presented. Piezoelectrics are smart materials that can be used to harvest energy from dynamic vibrational sources. It is evident that harnessing energy through Piezoelectric materials provides a cleaner way of powering lighting systems and other equipment or stored for later use. It is a new approach to lead the world into implementing greener technologies that are aimed at protecting the environment. Piezoelectric energy harvesting systems are a onetime installment and they require very less maintenance, making them cost efficient. Further experimentation has to be carried out for its implementation on a larger scale, with an efficient interface circuit at a low cost in universities. Research is being conducted to enhance current piezoelectric materials and to develop new materials.

The project **"Micro Energy Harvesting Using Piezoelectric Material"** is successfully tested and implemented which is the best economical, affordable energy solution to common people.

This can be used for many applications in rural areas where power availability is less or totally absence As India is a developing country where energy management is a big challenge for huge population. By using this project we can drive both A.C. as well as D.C loads according to the force we apply on the Piezolectric sensor.

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