UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Design and Development of Piezoelectric Energy Harvester for Ultra Low Energy Electronics

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

By

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honor's. The member of the supervisory is as follow:

……

(Project Supervisor)

ABSTRAK

Tujuan kajian ini adalah untuk mengenal pasti kebolehan system piezoelektrik dalam menuai kuasa elektrik dari kasut. Kaedah yang baru ini sendiri akan digunakan dan dijangka akan boleh menghasilkan voltan arus terus, sebagai contoh, telefon bimbit. Sensor piezoelektrik adalah komponen utama yang digunakan di dalam reka bentuk sistem ini. Ia berfungsi dengan penekanan yang ditekankan kepadanya sebagai kuasa mekanikal untuk diubah kepada keluaran elektrik. System penghasilan kuasa piezoelektrik akan diletakkan diantara dua dataran dalam keadaan ketinggian yang sama dengan permukaan jalan. Hasil akan disumbangkan oleh mana-mana hentakan kaki dimana kaki memijak permukaan dataran seterusnya menghasilkan getaran dan akan memberikan penekanan kepada sensor piezoelektrik untuk menghasilkan arus elektrik. Selepas itu, arus elektrik yang akan terhasil dalam keadaan voltan akan digunakan untuk mengecas semula superkapasitor sebagai alat penyimpan sebelum diterbalikkam untuk digunakan oleh elektronik ultra rendah. Projek ini adalah sangat berkesan dan mampu untuk digunakan sebagai satu kaedah baru menghasilkan tenaga yang sia-sia untuk membangunkan satu sistem yang boleh menjana kuasa daripada pergerakan menggunakan konsep kesan piezoelektrik. Kelebihan utama dari sudut positif yang boleh diambil adalah arus elektrik akan terus terhasil selagi kaki terus bergerak. Selain itu, projek ini juga mengambil berat tentang alat berasaskan teknologi hijau seperti yang disyorkan dan pengguna yang menggunakan kasut boleh mendapatkan manfaat oleh sistem.

ABSTRACT

The reason for the study is to build up the potential power produce by the energy harvesting utilizing piezoelectric from the shoe. This new strategy for collecting itself will be utilized and anticipated that would capable of producing a DC voltage output, for instance, mobile phone. The piezoelectric sensor is the fundamental part in the design. It works with the pressure paced on it as a mechanical energy to be changed over into electrical energy. The piezoelectric energy harvesting system will be connected between rectangular planes at the base shoe. The results will be contributed by any hit of feet which the feet will step on the planes, in this manner will vibrates and giving the energy to the piezoelectric sensor to create power. At that point, the power produced in voltage is to revive the supercapacitor as capacity device before altered to be utilized for ultra low electronic. The project is an extremely compelling and competent to use as another method of the wasted energy harvesting to develop a system that can create power from movement utilizing the concept of piezoelectric transducer. The positive side to take as the main advantages is that the power will remain produced as long as the feet will continue moving. Moreover, the task is making into account of the eco green product as suggested and users who are utilizing the shoe can get benefits by the system.

DEDICATION

To my beloved mother and father, my family, my teachers and my fellow friends, thank you for the support and help given to me on completing this thesis.

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Firstly, most thanks to Allah S.W.T for giving me the opportunity to complete this report "Projek Sarjana Muda 1" with a success after I went through a lot of obstacles with patience. I would also like to thanks my parents for encouraging me throughout all the heavy situation I am facing and keep supporting on my financial. I would not be in this university and not be able do my degree project without their permission and blessing. Not to forget, I would like to thanks my supervisor, Puan Emy Zairah Binti Ahmad for guiding me in completing this project and report. She has taught me a lot of useful things and knowledges not only in theoretical but also practical. Furthermore, thanks to all lecturers and technicians that have guided me to get a good knowledges and experiences either in the class or in the lab sessions. Besides that, I would also like to thanks all my fellow friends including my friends under the same supervisor for sharing and comparing opinions and report. Finally, I would like to thanks anyone that has contributed either they are in connection with me or not, for giving me the support and help in to makes this project success.

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AC	-	Alternating Current
DC	-	Direct Current
MEMS	-	Micro Electro Mechanical System
MHz	-	Mega Hertz
PZT	-	Lead Zirconate Titanate
BaTiO3	-	Barium Titanate
E	-	Energy Consumed
V	-	Voltage
C	-	Storage Capacitor
USB	-	Universal Serial Bus
BJT	-	Bipolar Junction Transistor
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
mF	-	Mili Farad
Ω	-	Ohm
H	-	Hertz
Vrms	-	Root Mean Square Voltage
PSM	-	Projek Sarjana Muda

CHAPTER 1

INTRODUCTION

1.0 Introduction

This section explains the project background, objectives, scope, problem statement and project significant.

1.1 Background

Nowadays, electricity is very important in daily life that can give energy to community. Electricity is a form of energy that comes in positive and negative forms, that occur naturally or is produced as in a generator. It is a form of energy which we use to power machines and electrical devices. Renewable energy also known as natural energy sources. It can be utilized as a part of an extreme long scope of times and without a doubt to never run out. Today, many countries all over the world are concentrating on some option approaches to create power by proposing out a great deal of new strategies for energy collecting because of the desire to decrease the reliance of the present unsustainable sources. With all option suggested, piezoelectricity eras happens to be one strategy of energy harvesting and can possibly be created to a huge scale and can produce adequate measure of power.

Besides that, electrical energy will produced because idea of the piezoelectric energy harvesting is concentrating on the system that captures wasted energy from vibration to get some electricity. The power created can be put away in the capacity device and then used to power electronic such as mobile phone, mp3 especially for athlete that utilization sport shoes. The innovation depends on a standard called the piezoelectric impact, in which certain materials can develop an electrical charge from having vibration and strain applies to them.

Capacitor that are use is super capacitor that have high storage to store energy, they typically store 10 to 100 times more than electrolytic capacitor, can accept and deliver charge much faster than batteries. The harvested energy is then will be rectified and changed into power electric before exchanged to energy storage device.

The proposed system requires a certain movement or vibrations on the piezoelectric material to convert vibration to electric current to electric current. Therefore, the system is designed to be implemented in shoes sole because have vibration when the shoes will moving.

1.2 Problem statement

Electronics and electric is very important in our daily life as energy is one of the most thing needed in the world. Bad management of energy will affect the development of company and social growth and in the same time will also affect human life. Nowadays, there are lot of electronics product in market that need energy as a power supply such as mobile phone, radio and so on. Without power supply, mobile phone will run out of the battery, radio will not be able to function well, human are not able to watch television since there are no power to switch the TV on.

Nowadays, there are so many wasted energy. Human activity is overloading the atmosphere with carbon dioxide and other global warming emission, which trap heat, steadily drive up the planet's temperature, and create significant and harmful impact on our health, our environment, and our climate. The energy that have been wasted actually can be renewed and converted to the useful form such as eco-system project.

By using renewable energy, it gives many potential benefit especially in human life and environment. There are so many forms of renewable energy. Most of these renewable energies depend in one way or another on sunlight. Wind and hydroelectric power are the direct result of differential heating of the Earth's surface which leads to air moving and precipitation forming as the air is lifted. Solar energy is the direct conversion of sunlight using panels or collectors. Biomass energy is stored sunlight contained in plants. With an endless supply of renewable energy, the world will have more energy supplies to sustain planet, protect human race, generation and also bring economic benefit to many regional area.

However, the biggest problem for this renewal energy system is, the cost are higher than non-renewable energy and sometimes it contribute to serve air pollution problem. New ideas are being tested by researchers from all over the world and also by various innovative pilot project around the world. Beside than that, other solution that can be investigated are some other new assets, for example, hydroelectric power generators. So the easiest, cheapest and suitable to eco-system should be consider first.

1.3 Objective

The objective of this project are:

(a) The aim of this project is to develop a system that can generate power from movement using the concept of piezoelectric effect.
(b) To analyse the performance of designed system.

1.4 Scope

In this project, I decided to study on the potential of piezoelectric in generating electricity. For implementing this project, firstly I need to design the sizing of piezoelectric sensor. The design of piezoelectric must be suitable for this project. I also want to focus on function of piezoelectric in this project to build some benefits to community. The output on power supply will enough to use in low power gadget or electronic device like mobile phone. Besides that, I will explain the working principle on this project that can save consumption of electrical energy. The operation of piezoelectric will be included because this project will be tested to its performance in piezoelectric.

1.5 Project Significant

In project significant, mobile phone is main output can use in this project. The design will proposed energy conservation system for ultra-low energy electronics has been introduced in this paper. The design presented here will be quite effective in giving a substitute means of power supply for the mentioned devices during emergency. It will focus on how effectiveness of energy harvesting by piezoelectric that had been implemented in shoes sole to generated ac output for ultra-low electronics devices. Moreover, it will help somebody during emergency to charging their mobile phone. Further, the the methodology introduced in this paper can be reached out to numerous different applications where there is scope for similar kind of energy.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this literature review section, it involves from the journal on the web, paper procedures and research, books and lectures. The literature review includes the cases investigation of the project that might be emerge to conquer the problem furthermore gives a capable learning on the basics of the fundamental project.

2.1 Piezoelectric Device

Piezoelectric is a component or device where it changes over the mechanical to the electrical form of energy through subjection of mechanical stress, either by vibrating or pressing it. Energy harvesting by piezoelectric devices has great potential applications in self-powered sensor networks, portable electronic devices, ubiquitous computing systems, and other areas. It uses piezoelectric effect to convert mechanical vibration or the strain variation with time into electric energy and store it in energy storage devices such as super-capacitors and rechargeable batteries (Junhui et al, 2010). Piezoelectric devices are implements that use material exhibiting piezoelectric effects. "Piezo," in Greek, means "pressure," which explains that when you apply pressure to piezoelectric

materials, you get a charge separation within a crystal and a voltage across the crystal that is sometimes extremely high (Colenso, 2008). When a pressure is applied to a piezoelectric material, it causes a mechanical distortion and a displacement of charges which are highly proportional to the applied pressure. Placing piezoelectric devices that are used to capture energy from shoes especially for athlete sport that can get a lot of vibration so it can effectively capture electrical energy and send it back to the power grid through rectifier, which are needed in order to convert the AC power, from the piezoelectric, into DC power to use for ultra-low power energy electronics like mobile phone, radio and so on.

2.2 Piezoelectric Material

Piezoelectric materials can be used as mechanisms to transfer ambient vibrations into electrical energy that can be stored and used to power other devices. With the recent surge of micro scale devices, Piezoelectric power generation can provide a conventional alternative to traditional power sources used to operate certain types of sensors/actuators, telemetry, and MEMS devices. (Henry et al, 2012).

In other words, piezoelectric are materials that can create electricity when subjected to a mechanical stress. They will also work in reverse, generating a strain by the application of an electric field. The phenomenon was first discovered in 1880 when Pierre and Jacques Curie demonstrated that when specially prepared crystals (such as quartz, topaz and Rochelle salt) were subjected to a mechanical stress they could measure a surface charge. A year later, Gabriel Lippmann deduced from thermodynamics that they would also exhibit a strain in an applied electric field. The Curies later experimentally confirmed this effect and provided proof of the linear and reversible nature of piezoelectricity. (Wolsky , 1984)

One of the first applications of the piezoelectric effect was an ultrasonic submarine detector developed during the First World War. A mosaic of thin quartz crystals glued between two steel plates acted as a transducer that resonated at 50MHz (Heung et al, 2011). By submerging the device and applying a voltage they succeeded in emitting a high frequency 'chirp' underwater, which enabled them to measure the depth by timing the return echo. This was the basis for sonar and the development encouraged other applications using piezoelectric devices both resonating and non-resonating such as microphones, signal filters and ultrasonic transducers. However many devices were not commercially viable due to the limited performance of the materials at the time.

The piezoelectric is a property of certain crystalline material such as quartz, Lead Zirconate Titanate (PZT), barium titanate ceramics and Rochelle salt which will develop electricity when the pressure is applied on the direct effect (Heung et al, 2011).

2.2.1 Crystal Quartz

It was found that for a small mass uniformly deposited over the crystal surface, the shift in resonant frequentcy is linearly proportional to the mass. Because of this simplicity, piezoelectric quartz crystals microbalances have been extensively used in thin film deposition processes as thickness and rate monitors. (Lu , 1975).

Several anisotropic crystals exhibit piezoelectric effect - mechanical deformation of such crystals generates oriented dipoles and electric voltage. In the opposite, alternating voltage applied on such crystals excites vibrations. At resonance frequency equal to the natural frequency of vibration, transfer of energy from the electric field to the crystal is most efficient and the energy remains

conserved in the oscillating system. (Skladal , 2003). The room temperature properties will be shown as Table 2.1.

Table 2.1: Room temperature properties of common piezoelectric crystals (James et al, 1998)

Crystal name	Chemical formula	Point group	Max. piezoelec. charge coef. (pC/N)		Dielectric constant K_{11}^T	K_{33}^T	Ref.
Amonium Dihydrogen Phosphate (ADP)	$NH_4H_2PO_4$	$\bar{4}2\,m$	50.0	(d_{36})	55.0	15.0	[67]
Barium Sodium Niobate (BNN)	$Ba_2NaNb_5O_{15}$	mm2	52.0	(d_{24})	246.0	51.0	[66,67]
Barium Titanate	$BaTiO_3$	4 mm	392.0	(d_{15})	2920.0	168.0	[67]
Ethylene Diamine Tartrate (EDT)	$C_6H_{14}N_2O_6$	2	− 12.3	(d_{23})	5.0	6.0	[67]
Lead Barium Niobate (PBN)	$Pb_{0.37}Ba_{0.63}Nb_2O_6$	4 mm	108.0	(d_{15})	600.0	135.0	[66]
Lead Potassium Niobate (PKN)	$Pb_2KNb_5O_{15}$	mm2	470.0	(d_{15})	1550.0	129.0	[67]
Lead Niobate	$PbNb_2O_6$	mm2	45.0	(d_{33})	—	180.0	[67]
Lithium Niobate	$LiNbO_3$	3 m	68.0	(d_{15})	84.0	30.0	[15,66]
Lithium Sulfate	$LiSO_4{\cdot}H_2O$	2	16.2	(d_{22})	5.6	6.5	[67]
Lithium Tantalate	$LiTaO_3$	3 m	26.0	(d_{15})	51.0	45.0	[15,66]
Quartz	SiO_2	32	2.3	(d_{11})	4.6	4.7	[67]
Potassium Dihydrogen Phosphate (KDP)	KH_2PO_4	$\bar{4}2\,m$	23.2	(d_{36})	44.0	21.0	[66,67]
Rochelle Salt	$NaKC_4H_4O_6{\cdot}4H_2O$	222	2300.0	(d_{14})	1100.0	9.2	[66,67]
Sodium Chlorate	$NaClO_3$	23	1.7	(d_{14})	5.8		[67]
Triglycine Sulfide (TGS)	$(NH_2CH_2COOH)_3{\cdot}H_2SO_4$	2	25.3	(d_{23})	8.6	5.7	[66,67]
Tourmaline	$CaAl_3Mn_6(BO_3)_3(SiO_3)_6(OH)_4$	3 m	3.6	(d_{15})	8.2	7.5	[67]
Zinc Sulfide	ZnS	6 mm	3.2	(d_{33})	8.6	8.0	[67]

2.2.2 Barium Titanate Ceramics

Barium titanate, BaTiO3 is the first ceramic piezoelectric material as in historical where it shows a high possibility of being revitalized as a popular lead-free piezoelectric material. This titanate is a ferroelectric ceramic material with piezoelectric properties. (Jaffe , 2012)

Barium titanate has attracted a considerable amount of attention over the years due to its excellent physical and electrical properties and numerous practical applications. The BaTiO3 based ceramics are widely used for multilayer capacitors