BUS STAND LAMP USING PIEZOELECTRIC ENERGY

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A report is submitted in partial fulfillment of the requirement for the degree of Bachelor in Electrical Engineering (Industrial Power)

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I declare that this report entitle "Bus stand lamp using piezoelectric energy" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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"I hereby declare that I have read through this report entitle "Bus stand lamp using piezoelectric energy" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : ……………………………….

Supervisor's Name : En Mohamad Na'im bin Mohd Nasir

Date : ………………………………

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ABSTRACT

The development of piezoelectric energy harvester has quickened up in last few years mainly due to semiconductor improvements. Harvesting ambient vibration energy through piezoelectric element is increasing lately due to the technology growing more to use free energy source. The prototype development of bus stand lamp using piezoelectric energy was developed to show the concept of the harvester system. This product overcomes the problem of lacking lighting system for bus stand at rural place. The piezoelectric disc was place on the floor to gain energy from people walking across this area. The location to place this piezoelectric disc is determined in order to maximize the harvesting output power from people step on it. Power that harvested will be stored in the supercapacitor or battery before delivered to the load. This product used light emitting diode (LED) to light the bus stand as energy efficiency of LED is high compared to the traditional lighting. This bus stand is using LDR sensor to make it only turns on light when at night. In this project, two experiments were conducted to determine the maximum output of this piezoelectric harvesting base that can generate. From the experimental results, it show that the piezoelectric energy harvester base can generate a significant output that can charge the battery.

ABSTRAK

Pembangunan penjanaan tenaga piezoelektrik semakin pesat dalam beberapa tahun kebelakangan ini disebabkan oleh peningkatan dalam bidang semikonduktor. Penjanaan tenaga getaran melalui bahan piezoelektrik semakin meningkat akhir-akhir ini kerana teknologi sekarang lebih kepada menggunakan sumber tenaga bersih. Prototaip pembangunan perhentian bas menggunakan tenaga piezoelektrik telah dibina untuk menunjukkan konsep sistem penjanaan ini. Produk ini dapat mengatasi masalah kekurangan sistem lampu pada perhentian bas khususnya di kawasan luar bandar. Piring piezoelektrik ditempatkan di atas lantai untuk megumpul tenaga daripada orang berjalan di kawasan tertentu. Lokasi untuk meletakkan piring piezoelektrik ini ditentukan terlebih dahulu untuk memaksimumkan keluaran kuasa dari orang yg memijak di atasnya. Kuasa yang dijana akan disimpan di dalam superkapasitor atau bateri sebelum dihantar ke beban yang lain. Produk ini mengunakan diod pemancar cahaya (LED) untuk menyalakan perhentian bas itu kerana kecekapan lampu LED adalah tinggi berbanding dengan lampu tradisional. Perhentian bas ini menggunakan sensor LDR untuk menghidupkan lampu (LED) apabila pada waktu malam. Dalam projek ini, dua eksperimen telah dijalankan untuk menentukan keluaran maksimum dari sistem penjanaan piezoelektrik ini. Daripada keputusan eksperimen, ia menunjukkan bahawa keluaran voltan dan arus dari penjana tenaga piezoelektrik boleh menjana output yang boleh mengecas bateri.

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LED	light emitting diode
AC	alternating current
DC	direct current
LDR	light dependent resistor
PZT	lead zirconate-titanate
PVDF	polyvinylidene fluoride

CHAPTER 1

INTRODUCTION

1.1. Introduction

Research for an alternative energy source that can provide power supply is increasing greatly with time as our technology is moving more to free energy source. The concept of implementing piezoelectric materials into the environment to provide a sustainable power source is drawing a lot of attention to the scientific community [1]. The ability of this material to harvest energy from vibration attracts people to do more research about the capability of this material to generate more energy.

The focus of this project is to develop a piezoelectric energy harvesting system, where the main design is to harness the vibration energy from walking people at bus stand and turn that wasted energy into electricity to power light emitting diode (LED) at that bus stand. Piezoelectric material can provide a solution to this design constrains because of their mechanical properties of being small, lightweight and their versatility in an endless array of applications [2].

1.2. Project Background

This project focuses on designing a piezoelectric energy harvesting system that can power up bus stand lamp. A product designed is environmentally friendly systems because it generates electricity by using wasted energy from the vibrations produced by people walking on the floor. It uses piezoelectric effect to generate voltage and then charge the battery to power up bus stand lamp at night. Piezoelectric elements are integrated in the floor at the bus stand to change the pressure and vibration into electrical power. This system provides control circuit that will turn on the lamps at night.

1.3. Problem Statement

In Malaysia, many incidents reported occur at bus stand especially at night. Usually this happens when they do not have adequate facilities such as lighting systems at the bus stop. In urban areas, bus stand normally is provided with lighting system, but in rural place, such things are not provided. Usually this occurs when the TNB pole is far from the bus stop so it is difficult to connect the supply to the bus stand. Nowadays in Malaysia, the increase in numbers of public transport users caused the bus stand always full with peoples. By taking advantages of this condition, wasted energy can be harness from foot step on the floor of the bus stand and ultimately manipulating the energy into something useful and beneficial to transport users.

1.4. Objective

The objectives of this project are:

- To analyze electrical performance of piezo energy.
- To develop a model of piezoelectric energy harvester system for bus stand lamp.
- To verify the reliability of bus stand model and energy harvester base.

1.5. Scope

This project focuses on designing energy harvesting system using piezoelectric ceramics disc. This project uses piezoelectric ceramics disk as an energy harvester that harvest energy from vibrations of people walking on the floor. It use super capacitor size 0.47 Farad 5.4Volt as energy storage element. This project also uses four diode functions as full bridge rectifier to convert AC voltage from piezo disc to DC voltage. Zener diode is used as a protection for super capacitor. For the lighting system, it uses light emitting diode (LED) and light dependent resistor (LDR) sensor for night detection system. The reliability of the system will be verified from the experiments by considering the output voltage and current.

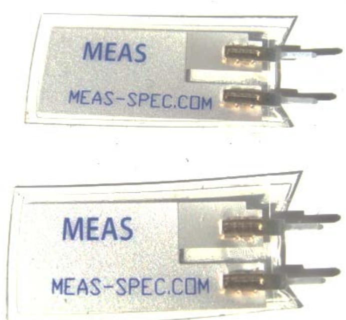
CHAPTER 2

LITERATURE REVIEW

2.1. Piezoelectric

Piezoelectric is an effect of the electromechanical relationship that allows certain materials such as crystals and synthetic ceramics to produce an output voltage power that come from mechanical stress or vibration. Piezoelectric elements are widely used in many applications such as acoustic transducers, mechanical actuator and for electric energy harvesting system. Ceramics such as lead zirconate-titanate or PZT and bimorph such as polyvinylidene fluoride or PVDF are common type of piezoelectric materials. Material type bimorph element has its own advantages like being soft and flexible, but they have lower dielectric and piezoelectric constant than ceramics [3]. Most efficient materials are quite expensive. For this project, cheaper materials such as ceramics disc that are much less efficient, but will still work to demonstrate the concept of piezoelectric energy harvesting will be used. Table 2.1 shows the different type of piezoelectric material that normally used in the energy harvesting system.

Table 2.1 Different type of piezo material

Type of material	Explanation
Ceramic disc 	Piezoelectric ceramics is referred to polycrystalline made by maxed oxide (zirconia, lead oxide, titanate, etc.)which experienced by high sintering and solid state reaction, then through high-voltage direct current polarized, so it have the general term of the piezoelectric effect of ferroelectric ceramics[4].
PVDF film 	Piezoelectric PVDF polymer is a long chain, semi crystalline polymer having the repeat unit (CH_2-CF_2). It is approximately 55% crystalline and has a molecular weight of typically 4 x 10^5.Piezoelectric PVDF polymer due to its perfect elastic properties and high piezoelectric constant can be good applicant for energy harvester [5].

2.1.1. Lead zirconate-titanate (PZT)

Lead zirconate-titanate (PZT) is the most commonly used piezoelectric materials for power generation. PZT ceramic is suitable for energy harvesting systems since the efficiency of conversion from mechanical to electrical energy controlled by the piezoelectric constants d and g and PZT ceramics have a high piezoelectric constant and the quality factor [6]. PZT form a tetragonal structure with a small atom in the center as shown in Figure 2.1. When the crystal is strained, the center atom displaces from its lattice site and creates a potential [7].For this project, the displacement at the center atom caused from pressure from people walking on the floor will allow energy harvesting process occurs.

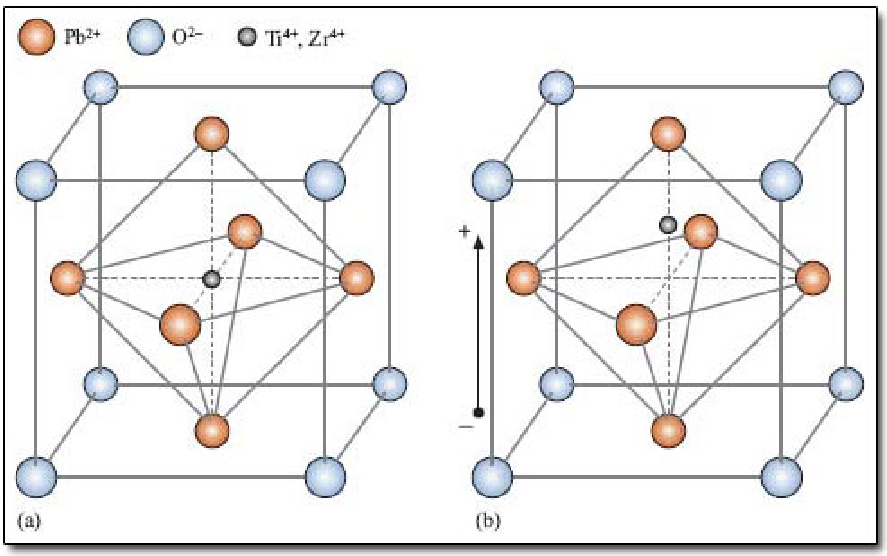


Figure 2.1 Lead zirconate-titanate crystal structures [7]

2.2. Application of piezoelectric

Piezoelectric ceramics are important high-tech materials, the laser information technology, electronics technology, sensor technology, measurement technology, precision machining technology, communications, biotechnology, medicine, navigation, automatic control, ultrasound and sound of water, fire and explosion in the army, commercial and public areas have been widely used [4].

Such as ultrasonic motors, it uses the inverse piezoelectric effect piezoelectric material to change the power to the elastic energy of mechanical vibration. Through friction between the stator and the mover to drive actuators perform rotary or linear motion; this is a new electric machine. Ultrasonic motor performance is dependent on the effective strain energy transmitted to the piezoelectric ceramic oscillator. Different locations in the piezoelectric ceramic oscillator vibration can stimulate different levels vibrator. So the optimum design and application of piezoelectric ceramic in ultrasonic motor is important [4].

Most conventional speakers are not designed to be thin, because the magnetic transducer driven requires additional depth to enhance low-frequency sound [8]. By using piezo disc, the vibration of that disc can transform it into a speaker.

In automotive, application of piezoelectric can be such as in air bag sensor and seat belt buzzer. In daily use, application of piezoelectric can be seen in cigarette lighter, musical instruments and also in depth finder device.

2.3. Piezoelectric Energy Harvester Circuit

Equivalent circuit of the piezoelectric harvester [9] can be represented as a spring mass system mechanically coupled to the electrical domain as shown in Figure 2.2. Here, L_M represents the mechanical mass, C_M the mechanical stiffness and R_M takes into account the mechanical losses. Domain mechanically coupled to the electrical domain through a transformer that converts the pressure to current. On the electrical side, C_P represents the plate capacitance of the piezoelectric material. At or close to resonance, the whole circuit can be transformed into electrical domain, in which the piezoelectric element when excited with sinusoidal vibrations can be modeled as a sinusoidal current source in parallel with a capacitance C_P and resistance R_P [10].

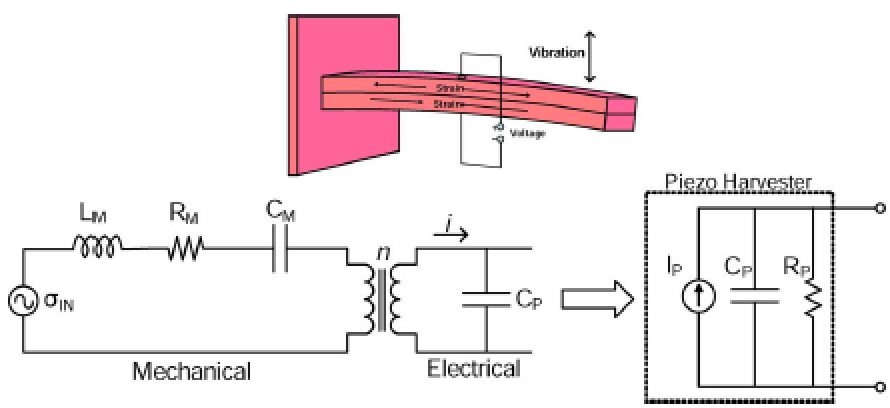


Figure 2.2 Equivalent circuit of a piezoelectric energy harvester showing the mechanical and electrical sides of the device [9]

Energy harvesting systems nowadays normally consists from four main important parts. It consists of energy source, full bridge rectifier circuit, energy storage and load. For energy source, piezoelectric element that harvest energy from footstep walking people on floor will be used. Component like piezoelectric element will produce an output in AC form. Full bridge rectifier circuit will be used to convert this AC form into suitable DC form. For energy storage, super capacitor will be used to store energy and transfer it to the light emitting diode (LED) as the load.

2.3.1. Full Bridge Rectifier circuit

Full bridge rectifier is usually used as a rectifier circuit to convert the AC output voltage of the piezoelectric harvester to DC voltage [10]. Common implementation of this rectifier circuit is shown in Figure 2.3. Capacitors C_{RECT} on the output rectifier are considered as large compared to C_P and thus holds the rectifier output voltage (V_{RECT}) is essentially constant in the cycle to cycle. With this assumption, the voltage and current waveforms associated with the circuit is shown in Figure 2.3[10].

The non-idealities of the diodes are represented using a single parameter V_D which is the voltage drop across the diode when current from the piezoelectric harvester flows through it. Every half cycle of the input current wave can be divided into two areas. For the full-bridge rectifier, in the period between $t=t_0$ and the $t=t_{OFF}$, piezoelectric current I_P flows into C_P to charge or discharge it. During this period, all the diode is reverse biased and no current flows into the output capacitor C_{RECT}.

This situation continued until the voltage across the capacitor C_P labeled as V_{BR} in Figure 2.3 is equal to $V_{RECT} + 2V_D$ in magnitude. When this happens, one set of diodes turn ON and the current starts flowing into the output. This is the interval between $t=t_{OFF}$ and in $t=t\pi$. This interval will last until the current I_P changes direction. The shaded part of the current waveform shows the amount of the charge is not transfer to the output of every half cycle. At low values of V_{RECT}, most of the charge obtained from the harvester to flow into the output but the output voltage is low. At high values of V_{RECT}, little charge flows into the output [10].

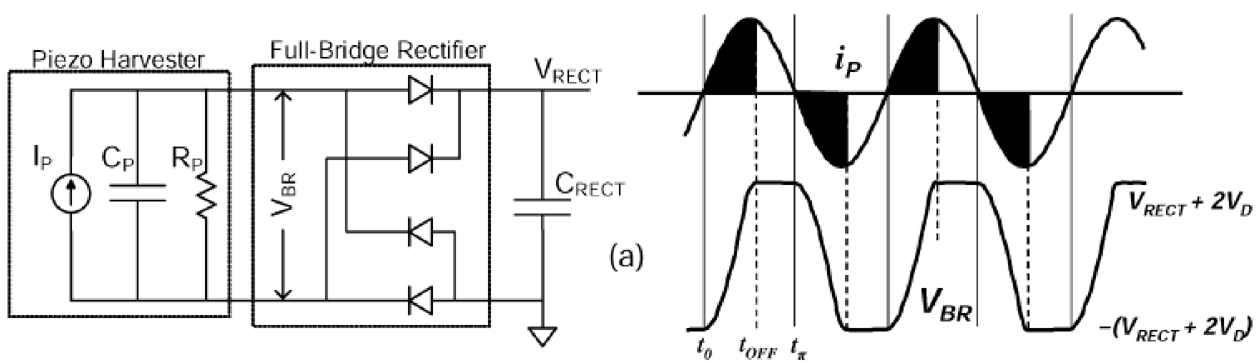


Figure 2.3 Full bridge rectifier used to convert AC signal to DC signal from piezoelectric energy harvester and associated generated voltage and current waveform [10]

The opposite trend causes full bridge rectifier output power to vary with V_{RECT}. Output power obtained by the full bridge rectifier in the presence of diode non-idealities can be given by equation 2.1 [10]

$$P_{RECT,\ FB} = 4C_P V_{RECT} f_P\ (V_P - V_{RECT} - 2V_D) \quad (2.1)$$

where the term V_P is the open-circuit voltage amplitude at the output of the piezoelectric harvester which can be represented as $V_P = I_P / \omega_P C_P$. The maximum power [11] that can be obtained using the full-bridge rectifier is given by equation 2.2

$$P_{RECT,\ FB}\ (max) = C_P\ (V_P - 2V_D)^2 f_P \quad (2.2)$$

and this is achieved at $V_{RECT} = V_P / 2 - V_D$.

2.3.2. Filter

A filter that usually used in the piezoelectric harvesting circuit is capacitor. This capacitor act as smoothing element and also called filter capacitor. Its function is to smooth the ripple in half wave / full wave output from bridge rectifier into smooth DC signal. Large value of capacitor is connected to the load function as a storages device. When the varying DC voltage from the rectifier is falling, this capacitor will supply current to the output.

The Figure 2.4 shows the full bridge circuit with smoothing capacitor and waveform that produce from smoothing process.

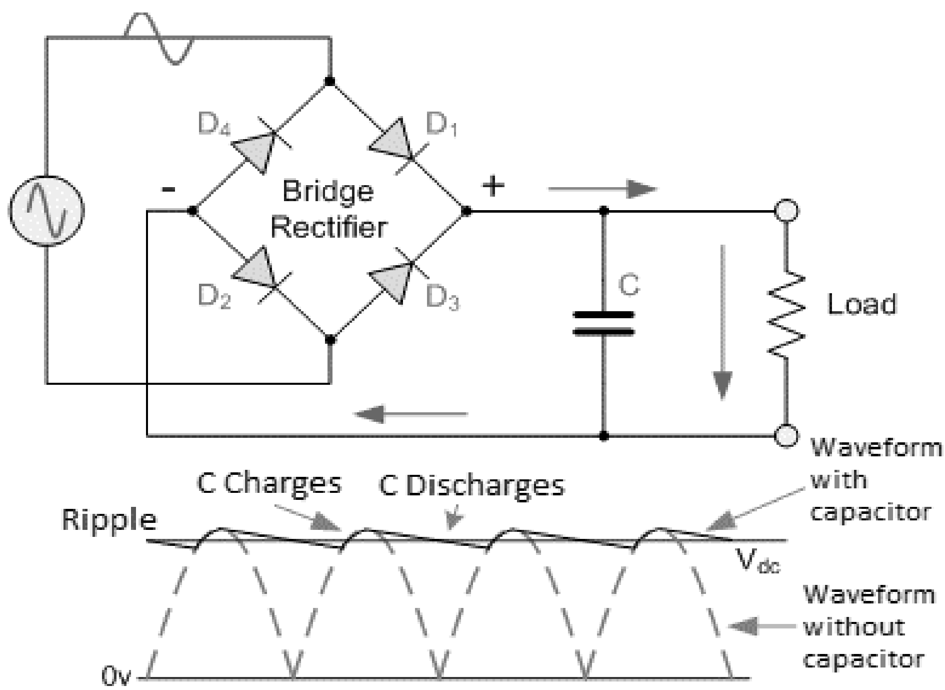


Figure 2.4 Full bridge circuits with smoothing capacitor and output wave