DESIGN AND OPTIMIZATION OF PIEZOELECTRIC ARRAY CONFIGURATION FOR IMPACT BASED ENERGY HARVESTING

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This report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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Specially dedicated to my loving parents and sibling who always stay by my side, give inspiration to me and taught me that difficult roads often lead to beautiful destinations.

ABSTRACT

In this era of technology development, the main concern is the need to identify 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 project is to design a piezoelectric generator with different configurations to get an optimum efficiency of energy conversion from kinetic energy to electrical energy. This project also will show that the presence of waste energy from human foot steps while walking on the floor which is able to transform into useful electrical energy. Systems involved in this project is energy harvesting allows the conversion of dynamic compression of piezoelectric material attached to the floors by people walking on it. However, there is a limitation on the amount of energy harvesting from piezoelectric which needs to be improved on the output power generation. The output power will be compared for each condition where all the piezoelectric strip were connected in parallel and series. The power generated by a piezoceramic is in the form of AC which is not directly used for battery charging, hence a rectifier circuit is designed to convert the AC voltage to DC and generating power which is stored in a capacitor. Then, the energy produced can be utilized to light up some LED miniature or electronic devices.

ABSTRAK

Pada zaman pembangunan teknologi ini, kebimbangan utama adalah keperluan untuk membangunkan sumber tenaga baru. Antara yang telah menarik perhatian adalah peranti yang dapat menukar jenis tenaga yang lain kepada tenaga elektrik. Tujuan projek ini adalah untuk mereka bentuk penjana piezoelektrik dengan konfigurasi yang berbeza untuk mendapatkan kecekapan optimum penukaran tenaga untuk penuaian tenaga. Ia akan menunjukkan bahawa kehadiran tenaga getaran yang terbuang secara sia-sia mempunyai beberapa nilai yang dapat digunakan. Sistem yang terlibat dalam projek ini adalah penuaian tenaga yang melibatkan penukaran tenaga getaran mekanikal yang terhasil apabila manusia berjalan pada bahan piezoelektrik kepada tenaga elektrik. Terdapat perkara yang perlu diperbaiki bagi meningkatkan jumlah penuaian tenaga elektrik yang dihasilkan daripada piezoelektrik. Tenaga yang terhasil akan dibandingkan untuk setiap keadaan ketika jalur piezoelektrik disambung secara siri dan selari. Tenaga yang dihasilkan oleh seramik piezo adalah arus ulang-alik dan tidak boleh digunakan dalam pengisian bateri, oleh itu litar penerus akan menukar arus ulang-alik ke bekalan arus terus dan kuasa yang dijana disimpan dalam peranti simpanan. Kemudian, tenaga yang dihasilkan boleh digunakan untuk menyalakan beberapa miniatur atau peranti elektronik LED.

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AC	:	Alternating Current
DC	:	Direct Current
PZT	:	Lead Zirconate Titanate
PVDF	:	Polyvinylidene Fluoride
API	:	Application Program Interface
RL	:	Resistor-Inductor
LED		Light Emitting Diode
PCB		Printed Circuit Board
UV		Ultraviolet

CHAPTER 1

INTRODUCTION

1.1 Background of the Project

Nowadays, clean energy and natural resources have become an important research area due to limited fossil fuel sources and nuclear power instability issues. In order to break the dependency on fossil fuels as energy resources, The International Energy Agency's (IEA) believes the revolution of the clean energy is needed to eliminate the environmental concern on the future[3]. The demand for energy harvesting technology will continue growing as we have a desire to look for more effective energy conversion from solar energy, watermill, or windmill. There is the type of technologies that can produce electrical energy from the mechanical pressure created by human walking motion called piezoelectricity.

Since the piezoelectric material can produce an amount of electrical pulse when mechanical strain applied to the element, it was highlighted as a self-power source system[2]. The latest development in micro-electromechanical systems (MEMS) technology have produced a great demand on the fast-growing for portable electronic devices. But, these electronic devices need their own power supply in order to functioning. They used a conventional battery as a supply which becomes problematic due to the limited lifetime of the battery. Hence, piezoelectric energy harvesting can be used as an energy source to power up the portable devices by converting mechanical vibration from the surrounding to electrical[8].

Furthermore, this electrical energy which is alternating can be captured and stored to the storage devices for further utilization. Then, to encourage the optimal energy saving result, there is some factor that effect on the usage of piezoelectric technology such as output power per step, battery storage, number of people step, distribution of high frequency walking areas, consumption facility, and cost[7].

These days, there are several advantages from the conversion of mechanical energy into electrical energy of piezoelectric element that has been studied. Besides that, it is necessary to implement a circuit that able to convert harvested energy from the transducer and store it at the storage element to achieve the complete energy harvesting procedure. Latest studies have concentrated on the improvement of the energy harvesting structures to get an optimum output to produce.

The main purpose of the project is to verify the optimum performance in terms of power output for series and parallel configurations of the piezoelectric transducer. The most optimal operating conditions for this energy generator will be determined from the design and experiment result.

Lastly, the component needed to construct the energy harvesting circuit is AC to DC bridge rectifier with a storage element such as a capacitor or battery. Generally, the output produced by the pressure or stress applied to a piezoelectric system is in mili Watt. The output power produces by the harvesting generator able to be used in practical applications such as powering small electronic devices and Light-Emitting Diodes (LEDs).

1.2 Problem Statement

Piezoelectric materials can be used as energy harvesting by generating the energy from the surroundings, which can help to a constraints energy source in the future. However, a single piezo-film produce very low output power in the range of mili Volt and micro Watt[2]. Therefore, it is not practical to apply the piezo-film as a power source in the direct application. Also, a storage device is required to collect output for future usage even though the power is weak but as we start to multiply the amount of piezo, we will see the potential to generate a significant amount of power. Furthermore, the battery has been the power source of most electric-driven devices but the physical dimension and limited lifetime of batteries have reduced the acceptance for some power critical or maintenance-free real-time embedded applications[1]. It can become a tiresome task to make a replacement for the battery on the portable electronic devices which could die at any time. If we can obtain the

natural energy in the surrounding medium, then the battery can be replaced to act a new energy source. One of the methods could be used is a piezoelectric material which can obtain the waste energy from human walking motion or pressure and convert to electrical. This captured energy may provide endless energy for the lifespan of electronic devices and can be used to extend the life of the power supply.

1.3 Objectives

There are three main objectives of this project. In order to have a clearer view to achieving the target result, these three objectives will assist as a milestone to the project. The objectives of the project are:

1) To design the piezoelectric array configuration for energy harvesting

2) To analyze the different configuration of piezoelectric for optimum output

3) To construct an energy harvesting circuit on the tile structure for energy conversion

1.4 Scope of the Project

This project will focus on modeling a 6 piezoelectric for energy harvesting with a different configuration of the piezoelectric array. The maximum power of each configuration will be measured to identify the optimum power. The piezo generator will be set up in the tile structure to absorb dynamic compression energy from people walking. Multisim software will be used to design and make a simulation for the energy harvesting circuit that will produce 5V which contain rectifier circuit that converting the AC supply to DC supply, while Proteus software will be used to build a printed circuit board. Next, the output voltage will be stored to the storage device like a rechargeable battery or supercapacitor.

1.5 Thesis Outline

The organization of the report divided into several chapters to make it more clear and structured. There will involve five chapters that consist of Introduction of the Project, Literature Review, Methodology, Result, and Conclusion.

Chapter 1 briefly explain the introduction of overall project concepts. This chapter will make it clear on the project background, problem statement, objectives of the project and the Scope of work. This chapter will act as a guideline for the whole project's research and analysis.

Chapter 2 will discuss the literature review of the project that covers the research previous studies and finding that related to the piezoelectric. The theory and application that have been discussed from the technical papers will be used as references along the project process.

Chapter 3 are explaining the methodology of the project which presented all the steps, projects block diagram, and flow chart. The project's process shows how the piezo generator can be mounted into the tile structure with the harvesting circuit and how it will work. The design of the project will be included in this chapter.

Next, Chapter 4 will present the result of simulation and experimental. The Multisim software used to run the simulation and test the circuit. The overall results will be discussed. The simulation and calculation result will proceed to the analysis.

Lastly, Chapter 5 is to conclude the objectives that have been stated before related to the result and will sum up the overall process throughout completing this project. Also, the recommendation for future work from the researches and result.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

In this section, there were theories and idea about how the piezoelectric worked to produce electrical energy. Besides that, this section also included some comparison between the available studies, researches, and projects. Next, there will explain briefly how the piezoelectric elements incorporated with the impact present from human foot step while walking on it. Literature review work as the beginning process to generate ideas about the projects which provides valuable information and further understanding on the topic.

2.2 Energy Harvesting

The terms of power harvesting are based on a process which obtaining energy from a system's environment and converted into the usable electricity. In other words, these sources are also known as the energy collected from the instrument’s immediate environment, which is fundamentally free and offering perpetual operation with no maintenance requirements[4].

Energy harvesting technologies include solar (photovoltaic and solar thermal), electromagnetic, mechanical vibration, thermoelectric (temperature differentials), and radio frequency (antenna wave) as shown in Figure 2.1. One of the main sources that can be obtained for energy harvesting and have a wide range of motion-powered energy harvesters is an ambient motion[1].

Figure 2.1 Type of energy harvesting from natural sources

The most common energy sources available for energy harvesting are light, heat, and vibration. This three energy sources transducer have some characteristic in common which is: