HEAT POWERED OPTICAL ALERT SYSTEM

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Dedicated to my father, Yaw Len and my mother, Cheong Yoke Ying.

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ABSTRACT

The report describes the heat powered optical alert system which will directly convert waste heat to electricity by using a thermoelectric device as a heat generator to light up the LEDs when there is a temperature difference between both hot side and cool side of the thermoelectric module. Thus, the fundamental objective is to design a more sustainable energy optical alert system which is able to provide electricity for free and without causing pollution or greenhouse gasses on the environmental. Briefly, all the basic parameter and fundamental theories will be described in detail. Lastly, the simulation results gained will also be discussed in the report.

ABSTRAK

Laporan ini menghuraikan bagaimana untuk menilai prestasi sistem haba powered isyarat optik yang secara langsung akan menukar haba terbazir kepada elektrik dengan menggunakan peranti termoelektrik sebagai penjana haba untuk menyalakan LED apabila terdapat perbezaan suhu di antara kedua-dua belah panas dan sebelah sejuk modul termoelektrik. Oleh itu, matlamat asas untuk mereka bentuk system amaran tenaga yang lebih mampan optik yang mampu untuk menyediakan tenaga elektrik secara percuma dan tanpa menyebabkan pencemaran atau gas-gas rumah hijau ke atas alam sekitar. Secara ringkasnya, semua parameter asas dan teori-teori asas akan diterangkan secara terperinci. Akhir sekali, keputusan simulasi yang diperolehi juga akan dibincangkan dalam laporan.

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LIST OF ABBREVIATIONS

LED	-	Light Emitting Diode
PCB	-	Printed Circuit Board
NiCd	-	Nickel Cadmium
NiMH	-	Nickel Metal Hydride
Li-Ion	-	Lithium Ion
Bi_2Te_3	-	Bismuth telluride
DC	-	Direct Current
AC	-	Alternate Current
GaAlAs	-	Gallium Aluminium Arsenide
InGaN	-	Indium Gallium Nitride
VDC	-	Voltage of Direct Current
NPN	-	Positive-Negative-Positive
TIP	-	Texas Instruments Power

CHAPTER 1

INTRODUCTION

1.1 Overview of Project:

The waste heat is considered as one type of the renewable energy resources. Recently, the Government encourages the usage of renewable energy due to three fundamental objectives [1]. The first objective is to make sure that the energy provision is adequate. The second objective is to gain a higher efficiency of energy consumption and the third is to minimize the disposal of negative impacts on the environmental. The renewable energy will never run out and can be utilized for energy saving because it is sustainable and renewable [2]. Besides, renewable energy produces little waste elements, such as carbon dioxide or other chemical pollutants, so there is minimal impact on the environment [1]. However, renewable energy is difficult to generate the amount of electricity that is as large as those produced by traditional fossil fuel generators [2]. Thus, more renewable energy facilities are needed to solve the problem. Another disadvantage is the reliability of supply. Renewable energy often relies on the weather. For example, hydro generators require rain to supply water flowing, wind turbines require wind to turn the blades, and solar panels require sunshine to generate electricity.

Heat powered optical alert system is a LED (Light Emitter Diode) lighting alert system which is powered up by heat generator. Therefore, the

major part for the system is the heat power generator which is purposely designed to convert waste heat into electricity by using thermoelectric device which generates voltage (electricity) when there is a temperature difference on both hot side and cool side [3]. Waste heat is chosen instead of solar energy because the amount of solar energy is difficult to predict and the electricity can only be produced during daylight hours. The power efficiency would be significantly reduced during winter season and cloudy days. However, waste heat can be easily generated by human activities, like driving vehicles, operating equipment, manufacturing processes and so on.

Proteus PCB design software (version 7.2) which is developed by Labcenter Electronics and has been used as the simulation tool for the designed circuit before going to build the project prototype. Proteus is chosen as the simulator tool because it is easier to be conducted for designing and analysing the circuits. Proteus PCB design software combines the ISIS schematic capture and ARES PCB Layout programs to provide a powerful and easy to suite of tools for PCB design. ISIS schematic capture is a tool used for placing components or devices to design a circuit. ARES PCB Layout is a PCB design system with the automatic component placer, rip-up, and retry auto router and interactive design rule checking. Therefore, users can simulate the designed circuit before going to build a prototype in order to minimize the failures happened in the printed circuit board (PCB).

Upon the completion of the project, the system can be used for emergency LED triangle light. This is the chosen application to verify the functionality of the system. The warning light is important during emergency especially at the highway. Some of the drivers do not realize that there is a vehicle parking beside the road because of the engine break down or maybe because of the flat tire. Thus, the number of accidents happened is increasing recently. The emergency LED triangle light will alarm the other drivers particularly during night and raining days. However, the waste heat may be reduced when the surrounding temperature is lower than sunny day especially during raining day and night. Then, the potential of the system to convert heat into electricity will be reduced significantly and the emergency LED triangle

light will be failed to light up as well. Therefore, the battery charger circuit is also required to charge the rechargeable battery so that the drivers can light up the emergency LED triangle light during emergency.

1.2 Objectives:

The objectives of the project are:

1. To convert waste heat into electricity which are renewable and green power sources in order to provide electricity for free and without causing pollution or greenhouse gasses on the environmental.
2. To develop a sustainable energy system with self-powering in order to face the energy sources shortage problem.
3. To replace other renewable energy sources which is unreliable, such as solar energy requires sunshine to produce electricity, wind turbines require wind blowing to turn the blades and hydro generators require raining day to supply the water flowing.
4. To minimize the impact on environmental because the renewable energy produces little chemical pollutants, such as carbon dioxide.
5. To increase the utilization efficiency because the renewable energy systems require less maintenance than traditional generators.
6. To build a DC booster circuit to step up the input voltage to a higher output voltage because of the low efficiency of the thermoelectric module.
7. To power the emergency LED triangle light because it is the chosen application to verify the functionality of the system.
8. To interface with the battery charger so that the emergency LED triangle light can be powered even the environment temperature is lower than usual especially during raining day and night.
9. To make sure the supply of energy is adequate to generate electricity which is important for daily activities because the renewable energy is sustainable.

1.3 Problem Statement:

In designing a thermoelectric generator, there are some problems and considerations need to be noted in selecting the suitable module. First and the most important consideration is the material and module construction because there are a lot of materials capable of producing power from a temperature difference and vary in cost, efficiency, and operating temperature. Module construction will also influence the output voltage and the maximum power of a module. Typically thermoelectric materials have low efficiencies (less than 10%) and some of the very cheap materials have only around 1% [4]. Bismuth telluride (Bi_2Te_3) is the most common material because it has the highest efficiency to be used in the temperature range [4]. High temperature bismuth telluride module may achieve 4% of maximum power efficiency [4].

Another problem is to maintain a large temperature difference across the module. It is one of the important considerations because the output voltage or the output power will be increased when the temperature difference across the module is larger. Therefore, a heat sink is necessary at the cold side because the cold side must be kept as cold as possible in order to maintain a large temperature difference across the module [4]. Without using the heat sink, it is difficult to get an enough temperature difference for power generation. While on the hot side of the module, the heat sink is less critical, even if there is no heat sink installation, the large temperature differential inside the car can compensate for it [4].

In order to power the LED by using thermoelectric module, a power electronic circuit will be required. The voltage and current will vary because of the thermoelectric module characteristics and the module temperature difference changes [4]. For maximum power, the load resistance must match the module internal resistance which also changes slightly with temperature [4]. Thus, the output voltage from the thermoelectric module may be boosted to power the LED if there is insufficient power for the whole LED lighting system [4].

1.4 Scope:

The most focusing part for the project is the thermoelectric module which will convert heat into electricity directly when there is a temperature difference across the module. The thermoelectric device has no moving parts and its operation is silent. The device should also require less maintenance and have an acceptable lifetime. In designing a thermoelectric generator, there are many statements that must be considered. Each component must be evaluated on how it will function with the rest components of the system. The basic components of the heat power generator system include thermoelectric module, electronics components, and load like LED to verify the system.

There are some considerations in selecting the most suitable module because the materials will be varied in cost, dimensions (L*W*H), maximum operation temperature and maximum temperature difference. Module construction will also affect the maximum power produced by a module and the voltage or current characteristic of the whole system because the module construction consists of the geometry of the thermo elements and the way for connecting the elements [4].

Bismuth telluride is the most common material used and it is relatively cheap [4]. Modules can be constructed to produce power but the geometry of the thermo elements will affect the output power of the module, the efficiency, and the voltage achieved. Therefore, the equation (1.4.1) below can be applied to estimate the power output of a module [4].

$$P = \frac{\alpha}{\rho}\frac{\Delta T^2}{2}\frac{NA}{L} \qquad (1.4.1)$$

where:

P is the module power.

N is the number of elements.

ΔT is the temperature difference between module hot side and module cold side.

A is the area of elements.

ρ is the electrical resistivity of the module.

L is the element length.

The equation (1.4.1) is very useful in estimating the power output of a module. However, unfortunately, it is difficult to get the related information from a manufacturer [4]. Normally the information shown in data sheet is only about dimensions, maximum temperature difference, maximum voltage or current. Thus, only the important observation can be made from the equation is that power is proportional to the temperature difference squared [4]. Another observation is that the power is not proportional to the thermo element leg length. The power increases when the thermo element leg length decreases [4].

Moreover, a DC booster circuit is needed to step up the input voltage to a higher output voltage because of the low efficiency of the thermoelectric module. Sometimes the environment temperature will be lower and cause the temperature gradient getting smaller between cold and hot sides. DC booster circuit can convert input voltage to a higher output values for useful applications.

On the other hand, the battery charger circuit will also be implemented to charge the rechargeable batteries, such as NiMH or NiCd rechargeable AA batteries are the common used batteries so that LED can be powered even the temperature is lower than usual especially during raining day and night.

For the electronic circuit part, Proteus PCB design software will be used to simulate the implemented circuit of the project. The designed system will be verified by connecting LEDs (Light Emitter Diode) in parallel connection. In order to power the LEDs, a LED driver circuit is also

implemented. There are a group of LEDs used to form the emergency triangle lighting system so as to be the optical alert system.

1.5 Project Outcomes:

It is expected that once the completion of the project, the heat powered optical alert system which is self-powering can be used for emergency LED triangle light in order to communicate with the road users. This is the chosen application to verify the functionality of the heat powered system.

The optical alert system is acted as a warning light which is important during emergency especially at the highway. Some of the drivers do not realize that there is a vehicle parking beside the road because of the engine break down or maybe because of the flat tire. Therefore, the number of accidents happened is increasing recently. Thus, the emergency LED triangle light will alarm the other drivers particularly during night or raining days.

However, the waste heat may be reduced when the surrounding temperature is lower than sunny day especially during raining day and night. Then, the potential of the system to convert heat into electricity will be reduced significantly and the emergency LED triangle light will be failed to light up as well. Thus, a DC booster circuit is one of the outcomes to step-up the input voltage to a higher output values. On the other hand, the battery charger circuit is also required to charge the rechargeable batteries so that the drivers can light up the emergency LED triangle light during emergency.

1.6 Methodology:

After registration of project title, the project starts with the searching of source and information regarding thermoelectric modules, heat power generation, rechargeable batteries types, battery charger circuit and the power circuit of LED. The regarding source and information are mainly obtained

from engineering journals, reference books and internet searching. Moreover, the related circuits of schematic diagrams are also referred from the engineering journals and then the related circuits will be simulated by using Proteus PCB design software. The simulation processes will be repeated until the desired results can be obtained.

After the simulation processes have been done successfully, the designed PCB layout can be drawn by using ARES PCB Layout which is a PCB design system with the automatic component placer, rip-up, and retry auto router and interactive design rule checking so that the components can be connected correctly before placing the components on PCB. For hardware part, the project prototype will be designed and built according to the simulation results. The electronic components are first connected and tested in the bread board before soldering the electronic components on the etching and PCB board.

1.7 Thesis Structure:

Chapter 1: The first chapter provides a general inspiration for the project. It includes the overview of project; the objectives of project, problem statement, scope of the project and project outcomes.

Chapter 2: Project's background is illustrated in this chapter. Generally, this chapter summaries the literature review that have been studied. The concept of thermoelectric and theory of the circuit schematic diagrams for DC booster circuit, battery charger and LED driver that are used for heat powered optical alert system will be explained in this chapter.

Chapter 3: The third chapter is discussed about the methodology of the project. The methods, materials and procedures used to conduct the project in achieving the objectives of the project are explained in details.