HUMAN-POWERED WIRELESS CONTROLLED LIGHTING FLOOR WITH PIEZOELECTRIC ENERGY HARVESTER

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DECLARATION

"I hereby declare that the work in this dissertation is my own except for quotations and summaries which have been duly acknowledged."

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SUPERVISOR DECLARETION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Electronic (Telecommunication Electronic)"

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ABSTRACT

The renewable energy devices have developed rapidly although present is having many of strategies develop the weather to produce energy but not kinetic energy. So, designing and developing a piezoelectric energy harvesting system is potentially to be carrying. This is to incorporating piezoelectric materials into floor tile system in generating electrical energy from human foot strike impact to operate wireless transmitter and LED. It need to be effectively extract and turn kinetic energy into usable electrical power as it will only produce milli watt low output power for every single foot stepped on prototype. Meanwhile, output power need to be rectified from AC source and stored as DC source to make sure the transmitter can be operated for longer time. This system will be charging a capacitor bank after power source being rectified, and then using the storing energy for lighting up light emitting diode and powering transmitter. By using capacitor, the LED or transmitter output when connected, it able operate for a longer time-consuming instead of just pulsating on while system is being triggered. The prototype supplement by battery source as it only generates mill watt power within a foot strike. Therefore, my objective is to design a prototype and demonstrate the possible of recycling the unused kinetic energy into a useful way together analyzed results. The experimental result shown obtained output voltage correspond to weight applied which is 0.4V harvested when 80kg applied. Thus, the transmitter is able to power up and send signal wirelessly.

ABSTRAK

Peranti yang berupaya menghasilkan tenaga elektrik daripada tenaga yang boleh diperbaharui telah dibangunkan dengan pesat walaupun padan zaman ini mempunyai banyak strategi untuk menghasilkan tenaga elektrik tetapi bukan tenaga yang seperti tenaga kinetik. Jadi, dengan membentuk dan membangunkan sistem penuaian tenaga piezoelektrik adalah berpotensi untuk dijalankan dan membuat kajian tentang ini. Sistem ini mengabungkan bahan-bahan piezoelektrik ke dalam sistem prototaip untuk menjanakan tenaga elektrik. Tenaga kinetik perlu ditukarkan dengan efektif disebabkan setiap pijakan ke atas prototaip hanya menghasilkan tenaga elektrik yang kecil, iaitu dalam mili watt. Sementara itu, tenaga hendakalah ditukar dari sumber AC kepada sumber DC. Sumber tenaga akan mengecas bank kapasitor dan tenaga simpanan ini digunakan untuk menghidupkan LED dan menjadi bekalan voltan kepada operasi pemancar. Dengan menggunakan kapasitor, LED atau pemancar tanpa wayar dapat beroperasi dalam masa yang lebih panjang tetapi bukan hanya denyut ketika sistem sedang dicetuskan. Prototaip ini boleh berjaya dimajukan untuk manjana jumlah tenaga yang lebih besar dengan menggunakan dalam kuantiti yang banyak. Prototaip ini dibekal dengan sumber bantuan bateri disebabkan ia cuma hasil milli watt dari setiap pijakan. Oleh yang demikian, matlamat saya adalah untuk mengkaji dan menunjukkan kemungkinan mengitar semula tenaga kinetik yang dibazirkan kepada sumber yang berguna. Keputusan esperimen telah dianalisis ke atas prototaip tersebut. Secara hasilnya, ia dapat menghasilakn voltan keluaran yang berlainan iaitu 0.4volt masa keberatan 80kg digunakan. Akhirnya, prototaip ini mampu menghidupkan operasi pemancar tanpa wayar dan menghantar isyarat secara wayarles denagan berjaya.

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ABBREVIATION LIST

UV	Ultraviolet
PZT	Lead Zirconate Titanate
PCB	Printed Circuit Board
AC	Alternate Current
DC	Direct Current
LED	Light Emitting Diodes
RF	Radio Frequency
TX	Transmitter
RX	Receiver
PVDF	Piezoelectric PolyVinyliDene Fluoride
MFC	Micro Fiber Composition
ASK	Amplitude Shift Keying
OOK	On-off Keying
CMOS	Complementary Metal-Oxide Semiconductor
IC	Integrated Circuit
TTL	Transistor-transistor Logic
GSM	Global System for Mobile Communication
WiFi	Wireless Internet Frequency Interphase

CHAPTER I

INTRODUCTION

1.1 Conceptual of energy harvesting

The procedure that taking little quantities of energy from natural sources in single or additional, hence collecting it and keeping these energy for future usage is called energy harvesting. A helpful job can be done by using an energy-harvesting tool which is proficiently and effectually capture, collect, store, and supply it to load. Likewise, an electronic device called energy harvesting module it can do the task to give power for a sensor as an alternating duty applications.

1.2 Reason of energy harvesting

Innovative practical growths require enlarged the effectiveness of a device to capture trace quantities of surroundings energy and converting into electrical energy. Furthermore, innovations in microprocessor technology is improving efficiency of power, successfully decreasing power intake desires. By combining these changes is sparkled attention in the communities of engineering to improve further and hence several applications can be advanced and generate power from energy harvesting.

Energy harvesting is an alternatives for pricey batteries and wall plugs by using an ordinary source where organized the remote application, and limitless fundamental on the such natural energy source. These principally free energy sources, when connected and developed correctly, is good for maintenance less and it are now available for the longer life span of the application. These systems are more dependable than battery or wall plug.

1.3 Energy harvesting's common resources

- Mechanical Energy –a sources like tension, mechanical force and vibration.
- Thermal Energy – heater, and boilers would produce wasted thermal source
- Light Energy – Solar panel and photo diode can collect sunlight from outdoor or indoor light.
- Electromagnetic Energy – inductors, transformers and coils
- Natural Energy – solar, water flow, wind, and ocean currents
- Human Body – body movements or reaction of bio-organisms
- Other Energy – the biological and chemical

It is essential to know that these energy sources are essentially limitless and basically unrestricted; it can be captured at the system site.

1.4 Important point for an energy harvesting system

The energy source like heat, air flow, vibration, and light is needed by an energy harvesting system. While another two important electronic components are:

- The piezoelectric component which able converts captured energy becomes useful electrical form by an energy transformation device.
- These devices like capacitor bank and full bridge rectifier is power sourced by an energy harvesting circuit which can captures, stores and manages power for it.

1.5 Optional components for the energy harvesting system

For the energy harvesting system, there have some additional components or parts are important to the operating process in some of the different applications. Below are some of the examples:

- A module of low voltage step up booster by powering the energy harvesting module as well as to amplify the low voltage source which is less than 500mV.
- A device that use to supplement the storage of energy for example super capacitors.
- A module that use in energy and power management that will control the output from the device of energy storage supplementary.

The optional key components need external energy to operate and hence will reduce the effectiveness of the system in overall energy capture and directly impact on the increasing of price as well as the weight.

1.6 Application of Piezoelectricity

By using piezoelectric systems, electrical power can be produced by converting the human foot strike. Hence, the device of piezoelectric used to generate energy is the fresh and fast concept of emerging. A modern renewable energy technology can be developed or promote which this kind of energy harvesting independent from the weather then it can be generated anytime and anywhere.

A sample of piezoelectricity's potential is a 1 cm^3 of quartz with 2kN, approximately 450lbs, of acceptably applied force can create a voltage of 12500V. In the field of renewable energy, piezoelectricity can be a very potential technology [11]. Some of the material can generate a thousand potential differences in Volts such as Quartz when the piezo used is contrast with the number of volts generated.

This would be very useful for wirelessly remote lighting application. In the situation of no light jogging track at night would be dangerous for the safety of jogger. This

application could be one of the best solutions that will avoid accident and robbery case happen during jogging at night. The piezoelectric can be the power source for LED lighting system along the jogging track as well as wireless transmitter for controlling jogging track lamp.

The self-generated wireless control lighting system is purpose to implement on an eco-park to enhance the safety of jogger while maintaining a healthier life style without paying extra money to fitness center. Meanwhile, it can reduce the cost of electric bill for lighting system in eco-park as the lighting system will only be activated to ON when jogger stepping on the piezo floor tile.

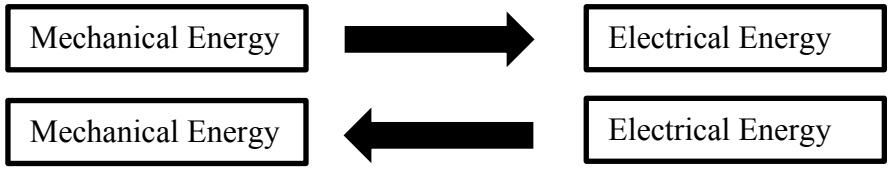

Figure 1.1: Piezo's direct and indirect effect

1.7 Significant of project

- It can be a backup power supply to open the possibility of lighting even without power source.
- It can generate non-weather dependent renewable energy source.
- It can recycle "free-energy" which is to utilize wasted energy generated by human foot strike.
- This project containing potential to implement on any suitable indoor or outdoor places with heavy foot traffic.
- It can promoting environmental friendly, green and sustainable technology by discarding the use of battery for wireless transmitter.

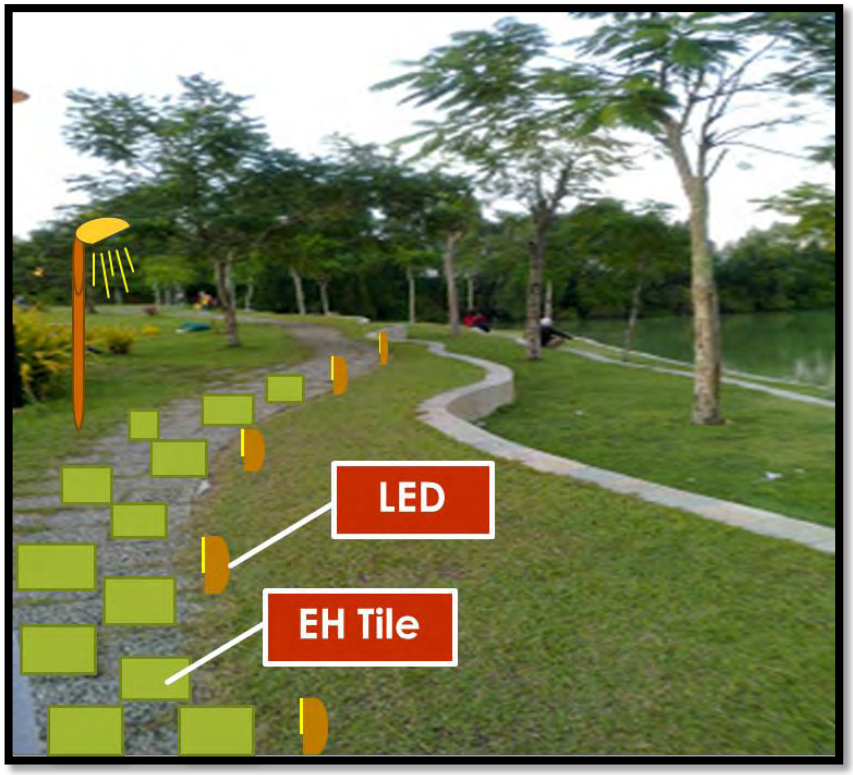

Figure 1.2: Initial concept of project implement

1.8 Product features

- Mechanical to Electrical energy conversion
- Rectifying circuit for AC-DC conversion
- Energy storage and load capability

1.9 Objectives

The objectives of this project are:

- To design a prototype floor tile that would harvest kinetic energy into electrical form.
- To fabricate and construct energy harvesting electronic circuit
- To analyze the voltage output generated by stepping-tile prototype
- To demonstrate the potential of transforming wasted kinetic energy into useful electrical energy.

1.10 Problem statements

The kinetic energy did exist whenever there is a movement including walking, dancing or even jumping, but the awareness to develop the energy still very uncommon among peoples. This could be a chance to optimize this less-attention but useful kinetic energy at the heavy foot traffic places such as public transport hub and eco-park jogging track.

The harvested kinetic energy is generating a low power output which is less than 500 milli watt so it would need to charge a capacitor bank and discharge to the connected load such as wireless transmitter or LED to make sure the sources is enough for powering up connected loads. Electric will only be generated every time when the prototype being stepped on. Therefore, this is a random AC source and it is not regulated.

1.11 Scope

The project scope is focused on hardware design structure and circuit design for energy harvesting. This project contains harvester circuit design, rectifier circuit, bank storage circuit design, transmitter circuit and receiver circuit.

These circuits will be designed by using Proteus software before fabricated on printed circuit board (PCB). The fabrication process will include the process of exposing UV light, developing for removing sensitized photoresist, etching for eliminating the unwanted copper, and drilling process.

The Multisim software will be used to test run the simulation for designed circuit. The simulation results will be compared with the practically testing result by using multimeter. The output voltage will be plotted based on the weight of applied on prototype.

The limitation of this project is the maximum weight of prototype can withstand is not going under the testing and measuring process. The energy harvester material and wireless radio frequency transmitter and receiver module will be obtained from

online market. This project will be conducted at the laboratory under supervision of technician.

1.12 Thesis structure

Each chapter is summarized at below:

Chapter 2

This section introduces the review of relevant literature review. This consists of fundamental comprehension of every stage function of circuit that required carrying out on this project.

Chapter 3

This section presented the overall methodology of the project beginning with construction design for prototype, circuit to rectify the random AC source from piezo materials, capacitor bank storage design, transmitter design, flow of development and expected result for this project.

Chapter 4

This section includes the results obtained from the hardware testing process and also simulation process. The result analysis and achievement of this project are discussed by plotting a graph and tableted the values obtained.

Chapter 5

This section discussed and concluded the objectives and goals that had set for this project. Recommendation on future work that can be implementing on this project is discussed as well.

CHAPTER II

LITERATURE REVIEW

2.1 Background of piezoelectric

According to Jacques Curie and Pierre Curie 1880, the technology of piezoelectricity was developed and discovered by them. Piezoelectricity is the phenomenon that detected by them on by pressuring certain crystals, electrical charges were split on the opposite face on the crystals [2]. In order by using material of piezoelectric to maximize the power created by some vibrations of mechanical and hence some summary of the parameters as below:

- ***Material*** such as Quick-Pack, PVDF and PZT. More energy produced by using Q-factor which is high quality factor material and hence higher efficiency to produce up to 65% of the input energy in term of mechanical on the piezoelectric micro fiber composite (MFC).

- ***Geometry***, large amount of energy is generated by using the tapered form as well as the strip form is available on market.

- ***Thickness***, output voltage is proportional to thickness of layer.

- ***Structure***, the output is doubled with bimorph structure than the structure of unimorph.

- ***Loading mode***, by only small forces applied more energy and larger strains generated.
- ***Resonant frequency,*** Fundamental vibration frequency need to be matched.
- ***Electrical connection***, in series to increase the source of output voltage while in parallel in terms to increase the current of the output.
- ***Fixation***, more strain generated by cantilever rather than the common beam.
- ***Load impedance***, piezoelectric impedance need to be same with the frequency of operating.

2.2 Operation of piezoelectric

The structure of the crystal has the unique materials and it will impact on the aspect of energy harvesting in piezoelectric. In Figure 2.1, the Lead Zirconate Titanate was shown and it is a type of ceramic, a tetragonal form with a small atom center will be produced. This center atom will creates a potential by displacing the from the site of lattice when crystal is strained [3]. By foot strike depressed, the energy harvesting displacement allowed in this project. Energy harvesting tiled relied on the force that applied on the materials and hence stress is corresponding with the potential difference and hence more energy is produced.

It is very critical in term to analyze the magnitude of force when walk on the ground, estimation on the power output of an individual walk on the floor tile was made. Approximately 1 – 1.5 times the weight of an individual was exerted on the force on ground when walking. By assuming the average of an individual body weight is 80kg which including male, female, carrying load, etc, hence the force on the ground will be 800N. This force on the tile will transform in a small number of Watt-seconds per step. There was appropriate 10.4 J/step will be harvested with a displacement of 0.01cm with a force yield of 100 N.

$$N \times depression\ of\ tile = Joule/step$$

$$ground\ reaction\ force \times body\ mass \times acceleration\ of\ gravity, (\frac{9.8m}{s^2}) = N$$

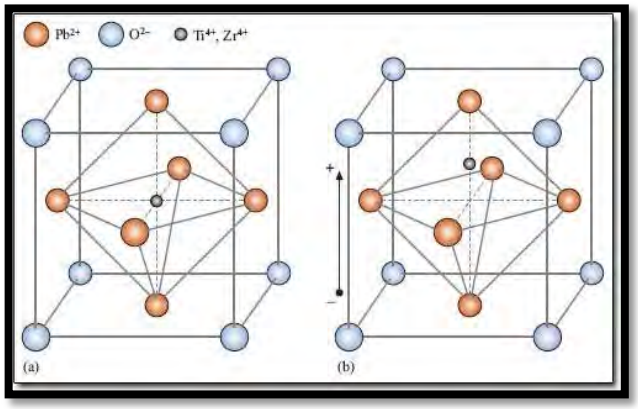

Figure 2.1: Crystal structure of Lead zirconate titanate.

2.3 Equation of piezoelectric constitutive

Within a constitutive equation of a material, piezoelectricity can be described in a mathematically form which defines how the piezoelectric material's stress (T), strain (S), charge-density displacement (D), and electric field (E) interact [5].

The piezoelectric constitutive law in a strain-charge form is:

$$S = S_E \cdot T + d^t \cdot E$$

$$D = d \cdot T + \varepsilon_T \cdot E$$

The matrix d contains the piezoelectric coefficient for the materials, and it appears twice in the constitutive equation (the superscript t stands for matrix-transpose). Below are the piezo symbol definitions:

Table 2.1: Definitions of piezo symbol

Symbol	Object type	Size	Units	Meaning
T	vector	6×1	$\frac{N}{m^2}$	Stress components
S	vector	6×1	$\frac{m}{m}$	Strain components
E	vector	3×1	$\frac{N}{C}$	Electric field components
D	vector	3×1	$\frac{C}{m^2}$	Electric charge density displacement components
ε	matrix	3×3	$\frac{F}{m}$	Electric permittivity
d	matrix	3×6	$\frac{C}{N}$	Piezoelectric coupling coefficient for strain-charge form

2.4 Usage for piezoelectric generator

There is numerous about the research of piezoelectric and it was a new concept on the past few years. Walking was founded as to be one of the best way to harvest energy and there are two way to harvest such energy by using magneto electric generation or piezoelectric. According to Roundy and Wright, a wireless transmitter is powered by using less than 1 cm^3 piezoelectric generation. The hypothesized and multiple layers piezoelectric can lower its impedance that would make it able to power a sensor without extra component.

There are various uses from a vibration control technology found by Ogando (2007). He labeled it as “adaptronics”. The energy and force is utilizing voltage output to show the difference between the two to physics classes with a simple circuit developed by Grove & Ehle (2002). Meanwhile, Kim stated that ratio of