DESIGN AND DEVELOPMENT OF PIEZOELECTRIC MICRO-GENERATOR FOR POWERING UP LOW ELECTRONIC DEVICE

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DESIGN AND DEVELOPMENT OF PIEZOELECTRIC MICRO-GENERATOR FOR POWERING UP LOW ELECTRONIC DEVICE

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

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Signature	:	……
Supervisor Name	:	Prof Madya Dr Kok Swee Leong
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DEDICATION

I would like to dedicate my thesis to my beloved family.

ABSTRACT

Battery always been the first choice for every low electronic device such as remote control, watches and etc. However, battery has limited lifespan and pollute the environment after disposal. One of the alternative ways is replacing battery is by using energy harvester that utilize the energy produced by the piezoelectric cantilever. The piezoelectric cantilever is able to generate electric charge in response to applied mechanical stress. However, the power produced by the piezoelectric is in AC form, which is not suitable for DC powered electronic device. Moreover, the vibration produce by the cantilever is inconsistent and random. Therefore, the aim of this project is to produce a piezoelectric micro-generator in the form of cantilever that able to power up the application with the energy harvested from ambient vibration sources and characterize the cantilever to have wider operating frequency band. The AC voltage is converted to DC voltage with a rectifier and stored in a supercapacitor up to 3.3V. The project was able to power up RF transmitter to send out signal with the energy stored in the supercapacitor.

ABSTRAK

Bateri sentiasa menjadi pilihan pertama untuk setiap peranti elektronik yang rendah seperti alat kawalan jauh, jam tangan dan sebagainya. Walau bagaimanapun, bateri mempunyai jangka hayat yang terhad dan mencemarkan alam sekitar selepas pelupusan. Salah satu alternatif untuk menggantikan bateri dengan menggunakan tenaga penuai yang menggunakan tenaga yang dihasilkan oleh julur dalam piezoelectric. Julur yang piezoelectric ini mampu menjana caj elektrik sebagai tindak balas kepada tekanan mekanikal Gunaan. Walau bagaimanapun, kuasa yang dihasilkan oleh pihak piezoelectric adalah berbentuk AC, yang tidak sesuai untuk peranti elektronik DC yang berkuasa. Selain itu, menghasilkan getaran oleh julur ini adalah tidak konsisten dan rawak. Oleh itu, tujuan projek ini adalah untuk menghasilkan mikro-penjana piezoelectric dalam bentuk yang dapat kuasa sehingga permohonan itu dengan tenaga dituai daripada sumber-sumber getaran ambien julur dan mencirikan julur mempunyai operasi yang lebih luas band frekuensi. Voltan AC ditukar kepada voltan DC dengan rectifier dan disimpan dalam supercapacitor sehingga 3.3V. Projek ini telah dapat kuasa pemancar RF untuk menghantar isyarat dengan tenaga yang disimpan dalam supercapacitor tersebut.

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Besides that, I am glad and grateful to the people that had helped me throughout this project so that I can complete the project in time. Upon completing this project, I have learnt managing time properly is crucial. Because completing this project is time-comsuming. I have to plan and implement this planning to have produce desired result.

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LIST OF SYMBOLS AND ABBREVIATIONS

RF	:	Radio Frequency
WSN	:	Wireless Sensor Nodes
AC	:	Alternating Current
DC	:	Direct Current

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CHAPTER 1

INTRODUCTION

1.1 Overview

In this present time, there are huge demands of energy harvesting technologies as our world is constantly enhancing the technologies to greener technology and environmental friendly. Energy harvesting can be known as a process of capturing and storing the ambient energy and converting it into a usable electricity. Thus, many low power electronic application is using energy harvesting system as it is a self-powered electronic system which greatly improve the performance as it does not require any external source to operate. There are many common ambient energies in our surrounding such as solar, thermal energy and etc. These energies also can be known as large scale high power generation and are highly potential as they can be harvested. These never-ending and free energy sources are captured, accumulated, stored and

lastly turning them to a usable electric energy source. According to the research, it stated that energy harvesting and large scale renewable energy generation has the same concept but in a very different scale whereby the large scale power generations is dealing with megawatts of power while the energy harvested can power-up low electronic components of the application which require power range from a few milli-watts to a few watts (Jing and Leong, 2017). Energy harvester offer another alternative way where the power range may be small but it can be in large number to accumulate more power. Besides that, this energy harvester is able to be embedded in building, floor and etc, which most of the large scale power generation is unable to be embedded. Example of the application that contains low-powered electronic components are automobile, medical, home appliance and others. In essence, ambient energies are for application which require low power consumption.

Piezoelectric is device which converts the mechanical energy to electric energy. Mechanical energy is available almost everywhere, which makes mechanical energy an excellent energy to be harvested for powering wireless sensor nodes (KWright and SRoundy, 2004). Piezoelectric has it owns advantages as it is small volume devices and simple technology which there are no external source. It is compatible with the micro electromechanical system (MEMS) where it has a high energy storage density and easier to be integrated with electronic circuit.

Many applications that use traditional battery as power source are able to be replaced by replacing it with energy harvesting system. Hence, design and development of piezoelectric micro-generator for powering up low electronic devices is proposed as a final year project in order to lower the cost and eliminates the needs of maintenances throughout the life span of the appliance itself. In the thesis, a

piezoelectric cantilever will be used, it has the same resonant frequency as a generator to power low electronic devices. Piezoelectric cantilever holds characteristics which it generates linear output when it is non-resonant and non-linear but higher output when resonant frequency. In short, piezoelectric cantilever can be create micro-power generator when the frequency is near to resonant since the power generated at this region is large. This research includes characterizing the frequency response of the piezoelectric cantilever by placing different proof mass with intention to alter the resonant frequency region of the cantilever into the required operating frequency range which is in between 210Hz to 230Hz. By adding proof mass, the resonant frequency will be lowered down to a lower frequency region in order to harvest maximum power at low frequency region. Therefore, piezoelectric cantilever with the altered resonant frequency which is in between 210Hz to 230Hz are functioned as wide-band energy harvesting.

A piezoelectric power conditioning and storing circuit is also included in this system as the electrical energy produce by the piezoelectric is an alternative current power with an instantaneous peak voltage which is proportional to the level of vibration. In order to have a direct current power, a rectifier circuit is needed. In short, rectifier circuit is able to convert AC power to DC power in order for the low electronic devices to operate. Moreover, in order to fulfill the requirement for the harvested energy application, other components in the circuit are also needed. In the end, the characterized micro-power generator is integrated with the piezoelectric power conditioning and storing circuit which consists of Radio Frequency (RF) to create a self-powered system.

1.2 Problem Statement

Piezoelectric is a component that generate voltage when there is mechanical stress. Piezoelectric cantilever produces the electrical energy in bending mode at the resonant frequency. Therefore, there are some problems stated by following below when handling the energy harvester:

a) Traditional battery uses on the low power electronic components have a short lifespan and can pollute the environment if not properly disposed.
b) The electrical energy generated by the piezoelectric will be in AC form. However, mostly electronic devices or components use DC form to power up. Hence, DC power is needed.
c) Piezoelectric that harvest energy from the ambient vibration produces inconsistent and random output voltage. Low vibration amplitude have insufficient energy to power out the low electronic devices while high vibration amplitude which generate excess electrical energy will damage the electronic devices. Hence, voltage generated by the piezoelectric should be regulated before being use on the low electronic devices

Piezoelectric cantilever based power generator uses the resonant regions to produce higher power value. The first things to do is to tune and characterize the piezoelectric cantilever by altering the mass so that it can achieve resonant frequency when vibrated at proposed frequency. Moreover, in order to transform AC power to DC power, a suitable rectifier circuit is needed. A rectifier is proposed as the ac-dc rectifier. Lastly, some storage elements are used to store and accumulated the harvested energy for intermittent use. Thus, supercapacitor is used as storage elements due to past research on piezoelectric (Guan and Liao, 2005).

1.3 Objectives

These are following three objectives for this final year project that need to be achieved:

a) To characterize the frequency response of the piezoelectric cantilever by changing its effective mass.
b) To fabricate the circuit for the energy storage of the piezoelectric micro-generator energy harvesting.
c) To test the functionality of the energy generated from the energy harvester on RF application.

1.4 Scope of Work

The research will be conducted in the laboratory where the required equipment is act as ambient vibration source. The equipment used included function generator from combo tester, electrodynamics shaker from Labworks INC, gain amplifier from Labworks Inc and oscilloscope from RIGOL. The materials used included piezoelectric cantilever from Piezo System Inc, Piezoelectric and power conditioning storing circuit and RF. This research is focus on the following properties:

a) Off-the-shelf piezoelectric material from Piezo System Inc is used in this research.
b) The performance of the system will be in the frequency range of 50 Hz to 500 Hz and acceleration level 1-g which resembles the ambient vibration source when characterizing the cantilevers
c) The operating frequency range between 210 Hz to 230 Hz.
d) Low power electronic components that will be used to show the functionality of the storing circuit and the voltage produced by the piezoelectric cantilever is RF.