HEAT ENERGY HARVESTING FOR PORTABLE POWER SUPPLY
(PosHEAT)

By

Ahmad Nazri Bin Haji Abd Razak

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical & Electronics Engineering)

MAY 2011

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

HEAT ENERGY HARVESTING FOR PORTABLE POWER SUPPLY (PosHEAT)

By

Ahmad Nazri Bin Haji Abd Razak

A project dissertation submitted to

Electrical and Electronics Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfillment of the requirements for the

BACHELOR OF ENGINEERING (Hons)

(ELECTRICAL AND ELECTRONICS ENGINEERING)

Approved:

Dr. Nursyarizal Mohd Nor

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2011

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.

AHMAD NAZRI BIN HAJI ABD RAZAK

ACKNOWLEDGEMENT

First of all, I would like to express my gratitude to God for giving me the strength and health to complete this project. Not forgotten to my parents and all my family members for providing everything, such as money and advises, which is most needed in this project.

I would like to thank my supervisor, Dr Nursyarizal Mohd Nor for sharing his knowledge and giving me the support and guidance throughout the project. I also would like to thank lecturers, especially Dr Taib Ibrahim and Ir. Faris Abdullah for assisting me to design the project.

My appreciation also goes to Universiti Teknologi PETRONAS especially Electrical and Electronics Engineering Department, by providing me the necessary assets and resources, not only to accomplish my task, but to enrich my knowledge further.

Last but not least, I offer my regards to those who support me especially all my friends and technicians in Electrical and Electronics Engineering Department for contributing their assistance and ideas for this project.

ABSTRACT

Nowadays, a lot of electrical, machinery and electronic appliances has been improved, recycled and reutilized to achieve high efficiency. From heavy equipment to the simple appliances, most energy is waste in form of heat. Usually the energy waste from vehicles exhaust are abundant, therefore new approach is required to reuse them as alternative source of energy. The aim of this project is to apply the thermocouple concept to generate electricity from the waste of heat. This project is using wasted heat from motorcycle exhaust and home heater to generate electrical energy that can be used to charge any mobile phones, PSP, MP3, MP4 and other digital products anywhere and anytime. Since mobile phone became very important to us for communication, so we need to make sure that our mobile phone is turn on anytime. This project designs a heat energy harvesting for potable power supply that can bring and use anywhere since we have the source of heat need to convert. As we know, heat also a type or energy that can be converting to electrical energy. Based on seebeck theory voltage is created in the presence of a temperature difference between two different metals or semiconductors. This project use seebeck unit to convert the waste heat energy to electrical power and boost converter is use to step up the DC voltage that produce. Then the energy is stored in rechargeable batteries and can use to charge up our mobile phone anytime. The batteries also can be used as a backup when we do not have any source of heat energy to be converted. This project will produce a new innovation and become the first mobile phone charger using waste heat. Since this innovation have no emission and completely silent, it will become one of the green technology and alternative energy.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS

LED	Light Emitting Diode
PosHEAT	Heat Energy Harvesting For Portable Power Supply
FYP	Final Year Project
DC	Direct Current
PMMA	Polymethyl Methacrylate
MMA	Methyl Methacrylate Monomer
PSP	Play Station Portable
MP3	Multimedia Player 3
MP4	Multimedia Player 4
CNC	Computer Numerical Control
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing

CHAPTER 1

INTRODUCTION

1.1 Background of study

In our daily live, abundant of waste heat release to environment is one of the main cause contribute to global warming. This project will come out with an innovative design called Heat Energy Harvesting for Portable Power Supply (PosHEAT) which can convert the waste heat to electrical energy. The energy produce can use to charge any mobile phones, PSP, MP3, MP4 and other digital products anywhere and anytime. This innovation will produce new renewable energy that we can get from waste heat and it also one of the green technologies.

The waste heat energy needs to convert by using thermoelectric converter, the process is known as seebeck effect. Rechargeable batteries are used to store the energy produce and also will function as a backup supply for the charger when the thermoelectric converter cannot produce any electrical energy. Thermoelectric converter will produce voltage when there is a different temperature on each side of that unit. Seebeck have many attractive features, such as no moving parts, completely silent, reduced maintenance and can be designed into a number of shapes for many specific applications [1].

Circuit for this project will be designed to boost and control the output voltage. Meanwhile, the prototype of this project is design according to the ability of sustained the high temperature, have high efficiency to absorb heat from exhaust and make this innovation portable to bring anywhere.

1.2 Problem statement

Nowadays, a lot of electrical, machinery and electronic appliances has been improved, recycled and reutilized to achieve high efficiency. From heavy equipment to the simple appliances, most energy is waste in form of heat. For example, our vehicles such as vans, buses, cars and motorcycle. Usually the waste energy from vehicles are abundant, therefore new approach is required to reuse them as alternative source of energy.

Every year the number of vehicles keeps increasing in our country. Therefore, many vehicles will produce waste heat, which can convert as electrical energy. By improvising the available thermoelectric generator by adding new features and design, it will encouraging people to use the wasted heat energy from their vehicles since it is free in term of electricity usage. Thus, this is can turn the waste energy issues to be useful secondary alternative energy solution. Furthermore, it is environment friendly as it is clean energy.

As this innovation is long term energy saver and portable, the target market of this innovation is for those who are ride a motorcycle in their daily life and people who tend to spend their life for travelling. This is the first mobile phone charger have at motorcycle and it only use the waste heat from motorcycle exhaust. The improvement of the innovation by adding new features is an effective ways where it will encourage people to utilized the waste energy as well as saving the cost of producing electricity.

1.3 Objectives

Upon completion of the project, some objectives set and satisfy the scopes of study that have been underlined, which are relevant to the requirement of the project. The objectives of this project are as follows:

1. To design a Heat Energy Harvesting for Portable Power Supply application for motorcycle exhaust. It used the waste heat from exhaust as the source of energy to charge a mobile phone. It also multipurpose which we can apply this innovation to any source of heat.
2. To obtain a green energy from heat coming from the engine of vehicles. Since this device has no moving parts and no emission to generate electricity, it can avoid from any pollution.

1.4 Scope of study

While the scope of study will consists of three major parts which are:

1. Research and survey on the seebeck unit application. The research is to give some ideas and relevant solutions to create and improve new application.
2. The experimental work is data gathering and identifying the processes and disturbance model of the application.

CHAPTER 2

LITERATURE REVIEW

2.1 Seebeck theory

Seebeck unit is a thermoelectric unit that is special manufactured to generate electricity from waste heat. Thermocouples that have in Seebeck unit are junction between two different semiconductors that produces voltage based on temperature difference shown in Figure 1. The bigger temperature difference, the higher voltage can be generated. This can be calculating using equation:

$$V = \int_{T_1}^{T_2} \left(S_B(T) - S_A(T)\right) dT \qquad (1)$$

S_A and S_B are the Seebeck coefficients and T_1 and T_2 are the temperatures of the two junctions. The Seebeck coefficients are non-linear as a function of temperature, and depend on the conductors' absolute temperature, material, and molecular structure. If the Seebeck coefficients are effectively constant for the measured temperature range, the above formula can be approximate as [2] :

$$V = (S_B - S_A).(T_2 - T_1) \qquad (2)$$

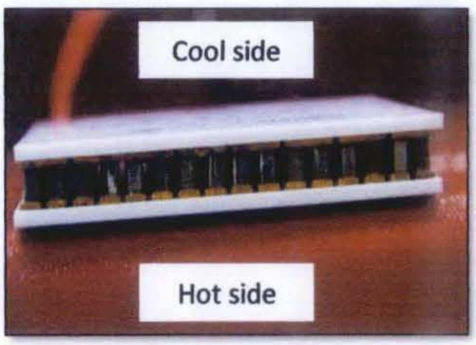

Figure 1 : Seebeck unit

Electrons on the hot side are more energize than on the cold side. These electrons will flow from the hot side to the cold side. If we have a complete circuit, electricity will flow continuously. Semiconductor materials are the most efficient, and combining in pairs of "*p* type" and "*n* type". The electrons flow from hot to cold in the "*n* type," While the ptoton flow from hot to cold in the "*p* type" This allows them to combine electrically in series to increase voltage and power output. A high temperature bismuth telluride (Bi_2Te_3) module has been selected due to its high efficiency and high operating temperature [3].

2.2 Thermoelectric power

A seebeck can produces electrical power from heat flow across a temperature gradient. As the heat flows from hot to cold, free charge carriers (electrons or holes) in the material are also driven to the cold end . The resulting voltage (V) is proportional to the temperature difference (ΔT) via the Seebeck coefficient, α, ($V = \alpha\Delta T$). By connecting an electron conducting (*n*-type) and hole conducting (*p*-type) material in series, a total voltage is produced that can be driven through a load. To achieve a few volts at the load, many thermoelectric couples element need to be connected in series to make the thermoelectric device.

A thermoelectric generator converts heat (Q) into electrical power (P) with efficiency η.

$$P = \eta Q \tag{3}$$

The amount of heat, Q, that can be directed though the thermoelectric materials frequently depends on the size of the heat exchangers used to absorb the heat on the hot side and release it on the cold side.

The efficiency of a thermoelectric converter on this project depends on the temperature difference $\Delta T = Th - Tc$ across the device. The efficiency of a thermoelectric generator is can defined as [4]

$$\eta = \frac{\Delta T}{T_h} \cdot \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+T_c/T_h} \tag{4}$$

Where the first term is the efficiency of exhaust and *ZT* is the figure of merit for the device. While the calculation of a thermoelectric generator efficiency can be complex, use of the average material figure of merit, *zT*, can provide an approximation for *ZT*.

$$zT = \frac{\alpha^2 T}{\rho \kappa} \tag{5}$$

Here, Seebeck coefficient (α), electrical resistivity (ρ), and thermal conductivity (κ) are temperature (*T*) dependent materials properties. Recently, the field of thermoelectric materials is rapidly growing with the discovery of complex, high-efficiency materials [5].

2.3 Theory of project

Based on electron theory, electricity is the movement of electrons in a conductor. It will move towards proton if the circuit completely connected. The voltage will produce across the connection. Charge carriers are the physical components of a material which allow it to conduct electricity. The fewer the number of electrons in an element's outer shell, the more loosely bound it is to the atom's nucleus, and the easier it is to make it flow with the application of a voltage [6]. It is also possible to produce a more conductive semiconductor material, the semiconductor can be doped by positively doped (P-type) or negatively doped (N-type). P type semiconductor will have proton as the charge carriers and for N type semiconductor will have electron as the charge carries.

Whenever an electrical conductor is strung between two different temperatures, the conductor is capable of transferring thermal energy from the hot side to the colder one. The process of transferring that heat also tends to move electrical charge carriers (proton and electron charge) within the conductor in the same direction as the heat. The movement of the charge carrier will generate current which follow the same direction with proton and opposite direction of electron movement. When we complete a circuit, it will produce voltage across the conductor. By using both types (N-type and P-type) of semiconductor in an element of seebeck, it will produce more current flow. In a seebeck, all the elements will connect in series to have higher voltage produced as shown in Figure 2.

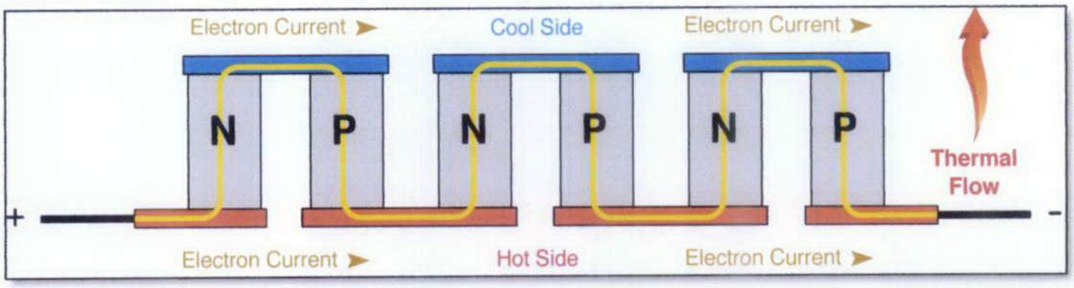

Figure 2 : Seebeck element in series [6]

CHAPTER 3

METHODOLOGY

3.1 Procedure identification

Figure 3 shows the flow of procedure identification through two semester period.

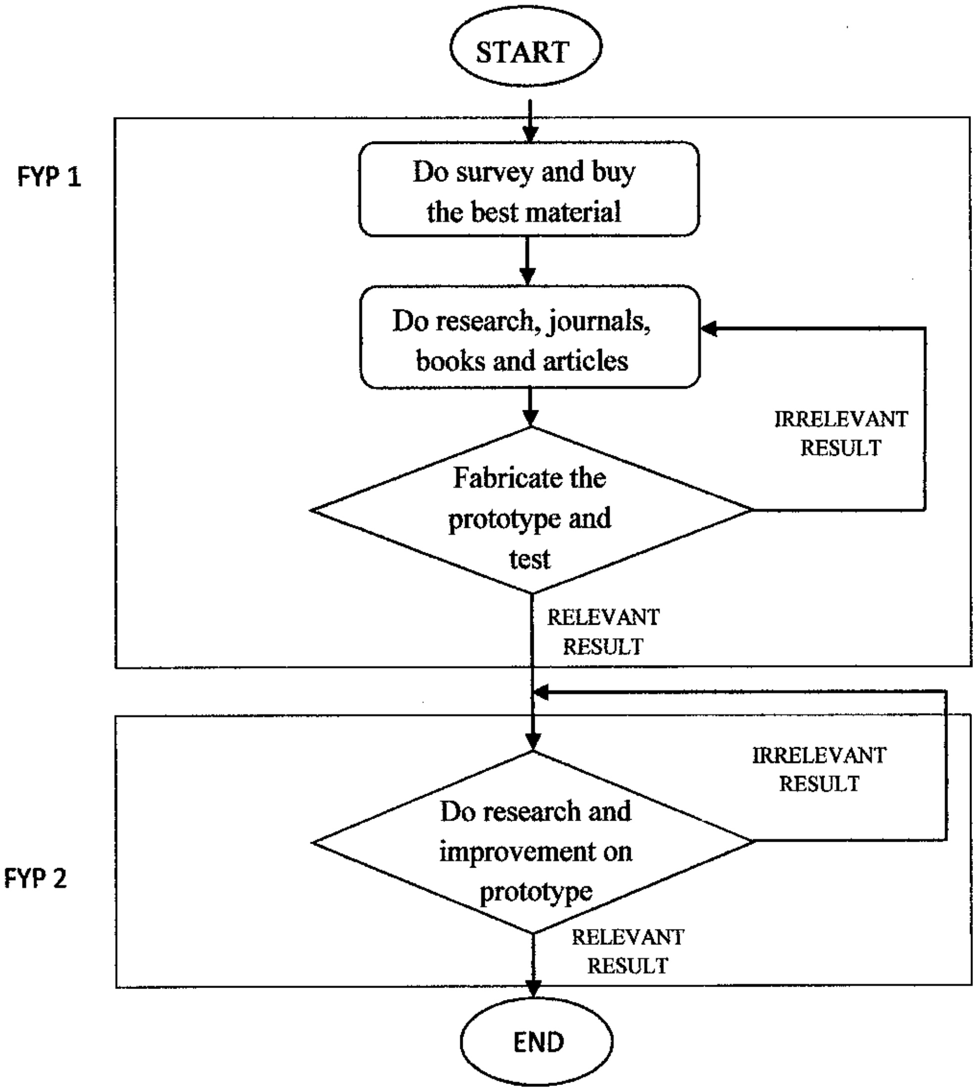

Figure 3 : Procedure identification

Every project must have a few steps to implement to get better result. Step progress of this project is tabulated, refer to Appendix A and B. All the desire output must be set the specification and can achieve the objective. The important step for this project as follow:

1. **Identify need**

   Construct a prototype of PosHEAT that can convert waste heat energy to electrical energy. This energy can use to charge a mobile phone and this innovation portable to use anywhere since we have a source of heat.

2. **Define problem**

   Nowadays, our earth has a biggest issue which is global warming. As we know the major cause of this issue because of abundant waste heat release from heat source such as engine, machinery, exhaust and anymore. From this project, it will use the waste heat energy and convert to electrical energy.

3. **Research**

   Conduct a research by surfing from internet, journals, conference papers and etc. about the thermoelectric effect and function of seebeck unit. Understand the concept of Seebeck effect and DC-DC boost converter that will use in this project.

4. **Set constraint**

   Target of this project is to complete fabricated and test the prototype of the innovation within the time given. Budget for this prototype is around RM200 which is cover all the material use for this project.

5. **Set criteria**

Cost effective, power efficient, portable, reliable, practical, marketable, green energy and safe for usage.

6. **Analysis**

All pros and cons of the proposed ideas are considered. The general idea must be clear understand and know how to construct the prototype. Alternative ideas are analyse as back-up plans if problems would arise unexpectedly in the future.

7. **Decision**

A final decision made by choosing the most practical considering the objective and other constraint to make it achievable.

8. **Specification**

Specification of the prototype made for detailed project report once everything has finalized and confirmed. Points to consider for specification are as follows:

Size → Handy

Design → Attractive

Quality → Lasting

Material → Affordable

Performance → Efficient

3.2 Tools and equipment required

3.2.1 Computer Numerical Control (CNC)

CNC is a machine that can manufacture parts quickly and efficiently. This machines are programmable, which can use CAD (Computer-Aided Design or drafting) to design any shape of desired parts. This CNC machines also able to process a variety of raw material from soft material such as plastic to hard material like titanium.

3.2.2 CNC Machining Procedure

Figure 4 shows the procedure involved before the design project is manufactured.

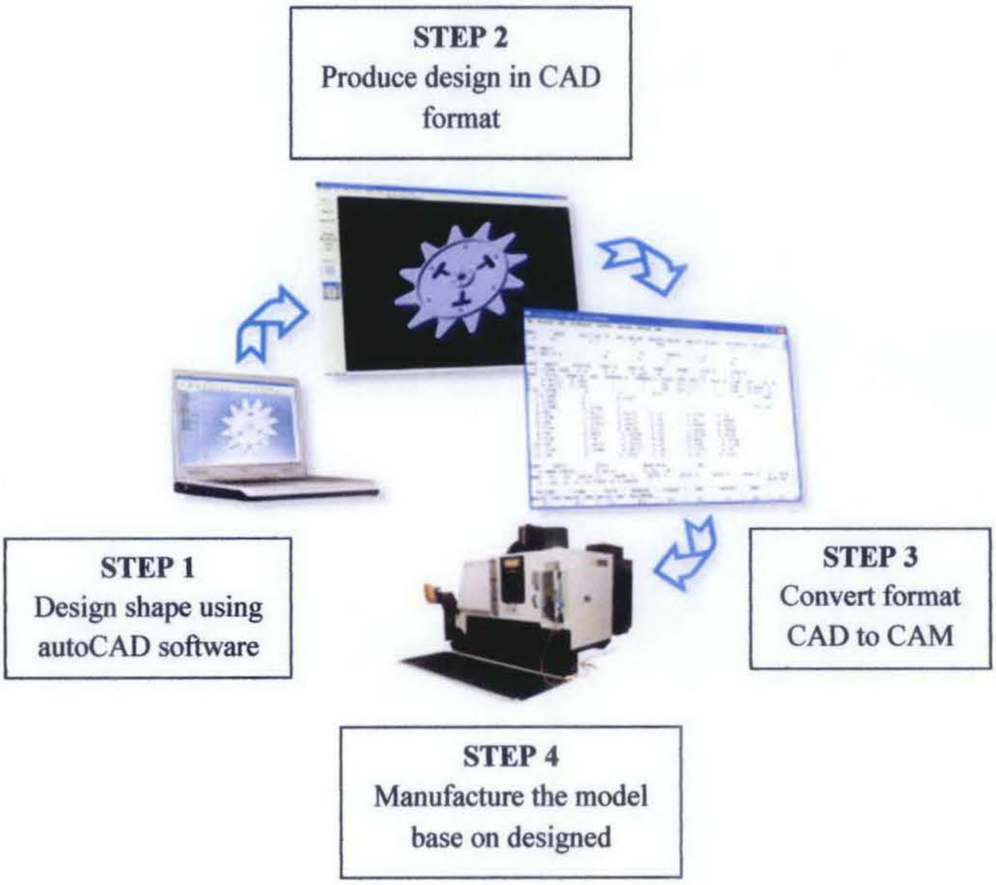

Figure 4 : Machining Procedure

A CNC machine is a multi-tooled lathe and milling machine. CAD is used to design parts quickly and precisely. The output from CAD will convert to machines program, CAM (Computer-Aided Manufacturing) to fabricate products. The step of program originating from a design is loaded onto the machine, the material is inserted appropriately, and the machine follows the program to manufacture the part. The CNC machine automatically switches heads, drills, mills, turns, and cuts unattended based on the program. Most CNC machining progresses through four stages, each of which is implemented by a variety of basic and sophisticated strategies, depending on the material and the software [7].

The stages are:

- **Roughing**

  This process begins with raw material, known as billet, and cuts it very roughly to shape of the design model.
- **Semi-Finishing**

  This process begins with a roughed part that unevenly approximates the model and cuts to within a fixed offset distance from the model.
- **Finishing**

  Finishing involves a slow pass across the model in very small steps to produce the finished part.

3.3 Justification for the material chosen

3.3.1 Seebeck unit

Thermoelectric is heart of this project. So, material selection of thermoelectric is the most important to have higher efficiency of this innovation. There have two types of thermoelectric unit, which is seebeck and peltier unit. Both of the units is same but have different function. Peltier unit is use to have temperature gradient when we supply voltage. Most of the peltier unit is used for small refrigerator application. But, seebeck is used to generate electrical power from temperature gradient. So, this project use seebeck unit to convert waste heat from exhaust to electrical power to supply for mobile charger.

The thermoelectric semiconductor material most often used in thermoelectric is an alloy of Bismuth Telluride that has been suitably doped to provide individual blocks or elements having distinct "N" and "P" characteristics. Thermoelectric materials most often are fabricated by either directional crystallization from a melt or pressed powder metallurgy. Each manufacturing method has its own particular advantage, but directionally grown materials are most common. In addition to Bismuth Telluride (Bi_2Te_3), there are other thermoelectric materials including Lead Telluride (PbTe), Silicon Germanium (SiGe), and Bismuth-Antimony (Bi-Sb) alloys that may be used in specific situations. Figure 5 illustrates the relative performance or Figure-of-Merit of various materials over a range of temperatures. It can be seen from this graph that the performance of Bismuth Telluride peaks within a temperature range that is best suited for most cooling applications [8]. Bi_2Te_3 is the best solution for using in this project compare to other materials because Bi_2Te_3 will produce more power at lower temperature.

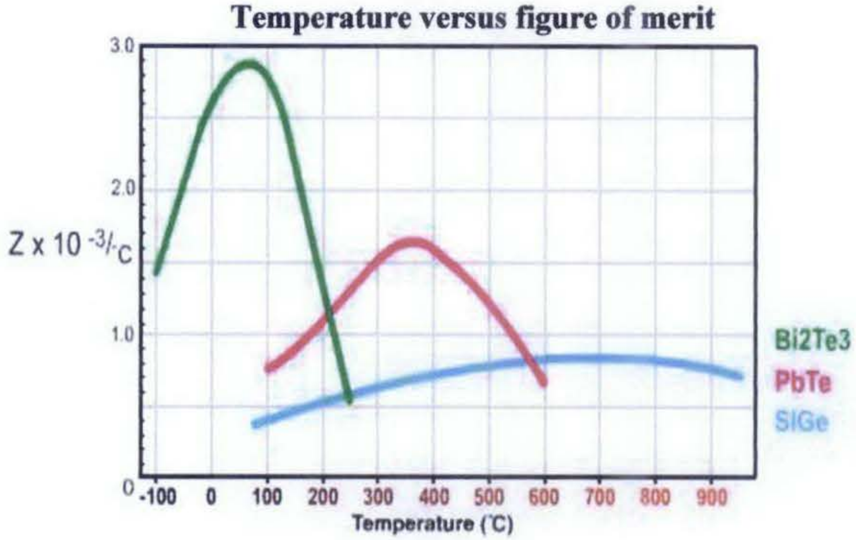

Figure 5 : Typical figure of merit for several TE materials [8]

Both N-type and P-type Bismuth Telluride thermoelectric materials are used in a thermoelectric unit. N-type material is doped so that it will have an excess of electrons (more electrons than needed to complete a perfect molecular lattice structure) and P-type material is doped so that it will have a deficiency of electrons (fewer electrons than are necessary to complete a perfect lattice structure). The extra electrons in the N material and the "holes" resulting from the deficiency of electrons in the P material are the carriers which move the heat energy through the thermoelectric material. Most thermoelectric cooling modules are fabricated with an equal number of N-type and P-type elements where one N and P element pair form a thermoelectric "couple."

After done some research, the best solution to use in this project is Bismuth Telluride (Bi_2Te_3), 127 P-N couple seebeck shown in Figure 6. The properties of the seebeck are:

- Convert heat directly into electricity.
- It is a solid state device with no moving parts and so it is completely silent and extremely reliable.
- The project is using 127 P-N couple, 10A, 15.2V
- Temperature gradient 67°C
- Dimension 40x40x3.3mm
- Resistance 1.16 Ω

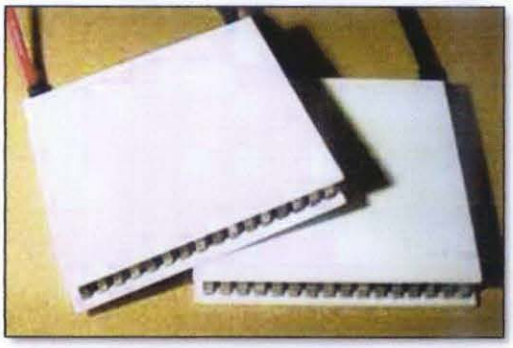

Figure 6 : Seebeck

3.3.2 Heat sink

Heat sinks are devices that enhance heat dissipation from a hot surface, usually the case of a heat generating component, to a cooler ambient, usually air. Heat sinks can be classified in terms of manufacturing methods and their final form shapes. The most common types of air-cooled heat sinks include:

1. Stampings: Copper or aluminum sheet metals are stamped into desired shapes.
2. Extrusion: These allow the formation of elaboratetwo-dimensional shapes capable of dissipating large heat loads.

3. Bonded/Fabricated Fins: Most air cooled heat sinks are convection limited, and the overall thermal performance of an air cooled heatsink can often be improved significantly if more surface area can be exposed to the air stream.

4. Folded Fins: Corrugated sheet metal in either aluminum or copper increases surface area and, hence, the volumetric performance. The most suitable heat sink can use in this project is shown in Figure 7. The properties of the heat sink are:

- Large surface area by having large amount of fine fins
- Good aerodynamics where the air can flow through the fins
- Thermal Conductivity 237 W m- K-1
- Specific Heat 900 J K-1 kg-1
- Linear Expansion Coefficient 23.5 x10-6 K-1

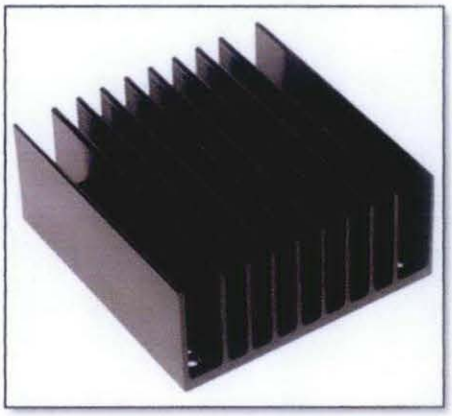

Figure 7 : Aluminium heat sink

3.3.3 *Aluminium cube*

Aluminium cube has chosen is suitable size with the design and easily can shape. The thermal conductivity is important for this material to absorb waste heat from the source. Aluminium is a silvery white member of the boron group of chemical elements. The properties of aluminium use are:

- It can be melted, cast and formed. Therefore it is very for fabrication.
- Highly corrosion resistant
- Density 3.80 g/cc
- Hardness, Mohs 9.00
- Tensile Strength, Ultimate 200 MPa
- Compressive Strength 2400 MPa
- Specific Heat Capacity 0.880 J/g-°C
- Thermal Conductivity 25.0 W/-K

3.3.4 *Perspex*

Perspex is a trade name of Lucite International and is polymethyl methacrylate (PMMA) acrylic sheet which is manufactured from methyl methacrylate monomer (MMA). The properties are:

- Low water absorption
- Low density 1.19 g/cm3
- Low flammability
- High weathering resistance
- Excellent weather and UV resistance
- Excellent optical clarity

3.4 Alternative Materials

There are possibilities that the components which are required could not be found. So it is important to have alternatives for the components. The material of seebeck is important to have a high efficiency. Bismuth Telluride is the best material for thermoelectric generator follow by Perovskite. So, the alternative for seebeck unit selection is using Perovskite seebeck.

- Bismuth telluride
- Perovskite
- Uranium dioxide
- Constantan
- Ytterbium Trialuminide
- copper oxide

The efficiency with which a thermoelectric material can generate electrical power depends on several material properties, of which perhaps the most important is the thermopower. A larger induced thermoelectric voltage for a given temperature gradient will lead to a higher efficiency. Ideally one would want very large thermopower values since only a small amount of heat is then necessary to create a large voltage. This voltage can then be used to provide power [9].

Peltier is another component which has the same material with seebeck. Although it is cheaper compare to seebeck in general, the seebeck which is ordered cost almost the peltier price. Besides that, the seebeck efficiency to generate electricity energy is higher compare to peltier. This is because peltier is use for cooling purpose instead of seebeck use for generate electrical power.

3.5 Construct the permanent flat surface on the exhaust

This project is using aluminium cube as raw material to make the permanent flat surface as shown in Figure 8. The actual scale of model was design in autoCAD software to produce desired shape. By using this software, the CNC machine can convert this CAD design to CAM design which the machine can start to manufacture based on design. The size of the flat surface must little bit smaller than the PosHEAT base to get fixed. The curve need to measure from actual motorcycle exhaust and the diameter of the curve calculated. In this project, EX5 motorcycle exhaust has chosen as the example of prototype. This type of motorcycle is similar for all HONDA motorcycle exhaust. So, the model of this prototype is flexible and can apply to all HONDA motorcycle. The flat surface is important to have maximum heat transfer from the exhaust. In this project, aluminium was chosen because have the higher thermal conductivity and not really heavy.

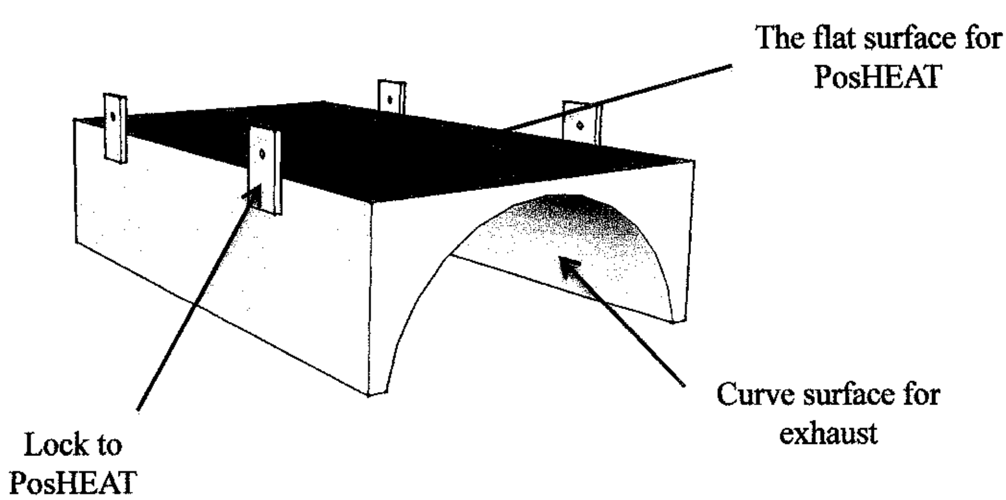

Figure 8 : Flat surface on the exhaust

3.6 Construct the portable power supply

Since it is portable, the size must be small to make easy to bring anywhere. The size of a seebeck unit is about 4cm x 4 cm. The base for the PosHEAT is made from aluminium to absorb all the heat from the flat surface on the exhaust. The aluminium will be cut based on desire dimension which same size with heat sink base as shown in Figure 9.

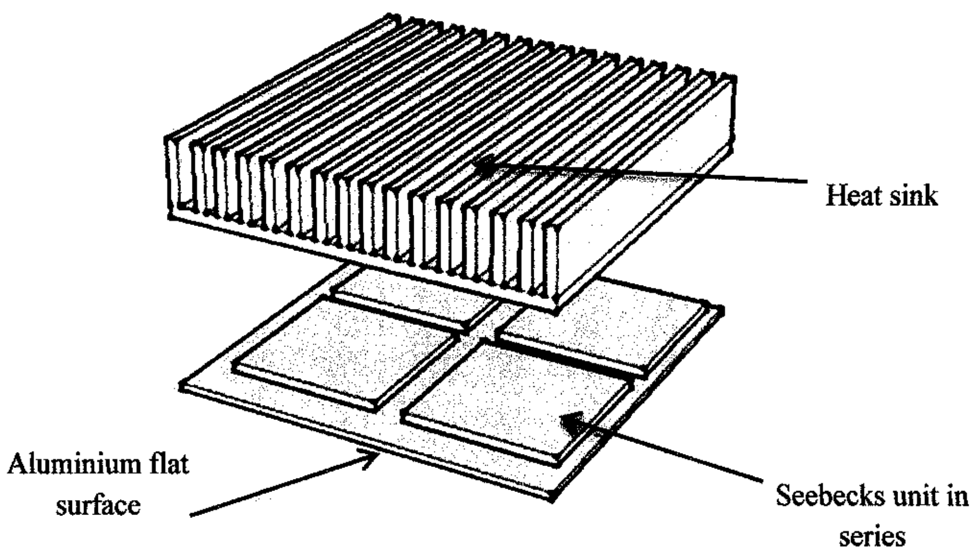

Figure 9 : Portable power supply

The seebecks is glued between heat sink and aluminium plate by using silicon high temperature glue. The heat sink will be remained uncover since it need an air circulation to discharge the heat in order to obtain a significant temperature difference. So, the direction of the air flow is important to make sure the heat sink can release the heat.

3.7 Construct the PosHEAT holder (application for home heater)

Since the PosHEAT is design for portable, it also can be applied at home heater since abundant of waste heat release. The design of the holder has adjustable lock which it can use to tight and remove the PosHEAT as shown in Figure 10. The clamper is used to clamp the holder at home heater wall and the adjustable of the clamper based on the width of the wall. All the material used is high temperature performance.

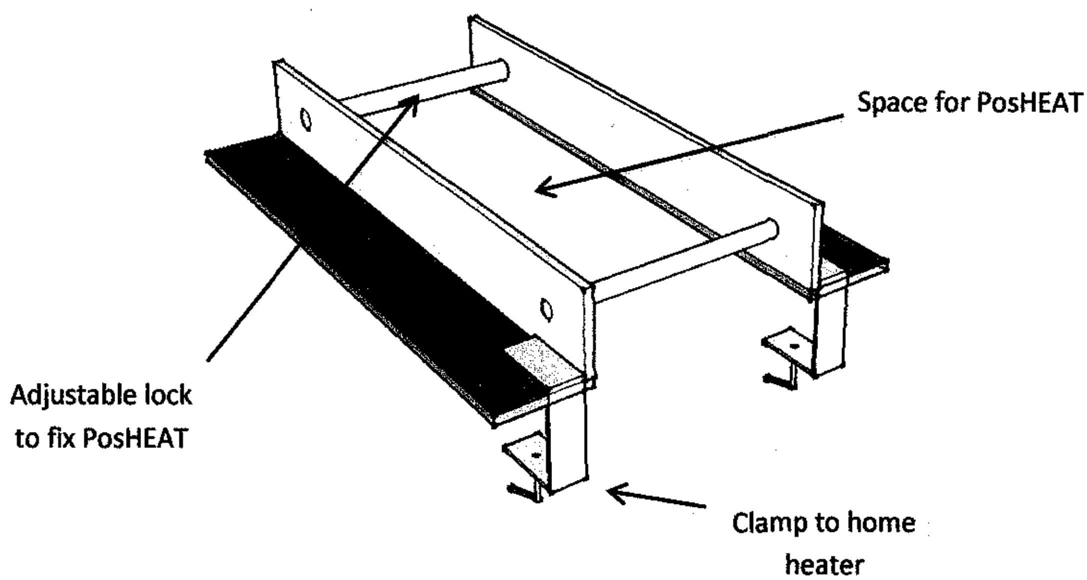

Figure 10 : PosHEAT holder application for home heater

3.8 Electric circuit

3.8.1 Booster circuit

The booster circuit is constructed using LT1073 which is a versatile micro power DC/DC converter that can easily be configured as a buck or boost converter. In this project, it is basically being used to step up 1.5 V of voltage that was produced by the battery to achieve 5 V of output. When the switch is ON, the diode is reversed biased, thus isolating the output stage. The input supplies energy to the inductor. When the switch is OFF, the output stage receives energy from the inductor as well as from the input. The schematic design of the booster circuit used in this project is shown in Figure 11.

In the steady-state analysis, the output filter capacitor is assumed to be very large to ensure a constant output voltage. The oscillator is set internally for 38 ms ON time and 15 ms OFF time, optimizing the device for step-up circuits where V_{OUT} » 3 V_{IN}. For example voltage higher than 1.5 V input can boost up to 5 V.

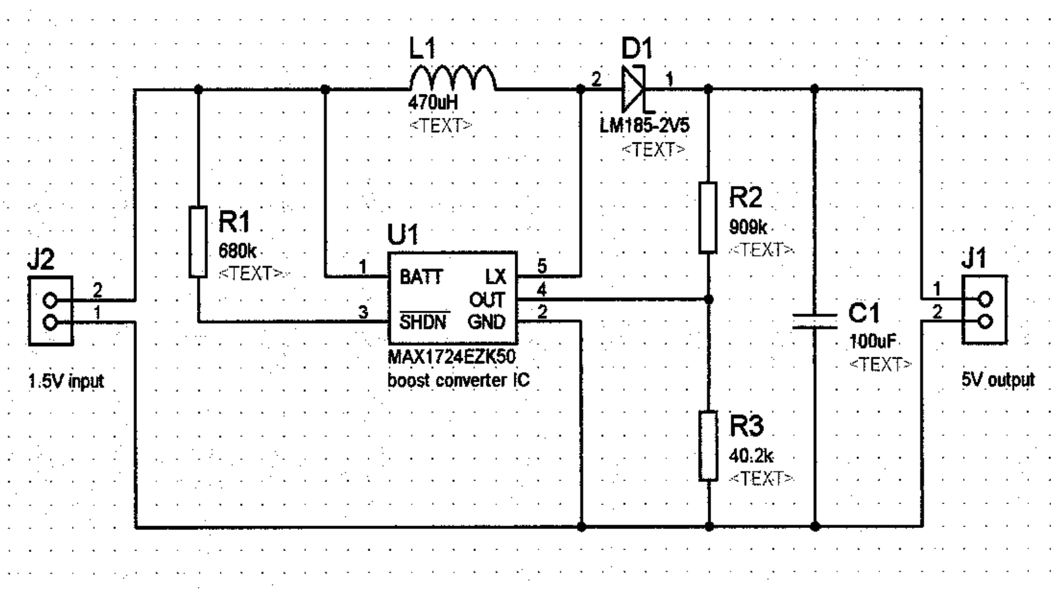

Figure 11 : Booster circuit

3.8.3 Main circuit

The complete circuit of this project is shown in Figure 12. When the switch is turn on (logic 1), D1 will lighting up for LED indicator when this circuit charging mobile phone using rechargeable batteries. The batteries supply 2.4 V and the booster will step up the voltage to 5 V before charging mobile phone. The connector will connect to the booster circuit. When this device applied to source of heat (motorcycle exhaust), turn off (logic 0) the switch and the LED indicator will light off. This will indicate the seebeck supply electrical power to rechargeable batteries to charge and at the same time, it also can charge mobile phone. The booster circuit also have indicator when it charge a mobile phone.

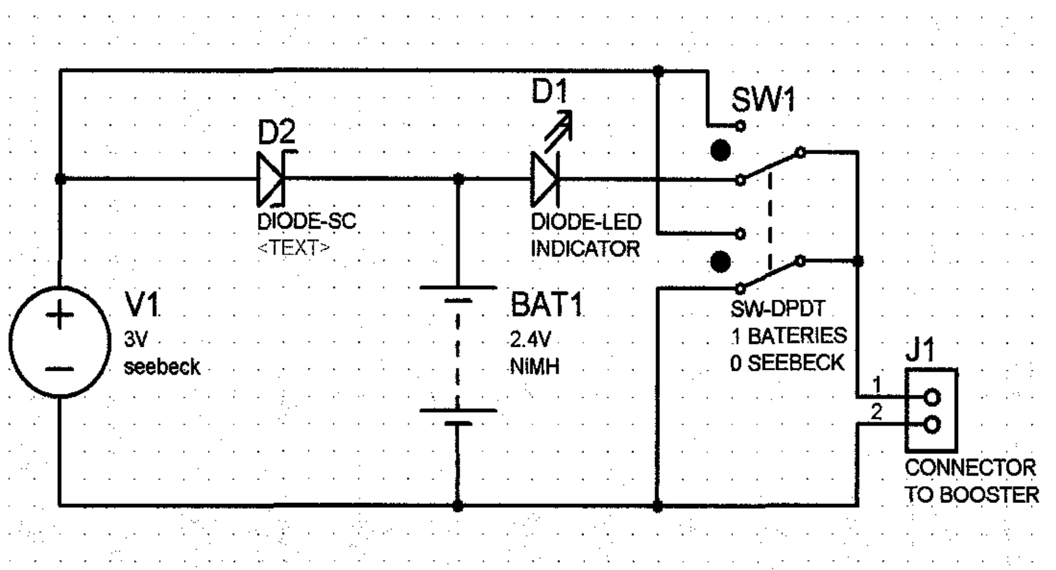

Figure 12 : Main circuit

CHAPTER 4

RESULT AND DISCUSSION

4.1 Data Gathering and Analysis

At the end of this project, the expected result that will achieve is a complete prototype of PosHEAT for application to motorcycle exhaust and home heater. It will have high efficiency to absorb heat from waste energy. It not only can use for motorcycle and home heater, but it also portable to bring and use anywhere in the present of heat. Before build the circuit, some measurements need to be done in order to get enough voltage to charge any mobile phone. The materials that have been used to convert from heat to electrical energy also need to be considered. From a literature review, the Bismuth Telluride (Bi_2Te_3) seebeck unit is the most suitable to achieve that purpose.

4.1.1 Experiment for Seebecks selection

Calculate dimensionless figure of merit (ZT) for the seebeck unit

$$zT \leq \frac{S^2}{2\left(\frac{k}{e}\right)^2} \tag{6}$$

$$1 \leq \frac{S^2}{2\left(\frac{1.381 \times 10^{-23}}{1.602 \times 10^{-19}}\right)^2}$$

$$S^2 \geq 1.4852^{-8}$$

$$S \geq \pm 1.2187 \times 10^{-4} \ \mu\text{V/K}$$

Electric charge (e) = 1.602176487(40)×10−19 coulombs

Boltzmann constant (k) = 1.380 6504(24)×10^{-23} J K^{-1}

Dimensionless Figure of Merit (zT) = 1

So, the strong thermoelectric material (zT = 1) need to have seebeck coefficient (S) at least 122 µV/K [10].

Open circuit test for variable Seebeck units.

We tested on a few seebeck units to choose the best performance for generator (which produce more power) and the result tabulated in Table 1. All the seebeck units need to use must have seebeck coefficient (S) greater than 122 µV/K.

Table 1 : Open circuit test result

	TEG031	**TEG071**	**TEG127**
P-N Couples	31	71	127
Internal resistance (Ω)	0.03	0.03	0.03
Size L x W x H (mm)	40x40x3.8	40x40x3.4	40x40x3.2
Seebeck coefficient, S (V/K)	0.036186	0.03966	0.04236
Temperature Th / Tc (K)	400 / 320	400 / 320	400 / 320
Open circuit voltage (V)	0.926	1.102	1.282

Based on this experiment, we can conclude that the best performance of generator depend on the P-N element couples of seebeck unit. So, in this project we used 127 P-N element couple to produce enough power.

4.1.2 Seebecks connected in series experiment

This experiment will test the seebeck unit without using heat sink. Four seebecks is used and connected with series to have more voltage. The result of this experiment is tabulated in Table 2.

At this level, the more seebecks is connecting to the circuit in series connection, the larger is the output voltage can produce. In order to get 5 V of output constantly to charge a mobile phone, a constant 5 V output is needed. Thus the boost converter and voltage regulator is used in this project.

Table 2 : Seebecks connected in series experiment

No of seebeck that been used	Output Voltage/V		
	1st reading	2nd reading	Average
1	1.8	2.0	1.9
2	2.6	2.8	2.7
3	3.9	4.2	4.1
4	5.2	5.2	5.2
After using boost converter/ voltage regulator	5.6	5.6	5.6

4.1.3 Prototype experiment

This experiment used PASCO Data Studio which is software for collecting and analysing data by using sensor system. Using this tool, it can measure voltage, current and temperature versus time. All this data will display at computer in table and graph. This experiment used hot plate as the source of heat which is representing motorcycle exhaust in real application of this project. To measure the temperature using PASCO, thermocouple wire is attached at the surface of the prototype to take reading. Voltage is measure in parallel with the seebeck and current is measure in series in that circuit. The connection of the circuit to measure is shown in Figure 13 and the result for this experiment tabulated in Table 3.

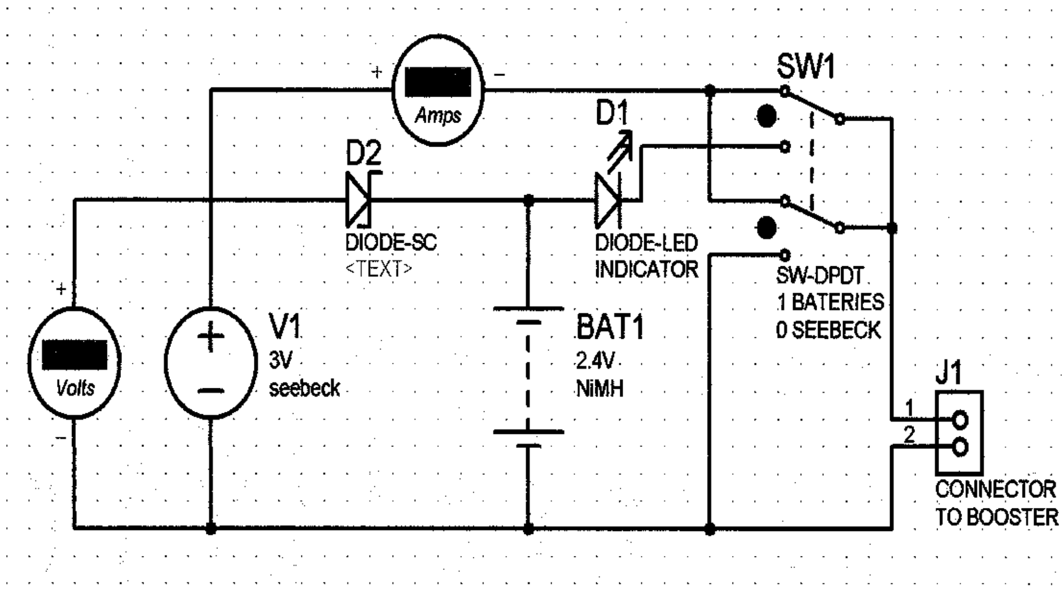

Figure 13 : Experiment circuit

Table 3 : Prototype experiment

No. Exp.	Difference Temperature (dT/K)	Voltage (V/V)	Current (I/A)	Power (P/W)
1	15	1.9	0.35	0.67
2	30	2.5	0.40	1.00
3	45	3.0	0.48	1.44
4	60	3.8	0.52	1.97
5	75	4.4	0.62	2.73

The data result of this experiment refer to Appendix C and the graph is shown in Figure 14 and 15. From the experiment, the highest value for temperature is around 150 °C and will get the maximum DC voltage 4.74 V. Since there is DC voltage, no need bridge rectifier. The voltage produce is enough to boost to 5 V using DC-DC boost converter. In this project need 5 V to charging mobile phone. Actually, the booster can boost minimum voltage 1.5 V and can regulate maximum voltage 5.6 V. From this experiment, the maximum current is 0.62 A. The higher current produce by the prototype it will decrease time taken for the mobile phone or batteries charging.

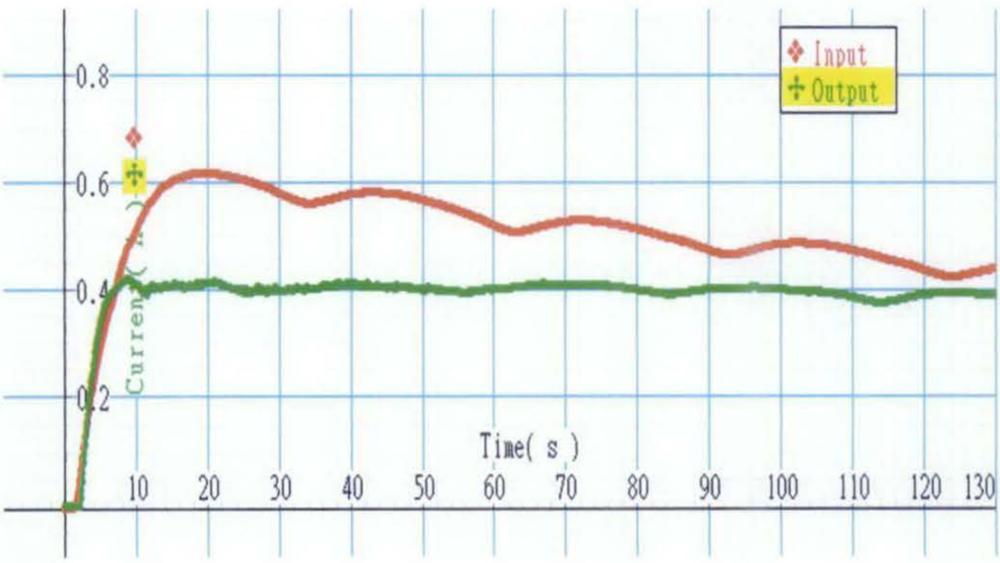

Figure 14 : Graph current versus time

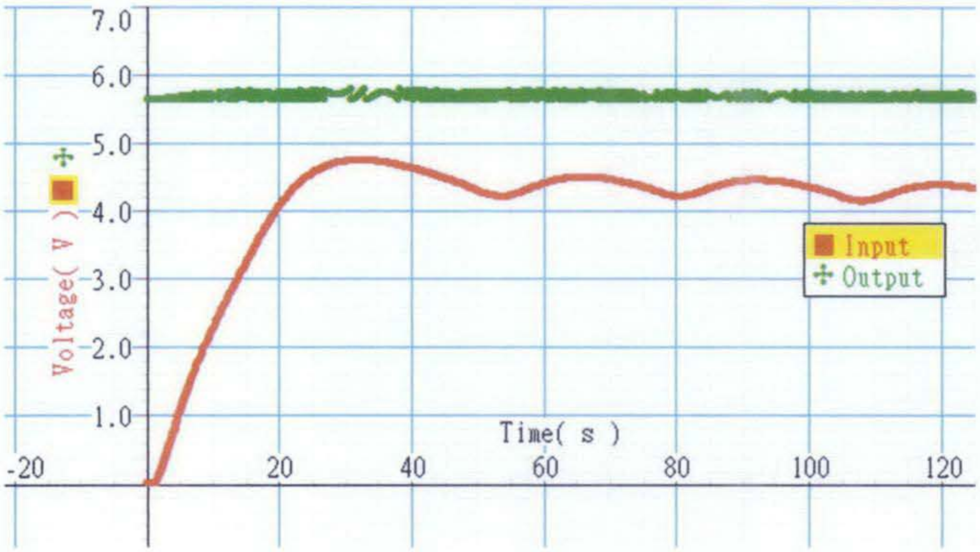

Figure 15 : Graph voltage versus time

Strong thermoelectric material, dimensionless figure of merit, $zT = 1$

Hot side temperature, $T_h = 423$ K

Cold side temperature, $T_c = 303$ K

Temperature different, $\Delta T = 75$ K

From equation (4),

$$\eta = \frac{\Delta T}{T_h} \cdot \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+T_c/T_h}$$

$$= \frac{120}{423} \cdot \frac{\sqrt{1+1}-1}{\sqrt{1+1}+303/423}$$

$$= 5.52\%$$

The result of real time application for this prototype:

- Output Voltage – 5.5-5.6 V
- Output Current – 400-500 mA
- Built in high capacity lithium polymer rechargeable batteries. It can recharge any mobile phones, PSP, MP3, MP4 and other digital products anywhere and anytime.
- Have standard mini USB and variety of converters configuration.
- LED indicator to show the recharge mode.
- Energy saving and use green energy which can contribute to environmental protection.
- High-efficiency and fast, just to recharge your mobile phone 80 minutes, and then you will achieve up to 120-180 minutes of talk time (Different brands and models of mobile phone is different charging time).
- Especially suitable for emergency when you work or travel in the wild, power cut occurred, PosHEAT will help maintaining your mobile phone in working state and contact with others.

4.1.4 Prototype fabrication

The prototype almost complete based on design concept and drawing from auto CAD. This prototype can be used for exhaust motorcycle which is have high temperature for highest efficiency and the shape almost cylinder. In this project, Based on the result, this motorcycle exhaust can give temperature greater than 120°C. From the theory, this temperature can produce more than 5 V voltages. But the real demonstration using this exhaust, it got less voltage than theory because due to heat release to environment. However, the exhaust is suitable for this project because it will produce enough voltage to charge mobile phone.

This innovation can use to charge any type of mobile phone, PSP, MP3, MP4 and other digital products anywhere and anytime. This prototype has a few multi-connectors to use for any type of device or mobile phone since all the device use variable of connector. Unfortunately, this innovation limited to small device which consume a small power and 5 V voltage.

This prototype is successful operated at motorcycle, as shown in Figures 16 to 19. The heat released by the exhaust pipe is utilized as an input of the product to produce electricity energy. The output of this prototype is used to charge a mobile phone.

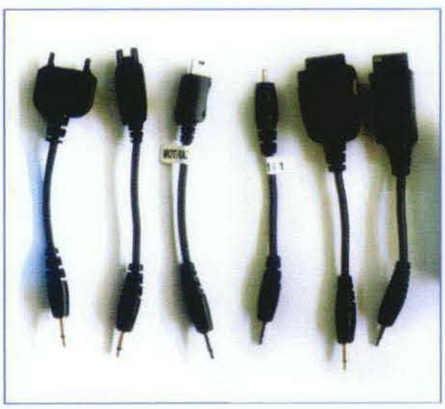

Figure 16 : Multi-connector

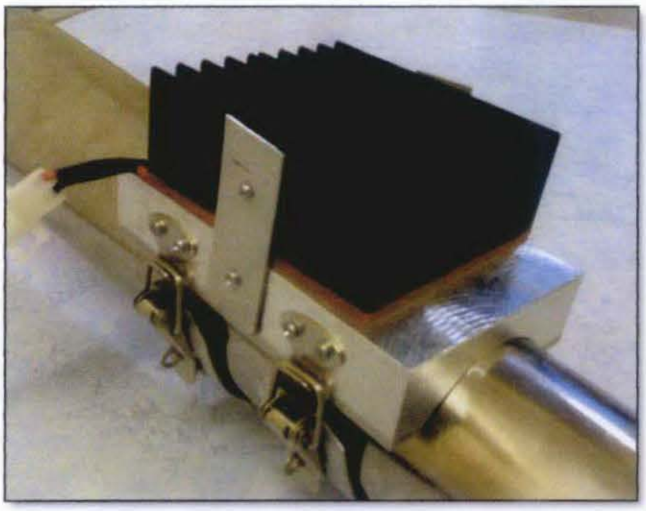

Figure 17 : Prototype PosHEAT and holder

Figure 18 : Prototype circuit casing

Figure 19 : Prototype at motor case

This project also has PosHEAT holder prototype application for home heater as shown in Figures 20. Since home heater also release abundant of waste heat, this innovation takes the opportunities to utilize the waste heat release. The performance of this innovation very depends on temperature different because more will be produce. This innovation have no limit of usage, it can be use anywhere and anytime since have source of heat.

Figure 20 : Prototype application for home heater

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This project is implemented base on Seebeck effect theory, which is produce energy from gradient of temperature. From this project, it can use the waste heat from motorcycle or home heater for electrical usage such as to charge any mobile phone, PSP, MP3, MP4 and other digital products. Since this innovation is portable and can use anywhere and anytime that have source of heat energy. The best thermoelectric unit which is Bismuth Telluride (Bi_2Te_3) is used in this project to generate more energy. A DC-DC boost converter and 5 V voltage regulator is used to increase and regulate the voltage produce to have around 5 V for mobile phone charging. This innovation also one of the green technologies since it has no moving parts and no emission to generate electricity, it can avoid from any pollution.

5.2 RECOMMENDATIONS

The improvement of the innovation by adding new features is an effective ways where it will encourage people to utilized the waste energy as well as saving the cost of producing electricity. Today seebeck unit cannot produce electrical energy for large usage since the efficiency of the seebeck is too small. But now, in our market already have Thermo Life which is very sensitive to gradient of temperature. It can use heat from human body to generate electrical energy for low power usage. In this project, the seebeck unit can replace with Thermo Life for more efficient [11].

In our market today seebeck application are limited and only a few country take opportunities to fabricate the seebeck unit. This will cause the difficulty to get the seebecks in the market and the price also will be expensive. So, a lot of peoples do not know about the seebecks and the function that can produce electrical energy from any source of heat. Actually, the application of seebeck can be more than small power generator if develop in large scale.

By using nanotechnology, the element of seebeck unit can be developed in nano size and this also will produce smaller size of seebeck unit. It will improve this innovation because the smaller size of the PosHEAT will reduce the weight and easy to bring to anywhere. The material of seebeck also can be revised because today technology already has the better material to fabricate the seebeck unit. For example Quantum well module with N-and P-type Si/SiGe on Kapton Substrate. [12]

Quantum well module with N-and P-type Si/SiGe on kapton substrate versus current Bismuth Telluride Bi_2Te_3 module at the same geometry and operating conditions ($\Delta T = 200$(C, heat flux= 10 W/cm^2) as shown in Table 4.

Table 4 : Future seebeck material [12]

	Quantum well module	**Current Bi_2Te_3 module**	**Performance**
Power (Watt)	50	14	3 times power
Voltage (V)	12	1.7	7 times voltage
Specific power (W/gm)	2.5	0.2	10 times higher specific power
Raw materials cost ($/Watt)	0.10	1.00	10 times lower raw materials cost

Based from idea of this project, a lot of application can use this concept in our daily life since we have abundant of waste heat. This project can be alternative renewable energy in the future. It also can reduce the thermal pollution since our earth has a big issue which is global warming.

REFERENCES

[1] New Physical Model for Thermoelectric Generators, Laboratory of Electrical Instrumentation, Department of Microsystems Engineering (IMTEK), Albert-Ludwigs-Universita¨ t Freiburg, D-79110, Freiburg, Germany, 2009.

[2] Seebeck effect, Wikipedia , 2010, 8 August 2010, from http://en.wikipedia.org/wiki/Seebeck_effect

[3] Producing Light from Stoves using a Thermoelectric Generator, Dan Mastbergen, Dr Bryan Willson, Sachin Joshi, Engines and Energy Conversion Laboratory, Department Of Mechanical Engineering, Colorado State University.

[4] Recent Concepts in Thermoelectric Power Generation, Gao Min and D M Rowe, School of Engineering, Cardiff University, Cardiff, United Kingdom, 21st International Conference on Thermoelectronics 2002.

[5] Small Thermoelectric Generators, G. Jeffrey SnyderThe Electrochemical Society Interface Fall 2008, California Institute of Technology (Caltech) in Pasadena, California.

[6] Tellurex Corporation-Frequently Asked Questions About Our Power Generation Technology, 2008, 20 April 2011

[7] Machining-Micropulse West Incorporated, 2010, 20 April 2011

[8] Basic Principles of Thermoelectric Modules & Materials, 2005, 31 October 2010 from http://www.silram-cor.co.il/gp.asp?gpid=56

[9] Thermopower, 2010, 1 November 2010 from http://en.wikipedia.org/wiki/Seebeck_coefficient

[10] Thermoelectric Technology of the Future, Cronin B. Vining, Defense Science Research Council Workshop, La Jolla, California, July 21, 1994

[11] Thermo Life™ overview, 2005, 16 September 2010, from www.PoweredByThermoLife.com

[12] Thermoelectric Developments for Vehicular Applications, John W. Fairbanks, Freedom CAR and Vehicle Technologies Energy Efficiency and Renewable Energy US Department of Energy, Washington, August 24, 2006

APPENDICES

APPENDIX A

GANTT CHART FYP 1

TITLE	WEEK													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Select the topics from list	■													
Confirmation of the topic	■	■												
Proposal		■												
Preliminary Report			■											
Material Selection/Design			■	■										
Analysis				■	■	■	■	■	■	■	■	■	■	
Fabrication														
Circuit					■	■	■	■	■					
Cutting/ Joining							■	■	■					
Assembling							■	■	■					
Testing					■	■	■	■	■	■	■	■		
Finishing									■	■	■			
Final Touch Up											■	■		
Report/Posters				■	■	■	■	■	■	■	■	■		

APPENDIX B

GANTT CHART FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14	15
1	Fabricate the circuit																
2	Testing the circuit																
3	Hardware & Software synchronization																
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

APPENDIX C

ACTUAL PROTOTYPE EXPERIMENT RESULT

Time (s)	Actual value		Voltage regulator	
	Current (A)	Voltage (V)	Current (A)	Voltage (V)
0	-3.91E-03	8.55E-03	-1.16E-03	5.6215
1	-3.11E-03	9.16E-03	-1.22E-03	5.6355
2	0.0345	0.13	-9.77E-04	5.6374
3	0.1339	0.4242	0.1392	5.6288
4	0.2218	0.7221	0.2601	5.6246
5	0.2877	1.0285	0.3374	5.6276
6	0.3414	1.3105	0.3767	5.6722
7	0.3894	1.5711	0.3977	5.6777
8	0.439	1.8104	0.4115	5.6453
9	0.477	2.0362	0.4166	5.7051
10	0.5073	2.2517	0.4074	5.6972
11	0.5359	2.4543	0.3941	5.732
12	0.5595	2.649	0.4005	5.735
13	0.5763	2.8364	0.4019	5.649
14	0.5896	3.0177	0.4075	5.6783
15	0.599	3.2002	0.403	5.6691
16	0.6058	3.3827	0.4061	5.7045
17	0.6106	3.5646	0.4021	5.624
18	0.6134	3.7373	0.4028	5.6642
19	0.6151	3.8984	0.405	5.6972
20	0.6149	4.0437	0.4111	5.7344
21	0.6138	4.1731	0.414	5.6648
22	0.612	4.2872	0.4077	5.6563
23	0.6096	4.3849	0.4008	5.735
24	0.6067	4.4691	0.3998	5.6362
25	0.6031	4.5387	0.392	5.6349
26	0.5993	4.5967	0.3934	5.7326
27	0.5956	4.6413	0.401	5.7631
28	0.5911	4.676	0.3929	5.7057
29	0.5859	4.7029	0.3945	5.6996
30	0.5794	4.7206	0.3964	5.7332

31	0.5723	4.7328	0.3964	5.6313
32	0.5663	4.7365	0.3948	5.7027
33	0.5618	4.7365	0.3989	5.7747
34	0.5595	4.731	0.3989	5.6716
35	0.5593	4.7206	0.4012	5.7161
36	0.5619	4.7078	0.4041	5.7308
37	0.5654	4.6907	0.4027	5.71
38	0.5694	4.6706	0.4063	5.6447
39	0.5728	4.6498	0.4074	5.6917
40	0.5759	4.626	0.4085	5.6832
41	0.5783	4.5985	0.4075	5.7686
42	0.5794	4.5698	0.4035	5.6374
43	0.5796	4.5405	0.4027	5.7399
44	0.5792	4.51	0.4028	5.6282
45	0.5784	4.4777	0.4006	5.7241
46	0.577	4.4447	0.4002	5.7308
47	0.5751	4.4118	0.4027	5.6453
48	0.5723	4.3788	0.401	5.7399
49	0.5695	4.3391	0.3971	5.6368
50	0.5662	4.2964	0.397	5.6209
51	0.5625	4.2579	0.4	5.7295
52	0.5588	4.2274	0.3961	5.743
53	0.5545	4.2091	0.3965	5.6752
54	0.55	4.2036	0.3949	5.663
55	0.5454	4.2177	0.3935	5.7057
56	0.5407	4.2445	0.3925	5.6667
57	0.5357	4.2805	0.3935	5.6691
58	0.5304	4.3208	0.3947	5.707
59	0.5245	4.3599	0.3977	5.627
60	0.518	4.3959	0.3972	5.6978
61	0.5125	4.4252	0.3997	5.6349
62	0.5082	4.4508	0.4001	5.7027
63	0.5061	4.4679	0.4012	5.7533
64	0.5067	4.4813	0.4021	5.6368
65	0.509	4.4874	0.4066	5.6233
66	0.5126	4.4899	0.4064	5.7051
67	0.5164	4.4868	0.4088	5.7369
68	0.5198	4.4807	0.4066	5.7161
69	0.5228	4.471	0.4063	5.6398
70	0.5249	4.4569	0.4052	5.6307
71	0.526	4.4404	0.4063	5.6832

72	0.5266	4.4197	0.4068	5.6697
73	0.5264	4.3977	0.4062	5.7125
74	0.5255	4.3757	0.4066	5.6874
75	0.5244	4.3483	0.4066	5.7112
76	0.5227	4.319	0.4047	5.6551
77	0.5201	4.2836	0.4025	5.6233
78	0.5173	4.25	0.401	5.7204
79	0.5142	4.225	0.3986	5.6417
80	0.5112	4.2085	0.3975	5.7228
81	0.5076	4.2061	0.3953	5.685
82	0.5039	4.2219	0.393	5.6679
83	0.5002	4.2482	0.391	5.6917
84	0.4962	4.2824	0.389	5.6667
85	0.4935	4.3171	0.3892	5.6923
86	0.4892	4.3501	0.3905	5.6624
87	0.4862	4.3788	0.3925	5.6771
88	0.4815	4.405	0.3954	5.7363
89	0.4763	4.4246	0.3963	5.7082
90	0.4714	4.4368	0.3982	5.6996
91	0.467	4.4447	0.3989	5.6972
92	0.4641	4.4484	0.3982	5.6929
93	0.4629	4.4459	0.3991	5.6789
94	0.4641	4.4411	0.3997	5.6429
95	0.4666	4.4325	0.4002	5.6893
96	0.4706	4.4215	0.4014	5.7033
97	0.4742	4.4063	0.4001	5.6783
98	0.4777	4.388	0.3989	5.7234
99	0.4805	4.3666	0.3973	5.721
100	0.4827	4.3452	0.398	5.6709
101	0.4839	4.322	0.3966	5.6758
102	0.4844	4.2976	0.3961	5.627
103	0.4848	4.2689	0.3943	5.6258
104	0.4838	4.2366	0.3925	5.6642
105	0.4827	4.2012	0.3936	5.6362
106	0.4815	4.17	0.3928	5.627
107	0.4795	4.1469	0.3912	5.6276
108	0.4771	4.1353	0.3888	5.6435
109	0.4743	4.1414	0.3865	5.6844
110	0.4715	4.1621	0.3837	5.688
111	0.4684	4.192	0.3802	5.6874
112	0.4652	4.2274	0.377	5.6276

113	0.4616	4.2598	0.3745	5.7088
114	0.4578	4.2903	0.3735	5.6709
115	0.4541	4.3178	0.3743	5.6887
116	0.4504	4.3397	0.3764	5.6655
117	0.4468	4.3568	0.3793	5.6832
118	0.4433	4.3672	0.3826	5.6404
119	0.4398	4.3745	0.3853	5.6282
120	0.4351	4.3751	0.3876	5.6337
121	0.4304	4.3739	0.3893	5.652
122	0.4264	4.366	0.3904	5.6764
123	0.423	4.3574	0.3911	5.6966
124	0.422	4.3434	0.3917	5.7064
125	0.4229	4.3257	0.3913	5.6954
126	0.4248	4.308	0.3912	5.66
127	0.4279	4.2872	0.39	5.6819
128	0.431	4.264	0.3891	5.6648
129	0.4338	4.1762	0.3886	5.6941
130	0.4362	3.8343	0.387	5.6752
131	0.4377	3.4864	0.3856	5.6941
132	0.4386	3.1745	0.3851	5.6545
133	0.4388	2.895	0.3839	5.6496
134	0.4381	2.6411	0.3815	5.6685
135	0.4371	2.4012	0.3795	5.6282

APPENDIX D

ACHIEVEMENT OF THIS PROJECT

26th Engineering Design Exhibition (EDX) UTP

- 25th – 26th Oct 2010
- GOLD Medal Award
- 2nd Runner Up Most Innovative Award

Malaysian Technology Expo (MTE)

- 17th - 19th February 2011

Geneva 39th Salon International Inventions , Switzerland

- 6th – 10th Apr 2011
- Silver Medal Award

27th Engineering Design Exhibition (EDX) UTP

- 13th – 14th Apr 2011
- GOLD Medal Award
- Champion Most Innovative Award
- EDX Chairman Award

5th International Power Engineering and Optimization Conference 2011 (PEOCO)

- 6th -7th JUNE 2011
- Gold Medal Award

Malaysia Industrial Pattern Design applied on Feb 2011

Conference Paper published in IEEE

APPENDIX E

CONFERENCE PAPER

Heat Energy Harvesting for Portable Power Supply

Ahmad Nazri Abd Razak*, Nursyarizal Mohd Nor**, Taib Ibrahim***
UniversitiTeknologi PETRONAS

E-mail: * acu.nazri @gmail.com, **nursyarizal_mnor@petronas.com.my,
***taibib@petronas.com.my

***stract*- Heat Energy Harvesting for Portable Power Supply sHEAT) is the renewable energy which produces electrical rgy from waste heat. PosHEAT has many attractive features, h as reduced maintenance, completely silent, no moving parts l no emission to generate electricity. Based on Thermocouple icept, the greatest material to produce more power is Seebeck de from Bismuth Telluride (Bi_2Te_3) . PosHEAT will convert it energy to electrical energy when it has temperature ference between two sides. Temperature play the main role in project to produce enough power. This paper highlights the beck theory and electrical system design to storage the rgy.**

I. INTRODUCTION

Nowadays, our earth has issue about global warming cause abundant of waste heat release to environment. A lot electrical, machinery and electronic appliances has been proved, recycled and reutilized to achieve high efficiency. m heavy equipment to the simple appliances, most energy waste in form of heat. Therefore new approach is required reuse them as renewable energy. The aim of this project is apply the thermocouple concept to generate electricity from waste heat such as motorcycle exhaust, barbeque set, ne heater, heat exchanger and others. The energy produce s storage in rechargeable batteries and will use to charge bile phone. Since mobile phone became very important to for communication, so we need to make sure that our bile phone is turn on anytime. This project designs a table and compact thermoelectric generator that can bring l use anywhere since we have the source of heat need to vert. As we know, heat also a type of energy that can be verting to electrical energy based on thermocouple cept, voltage is created in the presence of a temperature ference between two different metals or semiconductors. ebeck unit is used in this project to convert the waste heat to ctrical power and boost converter used to step up the DC tage that produce. Then the energy is stored in hargeable batteries and can use to charge up our mobile one anytime. The batteries also can be used as a backup en we do not have any source of heat energy to be verted. This project will produce an innovation that can any source of waste heat to generate power as an ernative and green energy.

This work was supported by UniversitiTeknologi PETRONAS

II. SEEBECK THEORY

Seebeck unit is a thermoelectric unit that is special manufactured to generate electricity. Thermocouples that have in Seebeck unit are junction between two different metals that produces voltage related to a temperature difference. The bigger the temperature difference, the higher the voltage can be generated. This can be calculating using equation [1] :

$$V = \int_{T_1}^{T_2} (S_B(T) - S_A(T))dT \quad (1)$$

S_A and S_B are the Seebeck coefficients and T_1 and T_2 are the temperatures of the two junctions. The Seebeck coefficients are non-linear as a function of temperature, and depend on the conductors' absolute temperature, material, and molecular structure.

If the Seebeck coefficients are effectively constant for the measured temperature range, the above formula can be approximate as [2] :

$$V = (S_B - S_A).(T_2 - T_1) \quad (2)$$

Electrons on the hot side of a material are more energize than on the cold side. These electrons will flow from the hot side to the cold side. If we have a complete circuit, electricity will flow continuously. Semiconductor materials are the most efficient, and combining in pairs of "*p* type" and "*n* type". The electrons flow from hot to cold in the "*n* type," While the electron holes flow from hot to cold in the "*p* type" This allows them to combine electrically in series to increase voltage and power output. A high temperature bismuth telluride (Bi_2Te_3) module has been selected due to its high efficiency and high operating temperature [3].

III. THERMOELECTRIC POWER

A seebeck can produces electrical power from heat flow across a temperature gradient. As the heat flows from hot to cold, free charge carriers (electrons or holes) in the material are also driven to the cold end . The resulting voltage (V) is proportional to the temperature difference (ΔT) via the Seebeck coefficient, α, ($V = \alpha\Delta T$). By connecting an electron conducting (*n*-type) and hole conducting (*p*-type) material in series, a total voltage is produced that can be driven through a load. To achieve a few volts at the load, many thermoelectric ıples element need to be connected in series to make the ·rmoelectric device.

\ thermoelectric generator converts heat (Q) into electrical wer (P) with efficiency η.

$$P = \eta Q \tag{3}$$

[he amount of heat, Q, that can be directed though the ·rmoelectric materials frequently depends on the size of the ıt exchangers used to absorb the heat on the hot side and ease it on the cold side. The efficiency of a thermoelectric ıverter on this project depends on the temperature ference $\Delta T = Th - Tc$ across the device. The efficiency of hermoelectric generator is can defined as [4]

$$\eta = \frac{\Delta T}{T_h} \cdot \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+T_c/T_h} \tag{4}$$

Where the first term is the efficiency of exhaust and ZT is : figure of merit for the device. While the calculation of a ·rmoelectric generator efficiency can be complex, use of the ·rage material figure of merit, zT, can provide an proximation for ZT.

$$zT = \frac{\alpha^2 T}{\rho \kappa} \tag{5}$$

Here, Seebeck coefficient (α), electrical resistivity (ρ), and ·rmal conductivity (κ) are temperature (T) dependent ıterials properties. Recently, the field of thermoelectric ıterials is rapidly growing with the discovery of complex, gh-efficiency materials. A diverse array of new approaches, m complexity within the unit cell to nanostructured bulk, nowire and thin film materials, have all lead to high ficiency materials [5].

IV. SEEBECK MATERIAL

The thermoelectric semiconductor material most often used thermoelectric is an alloy of Bismuth Telluride that has en suitably doped to provide individual blocks or elements ving distinct "N" and "P" characteristics. In addition to smuth Telluride (Bi_2Te_3), there are other thermoelectric aterials including Lead Telluride (PbTe), Silicon ·rmanium (SiGe), and Bismuth-Antimony (Bi-Sb) alloys at may be used in specific situations [6]. Figure 1 illustrates e relative performance or Figure-of-Merit of various aterials over a range of temperatures. It can be seen from is graph that the performance of Bismuth Telluride peaks ithin a temperature range that is best suited for most cooling plications [7]. Bi_2Te_3 is the best solution for using in this oject compare to other materials because Bi_2Te_3 will oduce more power at lower temperature.

V. RESULT

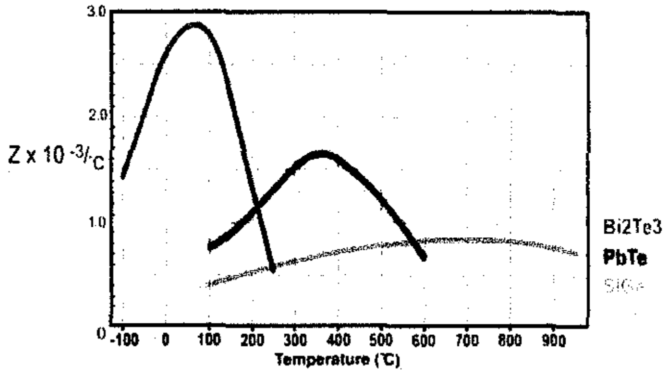

FIGURE 1: SEEBECK MATERIAL [7].

Calculate dimensionless figure of merit (ZT) for the seebeck unit

$$zT \le \frac{s^2}{2\left(\frac{k}{e}\right)^2} \tag{6}$$

$$1 \le \frac{S^2}{2\left(\frac{1.381\times10^{-23}}{1.602\times10^{-19}}\right)^2}$$

$$S^2 \ge 1.4852^{-8}$$

$$S \ge \pm 1.2187 \times 10^{-4}$$

So, the strong thermoelectric material ($zT = 1$) need to have seebeck coefficient (S) at least 122 μV/K [8].

Open circuit test for variable Seebeck units.

We tested on a few seebeck units to choose the best performance for generator (which produce more power). All the seebeck units must have seebeckcoefficient (S) greater than 122 μV/K.

- TEG031

P-N Couples : 31 couples
Resistance = 0.03Ω
Size: 40mmx40mmx3.8mm
S = 0.036186 V/K ≥ 122 μV/K
Th= 400 K ;Tc= 320 K
Open circuit voltage: 0.926volts

- TEG071

I Couples : 71 couples
sistance = 0.03Ω
e: 40mmx40mmx3.4mm
0.03966 V/K ≥ 122 μV/K
= 400 K ;Tc= 320 K
en circuit voltage: 1.102volts

- TEG127

I Couples : 127 couples
sistance = 0.03Ω
e: 40mmx40mmx3.2mm
0.04236 V/K ≥ 122 μV/K
= 400 K ;Tc= 320 K
en circuit voltage: 1.282volts

Based on this experiment, we can conclude that the t performance of generator depend on the P-N element iples of seebeck unit. So, in this project we used 127 P-N ment couple to produce enough power.

periment on actual prototype

This project success to create an innovation that can use ste heat to produce power. This power enough to charge mobile phone at everywhere since we have source of heat. e result for the prototype is in Table 1.

TABLE 1 EXPERIMENT RESULT

o. Exp.	Difference Temperature (dT/⁰C)	Voltage (V/V)	Current (I/A)	Power (P/W)
1	15	1.9	0.35	0.67
2	30	2.5	0.40	1.00
3	45	3.0	0.48	1.44
4	60	3.8	0.52	1.97
5	75	4.4	0.62	2.73

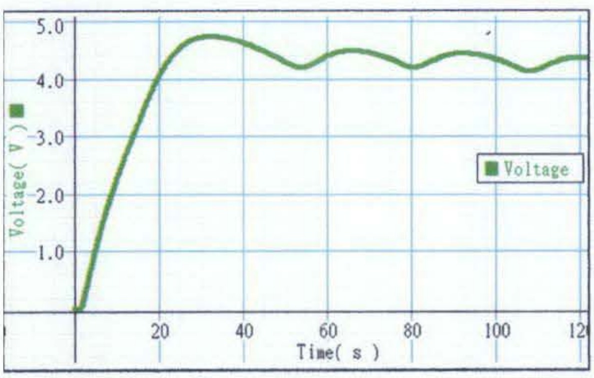

FIGURE 2: VOLTAGE VERSUS TIME

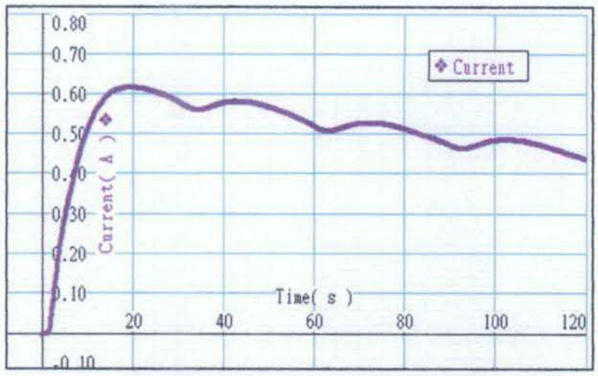

FIGURE 3: CURRENT VERSUS TIME

This prototype is successful operated at motorcycle, as shown in Figures 4 to 6. The heat released by the exhaust pipe is utilized as an input of the product to produce electricity energy. The output of this prototype is used to charge a mobile phone. The results of the real time application of the product are shown in Table 2.

TABLE 2: RESULT OF REAL TIME APPLICATION.

- Output Voltage –5.5V-5.6V
- Output Current – 400mA-500mA
- Built in high capacity lithium polymer rechargeable batteries. It can recharge any mobile phones, PSP, MP3, MP4 and other digital products anywhere and anytime.
- Have standard mini USB and variety of converters configuration.
- LED indicator to show the recharge mode.
- Energy saving and use green energy which can contribute to environmental protection.
- High-efficiency and fast, just to recharge your mobile phone 80 minutes, and then you will achieve up to 120-180 minutes of talk time (Different brands and models of mobile phone is different charging time).
- Especially suitable for emergency when you work or travel in the wild, power cut occurred, **PosHEAT** will help maintaining your mobile phone in working state and contact with others.

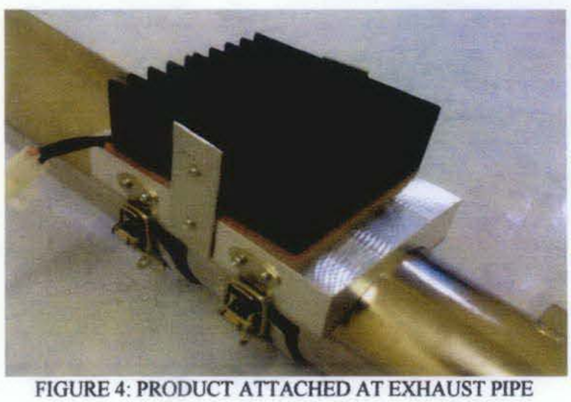

FIGURE 4: PRODUCT ATTACHED AT EXHAUST PIPE

FIGURE 5: THE ELECTRONIC COMPONENT

FIGURE 6: MOBILE PHONE PLACEMENT

VI. CONCLUSION

he development of this product is an initial step for native green energy that used heat as a source. From the lts obtained, the selected of seebeck can produce enough er to charge any type of mobile phone. This invention can ised at anyplace that heat is available such as solar panel, se heater, exhaust pipe (motorcycle) and etc. This product ractical and beneficial device, environmentally friendly, require operating cost and easy to install.

VII. REFERENCES

New Physical Model for Thermoelectric Generators, Laboratory of Electrical Instrumentation, Department of Microsystems Engineering (IMTEK),Albert-Ludwigs-Universita¨ t Freiburg, D-79110, Freiburg, Germany, 2009.

Seebeck effect, Wikipedia , 2010, 8 August 2010, from http://en.wikipedia.org/wiki/Seebeck_effect

Producing Light from Stoves using a Thermoelectric Generator, Dan Mastbergen, Dr. Bryan Willson, Sachin Joshi, Engines and Energy Conversion Laboratory, Department Of Mechanical Engineering, Colorado State University.

Recent Concepts in Thermoelectric Power Generation, Gao Min and D M Rowe, School of Engineering, Cardiff University, Cardiff, United Kingdom, 21st International Conference on Thermoelectronics 2002.

[5] Small Thermoelectric Generators, G. Jeffrey SnyderThe Electrochemical Society Interface Fall 2008, California Institute of Technology (Caltech) in Pasadena, California.

[6] New Materials And Devices For Thermoelectric Applications Jean-Pierre Fleurial, Alex Borshchevsky, Thierry Caillat and Richard Ewel l Jet Propulsion Laboratory/ California Institute of Technology.

[7] Basic Principles of Thermoelectric Modules & Materials, 2005, 31 October 2010 from http://www.silram-cor.co.il/gp.asp?gpid=56.

[8] Thermoelectric Technology of the Future, Cronin B. Vining, Defense Science Research Council Workshop, La Jolla, California, July 21, 1994

VIII. BIOGRAPHIES

Ahmad Nazri Bin Haji AbdRazak was born in Penang, Malaysia in1988. He obtained his Foundation at Penang Matriculation College. Presently he is a FYP student under the guidance of Dr. Nursyarizal Mohd Nor in University Teknologi PETRONAS, Tronoh, Perak. B Eng (Hons) in Electrical and Electronic Engineering. Majoring in Power System and minor in Electrical Machines.

Dr. Nursyarizal Mohd Nor obtained his PhD in Electrical Engineering from UniversitiTeknologi PETRONAS (UTP), Malaysia in year 2009. In year 2001 he obtained his MSc in Electrical Power Engineering from The University of Manchester Institute of Science and Technology (UMIST), UK. His areas of specialization are 'Analysis and optimization of large scale power systems' and 'State estimation'. He has several publications at his credit. His research interests are in Power Economics Operation and Control, Power Quality and Power System Analysis.

Dr. Taib Ibrahim was born in Kedah, Malaysia in 1972. He received the B.Eng (Hons) in electrical and electronics engineering, MSc. in electrical power engineering and PhD in electrical machine design from Coventry University, U.K. in 1996, University of Strathclyde, UK in 2000 and University of Sheffield, UK in 2009, respectively. His employment experience includes Airod (M) Sdn Bhd and UniversitiTeknologi PETRONAS (UTP). Currently, he is leader for power and energy cluster and co-leader for mission oriented research (energy) in UTP. His research interests range from motion control to electromagnetic devices and their associated drives.