PIEZOELECTRIC GENERATOR

By

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Dissertation submitted

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CERTIFICATION OF APPROVAL

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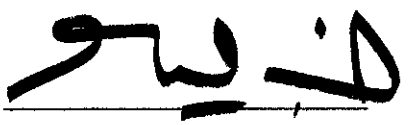
Approved:



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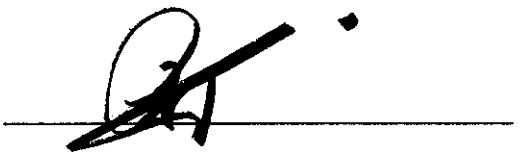
CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



(MOHD EZZUAN BIN AHMAD)

ABSTRACT

Piezoelectric are the materials that can be used to transform ambient vibrations into electrical energy. This energy than will be stored and used to power other devices. With the micro scale devices, piezoelectric power generation can provide an alternative power sources used to operate certain types of sensors or actuators. Piezoelectric generator is a device that will generate electrical energy from the vibration sources. This project will be using a milistructure of bi-morph piezoelectric material. This material will be used to transfer the ambient vibration into electrical energy. The piezoelectric generator is implemented on a motorcycle, where it will absorb the vibration from motorcycle in order to convert to electrical energy. Motorcycle always produce vibration when on the road, and thus can be used to generate electrical energy using piezoelectric. This electrical energy than will be used to power electrical components such as cellular phones, or any gadgets that required electrical input power. Based on the piezoelectric concept, it will convert the vibration energy to electrical energy.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In Malaysia, the main activity in generating electricity is using the non-renewable energy sources which are fuels and gases. This acitivity actually produce a lot of carbon dioxide that will increase the concentrations of greenhouse gases and will lead to the global warming. Moreover, the decreasing in these fuels and gases had prompted the world to find another alternatives energy sources. Thus, piezoelectricity is one of the alternative energy that will guarantee the 'green' energy.

The waste vibration energy needs to convert by using piezoelectric generator and store as electrical energy in a battery. The battery will function as a backup power supply for the charger when the piezoelectric generator cannot produce any electrical energy. All this is based on principle of piezoelectric that is direct effect, which can be converted from strain, mechanical or vibration energy to electrical energy. The source of vibration will be taken from any moving objects. In conjuction with that, motorcycle has been chosen to be the vibration source.

Piezoelectric have many attractive features, such as not produce any emission and have a high voltage. The circuit for this project will be designed to boost and control the output voltage and current. Prototype for this project will be specially designed to protect from damage due to high vibration, have high efficiency to absorb vibration from any moving objects and make this innovation portable to bring anywhere.

1.2 Problem Statement

Nowadays, in a rapid growth world, there are more fuel and gas burning in order to produce electricity. This is due to the increasing numbers of electrical appliances around the world. These non-renewable energy sources are decreasing rapidly and the world needs other alternatives energy sources. The piezoelectric is one of alternatives energy sources. This energy can be generated from any sources of vibration. One of the source of vibration is motorcycle. Every motorcycle always produce vibration on the road. This vibration is actually a kind of energy which we called as motion energy. So, instead of losing this energy for nothing, this energy actually can be converted to an electrical energy using the piezoelectric components. The piezoelectric energy has been used to generate simple electricity to power microelectronic device such as mosfet and power electronics equipments. However, the piezoelectric is not being used for any vehicles yet. Due to small voltage produced, the piezoelectric only be used for small applications only. This project will research on the power produced by the piezoelectric effect and develop an application that can be used to transfer the vibration from motorcycle to electrical energy.

1.3 Objective

Objectives of this project are as following:-

i. To identify the piezoelectric effect.
ii. To identify the behaviour of the voltage and current produced by the piezolectric effect.
iii. To develop a piezoelectric generator to generate electricity from vibration.

1.4 Scope of Study

This project required study from two aspects. First is to study the characteristics, concept and the effect of the piezoelectric. The behaviour of the voltage and current produced by the piezoelectric element will be emphasize in this project. Next, is to measure the sensivity of the piezoelectric element. This measurement will analyse the piezoelectric element weather the vibration from a motorcycle is enough to cause the piezoelectric to produce voltage and current. Both of this study then will be combined to produce a piezogenerator.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Piezoelectricity is the ability of certain crystals to generate a voltage in response to applied mechanical stress. The word is derived from the Greek piezein, which means to squeeze or press. The effect is reversible; piezoelectric crystals, subject to an externally applied voltage, can change shape by a small amount. The effect is of the order of nanometers, but nevertheless finds useful applications such as the production and detection of sound, generation of high voltages, electronic frequency generation, and ultrafine focusing of optical assemblies [1].

2.1 Fundamentals and Theory of Piezoelectric

The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect. Piezoelectricity is found in useful applications such as the production and detection of sound, generation of high voltages, electronic frequency generation, microbalances, and ultra fine focusing of optical assemblies. Piezoelectricity is the combined effect of the electrical behaviour of the material using [2]:

$$D = \varepsilon E \tag{1}$$

Where D is the electric charge density displacement (electric displacement), ε is permittivity and E is electric field strength,and using Hooke's Law:

$$S = sT \tag{2}$$

Where S is strain, s is compliance and T is stress. These equations may be combined into so-called coupled equations, of which the strain-charge form is:

$$\{S\} = [s^E]\{T\} + [d^t]\{E\} \tag{3}$$

$$\{D\} = [d]\{T\} + [\varepsilon^t]\{E\} \tag{4}$$

where [d] is the matrix for the direct piezoelectric effect and [dt] is the matrix for the converse piezoelectric effect. The superscript E indicates a zero, or constant, electric field; the superscript T indicates a zero, or constant, stress field; and the superscript t stands for transposition of a matrix.

The strain-charge for a material of the 4mm (C4v) crystal class (such as a poled piezoelectric ceramic such as tetragonal PZT or BaTiO3) as well as the 6mm crystal class may also be written as (ANSI IEEE 176):

$$\begin{pmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{pmatrix} = \begin{pmatrix} s_{11}^E & s_{12}^E & s_{13}^E & 0 & 0 & 0 \\ s_{21}^E & s_{22}^E & s_{23}^E & 0 & 0 & 0 \\ s_{31}^E & s_{32}^E & s_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & s_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & s_{66}^E = 2(s_{11}^E - s_{12}^E) \end{pmatrix} \begin{pmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{pmatrix} + \begin{pmatrix} 0 & 0 & d_{31} \\ 0 & 0 & d_{32} \\ 0 & 0 & d_{33} \\ 0 & d_{24} & 0 \\ d_{15} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} E_1 \\ E_2 \\ E_3 \end{pmatrix} \tag{5}$$

$$\begin{pmatrix} D_1 \\ D_2 \\ D_3 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{pmatrix} + \begin{pmatrix} \varepsilon_{11} & 0 & 0 \\ 0 & \varepsilon_{22} & 0 \\ 0 & 0 & \varepsilon_{33} \end{pmatrix} \begin{pmatrix} E_1 \\ E_2 \\ E_3 \end{pmatrix} \tag{6}$$

where the first equation represents the relationship for the converse piezoelectric effect and the latter for the direct piezoelectric effect.

In total, there are 4 piezoelectric coefficients, dij, eij, gij, and hij defined as follows:

$$d_{ij} = \left(\frac{\partial D_i}{\partial T_j}\right)^E = \left(\frac{\partial D_i}{\partial T_j}\right)^T \quad (7)$$

$$e_{ij} = \left(\frac{\partial D_i}{\partial S_j}\right)^E = -\left(\frac{\partial T_i}{\partial E_j}\right)^S \quad (8)$$

$$g_{ij} = -\left(\frac{\partial E_i}{\partial T_j}\right)^E = -\left(\frac{\partial S_i}{\partial D_j}\right)^T \quad (9)$$

$$h_{ij} = -\left(\frac{\partial E_i}{\partial S_j}\right)^D = -\left(\frac{\partial T_i}{\partial D_j}\right)^S \quad (10)$$

Where the first set of 4 terms correspond to the direct piezoelectric effect and the second set of 4 terms corresponds to the converse piezoelectric effect [3].

The conversion of mechanical energy into electrical can be generally achieved by converters alternator types or commonly known as dynamo. But, the piezoelectricity also can be used to transform the mechanical energy to electrical energy. The piezoelectricity used another type of conversion, which are from vibration or mechanical strain.

Basically, the piezoelectric effects exist in two ways, which are the first one is the direct piezoelectric effect and the other one is the reverse effect. The direct effect describes the material's ability to transform mechanical strain into electrical charge. This direct effect can be used as a sensor. Meanwhile, the reverse effect is the ability of the material to convert an applied electrical potential into mechanical strain energy. The application of the reverse effect is an actuator. Figure 1 shows a piezoelectric disk generates voltage when deformed.

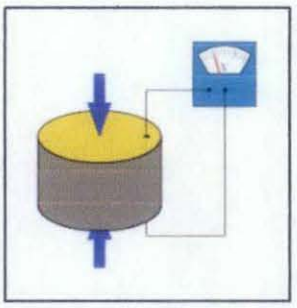

Figure 1 : A piezoelectric disk generates a voltage when deformed (change in shape is greatly exaggerated) [4]

2.2 Piezoelectric Generator Principle

The type of energy harvesting in this project is using the vibration source. The vibration source can be found at any movement and this project will take the source of vibration from the motorcycle. A motorcycle produces a constant level of vibration and therefore it can be used to convert to electrical energy using the piezoelectric element. The conversion will start from a mechanical energy source, which is motorcycle. The motorcycle vibrations will be converted into electricity through piezoelectric element. Then, the electricity produced will be converted before supplying a storage system or the load. The piezoelectric has been used in many wide applications.

The most popular application of this piezoelectric is in one of the subway in Japan, where they invented the new piezoelectric energy generating floor. The system will harvest the kinetic energy generated by crowds to power ticket gates and display systems [5]. This system use the piezoelectric element as the floor, thus when they are crowd stepping on this floor will generate an electricity as shown in Figure 2.

Figure 2 : Energy Generating Floor System [6]

The next application of this piezoelectric is to detect sound, e.g. piezoelectric microphones (sound waves bend the piezoelectric material, creating a changing voltage) and piezoelectric pickups for electrically amplified guitars. A piezo sensor attached to the body of an instrument is known as a contact microphone [7].

Piezoelectric materials are also being used as ultrasonic transducers for medical purposes, and for industrial nondestructive testing, or NDT. The transducer can act as both a sensor and an actuator. Ultrasonic transducers can inject ultrasound waves into the body, receive the returned wave, and convert it to an electrical signal (a voltage). Most medical ultrasound transducers are piezoelectric [8]. Figure 3 shows how the piezoceramic can be used as transducers.

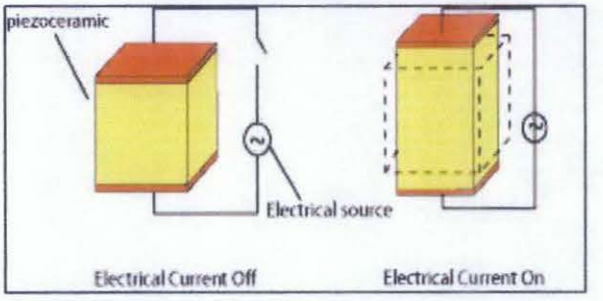

Figure 3 : Piezo Tranducers Concept [9]

2.3 Motorcycle Vibration

A study about motorcycle vibration has been made through around the world. The main objective of this study is to analyze the hazard that result from this vibration. Motorcycle vibration was studied to evaluate riding comfort and safety in terms of handling and stability. Since this project is about to harvest energy from motorcycle vibration, so it is very crucial to know how strong the vibration produced by the motorcycle. A research done by Motormu Yokomori, Takeo Nakagawa and Tadao Matsumoto show that motorcycle actually has many sources of vibrations [10]. The study stated that motorcylce vibrations are coming from the motorcycle itself, posture of the hands and arms during the gripping of the handlebars, the surrounding environment, and the period of time during which the motorcycle is ridden.

According to the study, vibration is transmitted from the motorcycle along the following three paths which are from the :-

- handlebars to the hand-arms and the body
- saddle to the buttocks,the waist, and the body
- foot ot the feet, the legs and the body

This study also stated that the vibration of the handlebars is caused by the engine vibration, the roughness of the road, and the vibration of the frame and the chasis. This shows that there are actually many sources that cause the motorcycle vibration. Thus, there are a bright future that these vibrations can actually produce enough to give the piezoelectric works.

2.4 Vibration to Electrical Energy Conversion

The vibration to electrical energy conversion is now used average in the world. This is because it is hard to find a constant type of vibration, especially in environment that can produce vibration. Unlike other source such as wind, waves, these can be found easily in our environment. The most popular invention of vibration to electrical energy is the Power Micro-Electro-Mechanical System (MEMS) which is a capacitive vibration to electrical energy converter with built-in voltage. This design actually makes a parallel-plate electrostatic spring mass system. The charging of the parallel-plate capacitor takes by utilizing materials with different works functions for the electrodes. The Micro-Electro-Mechanical System (MEMS) based capacitive energy is able to provide an output power of 4.28uW at an external vibration with a frequency of 1kHz and an amplitude of 1.96m/s (0.2g). [11]

From this study, it shows that a conversion of vibration to electrical really produce only a small amount of power. But this invention actually not use piezoelectric element in the product. It is using the parallel-plate electrostatics to produce the voltage.

CHAPTER 3

METHODOLOGY

3.1 Phases in Piezo Generator

There are four phases involved in this project. Each one of the phase will be achieved step by step.

3.1.1 Phase 1

This is the first stage of this project which is to identify the piezoelectric concept. The action to be taken in this stage is to do a deep research on how the piezoelectric works. A part from that, the situational analysis is essential to do in order to identify the piezoelectric concept.

3.1.2 Phase 2

The second stage in this project is to identify the measurement criteria for evaluating the produce current and voltage by the piezoelectric element. At this stage, a thorough search will be made via internet and from the library to collect all available information on the measuring knowledge. The collections of the technical report regarding the subject matter in the world are essential in order to identify the common criteria on measuring the current and voltage. The major deliverable for this stage is the criteria on measuring the produced current and voltage from the piezoelectric element. A part from that, the formula of converting from the vibration to current and voltage will be achieved at this stage.

3.1.3 Phase 3

To develop a energy converter from vibration is the third stage of this project. An agile methodology for developing the converter is adopted in this phase. This is to reduce time as well as to ensure the tool developed is parallel with the user requirements. The major deliverable for this stage is the completion of energy generator called Piezogenerator.

3.1.4 Phase 4

The final stage for this project is the implementation and user testing on the system. This system is test in the lab. Figure 4 shows the full phases in this project.

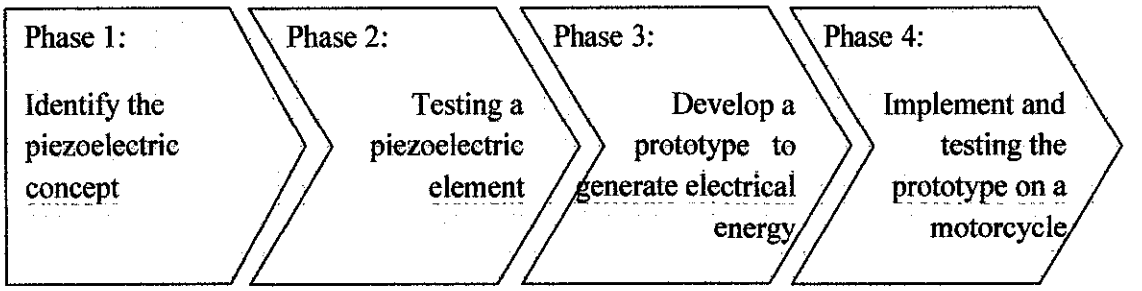

Figure 4 : Phases in Piezo Generator

3.2 Identification of Appropriate Hardware and Software

Table 1 and Table 2 show the list of suitable hardware, tools and software that are being used in this project.

Table 1 : Material and Description

Material	Description
Piezoelectric Bi-Morph Sensor	Crystal element that generates voltage when being stress or strain (vibration)
Electronic circuit	Amplifier, rectifier, stabilized and boost the electricity generated
Zinc	Material to be used as a beam due to low elastic modulus.
Aluminium	To be used as the base of the prototype
DC Motor	Use to generate vibration.

Table 2 : Jobs Parts and Software

Part	Software
Drawing	AutoCAD
Documentation	Microsoft Word 2003 & 2007
Electrical Circuit	PSPICE, Pasco Data Studio

3.3 Construct the Base of the Generator

This project is using aluminium plate to make the permanent flat surface. This is the base structure of the piezoelectric generator. Aluminium is used because it has a solid structure. So that, it can transfer the vibration more to the piezoelectric elements. Cutting machine is used to cut the aluminium plate to the desired dimension. Figure 5 illustrates the dimension.

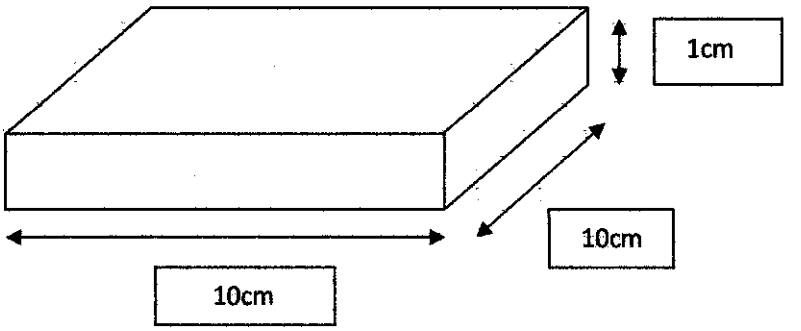

Figure 5 : Aluminium Dimension

3.4 Construct the Beam and the Piezoelectric Element

Basically, the beam that is used as the cantilever is using the Zinc plate. The Zinc has lower elastic modulus value that makes it less stiff than other metals materials. Thus, it can produce more vibration. The piezoelectric element will be glued using epoxy on the beam. Figure 6 shows how it is glued.

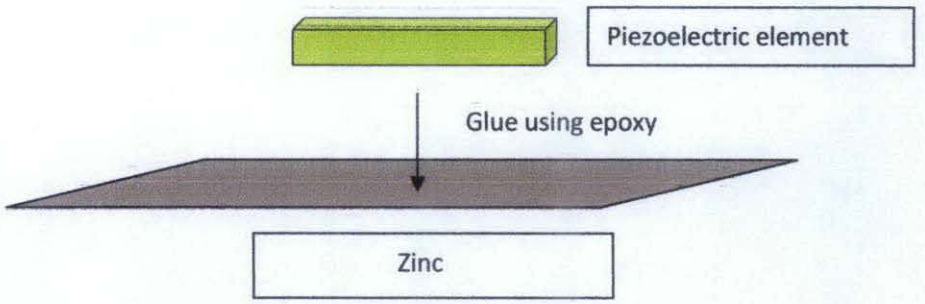

Figure 6 : Piezoelectric and The Beam

3.5 Electric Circuit

3.5.1 Full Bridge Rectifier Circuit

The voltage produced using piezoelectric element is in AC form. In other words, it is in sinusoidal wave. Therefore, in order to use for mobile charger, it needs to be converted into DC form. This is because; the mobile charger is using the DC voltage. Schottky diodes are used in this rectifier circuit as they have very minimum voltage drop, which is around 0.7 V. As to regulate the voltage, a 1μ Farad capacitor is placed at the output of the circuit. The capacitor also will be used to charge battery when it receives energy. Figure 7 shows the diagram of the full bridge rectifier used.

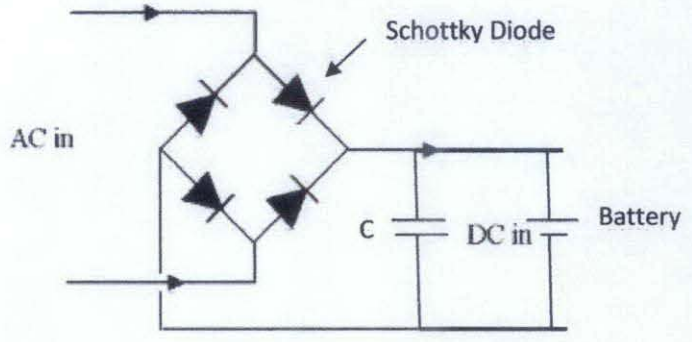

Figure 7: Full Bridge Rectifier Circuit

3.5.2 Booster Circuit

The booster circuit is constructed using LT1073. This circuit is a micro power DC/DC converter that be used as a step-up or step-down converter. In this project, it is basically being used to step up 2.5 V of voltage that was produced by the battery to achieve 5 V of output. When the switch is ON, the diode will be reversed biased, and will isolate the output stage. Then, the input will supply energy to the inductor. When the switch is OFF, the output stage will receive energy from the inductor as well as from the input.

The output filter capacitor is assumed to be very huge to ensure a constant output voltage when in the steady-state analysis. The oscillator is then set internally for 38 ms ON time and 15ms OFF time, and thus optimizing the device to step-up circuits where $V_{OUT} \approx 2\ V_{IN}$, e.g. 2.5 V to 5 V.

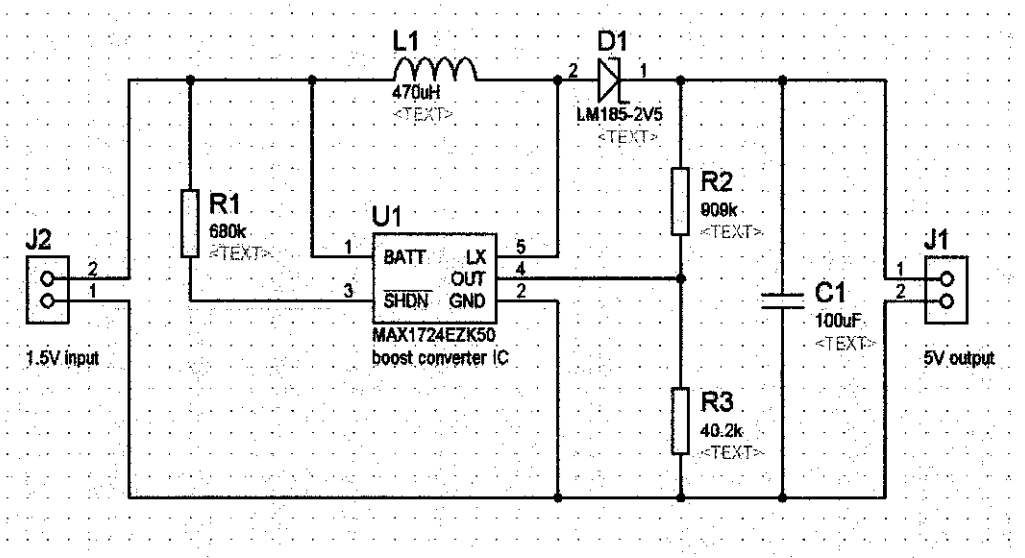

Figure 8 : The Booster Circuit

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Develop Work Bench for Piezo Generator

In order to test the piezoeleactric element, a work bench has been designed which can be used to check the behaviour of the voltage and current produced by this element. Actually, the work bench is almost the same with the prototype. The only different is that the work bench has many different cantilever beams, so that they can be tested using various experiment. This work bench is made for analyze on how much exactly the voltage can be produced by a certain level of vibration. This experiment is very crucial for this project because it will justify wether the vibration from the motorcylce can be used to make the piezo element to generate electricity or not.

The piezo element used for this experiment is the Piezoelectric Bi-Morph type. The testing tool is made up from zinc, aluminium, bolts and nuts. Basically, the zinc is used as the beam which the piezo will be placed on it, and the aluminium is used as the base for beam. There are several conditons that lead the chosen of zinc as the beam. The zinc has lower Elastic Modulus than the aluminium. The Elastic Modulus describes the mathematical description of an object subrtances's tendency to be deformed elastically when a force is applied to it [12]. According to the Static Properties of Materials under Standard Conditions (approximately 20), the elastic modulus for aluminium is 72(10) N/m meanwhile for the zinc is 13.1(10) N/m [13].

There is a huge difference between the value. The higher the elastic modulus value, the stiffer the material. So that, by this condition, the zinc will be used as the beam, as it will be more sensitive to any kind of vibration and it is easy to capture the vibration. Figure 9 shows the work bench of the piezo generator.

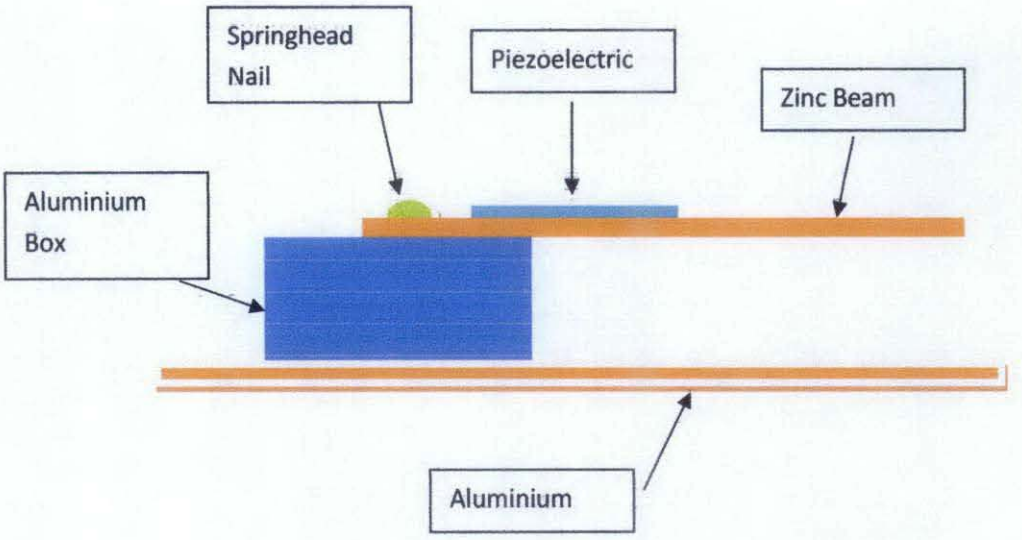

Figure 9 : Work Bench

The piezo element is glued on the beam and the beam will be placed on the aluminium box. The position of the beam and piezo element will be at 20 percent from the aluminium box. This is to ensure that when the beam start to oscillate, the piezo element will get easy to be bend. Next, the whole thing is placed on a piece of zinc surface. This zinc will be the medium for the vibration source to move. As a dc motor will be placed soon on this surface, it will generate a vibration and hence the surface will receive the vibration and transfered to the work bench. This work bench will be used for the experiment in order to determine how much voltage and currrent actually this piezoelectric element can produce due to vibration.

4.2 Prototype and Circuit Fabrication

The prototype has been designed using autoCAD software. The prototype is designed so that it can be put on motorcycle handlebar and anywhere that has vibration source. Below are the figures of the prototype and the circuit used.

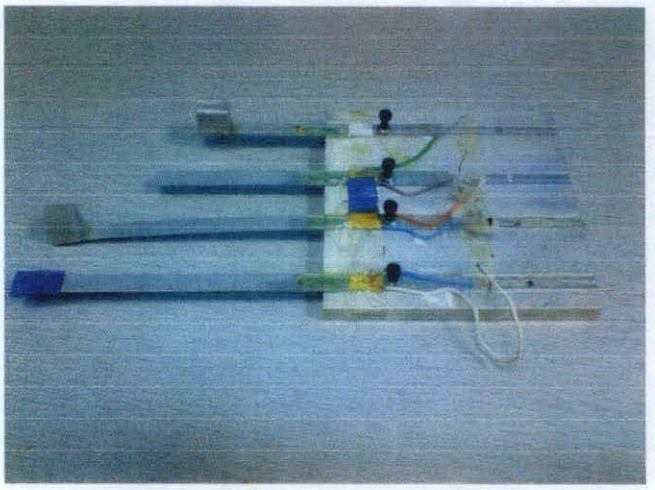

Figure 10 : The Prototype

Figure 10 shows the piezoelectric element with the base and the cantilever beam. While in Figure 11, shows the piezoelectric element connected with the full wave bridge rectifier circuit.

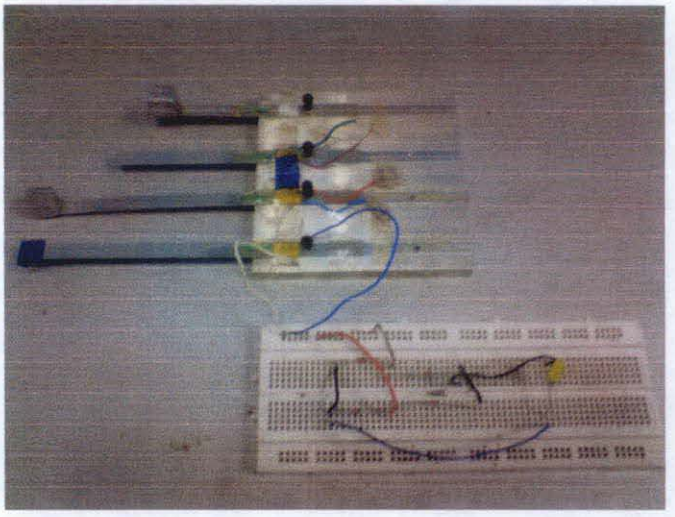

Figure 11 : The prototype with the Full Wave Bridge Rectifier Circuit

In Figure 12, shows the full wave rectifier circuit, which consists of Schottky 4 diodes, a 1kΩ resistor and 1μF capacitor. In Figure 13 shows the output from the rectifier circuit connected with the battery and then to the booster circuit.

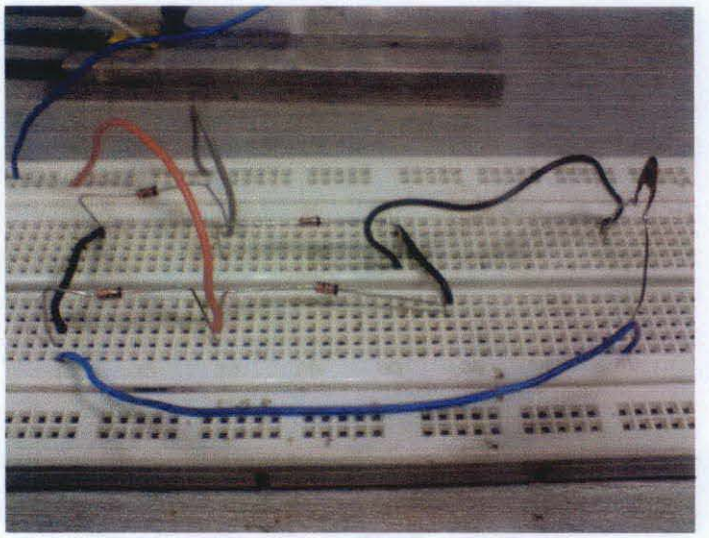

Figure 12 : The Full Wave Bridge Rectifier Circuit

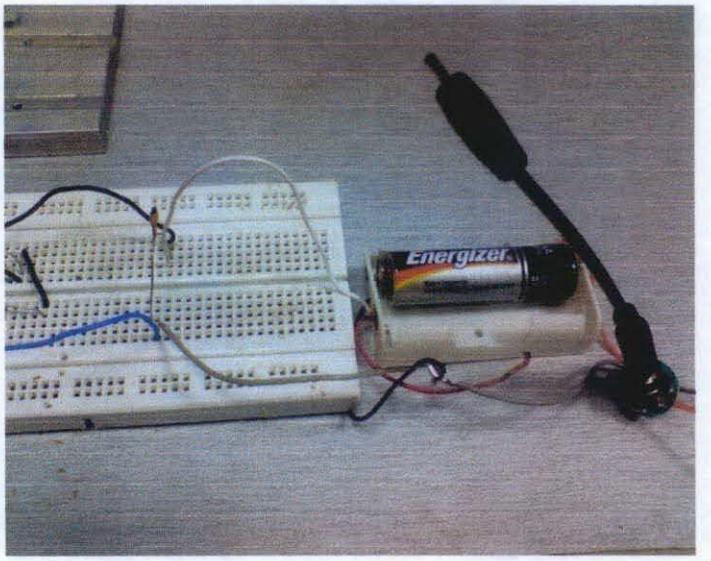

Figure 13 : Output from Capacitor to The Battery

Figure 14 shows the battery is connected with the circuit booster, while in Figure 15 shows the full prototype with the full circuit.

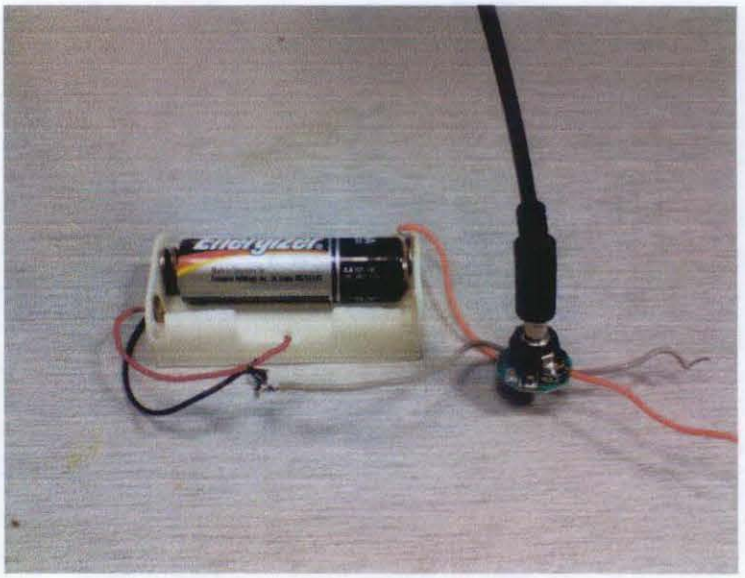

Figure 14 : Battery to the Circuit Booster

Figure 15 : The Prototype with the Full Circuit

4.2 Results of Experiment

The work bench is then tested using Pasco Data Studio Software. This software can be used to tested voltage and current, and frequency for this work bench. The motor used for the experiment is a DC motor which will cause vibration to the work bench when it turn on. As for the result, an AC voltage and current are produced. Three different experiments are conducted in this stage, which are the first one using DC motor as the source of vibration, the second experiment is using manual vibration, and the third experiment will be using with the full circuit of converter and booster to test the prototype. The voltage produced is the RMS voltage. In all three experiments, there are two piezoelectric element that has been tested with series connection.

4.2.1 DC Motor Experiment

For the first experiment, a DC motor is used for the source of vibration. A 12V DC motor with 50 Hz of frequency has been tested for this experiment. This experiment only use 2 piezoelectric elements to be tested. This is to determine how much actually the voltage and current can be produced with vibration. The frequency of the vibration in this experiment is around 32 Hz. The result of this experiment is tabulated in Table 3. For the sake of analysis, the tabulated data in Table 3 is converted in graph figure as shown in Figure 16 and Figure 17.

Table 3 : Result from Experiment 1

Time (Sec)	Voltage (V)		Time(Sec)	Current (A)
0	-2.3378		0	-0.00000354
0.1	-0.116		0.1	-0.00000452
0.2	1.7435		0.2	0.00000513
0.3	2.2397		0.3	0.00000458
0.4	0.1664		0.4	0.00000446
0.5	-2.471		0.5	-0.00000494
0.6	-0.2985		0.6	-0.00000543
0.7	2.1358		0.7	0.00000525

0.8	0.2462		0.8	0.00000347
0.9	-2.8358		0.9	-0.00000494
1.0	0.2734		1	0.00000525
1.1	1.7435		1.1	0.00000488
1.2	2.2397		1.2	0.00000494
1.3	0.1634		1.3	0.00000494
1.4	-2.371		1.4	-0.00000513
1.5	-0.2995		1.5	-0.00000494
1.6	2.1458		1.6	0.00000482
1.7	0.2362		1.7	0.00000482
1.8	-2.8558		1.8	-0.00000488
1.9	0.2704		1.9	0.00000482
2.0	1.7335		2	0.00000464
2.1	2.2297		2.1	0.00000447
2.2	0.1654		2.2	0.00000488
2.3	-2.471		2.3	-0.00000574
2.4	-0.2985		2.4	-0.00000813
2.5	2.1458		2.5	0.00000387
2.6	0.2362		2.6	0.00000456
2.7	-2.8358		2.7	-0.00000635
2.8	0.2704		2.8	0.00000484
2.9	1.7335		2.9	0.00000399
3.0	2.3297		3	0.00000511
3.1	0.1654		3.1	0.00000171
3.2	-2.471		3.2	-0.00000446
3.3	-0.2985		3.3	-0.00000418
3.4	2.1358		3.4	0.00000165
3.5	0.2362		3.5	0.00000551
3.6	-2.8457		3.6	-0.00000846
3.7	0.2704		3.7	0.00000177
3.8	1.7335		3.8	0.00000251
3.9	2.2297		3.9	0.00000304
4.0	0.1654		4	0.00000415
4.1	-2.471		4.1	-0.00000476
4.2	-0.2985		4.2	-0.00000584
4.3	2.1358		4.3	0.00000599
4.4	0.2362		4.4	0.00000655
4.5	-2.8458		4.5	-0.00000537
4.6	0.2704		4.6	0.00000244

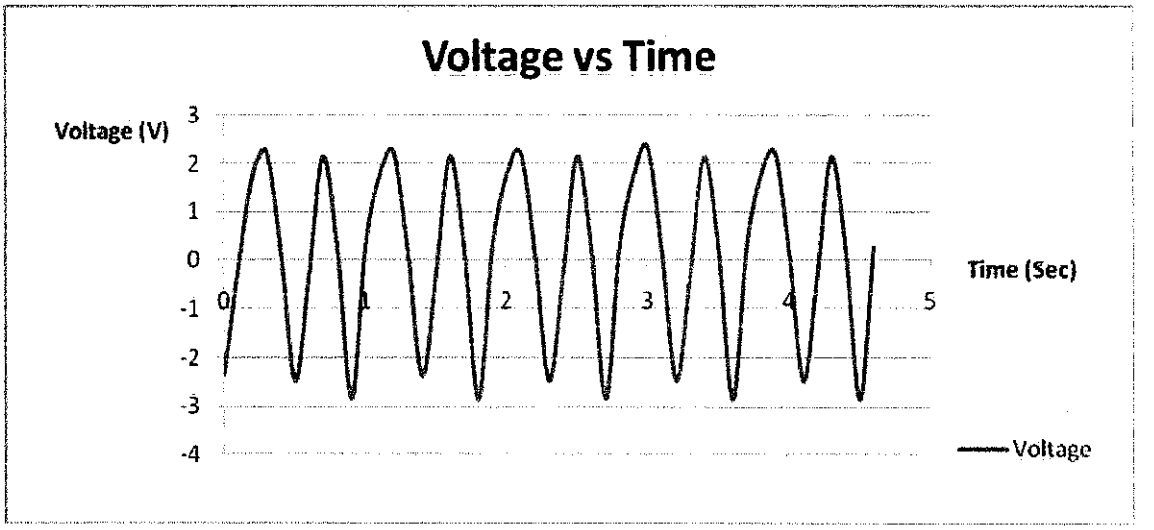

Figure 16: Voltage vs Time

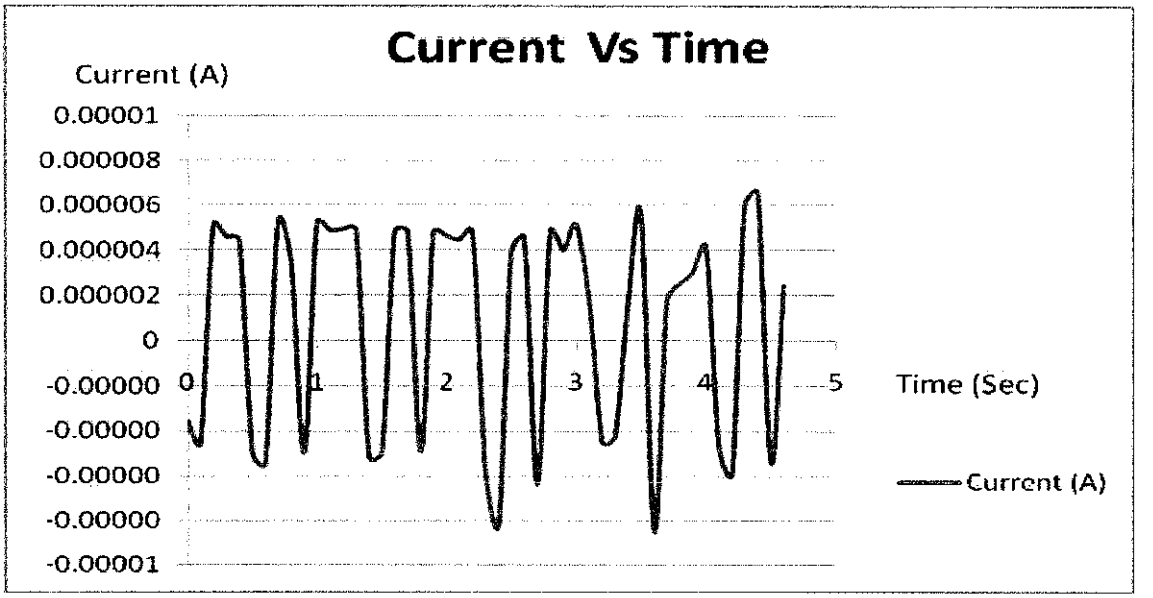

Figure 17: Current vs Time

4.2.2 Manual Vibration Experiment

In the second experiment, another type of movement is used.A human finger has been used as the source of vibration which mean that the finger is used to produce the vibration. In this experiment also, only 2 piezoelectric elements only will be tested. No external circuit is used. The frequency is around 28 Hz until 54 Hz. The result of this experiment is tabulated in Table 4. For the sake of analysis, the tabulated data in Table 4 is converted in graph figure as shown in Figure 18 and Figure 19.

Table 4: Result of Experiment 2

Time (Sec)	Voltage (V)		Time(Sec)	Current (A)
10	0.9223		10	0.00000355
10.1	0.1251		10.1	0.00000467
10.2	-0.3674		10.2	-0.00000512
10.3	0.976		10.3	0.00000433
10.4	-3.1892		10.4	-0.00000432
10.5	2.4494		10.5	0.00000454
10.6	0.1508		10.6	0.00000565
10.7	-0.2649		10.7	-0.00000567
10.8	1.6175		10.8	0.00000334
10.9	0.1459		10.9	0.00000456
11	-0.6397		11	-0.00000576
11.1	0.1886		11.1	0.00000444
11.2	-0.445		11.2	-0.00000496
11.3	1.3971		11.3	0.00000493
11.4	0.1953		11.4	0.00000523
11.5	-2.4378		11.5	-0.00000454
11.6	-0.116		11.6	-0.00000476
11.7	1.7335		11.7	0.00000482
11.8	2.2297		11.8	0.00000486
11.9	0.1654		11.9	0.00000443
12	-1.471		12	-0.00000465
12.1	-0.2985		12.1	-0.00000465
12.2	6.1458		12.2	0.00000499
12.3	0.2362		12.3	0.00000512
12.4	-1.8458		12.4	-0.00000832
12.5	0.2704		12.5	0.00000355
12.6	-10		12.6	-0.00000478

12.7	0.3638		12.7	0.00000634
12.8	-1.2336		12.8	-0.00000483
12.9	1.4972		12.9	0.00000398
13	-0.6775		13	-0.00000522
13.1	0.2411		13.1	0.00000176
13.2	-3.4419		13.2	-0.00000435
13.3	0.9265		13.3	0.00000419
13.4	-0.7477		13.4	-0.00000165
13.5	4.3214		13.5	0.00000551
13.6	0.2094		13.6	0.00000876
13.7	-1.8201		13.7	-0.00000156
13.8	0.0385		13.8	0.00000251
13.9	2.2761		13.9	0.00000355
14	-2.3536		14	-0.00000478
14.1	1.8616		14.1	0.00000444
14.2	0.4718		14.2	0.00000567
14.3	-0.0897		14.3	-0.00000588
14.4	0.2258		14.4	0.00000644
14.5	-0.2063		14.5	-0.00000563
14.6	0.4407		14.6	0.00000223

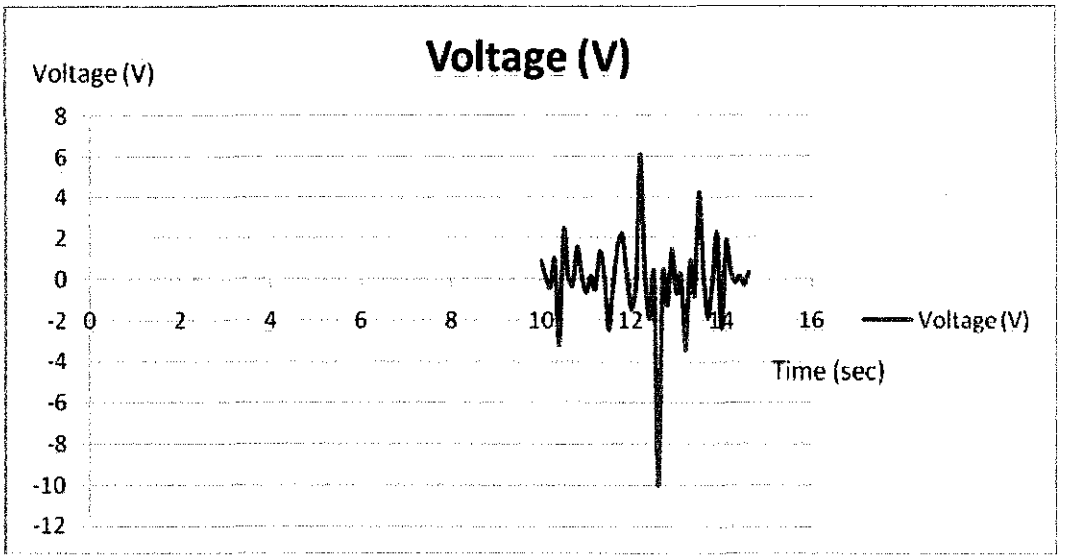

Figure 18: Voltage vs Time

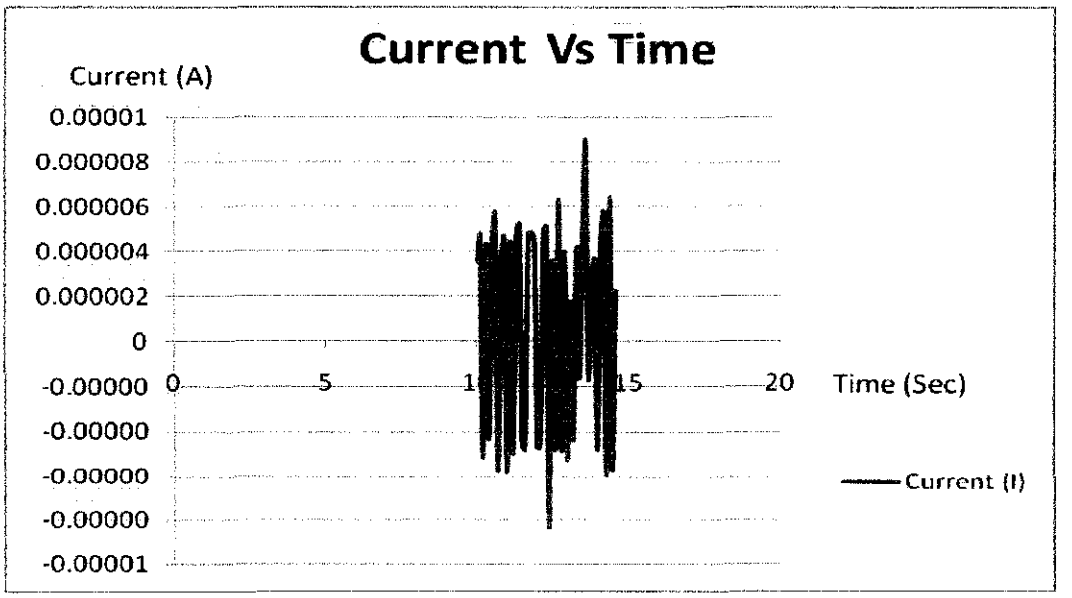

Figure 19: Current vs Time

4.2.3 DC Motor and Prototype experiment

This is the final experiment that determine the full result of this portable piezoelectric generator. In this experiment, the full prototype, will be tested on a dc motor at frequency of 32 Hz. Figure 20 shows of how this piezoelectric generator actually produce electricity in this experiment.

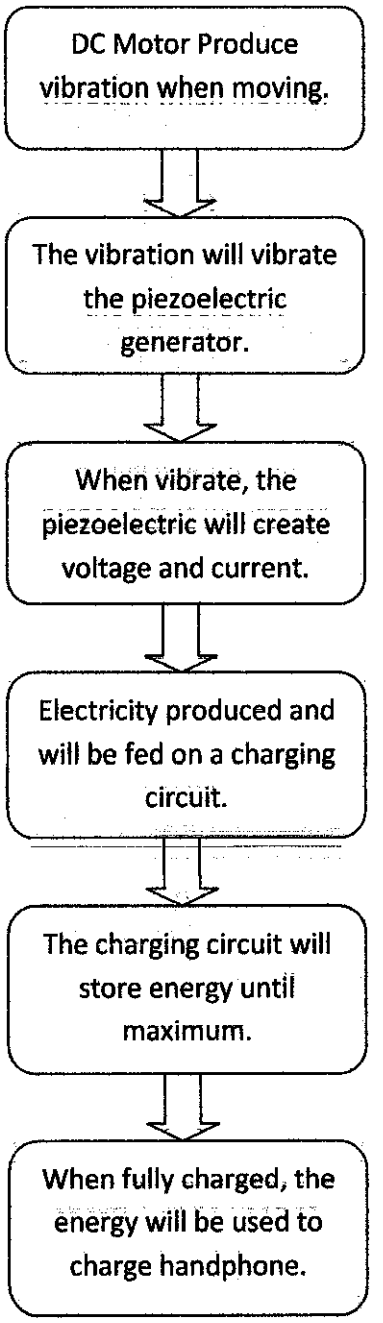

Figure 20 : Schematic Flow Diagram

In this experiment, an empty or discharged capacitor is used to be charged. This capacitor actually represent the battery and will determine the whether the voltage and current produced is enough to charge capacitor or not. Figures 21 and 22 below show the result of the graph obtained from this experiment. Due to long data, the table will not be included in this report.

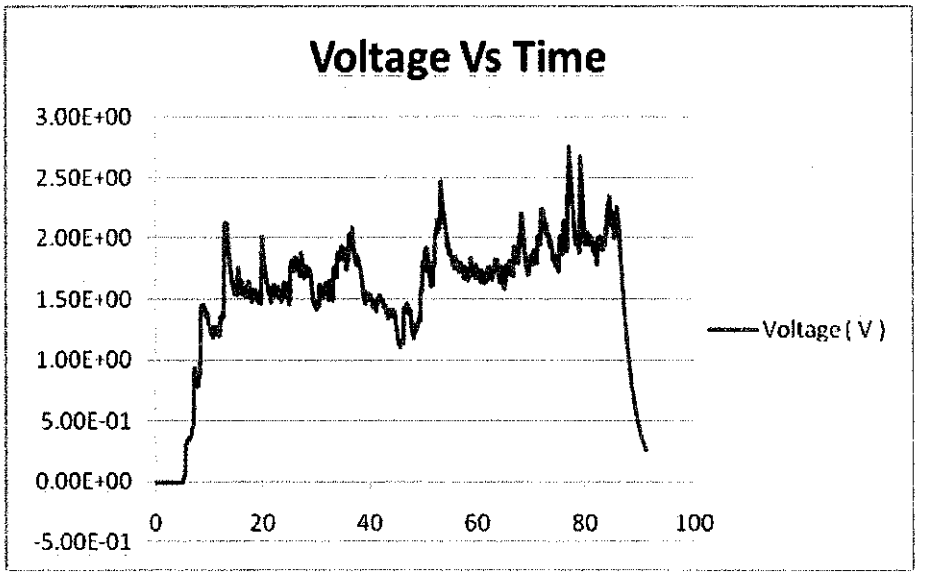

Figure 21: Voltage Vs Time

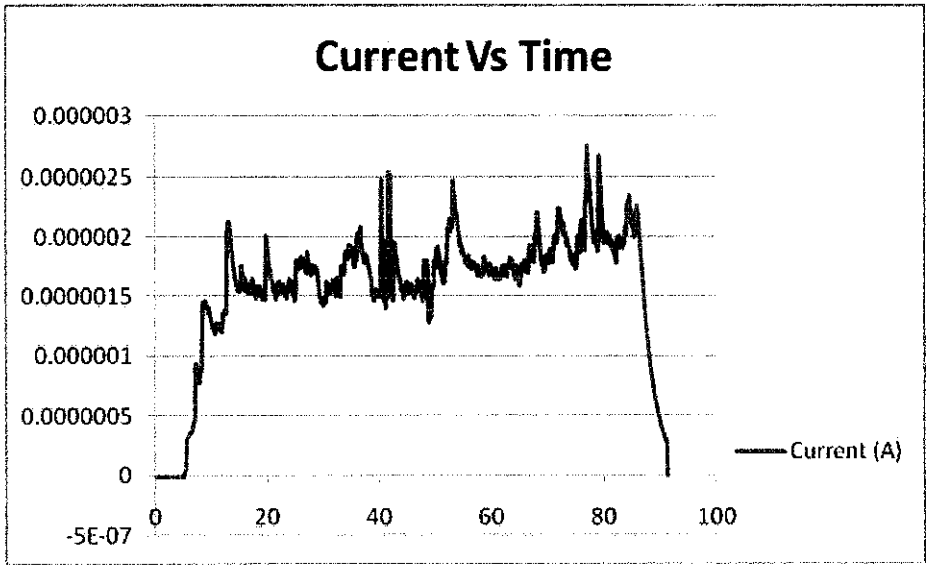

Figure 22: Current Vs Time

4.3 Discussion

4.3.1 Experiment 1 & 2

From experiments 1 and 2, the voltage produced is quite high. Using the DC motor, the voltage produced is approximately at constant 2 V. This value is actually the value of two piezoelectric elements which means that 2 V is the value of total voltage when the piezoelectric is put in series connection. Indeed, this voltage can go more higher than that because from the manual experiment, the voltage can reach until 10 V. It shows that the voltage produced is basically depends on how much the piezo element can vibrate. The more vibration it gets, the higher the voltage can produce. The target for this project is to ensure that the voltage and current produced can be used directly to charge at least a cellular phone. For that purpose, the required voltage and current needed is 5V at 100mA.

As for the current, from both experiments, the value of the current is very low. The value of the current can be said vary from 0.000001 A until 0.000008 A. This is equal to 1μA until 8μA. This value is too low for any direct applications. This is because of the piezoelectric does not produce high current. Due to the very low current is the reason why it still cannot be used to generate a large scale of electricity such as solar and hydro. So, the current produced is not enough to charge a cellular phone. Theoretically, to charge a cellular phone, the current required is at least around 100 mA. From both experiments, it can be concluded that the piezoelectric do produce high voltage but very low current value. Thus, the piezoelectric cannot be directly used to charge a cellular phone without any external circuit. Due to this situation, the generator will be used to store energy first. This is demonstrated by charging a capacitor.

4.3.2 Experiment 3

As for the third experiment, which is using the prototype and the full circuit, it can be seen that the graph produced is actually in charging mode. When the piezoelectric starts to vibrate, the voltage produce is around 2.2 V. But when it pass through the rectifier circuit, there is voltage drop occur. This is because the the diodes actually have internal resistance, and thus have voltage drop. When measured at the bridge output, the reading is around 0.74 V. But at the input, the reading is 2.1 V. When the value from the input minus the value from the output, it gives 1.36 V. This 1.36 V is actually the voltage drop in the circuit. So that 0.74 V is the actual output value from the bridge circuit. As for the current, the value is still the same, which is around 4uA. Then when it pass through the capacitor of 1μ Farad, the graph produce a charging graph. This shown that the voltage and the current produced is actually enough to charge the battery.

From the graph, the graph is increased and when the capacitor has been fully charged, the graph will decrease because it will discharge. The process of charge and discharge is so fast because the value of the capacitance used is small, which is 1μF. When lower value of capacitance is used, it will charge and discharge very fast, because it cannot hold the charge for longer time. The reason for using lower value of capacitance is because to prove that the voltage and current produced is enough to charge the capacitor. Bigger capacitor value such as 1 Farad can be used in this experiment, but it requires longer time to show the charging graph. Because when the capacitor is bigger, the time taken to charge the capacitor become longer and thus the graph obtained will be slow.

The graph produced is not consistently increase. This is because in order to charge the capacitor, a the current and voltage must be at steady state. However, because of this experiment cannot give a stable voltage and current, due to the vibration, it will not charge the capacitor steadily. Thus, as can be seen in Figure 21, the graph will not steadily increase. This experiment has shown that the voltage and current produced enough to charge the capacitor.

4.3.3 Justification of Result

From all experiments, it can be seen that the current produced is not enough to directly charge a cellular phone. This is because the current is too small and not sufficent, even to light up a single LED. Because of this situation, the current and voltage produced will be stored first in a battery. This is done by looking at the third experiment, the values are enough to at least charge a capacitor. The graph in experiment 3 shows that the voltage and current actually has charged the capacitor, although it is not charging consistently due to the inconsistent of vibration. The charging time will depend on the value of the current supply. The bigger the value of the current, the faster it will charge and thus will result in less time to charge. Meanwhile, if the current is very small, then it takes longer time to charge. The energy stored in the capacitor will then be used to charge acellular phone or other electronic devies. The average output from the piezogenerator is given below:

$$P = IV \tag{11}$$

Where P is the power, I is the current and V is the voltage. Taking average voltage of 0.74V and 5uA, substitute in the above equation gives:

$$P = 5uA \times 0.74V$$

$$= 3.7uW$$

Based on this result, the power will be stored first in a battery, and then the battery will be used for other purposes. As for the efficiency is calculated below:

$$\eta = \frac{P_{out}}{P_{in}} * 100 \tag{12}$$

$$= \frac{3.7\mu}{15\mu} * 100$$

$$= 24.67\%$$

The result of efficiency is very low and can be considered as not efficient enough. There are several factors that cause the low performance of this piezoelectric generator. The first one is because the it produce large voltage but with an extremely low current. When current low, it will affect the performance of the generator. Another reason is because the power is dissipated by electronic devices such as diodes, which will resulting in lower efficiency. From overal experiment, it can be said that the generator is able to charge the capacitor.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a conclusion, this project has actually succeed in all objectives that have been stated in the early of this report. This project use the piezoelectric effect theory, which produce electricity form the vibration energy. From this project, the vibration generated from the motorcycle will be used as the main source to generate electricity using piezoelectric element. This piezoelectric generator is portable, thus it can be used anywhere as long as there are sources of vibration.

The portable piezoelectric generator cannot directly charge a cellular phone the vibration because of low current. Then, it has been modified to be used as battery charger, which has been demonstrated by charging a capacitor. The piezoelectric generator will store energy in a battery, and then when the battery is fully charged, it will be used to charge a cellular phone. This project is considered as green technology since it produces no emission and thus it is environmentally friendly.

5.2 Recommendations

Improvising this project by adding some new features or functions is an effective ways to utilized the waste energy as well as saving the cost of producing electricity. Until now, the piezoelectric still cannot produce electrical energy for large usage due to lack of current. In our market today, there are still no electrical generator that use piezoelectric. The only thing available that use piezoelectric is such as buzzer, and speaker which is not being use to generate electricity.

In the future, a bigger size of piezoelectric sensor will be used in order to test output voltage and current. A current booster circuit will be designed so that the output current can be used to charge a cellular phone.

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APPENDIX

Gantt Chart For FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14
1	Design Current Booster															
2	Testing the circuit															
3	Analysis															
4	Submission of Progress Report															
5	Submission of Draft Report															
6	Submission of Technical Paper															
7	Submission of Final Report (soft copy)															
8	VIVA															
9	Submission of Final Report (hard copy)															

Process