

Staircase Power Generation Using Piezo-Electric Transducers

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Abstract:

With the decrease in energy consumption of portable electronic devices, the concept of harvesting renewable energy in human surrounding arouses a renewed interest. In this context, we are proposing the prototype of a piezoelectric generator that harvests mechanical vibrations energy available on a Staircase. Embarked piezoelectric transducer, which is an electromechanical converter, undergoes mechanical vibrations therefore produce electricity. A static converter transforms the electrical energy in a suitable form to the targeted lighting application.

Index Terms: Mechanical vibrations, Energy harvesting, piezoelectric material, Uninterrupted power supplies, lighting applications.

1. Introduction

Due to soaring energy prices and an increased environmental awareness there is a growing need for sustainable designs. The world around us has embraced this concept by incorporating solar panels, wind turbines, and promoting shared transportation via zip cars. Instead of looking for new ways to generate energy, we will be focusing on harvesting energy from everyday activities that would otherwise be lost. A person exerts lots of force when they walk down the stairs. The staircase power harvesting system intends to turn this energy into electrical power using a piezo-electric generator.

In this study, which is a first in the literature, we propose an alternative solution to the dynamo and an improvement for the battery lifetime. We are proposing the use of

piezoelectric generator, which is a clean and durable solution. Piezoelectric generators employ active materials that generate a charge when mechanically activated.

Today we see more and more applications using piezoelectric transducers. Their use as a source of electrical energy presents increasing interest for embarked electronic devices, low power consumption (less than 1 Watt) such as lamps based LED (Light-Emitting Diode), displays or sensors [1,2].

Noticing that the stairs vibrate when someone steps on it, and that 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 [1,2,3], such as piezoelectric materials. The electrical energy thus produced can be used to power the lightings available for the stairs.

1.1 Objective

We plan to capture energy from the everyday motion of people traveling up and down a staircase. We can modify a normal stair tread to move a small distance and the vibrational energy will be converted to electrical energy using Piezo-electric Generator. From there, the energy will be stored in a battery for future use. Our main goal is to harvest as much energy as possible, without compromising the reliability and safety of tradition stairs.

2. Overview

2.1 Design Objectives

i) Moving Stair Tread:

This is the physical staircase that users will step on. There will be a moving stair tread which rebounds to its raised position via several springs under the moving tread plate. The tread plate will be hinged in the back to restrict the tread to one degree of motion. The tread will be limited in its vertical travel to about a half inch. We will be able to adjust the vertical travel of the stair via screw with an adjustable wing nut.

ii) Piezo-Electric Material:

The Piezo-electric material palced in the gap between the tread plate and the base is used to convert the mechanical energy (Vibrations) into electrical energy with the Piezo-electric generator.

iii) LED or other Lightings:

The Electrical energy thus produced is used to power the LED's in the stairs or the other lightings for the surroundings depending upon the amount of power produced.

2.2 Overview of Application

The stair thread can be easily modeled with minimum labour. But care must be taken to look into the characteristics of the piezo-electric material used.

The conversion of mechanical energy into electrical one is generally achieved by converters alternator type or commonly known dynamo.

The piezoelectric effect exists in two domains; the first is the direct piezoelectric effect that describes the material's ability to transform mechanical strain into electrical charge, the second form is the converse effect, which is the ability to convert an applied electrical potential into mechanical strain energy

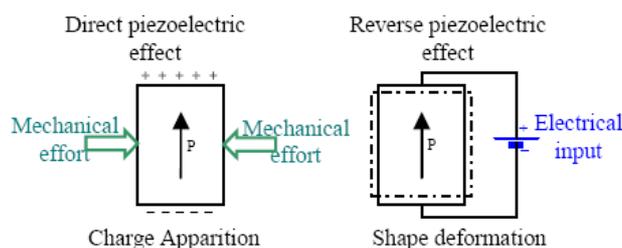


Fig. 1. Electromechanical conversion via piezoelectricity phenomenon

The direct piezoelectric effect is responsible for the materials ability to function as a sensor and the converse piezoelectric effect is accountable for its ability to function as an actuator. A material is deemed piezoelectric when it has this ability to transform electrical energy into mechanical strain energy, and the likewise transform mechanical strain energy into electrical charge.

The piezoelectric materials that exist naturally as quartz were not interesting properties for the production of electricity, however artificial piezoelectric materials such as PZT (Lead Zirconate Titanate) present advantageous characteristics.

Piezoelectric materials belong to a larger class of materials called ferroelectrics. One of the defining traits of a ferroelectric material is that the molecular structure is oriented such that the material exhibits a local charge separation, known as an electric dipole.

Throughout the artificial piezoelectric material composition the electric dipoles are orientated randomly, but when a very strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed poling.

Once the electric field is extinguished, the dipoles maintain their orientation and the material is then said to be poled. After the poling process is completed, the material will exhibit the piezoelectric effect.

3. Detailed Description

3.1 Architecture

When the material is deformed or stressed an electric voltage can be recovered along any surface of the material (via electrodes). Therefore, the piezoelectric properties

must contain a sign convention to facilitate this ability to recover electric potential in three directions.

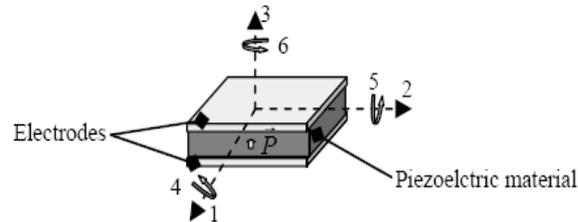


Fig. 2. Defining the lines of a piezoelectric material

The coefficients d_{33} of a piezoelectric bar, (C / N) shown in Table I, link the amount of electrical charge (Coulomb), appearing on an electrode perpendicular to the axis 3, to the strain (Newton) applied on both ends.

Table I: Typical piezoelectric materials coefficients

Material	$d_{33}(10^{-12} \text{ C/N})$
Quartz	2.3
BaTiO ₃	90
PbTiO ₃	120
PZT	560
PZN-9PT	2500

For the PZT, $d_{33} = 560 (10^{-12} \text{ C / N})$ means that 1 N applied strain produces $560 \times 10^{-12} \text{ C}$ electrical charge.

2.3 Piezoelectric Generator Principle

The vibrations energy harvesting principle using piezoelectric materials [4] is illustrated. The conversion chain starts with a mechanical energy source: Staircase. Movement on the stairs produces vibrations and they are converted into electricity via piezoelectric element. The electricity produced is thereafter formatted by a static converter before supplying a storage system or the load (electrical device).

In this study, before developing staircase piezoelectric generator, it was essential to begin with mechanical vibrations sources identification that means carrying out vibrations accelerations and frequencies measurement and analysis. So we have carried out measurement on an experimental Staircase to identify the situation where harvesting more energy is possible. We could then develop a piezoelectric generator adapted to the identified natural mode of vibration of the stair thread.

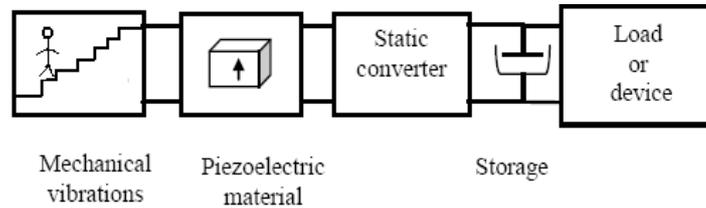


Fig. 3 General diagram of generator based vibrations energy harvesting using piezoelectric material

2.4 Proposed Electrical Design

- The actual circuitry of our device is quite simple. We will rectify the output of the Piezo Electric generator and then send it to a small battery for storage. From here, the energy can be used in any the user desires. It would be ideal to power LED lights which consume small amounts of power.
- For the battery we have chosen to use AAA sized NiMH batteries. They are safe and relatively easy to work with. These batteries will be able to hold a significant amount of energy.
- The batteries can be charged quickly or slowly depending upon the current that is provided to them.

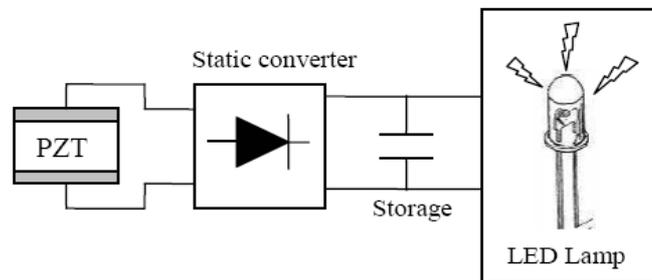


Fig. 6.. LED lamp supply using piezoelectric material

4. Advantages

- Harvest small, but still significant amounts of energy.
- An innovative approach to a device that people use every day.
- No compromise to safety or reliability.
- Marketing and appearance could encourage people to take the stairs instead of energy intensive alternatives such as an elevator or escalator.

4.1 Product Features

- Electricity is generated through stepping on stair tread.
- Stairs tread returns to “up” position via springs.

- Power can be stored for a future use.
- Design will be expandable to several steps and several Piezo-generators per step.
- Cost will be minimal to promote adoption.

5. Future Work

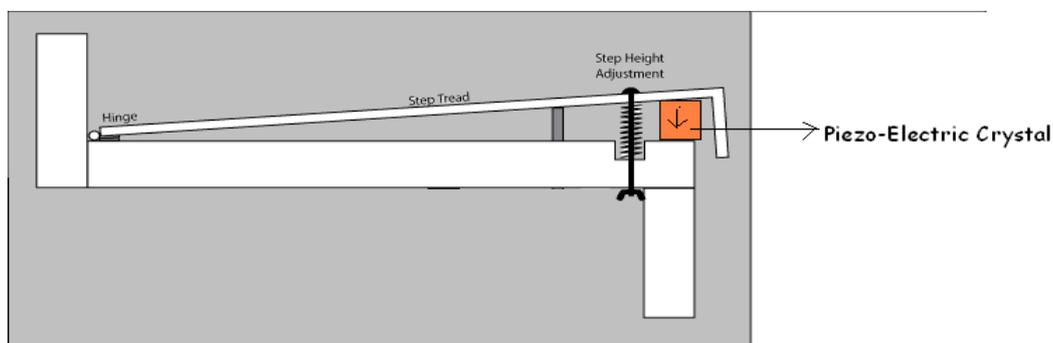
We aim to finish the initial Stage of our design as quickly as possible. This will give us another month to implement some improvements to our project which would expand the scope.

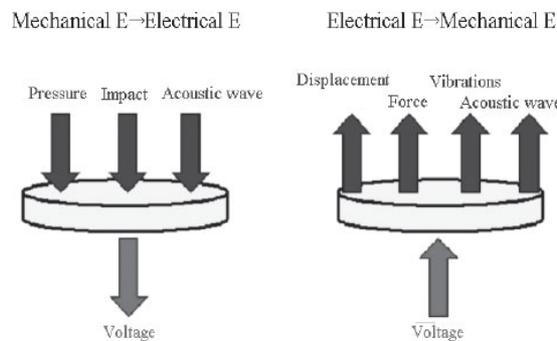
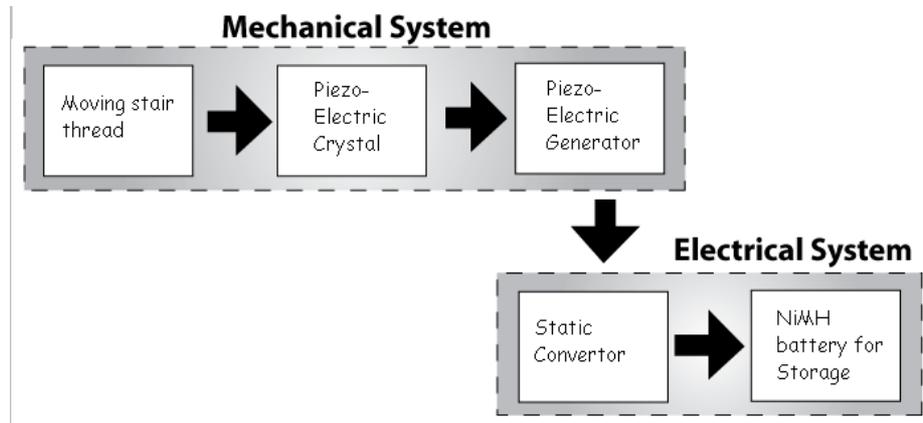
- Stage 2 of the project involves a microcontroller and a lighting system. We will put sensors on the stair steps to get signal of people walking on the stairs. A good way to incorporate the lighting system into the stairs is that when people are walking up or down the stairs, LEDs for the next two or three steps will light up.
- Another marketable system is to put advertisements on the front panel of the stairs and they will light up as people are walking up the stairs. These ideas will be implemented with LEDs as output from the sensors and the microcontroller.
- We also considered making a display that could be placed besides the stairs to inform users how much power they were generating. This would help promote the idea of “Green Design” by showing users that they really were generating energy. For this we would need a small microcontroller and some form of display. We would measure the voltage and current output of the generator.

Cost Analysis:-

The cost of the Piezo-electric generator may come upto Rs.500 and the setup for the staircase was designed by us. The NiMH battery is available in the market for Rs.800 and the other circuits add upto Rs. 500. So the final budget for this project is around Rs. 1800.

Proposed Mechanical Block





Block View

References

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