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ENERGY HARVESTING USING PIEZOELECTRIC EFFECT AND ITS PRACTICAL APPLICATIONS: AN EXPERIMENTAL APPROACH

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Abstract: Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanicalstress.The word Piezoelectric is derived from the Greek piezein, which means to squeeze or press, and piezo, which is Greek for "push".
Was discovered by Paul-Jacques Curie and Pierre Curie experimentally in 1880.
Whereas Piezoelectricity is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. And in this paper, we shall study how we can harness electricity through it, and output of energy harvestor

Keywords: piezoelectricity, piezoelectric ceramics, causes of piezoelectricity, application, and experimental approach

I. INTRODUCTION

As in today scenario where climate of earth is rapidly increasing and has increase on an average of 2 degree Celsius. There is a need for alternative fuels and ways to harness electricity, energy for human needs as the main cause of this climate change is rapid burning of fossil fuels which is the main source of energy on earth.
Moreover, at present pace of using the fossil fuel they will run out in near future.
So, as an alternative of this we will research about as alternative method of harvesting electricity using piezoelectric

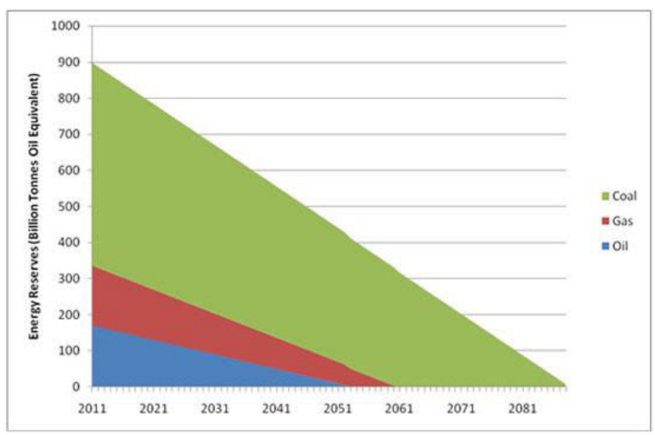

Figure 1Graph showing future energy reserves for coal, gas,[1]

For this first we must study about the material which possess piezoelectric effect which are commonly called as **piezoelectric ceramics,** some are naturally occurring, and some are human made with the advancement of science and technology.

II. PIEZOELECETRIC CERAMICS/MATERIAL

Piezoelectric materials/ceramics are materials that can generate internal electrical charge from applied mechanical stress.

Some of piezoelectric material are

Naturally occurring crystals:

Quartz (A stable crystal used in watch crystals and frequency reference crystals for radio transmitters), **Sucrose** (table sugar), **Rochelle salt**(Produces a large voltage with compression; used in early crystal microphones), **Topaz, Tourmaline**, **Berlinite ($AlPO_4$)**(A rare phosphate mineral structurally identical to quartz.)

Man-made crystals:

Gallium orthophosphate ($GaPO_4$) (a quartz analog), **Langasite ($La_3Ga_5SiO_{14}$)** (a quartz analog),

Piezoelectric ceramics:

Barium titanate ($BaTiO_3$)(The first piezoelectric ceramic discovered), **Lead titanate ($PbTiO_3$)**, **Lead zirconate titanate (PZT)**(Currently the most commonly used piezoelectric ceramic), **Potassium niobate ($KNbO_3$)**, **Lithium niobate ($LiNbO_3$)**,

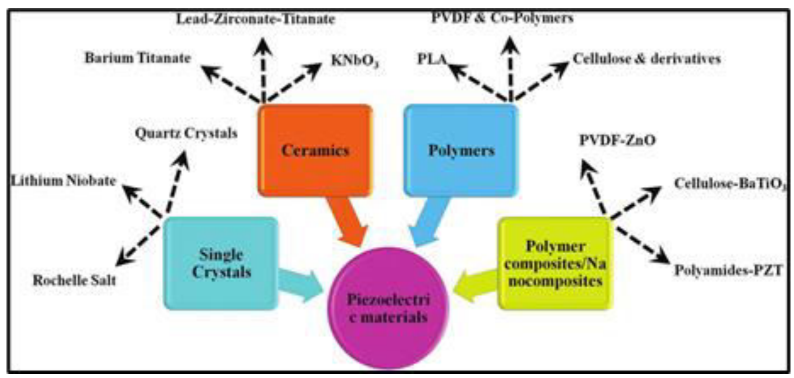

Figure 2piezoelectric material [3]

Lithium tantalate ($LiTaO_3$)**, Sodium tungstate (Na_2WO_4)**

Biological piezoelectric materials:

Tendon, Wood, Silk, Enamel, Dentin, Collagen

Piezoelectric polymers

Piezopolymers are lightweight and small, thus growing in popularity for technological application.[2]

III. WHAT CAUSES PIEZOELECTRICITY?

In most crystals (such as metals), the unit cell (the basic repeating unit) is symmetrical; in piezoelectric crystals, it isn't. Normally, piezoelectric crystals are electrically neutral: the atoms inside them maynot be symmetrically arranged, but their electrical charges are perfectly balanced: a positive charge in one place cancels out a negative charge nearby. However, if you squeeze or stretch a piezoelectric crystal, you deform the structure, pushing some of the atoms closer together or further apart, upsetting the balance of positive

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and negative, and causing net electrical charges to appear. This effect carries through the whole structure so net positive and negative charges appear on opposite, outer faces of the crystal.[4]

Applying mechanical energy to a crystal is called a **direct piezoelectric effect** and works like this:
A piezoelectric crystal is placed between two metal plates. At this point the material is in perfect balance and does not conduct an electric current.

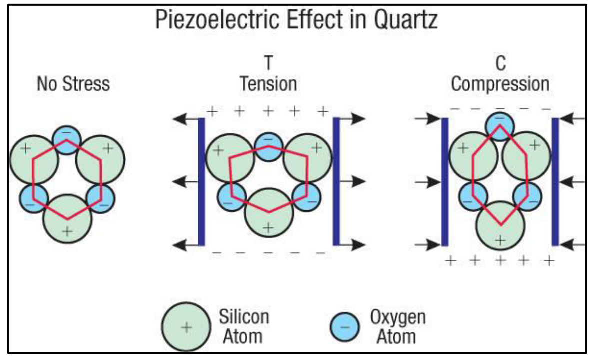

Figure 3 Causes of piezoelectric effect in crystal [5]

1. Mechanical pressure is then applied to the material by the metal plates, which forces the electric charges within the crystal out of balance. Excess negative and positive charges appear on opposite sides of the crystal face.

2. The metal plate collects these charges, which can be used to produce a voltage and send an electrical current through a circuit.[6]

Let us now look about the simple mathematical aspect of piezoelectricity

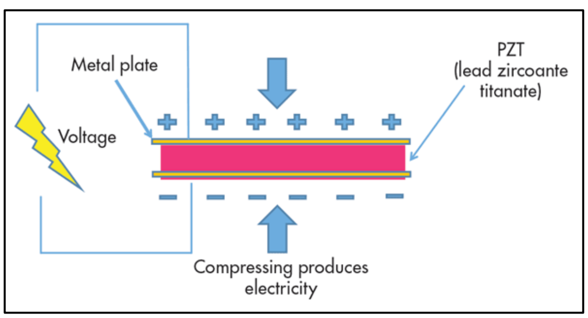

Figure 4 how piezoelectricity generated [7]

When placed under stress, the piezoelectric crystal produces a polarization, *P*, proportional to the stress that produced it.

The **main equation of piezoelectricity is P = d × stress**, where *d* is the piezoelectric coefficient, a factor unique to each type of piezoelectric material. The piezoelectric coefficient for quartz is 3×10^{-12}. The piezoelectric coefficient for lead zirconate titanate (PZT) is 3×10^{-10}.

IV. <u>ENERGY HARVESTING USING PIEZOELECTRIC EFFECT</u>

Typically, an energy harvesting system has three parts

• **Theenergysource**:representstheenergyfromwhichtheelectricalpowerwillbescavenged— this energy can be ambient (available in the ambient environment, e.g., sunlight, ambient heat or wind) or external (energy sources that are explicitly deployed, e.g., lightning, human heat or vibrations)

• **The harvesting mechanism** consists of the structure which converts the ambient energy into electricalenergy.

• **The load**: the sink which consumes or stores the electrical outputenergy. [8]

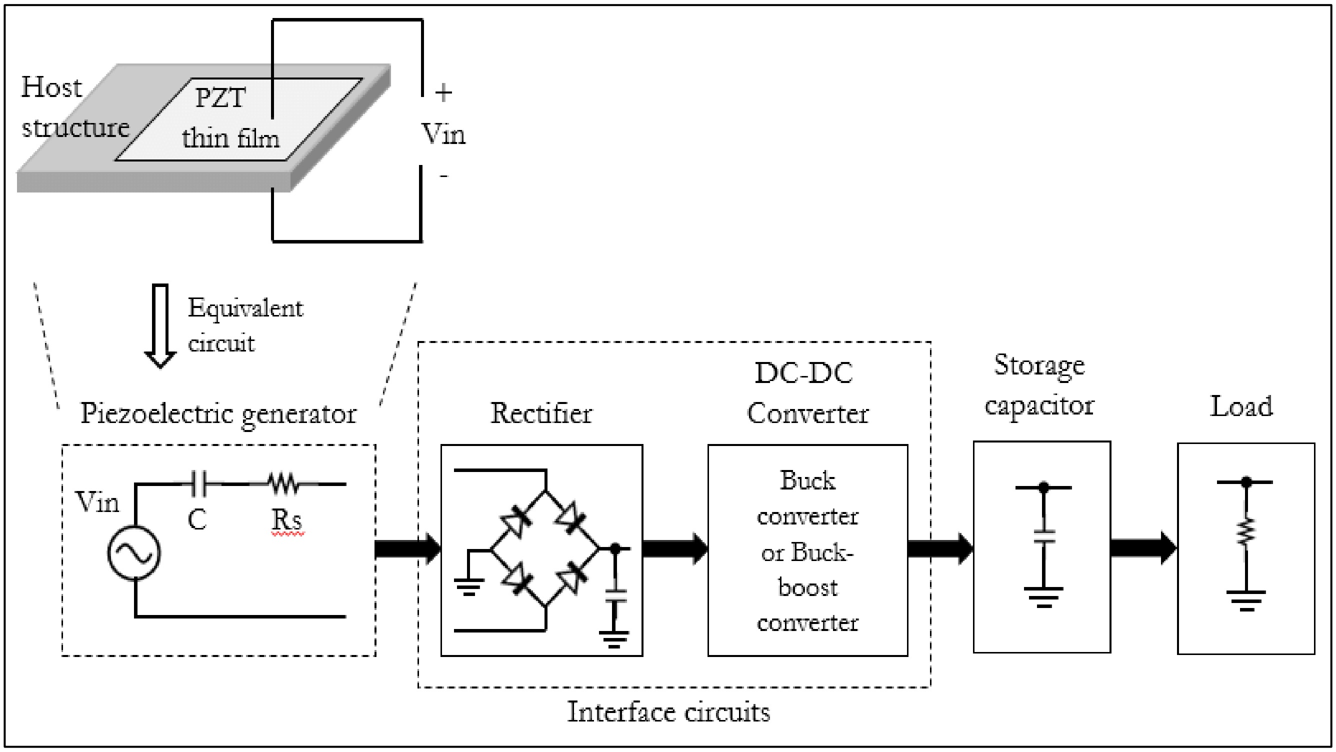

Figure 5 Block diagram of energy harvester using piezoelectric effect [9]

The classic (high efficiency) energy harvester system consists of an **energy generator, capture, storage, management electronics and load** designed to be powered by the harvester, typically a wirelesssensornetwork.Intheblockdiagramaboveapiezoelectriccrystalmembraneisshownas the energygenerator.

1. The piezoelectric generator/ sensor transforms mechanical vibrations, strain, or stress into electrical voltage/current. This mechanical strain can come from many different sources including human motion, bridge or other low-frequency seismic vibrations, aircraft or vessel vibrations and acoustic noise are everyday examples. Theses generator/ sensor are available in various configuration, they are listed below[10]

2. Full-bridge rectifier (**Buck Boost convertor** (the main objective of a buck-boost converter is to receive an input DC voltage and output a different level of DC voltage, either lowering or boosting the voltage as required by the application)) is commonly used as rectifier circuits to convert the AC output of a piezoelectric into a DC voltage. The rectifying circuits consist of 4 diodes. The voltage needs to rectify due to the need for constant supply of voltage light up the series of LED placed inparallel.

3. Step 2 initiates the capture and storage operation. The detector can accept instantaneous input voltages ranging from 0.0V to +/-500Vac and input currents from 200nA to 400mA ineitherasteadystreamofpulsesorintermittentandirregularmannerwithvaryingsource impedances. Early harvester electronics required a minimum of 4V input to capture and store the energy from PZT and other generators. More recent designs feature a front-end voltage booster and claim to initiate capture and energy storage with voltage inputs aslow as100mV.[11]

4. The energy is stored in **super capacitor /Li-on battery,** which when charged get utilize by load

(which can a low energy consumingdevice)

V. OUR EXPERIMENTAL SETUP

HARDWARE USE

1. **PIEZOELECTRIC SENSOR:**
piezoelectric sensor is the energy source of our project.We have use 5 piezoelectric sensors of 27mm diameter of quartz (positive end) with the base of good conductor here copper (negative end). Its operational temperature zone is 20 degree Celsius to 90 degree Celsius.

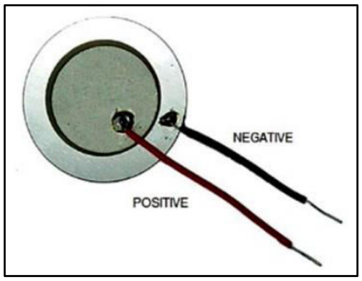

Figure 6 Piezoelectric Sensor [12]

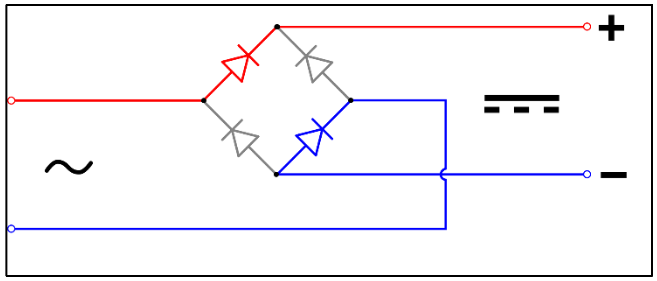

Figure 7 A Bridge Rectifier [13]

2. **BRIDGE RECTIFIER:**
As the output from piezoelectric sensor is alternating current and to get undeflected output we need to rectify the negative part of A.C. For this purpose, we use **Bridge Rectifier.** Which we make using 4 **1N4007 diode.** It will convert A.C from sensor to DC. The output of the bridge rectifier is pulsating DC

3. **BOOST CONVERTOR (XL6009 DC- DC Adjustable Step-Up Boost Power Converter Module):**
XL6009 module is a non-isolated step-up boost voltage converter featuring adjustable output voltage, high efficiency. It converts input voltage of 5-32V DC to an output voltage of 4-38V DC. The main purpose of this convertor is that it is economical to the project and its trusted output.

4. **ELECTROLYTIC CAPACITOR:**
Energy after rectification and boost need to be stored, and for this purpose we use an electrolytic **capacitor (rating: 2200uf 25v).** The main purpose of using electrolytic capacitor is due to its cost and its large capacity.It has two terminals in which the longer terminal is the positive one and shorter one is the negative terminal.

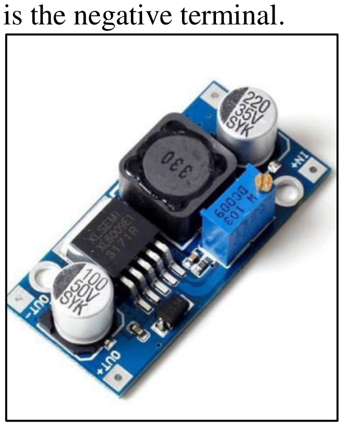
Figure 8 Boost convertor [14]

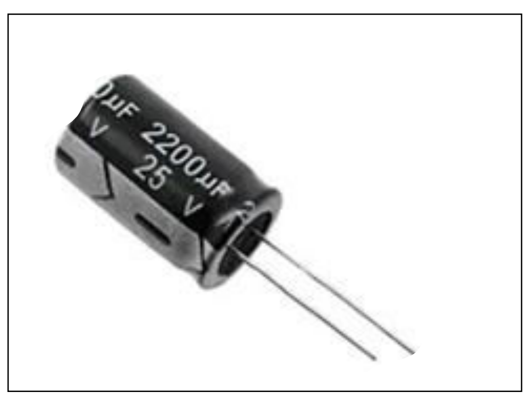

Figure 9 An electrolytic capacitor [15]

Figure 10Photograph of setup

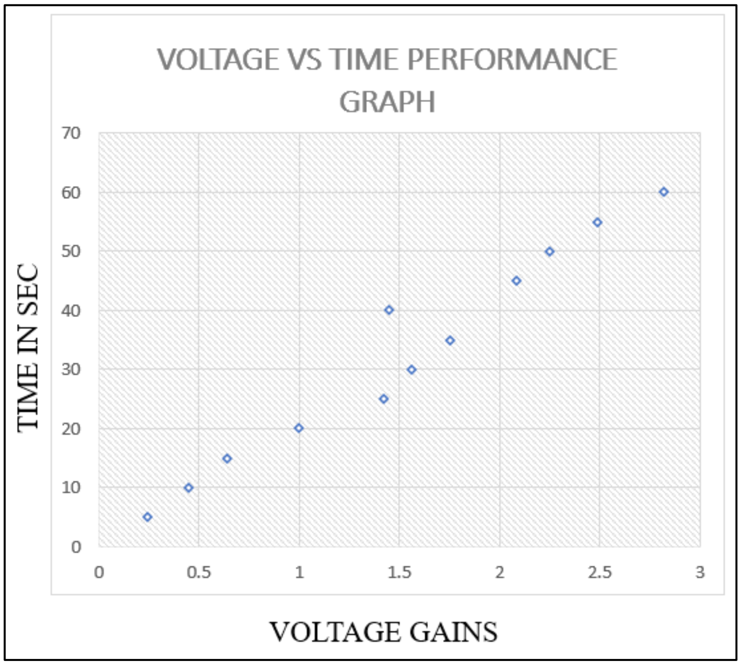

Figure 11 GRAPH SHOWING VOLTAGE GAIN BY CAPACITOR

OBSERVATION FROM PROJECT

- The rate of charging a electrolytic capacitor is not uniform in case of this piezoelectric experiment rather it depends on the amount of force the sensors are push.
- It takes on an average 7 mins to fully charge 25v capacitor
- The table showing the charging rate for 1 min with interval of 5 sec

VI. CIRCUIT DIAGRAM OF PROJECT

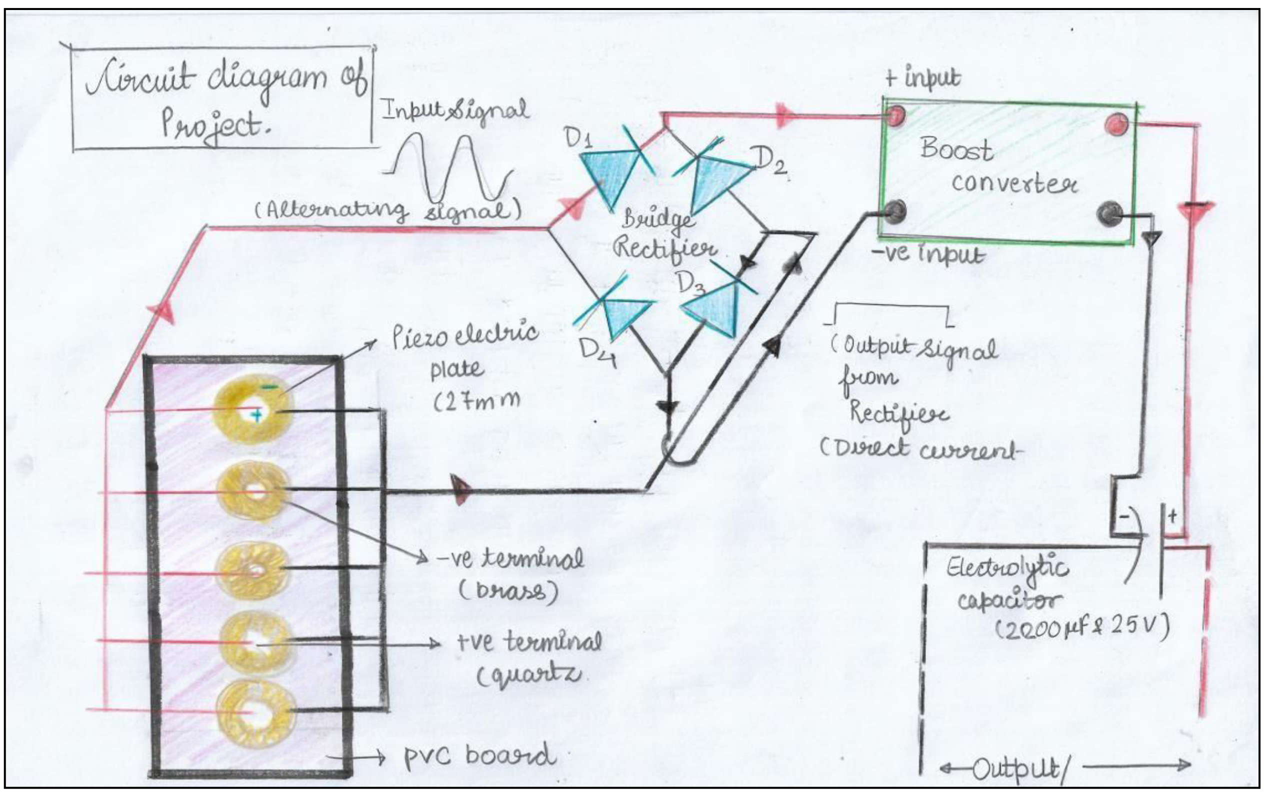

Figure 12 Circuit diagram of project

VII. APPLICATION OF PIEZOELECTRIC EFFECT

- harvesting electricity is the one of the major applications of piezoelectric effect.
- MEMS devices have become more commonplace as more integrated capabilities are required in smaller packages, such as cell phones, tablet computers, etc. The advantage of MEMS devices is that gyroscopes, accelerometers, and inertial measuring devices can be integrated into chip-sized packages. To accomplish such a feat, piezoelectric actuators and sensors are often used.
- In the field of small robotics, small power-efficient mechanical actuators and sensors are needed. With the use of piezoelectric actuators, building something as small as a robotic fly that can crawl, and fly is technically feasible.
- Many acoustic-electric stringed instruments utilize piezoelectric pickups to convert acoustic vibrations to electric signals.
- Some microphones (such as contact microphones for percussion instruments) use piezoelectric materials to convert sound vibrations to an electrical output.
- This is, perhaps, the most well-known and ubiquitous use of piezoelectricity. In a piezoelectric ignitor, a button or trigger is used to cock and release a spring-loaded hammer, and the hammer is used to strike a rod-shaped piezoelectric ceramic.
- Piezoelectric speakers are featured in virtually every application that needs to efficiently produce sound from a small electronic gadget. These types of speakers are usually inexpensive and require little power to produce relatively large sound volumes.
- Piezoelectric buzzers are like piezoelectric speakers, but they are usually designed with lower fidelity to produce a louder volume over a narrower frequency range.[16]

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