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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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **DESIGN AND DEVELOPMENT OF PIEZOELECTRIC ENERGY HARVESTER FOR ULTRA LOW ENERGY ELECTRONICS**

SESI PENGAJIAN: **2016/17 Semester 2**

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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.

ACKNOWLEDGEMENT

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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LIST OF ABREVIATIONS, SYMBOLS AND NOMENCLATURE

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

(MLCCs), PTC thermistors, varistors, and dynamic random access memories (DRAM) in integrated circuits. (Paunovic et al, 2016). The application of Barium Titanate will show in Table 2.2.

Table 2.2: The application of Barium Titanate Ceramics. (Tanaka, 1954)

Barium Titanate Ceramics and their Applications

Table

Crystal Type	Mode	d	g	ε	κ
Rochelle Salt	Lateral	165	0.093	200	0.54
Quartz	{Parallel / Lateral	2.3	0.058	4.5	0.10
A.D.P.	Lateral	24	0.177	15.3	0.28
$BaTiO_3$ Ceramic	Parallel	190	0.0125	1700	0.46
	Lateral	78	0.0052	1700	0.19

d : Piezoelectric modulus (10^{-12} meter/volt)
g : Voltage output coefficient (volt-meter/newton)
ε : Dielectric constant
κ : Electro-mechanical coupling coefficient

2.2.3 Lead- Zirconate - Titanate (PZT) Ceramics

Lead Zirconate Titanate or otherwise called PZT is a ceramic material that advances on the piezoelectric impact which utilized as a compound in a number of practical applications in the area of electro ceramics. By and large, the PZT materials and piezoelectric materials will display a special scope of properties. (James et al, 1998). They showed that piezoelectric polymer materials can generate higher voltage/power than ceramic based piezoelectric materials and it was possible to produce energy from renewable sources such as rain drops and wind by using piezoelectric polymer materials. (Heung et al,2011).The advantages of this PZT materials is that it exhibits a greater sensitivity and also have a higher operating temperature. The properties of Lead Zirconate Titanate will be shown in Table 2.3.

Table 2.3: Properties of Lead Zirconate Titanate (PZT) ceramics (James et al, 1998)

Designation	T_c (°C)	d_{33} (pC/N)	d_{31} (pC/N)	d_{15} (pC/N)	K_{33}^{T}	k_{33}	k_{31}	k_{15}	Ref.
PZT-2	370	152	− 60	440	450	0.63	− 0.28	0.70	[67]
PZT-4	325	285	− 122	495	1300	0.70	− 0.33	0.71	[68]
PZT-4D	320	315	− 135	n/a	1450	0.71	− 0.34	n/a	[68]
PZT-5A	365	374	− 171	585	1700	0.71	− 0.34	0.69	[68]
PZT-5B	330	405	− 185	564	2000	0.66	− 0.34	0.63	[68]
PZT-5H	195	593	− 274	741	3400	0.75	− 0.39	0.68	[68]
PZT-5J	250	500	− 220	670	2600	0.69	− 0.36	0.63	[68]
PZT-5R	350	450	− 195	n/a	1950	n/a	− 0.35	n/a	[68]
PZT-6A	335	189	− 80	n/a	1050	0.54	− 0.23	n/a	[67]
PZT-6B	350	71	− 27	130	460	0.37	− 0.15	0.38	[67]
PZT-7A	350	153	− 60	360	425	0.67	− 0.30	0.68	[68]
PZT-7D	325	225	− 100	n/a	1200	n/a	− 0.28	n/a	[68]
PZT-8	300	225	− 97	330	1000	0.64	− 0.30	0.55	[68]

2.3 Applications for the Piezoelectric Effect

The piezoelectric effect is nowadays used in many everyday products such as lighters, loudspeakers and signal transducers. Piezo actuator technology has also gained acceptance in automotive technology because piezo-controlled injection valves in combustion engines reduce the transition times and significantly improve the smoothness and exhaust gas quality. The direct piezoelectric effect may be defined as the change of electric polarization proportional to the strain. (Tichy et al, 2010)

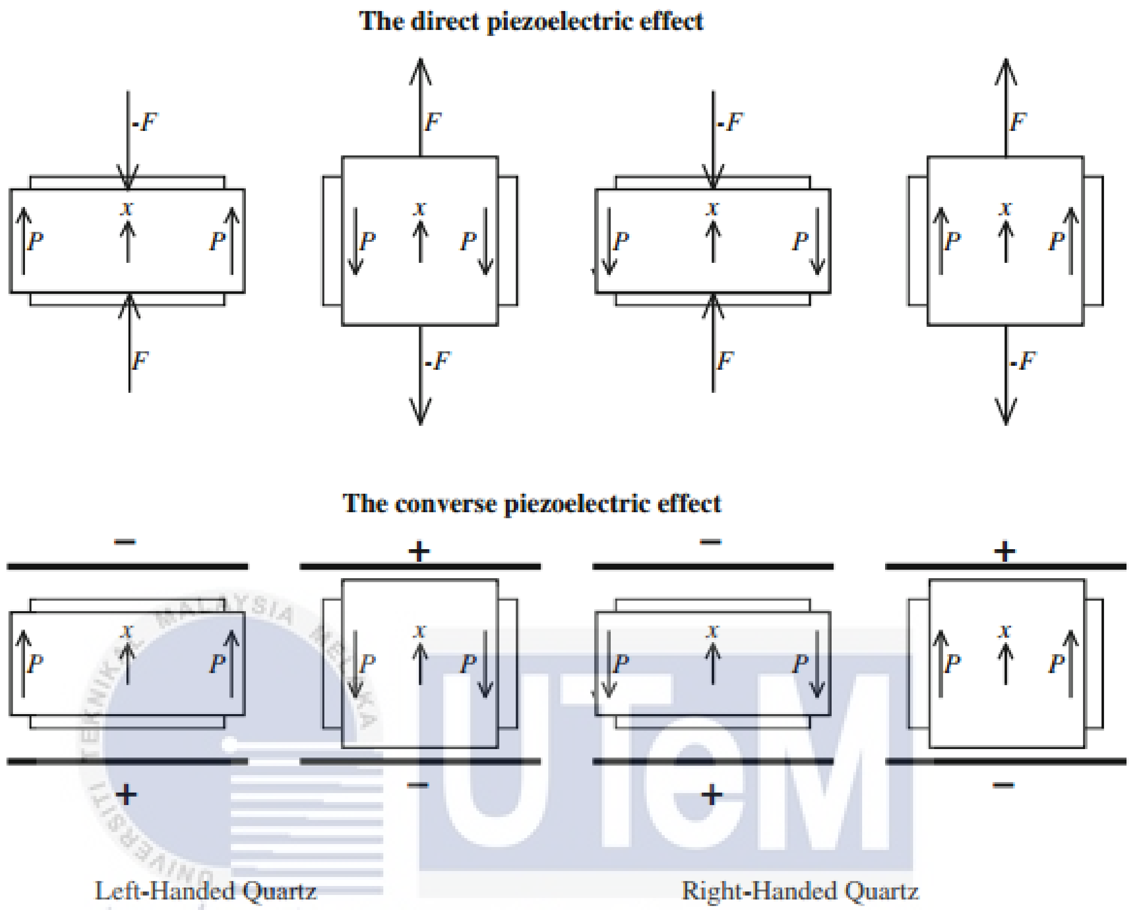

Figure 2.1: Direct and converse piezoelectric effect (Tichy et al, 2010)

Beside that, in mechanical applications, the PZT patches need to be adhesively bonded on the subject. The new paradigms in applying PZT patches for bio-medical applications, without the need for adhesive bonding. This is a challenging application since suitable measures need to be taken to ensure sound transmission of the force between the patch and the subject. (Shashank et al, 2014). The experiment procedure for pulse measurement will show in Figure 2.2 and Figure 2.3.

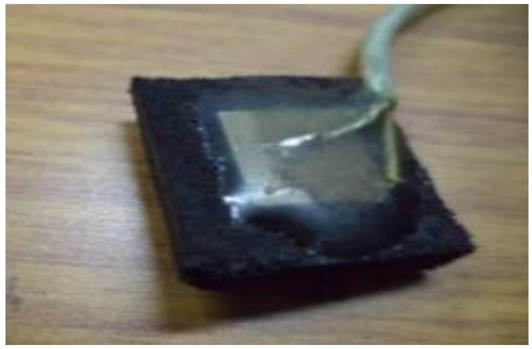

Figure 2.2: Piezo patch on rubber (Shashank et al, 2014)

Figure 2.3: Experiment set up (Shashank et al, 2014)

Because of the intrinsic characteristics at piezoelectric materials, there are various applications that get benefit when the people use:

2.3.1 High voltage and power sources

A case of uses here is the electric cigarette lighter, where squeezing a catch causes a spring-loaded hammer to hit a piezoelectric crystal, in this manner creating an sufficiently high voltage that electric current flows across a small spark gap, heating and touching off the gas. Most sorts of gas burners and ranges have a built-in piezo based injection systems.

2.3.2 High Temperature Applications

The application of a piezoelectric material at elevated temperatures presents many challenges, such as phase transitions, which in general lead to instability of the properties with temperature. Additional issues that piezoelectric materials face at elevated temperatures include, but not limit to: thermal instability of the dielectric, piezoelectric and electromechanical properties; increased attenuation of acoustic waves and dielectric losses with temperature (Zhang et al, 2011)

2.3.3 Piezoelectric Motors

This application relates to piezoelectric motors, and more particularly, to a piezoelectric motor capable of storing energy which may be used to propel the motor. In piezoelectric motors, an electro-active material is used to convert electric potential directly into mechanical strain. Piezoelectric motors rely on friction to convert micro strain to macro motion. (Cunningham et al, 2001)

2.4 Connection of the piezoelectric sensor

Power creation is the single biggest source of pollution in the entire world. The connection of the multiple piezoelectric sensors can be either in series parallel or series-parallel combination (Kiran et al, 2014). The connections of the piezoelectric sensor in the system is liable to be a very important aspect so as to get the highest output from the multiple combination. There is an equal advantages in term of output current and voltage for both series and parallel connections of the various piezoelectric sensors.

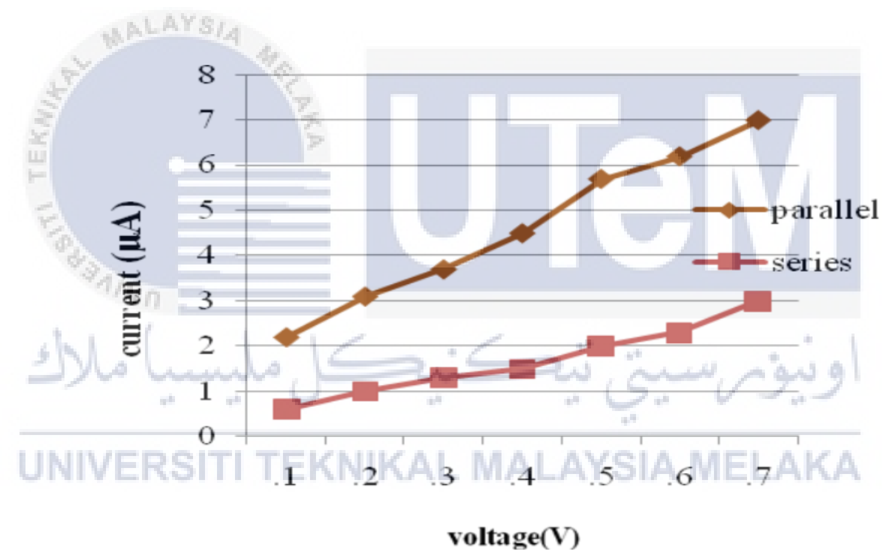

Figure 2.4: The V-I graph for the series and parallel connections (Kiran et al, 2014)

Figure 2.4 shows the parallel connection delivered a good current but the voltage is so poor while the voltage created from a series connection is good yet acquired a poor current. Moreover, the phenomena can be rectified in a series-parallel connection where a good voltage can be gotten and their current. (Kiran et al, 2014)

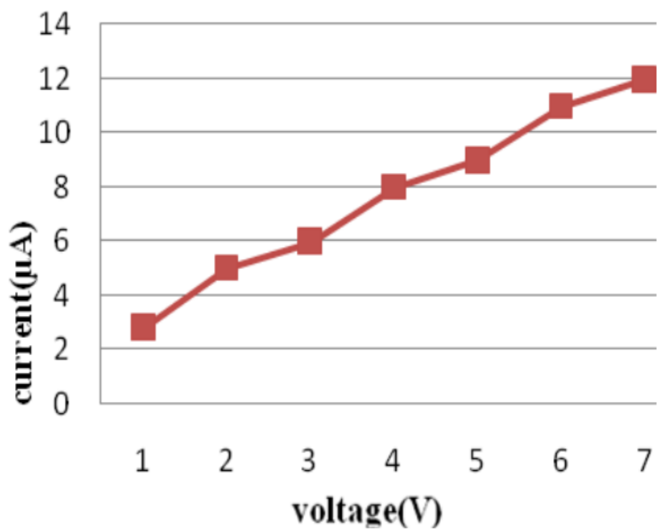

Figure 2.5: The V-I graph for the series-parallel combinations (Kiran et al, 2014)

Comparison between various piezoelectric material shows that PZT is superior in characteristics. Also, by comparison it was observed that series- parallel combination connection is more appropriate as appeared in Figure 2.5 above. It can likewise be utilized as charging ports, lighting of pavement side buildings.

CHAPTER 3

METHODOLOGY

In this approach area, it will describes further on how the procedure of the task from the begin until achieving its objective. It comprises of strategies that will be utilized as a part of request to accomplish the project objectives, the usage of the equipment and software including the type of the raw materials that will be used within the periods of time.

3.1 Introduction

The methodology of this project incorporates the overall design process of the piezoelectric system and the strategies for testing in experiments that will be taken so as to accomplish the project objectives. Besides that, this section will include the criteria on the type of piezoelectric sensors to get the optimum output. Therefore, the system is designed to be implemented in shoes sole as the strain exists while walking.

3.2 Flow Chart

The flow chart of the task will clarify the overall process flow in other words, the path of the project taken so as to achieve the final objectives of the project. The flow chart also shows the step by step to build the project to achieve the design and develop in piezoelectric as shown in Figure 3.1 below.

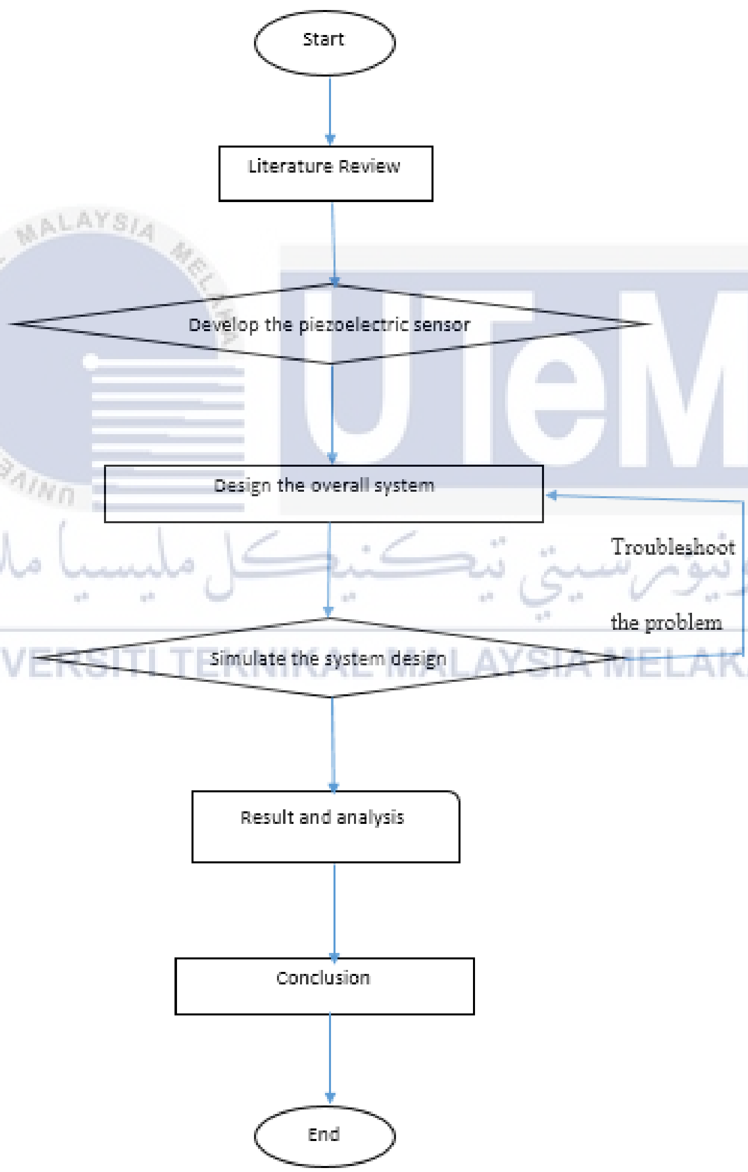

Figure 3.1: The flow chart of the project

3.3 Piezoelectric Sensor Development

In this project, the Lead Zirconate Titanate crystal (PZT) sensor or otherwise called piezoelectric transducer has been picked and created. The reason to choose this PZT sensor is because it has satisfy the criteria and has the focal point that required as the electric generations due to its affectability, operations and less expensive expense. This piezoelectric sensor will harvest energy in energy harvesting system.

The piezoelectric sensor is actually creates an AC electrical. The bridge rectifier is being utilized to change the output to a stable DC for the capacity to charge the rechargeable battery.

Moreover, the equations that is being utilized to calculate the energy produced from the piezoelectric crystal sensor is,

$$E=\frac{1}{2}V^2C \tag{3.1}$$

Where E is the energy consumed, V is the voltage delivered from the piezoelectric crystal sensor and C is the capacity capacitor.

The capability and effective of the connection of the piezoelectric crystal sensor is additionally considering into account either it is in series connection or in the parallel connection. The piezoelectric sensor in series connection usually happens to be more succesful on the output energy and the energy harvesting part is technically set up to be in series connection as it produces higher voltage meanwhile parallel will create the lower voltage . Conversely, there is more bridge rectifier circuit needed to connect with the piezoelectric sensor if the connection is connected in parallel connection according to get the greater output.

3.4 General Piezoelectric Energy Harvesting System Flow Chart

The general piezoelectric energy harvesting flow chart is clarifying the method of the system to achieve the last expectation result expectation result that includes the energy cathing, stabilizing, and changing as shown in Figure 3.2 below.

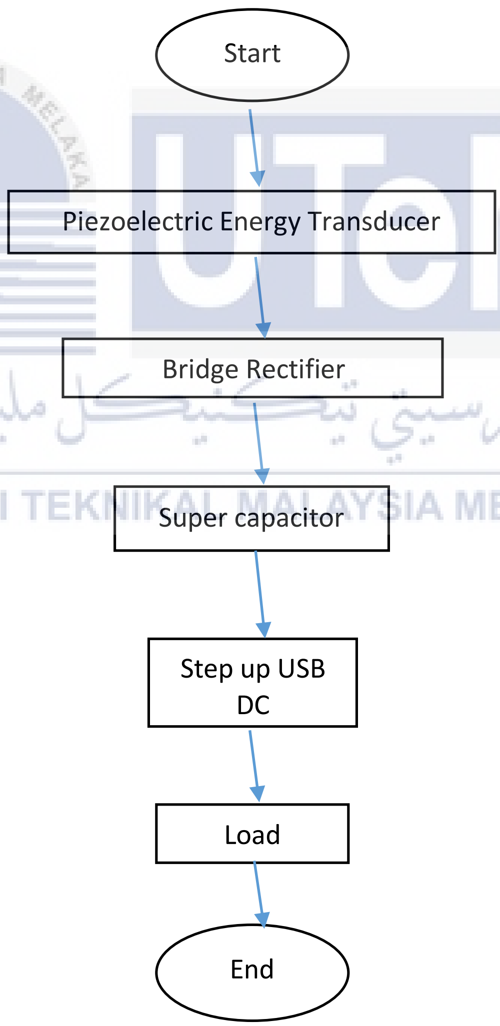

Figure 3.2: The Overall Piezoelectric Energy Harvesting System

3.5 Piezoelectric System Setup

This project will be discussed about the energy harvesting method from the shoes using piezoelectric harvesting system. The primary standard of a piezoelectric transducer is that a force, when connected on the quartz crystal, produces electric charges on the crystal surface. The charge that produced energy can be called as piezoelectricity. Piezo electricity can be defined as the electrical polarization will form by mechanical strain on certain class of crystal. So it can be used in this project, in other words, the piezoelectric will implement at the shoes because when the shoes keep moving, the electricity will produced but when the charge produced is very small, a charge amplifier is needed to produce an output voltage big enough.

The general piezoelectric harvesting system consists of three section. The first section is the energy harvesting part. The second section is the energy storage while the last part is voltage regulator to get the fixed output voltage. The piezoelectric framework happens to be utilized for day by day life especially for sport athlete as there are vibrations giving by the shoe soles from the running or walking to generate a source of electricity. The position of piezoelectric will be shown in Figure 3.3 below.

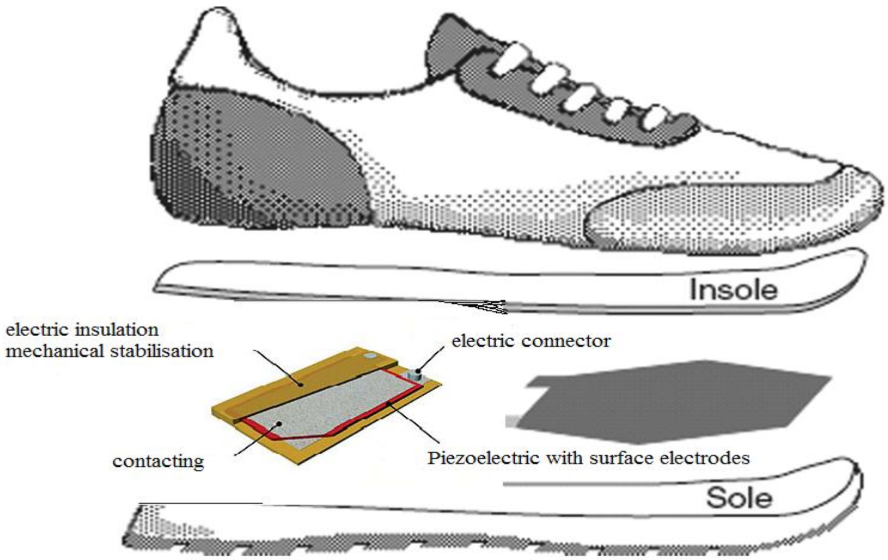

Figure 3.3: The Piezoelectric Harvesting System

3.5.1 The Energy Harvesting Part Setup

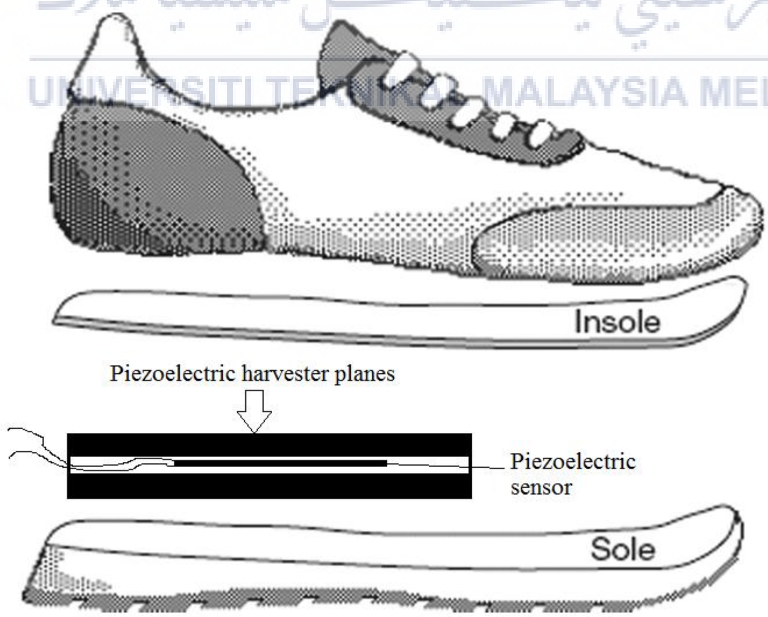

Figure 3.4: The Piezoelectric Harvester Planes

The energy harvesting part is set up by putting the piezoelectric sensor between a two rectangular plane surfaces at shoes to maintain a strategic distance from the piezoelectric sensor from harm as shown in Figure 3.4 above. The plane function is as the mechanical energy harvester as each step by the feet on the plane surface will produces the mechanical vibrations on the piezoelectric sensor.

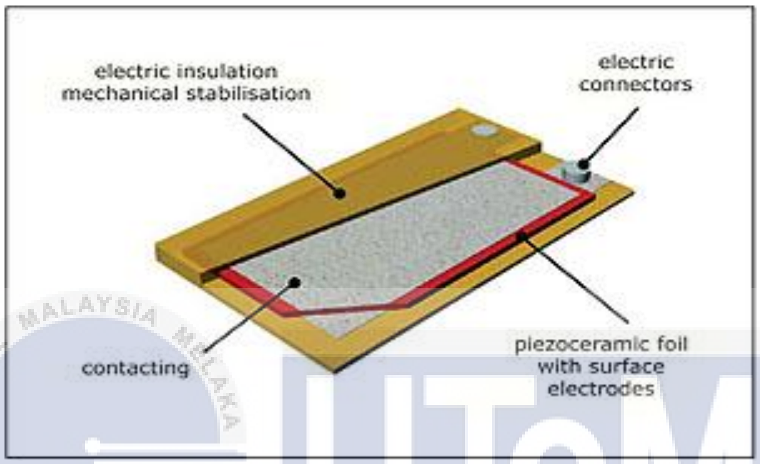

Figure 3.5: The PZT Type of Piezoelectric Sensor

There are two piezoelectric sensors that will be utilized as a part of harvesting system. The piezoelectric sensors utilized are from the Lead (PZT) crystal sensor that is put in the middle of two rectangular plane. These piezoelectric sensors is connected in series to create more output. The type of piezoelectric sensor will appeared in Figure 3.5 above.

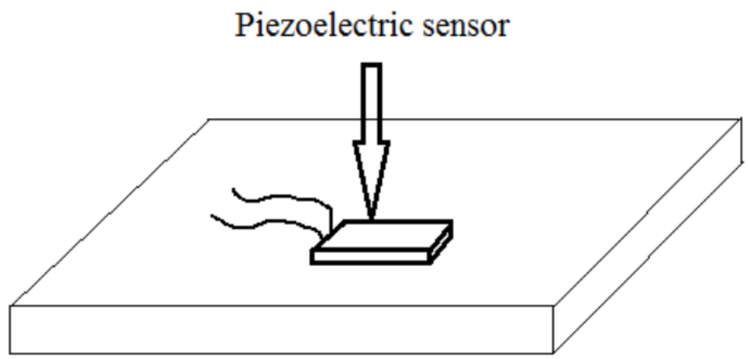

Figure 3.6: The piezoelectric sensors on the base plane

The idea of the energy harvesting with the assumptions of a feet stepping and hitting the top planes to move down toward the base planes. The top plane is arriving the base plane so that the vibrating force produced from the top plane is exchanged to the piezoelectric sensor on the base plane as appeared in Figure 3.6 above.

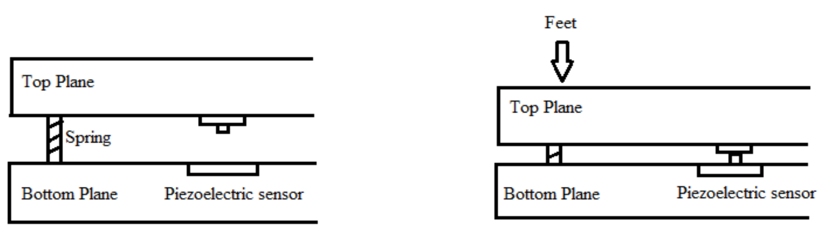

Figure 3.7: The state of the planes previously, then after the feet hit the top plane

The concept of this harvesting system consolidates the bouncing and vibrating activities. The spring in the middle of both planes is utilized to ensure that the top plane will climb again to the first beginning stage. The system is repeating with the same activities in harvesting energy by the feet.

3.5.2 The component that used in circuit

3.5.2.1 Full Wave Bridge Rectifier

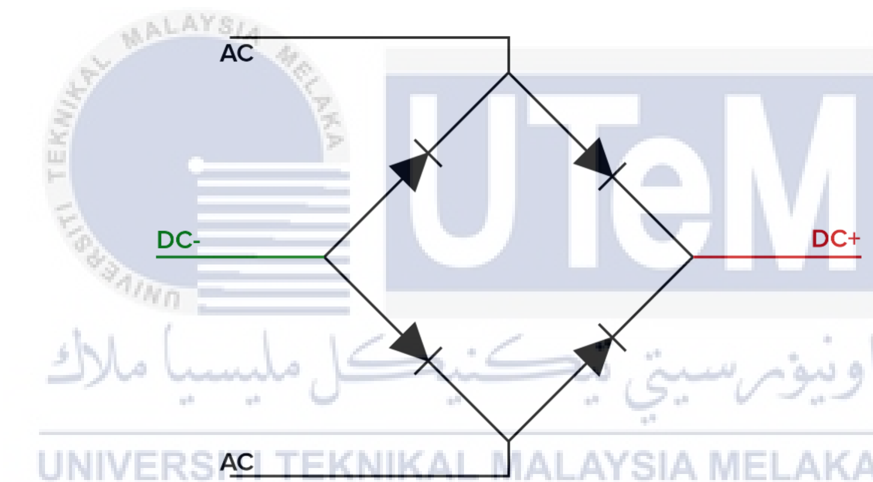

Figure 3.8: The full wave bridge rectifier of the system

Figure 3.8 demonstrate that the full-wave bridge rectifier utilized four diodes to perform full-wave rectification of an input AC voltages. Two diodes conduct during every half cycle, giving a full-wave rectified output voltage.

A full-wave bridge rectifier comprises of four diodes. Terminal 1 and 2 are the input terminals, so the input AC source in connected across 1 and 2. Terminals 3 and 4 are the output terminals, so the load is connected across 3 and 4.

At the point when the input cycle is positive, diodes D1 and D2 are forward-biased and D3 and D4 are reverse-biased. D1 and D2 therefore lead current current in the direction appeared. The voltage created is identical to the positive half of the input sine wave minus the diode drops.

At the point when the input cycle is negative, diodes D3 and D4 get to be forward-biased and conduct current in the direction appeared. Thus, the current flows in the same direction for both the positive and the negative of the input wave. A full-wave rectified voltage shows up over the load.

3.5.2.2 Supercapacitor

Figure 3.9: The supercapacitor of the system

Figure 3.9 shows that the supercapacitor, otherwise called ultracapacitor or double-layer capacitor, varies from a normal capacitor in that it has high capacitance. A capacitor stores energy by the meaning of static charge as opposed to an electrochemical response.

For this project, it will utilized the supercapacitor, appraised in farads, which is huge number of times higher than the electrolytic capacitor. The supercapacitor is utilized for energy storage undergoing frequent charge and release charge cycles at high current and short duration.

3.5.3 Step up USB DC

Figure 3.10: The voltage regulator of the system

A fixed output voltage will produces by a voltage regulator of a preset magnitude that remaining parts of changes to its input voltage or load conditions. There are two types of voltage regulators such as linear and switching.

Linear regulator employs an active (BJT or MOSFET) pass device (series or shunt) controlled by a high increase differential amplifier. It contrasts the output voltage an exact reference voltage and modify the pass device to keep up a steady output voltage.

The DC input voltage will switch by a switching regulator to a changed voltage connected to a power MOSFET or BJT switch. The filtered power switch output voltage is sustained back to a circuit that controls the power switch on and off times so that the output voltage stays steady regardless of input voltage or load current changes.

For this project, a switching regulator will be use but it will combine in some component that called step up USB DC as shown in Figure 3.10 above. The function of step up usb dc is this component will receive some voltage and will step up to 5V. The minimum value of voltage is 1.5V~5V and then will direct to output.

3.6 Design and Simulations

The software that have been tilized as a part of design the system is Multisim. In the analysis, the design of the energy harvesting is tried by utilizing Multisim programming.

The design is taking into records on the ability and the steadlines of the output that will be delivered keeping in mind the end goal to energize the super capacitor. Adjacent, the comparison between the amounts of the output from Multisim is taken for selecting the best data for making genuine model. Figure 3.11 shows that the energy harvesting part in system below.

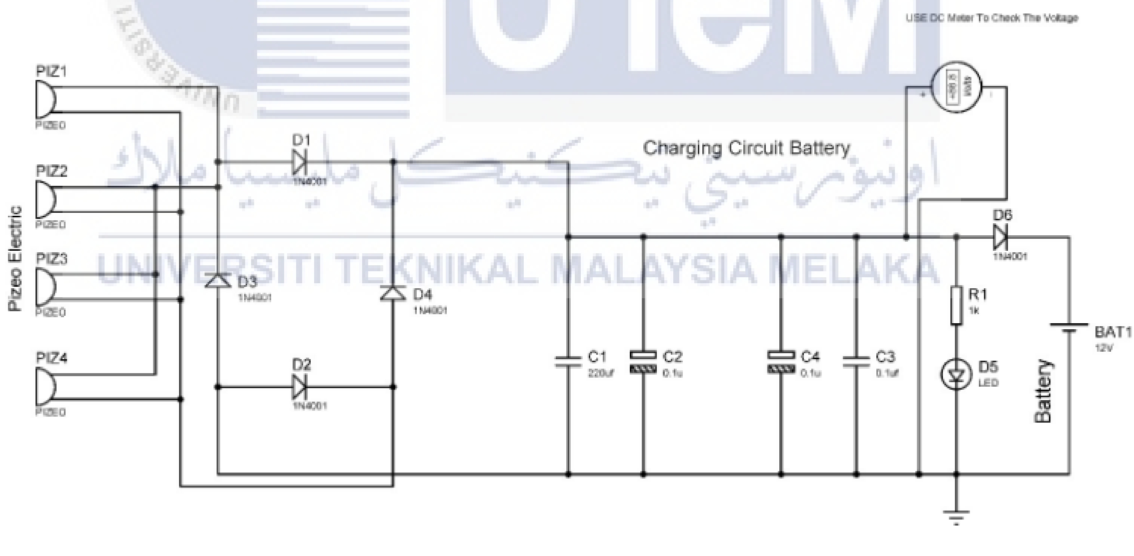

Figure 3.11: The circuit design of the system

3.6.1 The Harvesting Energy Part Simulation

The bridge rectifier is utilized as the output produced from piezoelectric sensor is in AC signal. It is additionally change the AC signal to DC signal for charging the capacitor as appeared in Figure 3.12 below. The energy created will be at first put away in the capacitor before enter to venture up USB DC.

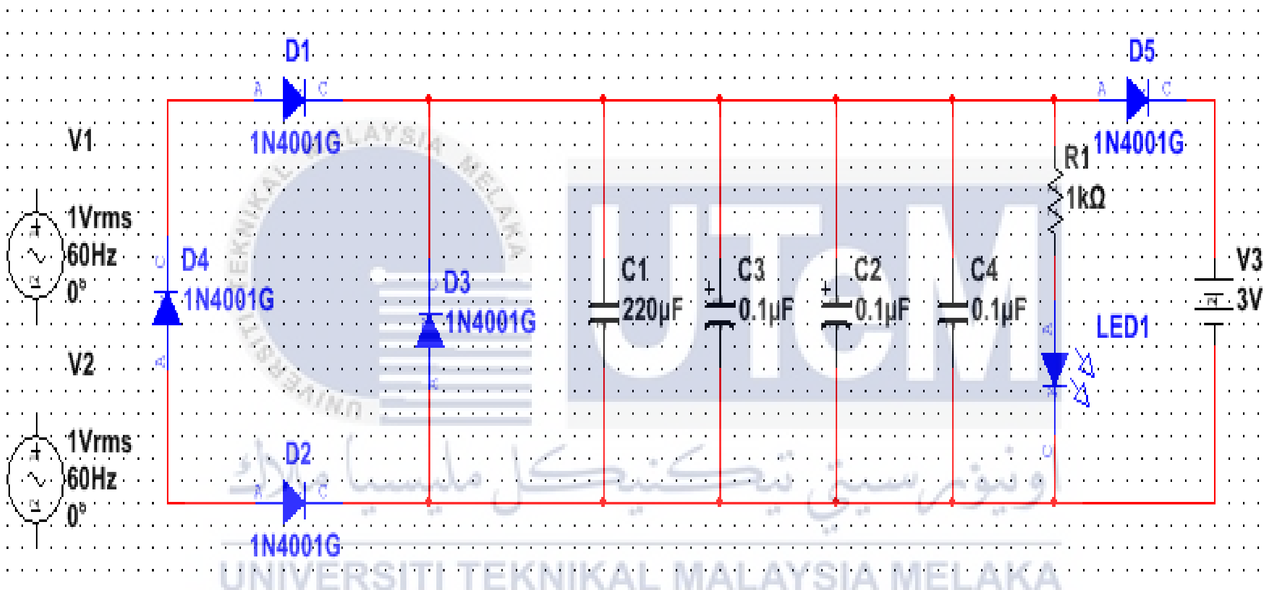

Figure 3.12: The circuit design using Multisim

The signal output after encountering the bridge rectifier and the progression up USB DC as a voltage regulator from the piezoelectric crystal sensor is bringing about the charging of the capacitor. The example of the output is appeared in Figure 3.13 below:

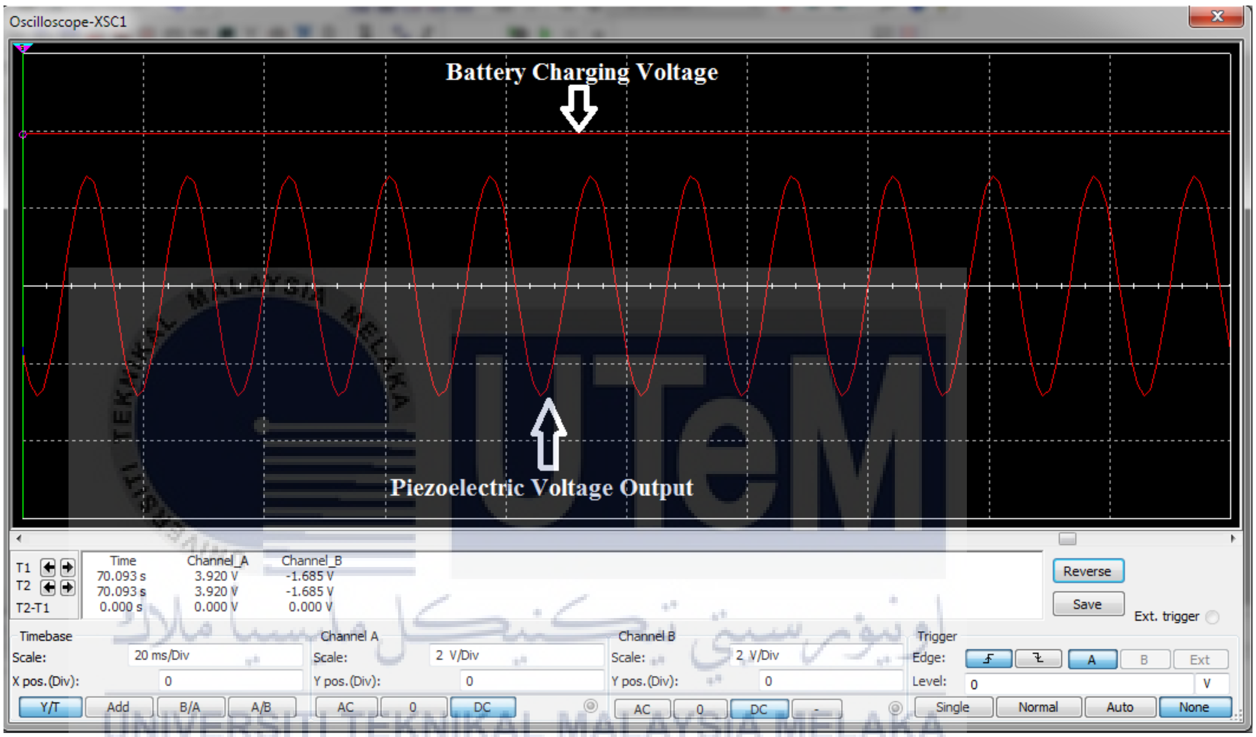

Figure 3.13: The output waveform

3.7 Conclusion

Overally, there are some procedure with respect to the project in mind the end goal to accomplish the objectives has effectively gone to a fulfillment. Introduction, literature review and methodology had done which is combine three chapter in one report at PSM 1. Firstly, the problem statement has been drilled down and took after by the objectives and the configuration of the framework. Information will proposed of the system from the past journals including how the piezoelectric sensor functions, the materials and the operations has been added to the literature review part. The literature review is then prompts the working flow of the system that is rotating on the ability of piezoelectric to harvest energy. To wrap things up, the development of the energy harvesting circuit in the system including the piezoelectric sensor connection type and the simulations utilizing the software has been finished. The instance of the output from the software will be taken as a reference and the outcome will be appeared in chapter 4 in the real project development in PSM 2.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this section, the result and data analysis will be taken and discussed using 2 different type of piezoelectric but using the same material. The material of piezoelectric that used to measure is ceramic. The type of piezoelectric as shown in Figure 4.1.1 and Figure 4.1.2 below.

Figure 4.1.1: The quartz piezoelectric crystals disc (first type)

Figure 4.1.2: The PZT of piezoelectric disc (second type)

The analysis will be taken with testing the project and checking the process. In this project, there are two main parts need to be build which are energy harvesting in the circuit and concept of piezoelectric effect can generate power from movement.

4.2 Testing and Checking

After all the component had be installed in the circuit, the continuity in the circuit done to checking the track all of the connection. It is because to confirm that the operation of this part will run nicely as shown in Figure 4.2.1 below.

Figure 4.2.1: Check the connection of output

The tools that use in this project are multimeter and LED indicator. By using LED indicator to detect the circuit will function or not and the multimeter to detect the value of voltage in order to get the output voltage. The output is connected to the digital multimeter in order to get the output voltage from the circuit. It shows that the circuit are able to produce voltage 6.8V of direct current (DC) from the multimeter as shown in Figure 4.2.2.

Figure 4.2.2: Result of output voltage at 3 minute

4.3 Analysis

4.3.1 Analyze the performance the first type of piezoelectric (quartz piezoelectric crystals)

The analysis will start with the first type of piezoelectric (quartz piezoelectric crystals) and do some procedure to make sure the operation will run smoothly. Firstly, the probe of multimeter be tap to the positive and negative connection at output circuit to measure the voltage as shown in Figure 4.3.1.1 below. The piezoelectric that used in the circuit will connect as an input as shown in Figure 4.3.1.2. The result of the voltage shows that the value become increase time by time and all the result on the multimeter is recorded as shown in Table 4.4.

Figure 4.3.1.1: Measure the voltage

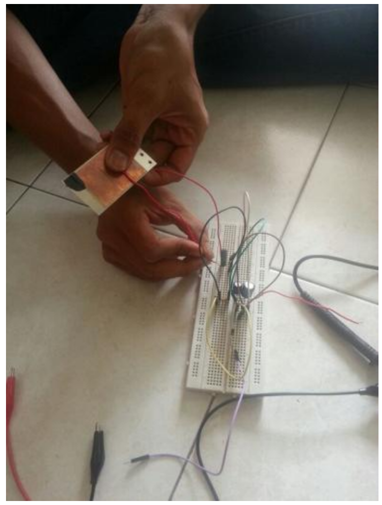

Figure 4.3.1.2: The connection of first type of piezoelectric

Based on Figure 4.3.1.3 and Figure 4.3.1.4, after 1 minute of time, the value of the voltage and current are recorded.

Figure 4.3.1.3: Data of the voltage using multimeter at 1 minute

Figure 4.3.1.4: Data of the current using multimeter at 1 minute

The value of time will measure minute by minute by using multimeter. Which are;

(a) 1 minute
(b) 2 minute
(c) 3 minute
(d) 4 minute
(e) 5 minute
(f) 6 minute
(g) 7 minute
(h) 8 minute
(i) 9 minute
(j) 10 minute

Based on Figure 4.3.1.5 and Figure 4.3.1.6, after 5 minute of time, the value of the voltage and current are recorded.

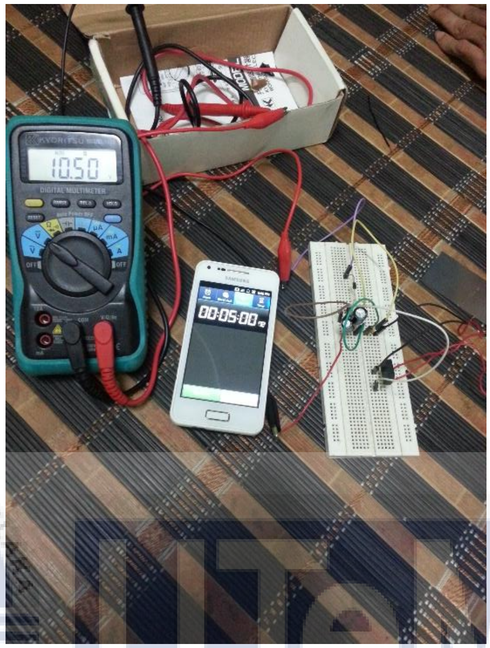

Figure 4.3.1.5: Data of the voltage using multimeter at 5 minute

Figure 4.3.1.6: Data of the current using multimeter at 5 minute

Based on Figure 4.3.1.7, after 7 minute and above of time, the value of the current are same and the data are recorded. After a 7 minute the data shows the value of the current will remain the same.

Figure 4.3.1.7: data of the current using multimeter at 7 minute

4.4 Measurement data using the first type of piezoelectric (quartz piezoelectric crystals)

The result are recorded using a multimeter of each of the time value as shown in Table 4.4. The value of voltage and current is used to calculate the value of power. The formula is used to calculate power to show in data analysis and it is of importance to investigate the

$P = I_{(mA)}V_{rms}$

$I_{(mA)} = P / V_{rms}$

Table 4.4: Data analysis measurement value

Time(min)	V	P(mW)	I(A)
1	3.60	0.18m	0.05m
2	5.49	0.44m	0.08m
3	6.80	0.82m	0.12m
4	8.20	1.15m	0.14m
5	10.50	1.58m	0.15m
6	11.20	2.13m	0.19m
7	12.27	3.07m	0.25m
8	13.06	3.27m	0.25m
9	13.38	3.35m	0.25m
10	13.55	3.39m	0.25m

4.4.1 Power analysis by using quartz piezoelectric crystal

In order figure 4.4.1.1 show the waveform power against voltage that have been recorded. It is important to measure the power to get the potential or ability to produce the power.

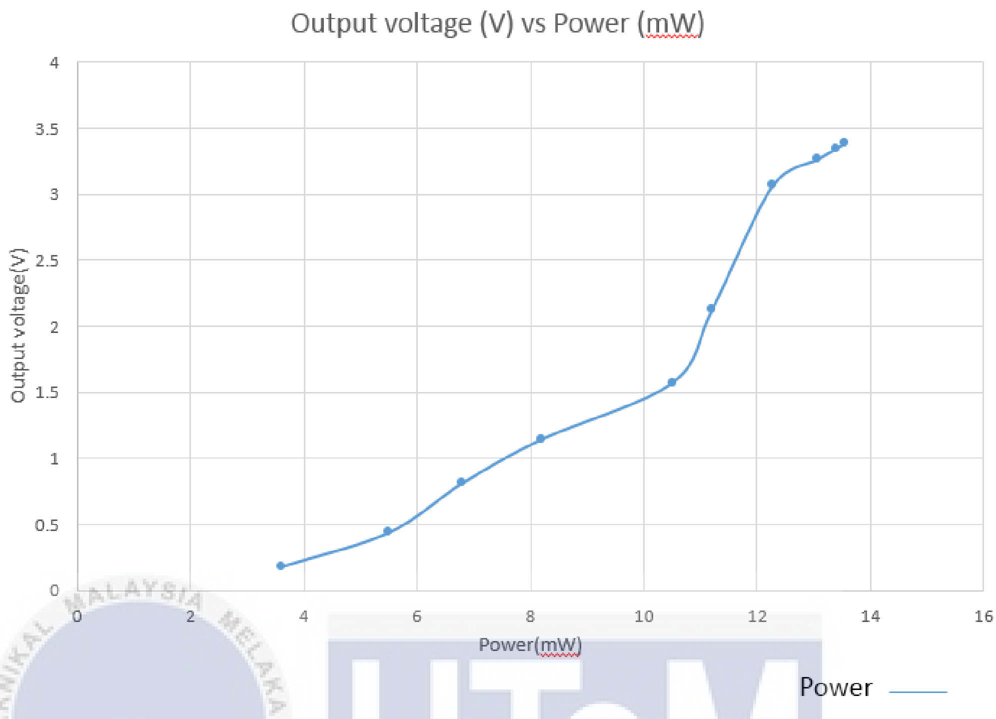

Figure 4.4.1.1 Output of voltage against power by using one side piezoelectric crystal.

4.5 Analyze the performance of second type of piezoelectric (PZT)

The second type of piezoelectric is used to measure the value of voltage and current. It is impossible to measure the current without knowledge to tab the probe of multimeter at the series condition of the circuit as shown in Figure 4.5.1 below. The connection of piezoelectric is connected to input of the circuit and the result is measured current using a multimeter.

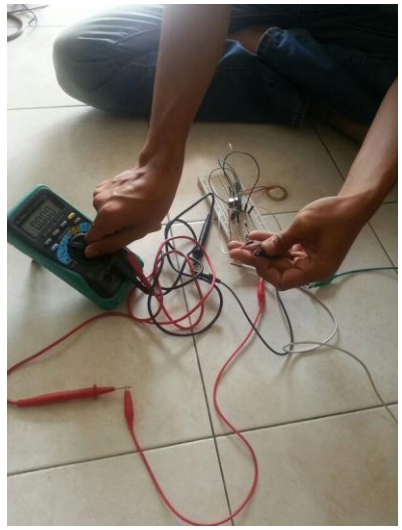

Figure 4.5.1: Tab the probe of multimeter at the series condition

The result for testing the output from the PZT type of piezoelectric. The circuit is tested in the project breadboard in order to get the output voltage and current. It can be seen that the PZT type of piezoelectric are not efficient between the one side of piezoelectric piston because the voltage are able to produce lower from the multimeter at the first minute as shown in Figure 4.5.2. The value of current are recorded as shown in Figure 4.5.3.

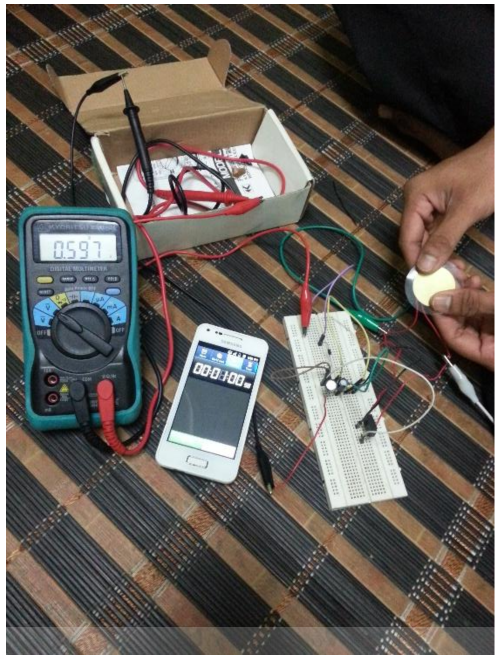

Figure 4.5.2: Data of the voltage using multimeter at 1 minute

Figure 4.5.3: Data of the current using multimeter at 1 minute

4.6 Measurement Data using the second type of piezoelectric (PZT)

Table 4.6 shows the value of the voltage and current using a PZT type of piezoelectric. It can be seen that the piezoelectric are able to generate below 5V in 10 minute. This type give the value of piezoelectric is less to generate higher voltage compare to one side of piezoelectric piston are able to generate 13.55V in 10 minute. The type of piezoelectric is not efficient to use because the piezoelectric depends on the pressure that being applied on it. When there is more of piezoelectric and get a large pressure exerted on it, the piezoelectric will produce the larger out AC voltage. Then, the time to charge up the capacitor will less.

Table 4.6: Data analysis measurement value

Time(min)	V	P(mW)	I(mA)
1	0.597	0	0
2	1.222	0	0
3	2.054	0	0
4	2.548	0	0
5	2.890	0	0
7	3.033	0	0
8	3.256	0	0
9	3.803	0	0
10	3.886	0	0

4.7 Discussion

The first type (quartz piezoelectric crystals) is more efficient than the PZT type because the output AC voltage from the first type is able to generate up to 13V in 10 minutes. If the time become more then it will actuate at the same time and will be able to get the high AC voltage. The output voltage from the piezoelectric depends on the pressure exerted on it. It also estimated that this product will need continuously function to continuously supply current to charge the battery. The current output from the both type of piezoelectric that being tested is less than 1mA because the piezoelectric material has the properties of high impedance and high frequency of operation. From the result, it can be seen the value of voltage and current are not stable because the piezoelectric have a resonant frequency because in theory, resonance is a phenomenon in which a vibrating system or external force drives another system to oscillate with greater amplitude at a specific preferential frequency. Other than that, maybe due to the tolerance of the multimeter.

Assume that a PCB Battery has the following specifications as shown in Figure 4.7.1:

3.6V Battery

8mA

80mAh

Figure 4.7: Specifications of PCB Battery

Table 4.7 shows the calculation of voltage, current and power consumption between normal PCB battery and the quartz piezoelectric crystal.

Table 4.7: Data between PCB battery and quartz piezoelectric crystal

	PCB Battery	**Quartz Piezoelectric Crystal**
Voltage	3.6 V	13.3 V
Current	$I = \frac{8\text{mA}}{24}$ = 0.333A	$I = \frac{0.25\text{mA}}{24}$ = 0.01mA
Power consumption	P= 3.6(0.333A) = 1.12 W	P=13.3(0.01mA) =0.133mW

In theory, human consumes 3300 watt hours of energy every day but the potential to produce more than 3 times that amount p to 11 000 watt hours of power from normal bodily function such as motion and the production of body heat. For example, walking produce 163 watts of power, while sprinting generates more than 1600 watts.

In this part, the minimum output that needs for charging is 0.006V in 20 second. Its show that the piezoelectric transducer gain more output voltage if the user step on it continuously. An average walking steps for human is 6201 in a day, 259 per hour. For charging the PCB battery by quartz piezoelectric crystal, it will charge 0.018V per minutes. So that, the battery can achieve 3 - 4 hours to get full charge of battery 3.6V depends on pressure that give on it. User must step continuous to gain more current and voltage, so that the mobile phone can be fully charge while walking, jumping, or running. This project very suitable for a person that use to hiking in emergency case need a supply.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

As a conclusion, this project is considered achieved all the objectives have been set. The circuit is successfully tested and implemented which is cost effective and affordable energy harvester to be used by human. The discussion based on the result data analysis that can be deduced are:

(a) To get a large of output current, the parallel in connection of piezoelectric must be used compared than series connection.

(b) The first type (quartz piezoelectric crystals) is more efficient to use compare than the PZT type because the first type can generate more output current and voltage even though only one piezo that used.

(c) The analysis for the quartz piezoelectric crystal is done by using time to measure. The value of voltage is varied from 3.598V until 13.55V and the current output have recorded. The results show that the output voltage and current is increase smoothly when the users continuously step on it.

(d) The both type of piezoelectric are capable producing high AC but in low current due to the piezoelectric has the property of high impedances and high frequency of operation.

5.2 Recommendation

A few recommendations have been listed in order to improve and make further development on the performance and effectiveness of piezoelectric transducer to get the best function.

(a) The bright LED indicator can be installed on the side of shoe. It will help the user walk at night by providing light at dark along the walk away. It is more effective based on piezoelectric generating electricity once they us stressed exist on piezoelectric disc.

(b) The project need to add more disc and stack it together. So that, the output voltage can be increasing smoothly.

(c) This project has some potential to be improved and make it to be able to charge the mobile phone battery. In future, this product can be useful for human in fact to change the human lifestyle in practicing the healthy one.

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