DESIGN OF PIEZOELECTRIC ENERGY HARVESTING CIRCUIT FOR HUMAN INTERACTION APPLICATION

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DEDICATION

I would like to dedicate this thesis to my beloved parents Cheong Yoke Hing and Chiu Shuk Yin for never stop giving off themselves in countless ways. Besides, I would like to dedicate this thesis to my dearest sister, Cheong Yi Yian for her prayers and mental support throughout my years of studies.

ABSTRACT

Batteries are one of the most popular power supplies for its portability and convenience. However, batteries have limited life and need to either be replaced, recharged or both which has ongoing costs associated. There is an alternative way to harvest electrical energy which is using piezoelectric material. The disadvantage is that energy harvested from piezoelectric energy harvester is in AC form and it is too low to charge up electronic devices such as smartphones. The project aims to design and develop a prototype that able to harvest electrical energy from human walking movement using piezoelectric materials. Firstly, a prototype of piezoelectric knee-joint energy harvester is developed to harvest electrical energy. The harvested energy will be rectified to 3.3V and stored into a super capacitor. The circuit will be used to power up a Radio frequency system to verify that there is sufficient output power from the circuit designed.

ABSTRAK

Bateri adalah salah satu bekalan kuasa yang paling popular untuk mudah alih dan kemudahannya. Walau bagaimanapun, bateri mempunyai kehidupan terhad dan perlu sama ada diganti, diisi semula atau kedua-duanya yang mempunyai kos yang berterusan. Terdapat cara alternatif untuk menuai tenaga elektrik yang menggunakan bahan piezoelektrik. Kelemahannya ialah tenaga yang dituai dari penuai tenaga piezoelektrik adalah dalam bentuk AC dan ia terlalu rendah untuk mengecas peranti elektronik seperti telefon pintar. Projek ini bertujuan untuk merekabentuk dan membangunkan prototaip yang dapat menuai tenaga elektrik dari pergerakan berjalan manusia menggunakan bahan piezoelektrik. Pertama, prototaip piezoelektrik pemanen tenaga lutut bersama dibangun untuk menuai tenaga elektrik. Tenaga yang dituai akan diperbetulkan kepada 3.3V dan disimpan menjadi kapasitor super. Litar akan digunakan untuk menguatkuasakan sistem frekuensi Radio untuk mengesahkan bahawa terdapat keluaran output yang mencukupi dari litar yang direka.

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LIST OF SYMBOLS AND ABBREVIATIONS

μ	:	Micro
AC	:	Alternating Current
AIN	:	Aluminium Nitride
D	:	Electric displacement
d	:	Piezoelectric coefficient matrix
D1	:	Diode1
D2	:	Diode2
D3	:	Diode3
D4	:	Diode4
DC	:	Direct Current
DIL	:	Dual in-line
E	:	Electric field vector
F	:	Farad
h	:	hours
Hz	:	Hertz
I	:	Current
IC	:	Integrated Circuit
IoT	:	Internet of Things
k	:	kilo

KEH	: Knee-joint energy harvester
LED	: Light Emitting Diode
LTC	: Linear Technology
M	: Proof mass
m	: milli
M	: Mega
MEMS	: Micoelectromechanical Systems
ms	: millisecond
NiMH	: Nickel-metal Hydride
PCB	: Printed Circuit Board
PKEH	: Piezoelectric knee-joint energy harvester
PM	: Primary magnet
PP	: Polypropylene
PVDF	: Polyvinylidene Fluoride
PZT	: Lead Zirconate Titanate
RF	: Radio Frequency
s	: Strain vector
S	: Compliance matrix
s	: seconds
SM	: Secondary magnet
T	: Stress vector
V	: Voltage
Vcc	: Voltage at the common collector
Vp	: Peak Voltage
Vrms	: Root-Mean-Square Voltage

W	: Watt
WCSN	: Wireless Communication Sensing Node
z	: Vertical displacement
ZnO	: Zinc Oxide
ε	: Electrical permittivity

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CHAPTER 1:

INTRODUCTION

1.1 Overview

Piezoelectricity is defined as the ability of generating electricity in response to applied pressure. When a piezoelectric material is placed under certain mechanical stress, an external electrical field will be produced due to the positive and negative charges accumulated in the centers of the material, resulting in an external electrical field. This is also known as the piezoelectric effect. In short, piezoelectric materials is capable of converting mechanical energy to electrical energy by applying mechanical stress or vibration. It is a trusted ambient energy source and is a good alternative way to reduce batteries usage.

There are many ambient energy sources like solar energy, wind movement, hydro and among these ambient energy, mechanical force such as impact and vibration can be found or obtained easily. For instance, the mechanical force that comes from human walking. Human motion consists of kinetic energy and such energy often being wasted. Actually, this kind of energy can be harvested using piezoelectric material for obtaining clean and sustainable energy which can be used to power up low power electronic device. Besides, such energy do not need to be replaced like battery and this make it more valuable and efficient to be used as an alternative power source. On top of that, the harvested mechanical energy can be commercialized in many field, for example wireless system sensor network and alarm system.

This project intends to show that harvested energy can be stored and even trigger low power application such as a RF transmitter which doesn't involve any batteries. Piezoelectric cantilever will be implemented as power generator. However, the energy produced must be converted from AC voltage to DC voltage before it can be used to charge or power up electronic devices. Therefore, a knee-joint energy harvester prototype which consists of rectifying circuit will be designed to harvest the mechanical energy from human walking. After rectifying the AC voltage to DC voltage, the voltage will be stored in a super capacitor before feeding into RF transmitter. The performance of system will be verified.