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Characterizations of thermoelectric for energy harvesting on low-level heat sources

A.M. Abdal-Kadhim*, S.L. Kok

Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: ali.challenger89@yahoo.com

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ABSTRACT – Electric power harvesting from thermal energy using thermoelectric (TE) has been getting popular as a potential electrical energy source to replace batteries due to its direct current output. The focus of this paper is on the investigation of low level thermal energy below 150 °C that generated from electronic devices and mechanical machinery, and using TE's to convert the heat energy, which normally treated as wasted energy into a useful amount of electrical power to power up portable low power electronic devices. For this study, the TE module is subjected to a range of heat source using heating element that resemble the real temperature that generated from the real electronic devices and mechanical machinery. The quantity of harvested electrical power was reported. From the experimental results it can be observe that the voltage output is linearity proportion to the applied heat gradient on the TE faces. At a temperature gradient of 60 °C, a voltage output of 4 V is measured. The voltage output can be increased by stacking the TE on top of each other, from 0.067V/Δ°C for 1 TE to 0.093V/Δ°C for 4 TE.

1. INTRODUCTION

The latest developments in thermoelectric materials and structures have led to revive the interest in thermal to electrical energy harvesting which presents a new and attractive substitutional solution to the conventional power supplies (batteries). One of the most common method of generating electrical power with the aid of heat is by producing a mechanical movement in turbines, where is considered very old approach. However, this is not the only way of generating electricity power via heat. Therefore, as an alternative to that classical approach, the thermoelectricity generator TEG principle is an emerging technology to be explored along with further development to increase the efficiency and the reliability [1,2]. The TE harvester employing Seebeck effect which it's discovered in 1821 by Tomas Seebeck. This behaviour is described as when heating up one surface of TE element, and cooling down the other surface, will cause to generate an electrical current at the end terminals of the TE element. A TE harvester has shown promising features such as long life cycle, no moving parts needed, simplicity and high reliability. These days, the interest of thermal energy harvesting growing faster and more investigations are moving into its area, where there are some successful industrial applications using TE generators. The Seiko Thermic watch considered the first application ever of thermal energy harvesting to a consumer product [3]. The wrist watch was driven via a TE module to convert the user body heat into electrical energy. A 22 μW can be harvested by the TE module with about a 1K temperature gradient between the wrist and the environment at room temperature. Moreover, this harvested energy not only drives the watch but also charge a 4.5mAh lithium-ion battery. Other researchers developed a novel ultralow-power management circuit for an autonomous multisensory system for agricultural application where was powered via thermal energy harvester [4]. They succeeded to harvest about 110-mV/°C and also prolog the system lifetime from 136 h to more than 266 h. Dejan Rozgic and Dejan Markovic in [5] present a thin-film array-based thermoelectric energy harvester fabricated in a 0.83cm2 footprint along with a power management unit integrated into 65nm CMOS. Their prototype was targeted for biomedical applications where they achieved 645μW regulated output power harvested in-vivo from a rat implanted.

2. LOW-LEVEL HEAT RESOURSES SURVEY

In this paper, a mini survey was conducted to investigate various low-level heat sources that can be categorized as household electrical appliances are presented. This survey was targeted low-level of heat emission (less than 150 ºC). These items considered good heat sources for the application of energy harvesting because they are operating almost 24/7.

Hanna (HI93552R) kjt-thermocouple thermometer was the main equipment used to conduct this study. From Figure 1 it can be observed that the tested devices are generally emitting from 40ºC in case of laptop charger up to 130ºC in case of steam pressure cooker during their operating time. Since the ambient room temperature was measured at about 28ºC. Therefore, the delta of temperature for every tested item in the figure can be obtained via "ΔT=Heat Emitted-Room Temperature", which its start from ΔT=18ºC up to ΔT=100ºC. So according to this data the following experiment and in order to characterize the TE output a ΔT within the range of (5ºC to 60 ºC) will apply to the TE element.

3. TE HARVESTER CHARACTERIZATIONS SET-UP

In order to characterize the TE output a PCB resistive heater 5.5cm^2 in size fabricated to simulate a variable heat source. A group of four TE's used here from

Laird xc31 connected in series. A heat sink with 19 cm in diameter and 9 cm in height used to sink out the heat on the other side of TE, Figure 2.

A variable power supply connected to the PCB resistive heater in order to generate a different ΔT within range of (5ºC to 60 ºC) to the TE under test, and the open circuit V-out was recorded via a digital voltmeter.

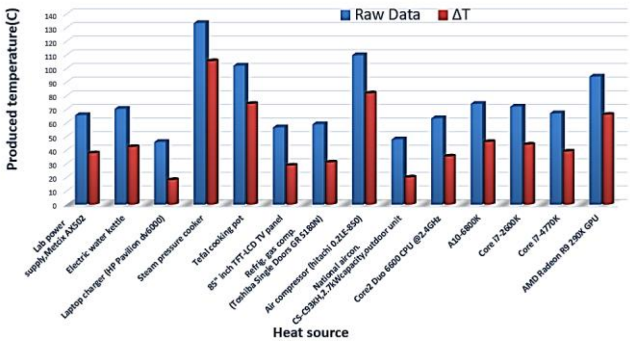

Figure 1 Low-level heat sources and their ΔT at room temperature =28ºC.

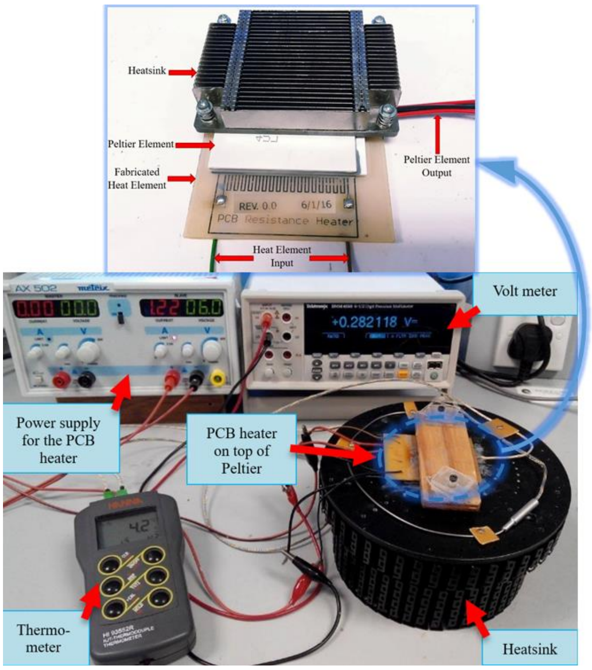

Figure 2 TEG Characterization experimental set-up.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The experiment starts with a single TEG element and then cascaded the rest sequentially by connected their output in series. Whatever using one TEG or more, they all generate about 0.5 DC.V at ΔT=5 ºC. Where then the V-out increased with direct proportional manner with ΔT. The maximum output can get from single TEG is 4DC.V at ΔT equal to 60ºC. Whereas the maximum output measure of cascading four TEGs recorded is about 5.5 DC.V, Figure 3 illustrates the DC. V-out harvested from multiple TEG at different temperature gradient.

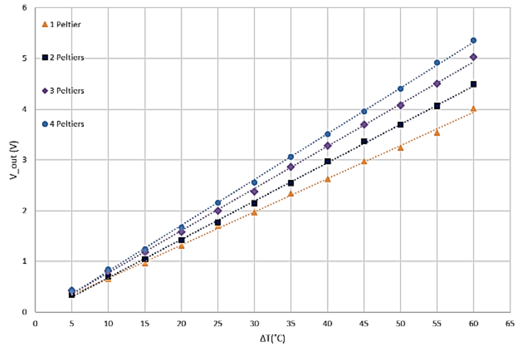

Figure 3 DC. V-out harvested from multiple TEG at different ΔT gradient.

5. CONCLUSION

A mini survey of low-level heat sources has been reported. PCB resistive heater used to apply different temperature gradient to the TEG. From the results can conclude that the increment of the TEG number doesn't have the biggest effect on the V-out as the ΔT. Where at ΔT=60 the V-out will be increased by 0.5 V only with every stacked TEGs.

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