# Evaluation of the Performance of the SP 1848-27145 Thermoelectric Generator Module

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DOI: 10.29322/IJSRP.12.02.2022.p12246
http://dx.doi.org/10.29322/IJSRP.12.02.2022.p12246

Paper Received Date: 30th January 2022
Paper Acceptance Date: 10th February 2022
Paper Publication Date: 21st February 2022

***Abstract-*** In this work, a simple thermoelectric generator (TEG) has been designed and constructed using the Bismuth Telluride-based SP1848-27145 generator module. The design comprises of the thermoelectric converter, a source of heat, a portable cooling fan, and a dc-to-dc step-up converter. Temperature, currents, and voltage measurements taken from the constructed generator show that as the temperature rises, the current and voltage output increases until the difference in temperature between the hot and cold side of the generator module reaches 70° C. At this maximum temperature difference of 70° C, the maximum voltage output of 2.20 V was measured. When the device is in operation, a temperature difference of 60° C, current of 100 mA, and voltage of 1.6 V was measured. The output voltage was stepped-up with a dc-to-dc voltage booster to 5.0 V, which can be used to power portable devices (such as ultra-bright LED lights, charging of cell phones, and other devices) that runs on a 5 V supply.
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***Index Terms***- Thermoelectric generator, voltage booster, portable devices, cooling fan.

## I. Introduction

A thermoelectric generator (TEG) also known as See-beck generator is a solid-state device that converts heat flux directly into electrical energy through a phenomenon function like that of a heat engine. It is less bulky and has no moving parts. A thermoelectric generator involves numerous ingot-shaped semiconductor elements coupled in series with metal strips and sandwiched between two ceramic plates that are electrically insulating but thermally conducting to form a very compact module [7].
Thermoelectric generators are very similar to photovoltaic generators or solar PV cells. Photovoltaic generator converts light directly into electricity while thermoelectric generators convert heat directly into electricity.
A thermoelectric generator (TEG) offers many advantages over traditional generators including highly reliability and consideration for the environment. The device is compact, needs minimal maintenance and has a geometry that makes it compatible with most industrial systems [1]. Due to such advantages, there has been considerable emphasis in recent years on the development of small TEG for a variety of aerospace and other applications. Recently, there has been increasing interest in waste heat recovery TEG using a variety of heat sources, including internal combustion engines, geothermal power plants, and other industrial heat generation processes [2],[3],[4],[5],[6]-[7]. As regards TEG for waste heat recovery power generation, there have been several ideas of a power conversion system that are capable of obtaining applications in this area and these designs involve the consideration of the maximum power output and conversion efficiency of different thermoelectric generators.

Thermoelectric generators are a promising device for waste heat recovery, and TEG's economics can be significantly improved when used for waste heat recovery. One of the more attractive options for waste heat recovery is construction. It integrates a TEG device that uses relatively simple heat exchange having a parallel plate with the commercially available thermoelectric modules. Here a simple TEG has been designed and constructed by attaching Aluminium heat sinks on both the hot and cold side of an SP 1848 - 27445 generator module with a 5 V cooling fan connected to the cold side.

## II. EXPERIMENTAL SET-UP

This research reports the design and construction of a simple TEG using the Bismuth Telluride-based SP1848-27145 generator module. The diagram of the experimental setup of our TEG for low- temperature waste heat recapture is shown in Figure 1. The system comprised of the heat exchanger/thermoelectric converter, a candle or wood burner, or a cooking stove can be the source of heat Q1 and a fan attached to the heat sink Q2 will expel the heat built up at the cold side of the thermoelectric device. Electrical power output will be taken from the TEG via a dc-to-dc step-up converter to power portable devices or charge mobile phones. A list of the components used in this design is given in Table 1. Figure 2 gives the image of these components listed in Table 1 according to their serial number. Note that item number five (No.5) is a thermal paste used for joining the parts together.

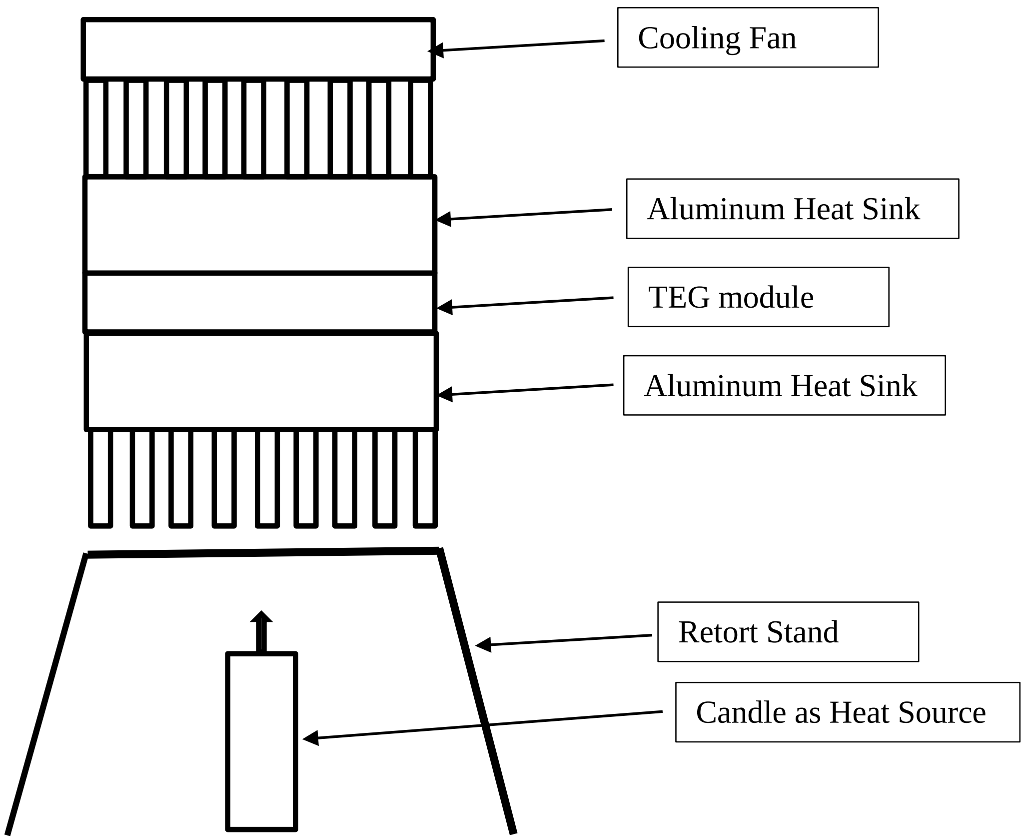


Figure 1. The schematic structure of the TEG system. Heat is extracted by the fan at the top, and the heat input comes from the candle below.

Table 1: Component list for the designed TEG.

| S/No | Item/Description | Quantity |
|---|---|---|
| 1 | TEG module: SP1848-27145, 4.8V 669 mA, 40x40mm | 1 |
| 2 | Aluminum Heat Sinks: 40mm X 40mm X 20mm | 2 |
| 3 | Dc-to-dc Step up booster – USB charger 0.9 V – 5 V to 5 V | 1 |
| 4 | 5 V 40mm X 40mm cooling fan | 1 |
| 5 | 5g Silicon thermal paste | 1 |

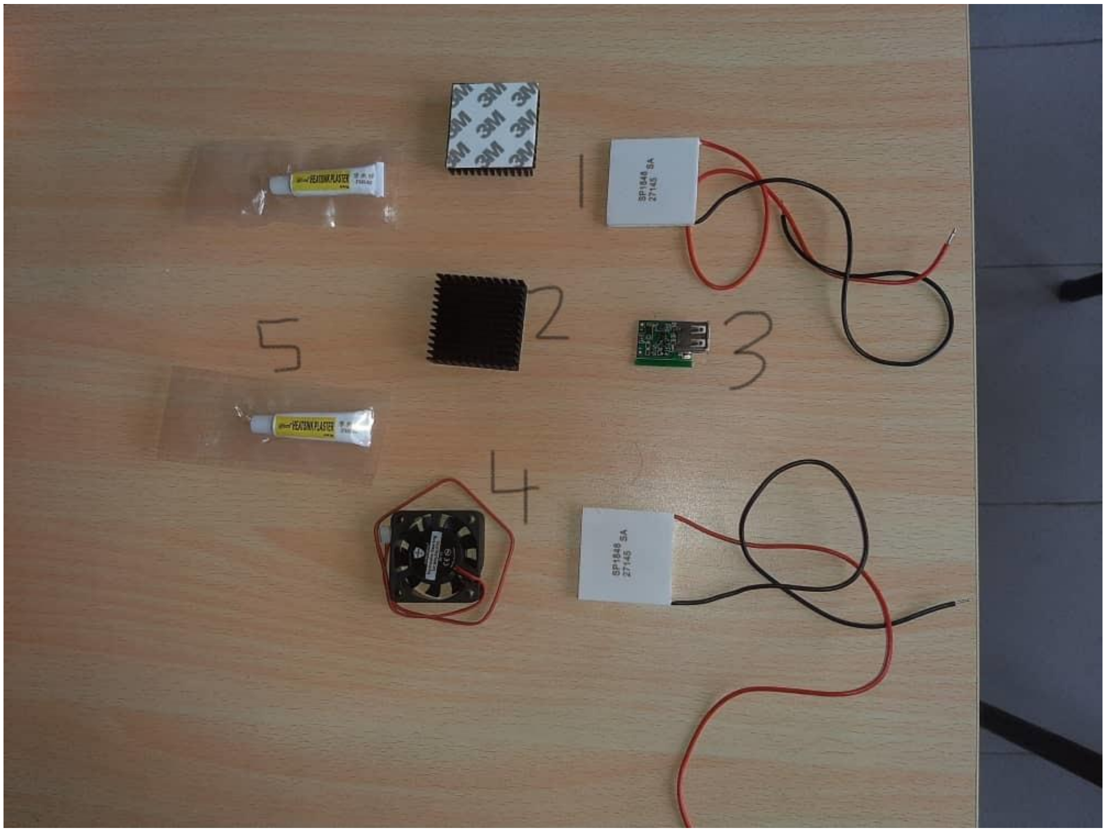


Figure 2: Images of items used in this project, where label No.1 is the TEG module, No.2 is the aluminum heatsink, No.3 is the dc to dc step up booster, No.4 is the cooling fan and No.5 is the silicon thermal paste.

To measure the performance of the device, we connect a voltmeter across the TEG module output and an ammeter in series, then a digital thermometer is used to measure the hot/cold side temperature. Figure 3 shows the diagram for the setup arrangement to measure the current, voltage, and temperatures. The apparatus used to carry out the measurements is shown in the image given in Figure 4.

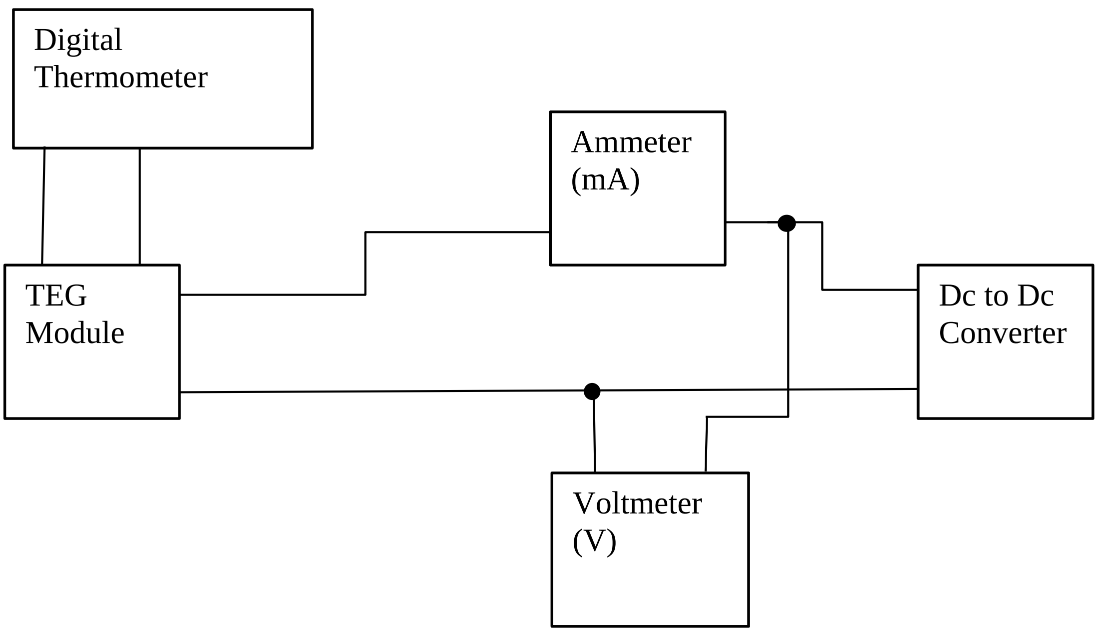


Figure 3: Setup for measuring the performance of the TEG.


Figure 4: Apparatus used for measuring the performance of our TEG: Left and Right are multi-meters used for currents/voltage measurements, while, the Centre equipment is the digital thermometer for temperature measurement.

## III. CONSTRUCTION

We started the construction by preparing a candle stand that the generator can be mounted on. The stand has to look like a tripod stand, so the candle can be placed under and the TEG mounted on top with the hot side of the device facing down. For the candle stand, we improvise by cutting through the top and side of a Nescafe container to allow for free airflow. This can be seen in Figure 5. Next, the aluminum heat sinks are glued to the hot and cold side of the TEG using the Silicon thermal paste (see Figure 5). And then the 5 V cooling fan is attached to the heat sink on the cold side of the TEG to help with cooling this side of the device. The output from the TEG is connected to the dc-to-dc step-up booster circuit to step up the output voltage of the generator to 5 V dc. Since 5 V is suitable for charging mobile phones and powering white LED lights. The constructed generator is shown in Figure 6.

ISSN 2250-3153

Figure 5: Image of the TEG construction in progress showing the openings on the Nescafe container and the aluminum heatsinks already glued to the TEG module.

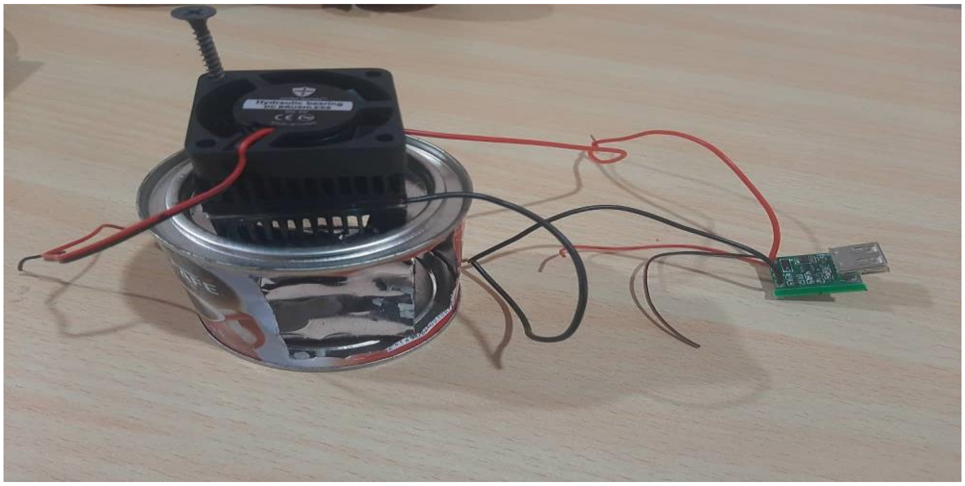

Figure 6: A picture of the finished portable thermoelectric generator.

## IV. RESULTS AND FINDINGS

First, the heat source (candle) was turned on and the cooling fan was powered by a 5 V dc power supply unit. A 10 Ω resistor was connected between the positive terminal of the TEG and that of the ammeter to aid the current measurement. After the setup, the data collection process was done. The performance of the TEG was evaluated by measuring the voltage, current, and temperature of the device. Then the power output was calculated using the relation:

$$W = \frac{V^2}{R_L} = I^2 R_L IV \qquad (1)$$

Where $R_L$ is the load resistance, $V$ is the output voltage, and $I$ is the output current.

Figures 7 and 8 depict the characteristics of the relation between the voltage and current output. These show that there is a linear relationship. As the voltage output increases, the output current increases as well. During the device operation, a maximum voltage of 1.6 V and current of 100 mA was obtained as can be seen in figures 3.1 and 3.2. The output power was computed to be 160 mW using equation 1.

It can be seen that the output current and voltage increase due to the temperature difference between the hot and cold sides of the thermoelectric generator. It can be clearly seen from the analysis of Figures 7 and 8 that there is some form of linearity attained in the results. In addition, it should be noted that curves have similar slopes; which implies that the internal resistance of the thermoelectric generator changes slightly when the operating temperature is changed.

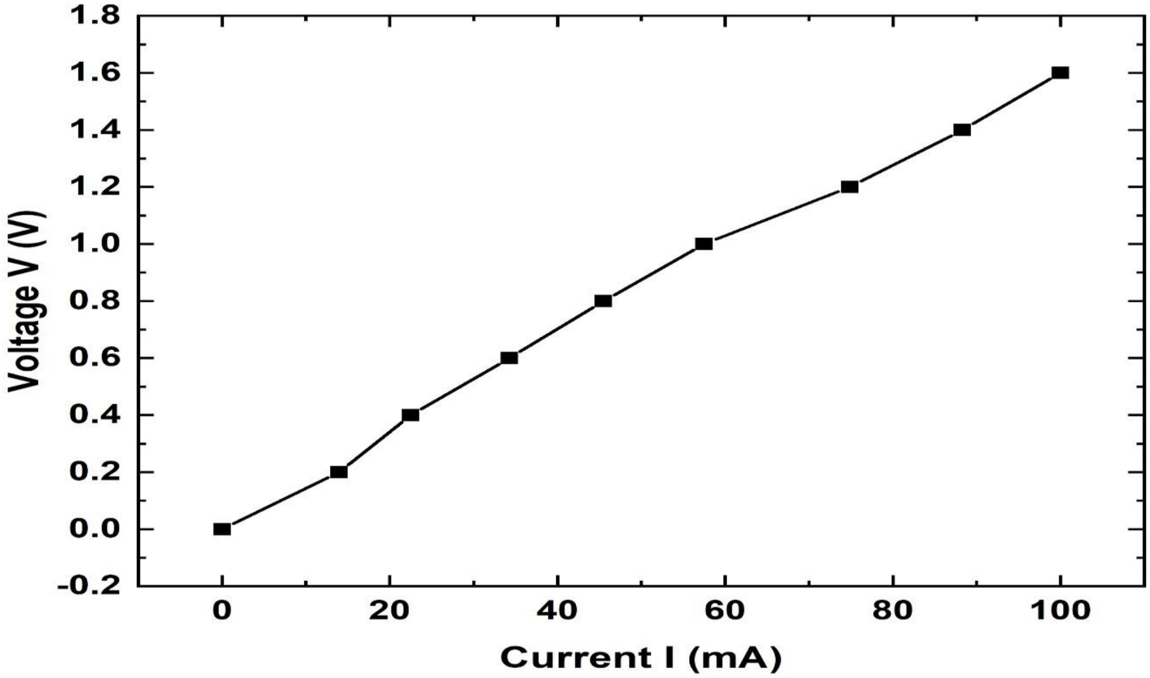


Figure 7: A plot of the output voltage V against output current I from the TEG.

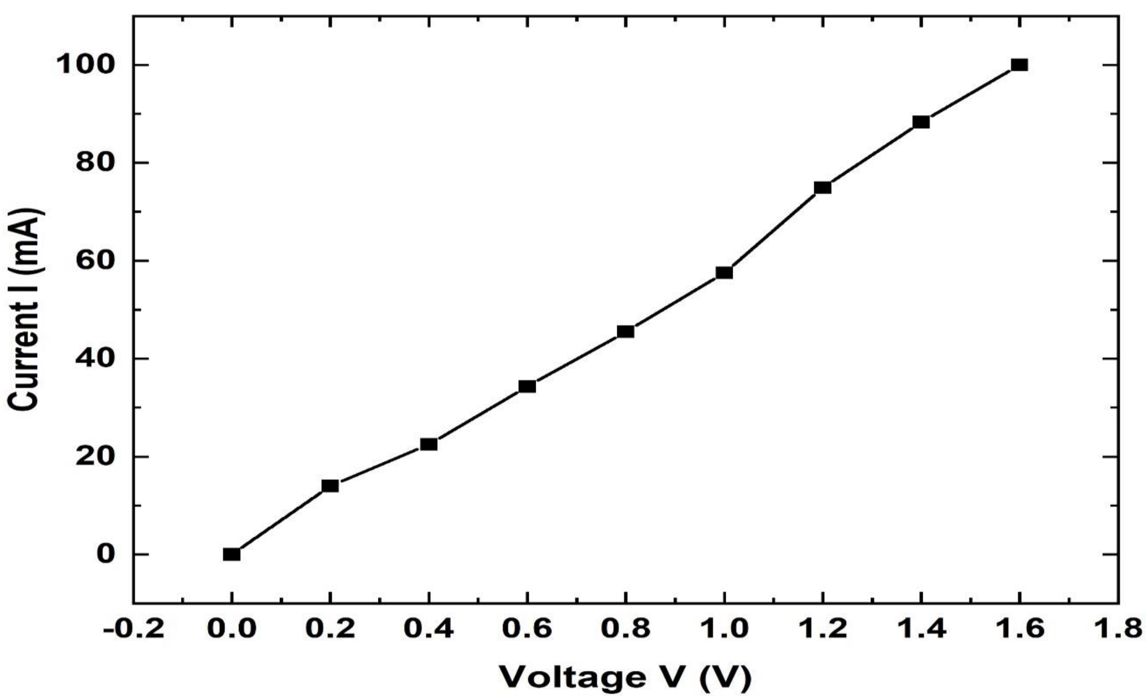


Figure 8: A plot of the output current I against output voltage V of the TEG module.

Figure 9 shows a graph of the output voltage V against temperature difference $T_1$-$T_2$. Figure 10 shows that of the current against temperature gradient $T_1$-$T_2$. The temperature gradient of the device was able to reach a maximum of 60°C while in operation as can be seen in figure 10. Figure 9 shows the open-circuit voltage V as a function of temperature differences ($\Delta T$). The open-circuit voltage increases somewhat linearly with the rise of the temperature difference. Since the internal resistance of the generator is close to zero, it is assumed that the electromotive force of a generator is equal to the open-circuit voltage.

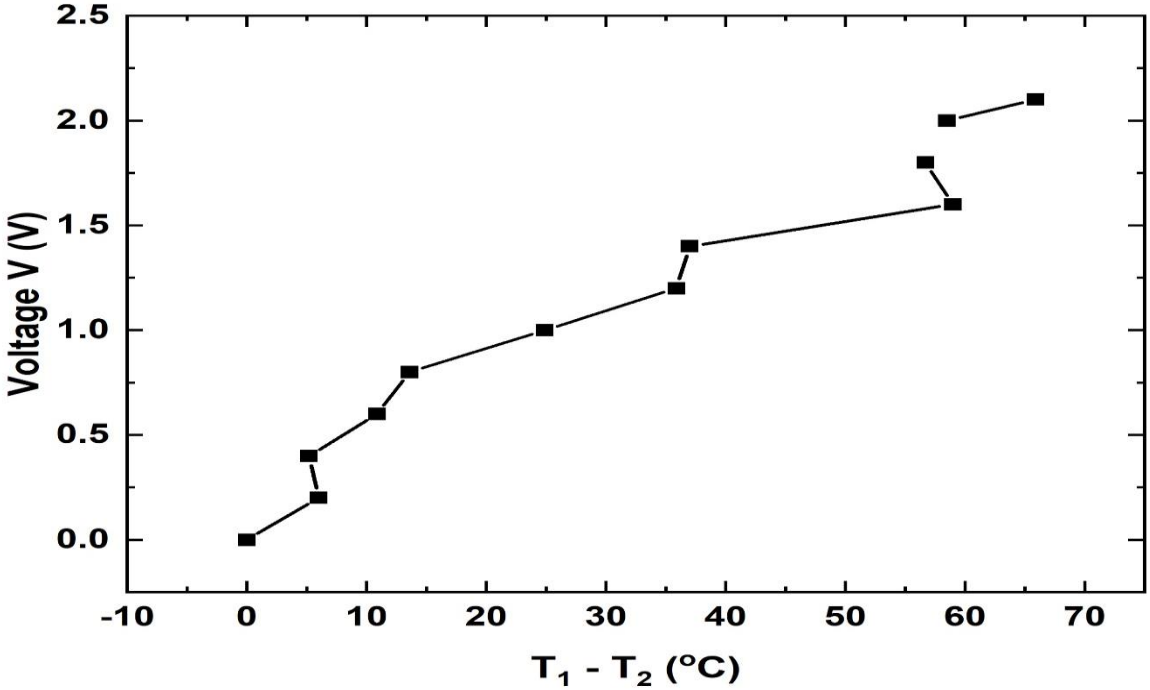


Figure 9: A plot of output voltage V against temperature gradient $T_1$-$T_2$.

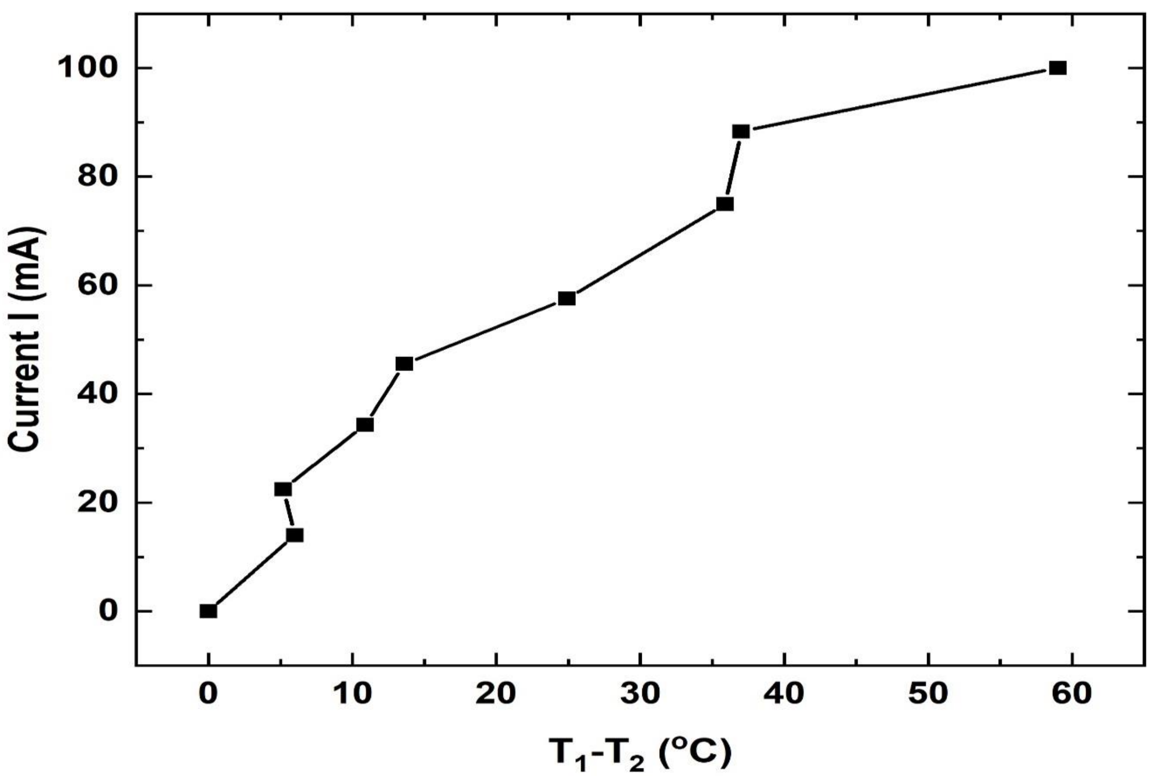


Figure 10: A plot of output current I against temperature difference $T_1$-$T_2$.

ACKNOWLEDGMENT

This research work was supported financially Dr. Nimibofa Ayawei.

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