Implementing Thermoelectric Generator on CPU Processor

Nuzul Hesty Pranita*
Engineering Physics
Telkom University
Bandung, Indonesia
nuzulhestypranita@gmail.com

Kiki Azura*
Engineering Physics
Telkom University
Bandung, Indonesia
kikizura@gmail.com

Abrar Ismardi
Engineering Physics
Telkom University
Bandung, Indonesia
abrarismardi@telkomuniversity.ac.id

Tri Ayodha Ajiwiguna
Engineering Physics
Telkom University
Bandung, Indonesia
triayodha@telkomuniversity.ac.id

I.P. Handayani
Engineering Physics
Telkom University
Bandung, Indonesia
iphandayani@telkomuniversity.ac.id

Abstract—**Computer has been part of our daily life. In order to work properly and to avoid over heating which might damage the machine, it required a cooling system which effectively distribute heat from the electronic devices into surrounding environment. Generally, the cooling system only distributes the heat. The potential heat conversion into electricity in computer has not been studied intensively. In this study, we implement a thermoelectric generator module which converts heat into electicity in combination with hybrid cooling system on CPU processor, a main crucial part in computer system which produces a lot of heat and its work is very temperature dependent.**

We used a thermoelectric module TEG241-1.0-12 which can generate electricity up to 12.1 volt at temperature difference of 110°C and Seebeck coefficient from 35 mV/°C up to 45 mV/°C. The available size of thermoelectric module is found to be matched with the CPU processor and the hybrid heat sink structure so that no structural adjustment is required. We used hybrid cooling system of PC Cooler Hybrid W120 which consists of an aluminium heat sink and water cooling with flow rate of 6.7 liters/minute. We found that a 2.5 V and 0.19 A (≈ 0.5 W) electricity can be generated when a thermoelectrics module is implemented in Intel Core i3-2100 microprocessor. The observed different temperature between hot and cold sides of thermoelectric is 54 °C while the processor temperature is 80 °C. This study shows the potential implementation of thermoelectric for heat conversion into electricity on CPU processor without endangers the machine.

Keywords—thermoelectrics; CPU processor; hybrid cooling;

I. INTRODUCTION

Thermoelectric is conductor or semiconductor material which can transform different temperature into electric and vice versa [1-6]. The voltage generation due to different temperature in two sides of thermoelectric module is called Seebeck effect whereas the generation of different temperature in two sides of thermoelectric when a voltage is applied in thermoelectric module is called Peltier effect [6, 7]. This system has a great potential for renewable energy in which the electrical energy is converted from wasting heat. However, the efficiency is still low (≤5%) [3, 8, 9].

A lot of attempts have been done in order to increase the efficiency, including searching for new materials and creating optimum condition for thermoelectric module implementations. In material researches some materials have been reported to have higher efficiency such as Cu-Mn-Al alloy [10], V_2O_5 [11], $CoSb_3$ [12], and thin film materials [13]. Furthermore, several thermoelectric configurations have been reported to provide better thermoelectric performances [14, 15, 7, 4]. Junpeng Zhu et al. [16] reported a maximum output power of 48 W when 8 thermoelectric modules are connected in serial-parallel configuration (four modules connected in parallel configurations, and each of the four modules has a pair connected in serial configuration). The energy conversion efficiency reached 3.5%. In addition, thermoelectrics has also been applied in other fields such as biomass fired thermal heater [7] and processor in CPU [17].

In our study we explore a potential development of a new electrical power generation from microprocessor computer using thermoelectric generator. We observed 0.5 W output generated from a single thermoelectric module. The size of thermoelectric module is well matched with the size of processor so that no structural adjustment is required. In order to obtain the characteristic properties of thermoelectric configuration we also develop a set up to test the serial-parallel thermoelectric configurations. Our data shows that the output power in serial-parallel configurations are limited by thermal and electrical resistance.

II. EXPERIMENTAL SETUP

We performed two experiments in order to explore the potential electricity generation using thermoelectrics. First experiment is for testing the thermoelectric module characteristics. In our experiment, we used TEG 241-1.4-1.2 which is commercially fabricated by EVERREDTRONIC. Ltd**.** The setup is shown in Fig. 1. It consists of aluminium heating plate which is mounted on the top of electric stove and is able to heat the thermoelecric module up to 100 ºC. A thermoelectric Peltier cooling (TEC) is placed in the cool side of thermoelectric generator (TEG) module and is able to cool the TEG module down to 8 ºC. An aluminium heat sink is mounted on the TEC hot side so that the heat is immediately tranfered conductively. An additional fan is placed on the hot side of heat sink to convectionally distribute the heat to the enviroment. Two DS18B20 temperature sensors are used to detect the temperature on the aluminium plate where the tested thermoelectric module is mounted. The electric stove is electrically on-off controlled using a RAYEXELEC LEG-12 relay. The expected stabil temperature is reached at 12 minutes after set point temperature has been determined. The whole system is automatically controlled and recorded using microcontroller Arduino Mega. Using this experimental set up we observed the generated voltage for various temperatures as well as for various serial and parallel TEG module configurations. .

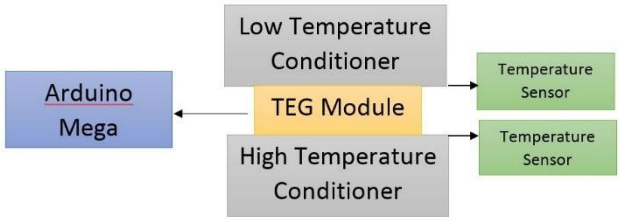

Fig. 1 Thermoelectric characteristic test setup

The second experiment was the observation of the generated voltage when the TEG was mounted in processor CPU. The configuration is shown in Fig. 2. In this experiment, TEG was mounted in between CPU processor and hybrid heat sink cooler to generate micro-scale power. In our experiment we used Intel Core i3-2100 microprocessor, which can generate heat up to 80 ºC by forcing microprocessor work using OCCT software. To avoid overheating, the TEG was connected to hybrid heat sink cooler which consists of aluminium heat sink with water flows inside the pipes of heat sink. The water flow rate was regulated by DC brushless pump and was kept constant at maximum value of 6.7 liters/minute. This system effectively distributed the heat conductively so that over heating in the processor can be avoided. The heat was convectively distributed to surrounding environment using fan. This configuration provided a stable temperature at cool side of TEG. The temperature on the processor and TEG were detected using Epcos NTC thermistor type B57891. All measurement are monitored and recorded using Arduino Uno. The generated electricity was charged into NiMH Sanyo Eneloop AAA baterry 750 mAh 1.2 V.

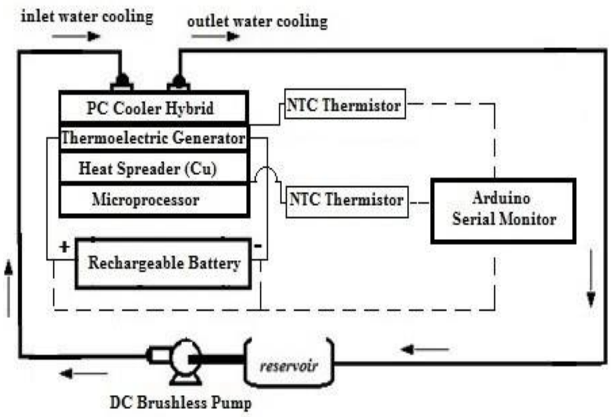

Fig. 2 Schematic configuration of TEG on CPU processor

III. RESULTS AND DISCUSSION

III. 1 MATERIAL CHARACTERIZATION

Fig. 3 shows the voltage and current produced by single TEG 241-1.4-1.2 as a function of temperature. The voltage is linearly dependent on temperature while the current tends to saturate at different temperature higher than 50 ˚C.

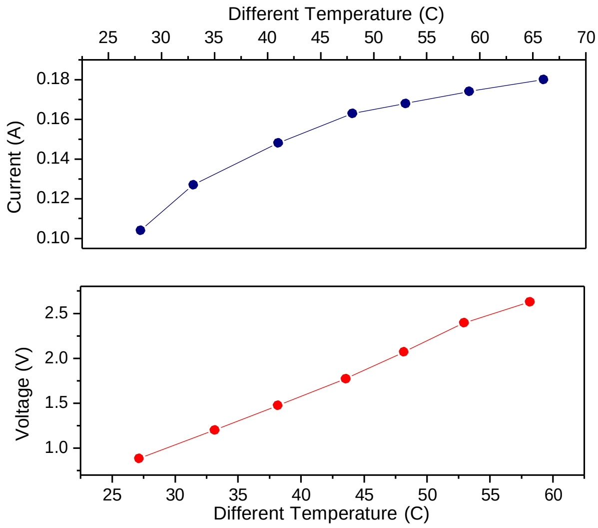

Fig. 3 The generated current and voltage as a function of different temperature

. Using experimental data in Fig. 3. (a), the Seebeck coefficient of TEG (S) can be determined using equation of $= \frac{-}{\Delta}$. The result is presented in Fig. 4. The Seebeck coffiecient is found to gradually increase with average temperature.

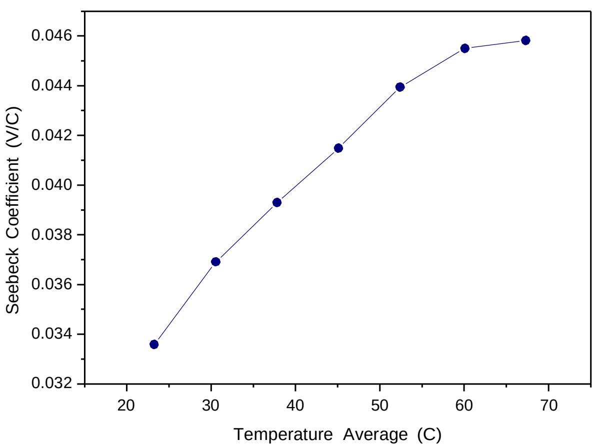

Fig. 4. Seebeck coefficient as a function of average temperature.

The Seebeck coefficient from module TEG 241-1.4-1.2 is between 0.033 up to 0.046 V/C. Seebeck coefficient increases linearly up to 60°C. It tends to be constant above 60°C . It is in contract with previous report on $COSb_3$ material which showed linear feature of Seebeck coefficient of 72µV/K [12].

The TEG output for parallel and serial configuration of two identical TEG are shown in Fig. 5. Both voltage and current increase nonlinearly with the increasing of different temperature. In serial configuration, the current is about 10 mA lower than the one in single TEG while the voltage is only about 1 V higher than the one in single configuration. It shows that TEG configuration is not completely similar like battery configuration. In parallel configuration, the current is 165 mA which is 34 mA lower than the one expected in two serial TEG. The voltage is 1,5 V which is 0.5 V lower than in single one. The increase of thermal resistance is suspected as the reason of this low voltage whereas the increase of electrical resistance causes the decrease of current. Technically, this problem is very challenging for high power thermoelectric application.

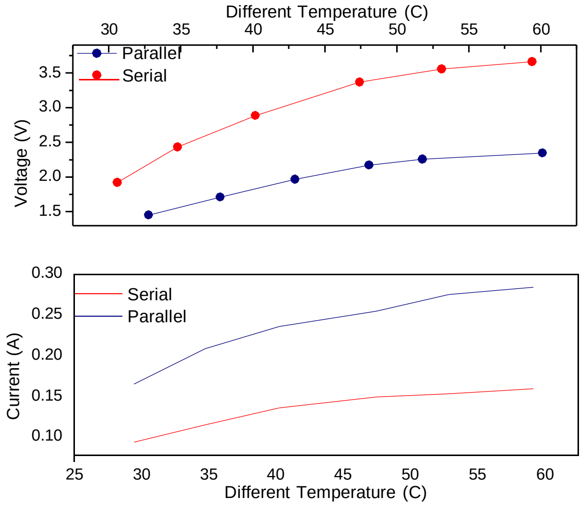

Fig. 5. The generated voltage and current as a function of different temperature for serial and parallel configuration.

III. 2. Implementing thermoelectrics in CPU processor

The current and voltage generated from CPU processor are shown in Fig 6. At maximum reached different temperature of 53 ˚C, the current and voltage are 190 mA and 2.4 V, respectively. These value are in good agreement with our characterization results suggesting that implementing TEG in CPU processor is electronically, thermally, and mechanically promising. The rasio of output and input power results on the efficiency of 4.25 %. Further investigation on the TEG module which has higher output is required to generate high power.

IV. Conclusion

Characterization and implementation of TEG 241-1.4-1.2 has been done on CPU processor to convert waste heat into electrical energy. The maximum generated current and voltage are 190 mV and 2.4 V, respectively. This implementation does not required mechanical-structural adjustment. A serial and parallel configuration of thermoelectrics is found to be less effective in increasing the output. This implies that further investigations on more efficient thermoelectric module is necessary to generate higher output. In application point of view an effective coolling process is also required to obtain higher output.

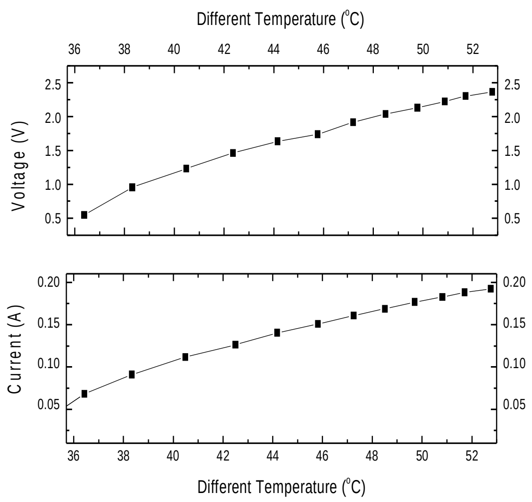

Fig. 6 (a) The generated current and (b) voltage of thermoelectric generator implementing in CPU processor

V. ACKNOWLEDGMENT

This project is financialy support by “Penelitian Dana Internal” Telkom University.

*NHP and KA contribute the experimental data equally.

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