ENERGY-EFFICIENT LED LIGHTING SYSTEM FOR RESIDENTIAL APPLICATIONS

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This thesis is dedicated to my parents.

For their endless love, support and encouragement.

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ABSTRACT

The purpose of this project is to design a prototype of an energy-efficient lighting system for residential application. The main advantage of the project is the ability to reduce power consumption system by using wasted heat energy from the surrounding area, specifically designed for housing lighting system. The energy saving is contributed from not only the light emitting diodes (LEDs) – that replace the traditional bulbs – but also the power supply. Apart from the LEDs, the main components that form the lighting system are the thermoelectric generator (TEG) module and the microcontroller circuit. The TEG module is the main energy source that converts the surrounding heat into electrical energy. The lighting system uses normal electric power as the backup energy source. During the time when the TEG module is incapable to provide sufficient electrical energy, the normal electricity supply will be activated. All operations including the power supply monitoring, switching and LEDs lighting up are controlled by the microcontroller circuit. The project has been successfully designed. However, a certain part of the system failed to function as expected. This is due to the failure of the TEG to generate sufficient amount of voltage to light up the LED. This project also contributes to green technology application and towards a greener Earth. Several recommendations are suggested for future work such as including rechargeable battery instead of AC power supply, upgrading the system by developing a hybrid of the TEG with a solar panel, and applying TEG to other electronic devices that releases wasted heat such as laptops so that the TEG can be used the heat released to charge the battery of the laptop or supply energy for any other purpose.

ABSTRAK

Tujuan projek ini adalah untuk membina satu prototaip sistem lampu cekap tenaga untuk aplikasi rumah kediaman. Kelebihan utama projek ini adalah keupayaannya untuk mengurangkan penggunaan kuasa dengan menggunakan tenaga haba yang terbuang dari kawasan sekitarnya, yang direka khas untuk sistem lampu rumah kediaman. Penyumbangan penjimatan tenaga bukan sahaja didapati daripada diod pemancar cahaya (LED) - yang menggantikan mentol tradisional - tetapi juga bekalan kuasa. Selain daripada LED, komponen utama yang membentuk sistem lampu tersebut adalah modul penjana termoelektrik (TEG) dan litar mikropengawal. Modul TEG adalah sumber tenaga utama yang menukarkan haba sekitarnya menjadi tenaga elektrik. Sistem lampu tersebut menggunakan kuasa elektrik biasa sebagai sumber tenaga sandaran. Apabila modul TEG tidak berupaya untuk menjana tenaga elektrik yang mencukupi, bekalan elektrik biasa akan diaktifkan. Semua operasi termasuk pemantauan bekalan kuasa, suis dan lampu LED dikawal oleh litar pengawal mikro. Walau bagaimanapun, bahagian tertentu system ini gagal berfungsi seperti yang diharapkan. Ini adalah disebabkan oleh kegagalan TEG untuk menjana jumlah voltan yang cukup untuk menyalakan LED. Projek ini juga menyumbang kepada aplikasi teknologi hijau dan ke arah Bumi yang lebih hijau. Beberapa cadangan yang disyorkan untuk kerja-kerja masa depan adalah seperti memasukkan bateri boleh dicas semula dan bukannya kuasa AC bekalan, menaik taraf sistem dengan membangunkan hibrid TEG dengan panel solar, dan mengaplikasikan TEG kepada peranti elektronik lain yang melepaskan haba seperti komputer riba supaya boleh digunakan oleh TEG untuk mengecas bateri komputer riba atau membekalkan tenaga bagi apa-apa tujuan lain.

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CHAPTER I

INTRODUCTION

1.1 PROJECT BACKGROUND

Energy is one of the issues that are causing the most controversy as fossil fuels are the greatest pollutants and the greatest contributors to the greenhouse effect. The increasing importance of environmental concern, fuel savings and unavailability of power has led to the renewal of interest in renewable energies [1]. It therefore stands to reason that developing countries whose energy consumption rate is increasing at a very fast rate should be investigating new energy systems based on renewable energies that do not pollute and which are inexhaustible.

Our addiction to electricity has generated a concurrent addiction to fossil fuels. However, the reserves of fossil fuels will soon be depleted, since oil is a limited resource. Over the years, the cost of electricity has risen to unprecedented levels due to the limited supply of oil and economic and political factors. Thus, renewable energy is a more attractive alternative to electricity generation, as it will also provide a cleaner environment for future generations. In the world today, there are many great solutions to renewable energy, but some are unfeasible. In this proposed project, a device will be created to introduce a way for humans to create renewable energy using thermoelectric devices.

Renewable energy can be created by many methods; for example, solar energy, wind energy, hydro energy, nuclear energy, and many more. For each of these different forms of creating electricity, there are certain limitations. Solar energy is the most common form of renewable energy that is used in applications ranging from household power to spacecraft electrical systems. However, solar energy can only be created when there is sunlight, necessitating the use of alternate energy sources, or a method of storing energy for later use. Wind energy and hydro energy have their own limitations, making them insufficient for wider usage. Nuclear energy is used in applications such as power plants and military vehicles. Nuclear sources can supply adequate amounts of energy, but produces hazardous waste that is harmful to the environment. This project aims to provide a source of renewable energy that overcomes the limitations of current methods.

The energy saving is contributed from not only the light emitting diodes (LEDs) – that replace the traditional bulbs – but also the power supply. Apart from the LEDs, the main components that form the lighting system are the thermoelectric generator (TEG) module and the microcontroller circuit. The TEG module is the main energy source that converts the surrounding heat into electrical energy. The lighting system uses normal electric power as the backup energy source. During the time when the TEG module is incapable to provide sufficient electrical energy, the normal electricity supply will be activated. All operations including the power supply monitoring, switching and LEDs lighting up are controlled by the microcontroller circuit.

1.2 PROBLEM STATEMENTS

The traditional incandescent light bulb has been widely used all around the world for so many years. However, according to some research, the traditional light bulb has been proven to be consuming higher electrical energy compared to the latest developed light bulb such as CFL and LED. Table 1.1 shows a comparison between a 60W traditional incandescent, 43W Energy-saving incandescent, 15W CFL and a 12W LED. Based on this fact, LED has been chosen to be used as the main lighting source of the system.

Table 1.1: Comparison between four types of light bulb

	60W Traditional Incandescent	43W Energy-Saving Incandescent	15W CFL	12W LED
Energy Saved (%)	-	~25%	~75%	~75–80%
Annual Energy Cost	$4.80	$3.50	$1.20	$1.00
Bulb Life	1000 hours	1000 to 3000 hours	10,000 hours	25,000 hours

The amount of wasted energy in Malaysia has increased from day to day. Therefore, this wasted energy should be used as an additional power supply in our daily life to create a reliable and energy-saving system. This project proposed the usage of TEG as an energy harvester to collect wasted heat from the surroundings as a new power source to the lighting system.

This project addresses the limitations of the traditional lighting system which can be summarized as the following:

1. The traditional bulbs consume high electrical energy.
2. A lighting system without additional power supplies is unreliable and inefficient.

1.3 OBJECTIVES

The project aims to achieve the following objectives:

1. To design a prototype of a low power lighting system using an array of LED lights.
2. To reduce further the power consumption by using the harvested heat energy as the main energy source for the LED lights.

1.4 PROJECT SCOPE

The scope of the work mainly relates to computer engineering including the following tasks:

1. Hardware design including the design, fabrication and test of LED lighting arrays, power supplies and microcontroller circuit.
2. Software development including the coding of the microcontroller that controls all operations of the lighting system.

1.5 PROJECT SIGNIFICANCE

The project significance is the benefits and the contributions that the project has to offer to the society. As for the Energy-efficient LED Lighting System, this project contributes to the following:

1. To reduce power consumption, mainly in housing lighting system, using wasted heat energy from the surrounding area.
2. In support of the green technology.

1.6 THESIS ORGANIZATION

This thesis comprises five chapters: Introduction, Literature Review, Project Methodology, Result and Discussion, and Conclusion and Future Work. The introduction of the project has been elaborated in this chapter where it specifically explains the background of the project for further understanding of the thesis. Chapter 2, the Literature review, reviews the theory on thermoelectric generator, energy harvesting, and existing work, also several other topics related to the project. Chapter 3 discusses the methodology of the overall project which is divided into two categories; hardware design and software design. Experimental results and discussion are explained in further details in Chapter 4. Finally, the thesis ends with Chapter 5 which concludes the overall project followed by a number of recommendations for future work and research.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter covers a fully-referenced review based on the relevant literature as well as the basic theoretical concept of an energy efficient lighting system, the concept of energy harvesting, and the research on the TEG. The chapter begins with the description of the existing domestic lighting systems, followed by studies on the related theoretical review and energy harvesting. Then, it explains the theory of thermoelectricity which includes the Seebeck Effect, thermoelectric generator, and the research on the existing work regarding the project. Finally, the chapter explains about microcontroller and Microchip's Peripheral Interface Controller (PIC). At the end of the chapter, a summary is provided.

2.2 EXISTING DOMESTIC LIGHTING SYSTEMS

Light is a natural phenomenon vital to human existence. The advent of a wide range of electric light sources contributes to less dependency of human upon light from the sun, moon and stars and flames from combustible fuels. Artificial lighting would not be required if the buildings were not occupied or visited by human beings [1]. The sole purpose of lighting installations is to allow people to adequately perform physical or visual tasks, and the effectiveness of performing these tasks correlates to the quantity and the quality of the lit environment.

In the ideal world lighting installations should be designed primarily for the comfort of the occupants within. The task efficiency, energy efficiency and aesthetic value of the lighting installation a secondary consideration. However, the importance of energy efficiency is greatly increased with issues such as climate change and energy prices, which all impact in our community. The major aim of lighting is to provide the correct lighting solution for the installation to attain the highest quality product, or image, whilst realizing the need for energy efficiency.

The quality of the lighting system is paramount - the quality of output, the morale of the employees and perceived working conditions are all directly related to the lighting system installed. The most important thing to remember is that lighting is based on 50% fact and 50% psychology. The needs of the site and the occupants, or potential customers, are critical. Many complaints stem from the perceived inadequacies of the lighting system. Artificial lighting is a key part of human’s everyday lives. They are used to:

- Help find the way around, to assist visibility
- Provide a safer environment
- Increase the number of useful hours in the day
- Help perform visual tasks, increase productivity
- Display objects and / or control how they appear, improve sales
- Attract attention
- Improve employee working conditions
- It is also possible to use lighting to reduce fatigue, encourage concentration or to improve awareness or decision-making. It can create an atmosphere of comfort, relaxation or trust or help people recover from illness or fatigue.

Incandescent lamps or bulbs have for many years been the most commonly used type of lighting. They work by heating an electric element to white hot [1]. They are inexpensive to buy and are available in a wide range of shapes and sizes, but their running costs are high. Incandescent lamps are the least energy efficient type of lighting, and are being phased out where ever possible over the next few years. Almost all of the electrical energy used by incandescent lamps is converted into heat rather than light. Standard incandescent bulbs only last about a thousand hours and must be regularly replaced. Incandescent lamps are most suitable for areas where lighting is used infrequently and for short periods, such as laundries and toilets. Incandescent bulbs produce light when an electric current passes through a filament and causes it to glow. Because they are less energy efficient than other light sources, they are best used for task lighting that demands high levels of brightness.

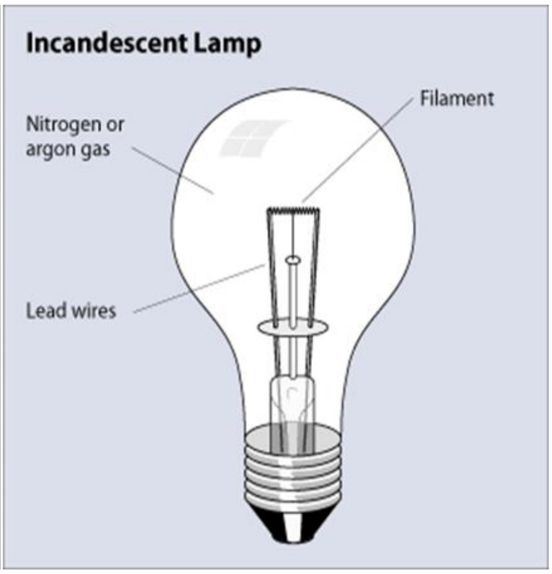

Figure 2.1: Incandescent Lamp

Fluorescent bulbs produce light when an electric arc passes between cathodes to excite mercury and other gases producing radiant energy, which is then converted to visible light by a phosphor coating. They use 1/5 to 1/3 as much electricity as incandescent with comparable lumen ratings and last up to 20 times longer. Compact types are used in smaller, trimmer fixtures such as recessed down lights, wall sconces, close-to-ceiling fixtures, and track lights. Screw-in types can be used in place of incandescent in standard lamp sockets. They are available in a wide spectrum of colors. Warm white tones best duplicate the color of incandescent. Today's fluorescent bulbs come in a wide selection of sizes and can produce warm tones of light similar to those of incandescent.

Figure 2.2: Fluorescent Lamp

Light Emitting Diodes (LEDs) produces light when voltage is applied to negatively charged semiconductors, causing electrons to combine and create a unit of light (photon) [14]. In simpler terms, an LED is a chemical chip embedded in a plastic capsule. Because they are small, several LEDs are sometimes combined to produce a single light bulb. LED lighting in general is more efficient and longer lasting than any other type of light source, and it is being developed for more and more applications within the home. LEDs are currently popular in under-cabinet strips and some types of downlights.

Figure 2.3: LEDs

2.3 RELATED THEORETICAL REVIEW

This section present studies and research of the theoretical review on the energy consumption of lighting system, light emitting diodes, also known as LED, and other related theories.

2.3.1. Energy Consumption for Lighting System

Finding efficient ways to manage the power and make lighting systems more effective is an increasingly important element in reducing operating costs. Figure 2.1 shows that the lighting system consumes the most energy compared to ventilation, cooling, refrigeration, office equipment, ect.

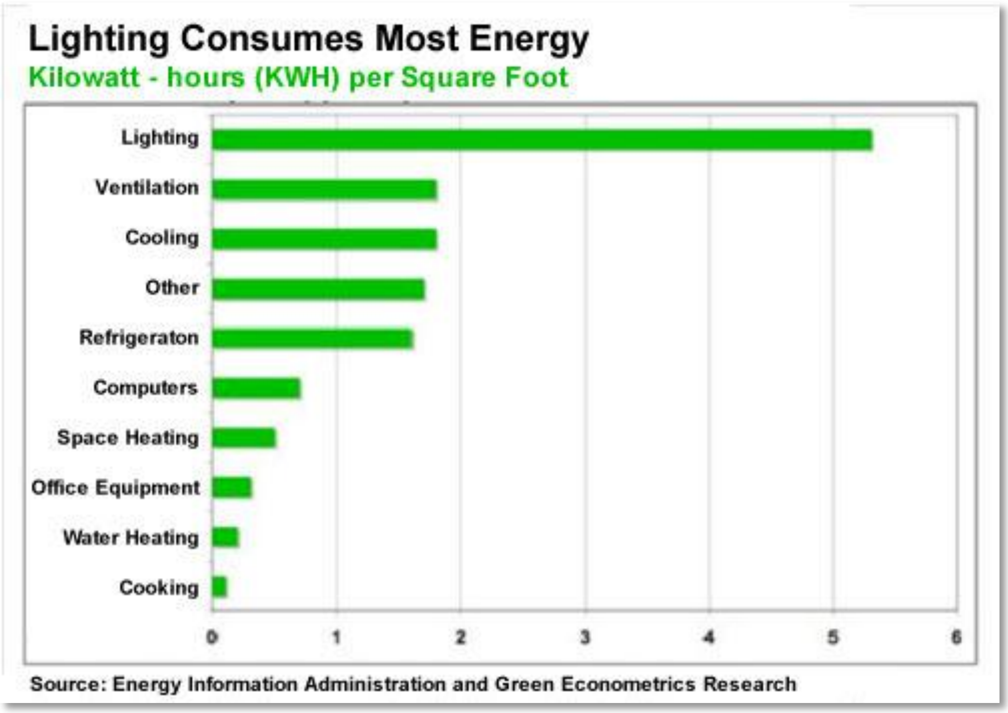

Figure 2.4: Energy Consumption for Lighting

Using smart lighting can significantly cut energy bills across an organization or a location, but the cost of installing and maintaining the sensor and a wireless network can outweigh the savings [14]. However, energy harvesting is now becoming a viable technique to help industrial systems designers reduce power. As the power consumption of wireless transceivers and microcontrollers falls, they can now be used with the low but constant power available from harnessing the energy from the environment.

Using solar or thermal energy can be used to power sensors and wireless networks, coordinating and controlling lighting across a wide area without having to retrofit miles of cabling. These systems do use batteries, but adding the small, incremental cost of energy harvesting brings large benefits in operational management, allowing the sensor nodes to be placed alongside lighting in inaccessible areas and eliminating the need to replace the batteries.

Although it is not viable to use the milliwatts generated by energy harvesting to power LED lights, this 'free' power from the environment can be used to drive sensors that can reduce or even shut down lighting when it is not needed. This technology can also power a wireless link which can optimize the lighting across a manufacturing floor or industrial environment, ensuring the most efficient use of the energy and reducing costs. Enabling the lighting only when someone is nearby, either by using a proximity or movement sensor or a notification from a central server, can significantly reduce the power requirement and thus reduce the overall operating costs.

Energy harvesting facilitates this capability, and can be added to an industrial lighting system without having to install cabling, as the nodes can be placed directly wherever they are required. As lighting is spread all over an area, this can save on the material and installation of miles of cabling and provide a quick and easy technique for retrofitting a control system. This can also work in conjunction with the design of the environment for what is called 'daylight harvesting'. This makes best use of the available daylight, reducing the artificial lighting to provide a consistent environment. This requires close control of the lighting systems, often linked back to software on a server that uses the layout of the facility.

Energy harvesting technology can provide an easy way to retrofit a wireless link into the lighting system to provide the necessary control [1]. While this may seem complex, the average saving from using 'daylight harvesting' is 24%, and in