Self-Powered Thermoelectric based Cooling system for LCD panel

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***Abstract*— Thermoelectric (TE) module converts heat energy into electrical energy where temperature gradient is applied on hot and cold surfaces of the module. Generally, large electronic system or electronic display generates heat which dissipates via the surface of the device which may affect the functionality and lifetime of the systems or devices. Therefore, TE module can be used to utilize the heat and converts it into useful electrical energy. In this paper, TE module will be used to power cooling fan as a self-powered system. Firstly, heat dissipated from an 85 inches Thin-film-transistor liquid-crystal display (TFT LCD) is characterized, which is mainly from the power board of LCD panel. There are three power board are used in the LCD panel. The highest temperature of the power boards of LCD panel are 72.7°C, 68°C, and 38.3°C respectively. After that, heater is used to simulate the heat dissipated for the LCD panel. There are 4 TE modules were used in the lab experiment. TE modules are stacked with each other and the output of each TE modules are connected in series. TE modules are placed between heater and heat sink to generate electrical energy. The open circuit voltage output is 2.8v and the power output is 0.24W. After that, the output will be boosted up by using DC to DC converter. The output voltage obtain is proven to be enough to power up the cooling fan. The operation of the cooling fan depends on the temperature gradient between the heater and heat sink. Therefore, cooling fan will turn ON when it is heating up, and it will turn OFF when it is cooling down.**

***Index Terms*— Heat Energy; Seebeck Effect; Temperature Gradient; TFT-LCD Panel; Thermal Analysis.**

I. INTRODUCTION

Energy harvesting is a process of energy conversion from wasted energy to electrical energy. There are two type of electrical energy output which are AC output and DC output. Piezoelectric is one of the energy harvester that convert motion energy to electrical energy [1,2]. Moreover, it produces AC output with high voltage output but low current output.

Besides, Thermoelectric (TE) module can be used as energy harvester to transfer heat energy to electricity also. Besides that, it became more popular due to its small size and potential to integrate on any electronic system. Thus, it was implemented into Seiko Thermic[3] watch project, and it was showed that the TE module has potential to replace battery as the main electronic power source. Besides, X.Lu and S.H.Yang[4] harvested heat energy for wireless sensor node. Since many of the wireless device and power electronic consume lesser energy, so energy harvester can power up the wireless devices such as zigbee, Radio Frequence(RF) transceiver, and so on.

Additionally, M.Risha and et al [5] proposed design cooling system embedded on biomass cookstove. In this project, DC to DC converter also used to boost up the output of TE module. They found out the output voltage of TE module is 3.25v while the ΔT is 200°C. Thus, it is enough to boost up by using the DC to DC converter and power up the cooling fan. Besides of the biomass cookstove, B.K.Rajeh and et al [6] used heat produce by godrej vikhroli plant as heat source for TE module. The voltage output of TE module is 3.2v while the ΔT is 70°C.

The motivation of this paper is green technology and environmental friendly for sustainable development. It can reuse the wasted energy and convert it into electrical energy. Besides, this system will be easy to install in any system such as refrigerator, car engine, industry machine and so on.

II. THERMOELECTRIC MODULE

Thermoelectric effect is any phenomenon that involves an interchange between the heat and electrical energy and this phenomenon is reversible. This phenomenon can be verified on two dissimilar semiconductor or metal and it is called junction. In addition, temperature gradient of the junction depends on the area of the semiconductor or metal used [7].

Seebeck effect is one of the thermoelectric effect, it was proposed by T.J.Seebeck in 1821. Seebeck noticed energy is produced from two different type of semiconductor junction. On the same time, these two types of conductors are applied for two different temperatures from upper and lower surface [8]. Therefore, Seebeck effect is the energy production between two dissimilar conductors. Two conductors connected in series and parallel junctions are held at two different temperatures T_H and T_C and an V appears between their free contacts:

$$V = -S(T_H - T_C) \tag{1}$$

where: S =Seebeck's coefficient (dependant on the material and manufacturing process)
T_H = Temperature on Hot surface of TE module
T_C = Temperature on Cold surface of TE module

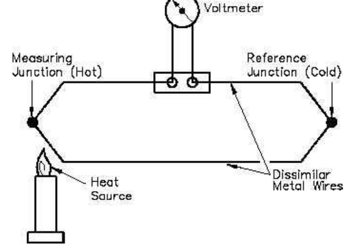

Figure 1: Simple Thermocouple Circuit [7]

Figure 1 shows the operation of thermocouple. Generally, thermocouple is used for temperature measurement and it use Seebeck effect for operation. There are two junctions on thermocouple, which are measuring junction and reference junction. Gradient of temperature is determined in between these two junctions [9].

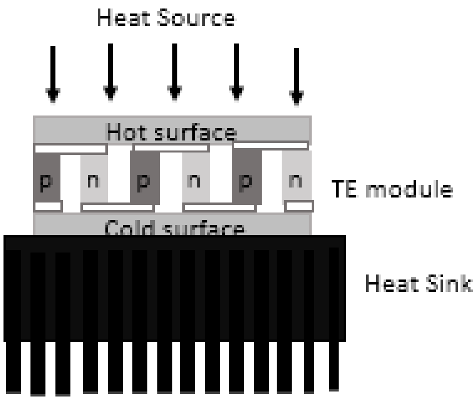

Figure 2: Thermoelectric module

Figure 2 shows schematic diagram of TE module. TE module usually used as cooling function. However, it also can be used to convert heat energy into electrical energy. TE module is combination pairs of thermocouple, it is connected electrically in series and thermally in parallel. Ceramic plates are used to cover these thermocouples, because ceramic plates are good heat conduction and high electric resistance material[10].

III. EXPERIMENTAL SET-UP

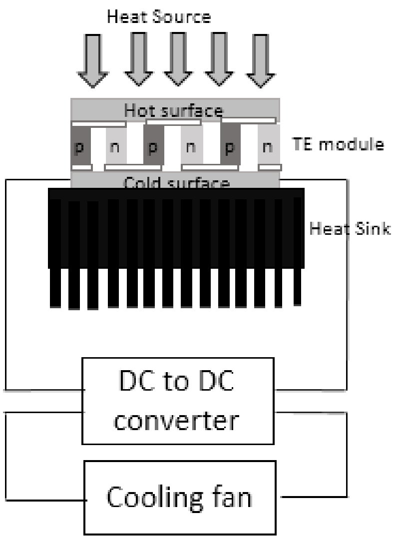

Figure 3: Block diagram of the self-powered cooling system

Figure 3 shows the design of the thermoelectric based cooling system. Heat source will be applied on hot surface of TE module, so TE module generate electrical energy. After that, DC to DC converter will boost up the output voltage of TE module and power up the cooling fan. In addition, the heater is being used as heat source for thermoelectric and it is assumed the hot temperature in LCD panel.

Firstly, the temperature of 85 inches liquid-crystal display (LCD) panel is characterized. There are three power boards used in 85 inches LCD panel, each temperature of power board for turned ON and turned OFF condition is collected and plotted in graph. Thermocouple is used to measure the temperature of power board.

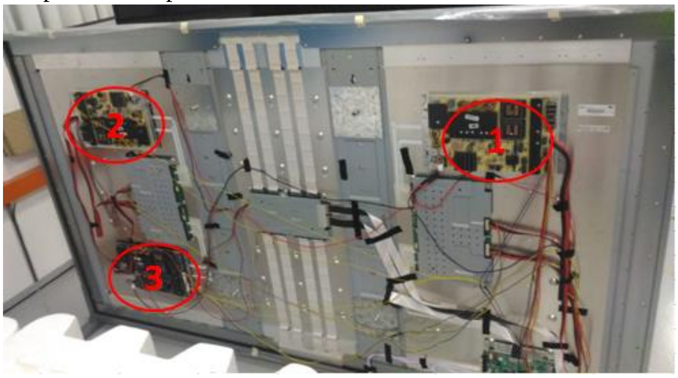

Figure 4: Places for thermal analyze on TFT LCD panel

Figure 4 shows the place to mount the thermocouple, and the power boards are tagged as 1,2 and 3. After that, the temperature are plotted in graph and compared. After collecting the measurement, the experiment is carried out in lab by using heater to simulate the temperature of power board. Besides, four TEGs are used in this experimental set-up and the TEGs are Laird Technology UltraTEC series. Four TEGs are stacked with each TEG and the voltage output is connected in series to obtain the higher voltage.

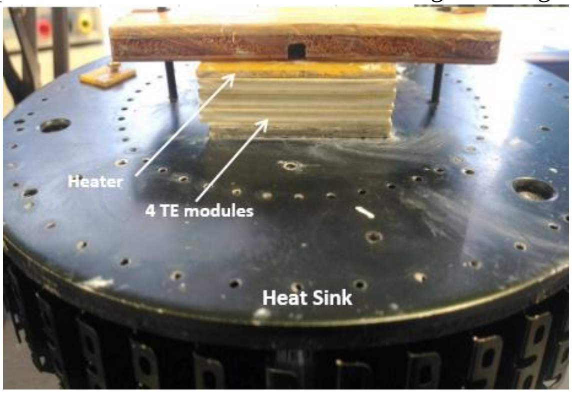

Figure 5: Stacked TEGs were placed between heater and heat sink

Figure 5 shows the place of TE modules, heater is used to simulate the temperature of LCD panel on hot side of TE modules. While the heat sink was placed on cold side of TE modules, so it can get higher temperature gradient. The size of heat sink used is 19cm diameter and 9cm height. Thermo paste is applied in between of heater, TE modules, and heat sink. This is because thermos paste can reduce the air gap between them and obtain better heat conduction. After that, the output voltage of TE module is plotted in graph.

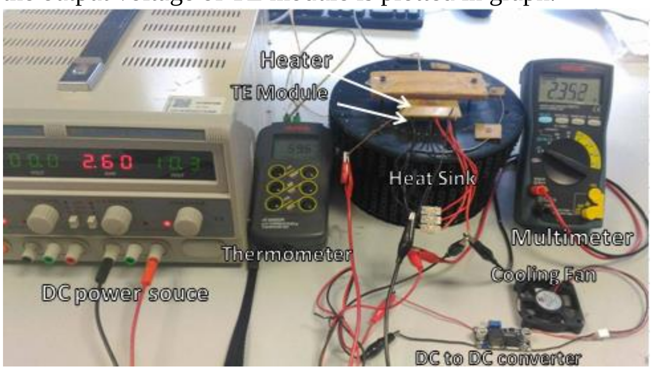

Figure 6: Experimental set-up for cooling system

Figure 6 shows the experimental set-up for cooling system. DC power source is used to power up the heater.

Next, TE modules are screwed tightly between the heater and heat sink. Thermometer was used to measure the temperature applied on TE module and temperature gradient of TE module. In addition, multimeter is used to measure the output voltage of TE modules. Then, the output of TE module connect with variance of resistance to obtain the power output of TE modules.

The DC to DC converter used is CN6009, the wide input voltage is between 2.8v to 32v, optimum operating voltage range is between 5v to 32v. Output voltage of TE modules is input voltage of DC to DC converter, and the output voltage of converter was used to powered up the cooling fan.

IV. RESULT AND DISCUSSION

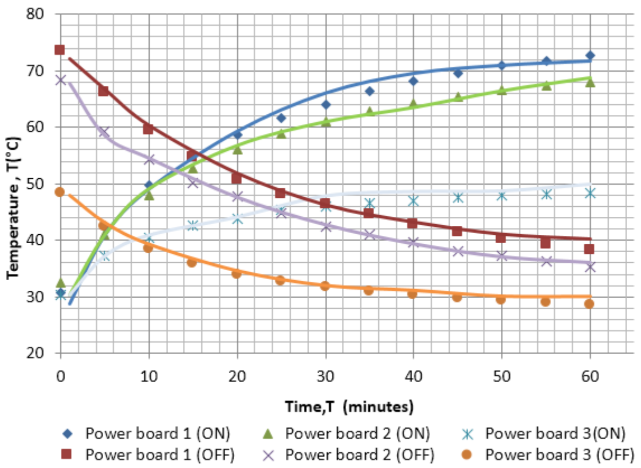

Figure 7: Temperature of power board LCD panel

Figure 7 shows the relationship between temperature power board of LCD panel and time. The temperature of power is increasing until the temperature saturated while the LCD panel is turned ON. Besides, the temperature is decreasing until its saturated while the LCD panel is turned OFF.

This graph can relate to the equation as below:

$$Temp = \frac{3.867k}{b}[(1+Time)^{\frac{1}{3}} - \frac{Time}{3}\ln(\frac{Time}{1+Time})]$$

Where, b is alter number, $0.08 \leq b \leq 0.5$.

The maximum temperature obtained from power board 1 and power board 2 are 73.5°C and 68.3°C respectively. Temperature for power board 3 is lower compare to power board 1 or power board 2, maximum temperature obtains from power board 3 is 48.4°C only. Since the power board 1 and power board 2 is supplying power to LCD backlight while power board 3 is applied to interface board of LCD panel, so difference in maximum temperature happens.

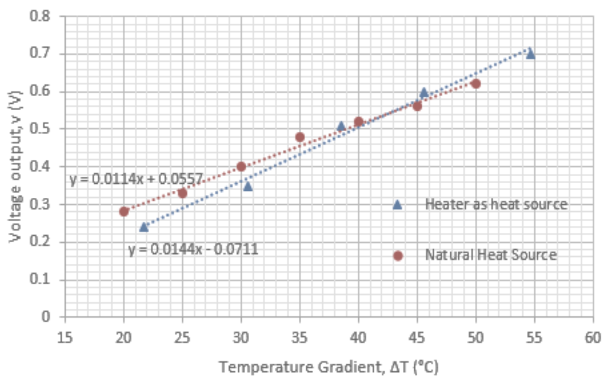

Figure 8: Voltage output of TE module with different heat source

Figure 8 shows the voltage output of 1 TE module by using heater and natural heat source. By using heater as heat source, the voltage output of TE module is 0.0144v/°C. On the other hand, voltage output of TE module is 0.0114v/°C by using natural heat source.

By using heater in this paper is because can control the hot temperature and experiment environment easily. Thus, it can obtain the exact data from the experiment.

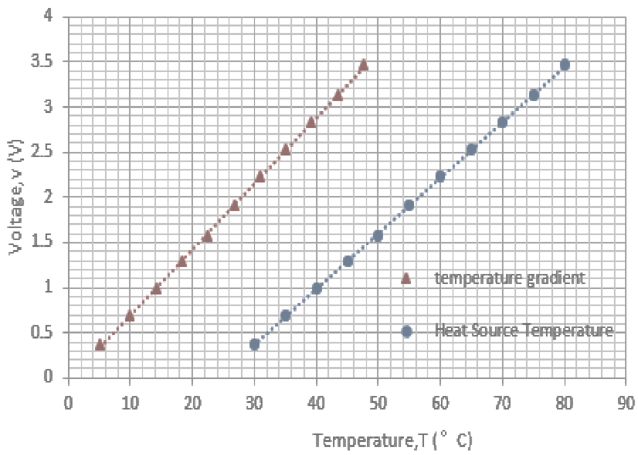

Figure 9: Voltage output of TE modules versus temperature.

Figure 9 shows the voltage output of TE module, the voltage output is directly proportional to temperature applied on TE module. The output voltage is taken every 5°C from 30°C to 80°C. The maximum temperature of power board is about 73.5°C. Refer back to figure 9, the output voltage of the TE module is 2.822v when the 70°C is applied on TE module. Besides, the temperature gradient is 39.2°C while the hot temperature is 70°C. Thus, it is enough to operate the DC to DC convertor.

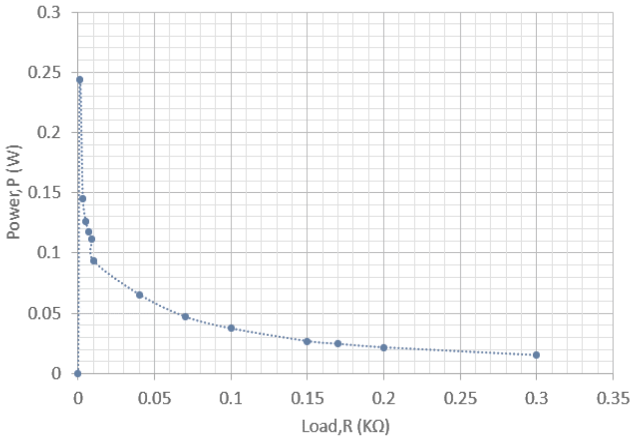

Figure 10: Power output of 4 TE modules connect in series

Figure 10 shows the power output of TE modules with variance resistance. The highest power can obtain from the TE module is about 0.243W. In addition, the internal resistance of the cooling fan is 0.34kΩ. From the graph of Power versus load, power output of TE module is 0.0150W while the load is 0.3kΩ. Therefore, the power require of the fan is about 0.015W.

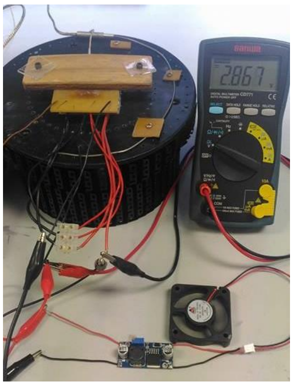

Figure 11: Cooling Fan is operating

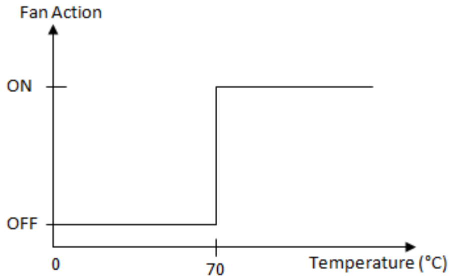

Figure 12: Fan action versus hot temperature applied on TE module

Figure 11 shows the cooling fan was operating when the output voltage of TE module reached to 2.8v. When the output voltage of TEGs is lower than 2.8v, the fan will turn OFF. Figure 12 shows the relationship between fan action and temperature applied on TE module. When temperature applied on TE module is greater than 70°C, the fan will turn ON. On the other hand, the fan will turn OFF when the temperature applied on TE module is lower than 70°C.

V. Conclusion

In this paper, a self-powered TE module based cooling system is successfully developed. The heat dissipated from LCD panel was characterized and plotted in graph. After that, the experiment was carried out in lab by using heater as heat source. The heater was used to simulate the temperature of LCD panel. After that, output voltage of TE module was boosted up by using DC to DC converter. Therefore, the cooling fan was turned ON when the output voltage of TE modules reach 2.8v and the power operating is 0.015W.

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