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Thermoelectric Power Generation with Load Resistance Using Thermoelectric Generator

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Abstract:* Thermoelectric power generation is a direct consequence of the Seebeck effect. The Seebeck effect is a device that converts heat into electrical energy due to difference in temperature between two dissimilar conductors and produces voltage. The Seebeck effect is the generation of an open circuit voltage (no load is connected) across a junction made or dissimilar material due to a temperature difference across this junction. They consist of one pair of p-type and n-type thermoelectric elements. (to perform such conversion) . The main focus of this paper is when four TEGs are connected in series combination and in parallel combination ,the input and output voltages, output current can be measured at different temperatures , and the corresponding graphs can be drawn . We can also calculate the power generated by the formula, P=IV .The measurements were done with the help of thermoelectric generators (TEP1 -1264 -1.5) and a measurement setup consists of controlled hotplate, a controlled fan. Thermistor is used for measuring temperature. At load resistance , R= 10Ω when four TEGs are connected in parallel , the maximum output current drawn at temperature 180^0 C is 0.4 A and the output voltage is 5.1V. In this case the output power calculated is P = I V = 2.04 W and the corresponding graphs are drawn between Temperature vs the output voltage , temperature vs output current, output current vs output voltage . When four TEGs are connected in series , the maximum current drawn at temperature 160^0C is 0.63A and the output voltage is 20.5V . In this case the output power generated is , P=IV= 12.3W and the corresponding graphs are drawn between temperature vs output voltage, temperature vs output current , output current vs output voltage.

***Index terms:* Thermoelectric generator (TEG), temperature controller, See beck effect**

I. INTRODUCTION

A. Thermoelectric generator

A thermoelectric generator (TEG) , is a device that converts heat directly into electrical energy with a phenomenon called the " Seebeck effect which is a form of Thermoelectric effect. [1,2] Thomas Johann Seebeck discovered that due to difference in temperature between the conductors produces voltage. The Seebeck effect is the generation of an open circuit voltage across a junction made of dissimilar material due to a temperature difference across this junction. With an internal resistance in series TEGs can be modeled in steady state as a voltage source. For a given temperature difference the electrical power delivered by the TEG varies depending on the current drawn by the electrical load connected to its terminals . According to maximum power transfer theorem to get maximum power load resistance is equal to internal resistance of thermoelectric generator internal resistance.

B. Formation of a Thermocoupl

The thermoelectric generator consists of p-type and n-type semiconductors. This pair forms a "thermocouple". When multiple thermocouples are connected in series , it increases the output voltage, and when thermocouples are connected in parallel can increase the output current.

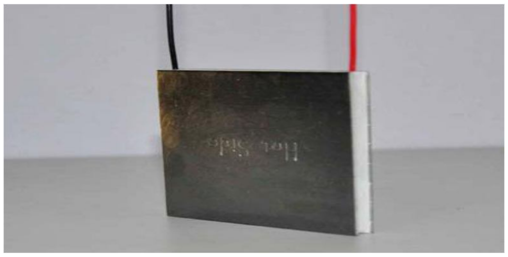

Figure 1: (a) Thermoelectric device(model TEP1-1264-1.5)

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C. Experimental setup

This paper presents the generation of electrical power by measuring output voltages and currents with load resistance at different temperatures by connecting the thermo-electric generators in series and parallel. Fig:1 (a) is the thermoelectric modules model TEP1-1264-1.5 works at temperatures of 300^0C and the area is 40mm x 40mm.

The Fig:1 (b) shows a combination of p-type and n-type thermoelectric elements of Thermoelectric generators. A thermoelectric produces electrical power from heat flow across a temperature gradient [3]. When the heat flows from hotside to coldside, the charge carriers are developed in the material to the cold end as shown in Fig. 1. The voltage will be produced .With the help of load , by connecting p-type and n-type materials in series and parallel which increases output voltage and output current. (b)

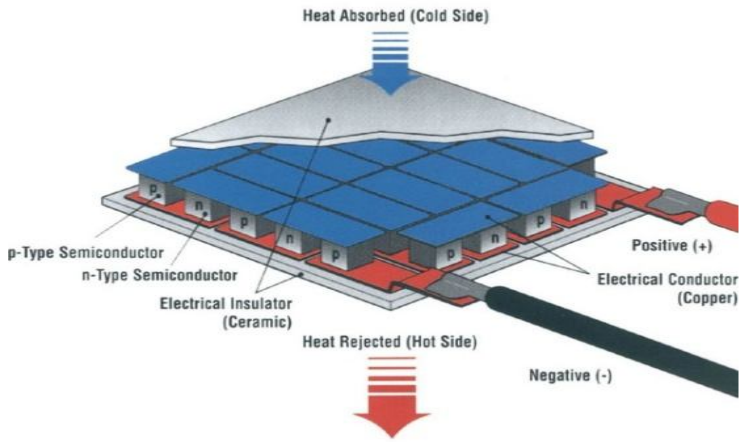
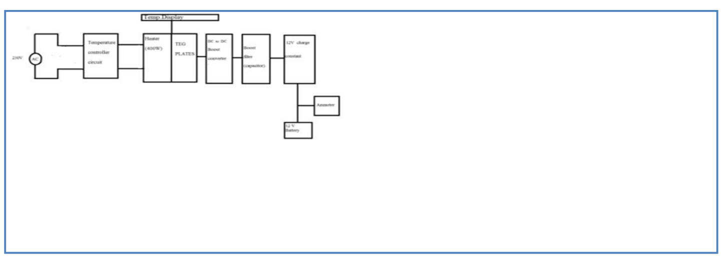


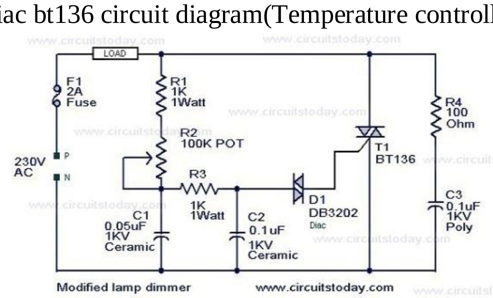
Fig: 2 Circuit Block Diagram



Block diagram components

1) Temperature controller circuit
2) Heater
3) TEG plates
4) Temperature display
5) DC to DC Boost converter
6) Boost filter(capacitor)
7) 12 V charge constant
8) Ammeter
9) 12V battery

Fig: 3 Triac bt136 circuit diagram(Temperature controller circuit)



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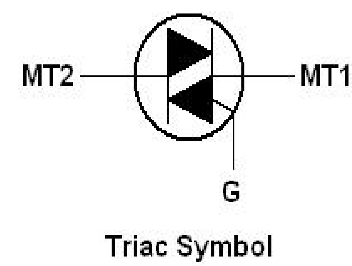
D. Triac circuit details:

With load triac works as a switching device and controls alternating current. Using triac circuit we can set the temperature readings of to 60^0, 70^0, 80^0 … etc.

Fig:4 Traic symbol:



Triac symbol is shown in Fig;5 and Triac consists of two main terminals, MT1 and MT2 and a gate and triac is also equal to two SCRs connected in inverse parallel.Triac is used for general purpose switching and to control motors.

E. Boost Converter

A boost converter contains two semiconductors a diode and a transistor and is used to reduce the voltage ripples . The power levels for this boost converter is from low to very high power transmission is a DC-to-DC power converter that steps up voltage , while stepping down current from its input to its output. Fig:5 below shows a DC-DC boost converter (XL 6009) circuit diagram.

Fig:5 DC-DC Boost Converter XL 6009 Circuit Diagram

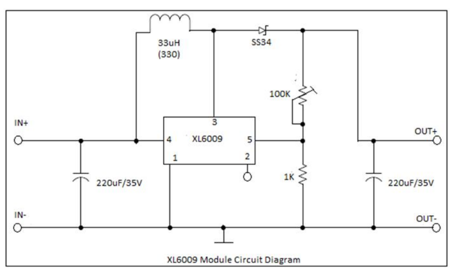


Fig: 6 Experimental Setup using a thermoelectric modules model TEP1-1264-1.5 Between a Controlled hotplate and a cooling fan

F. Working

When an alternating current of AC 230 V is supplied to the triac bt 136 circuit (temperature controller circuit) set the hot side temperature to be starting from 50^0 , 60^0 , 70^0…..etc. When 4 TEG plates are placed in series without load and with load resistance also taken the readings and graphs are drawn . A boost converter is a step up converter that sets up voltage when the current is decreasing. From any dc sources like rectifiers, solar panels a boost converter can get the power. A Boost converter is a voltage setting controller and draws a maximum current of 3 Amps.TEG uses load for power generation and this load is connected to TEG.A motor, light bulb and LEDs are used as load. When no load is connected a TEG is known as open circuit and when load is connected then it is known as closed circuit. When load resistance is equal to the internal resistance of TEG, then TEG gives maximum power output.

G. TEGs in series and parallel configurations

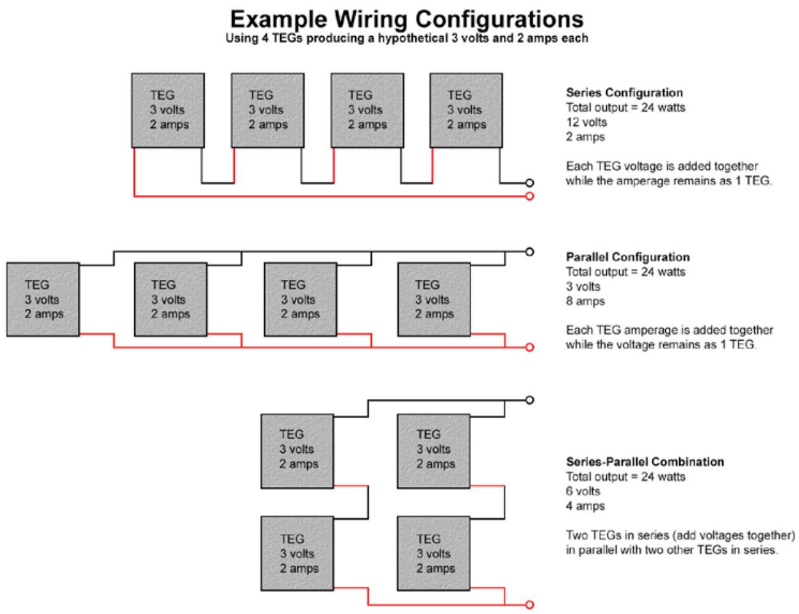


Fig:7 Using 4 TEGs connection in series and

Parallel combination

Fig:8 shows when 4 TEGs connected in series and parallel configuration and also series-parallel configuration. But we have taken only the two cases of series configuration and parallel configuration with each thermoelectric generator used is TEP1 – 1264-1.5

H. TEP Specifications

TEP1-1264-1.5

Size	40mmx40mm
Hot side temperature(^{0}c)	300
Cold side temperature (^{0}C)	30
Open circuit voltage (V)	9.4
Match load resistance (Ω)	2.8
Match load output voltage (V)	4.7
Match load output current (A)	1.56
Match load output watts(W)	7.3
Heat flow across the module watts(W)	~ 133
Heat flow density (wcm2)	~ 8.4
AC Resistance (Ω)Measured under 27^{0}C @ 1000 Hz	~1.3~1.8

II. RESULTS AND DISCUSSIONS WITH GRAPHS

Case: 1 When 4 TEGs are placed in parallel the output power generated is,

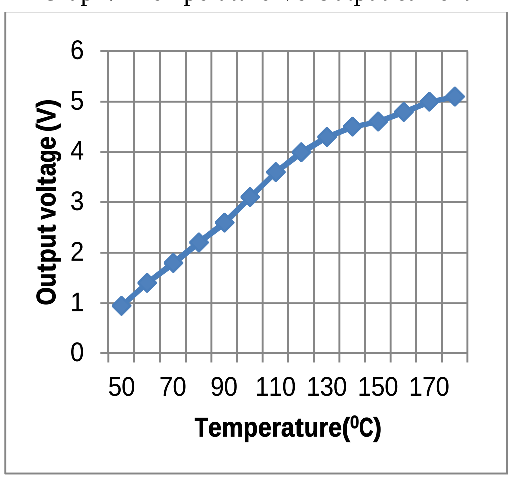
P = I V = 0.4 A X 5.1V = 2.04 W

And the corresponding tabular column and graphs are drawn at load resistance , R = 10 Ω

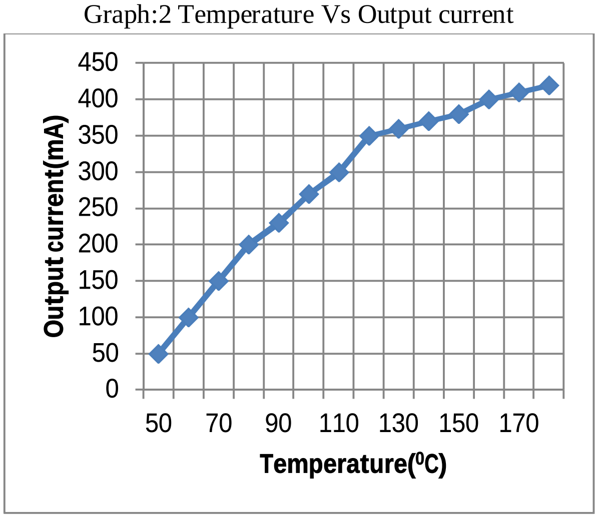
Table :1

S.No.	Temperature (^{0}C)	Output Voltage (V)	Input Voltage (V)	Output current (mA)
1	50	0.95	0.4	50
2	60	1.4	1	100
3	70	1.8	1.5	150
4	80	2.2	2	200
5	90	2.6	2.5	230
6	100	3.1	2.9	270
7	110	3.6	3.3	300
8	120	4	3.8	350
9	130	4.3	3.9	360
10	140	4.5	4.1	370
11	150	4.6	4.2	380
12	160	4.8	4.4	400
13	170	5	4.6	410

Graph:1 Temperature Vs Output current



Graph:2 Temperature Vs Output current



Graph:3 Output current vs output voltage

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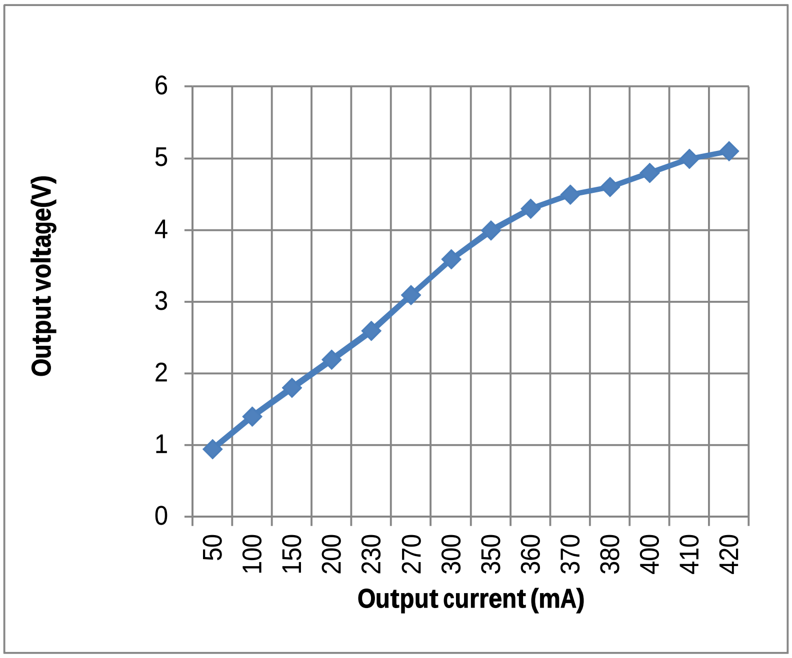

III. DISCUSSION

From the above table: 1 , When four TEGs are connected in parallel at different temperatures the input voltage , output voltage and output current is also increases at load resistance , R = 10Ω and the corresponding graphs are represented above between temperature vs input voltage, temperature vs output voltage, input voltage vs output current. The power generated is also calculated and it is 2.04 W

Case: 2 When the 4 TEGs are connected in series , the power generated is

P = I V = 0.63 x 20.5 = 12.3 W

And the tabular column and graphs are represented below

Table:2

S.NO.	Tempe Rapture (^{0}C)	Output Voltage (V)	Input Voltage (V)	Output current (mA)
1	50	5.1	3	300
2	60	6.7	3.5	350
3	70	8.4	3.8	360
4	80	10	4.4	380
5	90	11.9	4.9	430
6	100	13.7	5.5	480
7	110	15.4	6.1	540
8	120	17	6.5	570
9	130	18	6.8	600
10	140	19	6.9	610
11	150	20.1	7	620
12	160	20.5	7.1	630

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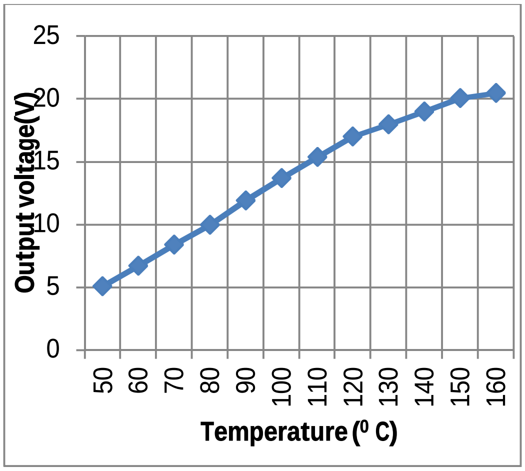
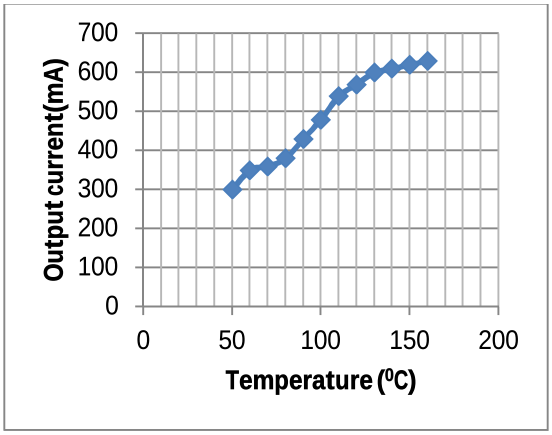
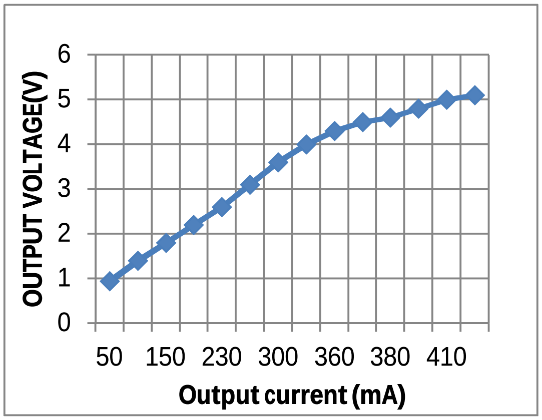
Graph: 4 Temperature vs Output voltage



Graph: 5 Temperature vs Output current



Graph:6 Output current vs Output voltage



IV. CONCLUSION

From table :2, when four TEGs are connected in series, at different temperatures input voltage, output voltage and output current is measured at load resistance , R = 10Ω . As the temperature increases the input voltage , output voltage and the output current will be increasing and the corresponding graphs are represented above between temperature vs input voltage , temperature vs output voltage , output voltage vs output current . The power generated in this case is 12.3 W and the output current will be 0.63mA

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