THE CONVERTER CIRCUIT FOR PIEZOELECTRIC POWER GENERATION

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"Dedicated to my family, my supervisor and to my friends"

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ABSTRACT

Piezoelectric materials have a crystalline structure that provides a unique ability to convert an applied electrical potential into a mechanical strain or convert an applied strain into an electrical current. The latter of these two properties allows the material to function as a power generator. In most cases the piezoelectric material is strained through the ambient vibration around the structure, thus allowing a frequently unused energy source to be utilized for the purpose of powering small electronic systems. However, the amount of energy generated by these piezoelectric materials is far smaller than that needed by most electronic devices. For this reason, the target of accumulating and storing the energy generated, until sufficient power has been captured and convert into power generated is the key to develop completely self-powered systems. This project quantifies the amount of energy generated by a piezoelectric material and investigates the compatible converting circuit thus produce higher efficiency, higher frequency and long operating duty cycle. Achieving project targeted was focus on the ability of mechanical vibration produce by piezoelectric material. Through the excitation of a piezoelectric energy stored, the compatible converter circuit is determine by the amount of the energy generate that needed by most electric devices.

ABSTRAK

Bahan piezoelektrik mempunyai struktur berhablur yang membekalkan kebolehan unik untuk menukar keupayaan elektrik yang diberi kepada tekanan mekanikal atau menukar keupayaan tekanan kepada arus elektrik. Dua sifat ini membolehkan bahan piezolelektrik berfungsi sebagai penjana kuasa. Dalam kebanyakan perkara, bahan piezoelektrik mempunyai tekanan melalui gegaran dari persekitaran di setiap struktur yang dapat memberikan punca tenaga yang tidak digunakan untuk penjanaaan sistem elektronik yang kecil. Walaubagaimanapun, jumlah tenaga dihasilkan dari bahan piezoelektrik ini jauh lebih rendah daripada yang diperlukan oleh kebanyakan alat elektronik. Oleh sebab ini, tujuan projek adalah pada pengumpulan dan penyimpanan tenaga yang dihasilkan sehingga tenaga mencukupi untuk penjanaan kuasa sehingga membolehkan pembentukan sistem tenaga itu sendiri. Projek ini mengkuantitikan jumlah tenaga yang dihasilkan oleh bahan piezoelektrik dan mengkaji litar penukar yang sesuai bagi menghasilkan kecekapan yang tinggi, frekuensi yang tinggi dan bertahan lama. Matlamat projek memfokuskan pada gegaran yang dihasilkan oleh bahan piezolektrik yang digunakan. Selaras dengan penyimpanan tenaga piezoelektrik, litar penukar yang sesuai ditentukan oleh jumlah tenaga yang dihasilkan untuk keperluan kebanyakan alat elektronik.

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LIST OF ABBREVIATION

CC	-	Converter Circuit
DC	-	Direct Current
IC	-	Integrated Circuit
RFID	-	Radio Frequency Identification
MEMS	-	Micro-Electro-Mechanical-Systems
PCB	-	Printed Circuit Board
PCBA	-	Printed Circuit Board Assembly
PCA	-	Printed Circuit Assembly
PSM	-	Projek Sarjana Muda
IEEE	-	Institute of Electrical and Electronics Engineer
AC	-	Alternate Current

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CHAPTER 1

INTRODUCTION

The capability of harvesting electrical energy from mechanical vibrations in a dynamic environment through piezoelectric transducers has been the topic of discussions for many years. Unused power exists in various forms such as vibrations, flowing water, wind, human motion and shock waves. Recent development to obtain these unused powers for energy source has newest interest in the converter application for generated power. The converter circuits (CC) have traditionally been use based on the device application. It converts from one source to produce output. For this project, the applications for piezoelectric power generation need to convert source from the vibration (mechanical energy) to produce output (electrical energy) determined by the amount of energy needed.

1.1 Motivation

Piezoelectric known as the generation of electricity or of electric polarity in dielectric crystals subjected to mechanical stress that can be used to power portable device. Recently, piezoelectric mechanism application used for microphones, accelerometers and roughness indicators. Besides, it exhibit good application potentials, particularly for Radio Frequency Identification (RFID) and Micro-Electro-Mechanical Systems (MEMS).

Radio Frequency Identification (RFID) is in use all around us. Example for that, if the *'Touch n Go'* card ever chipped with an ID through a toll booth or paid for petrol using bank card, that is a RFID. Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate through micro-fabrication technology. While the electronics are fabricated using integrated circuit (IC) process sequences the micromechanical components are fabricated using compatible "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices.

With the recent advance in wireless, RFID and MEMS technology, the demand for portable electronics and wireless sensors is growing rapidly. Since these devices are portable it becomes necessary that they carry their own power supply. In most cases this power supply is the conventional battery, however problems can occur when using batteries because of there finite lifespan.

For portable electronics replacing the battery is problematic because the electronics could die at any time and replacement of the battery can be a tedious task. If ambient energy in the surrounding medium could be obtained, then it could be used to replace the battery. The method is to use piezoelectric materials to obtain energy lost due to vibrations of the host structure. Due to these reasons, this project will review and analyze the compatible converter circuit use.

1.2 Objectives

The objectives of this project develop a generic model of CC power and to overcome the problem of CC power transfer limitations by combined operation of a number of CCs. Adhere to utilize the generic CC converter model for analysis and design of a CC converter with the desired characteristics maximum efficiency, high frequency harmonics and long operating duty cycle.

This motivated approach the following plan:

a) To design and explain the suitable converter circuit for different piezoelectric application devices purposes regarding the very general concepts of mechanical loading of piezoelectric converter
b) To design qualitatively converter circuit model with high power efficiency, higher frequency and long operating duty cycle as well as the converter transforms the mechanical input into electrical output
c) To analyze the optimal power transfer of piezoelectric with explanation mechanical loading process and losses power in both situations

1.3 Scope of Work

The scope of this project is developing a generic model of CC power and to overcome the problem of CC power transfer limitations by combined operation of a number of CCs. At this part, the scope was focus based on the generation of power from the piezoelectric. The scope is limited to the converter circuit modeling with some of the criteria listed and the works undertaken is limited for some following aspects. That is, find the converter circuit with higher efficiency, frequency harmonics and long operating duty cycles. Besides, determine the right choice of piezoelectric converter type. Further, the circuit simulate by using Multisim, PSpice and Proteus software. Thus, implement the hardware application circuit on Printed Circuit Board (PCB).

1.4 Problems Statements

Nowadays, energy-conscious is a powerful impetus to develop alternative sources of energy. Electrical systems operate remotely despite the constraints associated with traditional power sources. For example, there exists a demand for systems such as transducer and sensors. This has stimulated interest in the research of energy converter in which research interest has grown rapidly within recent years.

Enthusiasm in the emerging field of mechatronics has driven several energy transducer designs with energy transformed from an electrical form to an electrical form via mechanical vibration at piezoelectric material. For example, a significant amount of energy harvesting research has been conducted with a focus on piezoelectric materials, which generate a voltage upon the application of mechanical stress. Results thus far have been promising, as the materials generate a voltage useful for manipulation in electrical circuitry. However, the energy produce from the piezoelectric material was very small around µW to mW.

An alternative to the piezoelectric approach is the method of employing the converter circuit. By used the compatible converter circuit this approach offers an alternative to piezoelectric energy produced, which may be limited by some design factors because different application of piezoelectric device need with different amount of energy.

1.5 Thesis Outlines

This thesis outline is divided into five chapter and references. On the following section this part offer brief description of each chapter.

Chapter I briefly reviews the background and application of piezoelectric. Then, the objective, scope of work and problem statements was set.

Chapter II studies the effect of the piezoelectric, the power generated behavior in producing supply power, elements involve in the process and the characteristics of it. Further, this chapter briefly describe the operational principle of using power generate by the piezoelectric and the factors influence the operation. Besides, it shows the theory principle of the circuit characteristic works and the factors affected in directly and non-directly. The study highlight the circuit operation in terms of very low power was supplied.

Chapter III present methods in achieving the project targeted. Besides, the project stage in this project including methods in circuit design, simulation and hardware. Further, this chapter shows plan of the project implementation by considering the problems that might be happen and the time frame of the project complete.

Chapter IV present a comparative analysis based on the converter circuit design and implementation. Operating circuit considered the most important things in effected the whole project. Analytical model were introduced in defining the best condition of converter circuit operation in low powering circuit. Further, it shows the step of selected components and parameter used in hardware implementation by referring the ability on the power transfer and how fast the component switching. The result found and problems faced were discussed in measuring the successfulness of the project achievement.

Chapter V conclude the project with the summarization of the project theory compared to the real implementation based on the project target that is design and develop a converter circuit for piezoelectric power generation. Thus, recommend the further steps of analysis in improving the circuit operation ability.

CHAPTER II

BACKGROUND RESEARCH

2.1 Literature Review

The piezoelectric effect exists in two domains. First is the direct piezoelectric effect that describes the materials ability to transform mechanical strain into electrical charge. Second form is the converse effect, which is the ability to convert an applied electrical potential into mechanical strain energy. 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 transform mechanical strain energy into electrical charge.

The mechanical and electrical behavior of a piezoelectric material can be modeled by two linearized constitutive equations. These equations contain two mechanical and two electrical variables. The direct effect and the converse effect may be modeled by the following matrix equations (IEEE Standard on Piezoelectricity):

Direct Piezoelectric Effect: $\{D\} = [e]T\ \{S\} + \left[\left[\alpha\ S\right]\right]\{E\}$ (1) (1.1)

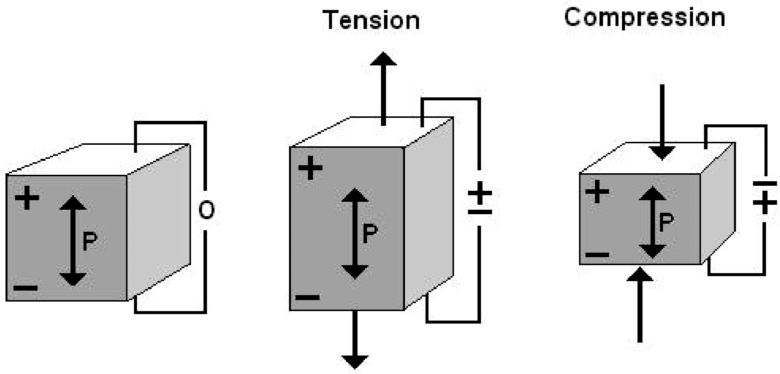

Figure 2.1 Direct piezoelectric effects

Converse Piezoelectric Effect: $\{T\} = [c^E]\{S\} - [e]\{E\}$ (2) (1.2)

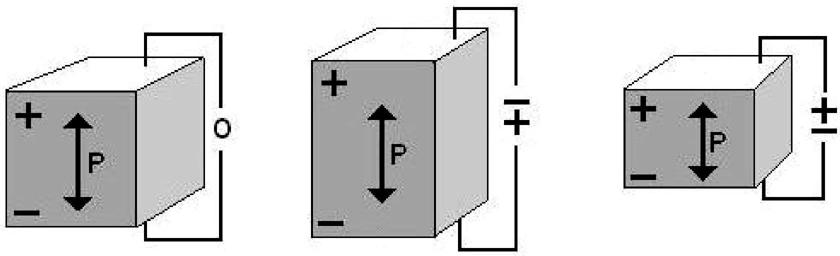

Figure 2.2 Converse electric effects

Where {D} is the electric displacement vector, {T} is the stress vector, [e] is the dielectric permittivity matrix, [cE] is the matrix of elastic coefficients at constant electric field strength, {S} is the strain vector, [αS] is the dielectric matrix at constant mechanical strain, and {E} is the electric field vector.

An electric field can be applied in order to induce an expansion or contraction of the material. However, the electric field can be applied along any surface of the material, each resulting in a potentially different stress and strain generation.

Therefore, the piezoelectric properties must contain a sign convention to facilitate this ability to apply electric potential in three directions. The following sections of the paper will break the various works in power harvesting into the