UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PIEZOELECTRIC ENERGY HARVESTING FLOOR MAT

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor’s Degree of Electronic Engineering Technology (Telecommunication) with Honours

by

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(Project Supervisor)
ABSTRAK

In this era of technology development, the main concern is the need to develop new energy sources. One of the sectors that have attracted much interest is devices that are able to convert other types of energy into electrical energy. The purpose of this "Piezoelectric Energy Harvesting Floor Mat" project is to develop a low-voltage electrical energy based on the concept of green technology. This project also will show that the presence of waste vibration energy might have some value to be used. Systems involved in this project is energy harvesting involves the conversion of dynamic compression of floors by people walking across piezoelectric materials into electrical energy, which exhibit electromechanical coupling between the electrical and mechanical domains. Mechanical vibration energy that results when people walk across received by the piezoelectric will generate a small electric energy, this electric energy also knows as a piezoelectricity and then the electricity will be connected to a voltage doubler circuit having a diode as a rectifier and convert an alternating voltage to a direct current voltage. When there is a direct current voltage, this voltage will be stored in the battery charger circuit which acts as a collector electric energy. Next, the recommendation area for this energy harvester circuit are at pedestrian, and this project had been connected with the traffic light.
ABSTRACT

Pada era zaman Pembangunan Teknologi ini, kebimbangan utama adalah keperluan untuk membangunkan sumber tenaga baru. Salah satu sektor yang telah menarik minat banyak adalah peranti yang dapat menukar jenis tenaga yang lain kepada tenaga elektrik. Tujuan terhasilnya projek "Piezoelectric Energy Harvesting Floor Mat" ialah untuk membangungkan tenaga alternatif elektrik yang bervoltan rendah berdasarkan konsep teknologi hijau. Projek ini juga akan menunjukkan bahawa kehadiran tenaga getaran yang terbuang secara sia-sia mungkin mempunyai beberapa nilai yang dapat digunakan. Sistem yang terlibat bagi projek ini adalah penukaran tenaga yang melibatkan penukaran tenaga getaran mekanikal yang terhasil apabila manusia berjalan kepada tenaga elektrik menggunakan komponen utama piezoelektrik, yang mempamerkan gandingan elektromagnetik iaitu antara domain elektrik dan mekanikal. Tenaga getaran mekanikal yang terhasil apabila manusia berjalan yang diterima oleh piezoelektrik akan menghasilkan tenaga elektrik yang berskala kecil dan seterusnya tenaga elektrik ini akan disambungkan kepada litar pendua voltage yang mempunyai diod sebagai penerus dan menukar voltan ulang alik kepada voltan arus terus. Apabila terdapat voltan arus terus, voltan ini akan disimpan pada litar pengecas bateri yang bertindak sebagai pengumpul tenaga elektrik. Seterusnya, kawasan yang sesuai untuk penuai tenaga ini adalah di kawasan pejalan kaki dan project ini dapat disambungkan dengan lampu isyarat.
Specially dedicated to

My loving parents,

Kamarul Anuar bin Rahillah
and
Noor Huzaini binti Othman

My siblings,

Khairul Hidayat and Nur Afiqah

Who always stay by my side, give inspiration to me and taught me that difficult roads often lead to beautiful destinations.
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CHAPTER 1
INTRODUCTION

1.1 Background of the Project

Nowadays, we are in an era of increasing energy costs and decreasing supplies of fossil fuels, other than that we are also with an emphasis on protecting the environment and creating a renewable source of energy are a sustainable form of having become vital now. This is because the energy is used in our daily life and one of the energies that we use every day is electric energy. Electrical energy is used to power electrical or electronic devices.

Around us, there are a variety of renewable sources for generating new energy sources such as mechanical vibrations produced when people walk across. The vibrations can be generated into electric energy by a piezoelectric device. Piezoelectric devices are implements that use materials exhibiting piezoelectric effects. "Piezo," in Greek, means "pressure," which explains that when you apply pressure to piezoelectric materials, you get an electric energy[1]. It is show that the presence of waste vibration energy might have some value.

The energy that yields from the piezoelectric sensor device is known as piezoelectricity. Piezoelectricity is a form of coupling between the mechanical and the electrical behaviours of ceramics and crystal belonging to certain classes[2]. This piezoelectricity concept is same as an Electromagnetics (EM) meaning which is known as the study of electric and magnetic phenomena.

But there is electric energy that produces by each piezoelectric is only in a few volts, to make this project is an energy harvesting it needs more volts. Voltage doubler circuit had applied to this harvesting energy so that the voltage that had produce is in more voltage. Besides that, battery charger circuit also had applied to
this harvesting energy it is because this battery charge circuit can storage an electric energy that had produced by voltage doubler. To know whether the electric energy from this Piezoelectric Energy Harvesting Floor Mat is enough to power such a small electronic devices, it will be testing to a simple traffic light circuit.

1.2 Problem Statement

In our daily life, thing that we are usually do is walking. Went we walking there are a dynamic compression on every steps we walking. Without we know, this dynamic compression is very useful to use.

A dramatic consumption of energy supply is high demand for the daily uses. So we need to think a renewable energy solution that can be used in the energy generated by the natural environment, ecosystem, humans and animal, which can help to constraints energy source in the future.

Other than that we are also an emphasis on protecting our environment. So, there is a concept that we can develop a new technology of renewable energy based on green technology concept. The goal of this technology is to provide a remote source of electric power and to recharge storage devices, such as batteries and capacitors. The concepts have ecological ramifications in reducing the chemical waste produced by replacing batteries and potential monetary gains by reducing maintenance costs.

In addition, there are many research activities in developing a new energy sources which are renewable, reliable and efficient. Nowadays, there are many countries have show their support towards “green technology” and renewable energy concept. Even for the developing countries such Malaysia, the government had show their support by implementing some rules and laws regarding the environment concept. However, those supports can only be seen as some kind of camping as to realize the concept into the citizen mind.
Beside, the “technology” terms are also not being implemented much as there are not so many products with green technology concept are produced. Therefore, this project is proposing for developing a device that capable for generating low-voltage electric energy and can be renewable.

By developing the “Piezoelectric Energy Harvesting Floor Mat” it utilize the dynamic compression to be applied at the sidewalk and pedestrian for generating electric energy. The electrical energy can be used for powering electrical appliance and facilities such as traffic light. Plus, this project perhaps could be implemented to aid hawkers and stalls especially at the market for their electrical use.

1.3 Objectives

There are three main objectives of this project. These objectives serve as guides and milestones to the project in order to have a clearer view of the target results. The objectives of the project are as follow:

I. To study an alternative electric power source based on green technology concept.
II. To know how piezoelectric can generate electrical energy.
III. To design device that can harvest energy from dynamic compression.

1.4 Scope of the Project

To start implant this project, there are several thing that need to plant which knows as scope. This is because to know the limit of the project, the following below is scope of this project.
The first scope of this project is to produce an energy harvest based on dynamic compression by walking. This mat will absorb dynamic compression energy by using piezoelectric transducer.

Next, voltage doubler had been used to receiver of voltage that piezoelectric transducer has produce. And then, voltage doubler circuit also used to change AC Voltage to DC Voltage and also double the input voltage.

To act this mat as energy harvester, battery charger circuit had applied to this project to store the voltage from voltage doubler circuit. This circuit had charge the battery until 12 DC Volt and at the same time this circuit also is apply the electric energy to switch on LED.

Lastly, this device also can be portable and easy to bring, this is because it can aid hawkers and stalls especially at the market for their electrical use.

1.5 Project Outline

This project outlines will briefly explain about the organization of the report that divided with the several chapters to make more clearly and structured. There will involve with five chapters that involved in Introduction to the Project, Literature Review, Methodology, Expected Result and Conclusion.

Chapter 1 is the Introduction for overall project concepts. This chapter will make clear about the Project Background, Problem Statement, Objectives and lastly the Scope of the project. The important of this chapter is it will be guideline for the whole projects analysis and researches.

Chapter 2 is the Literature Review of the project that covers the previous studies, researches and finding that related to the project. From this chapter the theory and application that discussed use inside researches will be references along the project
process. There are some researches and finding that related to the project be explain in this chapter.

Chapter 3 is the Methodology of the project which presented all the steps, projects flow chart, and block diagram. The projects process show how it works and will be discussed on this chapter. The design of the system will be included in this chapter.

Chapter 4 is the results from both simulation and experiment. The simulation software uses is Multisim to test the circuit. The overall results will be purposed in this chapter. The simulation and calculation result will proceed to the analysis.

Lastly, Chapter 5 is concluded the objectives that stated before. The conclusion is based on the result obtained at Chapter 4. In addition, it also will have discussion and also on recommendation for future work from the researches and result.
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this section, there were an idea and hypotheses about in how the piezoelectric worked to get an electric energy. Other than that, this section additionally will investigate and comparison between the available projects, researches, and studies. Besides that in this section there is also show how piezoelectric elements incorporated with the vibrations created by people walking across it into electric power. Literature review work as the initial process of generating ideas about the projects provides extra understanding and valuable information.

2.2 Energy Harvesting

The expressions of "power harvesting" or "energy scavenging" are likewise used to describe the same process. This process is based on a concept that is the process in which energy is captured from a system's environment and converted into usable electric power.[4] Or in other words, energy harvesting also know as energy that collected from the instrument’s immediate environment, offering perpetual operation with no connection to the grid and minimal or no maintenance requirements.[5]

Based on Figure 1 there are examples of energy source for energy harvesters is present as ambient background and is free. Ambient motion is one of the main sources of energy for harvesting and a wide range of motion-powered energy harvesters. Examples energy source include light (captured by photovoltaic cells),
vibration or pressure (captured by a piezoelectric element), temperature differentials (captured by a thermo-electric generator) radio energy (captured by an antenna); and even biochemically produced energy (such as cells that extract energy from blood sugar).[4]

Figure 1  Energy harvesting uses unconventional sources to power circuitry.[4]

The most common sources of energy available for harvesting are vibration (or motion), light and heat. The transducers for all of these energy sources have three characteristics in common:

- Their electrical output is unregulated and doesn’t lend itself to being used directly for powering electronic circuits
- They may not provide a continuous, uninterrupted source of power
- They generally produce very little average output power, usually in the range of 10µW to 10mW.

These characteristics demand judicious power management if the source is going to be useful in powering wireless sensors or other electronics[6]. Energy harvesting from a natural source where a remote application is deployed, and where such natural energy source is essentially inexhaustible, is an increasingly attractive alternative to inconvenient wall plugs and expensive batteries[5].
Energy harvesting holds great promise for both low-voltage and low-power applications in a wide range of portable or mobile markets such as medical equipment, consumer devices, transportation, industrial controls and military.[7] An energy harvesting system generally includes circuitry to charge an energy storage cell, and manage the power, providing regulation and protection.[4]

Then, energy harvesting can allow electronics equipment to operate when there's no conventional power source, eliminating the need to run wires or make frequent visits to replace batteries. In addition, energy harvesting can be used as an alternative energy source to supplement a primary power source and to enhance the reliability of the overall system and prevent power interruptions.

Besides that, there are another type of energy harvesting that are commonly used which is Photovoltaic Energy Harvesting, Thermoelectric Energy Harvesting and Wind Energy Harvesting. All of this energy harvesting has their unconventional source to produce energy power.

Example of unconventional source for Photovoltaic Energy Harvesting is light, this Energy Harvesting system will operate went Photovoltaic collects light energy from the environment. Photovoltaic is a popular power source for consumer electronic devices, example of electronic device that use this power source including calculators, watches, radios, lanterns and other small battery-charging applications. Figure 2 show the diagram of photovoltaic cell.
2.3 Method Used in Piezoelectric Element

2.3.1 Piezoelectric Energy Harvesting Shoe

A project by Abu Darda’ Bin Mohd Isham had developed a shoe as a efficiency of Energy Harvesting by using piezoelectric. The purpose of this project is to harvest the wasted energy from human walking and store it in battery. The energy inside the battery can be used for travellers in deep forest who needs source of light at night by light up torchlight. Piezoelectric had placed under sole of a shoe to create vibration. Figure 3 had show an example of design a Piezoelectric Energy Harvesting Shoe

![Figure 3 Example of design Piezoelectric Energy Harvesting Shoe](image)

The circuit had contain five piezoelectric, this is because if only use one piezoelectric is not enough to charge two battery 1.5V. Full wavebridge rectifier which contains four schottky diode had used to rectify a electric energy from alternating current(AC) to direct current(DC) that had been produce by piezoelectric. Battery and capacitor had use to act as a charging element.

Went tested had been done to this project it will find that the voltage had reached to 3.2V as a maximum value in 32 times knocked. After 32 times knocked, the voltage will drop until zero as the capacitor was discharging.[8]
2.3.2 Power-Generating Floor

A Demonstration experiment by Japan Railway Company had tested the “Power-generating floor” which is an environmentally friendly system that generates electricity by using the energy from the vibrations created by people walking on the floor. The piezoelectric elements incorporated inside the flooring transform pressure and vibration into electric power.

In Figure 4 had shows that this “Power-generating floor” was installed at the ticket gates of train stations in Tokyo where there is high traffic of people walking. Other than that, this “Power-generating floor” was using the electricity generated to cover a portion of the electrical output for such station facilities as automatic ticket gates and electroluminescence displays.

![Power-generating floor](image)

**Figure 4** “Power-generating floor” was installed at the ticket gates of train stations in Tokyo

Went this “Power-generating floor” was tested in 2 months, it had production of electricity reached a maximum of 10,000 watt-seconds per day (equivalent to the electricity needed to light a 100W light bulb for 100 seconds). [9]
2.3.3 Piezoelectric Bimorph model

As we know, piezoelectric is materials that can be used as a means of transforming ambient vibrations into electrical energy that can be stored and used to power other devices. The energy produced by these materials is too small and directly power to electrical device. However, if the material is use in a large scale and in a collective power as storage, it is shown that the small energy is just a turning point to harvest slightly large electrical energy.

In this paper by Mahmoud Al Ahmad and Amro M. Elshurafa et al, show a method to find the maximum power transfer conditions in bimorph piezoelectric-based harvesters is proposed. This paper show how there had using piezoelectric bender generators. A bending element could be mounted in many ways to produce a generator.

![Figure 5 A two layer piezoelectric material mounted as cantilever](image)

One of the ways is connecting two piezoelectric beams that are separated by a shim which also called the piezoelectric bimorph. Figure 5 shows that a two layer piezoelectric mounted as a cantilever beam with a mass placed on the free end. This type had chosen for two reasons. First, for a given force input, the cantilever configuration results in the highest average strain, and the power output is closely related to the average strain developed in the bender. Piezoelectric also preferred as they efficiently convert mechanical stress or strain to an electrical voltage or charge without any additional power. [10]
2.4 Basic of Piezoelectric

Basically, there are three basic vibration-to-electric energy conversion mechanisms which is electromagnetic, electrostatic and piezoelectric. Piezoelectric are materials that can make power when subjected to a mechanical anxiety. They will likewise work backward, producing a strain by the use of an electric field. Or in other word, piezoelectric is knows as crystals which get a charge when compressed, twisted or distorted are said to be piezoelectric.

The piezoelectric effect exists in two domains, the first is direct piezoelectric effect that describes the material’s ability to transform mechanical strain into electric charge, the second form is the converse effect, which is the ability to convert an electrical potential into mechanical strain energy. There are two types of piezoelectric signals that can be used in technological applications. These two types of piezoelectric signals had show in Figure 6.

![Direct and Converse Piezoelectric Effects](image)

**Figure 6** Direct and Converse Piezoelectric Effects

The direct piezoelectric effect that describes the ability of a given material to transform mechanical strain into electrical signals and the converse effect, which is the ability to convert an applied electrical solicitation into mechanical energy. This direct piezoelectric effect is more suitable for sensor applications, where the converse piezoelectric effect is most of the times required for actuator applications [6]. The piezoelectric materials that exist naturally as quartz, which process properties for the production of electricity in very small quantity, however compare to quartz an artificial piezoelectric materials such as PZT(Lead Zirconate Titanate) present advantage characteristics of generating more electricity[7].